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# A Hybrid Model for the Application of Convergent ICT in Process-Specific Health Solutions

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# A Hybrid Model for the Application of Convergent ICT in Process-Specific Health Solutions

Thesis for the degree of Doctor of Technology to be presented with due permission for public examination and criticism in Tietotalo Building, Auditorium TB104, at Tampere University of Technology, on the14th of January 2005, at 12 noon.

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**ABSTRACT**

Information and communication technology (ICT), a discipline of engineering, has radically changed the ways in which we process and use information. Medicine has been one of the first application areas of modern ICT, since even simple information and communication tools can often be of great help. As modern ICT develops and matures, its users in medicine and health care, and more broadly in health, need to follow the evolution of ICT and identify the trends which could provide the greatest benefits. ICT convergence is a trend which coincides with the contemporary challenges and changes in medicine and other areas of health provision. It has considerable potential for assisting in the development of new supportive solutions for problems encountered in health service provision.

A hybrid model for the application of convergent ICT in the health domain has been developed in this thesis to demonstrate the greater benefits expected from applying process-specific, convergent ICT as compared to using conventional manual and ICT solutions. The hybrid model consists of a process facilitation model and a process evaluation model. The former serves as a requirement taxonomy for an ICT convergent platform for process-specific health solutions. The latter defines a research methodology for the continuous evaluation (in the evaluation areas of health resource allocation efficiency, quality, usability, accessibility, and security) and improved implementation of process-specific ICT solutions in the health domain.

A technology platform for process-specific, convergent health ICT solutions has been developed, based on the process facilitation model. The platform is shown to facilitate information, communications, terminal, and systems convergence to enable the realization of seamless, process-specific health ICT solutions.

Finally, a selection of five process-specific health ICT solutions (from the three health strategies: tele-prevention, tele-treatment, and tele-rehabilitation) deployed on versions of the platform as both clinical and conceptual solutions are described and evaluated. The three tele-treatment solutions were evaluated extensively during clinical pilot use in primary health care settings. Evaluation of the oral anticoagulation treatment follow-up solution showed clear benefits over conventional treatment modalities in terms of efficiency, usability, and accessibility in three differing settings. The solutions for hypertension follow-up and guided asthma self-management were evaluated chiefly in terms of usability and accessibility; clear benefits over conventional treatment provision and support were observed. Objective evaluation of the two tele-prevention and tele-rehabilitation solutions was outside the scope of this thesis.

**PREFACE**

Health and medicine is an important application area of engineering where the evolution is towards a technology with a greater intensity of information. Application of modern information and communication technology (ICT) in health and medicine has the potential for illustrating the power of engineering to support change in the accepted methods of health service delivery.

The research work culminating in this thesis was carried out both in academic and operational settings. Research leading up to this thesis began with my participation in the Health Care TV research project at the Digital Media Institute (Institute of Signal Processing) of Tampere University of Technology from 2000 to 2003. The foundations laid in academic research were applied to an operational setting in Terivan Oy, a company focusing on health ICT solutions, founded by the researchers of the HCTV project. Convergence as a key concept in health ICT emerged already in the early stages of the research project and has since been applied in form of practical engineering solutions in the activities of Terivan Oy.

I would particularly like to thank the people from the Health Care TV project and Terivan Oy, including Mr. Heikki Mattila, Ms. Kirsi Keskiruusi, and Mr. Jari Yli-Hietanen for their help, support, and friendship. Special thanks go to Mr. Artur Lugmayr for all our interesting discussions and his support. My instructors, Professor Seppo Kalli and Docent Heikki Lamminen, provided invaluable help and the pre-examiners of this thesis, Research Professor Ilkka Korhonen and Professor Pirkko Nykänen, provided enlightening suggestions for improvement. I would finally like to thank my family for all their love and support.

Tampere, July 14th 2004

Samuli Niiranen

**CONTENTS**

## ABBREVIATIONS AND ACRONYMS

| | |
|---|---|
| AC | Anticoagulation |
| BMI | Body Mass Index |
| CDA | Clinical Document Architecture |
| CSS | Cascading Style Sheets |
| DBMS | Database Management System |
| DICOM | Digital Imaging and Communications in Medicine |
| DTD | Document Type Definition |
| DTV | Digital Television |
| DVD | Digital Versatile Disc |
| EJB | Enterprise Java Beans |
| EPR | Electronic Patient Record |
| FTP | File Transfer Protocol |
| GP | General Practitioner |
| GPRS | General Packet Radio Service |
| GSM | Global System for Mobile Communications |
| HIN | Health Information Network |
| ICD-10 | The International Classification of Diseases-10 |
| IP | Internet Protocol or Intellectual Property |
| INR | International Normalized Ratio |
| HIS | Health or Hospital Information System |
| HTML | HyperText Markup Language |
| HL7 | Health Level 7 |
| ICT | Information and Communication Technology |
| J2EE | Java 2 Enterprise Edition |
| JNDI | Java Naming and Directory Interface |
| JPEG | Joint Photographic Experts Group |
| LAN | Local Area Network |
| LDAP | Lightweight Directory Access Protocol |
| MDT | Mobile Data Telephony |
| MMS | Multimedia Messaging Service |
| MPEG | Motion Pictures Expert Group |
| MUMPS | Massachusetts General Hospital Utility Multi-Programming System |
| NDC | National Drug Code |
| OLAP | Online Analytical Processing |

| | |
|---|---|
| PC | Personal Computer |
| PDU | Protocol Data Unit |
| OODBMS | Object-Oriented Database Management System |
| OS | Operating System |
| PDA | Personal Digital Assistant |
| POC | Point-Of-Care |
| QoS | Quality-of-Service |
| RA | Rheumatoid Arthritis |
| RDBMS | Relational Database Management System |
| RIM | Reference Information Model |
| RMI-IIOP | Java Remote Method Invocation-Internet Inter-ORB Protocol |
| SFTP | Secure FTP |
| SMIL | Synchronized Multimedia Integration Language |
| SMS | Short Message Service |
| SNOMED | Systematized Nomenclature of Medicine |
| SGML | Standard Generalized Markup Language |
| SQL | Structured Query Language |
| UDDI | Universal Description, Discovery and Integration |
| WAP | Wireless Application Protocol |
| W3C | World Wide Web Consortium |
| WSDL | Web Services Description Language |
| XHTML | eXtensible HyperText Markup Language |
| WAP | Wireless Application Protocol |
| WML | Wireless Markup Language |
| WPS | Wireless Protocol Stack |
| XML | eXtensible Markup Language |

# 1 INTRODUCTION

Health is a concept which encompasses the areas of human existence and activity related to well-being in individuals and populations. Definition 1-1 is the entry for “health” in the Merriam-Webster Online Dictionary [Mer04].

**Definition 1-1** Health

“The condition of being sound in body, mind, or spirit; especially: freedom from physical disease or pain.”

The professional and mostly organizational side of health is health care, which is commonly used synonymously with medicine and medical services. Definition 1-2 is the entry for “health care” in the Merriam-Webster Online Dictionary [Mer04].

**Definition 1-2** Health Care

“Efforts made to maintain or restore health especially by trained and licensed professionals.”

Considering the dynamics in health care, the traditional system model of health care has emphasized hierarchical organizational structures with strict separation of organizational responsibilities within the framework of health care. In the Finnish context this hierarchy can be seen through the following points (see [Jär02] for an overview of the Finnish health care system):

- Strict organizational division of responsibilities between primary care (e.g., municipal GP-led health centers) and secondary care (e.g., regional specialist-led hospitals)
- Geographical separation of patient care responsibility (e.g., within primary and secondary care)
- Separation of duties between different health care professional groups (i.e., physicians and nurses) and specialties as well as separation of patients from the care process
- Separation between public and private care providers within the different levels

In the health care information and communication technology (ICT, see Definition 1-3) context, these hierarchical divisions can be seen in the implementation and scope of information and communication systems used by care facilitators. Separation is actually amplified when exchange of information is considered. Conventional health ICT systems supporting overall service provision are centralized and follow these boundaries closely, while system interoperability is often minimal. Information exchange between two providers is often reduced to exchange of printed material even if both have a fully electronic patient record system. Furthermore, direct patient access to electronic patient record information (e.g., over public networks) is typically minimal or non-existent. Similarly for professionals, the use of centralized ICT systems is restricted to the primary working facility.

**Definition 1-3** Information and Communication Technology

“The study of the technology used to handle information and aid communication.”

This traditional system model is facing several challenges and structural changes are unavoidable. For example, aging populations (e.g., Finland is likely to experience very high growth in the 60+ age group by 2025 [Nat00]), continued limits in public resource allocation (e.g., the share of public sources of finance has decreased from 80.9% to 75.7% of the total Finnish expenditure on health care from 1990 to 1999 [Soc01]), increasing specialization in medicine requiring convenient consultation tools (e.g., see [Don00] for a discussion on the phenomenon from an American perspective), and trends towards patient and non-physician empowerment (e.g., see [Neu03] for a discussion on patient empowerment and its consequences) drive the system towards the breaking down of strict organizational and other boundaries (e.g., towards process-orientation) in the search for better results. As a corollary of empowerment, the role of the health care customer is changing from the passive user of publicly funded services towards that of an informed health consumer using private insurance and his own assets to cover the expenses of medical and other health services. Commercialization of health service provision, driven forward in the European context by the European Union principles on the free exchange of services and labor, brings competition and other market mechanisms to the domain.

In Figure 1.1 we predict that these developments result in an evolution from hierarchies to networks and from ICT systems to services in health care service provision. For health care providers the evolution from hierarchies to networks breaks up stagnant and monolithic hierarchies into networks where each node in the network adapts its responsibilities as well as resource allocation in a dynamic way. Such networks enable seamless care chains where information is handled in a process-oriented way and flows seamlessly between different nodes; process-orientation enables the specialization of provider resources, which is a potential solution for increasing efficiency. The nodes of the model can represent both organizations and individual care process participators (i.e., health professionals and patients or consumers).

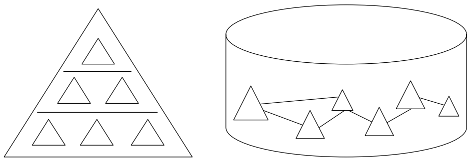

**Figure 1.1** Evolution from hierarchies to networks and from systems to services (adapted from a presentation given by Pentti Itkonen at the FinnWell technology program contact forum organized by the National Technology Agency of Finland in Helsinki, Finland on March 4th 2004)

However, in the supporting ICT domain the corresponding move towards distributed process-oriented service systems from monolithic centralized systems represents a challenge. Care process networks involving different organizations either as participators or as information pools require methodologies for sharing information and service components efficiently and securely in system-to-system interaction. Furthermore, the time, location, and use context independence required in human-to-computer interactions in a networked context require new solutions compared with centralized systems.

Simultaneously with these developments, common information representation standards, unified and distributed communication standards for both human-to-system and system-to-system interactions, and the related break-down of boundaries between private and public information systems are emerging. This trend towards ICT convergence (see Definition 1-4) is visible, for example, in the emergence of XML as a universal information syntax and in the possibilities offered by networked multimedia in the realization of seamless services.

**Definition 1-4** ICT Convergence

“A development towards universal information and communication models and standards in ICT”.

More broadly, the emergence of ICT convergence is visible in the technology mega-trend towards the convergence of information, communication, terminals, and systems. Figure 1.2 illustrates the convergence in the four domains and their coming together in the domain of systems convergence.

Convergence is important for computer-to-computer, human-to-computer, and computer-facilitated human-to-human service interactions. For example, ICT convergence facilitates human interaction and collaboration in ways not existing previously [Cov00].

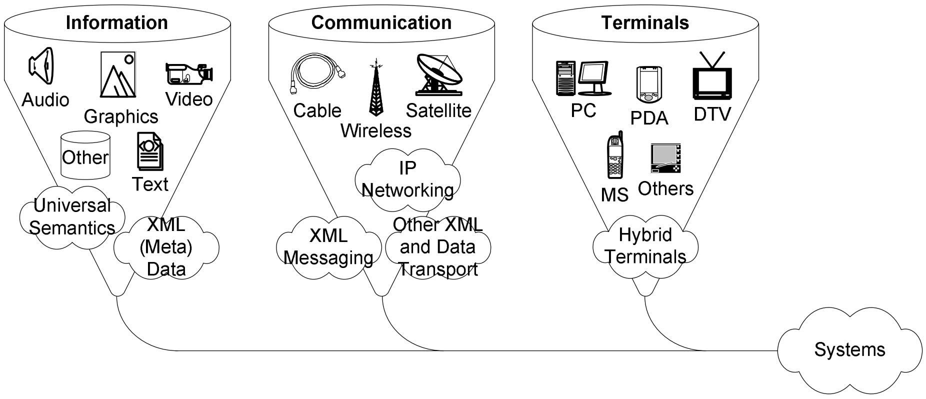


**Figure 1.2** Components of ICT convergence (adapted from [For00])

In addition to the discussed professional health care domain, health as a modern concept emphasizes the role of the individual consumer, or patient, as a facilitator of his own health. This health aspect will be central in further consideration of the application of convergent ICT in the broader domain.

## 1.1 Scope and Structure of the Thesis

The scope of this thesis is to study the application of convergent ICT in the implementation of process-specific health ICT solutions. The principle focus is on the development of a hybrid model for the stated application area. The hypothesis of this thesis is that convergent ICT

1. supports a health provision shift from hierarchies towards seamless, networked health services, illustrating the evolution in the health domain, by enabling a related technology shift from centralized systems towards distributed and process-specific services in health care ICT and;
2. provides a number of objective benefits to health organizations, professionals, and consumers when applied in this context and compared with the conventional ways.

Chapter 2 begins with a search for the definition and structure of the health domain (its different strategies and solutions, etc.) as well as evolution and trends within it. Based on the study of the structure and evolution of the health domain, the following postulate is made:

Due to the evolution from external drivers (e.g., aging populations) affecting the health domain, internal drivers (e.g., emergence of new health provision modalities) redefining service provision within it and the related impacts, new, innovative ICT methodologies are required. These methodologies should support the move from hierarchies to networks in health service provision and the corresponding move from monolithic systems to distributed process-specific services in domain ICT solutions.

To study the possible technological answers to these requirements, the history and structure of the application of ICT in the health domain (i.e., medical and health informatics) is considered. A focused taxonomy of the applied, clinical part of health informatics, current health ICT solutions, is developed to cover the structure of the application domain. As the focused taxonomy is considered together with the above postulate, it is noted that the technology currently in use in distributed and integrating health information systems provides a starting point for the implementation of process-specific ICT solutions in health. New ways to integrate, distribute, and access health information are required for the implementation of seamless process-specific solutions. The common theme is convergence. Based on this, the following postulate is made:

In supporting the evolution of the health domain towards process-specific services, convergent ICT is a potential technology solution.

To further elaborate on this postulate, ICT convergence in information, communication, terminals, and systems is considered and the key technology trends within each convergence domain are considered. Based on this elaboration and the identification of the potential of convergent ICT in the development of new ways to efficiently integrate, distribute, and access health information, the following claims are made which, if proven to be true, establish the feasibility and benefits of the use of convergent ICT in supporting the evolution of the health domain:

1. Convergent ICT enables the integration of telehealth solutions with legacy centralized systems and other information systems to create unified health information systems consisting of process-specific logical sub-systems for application within the different health strategies (tele-prevention, tele-treatment, and tele-rehabilitation).

2. Convergent ICT supports the development of novel, process-specific telehealth solutions through the application of convergent digital networked multimedia providing consultation-supporting, consumer-oriented, empowered, and networked human user access anytime, anywhere, and in any way.

3. Convergent ICT supports the creation of seamless, process-specific health provision chains through the use of convergent ICT providing common information semantics, syntaxes, and communication modalities as well as convergent terminal functionality and information integration facilities.

4. Use of convergent ICT in process-specific health provides benefits in terms of health resource allocation efficiency, quality, usability, accessibility, and security when compared to conventional ways.

To seek the validity of these claims the following postulate is made:

Formalization of the application of convergent ICT in the process-specific health domain is required in the form of a hybrid model.

The hybrid model helps in formalizing the complex research task at hand (i.e., seeking the validity of the claims made); health, and especially its health care component, is a convoluted domain of human activity. First, this formalization should define a requirement taxonomy (process facilitation model) for an ICT solution platform supporting the deployment of various process-specific health ICT solutions related to the three health strategies. The successful engineering development of such a platform and the established technical feasibility of deploying diverse solutions on it validate claims 1, 2, and 3. Second, the formalization should define a methodology for evaluating a diverse selection of solutions developed and deployed on implemented versions of the platform (process evaluation model) in terms of efficiency, quality, usability, accessibility, and security in order to establish the validity of claim 4.

Chapter 3 formalizes the application of convergent ICT in the health domain by describing a hybrid model to research the use of convergent ICT in the process-specific health domain. The hybrid model consists of a process facilitation model and a process evaluation model. The former serves as a requirement taxonomy for an ICT convergent platform for process-specific health solutions within the different health strategies. A number of top-level, converging engineering solutions related to the requirement taxonomy are presented with this model. The latter model defines a research methodology for the continuous evaluation and improvement of developed and deployed process-specific health ICT solutions.

Chapter 4 introduces a technology platform for process-specific health ICT solutions providing a plethora of possible service scenarios in a fully convergent setting. Functionality of the platform corresponds to the process facilitation model developed in Chapter 3. Furthermore, the logical and physical architectures of the suggested platform are described and the generic solution functionality available through the platform in the different health strategies (tele-prevention, tele-treatment, and tele-rehabilitation) is enumerated and described. The scope of available solution functionality will be used to establish the validity of claims 1, 2, and 3.

Chapter 5 describes the process-specific health ICT solutions deployed on versions of the developed platform with example solutions for each of the health strategies. Special consideration is given to tele-treatment solutions deployed in clinical settings. Some of the solutions have been used in a clinical setting, others in the laboratory within the activities of the Health Care TV project and Terivan Oy. Also described is the evaluation of the process-specific health ICT solutions, including used methodologies and corresponding results, related to the suggested application methodology. This includes lessons learned from the real-life use of deployed solutions. The enumerated evaluation results will be used to establish the validity of the claim 4.

Finally, Chapter 6 summarizes the research presented in this thesis, presenting the related results and conclusions. Important subjects for further research and key trends are also discussed. The conclusions represent the author’s view of the impact of the research on the application area.

### 1.2 Contribution of the Author

Several journal and conference publications have been prepared during the research leading to this thesis. The author has been the primary author of (or a highly significant contributor to) the research papers from which this thesis partially draws its concepts and results. Much of the work presented in this thesis, especially in a strictly technological scope, represents an evolution from the earlier publications. It also includes previously unpublished work prepared by the author both in technological and health domain contexts.

Published work related to the research at hand and where the author is the primary contributor includes [Nii02a], [Nii02b], [Nii02c], [Nii02d], [Nii02e], [Nii03a], [Nii03b], and [Nii03c]. The author's licentiate thesis [Nii03d] presents certain concepts also utilized in this thesis.

Other published work where the author is a secondary contributor and which is related to the current research includes [Lam02], [Lam02a], [Lam02b], [Lam02c], [Lam03a], and [Lam03b]. A book co-authored by the author [Lug04] also partly touches on current research in the health domain.

# 2 ICT IN THE HEALTH DOMAIN

## 2.1 The Concept of Health – an Introduction

Figure 2.1 illustrates the three fields of health: physical, mental, and social. The three components of health: absence of major negative health factors, absence of negative health factors, and presence of positive health factors serve as a measure for the quantity 'health' within each field. Both the absence of negative factors and the presence of positive factors define the state of health for an individual. How can the different fields and components be characterized? Physical health is the absence of physical disease and other physical impairments of the individual. Mental health similarly refers to the mental component of health. Social health is a more amorphous concept of the relative position of an individual within society. Looking at the components of health, absence of major negative factors generally implies the absence of disease or other serious impairment (physical, psychiatric, or social). The second component of health amplifies the first one to encompass the absence of ill health. Presence of positive health factors implies that the individual actively and personally seeks and observes health promoting factors. One example is the maintenance of a lifestyle which promotes good health. [Kem95]

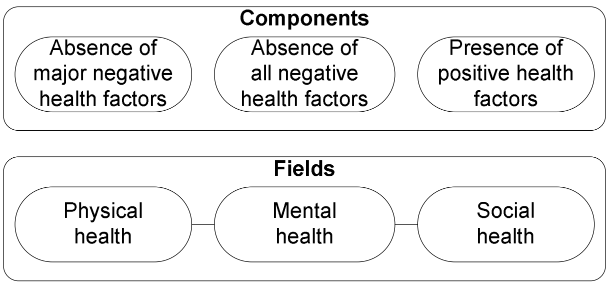


**Figure 2.1** Fields and components of health (after [Kem95, p. 23])

The key point in this discussion is that health encompasses a wide range of activities and conditions within the human experience. It is not merely the absence of disease or ill health but also the presence of positive health. As noted, health deals both with individuals and populations. As such, its provision is deeply intertwined into the organizational web a modern society represents.

As defined in the Introduction, the activity most commonly associated with the health domain is health care. Within the domain of health, health care relates mainly to the first two components of health within the three fields. The goal of health care is to alleviate the effects of negative health factors in individuals and populations mainly through an organizational approach based on conventional medical and hospital care.

## 2.2 An Evolution Model of the Health Domain

So far we have looked at health as a static concept with distinct fields and components. Apart from the given static model, the health domain is continuously evolving, especially with regard to its dynamic activities related to different health processes.

In Figure 2.2 we introduce a model for evolution of the domain due to external and internal drivers impacting on the distinct health strategies which define the basic activity methodologies within the domain. Health solutions and supporting ICT solutions are practical implementations of the methodologies within each strategy sector. Health providers, and ultimately patients and consumers as members of wider populations, utilize health solutions to retain or maintain good health. A key part of the evolution model is the continuous feedback to the drivers from providers as well as from patients and consumers.

This evolution model establishes a link between the dynamic, process-oriented activities of the health domain and external and internal factors driving change within the domain. It also serves as a comprehensive view of the structure of health provision realized through various activities.

We will next first describe the components of the evolution model, mostly in the Finnish context, and then consider the evolution currently taking place, also mostly in the Finnish context.

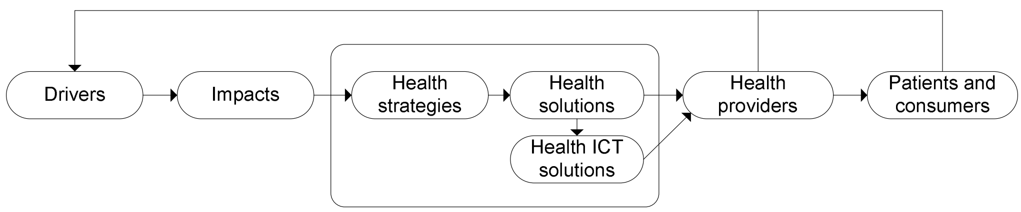


**Figure 2.2** Evolution in the health domain

### 2.2.1 Drivers

As noted, drivers represent the forces for change within the health domain. In practice, drivers are external and internal factors affecting the health domain. The internal factors come from the feedback component of the evolution model (i.e., from health providers as well as from patients and consumers). The external factors complement the internal factors by including wider societal changes which affect the health domain independent of the needs and requirements of the providers and patients/consumers. Current drivers in the Finnish context are discussed in Chapter 2.2.7.

### 2.2.2 Impacts

Impacts represent the directional changes in the health domain due to the various drivers. The impact is directly on the three health strategies and solution provision within them. Simply put, the impacts are *how* health solution provision within the different strategies responds to the different external and internal drivers by going through a number of changes. As such, impacts tell how the evolution initiated by the drivers affects practical health solution provision and they are directly visible to the patients and consumers. Impacts created by current drivers in the Finnish context are discussed in Chapter 2.2.7.

### 2.2.3 Health Strategies

Health strategies can be divided into three basic categories: prevention, treatment and rehabilitation. Each strategy relates to a specific stage in the overall strategy of health provision: the maintenance of good health. The strategies can be employed in any of the three fields of health. The human body can be conceptualized as a system where health represents the overall condition of the system. A deviation from a normal condition of the system can be detected through changes in a number of parameters, both physical and mental. The human body has a number of self-corrective capabilities (e.g., the immune system) which help in dealing with the disturbances. The purpose of health care is to aid the human body in the prevention, treatment, and rehabilitation of health disorders, which are disturbances of the normal condition of the conceptual human system.

To understand how the concept of a health disorder relates to the three health strategies, we first present a disability process model (see Figure 2.3). According to a classification by the World Health Organization, the consequences of a health disorder have three levels of significance [WHO81]:

- In the context of health, **impairment** is any loss or abnormality of psychological, physiological, or anatomical structure or function.
- In the same context, **disability** is any restriction or lack of ability, resulting from an impairment, to perform an activity within the range considered normal for a human being.

- Similarly, a **handicap** is a disadvantage for an individual, resulting from impairment or disability, limiting or preventing the fulfilment of the societal role normal for that specific individual.

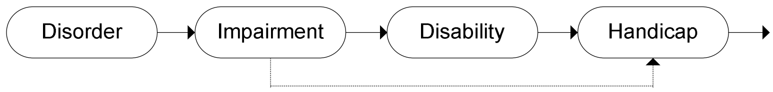


**Figure 2.3** The disability process according to WHO [WHO81]

**Prevention** is pre-emption of health disorders where the goal is to reach the risk group before the disorder occurs. Prevention can take place at three levels [Kem95, p. 28]:

- In **primary prevention** the goal is to prevent the disorder from ever occurring. Examples in the area include immunization of children against polio or the prevention of lung cancer through education promoting non-smoking.
- In **secondary prevention** the aim is to detect the presence of a health disorder before it causes any symptoms and is still conventionally curable. Examples include breast cancer screening and identification and counseling of early-stage alcoholics.
- In **tertiary prevention** the goal is to prevent the recurrence of a disorder or to prevent a disorder from causing complications or a handicap. An example of tertiary prevention is lifestyle consultation given to a heart attack patient to reduce the risk of recurrence.

Many estimates have been made about the benefits of prevention for the individual health consumer or patient and for society at large. The common theme is that efficient prevention reduces the need for care in the domain of the treatment strategy. On the other hand, some claim [Kem95, pp. 9] that in the long term prevention may increase health expenditures due to a lengthened average life span. The primary argument for prevention is increased quality of life for individuals and not a reduction in public health expenditures.

A key facilitator of prevention is education in its numerous forms; application of social engineering through legislative measures and environmental safeguards are also relevant for primary and tertiary prevention (see [Kem95, p. 26] for a comprehensive list). Considering education as a facilitator of prevention, the ideal methodology is to narrow the scope of education to the population sub-groups with most risk factors related to the particular instance of prevention. Mass education targeting, for example, an entire national population inhibits the application of tailored educative measures.

**Treatment** is a health strategy for individuals with a health disorder occurrence. The WordNet lexical database [Wor04] defines treatment as "…care by procedures or applications that are intended to relieve illness or injury…". The various forms of treatment are typically realized in a highly organized manner and are realized mainly in the domain of health care. The goal of treatment is to relieve the individual of the disorder with a minimum of permanent consequences. As with other health strategies, treatment is employed in all the three fields of health. Figure 2.4 illustrates the categorization of health disorders into physical, mental, and social with examples from each category. Naturally, the nature of treatment employed to cure an individual depends on the type of disorder experienced.

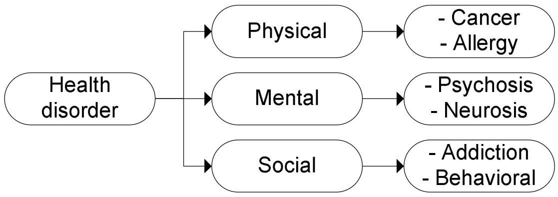


**Figure 2.4** Categorization of health disorders

To better understand the role of **rehabilitation** as a health strategy, we will look at its position within the disability process (see Figure 2.3). Rehabilitation targets disabilities and handicaps within the disability process. According to a broad definition of WHO [WHO81], rehabilitation *"…includes all measures aimed at reducing the impact of disabling and handicapping conditions, and at enabling the disabled and handicapped to achieve social integration"*.

This definition extends rehabilitation from the traditional, individual-oriented view, to consider the individual's environment as part of the domain of rehabilitation. On a practical level, the methodologies applied by a broad rehabilitation health strategy include medication, treatment-based, physical, educational, psychological, professional, and social measures. The goal is to integrate the individual into the society. [Sui95, p. 12]

As an example, we will consider the case of **atrial fibrillation**, a health disorder involving an abnormal rhythm of the heart, in relation to the three health strategies. In the **prevention** of atrial fibrillation, maintenance of normal blood pressure is one important goal. Education on the dangers of hypertension, a risk factor for developing atrial fibrillation [Med04], is a methodology in the prevention of atrial fibrillation. If atrial fibrillation is diagnosed despite preventive efforts, oral anticoagulant **treatment**, preventing the formation of blood clots often caused by atrial fibrillation [Med04], is the key methodology. Despite the anticoagulant treatment, the patient may experience heart failure or a stroke [Med04]. Stroke **rehabilitation** again relies on different methodologies, one of them being patient education.

### 2.2.4 Health Solutions

Health solutions typically function in the context of a health provider offering them to patients and consumers. Within the organizations, an obvious intermediary in reaching the patient and consumer is the health professional. Naturally, health solutions may impact directly on the patient or consumer without the intermediary organizations and professionals. Examples of health solutions within the treatment strategy are self-care services provided by Finnish municipal health centers. Looking at asthma care, the center (health provider) produces a service for the guided self-management of asthma (health solution) where health center professionals help in realizing improved asthma care for health center customers (patient) [Min94]. Obviously, a health ICT solution may accompany the generic solution facilitating, for example, professional-to-patient/consumer-to-professional communication in the example case of asthma self-management. Health ICT solutions range from such simple telemedicine applications to complex hospital information systems. They support overall health solution provision.

### 2.2.5 Health Providers

Health providers operate to provide health solutions to patients and consumers. Provider organizations exist in all sectors of the society from local, regional, and national government to private corporations and third sector organizations. In health care the emphasis is on the public sector in most industrialized countries. Public health care systems offer treatment as well as preventive and rehabilitative care to national or regional populations. The role of private and third sector institutions is typically to complement the services offered by the public systems. In terms of resource allocation, health care activities account for the bulk of private and public expenditures of the whole health domain*.

Figure 2.5 shows the structure of the Finnish system of health and health care providers (see [Jär02] for a description of the Finnish health care system).

At the left of the figure, the Finnish health care system is illustrated with the standard division into primary and secondary health care. The activities of the public sector within these two

* To give two examples, national health care expenditures reached 13% and 7% of the GDP in the US and in Finland in 2000, respectively [Org03].

sectors are mandated through national legislation (*The Primary Health Care Act of 1972* [Pri72] and the *Act on Specialized Medical Care of 1989* [Act89]). Characteristic of the Finnish public system is regional care organization and scaling, where each municipality is required to provide services for its population. Public primary health care is typically organized through municipality-level health care centers, while regional hospital districts, funded by the participating municipalities, handle secondary care.

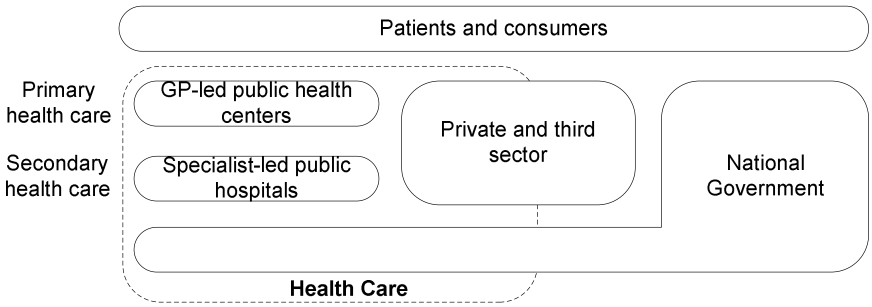


**Figure 2.5** Finnish health and health care providers

Responsibilities of the municipality health centers include (as mandated by [Pri72]):

- Organization of disease care, including facilitation of the corresponding treatments by GPs
- Health counseling, especially as part of maternal and pediatric care
- Medical rehabilitation, emergency duty, and first aid services in the area of the municipality
- School, student, and occupational health care

Apart from the municipality-funded primary and secondary care, the national government takes part in health care as a regulatory authority as well as through various national research and insurance institutions such as the *National Research and Development Centre for Welfare and Health* (STAKES) and the *Social Insurance Institution* (KELA). The private health care sector complements the services offered by public primary and secondary care providers. Care in the private sector is subsidized through health insurance available to all Finnish nationals through KELA. Third sector organizations take part in health care, for example, as educational providers specializing in specific diseases. The public sector also buys services from the private and third sectors. [Jär02]

Non-health care providers within the health domain in the lifestyle, complementary nutrition, fitness business areas, etc. operate privately and directly with patients and consumers. The national and local governments operate as regulatory authorities in this area.

### 2.2.6 Patients and Consumers

In this context, the patient and the consumer is the target of health solutions. The patient or consumer has access to health solutions through health providers, public or private. The term 'consumer' implies here a target taking a more direct role in his own health as opposed to the more passive 'patient'.

### 2.2.7 Current Evolution

As noted, health strategies take many forms, ranging from preventive educational information to the medical treatment of health disorders and to rehabilitation from the effects of disabling health disorders. As the domain evolves, so do the solutions which are the practical manifestations of the strategies. To study the evolution of the domain, we look at the primary drivers relevant currently or in the near future and at their impacts, chiefly in the Finnish context.

A key driver in the evolution of the health domain is the need for more efficiency (i.e., a need to provide the same services with a reduced cost). This need is caused by aging populations (see [Nat00]), continued limits in public resources available for health provision (see [Soc01) coupled with advances in health technology resulting in new, expensive health provision modalities (e.g., new drugs, treatments etc.) (see [Val03]). What is the response in the health domain, and more specifically in health care, to this need for more efficiency? Re-organization of professional service provision, prioritization and rationing of provided care, and devolution of tasks and responsibility to health consumers are commonly known examples of impacts created by the need for efficiency. Structural re-organization is a natural impact when a health care provider seeks to adapt to changes in available funding. Key structural re-organization methodologies are organization of care in process-specific[*] care chains spanning many providers in a seamless way (see [Min01] for a Finnish seamless service concept) and, on the other hand, centralization of the management of specific care processes (e.g., related to a specific treatment) as the responsibility of one large provider (see [Fos99] for an example from anticoagulant treatment). Moving of routine care tasks from the responsibility of (more expensive) physicians to (less expensive) nurses and use of cost-saving ICT are other examples of such re-organization.

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[*] The term 'process' denotes here the tasks and functions related to reaching a specific prevention, treatment, or rehabilitation goal.

Another important driver is the fact of increasing medical specialization (see [Don00]) visible in the need to provide enhanced consultation and decision support tools. The impact of this driver is the use of new (ICT) methodologies in information sharing for specialist to non-specialist consultation and in non-specialist decision support.

**Table 2.1** Examples of current drivers and corresponding impacts in the health domain

| Drivers | Possible impacts |
|---|---|
| Need for more efficiency due to aging populations [Nat00], limits in public resources for health [Soc01] and new, expensive provision modalities [Val03] | Professional service re-organization<br>Prioritization and rationing<br>Devolution of tasks and responsibility to health consumers |
| Need for enhanced consultation and decision support tools due to increasing medical specialization [Don00] | Use of new methodologies in information sharing and non-specialist decision support |
| Desire and need for health consumer independence and self-determination (i.e., empowerment) [Neu03], [Her01] | Devolution of tasks and responsibility to health consumers |

The desire and need for health consumer self-determination (see [Neu03], [Her01]) results in devolution of responsibilities from professional actors and empowerment of consumers in their health decisions. New innovative preventive measures and possibilities for self-care and independent rehabilitation for empowered consumers are examples of new health (ICT) solutions needed in response to the driving changes.

Furthermore, it should be noted that health providers and organizational users of health solutions have a dualistic role in the evolution model. As service organizations they provide their own drivers for evolution (e.g., in the search for improved medical care) but also need to respond to changes independent of them. Furthermore, public and private providers function typically from fundamentally differing starting points. Patients and consumers act as both the targets of evolved health solutions as well as provide drivers for change (e.g., the desire for independent living).

Drawing the drivers and impacts together, we predict that a general evolution from hierarchies to networks in health service provision and from corresponding ICT systems to services will result (see the Introduction). Approaching the topic of this thesis, it is asserted that innovative health ICT solutions are a key methodology in supporting and facilitating – not necessarily enabling – this evolution and the related transitions within the domain. ICT is not a new methodology for health solutions. However, recent technological advances open up a whole new world of possibilities. For example, patient and non-physician empowerment can be seen as an area where ICT may serve as an important tool.

