TAMPERE UNIVERSITY OF TECHNOLOGY

OLLI-PEKKA IKONEN

FUNCTIONALITY AND USER-EXPERIENCE OF ANDROID PLATFORM ON NON-MOBILE MULTIMEDIA DEVICES

Master of Science Thesis

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Android on Googlen kehittämä avoimeen lähdekoodiin perustuva matkapuhelimen käyttöjärjestelmä. Vaikka se oli alun perin tarkoitettu matkapuhelimia varten, Android on suunniteltu niin joustavaksi, että sen voi asentaa lähes mihin tahansa Linux-pohjaiseen laitteeseen. Eri laitevalmistajat ovat panneet merkille Androidin sopeutumiskyvyn ja mahdollisuuden käyttää tuhansia valmiita Androidin sovellutuksia eri laitteissa. Viime vuosien aikana laitevalmistajat ovat alkaneet tuoda markkinoille erilaisia ei-matkapuhelin multimedialaitteita, jotka kaikki käyttävät Android-käyttöjärjestelmää. Näiden Android-laitteiden ilmestyminen merkitsee sitä, että tietoliikenteeseen, multimediaan, ohjelmistokehitykseen ja muihin vastaaviin aloihin perustuvien yritysten täytyy päättää, ryhtyvätkö ne tarjoamaan Androidille erityisesti suunnattua sisältöä ja palveluja. Tämä työ on kirjoitettu auttamaan yrityksiä päätöksenteossa tarjoamalla niille tietoa siitä, miten toimiva Android-käyttöjärjestelmä on muissa laitteissa kuin matkapuhelimissa, miten eri laitevalmistajat käyttävät Androidia ja millainen tyypillisen Android-laitteen käyttökokemus on.

Työ on jaettu kolmeen osaan. Ensimmäisessä osassa esitellään Android-käyttöjärjestelmä, sen ominaisuudet ja arkkitehtuuri. Toisessa osassa tutkitaan lukuisia tämän päivän markkinoilta löytyviä Android-laitteita, kartoitetaan mihin Android pystyy ja mitkä ovat laitteille tyypillisiä piirteitä. Kolmannessa osassa esitellään yksi Android-pohjainen laite, Archos 5 Internet Tablet, ja käytetään sitä esimerkkinä siitä, millainen käyttökokemus tyypillisellä Android-laitteella voi olla tutkimalla sen käytettävyyttä Jacob Nielsenin heuristisen arvioinnin menetelmällä.

Työssä havaittiin, että vaikka Android-käyttöjärjestelmä voidaan mukauttaa erilaisten laitteiden tarpeisiin, se toimii parhaiten kosketusnäytöllisissä laitteissa. Useimmat Android-pohjaiset laitteet ovat erittäin riippuvaisia langattomasta yhteydestä, mikä voi tarjota markkinapohjaa teleoperaattoreille. Androidia on mahdollista laajentaa ja parannella siten, että se kykenee toistamaan hyvin korkealaatuista mediaa, mukaan lukien high-definition-videoita, mikä voi hyödyttää sisällöntarjoajia. Suurin osa tutkituista laitteista tukee Android-sovellutuksia, mutta sovellusten jakelu eri laitteille saattaa tuottaa vaikeuksia, sillä eri laitevalmistajat ovat päättäneet perustaa omia sovellus-verkkokauppojaan yksinomaan omia laitteitaan varten. Lisäksi todettiin, että Android-käyttöjärjestelmä ja siihen perustuvat laitteet kehittyvät edelleen nopeasti, joten työssä esitetyt tiedot voivat vanhentua muutaman kuukauden sisällä.

ABSTRACT

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Android platform is an open source mobile phone operating system developed by Google. Although originally meant for mobile phones, Android was designed to be so flexible that it can be installed to almost any device running a Linux-type kernel. Different device manufacturers have noted this adaptability and the potential of using thousands of ready-made Android-based applications on various devices. In the recent years manufacturers have begun to introduce different types of non-mobile-phone multimedia devices to the market, all of them running Android platform. The emergence of these non-mobile Android devices means that companies related to telecommunications, multimedia, software development, and other relevant fields need to decide whether or not they should begin to provide content and services tailored for Android. This thesis was written to help with this decision by providing information on how functional Android platform is on non-mobile devices, how different manufacturers are using the platform, and what the user-experience on a typical Android-based non-mobile device is like.