## 2.3 Health Informatics – Application of ICT in Health

What do we fundamentally mean with the terms information and communication in the context of modern, digital ICT? The basis for the field of information theory was introduced by Claude Shannon in 1948*. Information theory is the theoretical basis for contemporary digital information and communication technology. As an example, Shannon was first to define information as symbols that are uncertain to the receiver at the destination of a communications system; the elements of a communications system theory were described by Shannon as a source-encoder-channel-decoder-destination model [Sha48]. Most importantly, the communications system theory of information theory has enabled the scientific and engineering community to find ways to increase communication efficiency, eventually leading to modern digital information and communication technology.

The development of high-efficiency and high-capacity digital ICT in the years after the introduction of information theory materialized as a valuable asset in the health care or, more broadly, health domain. The first applications of digital ICT in the domain were computer systems and software developed for bioengineering, medical research, and hospital administration†. As the applications of ICT in the domain broadened, the multidisciplinary field of health informatics was born in the late 1960s and early 1970s. Originally known as medical informatics, the term ‘health informatics’ first surfaced in the early 1970s [Pro95].

### 2.3.1 Definition and Focused Taxonomy

Health informatics, previously known as medical informatics, is a discipline that currently has an important role in all aspects of health care delivery as well as in public or personal health promotion [Bem99]. Definition 2-1 from the UK Health Informatics Society [UKH04] gives a formal definition of the discipline. This definition emphasizes a broad and collaborative scope in

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* Claude Shannon's “A mathematical theory of communication" was originally published in two 1948 editions of the Bell System Technical Journal [Sha48]. The paper has appeared in a number of republications since.

† MUMPS, the Massachusetts General Hospital Utility Multi-Programming System, was one early system developed in the mid 1960s for medical record management. See [Bow76] for a historical look at MUMPS.

applying ICT in the health domain as opposed to limiting it strictly to the conventional medical context of medical informatics.

**Definition 2-1** Health Informatics

"…as the understanding, skills and tools that enable the sharing and use of information to deliver healthcare and promote health…" and "…also the name of an academic discipline developed and pursued over the past decades by a world-wide scientific community engaged in advancing and teaching knowledge about the application of information and communication technologies to healthcare – the place where health, information and computer sciences, psychology, epidemiology and engineering intersect…."

In [Sha02] Shahar expands on the role of the discipline as a multidisciplinary area involving academia, clinical health care users, and industrial developers. For a general review of the contemporary situation in the discipline, see [Tal02].

To consider the clinical application areas of health informatics in health care and health promotion, we will next develop a taxonomy of applied health ICT solutions (related to the three strategies of health presented earlier and supporting overall solution provision) from a systems perspective. This taxonomy omits the life sciences and biomedical engineering fields related to health informatics. It reflects the structure of the health domain presented earlier.

Figure 2.6 illustrates the division of health ICT solutions into three categories: centralized health information systems, distributed health information systems, and integrating health information systems.

**Centralized health information systems** can be further divided into patient-centered and hospital information systems and into medical knowledge and decision support systems (division adapted from [Bem99]). They represent the most commonly and traditionally used information systems in the domain of health. The term 'centralized' comes from the fact that the systems are utilized within a restricted physical area (e.g., a hospital or a health care center) and do not typically involve distribution of clinical tasks over geographical distances. These systems are almost exclusively used by medical and health professionals in a health care setting.

The core of patient-centered information systems is the idea of an *electronic patient record* (EPR), which replaces traditional patient records with electronic versions. We will next look at four key patient-centered information system types.

Primary care systems facilitate the management of primary care patient information in an electronic form. Typical functions of a primary care system include basic (e.g., basic patient records), medical (e.g., patient care history and plan records), pharmacy (e.g., patient medication assignments), scheduling (e.g., health center physician reception calendar), financial (e.g., costs of various procedures), communication (e.g., reception of laboratory results from external systems), and research modules (e.g., population statistics). Primary care systems are used by the personnel of a primary care provider, including physicians, nurses, and clerical personnel. [Bem99]

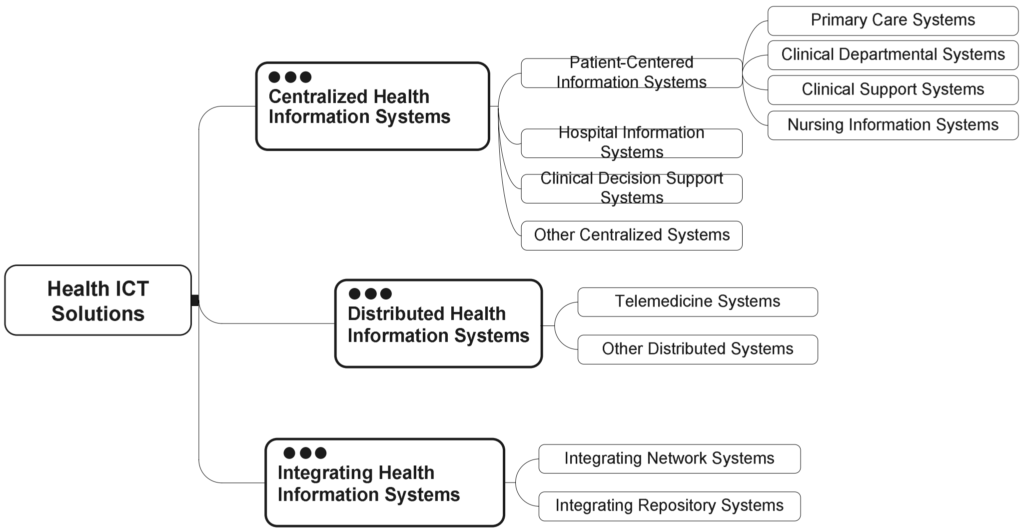


**Figure 2.6** Division of applied health ICT solutions (adapted from classification in [Bem99])

Clinical departmental systems complement HIS functionality to support the specific ICT needs of a clinical department of, for example, a secondary care provider. They do not replace the institution-wide EPRs. Clinical departmental systems are widely used in internal medicine, cardiology, surgery, neurology, psychiatry, and obstetrics. Intensive Care Units (ICUs) in critical care and radiotherapy units require also departmental systems. Applications of clinical departmental systems range from the collection of extended patient data to simulation, assessment, and research. [Bem99]

Clinical support systems typically include radiological information systems (RIS), various laboratory information systems (LIS), and hospital pharmacy information systems. RIS systems support the management of digital imaging information obtained from digital angiography, computer tomography (CT), magnetic resonance imaging (MRI), etc. systems. Communication and archiving of digital imaging data are realized with PACS (picture archiving and communication systems). RIS systems facilitate the various administrative and medical tasks related to the management of imaging information (e.g., handling of the radiology process from imaging to interpretation and reporting). RIS systems are often integrated with hospital information systems to achieve efficient sharing of patient records and imaging information. Laboratory information systems (LIS) support the operations of function (electrocardiography, spirography, and electroencephalography), pathology, hematology, etc. laboratories. Functions of LIS systems include storage and distribution (e.g., to a HIS) of measurement data from requested samples or patients and support of analytical quality control and reporting. Hospital pharmacy information systems are used for prescription management and administration. Clinical support systems are often integrated within HIS systems. [Bem99]

Nursing information systems are another complementary information system type designed to facilitate an optimal information handling environment for nursing purposes. The systems augment electronic patient records, for example, by presenting information with a syntax and semantics particular to nursing. [Bem99]

Hospital information systems (HIS) were among the earliest application areas of medical informatics. The first HIS systems included functionality for various hospital administration tasks such as admission, discharge, and billing of customers. Today HIS systems have evolved from a mainly administrative role into clinical information systems forming hospital-wide electronic patient record systems. HIS systems integrate information from patient-centered information systems to provide a common view of a customer’s clinical and administrative situation within a hospital environment. [Bem99]

Contemporary clinical DSS systems are by definition “…active knowledge systems which use two or more items of patient data to generate case-specific advice….” [Bem99]. The three main components of DSS systems are medical knowledge, patient data, and case-specific advice [Bem99]. The three components are combined in the system to generate domain-specific medical decision support advice for clinicians. DSS systems come in three basic categories: solicited and unsolicited advice systems as well as autonomous systems, depending on whether the clinician has to explicitly consult the system to receive advice [Bem99]. Unsolicited advice systems rely on existing EPR data and domain knowledge to generate advice, typically after a trigger event (e.g., input of new data) occurs. A common syntax for medical knowledge utilized in such systems is the Arden syntax. With Arden syntax knowledge is divided into discrete medical logic modules (MLM) to be utilized in institution-specific configurations to perform decision advice (e.g., reminder generation) generation [Poi97]. MLMs can be integrated, for example, into clinical departmental systems or HIS systems.

**Distributed health information systems** are information systems utilized in a distributed context where the human users of the system can be in geographically diverse locations and not tied to a professional medical setting. These systems typically employ more modern ICT than centralized systems to enable flexible yet secure use. A novel component is the direct involvement of patients and consumers in the utilization of distributed systems. The use of digital networked multimedia is a current trend in the area, as illustrated later.

Telemedicine, in a broad definition, covers all the applications of telecommunication technology in medical service and information provision. In an Australian government analysis of the telemedicine industry, telemedicine is concisely defined as a field consisting of the following components [Mit98]:

- The delivery of medical services (clinical, educational, and administrative);
- at a distance;
- through the transfer of information (aural, visual, graphical, etc.);
- using telecommunications;
- and involving a range of medical professionals, patients, and other recipients.

Wootton emphasizes that telemedicine should be understood as a process and not as a technology; advances in telecommunications technology and, partly related, continuing cost reductions have made the process of telemedicine much more feasible than it was in the past [Woo96].

Telemedicine is often categorized according to the medical field or disease domain of the application area. Table 2.2 uses a categorization based on the three health strategies presented earlier targeting patients in clinical health care and health promotion and illustrates the use of modern digital communication technology in the area (DTV is digital television, MDT is mobile digital data telephony).

As shown in Table 2.2, the applications of telemedicine within the three health strategies range from the historical use of analog television systems for distance tele-education and tele-consultation to the contemporary transfer of home-care data over digital communication domains between patients and professionals. Telemedicine is evolving from the use of classical telecommunication technology (e.g., analog television and telephony) to digital networks and systems, including the Internet and other digital media. Concurrently with this technological trend, telemedicine applications are diversifying in a health-oriented direction with more emphasis on consumer-based services.

**Table 2.2** A taxonomy of modern telemedicine related to the three health strategies

| | Communication | Example Medical Applications |
|---|---|---|
| Tele-prevention | | |
| Tele-education | Internet, TV, DTV | Diabetes patient [Ant04] |
| Tele-treatment | | |
| Tele-diagnosis | Video telephony | Tele-psychiatry [Bai97] |
| | Image telephony | Tele-pathology [Wei01] |
| Tele-consultation | Image networking | Tele-radiology [Nii01] |
| | Video telephony, TV | Tele-dermatology [Mck04] |
| Tele-care | Internet, MDT, DTV | Hypertension [Ari01] and asthma [Fin01] |
| Tele-monitoring | Data telephony | Blood pressure and ECG [Hun03] |
| Tele-rehabilitation | | |
| Tele-coaching | Internet, TV, DTV | Arthritis patient [Nii03c] |

The contemporary eHealth concept (see Definition 2-2) quantifies this technological evolution and application diversification in telemedicine. This definition from the Healthcare Information Management Systems Society [Hea02] identifies eHealth as a domain where patients and consumers are included as direct health ICT users (e.g., from a home setting). Ball in [Bal01] further stresses the changing effect eHealth has on the conventional physician-patient relationship. For further elaboration on the eHealth concept, see [Del01] and [Eys01].

**Definition 2-2** eHealth

"… application of Internet and other related technologies in the healthcare industry to improve the access, efficiency, effectiveness, and quality of clinical and business processes utilized by healthcare organizations, practitioners, patients, and consumers to improve the health status of patients…"

Of the medical applications presented in Table 2.2, [Ant04], [Ari01], [Fin01], and [Nii03c] clearly fall within the eHealth domain. For a further review of eHealth applications, including many consumer-oriented home health care ICT systems, see Chapter 3.4.1, where the domain is reviewed from a technological end-user media perspective.

**Integrating health information systems** operate in both vertical and horizontal health information integration domains. Vertical health information integration implies integration over health ICT solution division boundaries (i.e., the integration of centralized and distributed health information systems). Through vertical integration it is possible to fully integrate the capabilities of telemedicine and eHealth technology with legacy centralized systems. Horizontal integration implies interlinking various health information systems in order to share information over geographical or organizational distances. Integrating health information systems can be divided into two partly overlapping categories: integrating network systems and integrating repository systems.

Integrating network systems (e.g., health information networks (HIN)) are systems implemented at a regional or national level to facilitate sharing of health care information among different health care providers. The goal is to support seamless EPR information availability, for example, during the course of treatment of a patient moving between primary and secondary health care providers.

The functionality of a typical HIN can be defined as follows [Bem99]:

- To identify, link, store and retrieve and transmit electronic health care data between systems and providers separated geographically or organizationally and with varying local information systems. For example, this functionality can enable primary care personnel to directly access electronic patient records generated of a patient during secondary care.
- To diversify and improve health care data communication modalities and technology within the operating region in both internal and external communications. This implies the development of telemedicine and eHealth solutions involving both health professionals and patients in a regional setting.

In conclusion, integrating network systems seek to establish seamless health information chains to facilitate the optimized utilization of health care information during clinical health processes carried out by multiple organizations.

Integrating repository systems bring together health information from various sources on a regional or national level for use in population research and public health. The systems are primarily used for epidemiological studies and other relevant health care research, public health surveillance, reference, policy support, and resource allocation and financial planning. [Bem99]

Typical aspects of integrating repository systems include [Bem99]:

- Regionally, nationally, or in some cases (e.g., transplant donor registries) internationally maintained

- Data refinement capabilities for extracting knowledge from raw medical and other medical data: recording raw data abstracted at a lower level, publishing the refined knowledge, and passing an abstract to a higher level.
- Sensitive personal and patient data are usually stored anonymously to provide a high level of confidentiality.

Examples of integrating repository systems include disease, intervention, transplant, and immunization registries [Bem99].

See [Min01] for a review of Finnish health ICT solutions within the three categories.

### 2.3.2 Current Health Domain Evolution and Health Informatics

As a health-oriented view of medical informatics, health informatics, has become the norm, the paradigm of the domain has also evolved from traditional medical data processing and information systems. According to one definition from 1992, the four cornerstones of medical or health informatics highlighting this change of paradigm are [Lor92]:

- Management of change among people, processes, and information technology so that the use of information is optimized
- Integration of information from diverse sources to provide more than the sum of the parts, and integration of information into work processes so that it can be acted on when it can have the largest effect
- Production of structures to represent data and knowledge so that complex relationships may be visualized
- Development of methods for acquisition and presentation of data so that overload can be avoided

This redefinition emphasizes health informatics as a process-oriented, integrating, and optimizing tool designed to support change and evolution in the domain. It reflects on a general level the changing needs in the health domain due to its evolution.

In the previous sub-chapter we developed a taxonomy for contemporary clinical and applied ICT health solutions related to the three strategies of health. The division is a distinct subset of health informatics geared towards clinical and applied tasks where the goal is to care for and to promote health in individuals and populations. The current solutions presented in this taxonomy partly reflect, in a non-unified way, the paradigm change in health informatics towards networked services and process-orientation and the underlying evolution of the domain.

However, from the viewpoint of the current status in applied health ICT, the solutions contained in the taxonomy fail to fully consider the current and future evolution in the health domain. Most importantly, a unified view is missing. As the rate of evolution of the health domain increases due to the various drivers and related impacts within the field, new approaches are required to cope with the challenges faced.

In approaching the question of how current applied health ICT solutions are affected by the evolution in the domain, we note that the current drivers in the health domain

- need for more robust resource allocation and efficient use of allocated resources (e.g., due to aging populations, limits in resource allocation, and increasing health care costs);
- need for enhanced consultation and decision support tools for non-specialists due to increasing medical specialization;
- desire for consumer empowerment in matters related to their own health;

and the related impacts all point towards the adoption of technologies and methodologies applied currently in the distributed health systems of the taxonomy to support the transition from hierarchical to networked, process-oriented health service provision. As such, the implementation of centralized health systems is moving towards the solutions proven in modern distributed systems and in telemedicine and eHealth in particular. Simultaneously, there is a technology move within telemedicine towards digital networked multimedia and related open information and communication standards, visible especially in the eHealth concept. The common trend is towards a fusion of centralized and distributed health information systems as telemedicine and eHealth integrate with centralized systems to create unified health information systems. However, it should be noted that the term ‘unified’ does not imply the creation of physically monolithic systems. Rather, a move towards networked, process-specific ICT services from monolithic systems is the future path.

Integrating health systems have an important role in facilitating information sharing among unified, process-specific systems. Regional health information networks span geographical and organizational boundaries to help facilitate seamless health care process chains as data flows easily between health providers. However, regulatory boundaries often hinder the full adoption of information sharing among different systems and organizations and represent an important challenge.

Supporting the relevance of these considerations in the Finnish context, The National Committee for the Strategy for Utilizing of ICT in Social Welfare and Heath Care has proposed a new citizen-centered care model known as seamless services. In these services the individual citizen will be an active partner and the present organizational and information barriers are made invisible in ways approved by the national regulators. Supporting the current considerations, the committee has also noted that as seamless services also require seamless information access, it is necessary to utilize the capabilities of modern ICT to make this possible. [Min01]

To facilitate these trends, we assert that the application of convergent ICT is a potential methodology, as described in the next sub-chapter.

### 2.4 Convergent ICT and the Health Domain

Convergence as a term connotes moving towards union or uniformity. As noted in the Introduction, convergence implies, in the domain of digital ICT, a development towards universal information and communication models and, ultimately, common and open standardization. Emergence of ICT convergence was also stated to be visible in four convergence components: convergence of information, communication, terminals, and systems. We will next look at these components both in general and specifically in the health domain.

#### 2.4.1 Information Domain Convergence

Convergence in the information domain is apparent in the convergence of syntaxes, semantics, and storage systems. Syntax convergence implies the use of universal ways for structuring information with varying vocabularies, semantic convergence means mainly the emergence of common vocabularies, and storage convergence implies the use of unified solutions for information storage systems.

The emergence of universal multimedia content and metadata structure standards indicates a trend towards information convergence. For digital audio and video, the MPEG (*Motion Pictures Experts Group*) family of standards has emerged as the de-facto standard for compression, representation, and structuring of information [MPE04]. The MPEG standards are basically a family of standards used for coding audio-visual information (e.g., movies, video, and music) in a digital compressed format [MPE04]. MPEG has developed such standards as MPEG-1 (A/V compression, a file format), MPEG-2 (A/V compression used in DTV and DVD systems, a file format), MPEG-4 (A/V compression, an object-oriented information representation framework for synthetic content, etc.), MPEG-7 (a multimedia metadata framework for content description), and MPEG-21 (packaging of multimedia information during the entire value-chain with a fundamental unit of distribution) [MPE04]. Similarly, JPEG (*Joint Photographic Experts Group*) provides a common compression standard for still images [JPE04]. In the health domain, the DICOM (*Digital Imaging and Communications in Medicine*) standard includes a standard representation (file format) for medical images [Nat04]. The key point with these multimedia information standards is their universal use and acceptance, which serves as a starting point for information convergence.

Metadata (see Definition 2-3) takes information convergence further by enabling the separation of the meaning of information from its representation. It renders fixed syntaxes obsolete and enables a new level of information convergence by providing a tool, for example, for flexible transformation of information from one syntax to another.

**Definition 2-3** Metadata

“data about data”

Naturally, metadata itself requires a standardized structure. MPEG-7 and MPEG-21 from MPEG are two examples of metadata standards mainly for A/V multimedia content.

MPEG-21 is especially interesting from the convergence point of view as it establishes a unified framework for multimedia delivery and consumption through the entire value-chain (e.g., packaging of multimedia information and metadata for delivery over ubiquitous networks). MPEG-21 introduces a fundamental unit of distribution and transaction for multimedia information (a Digital Item) and the concept of User interacting with Items. [ISO02]

The W3C (*World Wide Web Consortium*) has defined a family of metadata standards using XML (eXtensible Markup Language) derived from SGML as the common syntax. XML-based W3C metadata standards are dominant in hypermedia presentation (i.e., combinations of textual and image data; XHTML) as the original markup language of the web, HTML (*Hypertext Markup Language*), was the starting point of the consortium’s work. [W3C04]

Subsequently, XML has been chosen as a metadata standard by a large number of organizations. For example, MPEG metadata standards, MPEG-7 and MPEG-21, use XML as syntax [MPE04]. In the health domain, XML has been chosen by the HL7 (*Health Level 7*) consortium as the standard encoding syntax for the new versions of the HL7 standards. HL7 defines a set of standards for the “*… exchange, management and integration of data that support clinical patient care and the management, delivery and evaluation of healthcare services. Specifically, to create flexible, cost effective approaches, standards, guidelines, methodologies, and related services for interoperability between healthcare information systems …*” [Hea04]. The key components of HL7 v.3 are the RIM (*Reference Information Model*), the

Messaging Standard and the CDA (*Clinical Document Architecture*). RIM is an object model created as a pictorial representation of the clinical data and domains supported by HL7. It identifies the life cycle of events that a single HL7 message or a group of related messages carries [Hea04]. In addition to messaging, RIM is also used within the CDA as a semantics model. The Version 3 Messaging Standard uses an object-oriented development methodology to create messages for information sharing between health care providers and systems [Hea04]. The messages are encoded in XML syntax. Similarly, CDA is basically an XML architecture for the exchange of clinical documents (e.g., discharge summaries) [Hea04]. Unlike the messaging standard, CDA documents are meant to be transformable into human-readable form. XML is being adopted as syntax also for other health-related information standards. For example, GLIF (Guideline Interchange Format), the specification for structured representation of medical guidelines, has adopted XML as the syntax in its newest version GLIF3 [Pel00].

Apart from the development of XML as a universal syntax, common semantics (i.e., standardized vocabularies) are also emerging. In the health domain, such vocabularies as the ICD-10 (*International Statistical Classification of Diseases and Related Health Problems*) disease classification [Wor04b], the American NDC (*National Drug Code*) drug classification [Fed04], and the SNOMED (*Systematized Nomenclature of Medicine*) umbrella standard for a clinical reference terminology [SNO04] are emerging as such. Many of these are included in the HL7 RIM [Hea04b].

In conclusion, convergence in the information domain is apparent through the adoption of common content and metadata syntaxes (often based on the XML syntax) and of standardized vocabularies. As shown, these broad ICT developments can also be seen within health domain information standardization.

### 2.4.2 Communication Domain Convergence

Communication domain convergence is best considered in relation to the OSI reference layer model for communication systems. For our study, we divide the originally seven-layer model into two categories: layers 1-4 are designated as the upper layers and layers 5-7 as the lower layers [Cis04]. The upper-layers handle application-level communication issues. In other words, they provide mechanisms for applications and ultimately for communication system users to exchange data without consideration of the underlying communication network. The lower layers handle data transport and provide for the actual piping of data through a physical network between two or more communication points.

Communication domain convergence in the upper layers is related both to convergence issues in the lower layers in a communication system context as well as to the needs of applications and convergence of information within them. As we established in our consideration of information domain convergence, XML representation is rapidly becoming a standard syntax for both content and metadata describing it. With this in mind, we consider convergence in the upper layers mostly in relation to the exchange of XML encoded data by applications. Exchange of XML encoded data can be broadly divided into two categories: XML messaging and other XML transports. XML messaging involves the exchange of data in computer-to-computer interactions. The application layer protocol SOAP (Simple Object Access Protocol) supports XML-based RPCs and messaging over HTTP transports covering XML messaging [W3C03b]. Other XML transports include the exchange of XML encoded data directly over the HTTP protocol. Considering the applications of XML messaging in health ICT solutions, we note that SOAP is a natural choice for exchanging XML encoded HL7 messages and CDA document instances. SOAP can also be utilized to exchange XML encoded MPEG-21 digital items, for example, as part of telemedicine solutions utilizing networked multimedia. Considering other XML transports, direct transport of XHTML metadata and related data (images, video, etc.) over HTTP for hypermedia-based telemedicine applications is an important application area.

Convergence in the lower layers directly facilitates the communication needs of the upper layers. As we have established that the HTTP protocol is central to convergence in the upper layers, it is natural to consider IP convergence in the lower layers. Figure 2.7 and Figure 2.8 illustrate the change to IP convergence in three computer-to-human communication domain physical configurations: in the Internet, wireless, and broadcasting domains.

The Internet communication domain designates a communication configuration where network traffic is carried over the public Internet or a closed Intranet in IP-based networking. IP traffic is carried over various physical telecommunication networks including optical fiber, coaxial cable, and satellite links. In this configuration the network typically interconnects such terminal devices as PCs and PDAs with a remote server providing web, e-mail, FTP, etc. services. The wireless communication domain (see Chapter 3) is a configuration where a circuit-switched digital mobile phone network (e.g., a GSM network) provides voice, SMS, and data services to customers with mobile stations or phones (see Chapter 3 for more details).

The broadcasting communication domain (see Chapter 3) configuration represents a DTV (Digital Television) system based, for example, on the European DVB and MHP standards. The system consists of two basic networking components: a broadcast network and an interaction network. The broadcast network provides a unidirectional MPEG-2-based digital A/V stream to consumers equipped with a DTV terminal device. The broadcast stream may carry software components to be executed locally on the consumer-side. The consumer terminal device may also support interactive use over the interaction network. This is typically done through an Internet communication domain configuration.

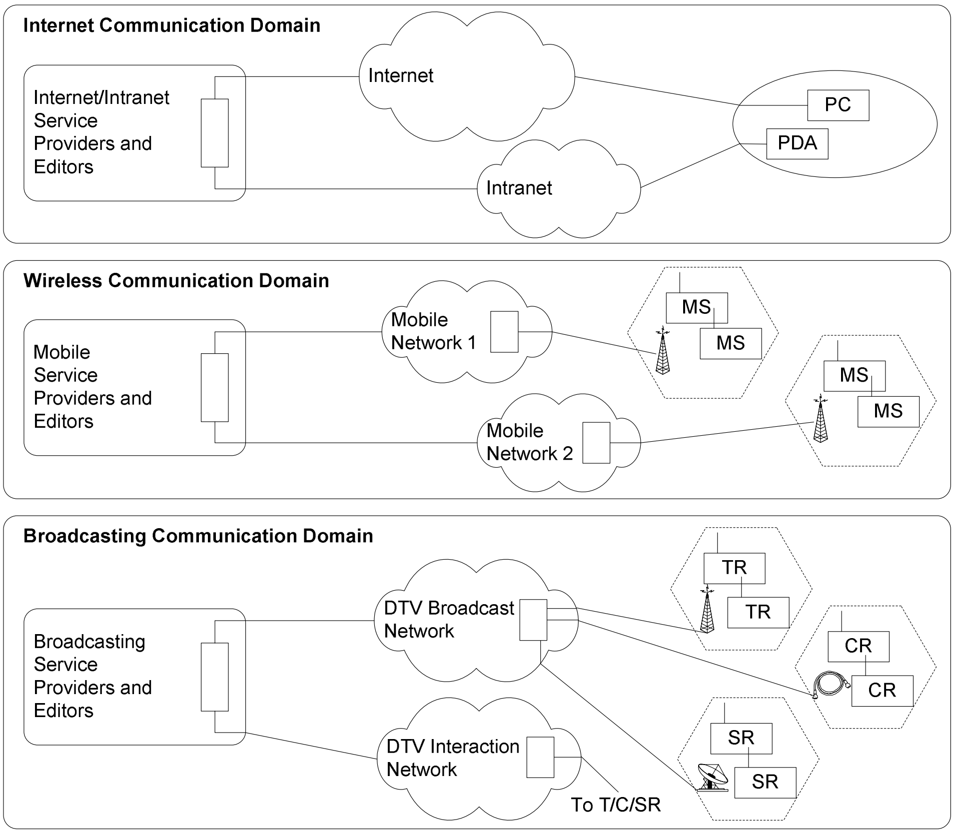


**Figure 2.7** Separate communication domain configurations (adapted from [Aal03])

In an IP convergent communication domain configuration, IP traffic can be routed through all the three separate communication domain configurations. Considering IP convergence implementations, IP data broadcasting over the broadcast network is supported by DVB DTV systems through the encapsulation of IP datagrams in the MPEG-2 stream (IP Datacasting) [Eur99], while the GPRS (General Packet Radio Service) overlays a packet-switched air interface over an existing circuit-switched (e.g., GSM) mobile network enabling direct IP-based traffic over mobile phone connections [Buc00].

Basically, IP convergence enables the provision of truly multimodal networked multimedia to various terminals using IP-based upper layer protocols. It also enables the use of Internet-proven technologies and services in other configurations relying on legacy standards. It should be noted here that IP convergence is trivial in computer-to-computer interactions as all communication can be facilitated over the Internet communication domain.

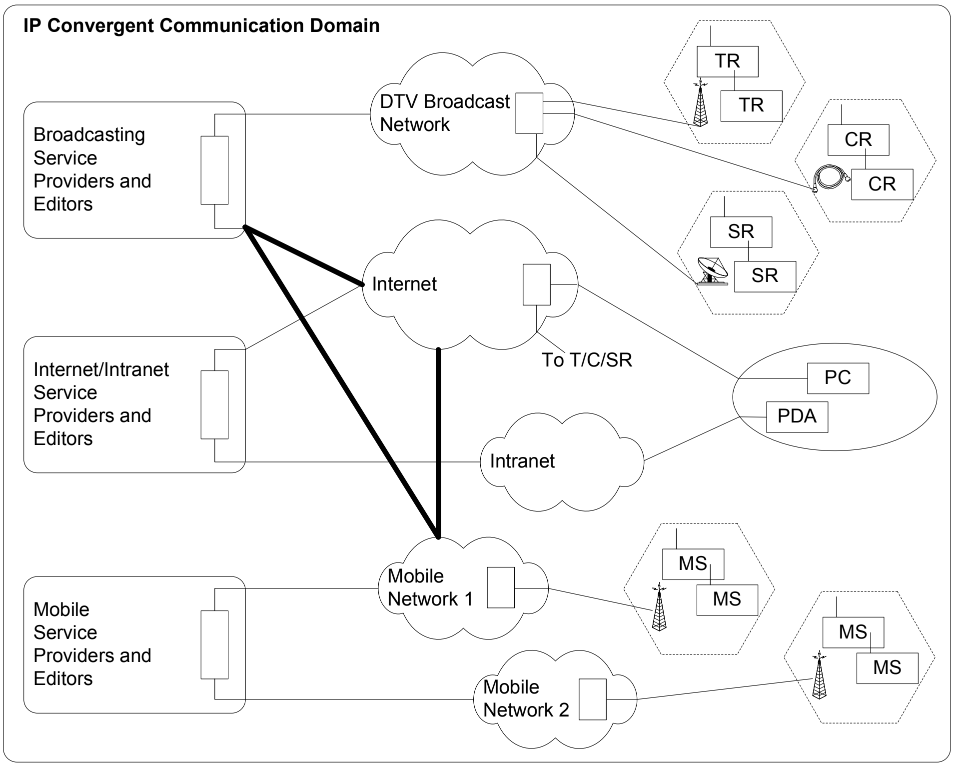


**Figure 2.8** IP convergent communication domain configuration (adapted from [Aal03])

In conclusion, XML messaging and XML and other data transports (corresponding to convergent information domain data) over standard upper layer protocols (e.g., SOAP and HTTP) in an IP convergent network configuration represent communication domain convergence.

### 2.4.3 Terminal Domain Convergence

Terminal domain convergence comes under consideration within computer-to-human interactions where a health consumer or professional utilizes a communication terminal to access distributed resources over a network. The starting point for convergence is terminal-independent support for convergent information domain standards (i.e., for the most common content and metadata formats). Hypermedia presentation access with XHTML browsers is emerging as one standard solution for accessing distributed content. The second aspect of terminal domain convergence is support for the same services on multiple terminals. This scenario extends support for common information standards to the provision of the same service functionality on several terminals. This can be successfully provided through services supporting automatic terminal adaptation and accessed with an XHTML browser. The third aspect of convergence is the use of hybrid terminals which support two or more communication domain configurations by, for example, implementing two radio interfaces. One example of such a terminal device is a DVB-H enabled GSM mobile phone. DVB-H is a standard for IP-based DTV broadcast network access from mobile terminals [Hen04].

### 2.4.4 Systems Domain Convergence

So far we have mostly considered ICT convergence from the point of view of separate convergence components: convergence of information, communication, and terminals. Systems domain convergence brings together these three convergences and adds new convergence components. Systems convergence implies both the convergence of separate systems into integrating macro systems through computer-to-computer interactions as well as integration of the described convergence components and into process-facilitating human-to-computer (macro) systems.

Integration of separate systems into macro systems involves many technologies. A key emerging standard in the area is the Web Services concept, which implements system-to-system communication in a standardized way. Web Services is built on existing standards such as HTTP, XML, SOAP, WSDL (Web Services Description Language), and UDDI (Universal Description, Discovery, and Integration) [Kre01]. The Web Services concept allows systems and applications to be integrated utilizing XML messages centered on message service semantics, which enables a loose integration of business intelligence [IBM01]. This is an ideal characteristic for a methodology meant to connect system functions in a distributed setting. In addition to messaging, the Web Services concept includes syntaxes and tools for service description (WSDL) and service locating (UDDI).

In process-facilitation convergence, system-to-system integration (e.g., through a Web Services methodology) is brought into use in a computer-to-human system implementing a particular process as a distinct service: a process-specific service. These systems facilitate the integration of different information sources in one service and are accessible in a highly-distributed setting. An example of such a system in the health domain is a service which collects the clinical records of a patient from separate sources related to a specific treatment and makes it available from multiple terminals in a seamless way.

### 2.4.5 Implications for the Health Domain

Considering the health domain, the current trend towards decentralization in health information storage, distribution, and access (e.g., related to the empowerment of patients and non-physicians in health care) creates a need for developing new ways to efficiently integrate, distribute, and access health information in process-specific contexts.

As noted, this trend coincides with information technology trends towards information, communication, terminal, and systems domain convergence. As such, convergent ICT represents a technology answer to the needs of the evolving health domain. Convergent ICT is distributed, universal, accessible, and open. It enables access to health information on open platforms anytime, anywhere, and in any way.

A hybrid model for the application of ICT in the health domain is developed in the next chapter. It considers both technological process facilitation and clinical process evaluation and represents a formalization of the application of convergent ICT in the health domain.

## 2.5 Summary Points

In this chapter we approached the application of ICT in the health domain by first describing the concept of health and the structure and evolution of the health domain. Medical or health informatics is a field of research concentrating on the application of ICT in the health domain. The taxonomy of health ICT solutions with the focus on the clinical and applied part of health informatics was described exhaustively. Evolution of the health domain due to external and internal drivers and the related impacts was recognized as a key motivator for the adoption of novel process-specific solutions in the area of health ICT categorized by the taxonomy. It was further postulated that convergent ICT is the key technology domain for these novel solutions. A description of the development of convergent ICT with consideration of process-centric health domain requirements was finalized with the observation that convergent ICT provides a number of technological possibilities in the process-specific health domain.

# 3 A HYBRID MODEL FOR PROCESS-SPECIFIC ICT IN THE HEALTH DOMAIN

Humanity's capability to use abstraction in conceptualizing our environment is a key tool in the engineering of complex systems. Abstract models help in hiding the details and in accentuating the key aspects of any entity.

As an application area for ICT, health is a complex and multifaceted field. Health strategies and their manifestations as process-specific health ICT solutions, which support overall health solution provision, require varying functionalities from ICT systems facilitating the process corresponding to each solution. By 'process' are meant here the tasks and functions related to reaching a specific prevention, treatment, or rehabilitation goal.

Obviously, an abstract model is required for the definition, implementation, utilization, and evaluation of process-specific ICT in the health domain. In the Introduction we postulated that convergent ICT is a potential solution in allowing for the robust facilitation of health solutions supporting specific processes. Four specific claims related to this postulate were made defining the research tasks at hand. It was further postulated that formalization of the application of convergent ICT in the process-specific health domain is required in the form of a hybrid model to support in seeking the validity of these claims. The topic of this chapter is to develop this hybrid model, which seeks

1. to map the requirements defined by different health domain processes and to further package broad implications of these requirements as converging engineering solutions for the implementation of a platform for process-specific health ICT solutions facilitating the said processes and exhibiting convergent ICT and;
2. to define a methodology for the evaluation of process-specific health ICT solutions utilizing versions of this platform to allow for their continuous evaluation within different evaluation areas.

As such, the presented hybrid model has two separate sub-models: a process facilitation model (PFM) and a process evaluation model (PEM). The first serves as a requirement model for a convergent ICT platform, which supports the implementation of various process-specific health ICT solutions. This model takes requirements related to processes from the three health strategies (see Chapter 2) and uses them to define a tier model serving as a basis in the building of a health ICT solution platform supporting overall health solution provision. The second model is an evaluation model for health processes developed and deployed on versions of the platform.

Apart from its use as a research methodology in this thesis, the hybrid model represents a holistic approach to the development and adoption of ICT in health solutions (see Figure 3.1). *Drivers* in the health domain have impacts on the three health strategies and create needs for new or re-defined health solutions. The *adaptation of a supporting ICT solution* for a specific process targeted by the needs requires an ICT service platform capable of supporting the process requirements. We seek to define the requirements of such a platform through the first component of the hybrid model: requirement modeling. *Formative evaluation* (see Chapter 3.5) helps during the adaptation process to fine tune the solution functionality. As a health ICT solution is *adopted,* verifying its benefits is an important consideration. This can be done through constant *summative evaluation,* resulting in a *re-assessment* and improvement of the process-specific ICT solution. Re-assessment provides a feedback loop to adoption. The second component of the hybrid model, evaluation modeling, defines evaluation targets and methodologies. It can be used as a tool for health providers utilizing a convergent ICT system in the facilitation of health services.

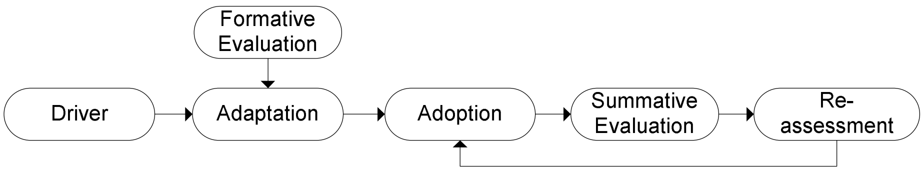


**Figure 3.1** Flow diagram for the adoption of a health ICT solution

### 3.1 PFM: Requirement Taxonomy

The health domain by its nature defines a number of requirements for solutions implementing health processes within the three strategies of health. To approach the question, we seek to define a requirement taxonomy for health ICT solutions which facilitate specific processes and support overall health solution provision. Figure 3.2 illustrates the seven requirement areas related to health ICT solution provision. First, the basic requirements related to information and communication needs within the three strategies form the basis of the requirement taxonomy. Second, service provision within the health domain is heavily regulated through national and international statutory requirements. The statutory requirements are especially evident in the medical context where data directly related to individuals is handled in non-anonymized form in an ICT solution. Statutory requirements manifest themselves primarily as security and quality requirements. Irrespective of legal requirements, privacy of medical information and overall data security in medical services is an important consideration. Accessibility, usability, quality, and efficiency are other requirements to be considered.

A brief description of the motivation behind the overall requirement taxonomy is given here. In order for an ICT solution to be able to be utilized, it has to be accessible in ways required by the process in question. Once a service is accessible, it has to be usable for the users of the same solution processes. Furthermore, successful use of the service requires a level of security again dependant on the health strategy and the specific solution. Quality and efficiency are important domain considerations related to the implementation of the processes as solutions. And as noted, the basic information and communication needs of health solutions within the three strategies form the basis of the requirement taxonomy. The basic requirements often relate to other requirement areas.

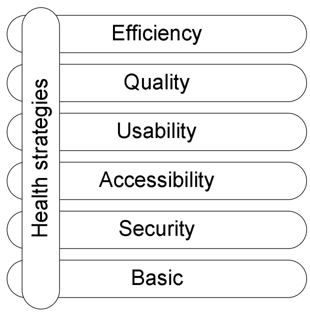


**Figure 3.2** The health requirement taxonomy

### 3.1.1 Basic Requirements

Health ICT solutions, mapped to the support needs defined by the three health strategies covering health solution provision (see Chapter 2) and related to the facilitation of specific processes, have to fulfill a set of basic requirements. This basic set of requirements can be seen to consist of two basic components: asset taxonomy requirements and communication and interaction taxonomy requirements. At a basic level, we can abstract process-specific health ICT solutions as services facilitating the exchange and intelligent utilization of health assets for specific processes through various human-to-computer and computer-to-computer communication and interaction modalities. The systems facilitate the implementation of the corresponding processes related to the three health strategies. We map the set of basic requirements by looking at the asset and communication taxonomies for processes related to the three strategies. Table 3.1 presents an overview of the asset types and communication and interaction modalities employed within the processes of the three strategies.

**Table 3.1** Basic asset and communication requirements of process-specific health ICT solutions

| Health strategy | Assets | Communication and interaction |
|---|---|---|
| Prevention processes | Generic multimedia content asset types;<br>Generic descriptive metadata asset types | Human-to-computer:<br>Push- and pull-type solutions;<br>Primarily local interaction;<br>One-way communication sufficient<br>Computer-to-computer:<br>Fetching of multimedia, etc. assets from remote systems |
| Treatment processes | Generic and proprietary multimedia content asset types;<br>Generic and proprietary metadata asset types;<br>Generic and proprietary non-multimedia asset types | Human-to-computer:<br>Primarily pull-type solutions;<br>Primarily non-local interaction;<br>Mostly two-way communication required<br>Computer-to-computer:<br>Exchange of medical, etc. messaging data |
| Rehabilitation processes | Generic multimedia content asset types;<br>Generic descriptive metadata asset types | Human-to-computer:<br>Pull-type solutions;<br>Primarily local interaction;<br>Mostly one-way communication<br>Computer-to-computer:<br>Fetching of multimedia, etc. assets from remote systems |

For preventive solutions (see [Nii03c] for an example) the applicable health assets include primarily various standard multimedia assets and related metadata employed, for example, in informational tele-prevention services providing multimedia information to consumers. The multimedia content assets include visual, aural, and textual assets wrapped typically together with the help of metadata descriptors. In the engineering domain, the visual assets include image and video data encoded with such standards as JPEG and MPEG. Similarly, the aural assets include among other things MPEG-encoded audio. Textual assets utilize standard data representation for text (e.g., at the base level ASCII encoding). For wrapping multimedia content assets together to generate informational preventive solutions, standards such as XHTML can be used. For example, XHTML is used to generate an information package or presentation from independent multimedia content assets. It should be noted that a health domain specific asset or metadata specifications are not generally used in preventive solutions.

Considering human-to-computer communication modalities, preventive services are provided to the target group, consumers, in both push- and pull-type solutions. However, availability through push-type service provision is a key requirement as prevention relies on activating passive consumers to take more responsibility for their own health. In push-type communication, the solution and its content is pushed to the consumer without his own initiative. Broadcasting services are an example of push-type service provision. In preventive services, interaction is primarily local, meaning that a two-way communication system between the provider and the consumer is not a necessity. Computer-to-computer communication is not a key element in preventive solutions. However, fetching of multimedia assets from a remote system to be included in the preventive information package is a possible scenario.

In treatment solutions (see [Nii03c] for an example) health assets include a multitude of different types ranging from generic multimedia content and metadata types to proprietarily-encoded medical data. The normative case for a treatment solution is a tele-treatment service where information is exchanged between partners (e.g., a patient or a nurse and a physician) involved in a treatment chain. The generic multimedia content and metadata asset types described earlier for preventive services generally apply for treatment services as well. In addition to them, proprietary medical multimedia standards such as DICOM for medical imaging data are applicable. Proprietary non-multimedia asset types related to treatment solutions include patient record information syntaxes and semantics (CDA, ICD-10, SNOMED, etc.), medical guideline knowledge representation formats (GLIF, etc.), and medical messaging data (HL7, etc.). Generic non-multimedia asset types include standard textual and numeric data. Human-to-computer communication in treatment solutions is mostly pull-type where users access services based on their own initiative. Reporting of changes in data available in the system (e.g., new treatment data available) may involve push-type communication to the involved users. Interaction is primarily non-local so that two-way communication facilities are required. Treatment solutions also often require computer-to-computer communication to facilitate the exchange of medical, etc. messaging data between systems.

For rehabilitation solutions (see [Nii03c] for an example), the asset-type requirements are basically the same as for prevention. A prototype for a rehabilitation solution is a service aiding the patient in physical rehabilitation, for example, in the form of exercise video combining an instructing value-added service. Human user pull-type service provision where the initiator is the rehabilitated person is the norm. Interaction is primarily local, with the exception of rehabilitative solutions involving direct, electronically mediated consultation (e.g., with a physician). Thus, one-way communication in human-to-computer interactions is adequate for most rehabilitative solutions. Similarly to preventive solutions, health domain specific asset or metadata specifications are not generally used. Possible computer-to-computer communication is similar to that of preventive solutions.

### 3.1.2 Security Requirements

Security considerations are important for health ICT solutions dealing with identifiable and confidential clinical patient records and other personal health information. Considering the different health strategies, treatment-focused health solutions handle the largest amount of sensitive patient record information and are most vulnerable from an operative point of view to security failures.

National and international regulatory and statutory requirements form the basis for compulsory security requirements for health and health care information management. In the Finnish context, the *Personal Data Act of 1999* [Per99] and the *Act on the Status and Rights of Patients of 1992* [Act92] define the basic national guidelines for the management of sensitive patient record information. Other acts and decisions by regulatory agencies have further defined health information security requirements in the ICT context. For example, the experimental *Act on Experiments with Seamless Service Chains in Social Welfare and Health Care Services and with a Social Security Card of 2000* [Act00] establishes the security, etc. guidelines for the seamless organization-to-organization sharing of electronic patient record information based on regional reference databases and electronic client Smart Cards. The basic principle is the requirement of explicit patient authorization for each data reference shared. Further description of the Finnish health ICT security regulations is available in [Kou00].

ICT security in the health domain follows the same principles as ICT security and information security in general. The key point is that health ICT solutions handling sensitive patient record information need to fully implement the available security services to achieve the required level of security.

What is security in the ICT context? ICT security is basically built around three properties of information [Lii98]:

- **Confidentiality** means that only those who are entitled to the information have it. Confidentiality protects privacy and information property rights. **Access control**, the limiting and monitoring of access to information, ensures confidentiality.

- **Integrity** implies that information does not change during storage or communication. Ensuring integrity in communication always includes **authentication**, identification of communicating parties, of the sender and the receiver in a generic bi-directional sender-receiver communication model. Integrity and authentication together ensure that information is received exactly in the form it was sent in. **Non-repudiation**, the condition that the sender or receiver can not repudiate his role as the sender or receiver of received information, is a strong form of authentication. Access control is another tool in maintaining integrity.
- **Availability** means that information is reliably available to those entitled to it.

The six concepts highlighted above (confidentiality, access control, integrity, authentication, non-repudiation, and availability) have been defined by the Internet Engineering Task Force as security services establishing ICT security in modern, distributed, and convergent ICT systems. These principles apply as such for health ICT solutions. Questions related to ICT security in the health context are further elaborated in [Nii02c].

#### 3.1.3 Accessibility Requirements

Accessibility implies here easy and egalitarian access to health ICT solutions and information conveyed within them. The concept includes **geographical** and **temporal** accessibility.

Geographical accessibility means that health solutions and related information can be accessed independent of the location of the user of the service representing the solution. Sparsely populated rural areas, the related large distances to and between health and health care providers and a lack of adequate fixed communication facilities, represent a challenge for accessible provision of services to both consumers and professionals. Geographical accessibility requires mobile access or intelligent utilization of fixed legacy communication systems to facilitate adequate spanning of distances (e.g., in tele-treatment). Utilization of wireless communication is an obvious choice of technology for dealing with geographical separation within solutions related to all three domains of health. From the user's point of view, health professionals working in rural areas need portable terminals for access to health ICT solutions, for example, in home-care situations where consultations to a remote primary care health center are required. In the patient-professional communication of treatment solutions, the availability of any direct ICT communication tool for exchanging information over large geographical distances represents an improvement over the typical conventional situation. In preventive or health information provision, the possibility to reach large audiences in a push-type service model is a key tool in facilitating access.

Temporal accessibility implies that health solutions are available independent of temporal restrictions (e.g., the office hours of a health provider). A key communication modality related to temporal accessibility is asynchronous communication. In the current context this implies that the receiver and sender need not be simultaneously active to facilitate a communication session. Various queuing or storing messaging methods (e.g., conventional mail or e-mail) provide such functionality. In the health domain, especially when considering treatment solutions involving frequent patient-professional communication, asynchronous communication facilitated through ICT enables flexible use of time for busy professionals as well as a reliable way for consumers to reach the professional.

#### 3.1.4 Usability Requirements

Usability refers to the ability of all relevant user groups to successfully employ and use accessible health solutions. For both health professionals and patients, unique sets of usability requirements arise within each health strategy domain. If health ICT solutions (especially within the treatment strategy) are to be implemented with a more process-centric methodology, a key question for professionals is desktop integration where a number of process-specific ICT solutions integrate on one (e.g., workstation) desktop. Another important usability issue for professionals is the possibility to handle routine tasks with minimal time and complexity. For treatment solutions, the availability of a use context optimized for each user and use situation is a key usability consideration. Personalization and use of situation awareness in user interfaces helps users to handle tasks more efficiently. Multimodal access (diversity of end-user platforms) is required to fulfill the numerous imaginable scenarios and situations of use.

Considering the health consumer, a key observation is the fact that the typical consumer of health care and health solutions deviates from the average one in many characteristics. For example, health consumers represent an older-than-average sub-population with the difference being amplified in health care-related activities. Obviously, ICT proficiency reduces significantly with age, resulting in a hindrance in the adoption of ICT solutions used directly by consumers. One solution for this problem is to use end-user technologies with simple interfaces and a high degree of usability. Another methodology for providing good usability is personalization, where contents and user interfaces are provided in an individualized way for each consumer group or individual. ICT personalization within and beyond the health domain is considered in further detail in [Nii02b], [Nii03d], and [Lug04]. Usability relates to ICT solutions within all three health strategies. However, in treatment solutions it is of critical importance in achieving a successful implementation.

### 3.1.5 Quality Requirements

Quality or effectiveness implies here improvements in the health of the individual and populations achieved with the help of health solutions. In our consideration, quality is explicitly separated from the concept of efficiency as it is often difficult to consider it in strictly economic terms. Naturally, quality and efficiency are closely intertwined in real-life health service provision. Health service providers, especially in the narrower field of health care, seek to provide health services with maximal attainable effectiveness or quality. Ultimately, quality manifests itself in improving the quality of life of health consumers or patients.

Considering the different health strategies, we note that in treatment and rehabilitation quality is a clinical measure. In other words, it is mostly related to professional and health care activities. Clinical measures of quality include the risk for reoccurrence of disease after treatment, the effect of rehabilitation on the patient's disability, etc. Quality of prevention is on the other hand a public health measure with a wider scope and is harder to measure. Nevertheless, quality is a key requirement of all health (ICT) solutions. That is, all new solutions, especially those seeking to radically change old conventions, should at minimum show similar quality or effectiveness as the conventional solution. In order to achieve objective improvements in quality, a deeper understanding of underlying health processes and mechanisms is required. From an ICT perspective, intelligent use of refined data of a higher abstraction level (i.e., knowledge) is a potential facilitator of more effective health solution provision.

### 3.1.6 Efficiency Requirements

The requirement for efficiency in the health domain, especially in health care, flows from the basic premise of limited resource allocation; the cost factor is a critical condition within most activities of the health domain. This statement illustrates the fact that efficiency as a concept relates to economic realities rather than to the core goals of health. However, as the general cost of medical procedures increases with the introduction of new expensive modalities and as populations age and higher health aspirations on the part of the general population emerge [Tav04], health care providers face difficult challenges in maintaining the current level of service provision without reaching the limits of available resources.

Considering this, efficiency in the health domain is mainly a management problem. Effective allocation of the available limited resources as a management strategy is a key methodology in maintaining the stability of the health care system.

Several approaches enable increasing efficiency in health solution provision. For example, management of treatments through high-volume clinics responsible for one area or disease potentially enables more efficient resource allocation through increased specialization (see [Fos99] for an example from anticoagulant treatment). From an ICT perspective, efficiency is a requirement area where ICT has potentially much to offer. Electronically stored and mediated data can help to increase the speed of communication between consumers and their health professionals dramatically and to help in workload organization and sharing for professionals.

### 3.2 PFM: ICT Tier Model for Process-Specific Health Solutions

As we have now considered the generic requirements of process-specific health solutions operating within the three strategies, we will next consider how the requirements map out in a technological context. As noted, ICT health solutions are implemented to support complex processes as defined by the specific application areas within the three strategies of health. Abstract technology modeling of these processes helps to define and assess the unique requirements thrust upon ICT solutions supporting health processes in the engineering domain.

Tier models are a common tool in ICT, helping to abstract processes to be implemented as ICT services. An ICT tier model developed for health domain process-specific services is presented next. The model is an abstraction of a generic, distributed ICT system where data flows between a human health user (consumer or professional) or another system accessing the client tier and the resource tier which represents health data to be utilized in health solutions. Vertical communication tools facilitate the bi-directional flow of health data, information, and knowledge within the tier model. The bi-directional information flow represents the functioning of the practical manifestations of the abstract model: process-specific health ICT solutions. Deployment and execution tools provide facilities for the deployment and execution of components realizing functionality of different tiers.

The developed ICT solution requirement taxonomy defines the properties for components of the model and the modes of communication between them. The tier model (see Figure 3.3) consists of five tiers: resource, integration, processing, presentation, and client tiers.

As noted, health processes serve as a source of requirements for the tier model components and the vertical tools. The requirements flow from the six requirement areas of the health process domain.

Health assets – health data, information, and knowledge – and service components are persisted on the **resource tier**. The tier represents a permanent health asset repository.

Engineering implementations of the resource tier include among other things various database systems serving as data repositories or service component access facilities.

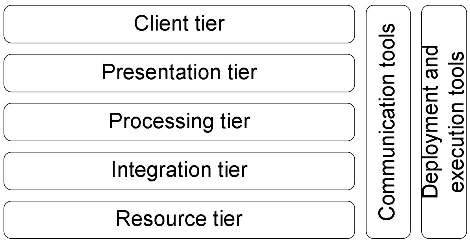


**Figure 3.3** The health ICT tier model (adapted from [Alu01])

The **integration tier** facilitates access to resource tier assets and service components from the processing tier. In the engineering domain, this integration domain functionality is implemented through various middleware technologies. In a distributed system, the physical location of the resource tier is not visible to tiers above the integration tier. In the case of a remote resource, the integration tier accesses the client tier of another system in system-to-system interaction. The tier thus serves as an abstraction layer for unified access to different asset and service depositories.

The **processing** tier implements the primary business logic of the process-specific health solution supported by an ICT service. To implement the business tasks of the process in question, the tier components organize, aggregate, refine, and otherwise process assets retrieved through the integration tier from several sources for presentation. The processing tier may also access external service components through the integration tier, for example, to facilitate a sub-process of the process task at hand.

The **presentation tier** includes all presentation logic required to service the clients accessing the system [Alu01]. When the client is a human, assets retrieved from the processing tier are combined with user interface templates into human-usable services with process-stage dependant user interfaces. In this case, as an interface for human users, the tier handles the provision of health data, information, and knowledge to and from human users through implementing server-side user interface logic. With system clients, the presentation tier facilitates access to the local processing tier functionality.

The **client tier** represents human user client terminals or system clients accessing the services provided by the system.

**Communication tools** pipe assets and service functionality through various communication channels to enable asset exchange and service functionality within tiers of the system represented by the model. The tier facilitates asset and service function flow both in computer-to-human as well as in computer-to-computer interactions.

**Deployment and execution tools** provide the facilities for the deployment and execution of components realizing functionality of the different tiers.

### 3.3 PFM: Requirements for ICT Model Tiers

Naturally, each specific process specifies its unique requirements on a health ICT solution supporting it. However, it is not feasible to look at each specific process separately. To approach the question formally, we look at requirements for each ICT tier model component at the more abstract level of health strategies (i.e., prevention, treatment, and rehabilitation). See the Appendix for a detailed description of the health strategy requirements for the different tiers and tools.

### 3.4 PFM: Converging Engineering Solutions

In the previous sub-chapter we identified the individual requirements for the tiers and tools of the ICT tier model as defined by process-specific health solutions within the three health strategies. While the identified individual requirements serve as a listing of the relevant properties of the sub-parts of a comprehensive and process-oriented health ICT solution platform, an abstraction of the properties to a systems level is required. Considering the requirements specified in the Appendix, the following generalized requirements can be identified for a process-oriented health ICT platform:

- Support for a wide variety of asset types and their combinations, ranging from common multimedia content and metadata assets to proprietary health asset types and other asset types. Often different asset types are exchanged in human-to-computer and computer-to-computer interactions.
- Human access to the same health ICT solutions from multiple client platforms with platform and personalization adaptation in contents and user interfaces
- Integration of process-specific health, especially treatment, ICT solutions into centralized health ICT systems to exchange patient records and other data
- Comprehensive security solutions, especially for treatment solutions where sensitive patient record information is handled

- Intelligent utilization of knowledge, especially in treatment solutions, facilitating personalization, medical decision support, etc.

The following converging and ICT model tier-spanning engineering solutions help in facilitating these generalized requirements:

- Converging networked multimedia (mainly facilitates requirements 1 and 2)
- Converging middleware (mainly facilitates requirements 1 and 3)
- Converging security (mainly facilitates requirement 4)
- Converging discovery and use of knowledge (mainly facilitates requirement 5)

Naturally, these four engineering solutions are interconnected and overlap each other in a systems context. However, in requirements analysis they help in identifying important design considerations. The next chapter considers, among other things, systems integration of these engineering solutions.

### 3.4.1 Converging Networked Multimedia

What is networked multimedia? From an engineering science point of view it can be considered a discipline of signal processing. A basic definition for the term "networked multimedia" is given below.

**Definition 3-1** Networked multimedia

"The concept of networked multimedia conveys the idea that multimedia content and services are provided in a distributed context, utilizing modern digital communication media and terminals."

Networked multimedia is emerging as an important tool in health ICT and relates to three of the four ICT convergence trends identified in the previously: to information, communication, and terminal convergence. Each of these convergence trends has applications in the health domain.

As an increasing amount of health and health care information is available by default in multimedia form, converging asset syntaxes and semantics aid their provision in distributed ICT services. Wrapping of metadata with multimedia content assets to create hypermedia service representations accessed in a distributed setting is a key information convergence trend. XHTML and other W3C standards are emerging as a standard content and service user interface representation format in networked multimedia. Additionally, representation of originally non-multimedia health care information as multimedia in the same context provides enhanced visualization and conceptualization for human users.

In a communication and terminal context, networked multimedia offers a solution for providing more distributed access to health and health care information. Distributed access is needed due to the trends of devolution of responsibility to non-physician actors and empowerment of patients in health care. Networked multimedia brings health information and services to a distributed context where modern digital communication media serve as a service nexus enabling access anytime, anywhere, and in any way. This is possible by enabling access to the same services through communication and terminal convergence.

Figure 3.4 illustrates the application of converging networked multimedia in process-specific health ICT from a communication domain perspective.

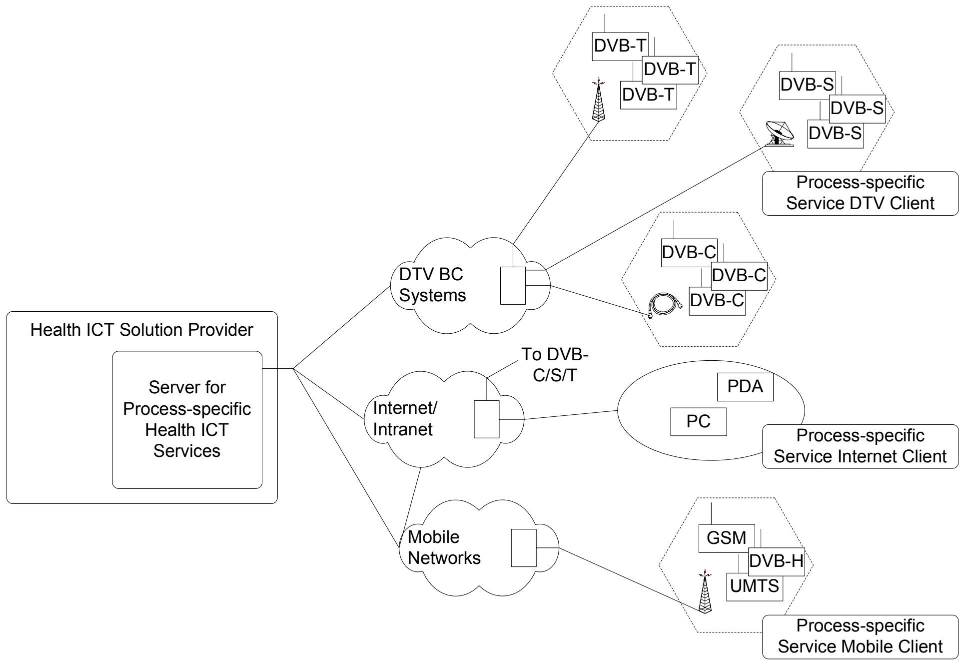


**Figure 3.4** Converging networked multimedia in process-specific health ICT

The health ICT solution provider maintains a process-specific ICT service in a setting with communication domain IP convergence in the interactive communication domains as well as support for proprietary broadcasting and mobile systems. Terminal convergence is implied by the availability of the service functionality in different client domains. Information convergence means that common information representation formats and semantics are used in the data piped between the server and the clients.

Typically this means the use of XML metadata (e.g., XHTML) to describe a hypermedia service with content provision and interaction support for different client domain terminals. Naturally, the hypermedia representation is formatted to comply with the specifications of each client. Apart from hypermedia representation (i.e., XML metadata and textual and image content), data such as A/V streams in broadcasting and proprietary messaging in the mobile domain are supported. As a tier-spanning engineering solution, networked multimedia is mainly a solution for presentation and client tier functionality of the abstract ICT tier model for a process-specific health ICT solution platform. The relevant communication tools are also covered here.

We will next elaborate further on the technologies and health domain applications of the three main networked multimedia domains: the Internet, mobile, and broadcasting domains. We seek to identify the characteristics, advantages, and drawbacks of each domain in the three strategies of health.

**Internet Multimedia – the Standard Approach**

The term “Internet multimedia” is meant here to refer to networked multimedia used from personal computers or other computer-like terminals such as PDAs. Standard Internet multimedia technology is built around the use of web browsers to access hypermedia presentations from a server-side implementation. In ICT terminology the World Wide Web (web) denotes (X)HTML-based and hypermedia-oriented services accessed with the HTTP protocol over the public Internet or private intranets from PCs and similar terminals using standard web browsers.

A universally understood metadata language is required to publish information for global distribution. The publishing metadata language used in the web is HTML (from HyperText Markup Language) based on the SGML standard. [W3C99]

HTML enables authors and service providers to [W3C99]:

- Publish online hypertext documents
- Retrieve online information via hypertext links
- Design forms for conducting transactions with remote services
- Include external applications (e.g., video clips) directly in their documents

The history of HTML begins with efforts by Tim Berners-Lee and the Internet Engineering Task Force (IETF) in the early 1990s with the introduction of HTML 1.0 and HTML 2.0. HTML Versions 3.0 and 3.2 developed under the aegis of the W3C came in the mid 1990s and added several new features to HTML. HTML 4.0 further extends HTML with mechanisms for separating content from its presentation (CSS style sheets), provision for standardized scripting support (JavaScript), and object embedment, among other characteristics. [W3C99]

Illustrating the trend towards XML syntax convergence in metadata representation, eXtensible HyperText Markup Language (XHTML) is a family of hypermedia document types and modules which reproduce, subset, and extend standard HTML, represented in XML syntax. XHTML 1.0 was W3C's first recommendation for XHTML, developed based on earlier HTML standards. XHTML 2.0 is currently under development. [W3C03]

Apart from basic XHTML metadata-based web services, other Internet domain technologies relevant to the health domain exist. Internet e-mail utilizing such OSI reference model application layer protocols as SMTP (Simple Mail Transfer Protocol) and POP (Post Office Protocol) and PC or PDA mail client software for sending and receiving e-mail messages are important in converging messaging services for process-specific health ICT solutions. Furthermore, custom applications launched within (X)HTML documents from web browsers, such as Java Applets and Microsoft ActiveX controls, bring distributed applications to the Internet domain. In fact, it has been asserted that Internet services relying on XHTML markup and current browser technology significantly restrict service functionality when compared to stand-alone operating system applications [Tog21]. For example, manipulation of complex A/V content or user interface components for complex data submission is impossible or lacking on standard web browsers. A solution within the Internet domain is the adoption of technologies which enable seamless download and/or execution of OS or platform independent applications over internetworking protocols. The aforementioned Java Applets, where Java application byte code is downloaded from a remote server from a web browser and executed on a local JVM (Java Virtual Machine), are one such solution.

Communication convergence within the Internet domain is practically automatic as Internet services by definition rely on TCP/IP networking.

Several health ICT solutions have been implemented in the Internet domain (see [Lam02b] for a review). We consider here the consumer, multimedia, and health process oriented applications related to the three strategies of health.

A report by the U.S. Alliance of Community Health Plans [All03] concludes that the Internet is an important and common tool for the dissemination of preventive information and educational services to health consumers (i.e., tele-prevention). Typical consumer-oriented tele-prevention solutions in the Internet domain include educational web sites about nutritional choices and discussion forums where prevention issues are discussed and expert knowledge is available. Informational web pages with personalized preventive content and services allow more targeted facilitation of prevention than traditional means.

A report by the California Health Foundation [Cai00] points out that up to 60% of consumers searching for health information on the Internet are in good health and do not have a medical diagnosis or a chronic disease. For this group preventive information is one of the key areas of interest. Considering how successful consumers are in finding preventive and other information on the web, a study from the year 2002 [Eys02] showed that it took an average of less than six minutes for the studied consumer group to locate answers to individual health questions. However, it was also observed that the studied consumers did not consider criticism of sources important when searching for information on the web. Despite several efforts to bring content quality evaluation tools to the web (e.g., HON certification of health web sites by the Health on Net Foundation, see www.hon.ch), reliability and credibility evaluation of the health information available on the open web (and consumer attitudes towards criticism of sources) remains a key problem. Despite being a convenient tele-prevention dissemination methodology, the openness of the web makes it difficult to ensure consumers that the information made available is reliable, and on the other hand it inhibits the promotion of the web as a reliable source for preventive information. This is due to the amount of questionable information available in the media. Another downside to the Internet domain is the fact that web services are a pull-type service requiring the consumer to actively search for the service. There are consumer groups targeted in health prevention for which Internet penetration remains very low. In some prevention solutions, for example those targeting large population groups as part of a national campaign, a better penetration can be achieved with push-type service provision not available with web services. An Internet domain technology suited in principle for push-type prevention is e-mail. However, e-mail as a mass media tool suffers from information overflow (i.e., unsolicited e-mails) related to the openness of the service.

Several tele-treatment solutions have been deployed in the Internet domain. Typically these solutions extend centralized health ICT systems used in primary care with process (disease) specific tele-care disease management systems deployed on the Internet or on an intranet. Tele-care often involves the direct participation of patients operating in a home environment as users of the tele-care service and point-of-care (POC) follow-up testing with a portable meter in self-care and self-follow-up (home health care systems). Internet-based or Internet-supported tele-care systems have been deployed in asthma self-care [Fin01], respiratory patient follow-up [Mor99], diabetes care management [Bak01] and self-management support [McK98], and anticoagulation medication follow-up [Lam03a] with generally positive results. Advanced Internet domain tele-care solutions typically combine an electronic follow-up card (or another process-specific virtual data repository) realized as interactive web pages with an asynchronous communication methodology (i.e., a messaging system similar to e-mail). These two can facilitate patient-to-physician communication in self-care and patient-nurse communication in home-care. Internet e-mail can be used as a converging tool notifying users of changes (e.g., new messages or measurements) in the service. The Internet domain has also been applied in other tele-treatment domains, including tele-diagnosis, tele-consultation, and tele-monitoring. As an example of Internet tele-monitoring, hypertension blood pressure monitoring data was transmitted over the Internet from patient homes in a study by Aris et al. [Ari01].

Considering the Internet domain and tele-treatment from a usability point of view, the PC web browsers used allow a large degree of complexity in user interfaces and contents. This is typically the requirement for professional user (i.e., physician and nurse) interfaces to tele-treatment solutions. Professionals require extensive visualization, printing, and service maintenance facilities from tele-treatment solutions. These are ideally implemented in a PC web browser setting and are hard to realize in other networked multimedia environments. For consumers already familiar with computers and possessing the necessary, relatively expensive, equipment, PC-based Internet, web, and e-mail are an optimal solution for tele-treatment participation as the domain offers the maximum amount of flexibility. However, for user groups unfamiliar with modern ICT, the hurdle in using the relatively complex PC-based Internet domain solutions is very high. Also, a high degree of mobility for users, which can be beneficial in tele-treatment solutions, is not possible in the conventional Internet domain, which relies on fixed terminals. It should also be noted that when tele-treatment services are used over the public Internet, security guarantees are of special importance.

Tele-rehabilitation is not currently a commonly deployed solution type in the Internet domain. Rehabilitation services like tele-coaching in the context of rehabilitative physiotherapy require facilities for the reception of high-bandwidth streaming audio/visual content, for example, to observe a therapy coaching video. Another example of high-bandwidth tele-rehabilitation is virtual face-to-face consultation with a physician over a high-speed video link. Bandwidth limitations and QoS (Quality-of-Service) issues in the Internet domain limit the provision of such content to PC-based web browsers. However, in a study by Russell et al. [Rus03] on knee arthroplasty telerehabilitation consultations, limited evidence for the efficacy of low-bandwidth tele-rehabilitation over the Internet was observed. As and if more network bandwidth with better QoS becomes available, the potential for tele-rehabilitation in the Internet domain will increase.

Apart from the depicted tele-coaching and tele-consultation involving rehabilitation, standard informational web services for the more limited area of rehabilitation information dissemination (similar to prevention web services) exist. However, simple information dissemination is only a small part of rehabilitation.

**Mobile Multimedia – Time and Location Independence**

Mobile multimedia refers here to networked multimedia services delivered over digital mobile phone networks. We omit other wireless technologies with strictly local networks, such as wireless LANs or Bluetooth connectivity. The most commonly adopted standard for digital mobile telephony is the 2G GSM (Global System for Mobile Communications) standard. The primary application area of GSM mobile phone systems is digital and secure standard voice call service. SMS (Short Message Service) text messaging [Buc00b] and MMS (Multimedia Messaging Service) multimedia messaging [GSM04] augment standard GSM voice services with the possibility to receive and send messaging data with GSM mobile stations.

Apart from messaging services, GSM mobile systems support hypermedia service provision similar to (X)HTML services on PC-based web. The WAP Forum has developed standards for mobile Internet. WAP (Wireless Application Protocol) is a set of standards specifying all protocols, languages, and component behavior required for the implementation of mobile Internet applications and browsing. WAP 1.x standards include the markup metadata language WML (Wireless Markup Language), which is similar to HTML but optimized for mobile terminals, and the networking protocol WPS (Wireless Protocol Stack). The WAP 1.x standards introduced in the late 1990s have severe limitations, and services based on them have generally not been commercially successful. As an example, WML does not include support for formatting of content, resulting in drastically different presentation of the same WML page on different terminals. [Nok02]

With WAP 2.0, mobile hypermedia-based multimedia is moving towards XHTML convergence in the information domain. XHTML (MP or Mobile Profile) is an adaptation of the XHTML Basic DTD defined by the W3C for the mobile phone terminal domain (see Figure 3.5). [Nok02]

Importantly, XHTML (MP) includes support for a mobile version CSS (Cascading Style Sheets), bringing standardized content formatting and layout support to mobile hypermedia. WAP 2.0 compliant dual-mode browsers in mobile phones will support both WML 1.x and XHTML (MP). [Nok02]

In addition to messaging and hypermedia services, existing and upcoming mobile phones equipped with Java and other open platforms enable direct application development (e.g., for specialized multimedia applications).

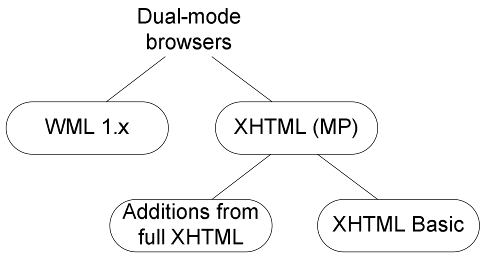


**Figure 3.5** Support for markup languages in future mobile terminal browsers

The data throughput to a standard GSM mobile phone is generally limited to 9.6 kbit/s. As noted earlier, an extension to GSM, the 2.5G GPRS (General Packet Radio Service), allows bandwidths up to a theoretical maximum of 170 kbit/s, enabling more complex multimedia services than standard GSM. GRPS also introduces packet-based data services to the mobile domain. GPRS facilitates communication convergence in the domain of mobile multimedia as it enables direct IP-based internetworking over mobile networks. [Buc00]

3G mobile standards such as 3GSM extend 2.5G GPRS by bringing even more bandwidth to the mobile terminal with the introduction of a new radio interface and new terminal types with enhanced capabilities [Buc01]. Together these make possible a new range of multimedia services in the mobile domain, including high-bandwidth A/V streaming.

Similar to the Internet, numerous health ICT solutions have been implemented in the mobile domain. As in the Internet domain, the consumer, multimedia, and health process oriented applications related to the three strategies of health are considered here. A paper by Tachakra et al. [Tac04] reviews current trends in wireless communication and their application in telemedicine and health care. According to the authors, modern digital mobile communication technology can make remote medical monitoring, consulting, and health care more flexible and convenient especially in terms of time and location independence.

Considering the three strategies of health, mobile phones are rarely used in the dissemination of educational or preventive information in tele-prevention. The display size and quality of most mobile terminals limit the provision of rich multimedia content on the platform. Mobile phones do support push-type service provision, which is important in some preventive solutions, in the form of text or multimedia messaging. However, consumers are not used to mass media service provision to mobile terminals and unsolicited telephony is generally considered an invasion of privacy.

Tele-treatment is the most important health ICT strategy for mobile multimedia. Numerous tele-monitoring solutions use digital mobile phones, networks, and multimedia for remote (home) monitoring. Medical application areas include asthma tele-monitoring over digital phone networks [Fin98] and WAP-based blood pressure and ECG monitoring [Hun03]. In the asthma tele-monitoring example, self-testing asthma patients were equipped with a portable spirometer and pocket-sized palmtop computer connected to a cellular network for data exchange between the home environment and professionals [Fin98]. In the latter example, WAP browser equipped mobile phones were used for accessing multimedia representations of monitored patients' blood pressure and ECG data [Hun03]. Mobile phones have been widely applied in tele-care solutions where two-way communication and interaction, for example between a physician and home-management patients, are important. In a study by Maglaveras et al. [Mag01], WAP browser equipped mobile phones were used in diabetes home-care to facilitate information exchange between the diabetic patient and reviewing physicians (e.g., submission of home-measurement glucose values by patients and educational messages by the submission reviewing physicians). Apart from these examples from mobile multimedia, mobile SMS (see [Buc00b]) and MMS messaging (see [GSM04]) has potential applications in delivering treatment or medication guidelines to home-restricted patients. Digital mobile phones and mobile multimedia have also been applied in radiological tele-consultations [Nii01].

Common to all applications of mobile multimedia in tele-treatment is the achieved time and location independence. Mobile terminals with cellular communications are easy to carry and enable versatile connectivity from almost anywhere. Furthermore, it can be argued that more people are familiar with the use of mobile phones (especially among the older age groups overrepresented among health consumer groups) than with Internet technology[*]. Similar to the Internet domain, security is an important topic for tele-treatment mobile multimedia dealing with patient record information.

See [Win02] for an overview of tele-rehabilitation with special emphasis on the possibilities of mobile communications in the area. As an example of mobile tele-rehabilitation, multimedia teleconferencing between a rehabilitated patient (a mobile terminal) and a practitioner (a fixed terminal) is an increasingly feasible service model with increasing mobile network bandwidth.

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[*] 90% of Finnish households had a mobile phone in 2001, while only 37% had an Internet connection [Sta04].

Apart from digital mobile phones, health applications utilizing wireless LANs and Bluetooth device-to-device connectivity exist. The main difference between these and traditional mobile networks is the communication coverage and range.

**Broadcasting Multimedia – a Diversity of Possibilities**

Broadcasting multimedia is a common denominator for networked multimedia platforms which involve the use of a unidirectional broadcast channel to convey high–speed digital A/V services to consumer DTV receivers. This basic service provision can be augmented through the implementation of a bi-directional interaction channel enabling non-local interaction for end-users as well as standardization for the conveyance and execution of value-added services and data to the consumer receiver over the broadcast and interaction channels. Broadcasting multimedia is considered here in the context of digital television (DTV) systems and standards. [Lug04]

Considering the functionality and structure of contemporary DTV systems, the ISO/IEC 13181 family of standards (see [ISO00]) defines the basic technology, MPEG-2, for the compression and encoding of complex services combining A/V and other data streamed over different physical broadcast networks.

This basic service provision defined by ISO/IEC 13181 is augmented in the respective DTV standards through the introduction of MPEG-2 transport stream (TS) transmission technologies for various physical broadcast transmission media including satellite, cable, and terrestrial systems and high-level mechanisms for broadcasting application data in the TS. The standards also define how interactive services are realized in the respective platforms, including software APIs for end-user terminals and standards for the utilization of interactive media. The APIs for consumer receivers define a platform for the deployment of value-added services with support for accessing resources from the digital TV broadcasts and through a feedback network. The Sun Microsystems' JavaTV API serves as a fundamental building block for the consumer terminal software APIs. As MPEG-2 is the basic technology for uni-directional DTV broadcasts, an IP convergent approach is the norm in the interactive DTV communication domain. [Lug04]

The DVB (Digital Video Broadcasting) consortium has developed a set of standards towards a DTV system augmenting the basic MPEG-2 standards. The DVB system reference architecture corresponds to the one presented in the broadcasting domain part of Figure 3.4. The DVB standards specify modulation and other transmission technologies for MPEG-2 TS streams for satellite, cable, and terrestrial broadcast networks as well as standards for DVB data broadcasting [Eur99]. They define functionality of the DVB broadcast channel and network from the broadcasting service provider to the consumer receiver. The DVB interaction channel and network allow the bi-directional flow of data between the consumer receivers and the interactive service provider. IP convergence is a normative approach of DVB to interactive communications [Lug04].

Multimedia Home Platform (MHP) (see [Eur01]) adds a technical solution for the consumer receiver or STB, enabling the reception and presentation of applications in an open and vendor, author and broadcaster neutral framework. In practice, MHP defines a Java-based STB API for value-added services in DVB broadcast systems. It relies on the DVB DTV system reference model with standardized broadcast and feedback channels [Lug04].

A layer model for an MHP receiver or set-top-box, combining software and hardware components, is illustrated in Figure 3.6. The blocks on the right–hand side of the figure describe access to and use of basic digital TV A/V broadcast services (i.e., viewing different TV channels) of the MHP receiver. An MHP receiver includes as a standard feature a navigator application for selecting and tuning digital TV A/V services, which may include interactive value-added services. The layer model for value-added MHP applications is shown through the blocks on the left-hand side of the figure. Interactive application code and data are typically transported to the receiver through the DVB data broadcast DSM-CC object carousel mechanism over the broadcast MPEG-2 TS. The application code and data can also be uploaded over the interactive channel. An MHP receiver can support two types of interactive applications controlled by its application manager [Lug04]:

- Procedural DVB-J applications
- Declarative DVB-HTML applications.

DVB-J is an adaptation of the Sun Microsystems' Java programming language and J2SE API to MHP receivers. DVB-J defines a DVB-J application model and a DVB-J platform. The API includes various components for the realization of interactive value-added iDTV services, including standard J2SE features (e.g., for networking and basic I/O services (Core Java)) and DVB Java components (e.g., for television-oriented GUIs and for accessing data broadcasting resources). DVB-J applications are executed on the receiver STB and can be controlled by signaling received from the broadcast or through consumer interaction. [Lug04]

The declarative DVB-HTML application is a set of DVB-HTML compliant HTML documents and content objects. DVB-HTML applications can be considered an adaptation of the World Wide Web to digital TV. DVB-HTML is an adaptation of XHTML to the DTV domain, representing a convergence towards XHTML in hypermedia presentation on the platform. MHP defines an application, life–cycle, and signaling model for DVB-HTML applications similar to those of DVB-

J applications [Lug04]. DVB-HTML standardization may also be utilized through the development of DVB-J compliant XHTML browser applications which can be used to access XHTML hypermedia content and interaction services similar to those on the PC-based web from a DTV receiver.

The system software for both standard digital TV A/V services and interactive value-added applications relies on the hardware and software resources available in an MHP receiver.

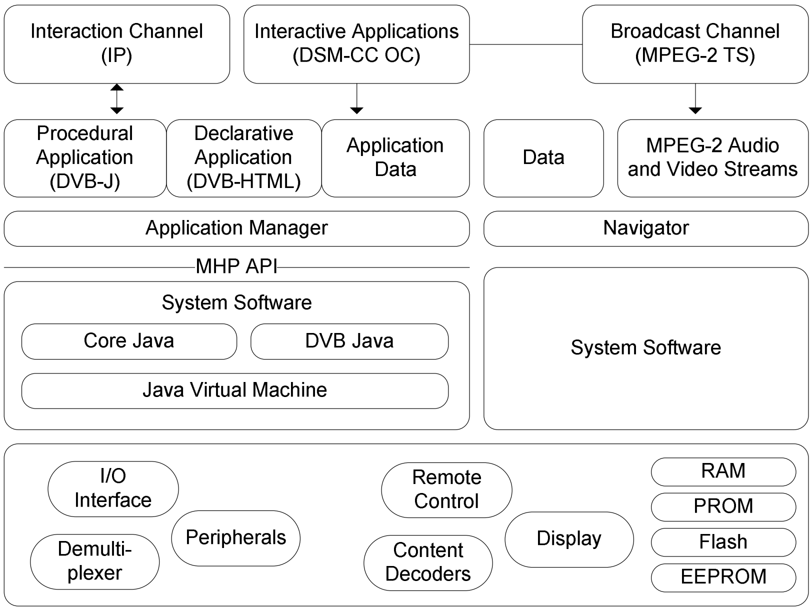


**Figure 3.6** MHP receiver architecture (adapted from [Lug04])

From a service type point of view, DVB interactive applications can be either related to the DTV A/V broadcast they are broadcasted with or be independent of them. Considering display on the TV screen, both DVB-J and DVB-HTML applications are layered on top of the video layer with optional transparency and video layer scaling. Interactive applications are typically controlled with a remote controller or a wireless keyboard.

As a subset of networked multimedia, broadcasting multimedia is a fascinating area in health service and information distribution and access, providing the ability to combine high-speed A/V streaming with value-added services. Application of DTV in the health domain has been further considered in [Lam02].

Considering the three strategies of health, interactive DTV is a potential media for the dissemination of educational or preventive information in tele-prevention. Tele-prevention services can be provided to the consumer with a push-type service model and can combine rich multimedia types, including preventive TV programming enhanced with related value-added services. In a resources review by Hain [Hai02] considering DTV as a source for health information, it was observed that the general population dislikes textual information as a source for health information. Video-based services through DTV were seen as a better methodology for reaching wide audiences. In a questionnaire survey by Nicholas et al. [Nic03] studying the use and perception of two DTV health information services, it was observed that the services were relatively widely used and, on the whole, rated favorably. However, reaching older age groups with preventive services remains a challenge as relatively few of the elderly have digital TV equipment. In a 2002 European survey of elderly people by Stroetmann et al. [Str02] on their interest in eHealth, it was observed that only 13% had digital TV receivers, while 98% did have access to conventional analog television.

In tele-treatment, DTV is a potential platform for special patient groups in tele-care. For example, the large screen size and simple user interfaces of interactive DTV tele-care services make them potentially feasible for the vision-impaired or the elderly with limited use abilities. Tele-care through DTV can involve the use of the receiver as a browser platform for accessing simple hypermedia-based (e.g., XHTML) tele-care services to submit home measurement results, for example in asthma home-care, and to communicate with treatment personnel. In a study of a home tele-care system using TV as the consumer display device, it was observed that the use of a familiar terminal device facilitates successful adoption by patients [Gui02]. Utilization of interactive DTV in home tele-care has been further studied in [Lam02a], [Mag03], and [Nii02a]. Despite being a convenient use environment for certain user groups, DTV places severe restraints on the complexity of user interfaces and information provided, excluding use by health professionals or consumers requiring advanced functionality. DTV has also been applied in other tele-treatment domains, mainly tele-monitoring, as part of a tele-care platform [Mag03]. One novel application area of DTV is the provision of treatment guideline data to tele-care patients using just the DTV broadcast channel. The DTV object carousel mechanism can be used to carry encrypted and uniquely identified image or textual representations of new treatment guidelines to the patients' DTV STBs. There they are identified and decrypted based on unique information available on each patient's STB with the help of a proprietary value-added service and displayed on the TV screen for the patient. The novelty is that an interactive media is not required for the reception of these guidelines.

Application of DTV in tele-rehabilitation is an interesting application area. One potential service type is the combination of a video feed depicting a physical exercise program in tele-coaching and an assisting value-added service.

### 3.4.2 Converging Middleware

The term 'converging middleware' is used here in the context of integration and presentation tier functionality of the abstract ICT tier model related both to connectivity to external systems and to the provision of services for external system clients. For the process-specific health ICT solutions considered, it is essential that information and services from external systems can be seamlessly utilized and, on the other hand, that information and services can be made available to other systems. This convergence is especially important for tele-treatment solutions where the need to access and share electronic patient record information is a necessity. The following considerations relate primarily to tele-treatment solutions.

Converging middleware relates to three of the four ICT convergence trends identified in the previous chapter: to information, communication, and systems convergence. All of these have applications in the health domain.

The task of converging middleware in the integration and presentation tiers is to provide unified solutions for accessing and sharing health information, respectively, in computer-to-computer interactions. As noted in the previous chapter, information convergence in the health domain is moving towards common syntaxes and semantics. We previously considered how this trend manifests itself in the human-to-computer interactions through developments like XHTML convergence. HL7 and its reference information model (RIM) are emerging as a similar development in computer-to-computer interactions. The RIM seeks to umbrella most medical semantics standards (e.g., ICD-10, SNOMED, and GLIF) under one model which can be directly applied in the HL7 Messaging and CDA methodologies of HL7. HL7 Messaging and CDA rely on a common syntax, XML, for message and document representation. XML-based HL7 messaging and CDA documents are becoming the de-facto standard for system-to-system communication in the health domain (CDA documents can also be viewed directly by human users through appropriate formatting).

As discussed in the previous chapter, a standardized methodology for exchanging XML-based information exists. The practical engineering solution for converging middleware is the implementation of the functionality of this methodology, Web Services, within the integration and presentation tiers. Apart from HL7-related functionality, Web Services technologies are beginning to integrate other standards related to health ICT system-to-system co-operation, such as LDAP [Kea02]. LDAP (Lightweight Directory Access Protocol) is a protocol for accessing directory resources. LDAP directories can be used in maintaining common authentication repositories. These enable common login functionality for different systems, which is a key consideration for process-specific health ICT systems. Also, Web Services supports the advertisement of available system-to-system services of a local process-specific health ICT platform through the UDDI protocol. This helps to make them available to other systems. See [Lar02] for more information about Web Services integration for health care.

### 3.4.3 Converging Security

Earlier in this chapter we considered the security requirements of process-specific health ICT solutions. Security is a tier-spanning engineering consideration. We will next look at the engineering security solutions facilitating the security requirements on all tiers of the ICT tier model for a process-specific health ICT solution platform.

There are three ICT security methodologies [Lii98]:

- Technical security
- Physical security
- Administrative security

We consider here technical security as it relates directly to the considered ICT tier model. We look at technical security solutions within each of the three security requirements: confidentiality, integrity, and availability.

**Confidentiality** is maintained through the encryption of data both on the resource tier and during communication from the resource tier up. Resource tier encryption is realized by encrypting the sensitive data stored in the databases and other asset repository systems used. Communication encryption relies on encrypting protocols and networks.

There are many options in IP convergent communication encryption, ranging from OSI network layer encryption, such as IPSec or various VPN solutions, to OSI transport layer encryption through SSL or TLS (see Figure 3.7) and to various proprietary OSI application layer encryption solutions (e.g., S/MIME e-mail encryption). SSL (or the newer TLS encryption) is the standard methodology to encrypt application layer TCP/IP protocols like HTTP. As a TLS session is established, the server begins by announcing a public key to the client embedded in an X.509v3 server certificate. Encryption is not used at this stage, so both parties can read the public key. However, the client can now transmit information to the server encoded in a way that no one else can decode. The client generates 46 bytes of random data and forms them into a single very large number according to PKCS#1. The client encrypts the bytes with the server's public key and sends the result to the server. Only the server, with its private key, can decode the information to determine the 46 original bytes establishing server authentication. This shared secret can now be used to generate a set of RC4 stream cipher keys. The keys are used to encrypt the utilized application layer protocol (e.g., HTTP) on the transport layer for the rest of the session. [Bac97]

SSL/TLS encryption is supported by most modern web server software (Apache, etc.) to establish secure HTTP transport.

Support for at least transport layer encryption is a requirement for the service platform for process-specific health ICT solutions.

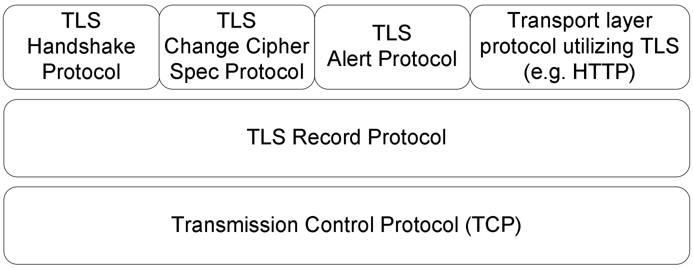


**Figure 3.7** The TLS protocol consists of four protocols (adapted from [Lin03])

Access control includes user (both human and computer) identification ranging from weak password-based to strong PKI and Smart Card-based identification as well as network isolation techniques (i.e., firewalls exposing an access point to a public communication network). Support for secure identification is a requirement for the service platform. Access control includes also the management and use of patient authorizations to constrain inter-organization patient record sharing through a reference database if this is (e.g., statutorily) required. Basic support for such functionality is a requirement for the service platform.

Password-based authentication comes in two basic forms: static and changing password authentication. In static password authentication, the user authenticates himself by presenting a user id-password pair. The password remains the same between subsequent authentications or is changed at regular time intervals. In changing password authentication, a different password is used for each authentication session. The user has a list of passwords which he uses in a sequential order. The difficulty with the changing password system is the maintenance of user password lists. In the Finnish context, there is a de-facto standard solution available for changing password authentication in a networked system. The Finnish Bankers’ association offers the TUPAS service, used by member banks for Internet banking authentication, also for use by third party service providers. The TUPAS service, described in detail in [Fin02], is integrated with the third party service provider’s authentication system so that bank customers can use their user id-password list to login, for example, to an Internet shopping service.

Strong PKI authentication is commonly implemented in conjunction with SSL/TLS server authentication and transport layer encryption. As X.509v3 certificates are used to authenticate the server, the client can be authenticated as well by presenting a certificate of its own (the client certificate) during the establishment of a SSL/TLS session. Client authentication, however, is optional. To achieve client authentication, the client computes a hash of all the SSL messages exchanged up to a certain point, encrypts the result with its private key, and sends the encrypted result to the server. The server, which can compute the same hash value, can decrypt the result sent by the client, using the client's public key, which is part of the x.509v3 client certificate, and verify that the two results are the same, establishing client authentication. [Bac97]

The client certificates are made available to the client platform through various means. Smart Cards are a physically secure way of storing a personal client certificate. In a typical SSL/TLS client authentication scenario, web browser-based client authentication is used on a PC equipped with a Smart Card reader. The Smart Card reader software provides a plug-in to the web browser used so that an X.509v3 client certificate is available for SSL/TLS client authentication from the web browser. This is true as long as the Smart Card is in the reader and the user has given the correct PIN code for card reader software. [Lin03]

See [Lin03] for a detailed overview of PKI and Smart Cards.

In the Finnish context, the FinEID (Finnish Electronic Identification) platform provided by the National Population Register Center includes a Smart Card issued to Finnish residents. The card includes a personal X.509v3 client certificate which can be used in SSL/TLS client authentication, S/MIME e-mail encryption, etc. The FinEID platform includes services for establishing that the client certificate has not been placed on an expiration list and for linking the unique person identifier of the client certificate (SATU code) with the Finnish person identification number (SaSu gateway) and other personal data maintained in the national population registry. [Pop03]

See [Pop03] for detailed application guidelines for the FinEID platform.

Management and use of patient authorizations can be used to constrain inter-organization patient record sharing. The basic idea is to require explicit patient authorization for sharing each piece of the patient EPR maintained on the local service platform to external systems and vice versa. The two-directional sharing can, for example, be done via a reference database system. The authorizations can be collected from the patients, for example through signed permission forms or through digital signatures using the PKI (Public Key Infrastructures) mechanism of a Smart Card.

**Integrity** is maintained through the use of error-resilient communication protocols, which is standard in IP convergent communication. A strong authentication with non-repudiation requires solutions like digital signatures relying on PKI. Logging of all system activity is required to maintain integrity. Support for strong authentication is a requirement for the service platform.

**Availability** is maintained by deploying redundant systems where each system component has an identical backup component. Replication of resource tier assets through backups ensures availability in case the primary storage is compromised. Both are requirements for the service platform.

### 3.4.4 Converging Discovery and Use of Knowledge

An additional requirement for the health ICT solution platform implementing the ICT tier model is the embedment of health domain knowledge tools. Medical knowledge exists in the form of descriptive statistical parameters derived from medical population data with known distributions, as ensembles of rules mined from medical decision history data, medical guideline knowledge defined by domain experts, etc. Apart from strictly medical knowledge, other forms of knowledge may be utilized. For process-specific health ICT (especially treatment) solutions, computer-facilitated and knowledge-based intelligence can serve as a support tool in clinical decision-making for health care professionals, in medical research, as an enabler of empowerment for non-physician actors, and in personalization of the same solutions.

Key methodologies in the implementation of knowledge-enhanced solutions include the acquisition of medical and other health knowledge from raw data and knowledge integration and presentation tools.

**Acquisition of Knowledge**
When the goal is to acquire medical or other knowledge from raw data, many tools may be utilized. The most commonly adopted tools rely on conventional statistical analysis, assuming that the phenomenon producing the data has a normal distribution.

Knowledge discovery in databases (KDD), often referred to as data mining, is an information technology tool for the acquisition of patterns or knowledge from large amounts of data. KDD goes beyond conventional statistical analysis by providing a broader toolset automating the entire process of data analysis. [Fay96a]

The KDD process has been given the following definition [Fay96b]: “The non-trivial process of identifying valid, novel, potentially useful and ultimately understandable patterns in data." KDD benefits from ICT convergence as data from multiple sources can be efficiently brought together for analysis.

Fayyad et al. [Fay96a] have described KDD through a process-centric framework consisting of nine steps from data selection to pattern interpretation or evaluation, as shown in Figure 3.8.

Online analytical processing (OLAP) is a key data mining methodology. OLAP tools enable the analysis of different dimensions of multi-dimensional and consolidated enterprise data. Examples include time series and trend analysis views. [Web03]

Apart from the local generation of medical and other knowledge, ready knowledge can be acquired from remote sources with the help of converging middleware. One example of this is acquisition of medical process guideline knowledge from an expert organization to be utilized in the implementation of a tele-care solution.

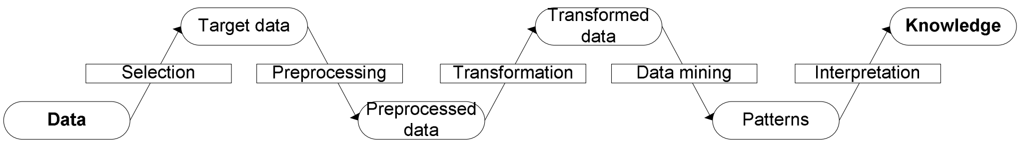


**Figure 3.8** The overall KDD process as adapted from Fayyad et al. [Fay96a]

**Integration of Knowledge**

A key consideration in the successful utilization of medical knowledge is its integration within standardized medical and other semantics and syntaxes used within a process-specific ICT health solution. As described earlier, The HL7 RIM encompasses a number of medical knowledge information standards (e.g., the GLIF clinical guideline standards). Incorporation of advanced medical knowledge acquired through KDD methodologies within information models used in the process-specific ICT solution assists in its successful utilization. Furthermore, use of standardized formats for knowledge assists in sharing and acquiring them from remote sources through converging middleware technologies supported by the platform.

**Presentation of Knowledge**

Medical knowledge as represented by machine-readable formats is in many cases difficult for human users to quickly assimilate and utilize in medical decision-making and other applications. Intelligent visualization and summarization of complex medical knowledge for human actors provides a tool to facilitate the rapid adoption of medical knowledge in clinical work.

### 3.5 Process Evaluation Model

As noted at the beginning of the chapter, the second component of the hybrid model, evaluation modeling, defines evaluation methods, study designs, and evaluation areas for the evaluation of process-specific health ICT solutions both during the development stage as feedback to the developers (i.e., formative evaluation, see [Wya03]) and after their initial adoption and subsequent re-adoptions (i.e., summative evaluation, see [Wya03]) for broad feasibility consideration. Obviously, evaluation is most important for treatment strategy solutions, which is the focus of the process evaluation presented here.

Considering first the general effects of applying ICT in the health domain, it has been claimed that robustly increasing the use of ICT and carefully re-engineering existing ICT can provide an increase in the level of technical security (i.e., enhanced security) [Gri04], easier access to care services for patients (i.e., enhanced accessibility) [McK04], better perceived end-user usability (i.e., enhanced usability) [Ter98], a reduction in errors and better patient safety (i.e., enhanced quality) [Bat01], and more cost-effective care (i.e., enhanced efficiency) [Lam01b]. Meta-analysis of published evaluation studies is also available (see [Bal96] for an example).

However, much debate remains about exactly how health ICT should be evaluated. The aforementioned examples – where enhancements over the *status quo* are claimed in a number of evaluation areas – employ a myriad of evaluation research methods ranging from carefully executed quantitative studies to subjective observations or opinions. The result is that the conclusions reached necessarily have differing degrees of validity.

The problems of evaluating health ICT are discussed for example in [Moe01], [Wya03], and [Amm03], where the general conclusion is that health ICT is a difficult evaluation area where objectively valid evaluation results are difficult to reach and studies are hard to practically realize.

Ammenwerth et al. [Amm03] state that there are three general problem areas in health ICT evaluation:

1. Complexity of the evaluation object (e.g., a moving and hard-to-define evaluation target)
2. Complexity of the evaluation projects (e.g., many different user types)
3. Motivation for evaluation (e.g., difficulty in obtaining funding and participants)

How then can these problems in health ICT evaluation be overcome? Ammenwerth et al. [Amm03] list the following recommendations:

1. Reserve enough time for planning and executing the evaluation
2. Document all decisions and steps in a study protocol
3. Secure management and long-term financial support
4. Clarify the goals of evaluation
5. Limit the number of evaluation questions to a number that can realistically be handled
6. Thoroughly and continuously describe the evaluated ICT and environment
7. Select an adequate evaluation method
8. Select an adequate study design
9. Motivate sufficiently many users to participate
10. Use validated evaluation instruments
11. Be open to unwanted and unexpected results
12. Publish the results to disseminate the results to a wide audience

Evaluation of process-specific health ICT solutions – in evaluation areas selected to be relevant for specific solutions – with adequate evaluation methods and study designs, while taking into account the other presented recommendations, constitutes the process evaluation model.

### 3.5.1 Evaluation Methods and Related Study Designs

Evaluation of health ICT solutions involves two basic research methods with related study designs for the quantitative methods [Uni01].

**Quantitative methods** involve the formalized collection and analysis of quantities and relationships between attributes related to the evaluated health process. Quantitative methods include descriptive surveys as well as experimental and quasi-experimental study designs. Surveys seek to measure behavior, knowledge, and attitudes through personal interviews or self-administered questionnaires carried out on a representative sample of the population of interest. Surveys aim to describe populations, to study associations between variables, and to establish trends. Surveys can be either cross-sectional or longitudinal. Cross-sectional surveys are based on a random cross-section of the population of interest and are carried out at a single point in time. Longitudinal surveys aim to analyze cause and effect relationships by typically surveying a static population over multiple points in time. Both cross-sectional and longitudinal surveys are relevant to the evaluation of an adopted health ICT solution. With experimental and quasi-experimental study designs, the accurate assessment of the outcomes of an intervention, the adoption of a health ICT solution, is realized through a controlled analysis of the intervention group and a control group which does not receive the intervention. Elimination of systematic and random errors is critical in experimental designs. Advanced statistical analysis with differing levels of sophistication is typically involved. [Uni01]

Quantitative methods are to be mostly employed in summative evaluation. Formative evaluation related to the solution development stage typically represents a too volatile situation for serious quantitative studies.

**Qualitative methods** involve non-formal and non-statistical studies carried out in natural, social settings [Uni01] or in a technical evaluation context. For health ICT solution evaluation, in-depth interviews of ICT solution users or patients and security benchmarking are examples of qualitative methods. Qualitative methods are employed both in formative and summative evaluation.

These two basic evaluation methods and related study designs are applied in the different evaluation areas, which roughly correspond to the requirement areas described earlier. The evaluation areas also benchmark the solutions against the corresponding requirement areas, depending on solution type and evaluation area.

### 3.5.2 Security Evaluation

Security evaluation means here both technical and perceived security evaluation. Technical security evaluation involves benchmarking the solution’s security performance against regulatory and other security standards. Confidentiality, integrity, and availability (see Chapter 3.1.2) are the key evaluation areas. Technical security evaluation belongs to formative evaluation and employs qualitative methods. Evaluation of how users perceive security involves comparing the perceptions before and after the adoption of the solution. Such evaluation may be realized as a cross-sectional or longitudinal survey, or during a qualitative in-depth interview as part of a summative evaluation.

### 3.5.3 Accessibility Evaluation

Accessibility evaluation involves assessing how the health ICT solution professional users and patients perceive the geographical and/or temporal accessibility of the solution (see Chapter 3.1.3). Accessibility evaluation may involve a cross-sectional or longitudinal survey or a qualitative in-depth interview categorized according to the geographical location and expected temporal use needs of the users or patients studied. Accessibility evaluation belongs to summative evaluation.

### 3.5.4 Usability Evaluation

Usability evaluation assesses the usability of the health ICT solution for both professional and patient users. Some advanced usability evaluation methods are presented for example in [Kau03] and [Kus04]. Usability studies may be based on a rigorous experimental design for a usability study, on cross-sectional surveys, or on a qualitative in-depth interview. Experimental study designs will give the most reliable quantitative usability results. Usability evaluation belongs to both formative and summative evaluation.

### 3.5.5 Quality Evaluation

Quality evaluation involves mostly experimental design studies where quality effects of the adoption of the process-specific health ICT solution are assessed with the help of control groups and a number of clinical measures (see Chapter 3.1.5). These quantitative quality evaluations may involve the study of trends in physiological parameters describing the successfulness of a patient's treatment facilitated with a tele-treatment solution. Quality evaluation belongs to summative evaluation.

### 3.5.6 Efficiency Evaluation

Table 3.2 lists the most common efficiency evaluation methods utilized in the health domain and measures related to them.

Efficiency evaluation is carried out in the context of comparing two or more health facilitation modalities. The methods and the related measures are used to rank the modalities from an efficiency point of view. Efficiency evaluation methods rely mostly on rigorous experimental study designs. Efficiency evaluation is a critical area, especially for treatment solutions.

**Table 3.2** Efficiency evaluation methods and related measures (adapted from [Lam01])

| Method | Measures |
|---|---|
| Cost-effectiveness | Number of saved years of life or avoided disability days |
| Cost-minimization | No difference in the nature of consequences |
| Cost-benefit | Cost achieving a specific goal measured with an economic unit |
| Cost-utility | Number of healthy years |

As noted, efficiency can be measured in different ways, which may result in disparate and conflicting results. This should always be considered when evaluating health efficiency studies. Efficiency evaluation belongs to summative evaluation.

### 3.6 Summary Points

In this chapter we developed a hybrid model for the application of convergent ICT in process-specific health ICT solutions. The developed model consists of two parts: a process facilitation model and a process evaluation model. The process facilitation model maps the general technological requirements of a service platform facilitating process-specific health ICT solutions in the three domains of health. The requirements were mapped against a tier model describing the service platform at an abstract level. Based on these tier-specific requirements, a set of tier-spanning engineering solutions essential in the development of the platform were described. Identified key properties of the service platform include a high-level of flexibility in both human-to-computer and computer-to-computer interactions achieved through the use of converging networked multimedia and middleware, respectively. Furthermore, facilities for the acquisition and use of knowledge and robust security were recognized as important properties of the service platform. The process evaluation model defines the different evaluation methods, study designs, and areas used in the evaluation of a process-specific health ICT solution during development and after adoption. Apart from its use as a research tool in this thesis, use of the model enables feedback from operational solution development and use. This enables the continuous refinement and improvement of the process-specific health ICT solution.

# 4 A PLATFORM FOR PROCESS-SPECIFIC, CONVERGENT HEALTH ICT SOLUTIONS

The realization of process-specific health ICT solutions requires the development of a platform for the deployment of the supportive processes in question. Such a platform provides the advanced functionality set out by the abstract process facilitation model defined in the previous chapter. The purpose of the platform is to enable supportive service provision meeting the requirements defined by the various domain requirements. The application platform represents a practical engineering solution to a situation mapped by these requirements. It is a solution for the management of the process-specific health information and applications in a distributed, networked context utilizing the possibilities of ICT convergence.

The platform supports the simultaneous deployment of several process-specific applications, which can have both common implementation and data components, coming from the three strategies of health: tele-prevention, tele-treatment, and tele-rehabilitation. Figure 4.1 illustrates the abstract layer structure of the platform.

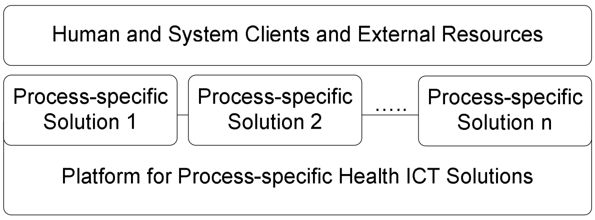


**Figure 4.1** Abstract layer structure of the platform

To approach the question of detailed development of the platform, we will define logical and corresponding physical architectures for an ICT platform providing the required functionality. The logical platform architecture defines the functionality of the platform and its components, but does not address their implementation in the engineering domain. The physical platform architecture consisting of software and hardware architectures provides for this.

## 4.1 Logical Platform Architecture

Figure 4.2 represents an overview of the logical platform architecture for process-specific health ICT solutions. It introduces two fundamental architecture concepts:

- **Tiers** represent the logical distribution of functionality within the platform.

- **Layers** represent the logical separation of logic within the platform spanning multiple tiers.

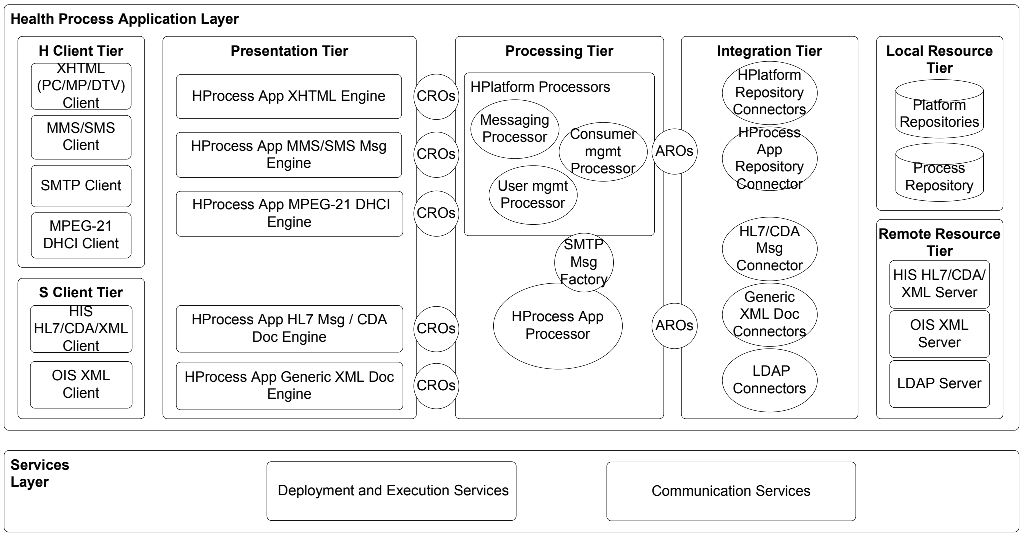


**Figure 4.2** Logical platform architecture

In the architecture model, the tiers (client, presentation, processing, integration, and resource) form a functionality division model for a distributed platform corresponding to the process facilitation model of the previous chapter.

The logical platform architecture consists of two layers: the health process application layer and the services layer. The health process application layer includes platform and process-specific logic supporting the functionality of a process-specific health ICT solution. The services layer includes deployment and execution services for the application layer components as well as communication services utilized by the components to facilitate tier-to-tier communication. The services layer also includes both local and remote physical facilities required to implement the stated services layer functionality.

### 4.1.1 Client Tier

The client tier includes both human and system clients. The primary human clients are XHTML hypermedia browsers accessing XHTML services of the health process application. The services are customized for each client platform and are provided by the presentation tier. Native XHTML browsers (i.e., PC web browsers or mobile phone WAP browsers) are used when they are available. Proprietary XHTML browsers are used on platforms where they are not available as native applications (e.g., DVB-HTML browsers on a DTV MHP terminal). MMS/SMS mobile messaging and SMTP messaging clients augment the hypermedia services by providing an asynchronous communication facility for human users. Another human user client type is a MPEG-21 DHCI (Digital Health Care Item) browser client accessing DHCI services of the health process application, again provided by the presentation tier.

System client tier includes health (HIS) and other information system (OIS) clients accessing resources of the health process application. HIS connectivity is realized through HL7 messaging and CDA document exchange as facilitated by presentation tier functionality. For non-health care system clients, connectivity based on generic XML documents provided by the presentation tier is used.

To facilitate secure communication between the client and presentation tiers, various communication services from the services layer are utilized as described later.

Health functionality of the client tier includes health professional, patient, and consumer human users accessing process-specific solutions as well as various health and other system clients accessing information and services provided by the platform solutions.

#### 4.1.2 Presentation Tier

The presentation tier includes three components for human client connectivity and two components for system client connectivity.

The health process application **XHTML engine** provides both static and dynamic XHTML services for the various XHTML client platforms as well as a gate service for the dynamic services. Figure 4.2 illustrates the functionality of the health process application XHTML engine.

The static XHTML engine is basically a collection of linked XHTML metadata and associated resources (CSS style sheets, JavaScript files, graphics components, etc.) serving as part of the health process application. Each atomic resource is provided for the XHTML client platforms supported by the application with appropriate internationalization. XHTML metadata resources provided by the static XHTML engine can be accessed either interactively through an IP convergent interactive media (i.e., from PC web clients, from mobile phone WAP clients, and from DTV MHP XHTML clients through the DVB interaction channel) over the HTTP(S) protocol or can be packaged for use in a DTV broadcast service without an interaction channel. Static XHTML engine documents can provide links to the access point of the dynamic XHTML engine through the XHTML gate engine.

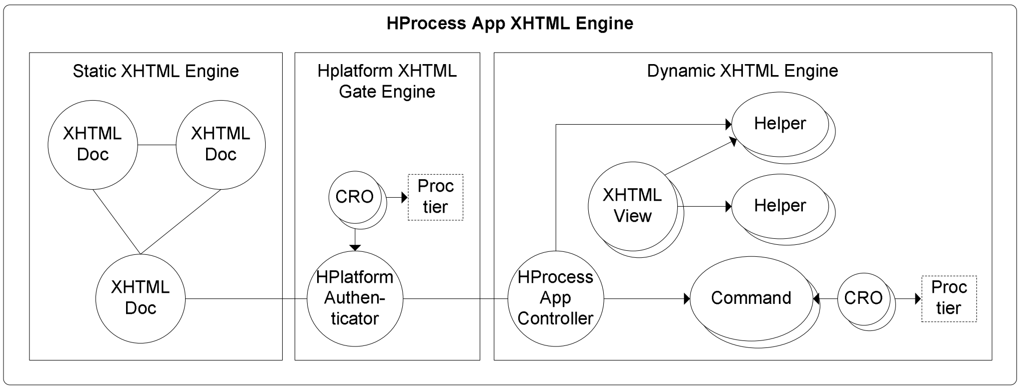


**Figure 4.3** Health process application XHTML engine (logical view)

The XHTML gate engine authenticator serves as a single access point for all interactive XHTML clients for all platform applications and implements:

- XHTML client type identification (PC-based web browser, mobile XHTML(MP), or DTV XHTML)
- Human user access control leveraging either password-based identification or Smart Card-based PKI identification to authenticate the user with personalized access rights
- Provision of access to XHTML engine access points for different health process applications, depending on the personalized access rights of an authenticated user

As an example of gate engine functionality for XHTML clients, as a human user accesses the gate engine with a PC-based web browser, the browser type is detected and the user is forwarded to a browser-adapted login page. At the login page the user can authenticate himself through simple or TUPAS password authentication or using Smart Card-based FinEID PKI SSL/TLS authentication (see previous chapter for information on password and PKI authentication). The gate engine compares submitted identification data with user management records available from the platform user management component of the processing tier and provides a listing of health process application user roles available to the authenticated user. The user can subsequently select the process application and user roles he wishes to log into. After this the user is forwarded to the dynamic XHTML engine access point of the select application with appropriate authorization information. In the case of FinEID PKI authentication, the client certificate includes a client identifier (e.g., the name of the person for whom the certificate was created) which can be used to bind the client to a specific user within the health service platform after SSL/TLS authentication. The static XHTML services of process applications are available also for non-authenticated clients.

The dynamic XHTML engine provides tools for deploying complex XHTML hypermedia presentations and interaction contexts which dynamically access processing tier resources. It realizes XHTML human user presentation and interaction context generation and handling. The engine contains as distinct components a controller component and a number of command, helper, and XHTML view components. The controller serves as a single access point for all dynamic XHTML clients and manages the handling of all client requests, including verification of authentication and authorization, automatic client type detection providing full XHTML terminal convergence, delegation of business processing, and XHTML view management as realized by the command and helper components [Alu01]. In a sequence of operations (see Figure 4.4), the controller first calls filter helpers to access authentication verification and request processing, executes user-defined command logic accessing appropriate processing tier resources (e.g., submits or retrieves resources as CROs; see processing tier), and dispatches to the user-defined XHTML view. The XHTML view component utilizes helper components to access processing tier resources (e.g., CROs) retrieved by the command component. The helper components provide, for example, graphical representations of dynamic application resources accessed within an XHTML page. The XHTML view components support user-based personalization and internationalization of the view. View components can also be constructed from sub-components to realize composite views.

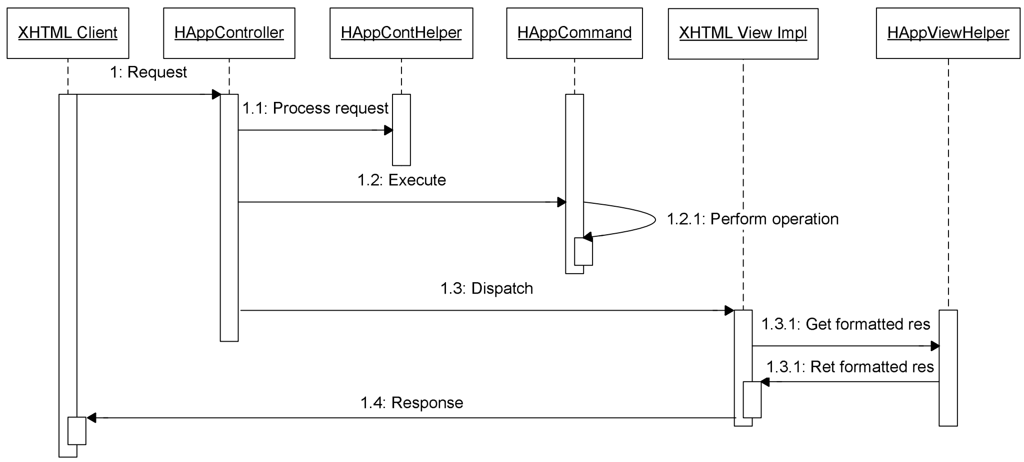


**Figure 4.4** Sequence diagram of dynamic XHTML engine client request handling

In addition to the described functionality, the XHTML engine can also include support for human client medical device connectivity (e.g., for direct data submission from a point-of-care meter used by a human client). This is implemented through functionality embedded in the XHTML presentation provided to the human user client. The said medical devices are interfaced with the XHTML browser platforms on the client tier.

In essence, the dynamic XHTML engine formats existing health process application resources as XHTML metadata and related content and generates XHTML user interfaces for storing new health process application resources. It transforms health application resources between human and system readable forms.

XHTML metadata resources provided by the dynamic XHTML engine can be accessed interactively through an IP convergent interactive media (i.e., from PC web clients, from mobile phone WAP clients, and from DTV MHP XHTML clients through the DVB interaction channel) over the HTTP(S) protocol.

Figure 4.5 illustrates the process application **MMS/SMS engine**. The engine facilitates two-way mobile messaging services for MMS/SMS clients.

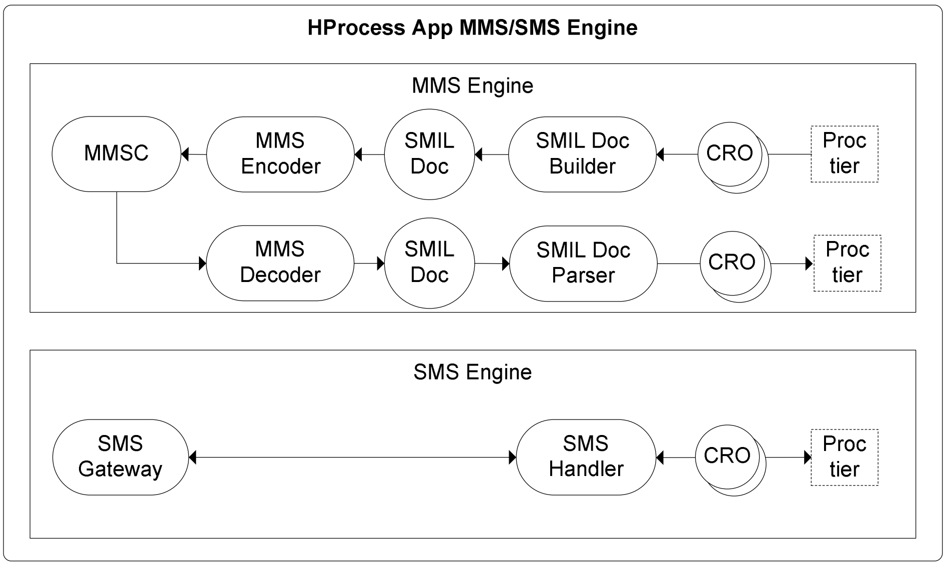


**Figure 4.5** Health process application MMS/SMS engine (logical view)

The MMS engine includes as distinct components an MMS decoder and encoder as well as a SMIL document parser and builder. The engine connects to mobile networks through an MMSC (MMS Center) which relays MMS messages between the health process application and clients operating in a mobile network. The MMSC is integrated with a number of mobile networks (e.g., GSM or 3G).

In client-to-process application communication, the MMS decoder receives MMS messages encoded as MMS PDUs (see [OMA03a]) carried in a HTTP(S) transport from the MMSC (MMS

Center). The message is decoded into a SMIL (Synchronized Multimedia Integration Language) document. The XML-based SMIL language enables simple authoring of interactive A/V presentations which integrate streaming audio and video with images or text [W3C01]. MMS messaging utilizes a subset of the capabilities of the generic SMIL 2.0 language known as MMS SMIL [OMA03b]. In the context of MMS messaging, SMIL is used to compose simple slide shows consisting typically of image and text content [OMA03b]. Apart from decoding the SMIL document, the client mobile station identifier (e.g., the MSISDN number) is extracted from the encoded message for client identification. User management services of the processing tier are invoked to establish authentication for the received client identification information. The parser extracts textual and/or image information from the SMIL document submitted by the client and encapsulates this information in CROs relayed further to the processing tier, for example, for permanent storage.

Conversely in process application-to-client communication, process application resources retrieved from the processing tier as CROs are reformulated as SMIL presentation information by the SMIL document builder and encoded as MMS PDUs for transport over the HTTP(S) protocol to the MMSC. Similarly to identification in message reception, a unique recipient mobile network identifier (e.g., the recipient MSISDN number) is encoded into the sent MMS message. This enables the message to be relayed to the correct mobile client by the MMSC. Furthermore, personalization and internationalization of composed messages is supported.

The SMS engine includes as a component an SMS handler. The engine connects to GSM or equivalent mobile networks through an SMS gateway. It relays SMS messages between the health process application and clients operating in a mobile network similarly to the MMSC in MMS messaging. SMS was originally created as part of the GSM Phase 1 standard and each short message may contain up to 160 Latin alphabet characters [Buc00b].

In client-to-process application communication, the SMS handler receives plain-text messages from the SMS gateway over an HTTP(s) POST. The received information includes at minimum the MSISDN of the sending client as well as the SMS message body. The client is authenticated based on the MSISDN through a security service invocation. The handler parses structured information from the message body and encapsulates it into CROs which are relayed to the processing tier, for example, for permanent storage.

In process application-to-client communication, the same procedure is realized conversely. See also the description for the same communication model for MMS messaging.

Figure 4.6 illustrates the health process application **MPEG-21 DHCI** (Digital Health Care Item) **engine**. The engine provides for the exchange of logically itemized health care multimedia information between the engine and a human client equipped with an MPEG-21 enabled terminal device.

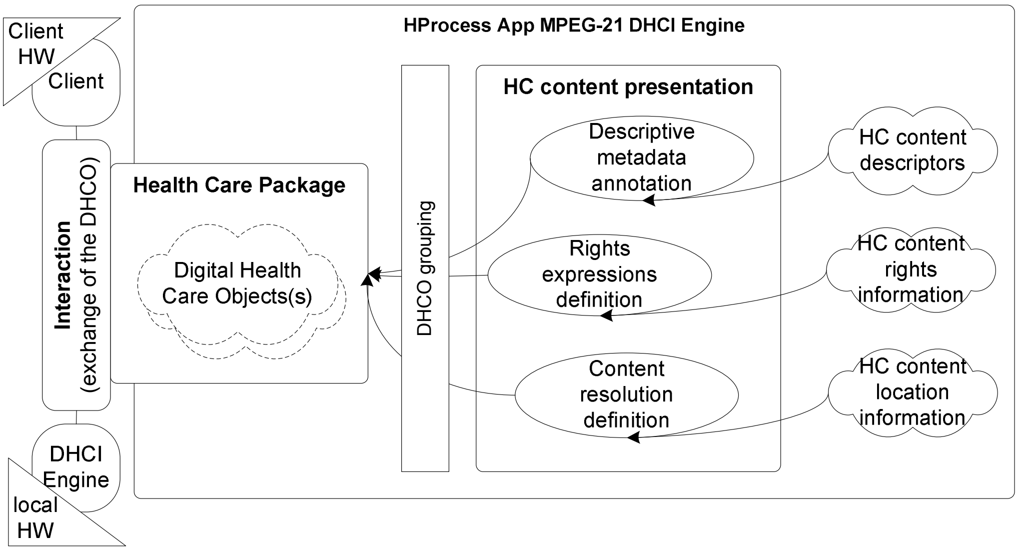


**Figure 4.6** Health process application MPEG-21 engine (logical view) (adapted from [Nii03a])

To approach the functional description of the engine, we note that MPEG-21 aims at defining a normative open framework for multimedia delivery and consumption over heterogeneous networks and terminals for use by all players in the delivery and consumption chain. The MPEG-21 framework consists of two basic concepts: definition of a fundamental unit of distribution and transaction (the digital Item or DI) and the concept of two Users interacting with digital items [Bor02]. Importantly, a digital item is a logical entity structuring resources and related metadata in one package with references to external multimedia resources.

A DI can contain sub-items with multiple components for individual resources and is divided into its declaration (metadata annotations) as defined by the MPEG-21 digital item declaration language (DIDL), references to resources available in a distributed network architecture (MPEG-21 reference elements), and the actual resources defined by different multimedia standards. The standard representation language for the DI is based on XML. Apart from these considerations, MPEG-21 provides mechanisms for the unique identification, IP rights management, and end-user terminal adaptation of instantiated items, among other things. [Nii03a]

The MPEG-21 DHCI engine relies on the MPEG-21 multimedia framework, the DI concept, and the DHCI methodology described briefly in [Nii03a]. The methodology is applied here first by defining that the basic type of interaction is the exchange of an instantiated DHCI(s) (a Digital Health Care Object) contained within a Health Care Package (see [Nii03a]) between the DHCI engine and the human client device. In our view individual digital objects are basically XML documents populated as defined by the XML Schema of the corresponding typed DHCI, a specialized digital item. We limit the interaction to a simple request-response model where the human client requests a health process-related health care package from the engine. The instantiation of the package is illustrated on the right side of Figure 4.6. Content resolution, description, and rights expression information is packaged into DHCOs optionally grouped into packages. Content descriptors define, for example, the multimedia information types contained in a DHCO, rights information describes, for example, the replication restrictions for the objects received by the client, and the content location information gives the locations for the atomic content units logically included in the DHCO. A practical example of a content locator is an URL to a resource (e.g., an image) provided by the XHTML engine; the MPEG-21 DHCI engine utilizes other presentation tier components as resource pools.

The grouped health care package, basically an XML document, is transported to the human user client with the SOAP protocol over an HTTP(s) transport in an interactive setting. Optionally, the XML document can also be carried with DTV data broadcasting mechanisms to a non-interactive DTV human user client.

Figure 4.7 shows the structure and functionality of the health process application **HL7 message/CDA document engine**. The engine facilitates computer-to-computer connectivity by providing access to a set of process application services for HL7 messaging and CDA document system clients. The purpose of the presentation tier engine is to provide access to value-added services realized by the process application; the process application realizes Web Services server functionality. Connectivity to external resources utilized by the process application is realized logically from the integration tier where the process application is in the role of a Web Services client. The engine implements a Web Services endpoint with optional publishing of offered services to an external Web Services directory. Clients bind with the HL7 and CDA web service endpoints components as discovered from the optional directory or as based on a fixed configuration on the client side. UDDI (Universal Description, Discovery and Integration) and WSDL (Web Services Description Language) Web Services standards are leveraged to implement the described publishing, discovery, and binding functionality.

The HL7 message engine includes as components a HL7 message Web Services endpoint and a HL7 message builder/parser. HL7 messaging services provided by the service endpoint are optionally published in an external UDDI directory. The endpoint provides descriptions of available HL7 messaging services through WSDL descriptions which contain network locators of the provided Web Services, among other things. Messages are exchanged between the HL7 client and the endpoint corresponding to these descriptions. The HL7 Web Services endpoint supports XML messaging using the SOAP protocol carried in a HTTP(s) transport. SSL client authentication can be invoked, if necessary for the application, to authenticate the HL7 client. Depending on the direction of the message transport, the HL7 message builder/parser either builds or parses new HL7 v.3 messages in XML syntax; message semantics is based on the HL7 RIM. In the former case, the message instance to be built is populated by data retrieved from the processing tier as CROs. Semantics conversions between the process application data model and the HL7 RIM are done if necessary. In the latter case, the received message instance is parsed and its content is transformed into a number of CROs sent to the processing tier.

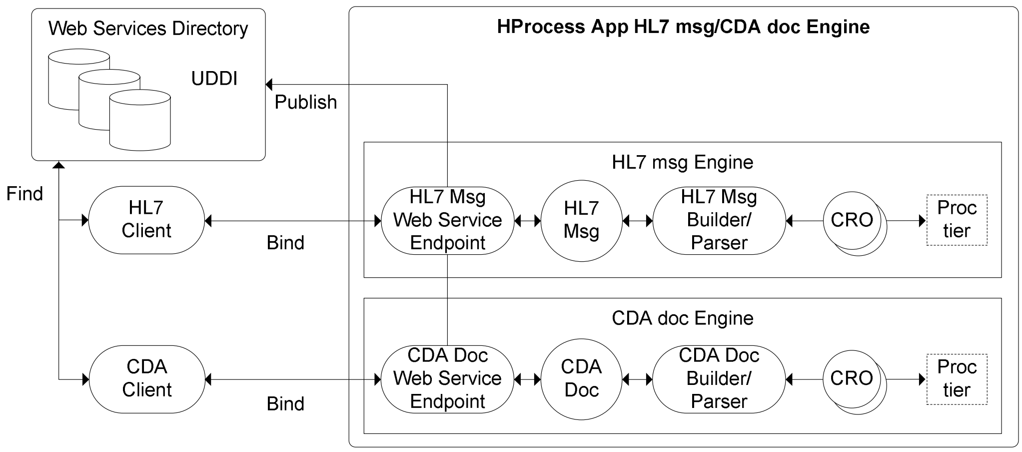


**Figure 4.7** Health process application HL7 message / CDA document engine (logical view)

Functionality of the CDA document engine is in principle similar to the HL7 message engine with the exception that the handled XML data are CDA documents and not HL7 messages.

The **generic XML document engine** is similar in functionality to the HL7 message / CDA document engine. However, the engine is not bound to a Web Services methodology but rather implements proprietary XML transport services over different protocols such as HTTP(S) and (S)FTP. Furthermore, the semantics of the XML documents are proprietary and not bound to a specific model.

Health functionality of the presentation tier includes as the central component XHTML hypermedia user interface and UI generation for human clients. The XHTML engine provides tele-prevention and tele-rehabilitation multimedia content services presented on various XHTML client devices. The services can be combined with other contents, including broadcasting multimedia A/V streams, and can be accessed both statically and dynamically. For tele-treatment solutions the XHTML engine implements a process-specific UI for treatment information management including, for example, virtual patient follow-up cards and related consumer, user, and archiving views. The MMS/SMS and MPEG-21 engines are primarily a solution for tele-treatment services, for example, to send medication or similar information to consumers equipped with mobile phones. Similarly, the HL7/CDA and generic XML engines service system clients accessing process-specific patient records, etc. in tele-treatment services. The latter can also be utilized for dynamic content management in tele-prevention and tele-rehabilitation.

#### 4.1.3 Processing Tier

The processing tier includes a number of processor components implementing the business logic functionality of the health process applications. The processing tier includes components common to all process applications deployed on the platform. These include the consumer management, user management, and messaging processors. In addition to these common processors, the tier includes a health process application specific processor component for each application.

The basic task of the processing tier components is to handle data processing as initiated by the presentation tier components. To achieve this, the processor components access, store, and retrieve both local and remote resources through integration tier connectivity to data repositories and systems. In addition to conveying data verbatim between the adjacent tiers, the processing tier components

- **aggregate** the transformed data into composite resource objects representing the needs of particular sub-processes within the health process application and;
- **distill** the same data into information or knowledge, for example to support resource personalization transformations or to facilitate medical decision-making functionality within the health process application. KDD and data mining are leveraged by the processing tier components to achieve this distillation.

The processor components are implemented as stateless objects which serve as a façade to business logic functionality from the presentation tier. Data, information, and knowledge are exchanged between the presentation and processing tiers as application specific or platform generic **composite resource objects (CRO)**. These objects can carry data structures which represent resource tier data in a semantically verbatim form or as their complex composites as realized through resource aggregation and distillation. The processing tier accesses resource tier repositories and systems through the integration tier as **atomic resource objects** (ARO). Accessed repositories and systems include relational databases, multimedia content databases, and HL7 messaging servers.

Considering the health functionality of the platform processors, the consumer management processor implements access to consumer resources used commonly by the platform applications. The resources include basic personal information such as names, home addresses, phone numbers and e-mail addresses, basic patient information such as medications, and diagnoses of the consumers participating within the health process platform applications as patients or optionally as users. Another important resource is consumer authorizations for basic and process-specific patient information access by health professional users in different organizations. The authorizations can be used to constrain access to basic and process-specific patient information (available locally or remotely) over organization boundaries. Consumer resources are mainly aggregated from multiple remote systems through integration tier components. Leveraged remote systems include:

- **National population register center systems** for access to up-to-date name, address, and other personal information
- **Vocabulary service systems** for access to up-to-date standardized medical and other vocabularies utilized in diagnosis, medication, etc. coding on the platform
- **Centralized health information systems** for (optionally patient authorization constrained) access to, for example, general primary and secondary care patient records and histories including medication, diagnosis, and other general patient information
- **Integrating health information systems** for (optionally patient authorization constrained) access to the same resources as in centralized HIS access. The resources are available, for example, from a regional system collecting the same data or through a reference database system

User management processor implements access to user resources used commonly by the platform applications. Resources include **user identification and authentication data** such as user identifiers and passwords stored locally and used in password-based client authentication. Other locally stored user resources include **user role and access rights management data**. Remote systems such as national population register center systems and regional health information networks are accessed in the context of PKI authentication and user data sharing. The user management processor also handles **personal data management for non-patient persons** using the application (i.e., health professionals).

The messaging processor implements the business logic for a two-way messaging system for secure health process application user-to-user or user-to-multiple-users communication.

The health functionality of the application processor includes provision of access to process-specific local repositories for retrieval, storage, and archiving of data. Such data includes **process-specific patient information**, especially in tele-treatment applications including, for example, treatment follow-up measurement data, POC meter quality control data, and treatment duration and management data.

Remote systems are leveraged to access information such as:

- **Process-specific laboratory and other result data** related, for example, to a specific treatment supported by a tele-treatment solution deployed on the platform (optionally patient authorization constrained access)
- **Process-specific medical guideline knowledge** (e.g., in GLIF syntax) utilized especially in tele-treatment applications to provide decision support mechanisms for professionals and patients
- **Process-specific, dynamically updated medical and other content**, for example, in the form of textual medication advice knowledge integrated within the health process application

The application processors transform and aggregate data to and from process-specific repositories and systems together with resources accessed from platform processors as required by the process application.

Another health functionality of the application processors is to distill information and knowledge from raw medical data retrieved from both local repositories and remote systems. As noted, KDD and data mining methodologies are implemented in the processors to realize this (see previous chapter for information on KDD methodologies). Such information and knowledge is utilized among other things in:

- **User-based personalization of application functionality and content**
- **Analysis tools providing overviews of trends in process-specific medical data** (especially in tele-treatment applications)

A separate processing component utilized by both the platform and application processors is the SMTP message factory. It is utilized to generate and send e-mail messages to human users of the platform to inform of events within the process flow of the application. Examples of such events include new messages sent to a human user or the arrival of new laboratory results from an external system. The e-mail messages typically include a description of the event in question and a hyperlink to the user interface provided by the presentation tier XHTML engine.

### 4.1.4 Integration Tier

Integration tier components, denoted here connectors, facilitate two-way communication with local and remote resource tier repositories and systems. The connectors access resources from the resource tier and parse them into a format applicable on the platform in an upstream flow of data and vice-versa in a downstream flow. Data flow between the integration and processing tier is facilitated through the exchange of atomic resource objects (AROs), which represents the format applicable on the platform. The processing tier is coupled with the integration tier whenever its processors require data or services located in the resource tier.

Five distinct connector types are deployed in the integration tier: platform repository connectors, an application repository connector, HL7/CDA connectors, generic XML connectors, and LDAP connectors.

Platform repository connectors provide access to local consumer, user, and messaging data repositories as referred to earlier. These local repositories are typically implemented as relational databases and the connectors provide a mapping of relational database resources into atomic resource objects. Similarly, the application repository connector provides similar access to a local process-specific relational database.

HL7/CDA connectors provide access to remote systems through connectors realizing connectivity to services similar to the presentation tier HL7 message / CDA document engine. The connectors act as Web Services clients and HL7 messages or CDA documents are carried over the SOAP protocol to the connector. Systems accessed via HL7/CDA connectors include vocabulary service systems, centralized and integrating health information systems for remote platform consumer data access, and various other systems related to process-specific data needs as discussed in the context of the processing tier.

LDAP connectors connect to remote systems for directory information access. Directory systems accessed through LDAP connectors include various user management-related repositories, including national population register center systems and regional health information networks.

### 4.1.5 Resource Tier

Resource tier components can be divided into two distinct categories: local resource tier and remote resource tier components.

Local resource tier components include platform and process application repositories. Standard 2D relational databases are mainly used for the local storage of consumer, user, messaging and process-specific data. Higher dimensional data, such as XML content, is stored in object databases.

Remote resource tier components represent remote server endpoints, including HL7/CDA Web Services, generic XML services, and LDAP services.

### 4.1.6 Services

The services layer includes two service components: deployment and execution services and communication services. These service components support the realization of application layer functionality residing on its different tiers. The services provide both high-level and low-level functionality.

**Deployment and execution services** provide a run-time environment for the deployment and execution of application tier software components in the presentation, processing, and integration tiers local to the platform. Software components implement the dynamic functionality of the health process applications. Deployment and execution services include application server software serving as the runtime environment for the local software components. Characteristics of a suitable application server software environment include the following:

- Support for the deployment and execution of modern, distributed n-tier applications
- Support for an object-oriented programming language for the implementation of the software components
- Support for dynamically deploying and maintaining multiple applications sharing common components
- Availability of APIs for common server-side functionality including I/O APIs (e.g., for basic XML processing and IP-based communication)

The deployment services also include local relational and object-oriented database management systems (RDBMS and OODBMS) facilitating the deployment of local resource tier repositories. SQL-enabled database systems are the standard choice for RDBMS, while various XML OODBMS serve the needs for higher-dimensional local repositories.

**Communication services** provide facilities for communication between the different tiers of the health process application layer.

Figure 4.8 illustrates the communication services protocol stack serving tier-to-tier communication within the health process application layer.

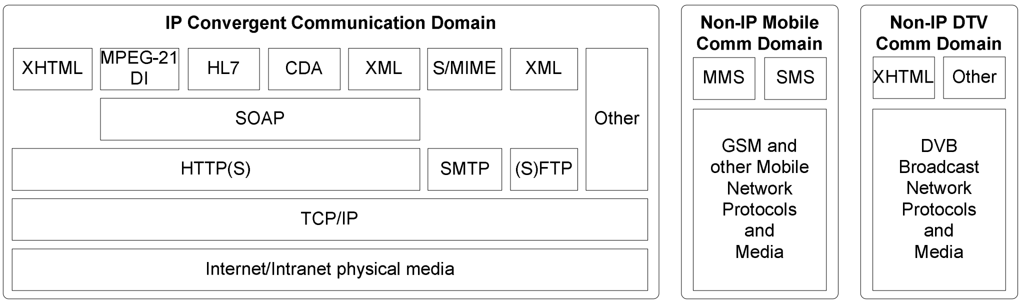


**Figure 4.8** Communication services protocol stack

The IP convergent domain provides for most of the communication services utilized by the application layer. HTTP(S) services carry XML-based metadata and other related data in both human-to-computer (XHTML) and computer-to-computer (SOAP) client tier-to-presentation tier and integration-tier-to-remote resource tier interactions. SMTP services carry (S/)MIME-encoded e-mails in processing tier-to-human-client messaging. (S)FTP services are leveraged in generic XML system-to-system communication in client tier-to-presentation tier and integration tier-to-remote resource tier interactions. Other TCP/IP-based services, depending on the application server software, are used in presentation tier-to-processing tier, processing tier-to-integration-tier, and integration tier-to-local resource tier interactions.

Non-IP communication is used in client tier-to-presentation tier service provision involving human clients and mobile and DTV networked multimedia environments. Mobile (typically GSM) MMS and SMS messages are carried in mobile networks typically over non-IP protocols. In DTV broadcasting the typical application for non-IP communications is the transport of static presentation tier XHTML engine resources over DVB data broadcasting protocols.

Logical platform architecture low-level services provide facilities for the deployment of upper service layer functionality described previously and subsequently for their use within the health process application platform. Local facilities include server-side low-level software and hardware facilities which house the layer functionality. The local facilities consist of a number of hardware servers equipped with operating system software enabling the deployment of application and DBMS servers on the server hardware.

### 4.2 Physical Platform Architecture

As we have now established a view of the logical platform architecture, we will next look briefly at one possible physical platform architecture supporting the functionality of the logical architecture. Figure 4.9 shows a layer model of the physical platform architecture from local server hardware to local process application implementations and external clients and resources.

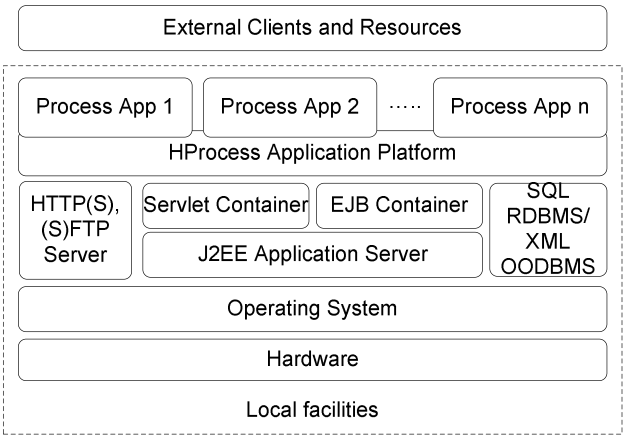


**Figure 4.9** Layer model of the physical platform architecture

There are two views of the physical platform architecture: a software architecture view and a hardware architecture view.

Figure 4.10 illustrates the physical software architecture of the health application platform. As shown in the figure, the physical software architecture relies on four physical infrastructure components: HTTP(S) and (S)FTP servers, a J2EE (Java 2 Enterprise Edition) servlet container, a J2EE EJB container, and SQL and XML RDBMS and OODBMS servers.

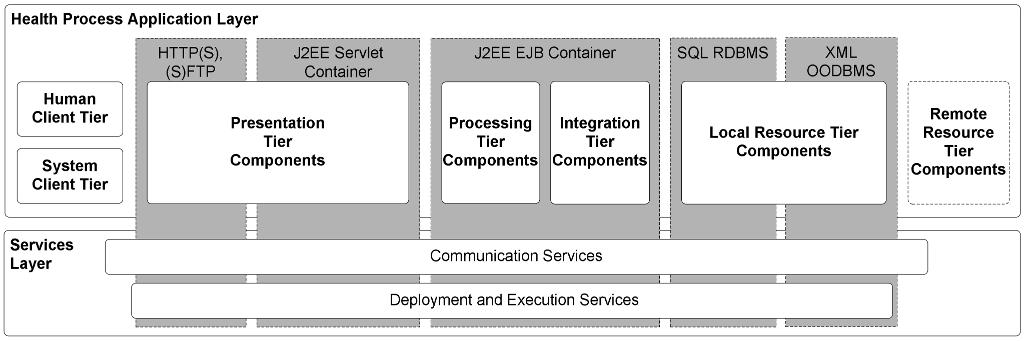


**Figure 4.10** Physical software architecture

The J2EE servlet and EJB containers are typically embedded in a J2EE application server. J2EE (Java 2 Enterprise Edition) is Sun Microsystems' architecture leveraging the Java programming language for server-side enterprise-level solutions [Sha03]. Adoption of the J2EE platform in the infrastructure of the physical software architecture has the following benefits:

- Enables implementation modularity and distributability as well as a clean separation of tiers in n-tier, distributed applications
- Possible to achieve separation of tiers, modular, distributed, etc.
- Open source implementations available for different server components
- Java as programming language does not have a steep learning curve
- Good support for common middleware technologies (Web Services, IP networking, etc.).

For a detailed description of the latest J2EE platform see [Sha03].

The HTTP(S) and (S)FTP servers serve as a front-end for presentation tier components accessed by the different client tier components connecting them to public/private external networks. From a security point of view, the servers support the implementation of PKI-based client authentication for presentation tier authentication and isolate the infrastructure components serving the lower tiers from direct external network access. A number of both free and commercial HTTP(S) and (S)FTP servers are available.

The J2EE servlet container serves as a deployment and execution facility for components implementing rest of presentation tier functionality. A J2EE servlet container supports the deployment of Servlet and JSP components as well as other Java classes. These are used to implement the five connectivity engines described in the logical platform architecture description. The J2EE platform includes a number of APIs for IP-based communication, XML parsing, Web Services functionality, etc., which can be utilized by the deployed Java components.

Processing tier and integration tier components are deployed in the J2EE EJB container. The processor components of the processing tier are ideally implemented as EJB session beans while integration tier connectors for local relational SQL databases can be easily implemented as EJB entity bean components. Connectors to other resource tier components typically require proprietary implementation. Composite resource objects (CROs) which carry data between the presentation and integration tiers can be implemented as bean-type Java objects. Processing tier components (i.e., the processors implemented as session beans) are accessed from the presentation tier using technologies such as JNDI (Java Naming and Directory Interface) for processor session bean lookup and the RMI-IIOP (Java Remote Method Invocation-Internet Inter-ORB Protocol) protocol for processor session bean method invocation and transport of CROs between the tiers. Atomic resource objects (AROs), which carry data between the processing and integration tiers and model resource tier data verbatim, are also implemented as bean-type Java objects; Integration tier components convert native data models and types of each resource tier into Java-based AROs. A number of both free and commercial J2EE application servers are available, implementing both containers. The J2EE platform APIs are accessible also in the EJB container.

Local resource tier components, 2D relational databases and XML object databases, are hosted by the relational SQL database servers and XML object database servers. Connectivity between the integration tier and the resource tier is typically implemented through a J2EE EJB container JDBC driver for each database server. A number of both free and commercial SQL RDBMS and XML OODBMS systems are available.

The physical hardware architecture and network topology of a health process application platform configuration is shown in Figure 4.11. The configuration consists of a local health process hardware platform with a number of clustered hardware resources on top of which the health application platform software components (including server software and process applications) are deployed. Accessed external resources and/or system clients include a laboratory information system (LIS), a regional health information network system (RIS), and an additional private information system (PIS). Clients are represented by the standard networked multimedia human clients. Communication between the external resources and clients is facilitated as described in the logical platform architecture description.

The topology of the local process application hardware platform represents a high availability (HA) system which eliminates or minimizes the loss of service due to either unplanned or planned outages. There are two physical hardware server clusters with one or more hardware and corresponding software servers for each layer of the topology, building two identical domains with identical hardware and software configurations. This topology represents a gold standard for a high availability hardware architecture and is an adaptation of the one presented in [Alc01].

The hardware firewall separates the lower layers of the hardware topology from external networks. The firewall has failover functionality realized by a backup firewall.

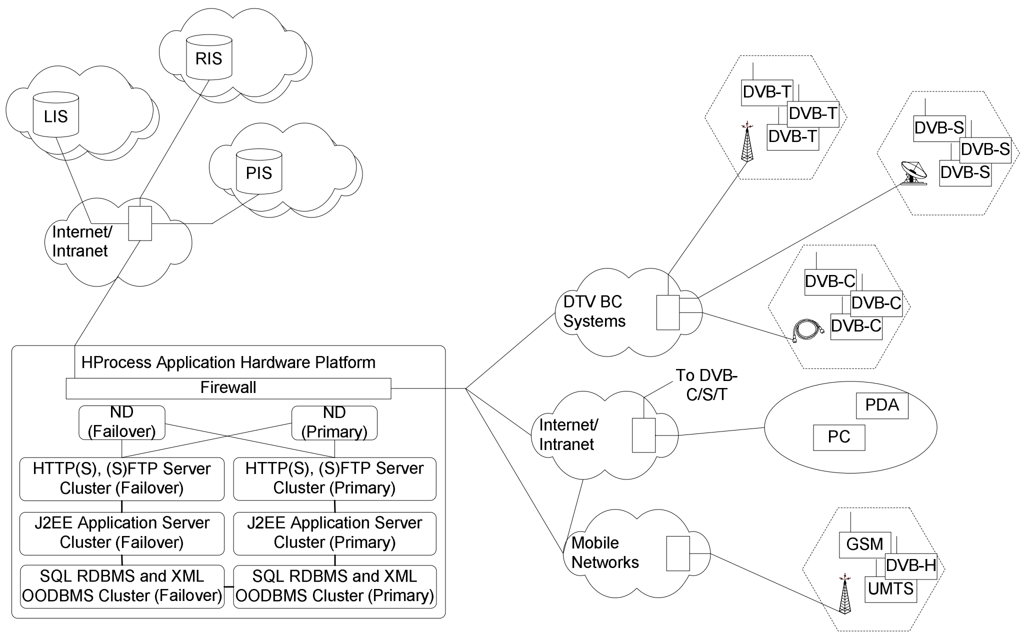


**Figure 4.11** Physical hardware architecture and network topology (adapted from [Alc01])

The NDs (Network Dispatchers) serve as sprayer components for IP traffic, dividing traffic between HTTP(S) and (S)FTP servers of the corresponding domain for load balancing and also forward traffic to the failover domain server cluster in case all servers in the primary system fail. When the primary domain ND is available, all traffic is routed through it.

Both HTTP(S), (S)FTP, J2EE application server, and DBMS clusters have 1…n factor server hardware duplication. In addition, the databases of the primary domain DBMS systems are replicated online to the failover domain DBMS systems.

### 4.3 Available Solution Functionality

Table 4.1 lists the functionality provided by the developed platform for process-specific health ICT solutions. Compared with the requirements specified in the previous chapter, we note that the platform provides functionality corresponding to primary requirements given.

Obviously, tele-treatment services require a bulk of the advanced functionality available within the platform. For example, advanced security, authentication, and system integration capabilities are central to the process-specific tele-treatment solutions. Tele-prevention and tele-rehabilitation represent more traditional networked multimedia services.

Information, communication, terminal, and systems convergence is clearly visible in the functionality of the platform. Again, the importance of convergence as an enabling tool is accentuated in tele-treatment solutions.

### 4.4 Summary Points

In this chapter we developed a platform for process-specific health ICT solutions. Description of the platform was begun with the introduction of a logical platform architecture describing the functionalities and components of the platform in a multi-tiered and multi-layered architectural view. Subsequently, one configuration for a physical platform architecture corresponding to the logical one was briefly described.

The developed platform enables the full utilization of convergent ICT to establish seamless provision of diverse health ICT solutions in a networked and service-oriented way as opposed to a hierarchical and system-oriented way. The platform enables the deployment of multiple process-specific services simultaneously and supports integration to various external systems acting as either clients or servers with the help of converging middleware solutions as well as flexible connectivity for human clients over converging networked multimedia. The platform also fully implements a converging security model and provides facilities for the converging use and discovery of knowledge in the platform applications.

**Table 4.1** Health solution functionality available within the three health strategies

| Health strategy | Available solution functionality |
|---|---|
| Tele-prevention | - Process-specific tele-prevention services, for example in targeted health education or national health promotion<br>- Multimodal multimedia content, mainly push-type, solutions including hybrid broadcasting multimedia content services<br>- Integration with external information system to facilitate dynamic updates of used multimedia content<br>- Personalization of solution multimedia content |
| Tele-treatment | - Process-specific tele-treatment solutions for clinical self-care, self-follow-up, home-care, etc. in (e.g., primary care) chronic disease management<br>- Multimodal networked multimedia human user access for both professionals and patients and intelligent event notification through e-mail or mobile messaging<br>- Integration with centralized and integrating health information systems for patient record information sharing, vocabulary and computer-readable guideline access, etc.<br>- Integration with other external information systems for other value-added solution functionality (e.g., to facilitate dynamic authentication or multimedia content services)<br>- High overall level of security<br>- Integrated process intelligence through knowledge-based processing for personalization, decision support, etc. |
| Tele-rehabilitation | - Process-specific tele-rehabilitation services for active rehabilitation self-management, etc.<br>- Multimodal multimedia content, mainly pull-type, solutions including hybrid broadcasting multimedia content services<br>- Personalization of solution multimedia content |

# 5 SOLUTIONS DEPLOYED ON THE PLATFORM AND THEIR EVALUATION

Versions of the platform for process-specific health ICT solutions have been utilized in the deployment of both clinical and conceptual ICT solutions supporting overall health solution provision. Between the years 2001 and 2003, early implementation versions of the developed platform were used in the Health Care TV research project (see [Nii03c]) to deploy a number of solutions for clinical pilot study use as well as for laboratory testing as conceptual solutions. During the Health Care TV project from 2001 to 2003, oral anticoagulant treatment follow-up and guided asthma self-management tele-treatment solutions were deployed in a clinical pilot study at the primary health care center of Ikaalinen, a rural municipality near Tampere, Finland. Eye injury prevention (tele-prevention) and rheumatoid arthritis rehabilitation (tele-rehabilitation) solutions were deployed as conceptual solutions and tested in laboratory settings at the organizing research institution, the Digital Media Institute of Tampere University of Technology. Within the activities of Terivan Oy, beginning in 2003, the oral anticoagulant treatment solution deployment at Ikaalinen moved into a semi-operational status. During 2003 and 2004 the same solution was in clinical use as part of a pilot study in the primary health care system of the cities of Helsinki and Tampere with some functional extensions. Hypertension follow-up was deployed for a clinical pilot study during 2003 and 2004 in the primary health care system of the city of Tampere. More advanced implementation versions of developed platform have been used within the activities of Terivan Oy. Ethical research permits were sought for the clinical studies.

Table 5.1 lists the five distinct solutions deployed on the platform within the activities of the Health Care TV project and Terivan Oy. The deployed tele-treatment solutions fall primarily within the scope of primary health care.

**Table 5.1** Solutions deployed on the platform

| Health strategy | Deployed process-specific solutions | Deployment type |
|---|---|---|
| Tele-treatment | Oral Anticoagulant Treatment Follow-Up | Clinical primary care (HCTV, Terivan) |
| | Hypertension Follow-up | Clinical primary care (Terivan) |
| | Guided Asthma Self-Management | Clinical primary care (HCTV) |
| Tele-prevention | Eye Injury Prevention | Conceptual (HCTV) |
| Tele-rehabilitation | Rheumatoid Arthritis Rehabilitation | Conceptual (HCTV) |

We will next consider in detail the deployed solutions, the service models implemented by them, the deployment environments as well as methodologies and results of corresponding summative evaluation studies.

### 5.1 Oral Anticoagulant Treatment Follow-Up

The number of patients on oral anticoagulant treatment in Finland, based on drug sale statistics, increased by 50 % in the six years leading to the year 2000 [Syr00] *.

This trend results from an aging population and from an increased knowledge of the benefits of oral anticoagulant treatment. The purpose of the treatment is to prevent the formation of blood clots through the oral intake of an anticoagulant, typically warfarin. Common indications for anticoagulation treatment include atrial fibrillation, deep vein thrombosis, and pulmonary embolisms [Esk96].

The anticoagulant effect of warfarin treatment is traditionally followed up with laboratory testing of venous blood samples, which guarantees that the correct anticoagulation level is maintained. The anticoagulation level is measured in INR (International Normalized Ratio) units. From an organizational point of view, anticoagulant treatment follow-up is realized in Finland by public primary care health centers covering the anticoagulated population of a whole municipality (or part of it in the case of larger population centers). It has been established that oral anticoagulant follow-up can be reliably monitored in primary health care as the general practitioner's responsibility [Vii99]. However, due to the significant increase in the need for anticoagulant treatment, new treatment modalities are required to continue the provision of quality care with the current resources.

In general, if primary care physicians are to manage more patients more reliably and at least as safely, they will need accurate and efficient tools, like near patient POC testing, to assist their decisions [Hob96]. In the follow-up of oral anticoagulant treatment, portable INR meters used together with a process-specific ICT solution in near-patient POC testing provide a basis for the development of new service models. The process-specific ICT solution provides an interface for patients, nurses, and physicians for storing, retrieving, and evaluating follow-up data. It supports the adoption of new clinical treatment modalities where increased non-physician activity and empowerment is emphasized: anticoagulation home-care and self-follow-up.

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* ~0.7% of a studied Finnish population was on oral anticoagulant medication in 1996 [Esk96].

For optimal functionality, such a solution needs to be integrated with laboratory and basic primary care information systems to provide for automatic conveyance of P-INR laboratory test results to the solution as well as desktop integration with the primary system.

### 5.1.1 Service Models

Figure 5.1 illustrates the generic process chain available through the adoption of the process-specific ICT solution and POC follow-up testing in primary care oral anticoagulant treatment follow-up.

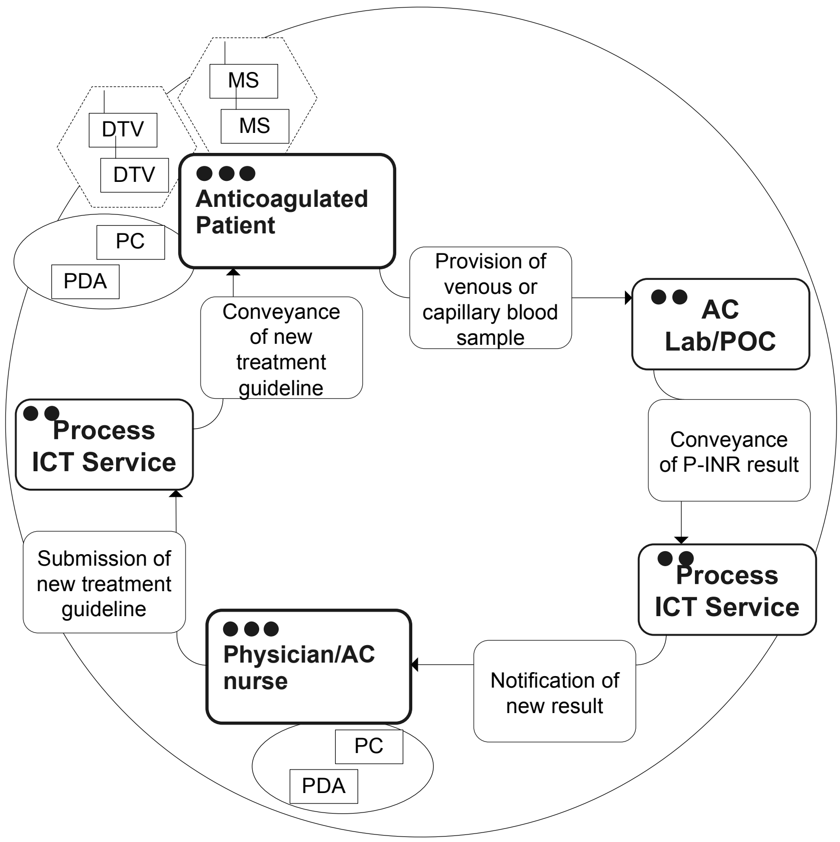


**Figure 5.1** Oral anticoagulant treatment follow-up process chain

The basic clinical process chain consists of the following components:

1. Regular venous or capillary blood sampling of an anticoagulated patient. Capillary sampling is done by the patient himself or by a home-care nurse at home in self-follow-

up or POC-supported home-care. For venous blood sampling the active patient travels to the primary health care center, while in home-care the nurse collects the sample at home.

2. Laboratory or POC anticoagulant follow-up testing of the blood sample to determine the current anticoagulation level, the P-INR result, and its conveyance to the process ICT service.
3. Notification of the primary care physician or anticoagulation care nurse responsible for the patient's treatment of the new result. Typically anticoagulation nurses are notified of results within the P-INR treatment range and physicians of those outside it.
4. Submission of new treatment guideline, including daily anticoagulant dosages and date of the next follow-up, by the treating anticoagulation nurse or physician to the process ICT service.
5. Conveyance of the treatment guideline to the anticoagulated patient.

This basic process flow supports the following service models:

1. **Active patient laboratory follow-up**. The patients visit the primary health care center for blood sampling. The sample is tested at a laboratory and the result is evaluated by an anticoagulation nurse or physician. The new treatment guideline is conveyed to the patient by the primary care health center patient office typically in the form of a printed anticoagulation notebook containing the new guideline or through a phone call made by the patient to the patient office. A patient with a web-browser equipped PC, a mobile phone, or interactive digital TV STB can also receive or access the new treatment guideline through networked multimedia, etc.
2. **Active patient POC-supported self-follow-up.** The patient has a portable anticoagulation meter at home for follow-up testing and submits the follow-up test P-INR results using a networked multimedia terminal. As the new treatment guideline has been set by the treatment personnel, the patient receives or accesses it similarly as in laboratory follow-up.
3. **Laboratory- or POC-supported home-care follow-up.** The primary home-care nurse either draws a venous blood sample for laboratory follow-up testing or uses a portable POC meter for capillary sample near-patient testing during a patient visit. In the case of laboratory follow-up, the venous blood sample is processed in a laboratory and the P-INR result is handled similarly as in active patient laboratory follow-up. The new treatment guideline is conveyed to the patient during a second patient visit. In POC testing the home-care nurse has the P-INR result available instantly and can continue the previous treatment guideline for the patient in case the result is in the P-INR treatment range; otherwise the procedure is similar to that described previously.

4. **Laboratory- or POC-supported hospital-care follow-up.** The service model is similar to home-care follow-up with the exception that the primary care hospital ward is located at the primary health care facility so that traveling to the patient is not required.

The process ICT service basically implements a virtual anticoagulation notebook collection to facilitate the described process chain used in the implementation of the four service models. The service includes the following functional components to implement a virtual anticoagulation notebook collection.

**PC XHTML browser access for primary care professionals** provides web access to the virtual anticoagulation notebooks of the treated patients, to a professional-to-professional or patient-to-professional messaging service, as well as service maintenance functionality to maintain the anticoagulated patients' notebooks and professional and patient user accounts. Professional web access is implemented as a dynamic process application XHTML engine. The professional logs into the service through the platform XHTML gate engine. PC web access is optimal for the professional as it provides the possibility to view large amounts of information simultaneously and to implement decision support functionality such as an anticoagulant medication calculator. A PC equipped with an XHMTL browser is typically available at the working place of the primary care professional.

The virtual anticoagulation notebooks of individual patients contain:

- Graphical and tabular representations of P-INR and anticoagulation medication dosage history
- Functionality to add new and update follow-up data, including P-INR results and treatment guidelines
- A view of the patient's personal (name, e-mail address, etc.), diagnosis, medication, and permanent anticoagulant treatment information (anticoagulant treatment start date, P-INR target range, treating physician, etc.)

When a new follow-up measurement is done for a patient either in laboratory or POC testing, the correct professional is informed of the new P-INR result through the sending of an e-mail message. If the anticoagulation nurse model is used, the treating physician is notified only of new follow-ups outside the P-INR target range. The patient's anticoagulation nurse handles routine follow-ups based on permanent instructions from the physician.

To facilitate the efficient setting of new treatment guidelines, the virtual notebook includes an intelligent anticoagulant dosage calculator which can be used to divide up a weekly anticoagulant mg dosage between the individual days of a week. The process ICT service can be integrated to a LIS system containing the new P-INR results to facilitate the automatic reception of new laboratory follow-ups. The integration can be based, for example, on HL7 messaging or a proprietary XML messaging service. The messaging service can be used by the professionals to send secure text-based messages to other professionals and patient users of the service. The recipient is optionally notified about the arrival of a new message through the sending of an e-mail message.

Apart from setting new treatment guidelines, the professional web service is also used by the primary care patient office, home-care, and hospital-care nurses to print anticoagulation notebooks and to submit POC follow-up test results. The maintenance functionality supports adding, archiving, and restoring of anticoagulation notebooks of individual patients as well as professional and patient user account maintenance.

**PC and DTV XHTML browser access for active anticoagulated patients** is similar to professional web browser access (see Figure 5.2) with the exceptions that the patient can only access his own anticoagulation notebook, that the maintenance functionality is not available, and that the service can also be accessed from a MHP DTV platform equipped with a return channel and an XHTML browser. DTV XHTML access is ideal for patient groups not accustomed to using PCs and provides an easy and user-friendly environment for anticoagulation follow-up data access.

XHTML browser access for patients is two-tiered. In active patient laboratory follow-up, the patient uses the system to access new treatment guidelines set by the professionals based on the new results. The patient can also communicate with his own professionals through the messaging service. In active patient POC-supported self-follow-up, the patient also submits new P-INR results for professional evaluation.

**SMS/MMS messaging access for active anticoagulated patients** provides a possibility for self-follow-up patients to send new follow-up test P-INR results as SMS messages to the notebook for professional evaluation and to receive new treatment guidelines as SMS or MMS messages. SMS/MMS messaging functionality is implemented through a process application SMS/MMS engine.

Mobile messaging brings time and location independence for active patients as a mobile phone and the POC meter can be taken almost anywhere.

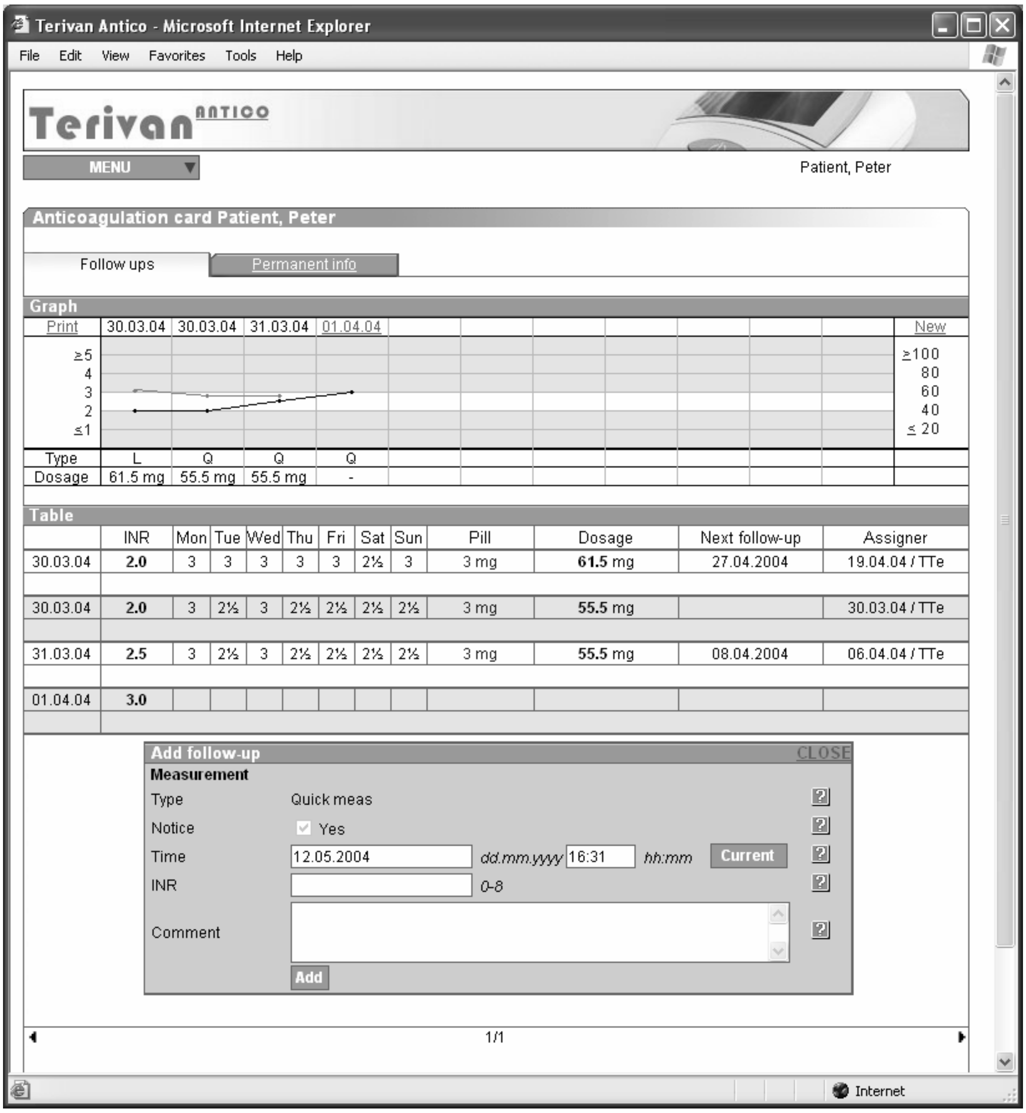


**Figure 5.2** Screen shot PC XHTML browser access for active anticoagulated patients

**PC XHTML access for secondary care researchers** enables them to access anticoagulant treatment follow-up data for research purposes. The service provides access to anonymized follow-up data on a primary care unit or regional level. It includes facilities for distilling process knowledge from raw follow-up data in human readable report form through knowledge extraction and statistics functionality implemented in the application processing tier.

The secondary care service is a tool for secondary care professionals responsible for regional primary care development and quality research in the area of anticoagulant treatment.

Table 5.2 compares conventional and process-specific ICT-supported anticoagulant treatment follow-up from the point of view of the primary care clinic, its professionals, and the individual patient. The assumed conventional service model is a manual, paper-based anticoagulation notebook.

**Table 5.2** Comparison of conventional and process-specific ICT-supported anticoagulant treatment follow-up (originally presented in [Nii03b])

| Variable | Conventional | Process-specific ICT |
|---|---|---|
| Data gathering media | Manual: anticoagulation notebook | Electronic: virtual anticoagulant notebook or partial message accessed via a networked multimedia terminal |
| Data access | Local and delayed: presence of the anticoagulation notebook is necessary | Global and real-time: via networked multimedia |
| Data analysis | Requires examining the hand-written data | Reports, statistics, etc. can be produced both for individuals and groups |
| Skill requirements for the nurse / patient | Low: hand writing | Moderate/high: use of a digital media service for sending or retrieving data |
| Role of the physician | General advisor and medication: care is based on general medical knowledge and tacit knowledge of anticoagulation treatment | Personal coach: individual data enable accurate interpretation and adjustment |
| Role of the nurse / patient | Passive care: follows the instructions (e.g., notifies of data in the notebook) | Active care: takes responsibility more for patient's/one's own treatment |
| Communication modality between nurse/patient and physician | Discontinuous: No face-to-face check, when severe problems or complications. | Continuous: direct access to up-to-date data and possibility of immediate contact and feedback. Automatic notification of new events. |

Apart from this comparison within traditional primary care follow-up, adoption of the process-specific ICT service supports the overall organizational re-organization of oral anticoagulation treatment follow-up. Anticoagulation clinics – where a single, centralized clinic handles regional anticoagulant treatment follow-up in the area of several primary care health centers – are a service model where benefits of a distributed, process-specific ICT service are potentially amplified. Large distances can be efficiently covered through electronically mediated information exchange enabled by the service.

### 5.1.2 Deployments and Evaluation

Table 5.3 lists the three deployments of the oral anticoagulant treatment follow-up solution.

**Table 5.3** Oral Anticoagulant Treatment Follow-Up Solution Deployments

| Deployment location | Location characteristics | Deployment service models |
|---|---|---|
| Municipal primary health care center of Ikaalinen<br>(from 2001 on) | Geographically large and rural municipality with a sparse and aging population | Active patient laboratory follow-up<br>(no AC nurse; PC XHTML)<br>Active patient POC self-follow-up<br>(no AC nurse; PC XHTML, SMS)<br>Home-care POC follow-up<br>(AC nurse; PC XHTML)<br>Hospital-care POC follow-up<br>(POC, AC nurse; PC XHMTL) |
| Paloheinä health station of the city of Helsinki primary health care<br>(from 2003 to 2004) | Geographically small and suburban setting with a dense and young population | Active patient laboratory follow-up<br>(AC nurse; PC XHTML)<br>Home-care POC follow-up<br>(AC nurse; PC XHTML) |
| Hervanta health station of the city of Tampere primary health care<br>(from 2003 to 2004) | Geographically small and suburban setting with a dense and young population | Home-care POC follow-up<br>(AC nurse; PC XHTML) |

As noted, the deployments cover the time span from 2001 to 2004 and the activities of both the Health Care TV research project and Terivan Oy. The three deployment environments include two distinct location types: a rural and two suburban settings with unique geographical and population characteristics. This enables the realized evaluation to cover most situations in the Finnish setting.

**In Ikaalinen** use of an early version of the anticoagulation service began in the spring of 2001 with voluntary mostly senior, but active, patients in POC-supported self-follow-up (n=5, all adults, ages from 44 to 72). In addition, one Ikaalinen primary care health center physician participated in the study to set new treatment guidelines for the five patients.

In the fall of 2001 use of the service was extended to cover a number of home-care patients in POC-supported home-care follow-up (n=11, all adults, ages from 64 to 87). The participating patients were served by a separate home-care unit of the Ikaalinen health center located approximately 30 kilometers from the health center main facility. At the same time selected home-care nurses from the remote unit began use of the service. The physician participating in the first study also covered the 11 home-care patients.

In early 2002, the service was extended to cover active patient laboratory follow-up, POC-supported hospital-care follow-up, and the rest of the home-care patients, bringing the whole anticoagulated population (n=~200, all adults) within the use of the service. At this time other health care center physicians and nurses began use of the service. Finally, in early 2003 the service moved into semi-operational status from the HCTV project to Terivan Oy. Currently, in the spring of 2004, the service covers the treatment of all Ikaalinen patients on oral anticoagulant treatment. All users, both professionals and self-follow-up patients, use the service with a PC XHTML browser. Use of SMS messages in storing self-follow-up P-INR results was also briefly tested in 2002. Laboratory P-INR results are inserted manually into the process ICT service by health center personnel. The anticoagulation nurse model is not in use in Ikaalinen in the handling of new laboratory follow-ups. It is used only in home-care and hospital-care.

An overall description of the Ikaalinen anticoagulation pilot study and related evaluation is given in [Lam03a]. We will overview here the results of the evaluation studies within the five evaluation areas (security, accessibility, usability, quality, and efficiency) corresponding to the process evaluation model developed in this thesis.

The Ikaalinen deployment was evaluated based on:

- Interviews of self-follow-up patients (n=5), the original home care nurses (n=2), and physician (n=1) about the perceived security, accessibility, and usability of the process ICT service in clinical pilot PC XHTML browser use combining POC anticoagulation testing. The home care nurses and the physician were also queried about their opinions on quality and efficiency effects of the new service model.

Methodology: half-structured theme interviews (by HCTV researchers) in spring 2002 analyzed by qualitative content analysis.

- Mapping of the quality problems of conventional, paper-based anticoagulation notebooks (n=31).

  Methodology: a document review (by HCTV researchers) in fall 2001 counting missing, inconclusive, and unreadable markings analyzed quantitatively. The reviewed notebooks were randomly selected among those of permanently anticoagulated patients.
- Comparison of the economic efficiency of conventional and process-specific ICT and POC-supported service models in remote unit home-care and self-follow-up in the Ikaalinen setting.

  Methodology: case analysis was used to develop cost functions from collected economic data, which were analyzed to determine the break-even point in total cost between conventional and process-specific ICT and POC-supported service models.

The interviewed self-follow-up patients considered that the flexibility of the process ICT service was considered the biggest advantage when compared to conventional active patient laboratory follow-up involving paper-based anticoagulation notebooks and phone queries or visits to the health center for new treatment guidelines. The patients stated that the submission of new follow-up test results was now possible anywhere a web browser equipped PC was available. The fact that the new treatment guideline could be flexibly received from the personal physician without phoning the health center patient office within the mandated tight schedule and also during travel were considered important benefits. None of the five stated a clear disadvantage from the use of the service.

Concerning the possibility to send P-INR results as SMS messages compared to submission with a web form, the self-follow-up patients mostly preferred the web form as they had been accustomed to using it and had a PC at home. However, during travel the possibility to use a mobile phone for conveying results and receiving guidelines was considered important. The patients could not state a concrete opinion about the possibility to use DTV in anticoagulant treatment follow-up as they had not used the service through television.

The patients considered the usability of patient XHTML web access and readability of the virtual anticoagulation adequate. They also perceived that the security of XHTML web access was adequate. Suggested improvements included notification of the arrival of new guidelines through e-mails. Four of the patients were also personally willing to move to self-care where they would control the anticoagulant medication dosage personally as long as a physician could be consulted in problematic cases. As a precursor of the self-follow-up patient interviews, the interest of anticoagulated Ikaalinen patients in self-follow-up (POC testing and use of process ICT service) was evaluated with a phone interview (n=40) in early 2001, as described in [Lam02c]. Approximately 50% were willing to use POC testing, while 20% were ready to use a digital media process ICT service [Lam02c]. The five self-follow-up patients were selected from the latter group. This selection bias should be taken into account when considering the positive results of the self-follow-up patient interviews.

Self-follow-up patients considered personal POC testing highly usable and saw that its biggest benefits included elimination of the long trips (up to 40km in Ikaalinen) to the health center for blood sampling used in laboratory testing, the possibility to carry out follow-up testing during travel, and based on the personal condition, time and location independently. However, the cost of the POC meter (670€ in 2002) and a single test strip (6€ in 2002), if purchased personally without a public subsidy, was considered prohibitive.

The interviewed home-care nurses from the health center remote unit were very satisfied with the usability of the process ICT service. They considered that the service, when combined with POC follow-up testing, brings practical benefits to the care of anticoagulated home-care patients. Among the observed benefits was elimination of traveling, a perceived increase in care security, and care organization timetable flexibility due to the fact that POC testing was used and that the P-INR result was available immediately during patient visits. For example, conventionally the venous blood sample had to be taken to the health center laboratory for follow-up testing, which resulted in trips to the main health center facility. Also, the home-care nurses could continue the current anticoagulant medication based on permanent instructions from the physician when the P-INR value was in treatment range (anticoagulation nurse model).

The home-care nurses considered the virtual anticoagulation notebook easier to read than the old handwritten one, which helped in eliminating erroneous markings. Also, the exchange of anticoagulation follow-up data in physician consultations (a physician was located at the main health center facility) using the process ICT service was considered as time-saving and as increasing flexibility.

The interviewed health center physician appreciated the timetable flexibility provided by the process ICT service (setting of new treatment guidelines can be done time and location independently) and the enhanced communication and consultations directly with the patients in the case of the self-follow-up patients.

The physician also considered the P-INR trend graphs and the anticoagulant medication dosage calculator to be useful tools. The fact that the virtual anticoagulation notebook contained up-to-date and easy-to-read follow-up and other patient information (including the P-INR treatment range and the treatment duration) were considered to increase care security.

A review of the problems of the conventional, paper-based notebook is described in [Nii02e]. It was observed that in 50% of the paper-based anticoagulation notebooks of the selected patients the P-INR range and/or planned treatment duration were missing. Missing (in 8% of follow-ups), inconclusive (in 3% of follow-ups), and unreadable markings (in 1% of follow-ups) were also observed in follow-up test and treatment guideline markings. This finding highlights the care quality enhancement possibilities a virtual anticoagulation notebook provides as it forces the submission of complete information.

The economic efficiency comparison between conventional, paper-based laboratory follow-up and POC and process ICT-supported follow-up in Ikaalinen home-care and self-follow-up is described in [Nii03b]. Figure 5.3 illustrates the number of patients required to achieve cost break-even between the conventional and new service models in the Ikaalinen setting with the assumption that the process ICT service has a yearly cost of 100 €/patient.

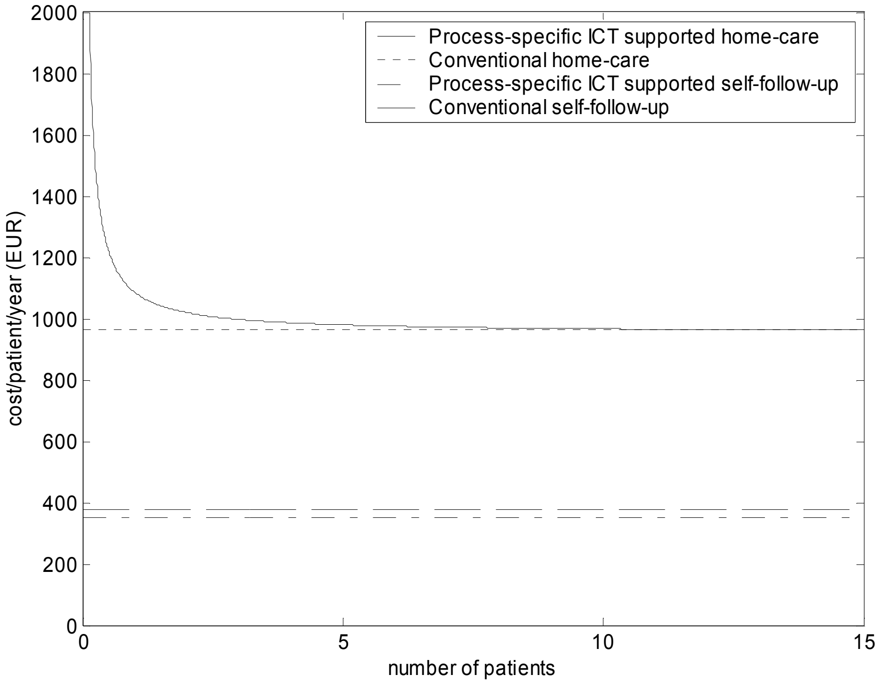


**Figure 5.3** Number of patients required for break-even in Ikaalinen (originally in [Nii03b])

For home-care the break-even point was 14 patients, while in self-follow-up the new modality is always more cost-effective. The results suggest that use of process-specific ICT and POC testing in anticoagulant treatment follow-up brings about an economic benefit even with a small number of patients in the Ikaalinen setting. However, the sensitivity of break-even to perturbations in the individual costs of the economic models used remains high. The increased efficiency results mainly from decreases in traveling for home-care nurses and self-follow-up patients in the sparsely populated Ikaalinen setting where distances are large.

In addition to the described key evaluation studies, a preliminary comparison of laboratory and POC P-INR tests made for the same patients on the same day was also carried out in 2002 [Nii02d]. The goal was to look preliminarily into how the two measurement methods compared. In the evaluated small sample (n=12), the range of observed differences between the POC and laboratory results was from -0.44 to +0.25 INR. This suggests relatively good agreement of POC results with laboratory results.

**In the Paloheinä** deployment use of a virtual anticoagulation clinic was studied in co-operation between HUS (Hospital District of Helsinki and Uusimaa) laboratory diagnostics, the primary health care center of the city of Helsinki, Terivan Oy, and MyLab Oy from June 4th 2003 to June 3rd 2004. The deployment location for the pilot study was the health station of the Paloheinä suburb, located in northern Helsinki. The anticoagulated patients of Paloheinä (n=~120, all adults) and professionals involved in anticoagulant treatment follow-up (n=~20) participated in the study.

The pilot study clinic model revised the conventional anticoagulant treatment model in three areas:

1. Adoption of a process-specific ICT service for oral anticoagulant treatment follow-up as an addition to the basic patient record system used by the health station. The process service was integrated with the MultiLab II LIS (MyLab Oy) for the automatic transfer of laboratory P-INR follow-up test results to the process service. The service replaced the conventional model relying on the use of a manual, paper-based anticoagulation notebook. Professional PC XHTML web access was used in Paloheinä.
2. Adoption of the anticoagulation nurse model supported by the process service in laboratory and POC result evaluation and treatment guideline assignment
3. Adoption of POC testing in Paloheinä home-care for anticoagulated patient follow-up

The deployment was evaluated based on:

- Comparison of pre-pilot and in-pilot P-INR distributions to determine possible changes in care quality as measured by the distribution structure (e.g., share of P-INRs in the typical treatment ranges from 2.0 to 3.5 INR).
  Methodology: quantitative statistical analysis of Paloheinä and two demographically similar comparison units (located near Paloheinä in Helsinki) P-INR follow-up data gathered from the solution database and from a laboratory IT system.
- Comparison of pre-pilot and in-pilot follow-up interval distributions to determine a possible change in care efficiency as measured by a change in the frequency of follows-ups.
  Methodology: see previous.
- Comparison of treatment guideline assignment distribution between nurses and physicians during the pilot as well as time used for follow-up processing before the pilot and during the pilot study to determine a possible change in care efficiency due to a new task distribution and changed follow-up processing time use.
  Methodology: quantitative statistical analysis of Paloheinä treatment guideline assignment follow-up data gathered from solution database to determine assignment distribution. Manually performed logging (by Paloheinä personnel) of time used for follow-up assignment before the pilot and during the pilot.
- Gathering the experiences of nurses and physicians (n=~20) regarding the perceived security, accessibility, and usability of the process ICT service in clinical pilot PC XHTML browser use combining POC anticoagulation testing. Opinions on quality and efficiency effects of the new service models were also queried.
- Methodology: structured questionnaire forms e-mailed (by Terivan Oy personnel) to the personnel in spring 2004 analyzed by qualitative content analysis.

No significant differences were observed in P-INR or follow-up interval distributions between a pre-pilot comparison interval and an in-pilot interval or with the two comparison units (see Table 5.4 and Table 5.5). Thus, the patients observed similar treatment levels and were followed up in similar intervals before and during the use of the new service models.

It was observed that anticoagulation nurses assigned 66% of treatment guidelines, compared to the physicians' share of 34%. In a study of treatment guideline assignment time allocation, it was observed that the average time per follow-up used by a physician was reduced by approximately 23% (from 4.04 min to 3.12 min). The average time allocation of an anticoagulation nurse was 2.28 minutes. Table 5.6 illustrates the reduction in resource use in the management of 100 follow-ups when the conventional and process-specific ICT-supported models are compared.

**Table 5.4** Follow-up P-INR distributions in Paloheinä and comparison units

| Pre-pilot (January 1st 2003 – June 3rd 2003) | | | |
|---|---|---|---|
| INR range | Paloheinä (n=817) | Station 1 (n=1264) | Station 2 (n=1208) |
| 1.0 ... 1.5 | 7 % (56) | 8 % (96) | 9 % (108) |
| 1.6 ... 1.9 | 15 % (123) | 16 % (200) | 17 % (206) |
| 2.0 ... 3.5 | 73 % (598) | 70 % (881) | 68 % (815) |
| 3.6 ... 4.5 | 3 % (28) | 5 % (64) | 5 % (63) |
| > 4.5 | 2 % (12) | 2 % (23) | 1 % (15) |
| | | | |
| 1.0 ... 1.9 | 22 % (179) | 23 % (296) | 26 % (315) |
| > 3.5 | 5 % (40) | 7 % (87) | 7 % (78) |
| | | | |
| In-pilot (June 4th 2003 – December 31st 2003) | | | |
| INR range | Paloheinä (n=1107) | Station 1 (n=1543) | Station 2 (n=1630) |
| 1.0 ... 1.5 | 7 % (74) | 8 % (124) | 8 % (123) |
| 1.6 ... 1.9 | 18 % (197) | 19 % (285) | 20 % (320) |
| 2.0 ... 3.5 | 70 % (772) | 68 % (1046) | 67 % (1088) |
| 3.6 ... 4.5 | 4 % (49) | 4 % (63) | 4 % (68) |
| > 4.5 | 1 % (13) | 2 % (25) | 2 % (30) |
| | | | |
| 1.0 ... 1.9 | 25 % (271) | 27 % (409) | 27 % (444) |
| > 3.5 | 6 % (62) | 6 % (88) | 6 % (98) |

**Table 5.5** Average follow-up density (average time between subsequent follow-ups for different patients) in Paloheinä and comparison stations pre-pilot and during the pilot.

| Interval | Paloheinä | Station 1 | Station 2 |
|---|---|---|---|
| Pre-pilot<br>(January 1st 2003 – April 31st 2003) | 15.6 d | 20.3 d | 21.6 d |
| In-pilot<br>(September 1st 2003 – December 31st 2003) | 17.2 d | 21.3 d | 22.5 d |

**Table 5.6** Comparison of conventional, paper-based, and process-specific ICT-supported treatment guideline assignment for 100 processed follow-ups.

| 100 follow-ups | Conventional | Process-specific ICT |
|---|---|---|
| Physicians (42 €/h) | 283 € (404 min) | 74 € (106 min) |
| Anticoagulation nurses (19 €/h) | - | 48 € (150 min) |
| Total | 283 € (404 min) | 122 € (256 min) |

It can thus be stated that the adoption of the process-specific ICT-supported service model resulted in resource savings without a change in the quality of care.

Considering the gathered experiences, the personnel of Paloheinä (three nurses and three physicians provided answers to the questionnaire) considered the process ICT service reliable (i.e., no erroneous functionality was observed) and easy to use (e.g., few mouse clicks were needed to reach the desired functionality). They also perceived that it has made care more efficient and speedy (e.g., faster to use than the conventional follow-up notebook). However, occasional network problems were observed during use of the service. Physicians appreciated the ease-of-use and speed of the service in treatment guideline assignment, clarity of the virtual anticoagulation notebook, and the decision support tools (graphs, anticoagulant medication calculator, etc.). Also, the fact that part of the routine workload was transferred to the nurses was considered positive. The nurses' experiences of use showed that service was handy in the retrieval of up-to-date anticoagulation patient information. The replacement of manual notebooks was also considered useful. Use of POC meters in home-care enabled follow-up measurement and medication distribution during the same patient visit, saving one patient visit. Use of the POC meter was considered practical in the home-care setting.

The users saw as targets of further development the full integration of the process ICT service with the basic patient record system so that the service can be directly used from the patient record system city-wide. Another development recommendation was improvement of the mechanism used for notifying about new follow-up results (e.g., through e-mail notifications). This is now a standard part of the service, as described earlier.

**In the Hervanta** deployment the process-specific ICT solution for oral anticoagulant treatment was in POC-supported home-care follow-up clinical use as part of a pilot study from March 3rd 2003 to December 31st 2003. The pilot study was realized as co-operation between Finn-Medi Research, Terivan Oy, the primary health care of the city of Tampere, and the home-care unit of the Hervanta suburb health station in southern Tampere. A number of anticoagulated (n=15, all adults, ages from 65 to 91), mostly elderly, patients of the Hervanta home-care unit as well as one home-care team and one health station physician participated in the pilot study.

During the pilot study the home-care nurses performed POC follow-up testing during routine patient visits, replacing the conventional blood sampling for laboratory testing. The home-care nurses functioned as anticoagulation nurses assigning a share of the treatment guidelines. Laboratory follow-ups were submitted by hand to the service during the pilot study. The process ICT service replaced the paper-based, manual anticoagulation notebooks. Professional XHTML web access was used in the pilot study.

The deployment was evaluated based on:

- Comparison of pre-pilot and in-pilot P-INR distributions for the participating patients (see Paloheinä evaluation for the detailed methodology; no comparison units were used in the Hervanta evaluation).
- Comparison of pre-pilot and in-pilot follow-up interval distributions for the participating patients (see Paloheinä evaluation for the detailed methodology; no comparison units were used in the Hervanta evaluation).
- Comparison of POC and laboratory follow-up results made on the same day for the same participating patient to determine how the two methods compare.
  Methodology: a correlation between the two data sets gathered from the solution database.
- Interviews of home care teams nurses (n=2) and the physician (n=1) about the perceived security, accessibility, and usability of the process ICT service in clinical pilot PC XHTML browser use combining POC anticoagulation testing. The home-care nurses and the physician were also queried about their opinions on quality and efficiency effects of the new service model.
  Methodology: half-structured theme interviews (by a Finn-Medi researcher) in spring 2004 analyzed by qualitative content analysis.

No significant differences were observed in P-INR or follow-up interval distributions between a pre-pilot comparison interval and an in-pilot interval (see Table 5.7 and Table 5.8). Thus, the patients observed similar treatment levels and were followed up in similar intervals before and during the use of the new service model.

**Table 5.7** Follow-up P-INR distributions in Hervanta

| INR range | Pre-pilot (n=296)<br>(March 1st 2002 – January 31st 2003) | In-pilot (n=363)<br>(March 1st 2003 – January 31st 2004) |
|---|---|---|
| 1.0 ... 1.5 | 10 % | 11 % |
| 1.6 ... 1.9 | 25 % | 19 % |
| 2.0 ... 3.5 | 62 % | 63 % |

**Table 5.8** Average follow-up density (average time between subsequent follow-ups for different patients) in Hervanta pre-pilot and during the pilot.

| Interval | Hervanta |
|---|---|
| Pre-pilot<br>(March 1st 2002 – January 31st 2003) | 13.6 d |
| In-pilot<br>(March 1st 2003 – January 31st 2004) | 16.5 d |

Comparison of POC and laboratory follow-up test results made for the same patients on the same day showed generally good agreement. The average difference between a laboratory and POC result was 0.26 INR and the range of deviations was from -1.0 to +1.2 INR (n=116). For one of the participating patients the POC testing values showed a constant deviation of up to ~1.0 INR from the corresponding laboratory values creating many of the extreme deviations. We speculate that the POC method is unsuitable for some patients: it was decided for the pilot study that an initial difference of >0.4 INR between POC and laboratory values would remove the patient from POC testing (i.e., the difference was clinically significant).

Considering results of the interviews, both the home-care nurses and the participating physician considered the process ICT service convenient and easy to use and that it facilitated efficient follow-up information exchange in consultations between the home-care nurses and the physician. The physician also considered that wider use of the service within primary health care in Tampere would enable good accessibility for anticoagulation information as it could be accessed anywhere in the care system (e.g., when a patient moves between different care facilities). The physician also appreciated the structural and visual qualities of the virtual anticoagulation notebook. Increased reliance on ICT was on the other hand seen as a drawback. The physician also considered that the limited use of the new service model did not change the clinical quality of the treatment, a claim supported by the stability of the evaluated statistical indicators described earlier. The physician also saw that use of the service did not significantly change his time allocation for anticoagulant treatment management.

Use of POC testing in home-care was considered time-saving and convenient due to the elimination of second patient visits as the follow-up result was immediately available. Use of the meter was also seen as easy. However, for one of the participating patients the POC meter produced anticoagulation values differing significantly from laboratory follow-up; POC testing is not suitable for all everyone.

### 5.2 Hypertension Follow-up

In the year 1997 there were almost 450 000 patients entitled to publicly subsidized hypertension medication in Finland alone. The average yearly cost of hypertension medication treatment was approximately 280 €. Obesity and heavy use of alcohol or table salt in the daily diet greatly increase the risk of hypertension, among other factors. [Iiv98]

In the Finnish setting, conventional hypertension treatment follow-up consists of regular blood pressure monitoring and general practitioner visits by patients on hypertension medication in occupational or municipal primary health care centers. During the visits a physician evaluates progress in hypertension treatment by evaluating the condition of the patient (i.e., recent blood pressure history and the patient’s general health). The physician adjusts the patient’s hypertension medication and/or suggests lifestyle changes, which would alleviate the condition of the patient. Blood pressure home monitoring is becoming more common among the general population, replacing regular nurse or physician assisted measurements at the primary health care provider. Home measurements can potentially give more reliable blood pressure values. [Tur99]

The patient’s blood pressure monitoring history is typically recorded on a paper notebook while the primary health care provider keeps general records on the patient in a paper-based or electronic patient record.

The high incidence of hypertension calls for new ways in organizing hypertension care and follow-up. Solutions towards this include increased blood pressure monitoring at home and use of process-specific ICT solutions to convey hypertension follow-up and related data between hypertension patients and professionals.

#### 5.2.1 Service Model

Figure 5.4 illustrates the generic process chain available through the adoption of the process-specific ICT solution in primary or occupational care hypertension follow-up.

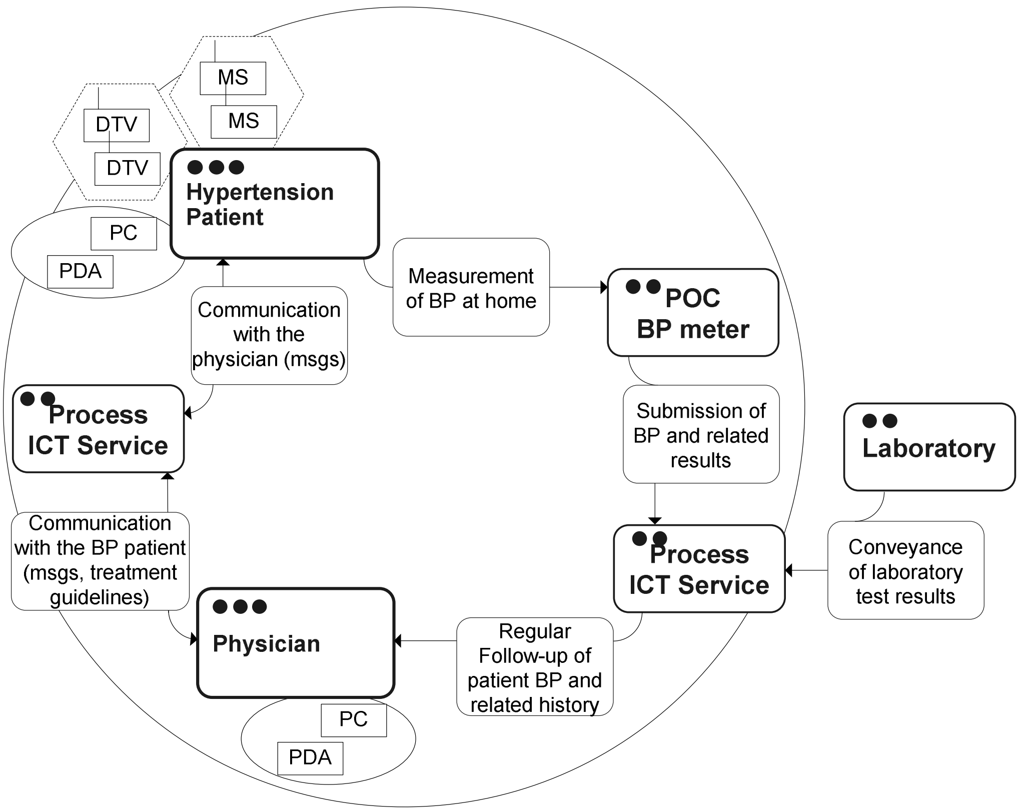


**Figure 5.4** Hypertension follow-up process chain

The basic clinical process chain consists of the following components:

1. Regular blood pressure measurements at home or at a care provider and submission of the pressure results (systolic and diastolic pressure values) along with related measurements (weight, pulse, measurer type, and measuring position) to the process ICT service.
2. Conveyance of related laboratory measurement data (e.g., cholesterol values) to the process ICT service from a LIS.
3. Regular follow-up, by the physician, of patient blood pressure and related history data from the process ICT service.
4. Two-way, text message, and treatment guideline-based communication between the physician and the patient through the process ICT service.

This basic process flow supports the following service models:

The **self-measuring patient** has at home a portable meter for blood pressure measurements. He submits the results of the measurements through networked multimedia. The physician monitors regularly the blood pressure measurements submitted by the patients and, if appropriate, sets new treatment guidelines. The patient accesses the updated notebook with the new guidelines using networked multimedia. In addition, results from laboratory tests can be conveyed automatically to the system. Patients and physicians can also communicate one-to-one with the solution messaging service.

In **home-care** patients are replaced by home-care nurses as the makers of home measurements. Otherwise, the model is the same as for self-measuring patients.

The process ICT service basically implements a virtual blood pressure notebook collection and a related treatment guideline and open messaging service to facilitate the described process chain used in the implementation of the two service models. The service includes the following functional components to implement a virtual hypertension notebook collection.

**PC XHTML browser access for professionals** provides web access to the virtual hypertension follow-up notebooks of the patients, to a professional-to-professional or patient-to-professional messaging service, as well as service maintenance functionality to maintain the patients' notebooks and professional and patient user accounts. Professional web access is implemented similarly as in the anticoagulation solution.

The virtual hypertension notebooks of individual patients contain:

- Graphical and tabular representations of blood pressure measurement (including systolic and diastolic pressures, measurement position, and measurer types and optional weight and calculated BMI (Body Mass Index) values)
- Functionality to add new and update blood pressure measurements
- Treatment guideline history data in tabular form
- Interface for adding and updating textual treatment guidelines for the patient
- A view to the patient's personal (name, e-mail address, etc.), diagnosis, medication, and permanent hypertension information (hypertension diagnosis date, systolic and diastolic target values, etc.)
- Laboratory result history data (LDL, HDL, cholesterol, etc.) in tabular form
- Functionality to add and update laboratory result data

The process ICT service can be integrated to a LIS system containing the new laboratory results to facilitate the automatic reception of new laboratory results. The integration can be based, for example, on HL7 messaging or a proprietary XML messaging service. The messaging service can be used by the professionals to send secure text-based messages to other professionals and patient users of the service. The recipient is optionally notified about the arrival of a new message with an e-mail message. The maintenance functionality is similar to the anticoagulation solution.

**PC and DTV XHTML browser access for hypertension patients** is similar to professional web browser access with the exceptions that the patient can only access his own hypertension notebook, that the maintenance functionality is not available, and that the service can also be accessed from a MHP DTV platform (see Figure 5.5). Again, PC and DTV browser access is implemented similarly as in the anticoagulation solution.

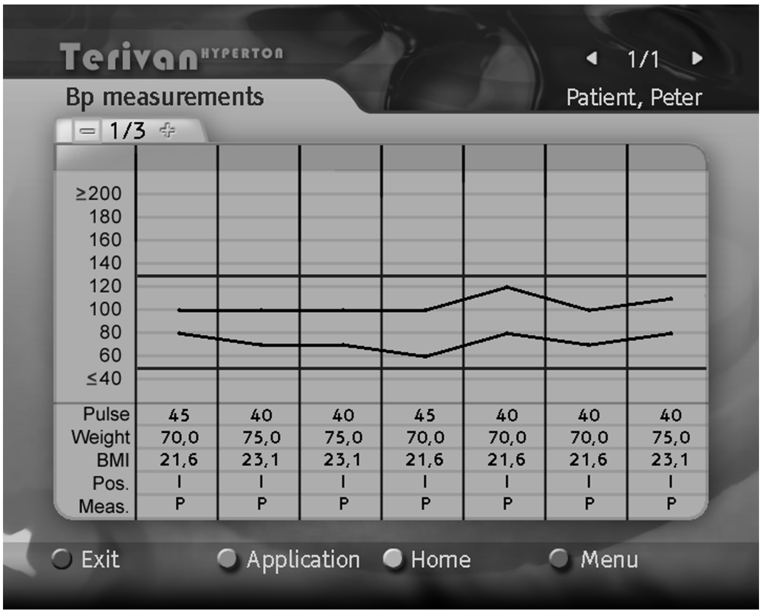


**Figure 5.5** Screen shot DTV XHTML browser access for hypertension patients

### 5.2.2 Deployments and Evaluation

Table 5.9 shows the characteristics of deployment of the hypertension follow-up solution at the Hervanta health station in Tampere, Finland.

In the Hervanta deployment the process-specific ICT solution for hypertension follow-up was in clinical use as part of a pilot study from October 27th 2003 to February 27th 2004. The pilot study was realized in co-operation between Finn-Medi Research, Terivan Oy, and the primary health care of the city of Tampere. A number of hypertension patients (n=5, all adults, ages from 44 to 68) of the Hervanta health station and one health station physician participated in the pilot study.

**Table 5.9** Hypertension follow-up solution deployment

| Deployment location | Location characteristics | Deployment service models |
|---|---|---|
| Hervanta health station of the city of Tampere primary health care (from 2003 to 2004) | Geographically small and suburban setting with a dense and young population | Self-measuring patients (POC, PC XHTML) |

During the pilot study, the five participating patients submitted blood pressure measurements made at home with a blood pressure POC meter and related data to the hypertension notebook of the service, using it as a replacement for the conventional paper-based notebooks. The health station physician monitored the submitted measurements, manually added new laboratory results, and updated the patients' treatment guidelines appropriately; the physician used the virtual notebook as a tool in hypertension care management. The patients and the physician also communicated with the two-way messaging service to exchange information related to hypertension care. Web access was used by both the patients and the physician.

The deployment was evaluated based on:

- Interview of the health station physician (n=1) about the perceived security, accessibility and usability of the process ICT service in clinical pilot PC XHTML browser use and also about his opinions on quality and efficiency effects of the new service model.
  Methodology: half-structured theme interview (by a Finn-Medi researcher) at the end of the clinical pilot study analyzed by qualitative content analysis.

Regarding the user experiences gathered in the interview, the participating physician stated that the self-measurements made at home and mediated electronically to care personnel may help to save resources and increase efficiency if adopted widely. He also estimated that with self-measurements the patients require fewer visits to the health station for blood pressure monitoring. This would reduce the workload of the station. The virtual hypertension notebook was considered more accessible and often easier to read than the conventional paper-based notebooks. Follow-up data can be conveniently accessed by the physician time and location independently. Concerning the effect of the adoption of self-measurements and the process-specific ICT service on care quality, the physician considered that the use of the service helps to motivate certain hypertension patient groups. Among these are middle-aged men participating in the pilot study. Patient motivation is central for good treatment results. In conventional care, the patient may feel healthy despite facts to the contrary and, as hypertension medication is expensive, may even stop taking the medication although continued use of medication would in fact be necessary. The visual tools of the service and constant self-measurements increase the awareness of the patient of his own condition and motivate him to continue the treatment. However, the physician also indicated his scepticism about the feasibility of extending the service to cover older hypertension patients, due to usability questions.

An improvement suggested by the physician to the process-specific ICT service was to include links to web pages in the patients' service to enable forwarding to hypertension information sources (e.g., about hypertension medication and weight management).

### 5.3 Guided Asthma Self-Management

Asthma is among the most common chronic diseases in the industrialized world. The conditions of asthma patients typically have unpredicted relapses or exacerbations during which they may require physician consultation or even hospitalization. In the USA, as an example, asthma is estimated to affect between 14 and 15 million people, resulting in 470000 hospitalizations each year with an estimated cost of $6 billion. [Din02]

It is essential that early action should occur in asthma exacerbation periods to prevent hospitalizations. Tools for recognizing exacerbations include an observed decrease in peak expiratory flow (PEF) measurement rates along with known symptoms and signs of asthma. These include increased dyspnea, combination of increased wheeze, cough, or mucus secretion, nocturnal asthma, increased use of short-acting bronchodilators (β2-sympathomimetics), increased exercise-induced asthma, and decreased morning PEF rates. Asthma patients need help in relieving these conditions. [Cha90]

Asthma self-management involves the patient making therapeutic, behavioral, and environmental adjustments in accordance with advice from health care professionals. Guided asthma self-management is a treatment strategy where patients are taught to act appropriately when the first signs of an asthma exacerbation appear. As insidious deterioration is common in asthma, many hospital admissions can be prevented and most of the patients admitted to emergency units have had alarming symptoms for at least one week. Unfortunately, many asthma patients do not exhibit appropriate behavior during asthma exacerbations. However, routine measurement of PEF in association with a self-management plan appears to be effective in reducing symptoms of asthma and improving lung function. [Bea89]

Essential elements of guided asthma self-management include [Lam03b]:

- Efficient patient education resulting in an informed patient
- Clear instructions for the patients on how to act in early exacerbations
- Flexible contact with the attending unit
- Reliable PEF and/or symptom-based follow-up
- Good quality and continuity of long-term follow-up

Patients who are suitable for guided self-management have moderate-to-severe asthma and the disease is variable [Lam03b]. They also have a history of hospital admissions due to asthma and a poor perception of the severity of the disease, combined with a co-operative attitude [Lam03b]. Poor treatment compliance is a major problem in all asthma treatment strategies, including guided self-management. Asthma medication use in Finland is estimated to be only approximately 50% of the recommended level among asthma patients, which is a major cause of asthma exacerbations [Suo00].

In the Finnish setting, the treatment of asthma patients has recently become mainly the responsibility of public primary care with a reduction in the activity of secondary specialist care [Min94]. Public primary care health centers typically arrange asthma treatment through designated asthma nurses and GPs who have responsibility for follow-up and guidance of the asthma patients located in the area of the health center or station. Guided asthma management is realized with the help of paper-based PEF and symptom follow-up notebooks as well as asthma education material and professional guidance.

A process-specific ICT solution for guided asthma self-management establishes a possibility to provide a convenient and accessible storage for self-management follow-up data, decision support tools for asthma physicians, and a flexible tool for asthma patient-to-professional communication to facilitate self-management guidance and other information exchange. Adoption of such a solution has potential for improving the poor treatment compliance of asthma patients and can facilitate information processing in asthma treatment and follow-up.

### 5.3.1 Service Model

Figure 5.6 shows the generic process chain available through the adoption of the process-specific ICT solution in primary care guided asthma self-management.

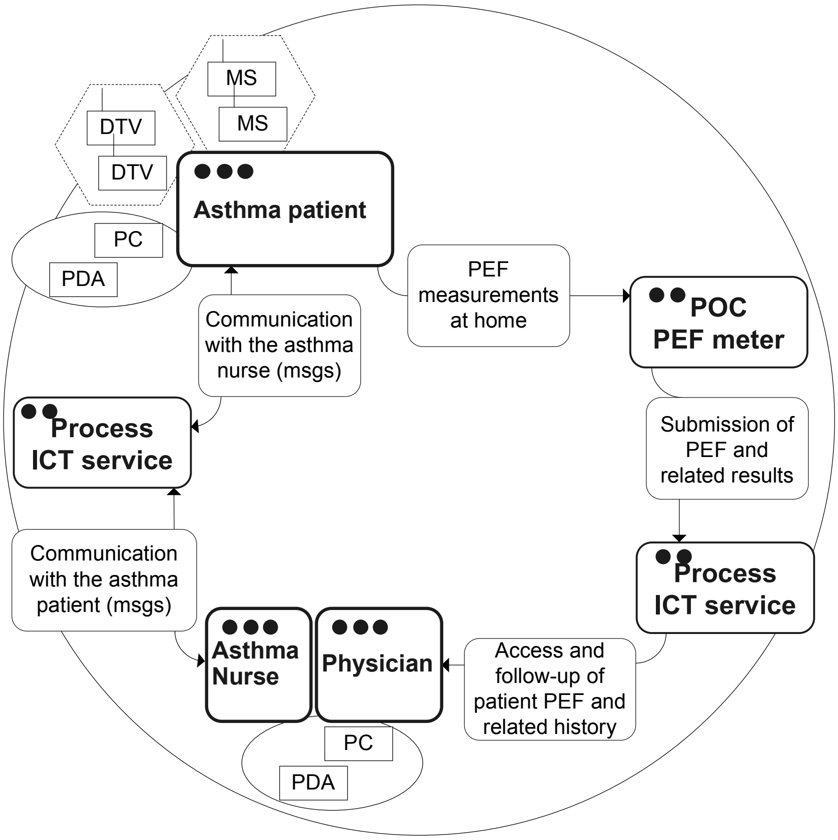


**Figure 5.6** Guided asthma self-management process chain

The basic clinical process chain consists of the following components:

1. PEF measurements at home and submission of the results along with related symptoms and number of taken bronchodilator doses to the process ICT service.
2. Access and follow-up of the patient PEF and other follow-up data by physicians.
3. Two-way, text message, and treatment guideline-based communication between the asthma nurse and the patient through the process ICT service.

This basic process chain supports **guided self-management** for asthma patients. In guided asthma self-management the patients submit follow-up data (PEF measurements made with a personal PEF meter, etc.) to the virtual asthma notebook during asthma exacerbations or pre-arranged follow-up periods using networked multimedia. The patient's primary care physician accesses and follows the patient's follow-up history and uses the asthma notebook during patient control visits to determine the status of the patient's asthma. Asthma self-management guidance comes particularly from the primary care asthma nurse with whom the patient can communicate one-to-one with the process ICT service messaging function.

The process ICT service basically implements a virtual asthma follow-up notebook collection and messaging service to facilitate the described process chain. The service includes the following functional components.

**PC XHTML browser access for asthma physicians and nurses** provides web access to the virtual asthma notebooks of the patients' follow-ups, to an asthma nurse-to-patient messaging service, as well as service maintenance functionality to maintain the patients' notebooks and professional and patient user accounts. Professional web access is implemented similarly as in the anticoagulation and hypertension solutions.

The virtual asthma notebooks of individual patients contain:

- Graphical and tabular representations of PEF measurement, symptom, and medication history data with decision support through automatic calculation of follow-up data indicators (e.g., daily PEF change)
- Functionality to add new and update PEF, symptom, and medication history data
- A view of the patient's personal (name, e-mail address, etc.), diagnosis, medication, and permanent asthma information (asthma type, optimal PEF level, allergies and pets, smoking data, etc.)

The messaging service can be used by the asthma nurses to send secure text messages to the guided asthma patients. The recipient is optionally notified about the arrival of a new message through the sending of an e-mail message. The maintenance functionality is similar to the anticoagulation and hypertension solutions.

**PC, DTV, and mobile XHTML browser access for asthma patients** is similar to professional web browser access with the exceptions that the patient can only access his own asthma notebook, that the maintenance functionality is not available, and that the service can also be accessed on a MHP DTV or mobile platform. Again, PC and DTV browser access is implemented similarly as in anticoagulation and hypertension solutions.

### 5.3.2 Deployments and Evaluation

Table 5.10 illustrates the characteristics of the deployment of the guided asthma self-management solution at the primary health care center of Ikaalinen.

**Table 5.10** Guided asthma self-management solution deployment

| Deployment location | Location characteristics | Deployment service models |
|---|---|---|
| Municipal primary health care center of Ikaalinen (in 2002 and 2003) | Geographically large and rural municipality with a sparse and aging population | Guided self-management (POC; PC, DTV, and mobile XHTML) |

The Ikaalinen deployment consisted of two phases realized during the Health Care TV project in co-operation with the primary health care center of Ikaalinen. During the first phase in the spring of 2002, asthma patients (n=4, all adults, ages from 24 to 50) motivated to participate in guided asthma self-management and on regular asthma medication were recruited among the Ikaalinen asthma patients. A physician (an asthma specialist) also participated in this phase in the role of an asthma physician. An asthma nurse did not participate during this phase. During the second phase in the spring of 2003 (from the beginning of February to the middle of May), Ikaalinen asthma patients (n=10, 7 adults and 3 children, ages from 8 to 55) were recruited to participate using the same selection parameters as in the first phase. The specialist from the first phase also participated in this phase, as did an asthma nurse from the Ikaalinen health center.

During the first phase, basic use of the virtual asthma follow-up notebook as a repository of follow-up data as a replacement for paper-based notebooks was tested. The patients were to submit follow-up data (PEF measurements, symptoms, etc.) to the service during observed asthma exacerbations. In addition to this, the patients also had the possibility to exchange short text messages with the participating specialist for self-management guidance. Web access was used by both the patients and the specialist. Willing patients were also provided with a digital PEF meter and were instructed in its use.

The first phase of the deployment was evaluated through the analysis of user experiences gathered in interviews. However, user experiences remained very limited due to the fact that the participating patients did not observe relapses during the pilot study. It was also quickly observed that an asthma nurse would be a more natural routine guidance partner for the patients as defined by the current process chain. The limited use experiences gathered, mostly related to the use of the virtual follow-up notebook as a repository for follow-up data, are similar to the experiences from the second phase.

In the second phase of the deployment, patients continued to use the virtual notebook as a repository of follow-up data. They agreed to submit follow-up data at least for the duration of one pre-determined follow-up week. In addition, follow-up data was to be submitted during observed asthma exacerbations. In addition to this, the patients used the service to actively communicate with the nurse for self-management guidance. At the end of the pilot study, the patients had a follow-up control visit at the participating specialist's reception to assess the progress of their treatment. During and before these visits the specialist used the process ICT service to access the patients' follow-up data and utilized the built-in decision support mechanisms (i.e., indicators calculated from follow-up data including daily PEF rate change quotients). Web access was used by the patients, the asthma nurse, and the specialist during the clinical study. Willing patients were also provided with a digital PEF meter and instructed in its use. At the end of the second phase, use of DTV and mobile phones for patient access was assessed in laboratory conditions at TUT.

The second phase of the deployment was evaluated based on:

- Interviews of patients (n=10), the asthma nurse (n=1), and the asthma specialist (n=1) regarding the perceived security, accessibility, and usability of the process ICT service in clinical pilot PC XHTML browser use. The asthma nurse and specialist were also queried regarding their opinions on quality and efficiency effects of the new service model.
  Methodology: half-structured theme interviews (by HCTV researchers) at the end of the clinical pilot study analyzed by qualitative content analysis.
- Interviews of patients (n=2) about the usability of the process ICT service in laboratory DTV and mobile XHTML browser use.
  Methodology: theme interviews (by HCTV researchers) after guided experimental laboratory use analyzed by qualitative content analysis.

The goal of the evaluations was to determine the feasibility of the solution in two basic categories:

- A tool assisting guided self-management asthma patients through its functionality as a repository for follow-up data and as a guidance communication tool
- As a decision support and resource management tool for asthma nurses and physicians through repository and communication tool functionality

Considering the clinical study interviews, the participating patients considered the virtual follow-up notebook a convenient and accessible replacement for the paper-based notebook. The patients stated that the electronic notebook was easier to fill than the small paper notebook and provided a possibility for clearer markings. An interesting anecdote from the parent of one of the participating child patients was that the conventional notebook is too small for children to fill easily, while the virtual notebook could be easily managed also by them. The automatically generated graphical representations of PEF data were also considered a significant benefit. The patients noted that the virtual notebook provides a more convenient way to access history follow-up data than a collection of paper notebooks. In the virtual follow-up notebook, data are automatically temporally ordered and easily browsable. An improvement suggested by one patient was that the service should provide an interface for adding multiple follow-ups simultaneously. The patients noted that it is more convenient to collect a number of follow-ups on paper and then to submit the data to service than to access the service after each PEF measurement. All patients noted that the service served as a motivator for asthma self-management. The possibility to communicate conveniently with the asthma nurse was considered the primary cause for this. For example, the possibility to consult first with the nurse in the case of an exacerbation to determine whether a visit to a physician is required was considered to provide an increased sense of security. Also, the fact that the nurse had approached the patient by telephone after receiving a message through the service was considered a positive development. The patients were convinced of the security of the service as it was realized in close co-operation with the familiar health care center. When the patients were asked whether they would be willing to pay personally for use of the service, most stated the service should be mainly paid for by the health center.

Use experiences of the asthma nurse were fundamentally positive especially due to the asynchronous messaging functionality of the service. Use of the message box in patient communication provided an increased level of flexibility due to time and location independence. Use of the service enabled the nurse to consider carefully the patients’ queries at a time and location most convenient for her. With conventional phone queries, other tasks at hand often prevent the careful consideration of answers. Also, the fact that the patient’s query is permanently recorded in the service helps to prevent omissions in answers to patients.

The participating asthma specialist was generally pleased with the service and the clinical pilot study. The virtual notebook proved to be a convenient tool for accessing the patients’ follow-up history. The embedded calculation of follow-up data indicators saved time during patient follow-up control visits. The physician suggested a number of improvements to the service, including a more structured representation for asthma medication used by the patients.

Regarding the DTV and mobile phone (a Philips TriMedia MHP STB and a Nokia 9210 Communicator) usability study realized in laboratory conditions, the two patients participating considered DTV use to be more convenient when compared to web and mobile access in PEF measurement submission. The user interface of the DTV XHTML service was considered highly usable even with a standard DTV remote control. However, the patients noted that for text-based communication, use of a standard remote control is more limited than a keyboard. The patients also stated that use of the DTV service might be more convenient due to the fact that the TV set can be accessed faster for follow-up data submission (e.g., during a TV commercial break) than a PC. However, it should be noted that the DTV service used by the patients in laboratory conditions eliminated some of the delays involved in the use of a production DTV system. Use of the mobile phone was considered difficult due to its small keyboard and display size. However, mobility of the device was considered a benefit.

## 5.4 Eye Injury Prevention

It is estimated that approximately 50000 eye injuries occur yearly in Finland and a majority of the injuries come from fragments or other foreign objects [Saa95]. Eye injuries can lead to serious damage to the eye, leading to vision impairment or even blindness. It is thus critical to examine the ways in which eye injuries can be prevented.

The key methodology in the prevention of eye injuries is the provision of information about eye injuries to the general population. This information includes both instructions on how to prevent injuries form occurring both at work and at home (e.g., recommendations for the use of protective eye gear) and instructions for what to do in case an injury occurs (e.g., washing of eyes in case of chemical exposure).

Considering the provision of eye injury prevention information to the general population, we assert that process-specific ICT solutions provide a tool for efficiently conveying this information to the general population to reach the goals of prevention.

Use of modern ICT in the wider medical field of ophthalmology is briefly considered in [Lam02d].

### 5.4.1 Service Model

Figure 5.7 shows the process chain available through the adoption of the process-specific ICT solution in eye injury prevention.

The process chain consists of provision of eye injury prevention multimedia information to an eye injury prevention target population through networked multimedia; a PC XHTML service and a DTV value-added XHTML broadcast service.

Two service models are available within this process chain. A consumer actively searching for the eye injury prevention information with a web browser in pull-type service provision and a more passive consumer reached through a push-type DTV service.

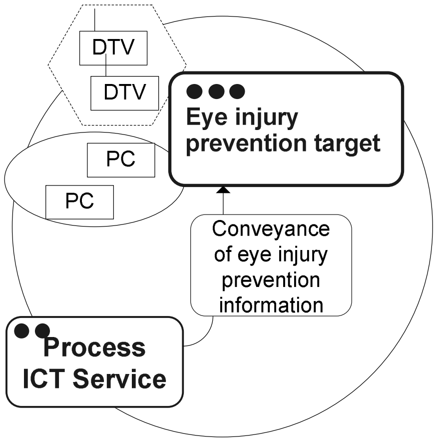


**Figure 5.7** Eye injury prevention process chain

**PC XHTML browser pull access for eye injury prevention targets** consists of a web site implemented as a static process application XHTML engine. A person accesses the web site in pull access service provision with a PC XHTML browser over the Internet.

The web site includes the following multimedia content components:

- General: General information about eye injuries and their prevention
- At home: Information about the prevention of eye injuries most common at home
- At work: Information about the prevention of eye injuries most common at work
- First aid: First aid procedures related to most common eye injuries (e.g., what to do in case an eye is exposed to a foreign object or a chemical compound)

The web site includes also functionality querying the demographic parameters of the person accessing the site to provide for personalization of components depending on the determined demographic group.

**DTV XHTML browser push access for eye injury prevention targets** contains the same multimedia content components as the web access service (see Figure 5.8). However, the service is provided through the DTV broadcast channel data to the general population in push-type service provision. The content is accessed with a generic XHTML browser also conveyed in the broadcast. The value-added service can be linked to a TV broadcast related to eye injury prevention (e.g., a public service infomercial about the dangers of eye injuries) where it serves as an additional information service component for the TV broadcast. The consumer is notified about the presence of the value-added service within the broadcast, for example with the help of a logo implicating its availability, enabling push-type service provision. Client-side personalization functionality similar to PC XHTML browser access is also available.

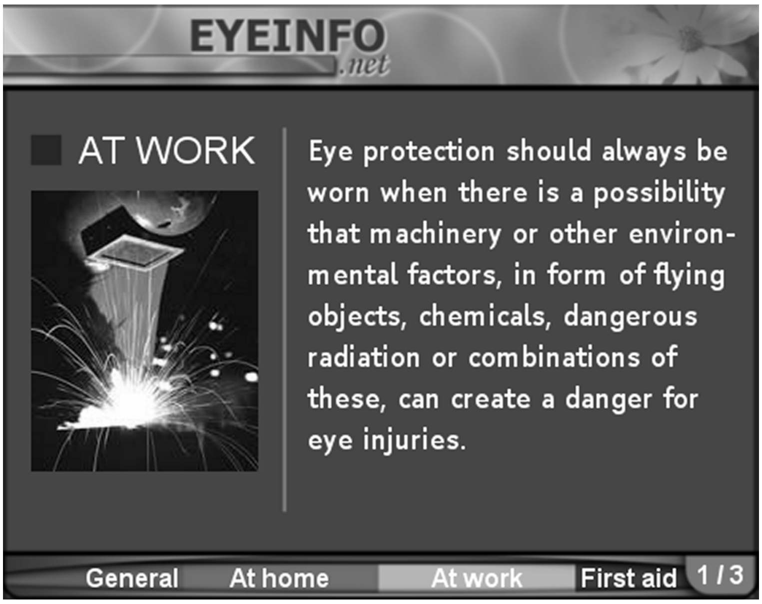


**Figure 5.8** Screen shot DTV XHTML browser access for eye injury prevention targets

### 5.4.2 Characteristics

The eye injury prevention service realized in the Health Care TV project in 2003 as a conceptual service was not deployed in an operational setting due to restrictions in DTV broadcast access. It is furthermore difficult or impossible to objectively evaluate the effectiveness of an ICT-facilitated mass media service targeting large populations without an elaborate consumer research study. Elaborate consumer research was outside the scope of the Health Care TV project. However, we will here subjectively consider the potential benefits of the described process-specific ICT solution for eye injury prevention. Also, the service was briefly demonstrated and used by the two patients evaluating the DTV asthma solution in laboratory conditions in the spring of 2003. We will also list their initial impressions of the eye injury prevention solution.

The depicted solution includes as an innovation the possibility to convey a value-added service through DTV to large consumer groups in a mass media deployment. Compared to a traditional broadcast TV informational A/V service, the development and deployment of a value-added hypermedia service is obviously more economic. Also, the basic fact that the service can be pushed to the general audience (e.g., when compared to web site access) provides a better way to reach generally passive consumer groups not actively seeking information. Potentially hundreds of thousands of targeted consumers can be reached simultaneously. Use of a value-added service also enables user group-based personalization in both web and DTV access not available in traditional TV broadcasting or paper-based material. Regarding the opinions of the two consumers for whom the DTV prevention service was demonstrated, they stated that the DTV service was very easy to use with a DTV remote control. They also stated that the service, as provided to the living room through television, should reach the common consumer better than a similar web site as less active searching for the information is required. The two evaluators also stated that eye injury first aid information might be accessed more easily and faster from the TV set in the case of an emergency than with a PC.

### 5.5 Rheumatoid Arthritis Rehabilitation

Rheumatoid arthritis is an inflammatory, auto-immune disease of the joints. There are approximately 30000 rheumatoid arthritis patients in Finland. The incidence among women is 2 to 3 times higher than among men and most diagnoses are made around the sixtieth birthday. While the precise cause of rheumatoid arthritis is unknown, genetic and hormonal factors as well as smoking increase the risk of arthritis incidence. [Lei02b]

The symptoms typically first appear in small and middle-size joints. The symptoms then develop slowly and new joints become inflamed gradually. The typical symptom is morning stiffness in joints, lasting at least one hour. Fatigue, a loss of appetite and a fever can accompany this specific symptom. Inflamed joints often exhibit motion sensitivity. [Lei02b]

Rheumatoid arthritis usually requires lifelong treatment and rehabilitation, including various medications, physical therapy, education, and possibly surgery aimed at relieving the signs and symptoms of the disease [Sup04].

Physical therapy and exercise are important components in rheumatoid arthritis rehabilitation in addition to medication and other aids. Motion, muscle, and fitness exercise are forms of physical exercise used in the rehabilitation. Motion exercise, involving stretching and other gymnastic motions, helps the patient to maintain or regain his joint and muscle mobility. The number of inflamed joints has been shown to decrease due to regular motion exercise [Reu02].

Muscle and fitness exercise support motion exercise, for example, by increasing muscle strength and by reducing fatigue [Reu02]. Successful rehabilitation supports the patient's participation in daily (e.g., working) life.

We consider here the use of a process-specific ICT solution in support of rheumatoid arthritis rehabilitation based on physical exercise. We assert that such a solution can serve as an empowerment tool for rheumatoid arthritis rehabilitation.

### 5.5.1 Service Model

Figure 5.9 illustrates the process chain available through the adoption of the process-specific ICT solution in rheumatoid arthritis rehabilitation.

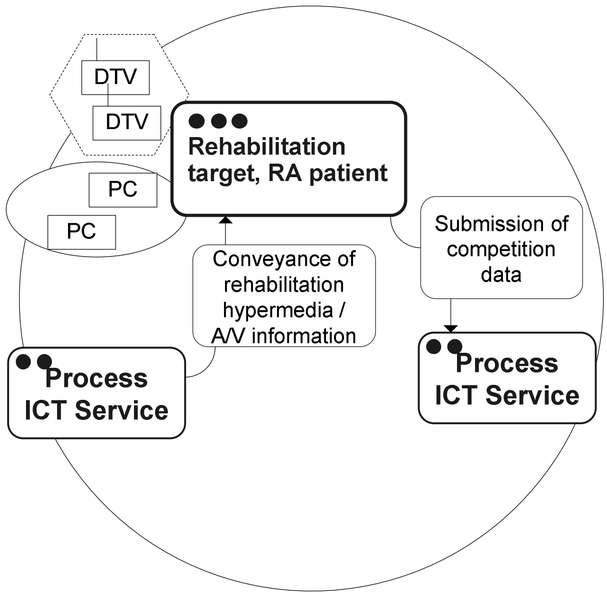


**Figure 5.9** Rheumatoid arthritis rehabilitation process chain

The process chain consists of the conveyance of rheumatoid arthritis rehabilitation hypermedia and/or A/V information to the rehabilitated patient through networked multimedia; a DTV XHTML broadcast service synchronized with a DTV A/V broadcast or a PC XHTML service. For both access types a simple interactive service is also included.

The service model available within this process chain is that of an active rheumatoid arthritis patient seeking an empowering rehabilitation aid.

**DTV A/V service with a synchronized XHTML service for the** rheumatoid arthritis **patient** consists of two components. The first component is a standard A/V TV broadcast depicting motion and muscle exercises. It is basically an exercise video with different motions performed by human actors.

The second component is a set of XHTML pages implemented as a static and dynamic process application XHTML engine and provided through the DTV broadcast and interaction channels. The pages are accessed with an XHTML browser supporting synchronization. The XHTML service includes three parts:

- The first part (“**Learn!”**) includes general static multimedia information about rheumatoid arthritis and its rehabilitation.
- The second part (“**Do!”**) includes multimedia information synchronized with the underlying A/V exercise video. As the muscle or motion exercise changes in the exercise video, so does the content of the value-added service explaining and further visualizing the current exercise. The XHTML browser application monitors for DSM-CC stream events embedded in the A/V broadcast of the exercise video to change the value-added service content.
- The third part (“**Win!”**) includes a simple form for answering a set of questions about the first part to participate in a competition. The results are conveyed to the process ICT service dynamic XHTML engine through the DTV interaction channel. The purpose is to motivate the patient to study the contents of the first part.

**PC XHTML access for the** rheumatoid arthritis **patient** is similar in functionality to the DTV service with the exception that the A/V exercise video service and the related “Do!” part synchronization is not realized. The service is accessed with a standard PC XHTML browser through the Internet.

### 5.5.2 Characteristics

The rheumatoid arthritis rehabilitation service, realized in the Health Care TV project in 2003 as a conceptual service, was not deployed in an operational setting due to restrictions in DTV broadcast access. As such it was not evaluated as a rehabilitation tool for rheumatoid arthritis patients. However, we will here subjectively consider the characteristics of the described process-specific ICT solution.

In the depicted solution the unique capabilities of DTV as a networked multimedia platform are clearly visible. The possibility to combine an exercise video with an explanatory and synchronized value-added service supports empowerment in rheumatoid arthritis rehabilitation. Compared to a traditional TV broadcast of an exercise video, the service includes additional supportive information for the patient. Also the competition component embedded in the service may help to motivate and empower the rehabilitated patient. Compared to the DTV service, the PC accessed service is obviously more limited.

### 5.6 Summary Points

In this chapter we considered the wide range of process-specific health ICT solutions supporting overall health solution provision that have been realized and deployed on versions of the ICT convergent platform developed in Chapter 4. Both the structure and evaluation of these solutions was considered. The most concrete and objective feasibility findings were discovered in the domain of tele-treatment, which included three solutions deployed in clinical settings. More subjective and speculative considerations were made for the conceptual tele-prevention and tele-rehabilitation solutions. Table 5.11 lists the highlights discovered from the evaluation of the process solution deployments within the three health strategies.

**Table 5.11** Highlights of the deployed solutions within the different health strategies

| Health strategy | Highlights |
|---|---|
| Tele-treatment | - Highly usable, accessible and secure storage, use and sharing of treatment follow-up data in virtual follow-up notebooks for both patients and professionals through multi-modal and convergent access from networked multimedia (anticoagulation, hypertension, asthma)<br>- Successful systems convergence with other information systems (anticoagulation)<br>- Successful utilization of process control and decision support tools including visualization tools, notification functionality, etc. (anticoagulation, hypertension, asthma)<br>- Convenient, asynchronous communication between the treated patients and professionals (anticoagulation, hypertension, asthma)<br>- Proven resource allocation efficiency improvements while treatment quality remains constant when compared to traditional treatment organization (anticoagulation) |
| Tele-prevention | - Excellent reach of prevention target groups through personalized prevention information carried with convergent networked multimedia.<br>- Unique capability of DTV to reach large audiences in push-type service provision at a limited expense |
| Tele-rehabilitation | - Unique capability of DTV in hybrid rehabilitation services combining a rich variety of content types with convergent networked multimedia |

# 6 CONCLUSIONS AND DISCUSSION

## 6.1 Principal Results and Conclusions

Four claims concerning the application of convergent ICT in the process-specific health domain were made in the introduction to the thesis. It was postulated that a hybrid model (developed in Chapter 3) defining a requirement taxonomy for a platform for process-specific, convergent ICT solutions supporting overall solution provision (process facilitation model) and an evaluation methodology for solutions deployed on the platform can be used to establish the validity of the claims. Based on the hybrid model, Chapters 4 and 5 present the results concerning these claims. We will next consider the claims made and the corresponding results one-by-one.

1. Convergent ICT enables the integration of telehealth solutions with legacy centralized systems and other information systems to create unified health information systems consisting of process-specific logical sub-systems for application within the different health strategies (tele-prevention, tele-treatment, and tele-rehabilitation).

The platform for process-specific health ICT solutions developed in Chapter 4 supports a wide range of integration (involving information, communications, and systems convergence), technologies. As noted, these are especially critical for clinical tele-treatment solutions. The platform supports the following integration functionalities:

- Integration with centralized and integrating health information systems for patient record information sharing, vocabulary and computer-readable guideline access, etc.
- Integration with other external information systems for other value-added solution functionality (e.g., to facilitate dynamic authentication or multimedia content services)

Integration is based on standardized HL7/CDA, XML, and Web Services technologies, as noted in Chapter 4.

2. Convergent ICT supports the development of novel, process-specific telehealth solutions through the application of convergent digital networked multimedia providing consultation-supporting, consumer-oriented, empowered, and networked human user access anytime, anywhere, and in any way.

The solution platform developed in Chapter 4 supports multimodal networked multimedia human user access (involving information, communications, and terminal convergence). Each solution deployed on the platform can provide the optimum end-user platform for each professional and patient group (i.e., direct patient access), which is especially important for tele-treatment solutions. The platform provides support for XHTML clients on PC, mobile, and DTV platforms as well as various mobile messaging services (SMS and MMS). Hybrid broadcasting multimedia services on the DTV platform involving high-speed, streamed A/V content and value-added multimedia services are a novel supported service type (e.g., for tele-prevention or tele-rehabilitation). The platform supports networked human user access to distributed services and offers time, location, and use context independence. Empowerment of patients, devolution of responsibility from physicians, as well as convenient inter-organizational task sharing and consultations are supported by networked service access.

3. Convergent ICT supports the creation of seamless, process-specific health provision chains through the use of convergent ICT providing common information semantics, syntaxes, and communication modalities as well as convergent terminal functionality, and information integration facilities.

The convergence capabilities of the platform enable process-specific solutions deployed on it to provide seamless service in terms of system-to-system communication and data linking. Time, location, and use context independence in human user access is enabled by multimodal networked multimedia access to support seamless professional and patient access in solution services.

4. Use of convergent ICT in process-specific health provides benefits in terms of health resource allocation efficiency, quality, usability, accessibility, and security when compared to conventional ways.

Chapter 5 described five solutions supporting overall health solution provision deployed on versions of the platform in both clinical and conceptual settings. The three tele-treatment solutions (anticoagulation, hypertension, and asthma) were evaluated during their deployment and pilot study use in clinical primary health care settings. Evaluation of the oral anticoagulation treatment follow-up solution showed clear benefits over conventional treatment modalities in terms of efficiency, usability, and accessibility in three differing settings. The solutions for hypertension follow-up and guided asthma self-management were evaluated chiefly in terms of usability, and accessibility; benefits over conventional treatment provision and support were observed. Subjective quality and security benefits were also observed for the three tele-treatment solutions. Objective evaluation of the two tele-prevention and tele-rehabilitation solutions was outside the scope of this thesis.

On the basis of the described results, we can state that the claims made were shown to be valid in the context of the developed technology platform and the clinically evaluated solutions deployed on versions of it.

### 6.2 Discussion and Future Work

As we have now reached the conclusion that convergent ICT, when applied through the use of an intelligent technology platform, is one valid support tool in managing the evolution of the health domain towards process-specific services, we may ask what this implies for health providers.

First of all we have observed a number of benefits resulting from the adoption of process-specific, convergent health ICT solutions. This is especially true for process-specific tele-treatment solutions where the comparison is with conventional paper-based treatment information management or with the use of centralized health information systems, for example, in a primary care setting. It should, however, be noted that the used evaluation methodologies, which established these benefits, may not always give a complete view into the feasibility of the solution. For example, the subjects who participated in the anticoagulation, asthma and hypertension clinical pilot studies as self-follow-up or self-care patients represent a self-selected group who volunteered to participate. Their use experiences from the pilot studies do not necessarily represent the capabilities or views of the wider treated population.

Discussing the benefits of process-specific and convergent health ICT solutions, we can note that such services can be carefully tailored to meet the needs of the specific process. Especially within the treatment strategy, conventional monolithic information systems are typically prohibitive as regards the adoption of highly customized and treatment-specific process services. The approach in these conventional EPR systems is chiefly to handle a patient’s medical history as a single file. Furthermore, adoption of process-specific and convergent ICT enables the adoption of new ICT methodologies within a reasonable time frame and thus enables the rapid establishment of new service modalities.

Despite the fact that convergence provides solutions for many of the practical challenges facing the adoption of process-specific ICT, some challenges still remain. From an engineering point of view, the fact that a new technology platform (such as the one described in this thesis) supports integration of health information and services to provide process-oriented and networked services does not negate the fact that legacy systems often do not support integrating convergence at the same level. Obviously, this hinders the adoption of seamless provision chains in clinical work. In an organization context, the adoption of new ICT services faces the natural resistance to change. The fact that public health care providers are often committed to the continued use of current ICT systems through long-term budgetary and contractual restrictions is another hindrance. Also, regarding direct use of ICT solutions by patients and consumers, the fact that modern ICT remains a relative unknown to demographic groups over-represented among users of health care (e.g., the elderly) places a limitation on the potential penetration of direct patient or consumer use.

When considering the use of ICT in the health domain, a key point of discussion is experience from and lessons learned in other domains. As observed in [Tut99], the lessons for non-health-care IT include the use of the simplest solutions for resolving problems, keeping the focus on data and what is done with it and not the software engineering implementation and, most importantly, avoidance of trying to provide all-reaching systems. The latter lesson is exactly what can be done with process-specific health ICT solutions having a sufficiently narrow scope.

In [Hau02] Haux et al. make a prognosis for the role of health care in the information society in the year 2013. According to their thesis, health care ICT has three major future development goals: patient-centered recording and use of medical data for co-operative care, process-integrated decision support through current medical knowledge, and the comprehensive use of patient data for research and health care reporting [Hau02]. Complementing this move towards knowledge-based computing and process intelligence, van der Lei (see [Lei02]) has augmented the considerations made by Haux et al. by identifying the emergence of automated feedback mechanisms as a key development in health care ICT. Feedback means return of a part of the output of a mechanism to its input. This part of the input constitutes information that reports discrepancies between intended and actual operation of the mechanism and leads to a self-correcting action [Lei02]. van der Lei identifies in his paper how the concept of feedback relates to the three goals defined by Haux et al. Without considering the details, we can state that his thesis is that feedback brings self-correctivity to health care processes through the introduction of intelligent process monitoring and reporting facilities enabled by ICT.

Considering the projected trends towards knowledge-based computing, process intelligence, and ICT facilitated feedback mechanisms, we may ask how the technology platform developed in this thesis relates to them. It can be stated that the hybrid model and the corresponding platform offer basic support for these trends, for example, through the process evaluation methodology and through the possibility to implement knowledge discovery functionality in the platform processing tier components. However, to fully support the developments, new fundamental approaches are required.

One area for future work is the use of integrated process modeling in the facilitation and research of process-specific health ICT solutions. Standards such as BPMN (Business Process Modeling Notation, see www.bpmi.org) and BPEL4WS (Business Process Execution Language for Web Services, see http://www.oasis-open.org) enable the embedment of a fundamentally process-oriented approach in health care ICT. With integrated process modeling, health ICT solutions can be easily developed as aggregates of existing distributed services and executed based on a metadata definition developed for the process. Logged process execution instance data automatically provide a refined view of the practical realization of the process. Such data can be used in health care ICT feedback mechanisms. In summary, we can state that integrated process modeling is the final ICT convergence step, especially in system-to-system communication and interoperability.

Apart from integrated process modeling, there are numerous topics for further research in the domain of networked multimedia convergence related to the provision of process-specific ICT. MPEG-21 is a topic which was referenced earlier in the Introduction as a converging multimedia description and distribution tool and briefly developed as a human user access methodology for the process-specific technology platform. The development of a detailed digital health care item methodology is a potential future research task.

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**APPENDIX: STRATEGY REQUIREMENTS FOR ICT TIER MODEL COMPONENTS**

**Table A.1** Prevention strategy requirements for the resource tier

| | |
|---|---|
| Basic | Storage of generic multimedia content asset and generic descriptive metadata asset types. Basic file systems, XML, and multimedia asset databases. |
| Security | Ensured availability of assets from the resource tier is required for successful implementation. For example, redundancy features in utilized asset repository facilities. |
| Accessibility | - |
| Usability | - |
| Quality | - |
| Efficiency | Use of cost-effective engineering solutions in repository implementation. |

**Table A.2** Treatment strategy requirements for the resource tier

| | |
|---|---|
| Basic | Storage of generic and proprietary multimedia content assets, generic and proprietary metadata asset types, and generic and proprietary non-multimedia assets. Basic file systems, relational SQL databases, XML, and multimedia assets databases. |
| Security | Provisions for maintaining the confidentiality, integrity, and availability of stored assets. Access control, encryption, and redundancy features in utilized asset repository facilities. |
| Accessibility | - |
| Usability | - |
| Quality | - |
| Efficiency | Use of cost-effective engineering solutions in repository implementation. |

**Table A.3** Rehabilitation strategy requirements for the resource tier

| | |
|---|---|
| Basic | Storage of generic multimedia content assets and generic descriptive metadata assets. Basic file systems, XML, and multimedia asset databases. |
| Security | Ensured availability of assets from the resource tier is required for successful implementation. For example, redundancy features in utilized asset repository facilities. |
| Accessibility | - |
| Usability | - |
| Quality | - |
| Efficiency | Use of cost-effective engineering solutions in repository implementation. |

**Table A.4** Prevention strategy requirements for the integration tier

| | |
|---|---|
| Basic | Seamless access to generic multimedia content asset and generic descriptive metadata assets of a distributed resource tier. Enabling middleware technologies include Web Services, etc. |
| Security | Ensured availability of access to distributed resource tier assets. |
| Accessibility | - |
| Usability | - |
| Quality | - |
| Efficiency | Use of cost-effective engineering solutions in middleware implementation. |

**Table A.5** Treatment strategy requirements for the integration tier

| | |
|---|---|
| Basic | Seamless access to generic and proprietary multimedia content assets, generic and proprietary metadata asset types, and generic and proprietary non-multimedia assets of a distributed resource tier. Enabling middleware technologies include Web Services, HL7 and LDAP. |
| Security | Provisions for maintaining the confidentiality and availability of resource tier access. Access control and redundancy in utilized middleware facilities. |
| Accessibility | - |
| Usability | - |
| Quality | - |
| Efficiency | Use of cost-effective engineering solutions in middleware implementation. |

**Table A.6** Rehabilitation strategy requirements for the integration tier

| | |
|---|---|
| Basic | Seamless access to generic multimedia content asset and generic descriptive metadata assets of a distributed resource tier. Enabling middleware technologies include Web Services, etc. |
| Security | Ensured availability of access to distributed resource tier assets. |
| Accessibility | - |
| Usability | - |
| Quality | - |
| Efficiency | Use of cost-effective engineering solutions in middleware implementation. |

**Table A.7** Prevention strategy requirements for the processing tier

| | |
|---|---|
| Basic | Support for basic processing of generic multimedia content assets and generic descriptive metadata assets accessed from a distributed resource tier through integration tier as required by the presentation tier. |
| Security | Ensured availability of processing tier functionality. |
| Accessibility | - |
| Usability | Low-level adaptation of assets (e.g., with the help of metadata) in personalization to reach the preventive optimum of specific consumers or consumer groups. |
| Quality | - |
| Efficiency | Use of cost-effective solutions in processing tier engineering implementation. |

**Table A.8** Treatment strategy requirements for the processing tier

| | |
|---|---|
| Basic | Support for basic processing of generic and proprietary multimedia content assets, generic and proprietary metadata asset types, and generic and proprietary non-multimedia assets of a distributed resource tier accessed through integration tier as required by the presentation tier. |
| Security | Provisions for maintaining the confidentiality and availability of processing tier functionality. Access control and redundancy in utilized middleware facilities. |
| Accessibility | - |
| Usability | Low-level adaptation of assets (e.g., with the help of metadata) in personalization to reach the preventive optimum of specific users or user groups. |
| Quality | Refinement processing of medical data into medical knowledge. |
| Efficiency | Use of cost-effective solutions in processing tier engineering implementation. |

**Table A.9** Rehabilitation strategy requirements for the processing tier

| | |
|---|---|
| Basic | Support for basic processing of generic multimedia content assets and generic descriptive metadata assets accessed from a distributed resource tier through integration tier as required by the presentation tier. |
| Security | Ensured availability of processing tier functionality. |
| Accessibility | - |
| Usability | Low-level adaptation of assets (e.g., with the help of metadata) in personalization to reach the preventive optimum of specific consumers or consumer groups. |
| Quality | - |
| Efficiency | Use of cost-effective solutions in processing tier engineering implementation. |

**Table A.10** Prevention strategy requirements for the presentation tier

| | |
|---|---|
| Basic | Support for the human-oriented presentation of processed generic multimedia content assets and generic descriptive metadata assets. Combination of assets with user interface templates in hypermedia presentations (e.g., XHMTL) and a user interface logic to create a presentation and typically local interaction system for a health solution. Support of A/V streaming. Networked multimedia presentation technology. |
| Security | Ensured availability of presentation tier functionality. |
| Accessibility | Support for multimodal client access enables the use of preventive solutions in an accessible way. |
| Usability | High-level personalization of contents and user interfaces to meet the requirements of specific users of user groups. |
| Quality | - |
| Efficiency | Use of cost-effective solutions in presentation tier engineering implementation. |

**Table A.11** Treatment strategy requirements for the presentation tier

| | |
|---|---|
| Basic | Support for the presentation of processed generic and proprietary multimedia content assets, generic and proprietary metadata asset types, and generic and proprietary non-multimedia assets. Combination of assets with user interface templates in hypermedia presentations (e.g., XHMTL) and a user interface logic to create a presentation and non-local interaction supporting system. Facilitation of access to local processing tier functionality for system clients. Networked multimedia presentation technology. |
| Security | Provisions for maintaining the confidentiality and availability of presentation tier functionality. Access control (reliable identification, etc.) and redundancy in presentation tier access points. |
| Accessibility | Support for multimodal client access enables the use of treatment solutions in an accessible way. |
| Usability | High-level personalization of contents and user interfaces to meet the requirements of specific users of user groups. |
| Quality | Intelligent presentation of medical knowledge supports high-quality treatment |
| Efficiency | Use of cost-effective solutions in presentation tier engineering implementation. |

**Table A.12** Rehabilitation strategy requirements for the presentation tier

| | |
|---|---|
| Basic | Support for the human-oriented presentation of processed generic multimedia content assets and generic descriptive metadata assets. Combination of assets with user interface templates in hypermedia presentations (e.g., XHMTL) and a user interface logic to create a presentation and typically local interaction system for a health ICT solution. Support of A/V streaming. Networked multimedia presentation technology. |
| Security | Ensured availability of presentation tier functionality. |
| Accessibility | Support for multimodal client access enables the use of preventive solutions in an accessible way. |
| Usability | High-level personalization of contents and user interfaces to meet the requirements of specific users of user groups. |
| Quality | - |
| Efficiency | Use of cost-effective solutions in presentation tier engineering implementation. |

**Table A.13** Prevention strategy requirements for the client tier

| | |
|---|---|
| Basic | Human user terminals with access to push- and pull-type solutions and common multimedia and metadata assets from the presentation tier. Support for local interaction and one way communication; digital TV STB with a hypermedia (XHTML) browser. |
| Security | Access universal and unrestricted; no security concerns on the client tier. |
| Accessibility | Access should be universal and unrestricted and reach mass audiences through push-type provision; digital TV STB. |
| Usability | Preventive solutions contain information which is best usable on clients which support live streaming of A/V content and hybrid solutions combining A/V content with value-added applications; digital TV STB. |
| Quality | - |
| Efficiency | Acquisition of client platform hardware specifically for accessing preventive solutions is not a likely course of action by consumers. Client types which are widely used by consumers for other purposes; digital TV STB. |

**Table A.14** Treatment strategy requirements for the client tier

| | |
|---|---|
| Basic | Human user terminals with support for generic and proprietary multimedia metadata and other assets and access to pull-type solutions from the presentation tier. Support for non-local interaction and two-way communication; PC web browsers, mobile phones, digital TV STBs. Support for proprietary non-multimedia asset types for system clients. |
| Security | Client tier security is critical for treatment solutions as identifiable and sensitive data are accessed with client platforms. Secure identification, etc. on the client tier is an essential requirement. |
| Accessibility | Treatment solutions require versatile human access from diverse conditions. As such, support for a high variety of client platforms is required. Mobility is a benefit for client platforms; PC web browsers, mobile phones, digital TV STBs. |
| Usability | Treatment solutions are often required by consumer groups with limited experience in ICT use; digital TV STB as an easy-to-use terminal. For professional users a terminal with the ability to display large amounts of information simultaneously; PC web browsers. |
| Quality | - |
| Efficiency | Support for the use of low-cost client devices. |

**Table A.15** Rehabilitation strategy requirements for the client tier

| | |
|---|---|
| Basic | Human user terminals with access to pull-type solutions and common multimedia and metadata assets from the presentation tier. Support for local interaction and one-way communication; digital TV STB with a hypermedia (XHTML) browser or PC web browsers. |
| Security | - |
| Accessibility | Support for multiple fixed client platforms for multimodal rehabilitation services. |
| Usability | Rehabilitation solutions contain information which is best usable on clients which support live streaming of A/V content and hybrid solutions combining A/V content with value-added applications; digital TV STB, PC web browsers. |
| Quality | - |
| Efficiency | Support for the use of low-cost client devices. |

**Table A.16** Prevention strategy requirements for communication tools

| | |
|---|---|
| Basic | Support for one-way server-client communication often sufficient. Two-way communication limited to support for navigation. Support for IP-based and digital TV broadcasting protocols. |
| Security | Basic support for maintaining data integrity support during communication is sufficient as no personal medical data are exchanged; reliable communication protocols. |
| Accessibility | - |
| Usability | - |
| Quality | - |
| Efficiency | - |

**Table A.17** Treatment strategy requirements for communication tools

| | |
|---|---|
| Basic | Support for two-way, fully interactive server-client-server as well as server-server communication required. |
| Security | Full support for maintaining data confidentiality and integrity is required; both reliable communication protocols and encryption are essential. Support for IP-based, mobile, and digital TV broadcasting protocols. |
| Accessibility | - |
| Usability | - |
| Quality | - |
| Efficiency | - |

**Table A.18** Rehabilitation strategy requirements for communication tools

| | |
|---|---|
| Basic | Support for one-way server-client communication often sufficient. Two-way communication mostly limited to support for navigation. |
| Security | Basic support for maintaining data integrity support during communication is sufficient as no personal medical data are exchanged; reliable communication protocols. Support for IP-based and digital TV broadcasting protocols. |
| Accessibility | - |
| Usability | - |
| Quality | - |
| Efficiency | - |

**Table A.19** Prevention strategy requirements for deployment and execution tools

| | |
|---|---|
| Basic | Support for the deployment of standard networked multimedia services in human-to-computer interactions. Limited support for the deployment of computer-to-computer interaction services. Local OODBMS and application server facilities. |
| Security | Physical security and redundancy in deployment and execution facilities. |
| Accessibility | - |
| Usability | - |
| Quality | - |
| Efficiency | Support for the use of low-cost deployment and execution facilities. |

**Table A.20** Treatment strategy requirements for deployment and execution tools

| | |
|---|---|
| Basic | Support for the deployment of standard networked multimedia and special medical multimedia services in both human-to-computer and computer-to-computer interactions. Local RDBMS, OODBMS, and application server facilities. |
| Security | Physical security and redundancy in deployment and execution facilities. |
| Accessibility | - |
| Usability | - |
| Quality | - |
| Efficiency | Support for the use of low-cost deployment and execution facilities. |

**Table A.21** Rehabilitation strategy requirements for deployment and execution tools

| | |
|---|---|
| Basic | Support for the deployment of standard networked multimedia services in human-to-computer interactions. Limited support for the deployment of computer-to-computer interaction services. Local OODBMS and application server facilities. |
| Security | Physical security and redundancy in deployment and execution facilities. |
| Accessibility | - |
| Usability | - |
| Quality | - |
| Efficiency | Support for the use of low-cost deployment and execution facilities. |

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