This thesis has been divided into three sections. The first section provides an overview on Android platform, its features and architecture. The second section studies numerous Android-based non-mobile devices on today's market and offers insight on Android's capabilities and what are the current trends among the devices. The third part presents a test case of one Android-based device, Archos 5 Internet Tablet, and uses it as an example for what usability on a typical Android-based device is like by evaluating it with Jacob Nielsen's heuristic evaluation method.

It was discovered that although Android platform can be adapted to numerous different types of devices, it functions best in a device with a touchscreen. Most Android-based devices are heavily reliant on wireless connectivity, offering a market opportunity for telecommunications operators. Android platform can be expanded to be capable of playing high-quality media, including high-definition video, giving an opportunity for content providers. Most of the studied devices supported Android applications, but the distribution of applications might be complicated because many manufacturers have chosen to establish their own application stores tailor-made for their own devices. Finally, it was noted that Android and devices based on it are still under heavy development, so the information provided in this thesis might grow outdated within a few months.

PREFACE

This Master of Science thesis was written as an independent work.

I would like to express my gratitude to my thesis supervisor, Professor Ari Visa, for his patient guidance throughout the writing of this work. I would also like to thank Antti Leinonen of TeliaSonera Finland for his inspiring advice.

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ABBREVATIONS

3G	Third Generation
API	Application Programming Interface
Appstore	Application Store
CES	Consumer Electronic Show
Dalvik VM / DVM	Dalvik Virtual Machine
GIF	Graphic Interchange Format
GPS	Global Positioning System
GSM	Global System for Mobile Communications
HD	High Definition
JPG	Joint Photographic Experts Group
LAN	Local Area Network
MID	Mobile Internet Device
OHA	Open Handset Alliance
OS	Operating System
PAL	Phase Alternate Line
PMP	Portable Media Player
PNG	Portable Network Graphics
SD	Standard Definition
SDK	Software Development Kit
SMS	Short Message Service
STB	Set-Top Box
UI	User Interface
USB	Universal Serial Bus

1. INTRODUCTION

This thesis examines how non-mobile multimedia devices on today's market are using Android platform, and how suitable the aforementioned platform is for devices other than mobile phones.

Mobile phones of today have evolved into more and more multipurpose devices. Merely providing telephony and text messaging services has not been enough for several years. Mobile phones of today can browse Internet, locate themselves via GPS (Global Positioning System), and play high-quality video and audio, to name only a few of their capabilities. Mobile phone platforms have likewise needed to evolve to meet the needs of today's mobile devices. The platforms have to be able to provide all the features of a multipurpose device and be able to adapt to different screen sizes on different devices. They also have to be flexible enough to accommodate new features that might be introduced to the phones in the future. This versatility has developed to the point that the device running a mobile phone platform might not necessarily even have to be a mobile phone. Google's Android is an example of a mobile phone platform that has expanded beyond mobile phones.

When Google first introduced Android in 2007 [1], the platform was slow to catch speed. The first mobile phone to support Android platform, HTC G1, was unveiled in September 2008 at the same time with the first full version of the Android SDK (Software Development Kit) [2]. The second device to support Android, HTC Magic, was not unveiled until almost half a year later in February 2009 [3]. However, the speed has been picking up, with new Android-based devices being released and shipped in increasing numbers. According to an independent advisory and consultancy firm Ovum, approximately five million Android-based devices were shipped in 2009. Ovum goes on to further estimate that in 2010 the number of shipments will increase past ten million. This momentum will continue to grow in the future and, according to Ovum, in year 2014 Android will be shipped in 72 million handsets. [1].

Android-based devices have also been increasingly noticed by consumers. ChangeWave Alliance Research Network conducted a survey about the popularity of different mobile phone platforms among consumers in September 2009. They found that 6% of the consumers who were planning to purchase a new smart phone within the next 90 days would pick Android as their platform of choice. ChangeWave conducted a similar survey again in December 2009, and just within three months the portion of consumers planning to use Android OS (Operating System) had risen to 21%. [4].

It might have been partly because Android had proven to be a success among mobile phones that manufacturers began to research ways to use it on other devices

besides handsets. Another likely reason is that Android platform is based on Linux kernel, which is these days fairly commonly found in many types of devices, thus making the porting of Android to them possible. There have been experiments to integrate Android platform to netbooks as early as the end of 2008 [5]. Others have installed Android to devices such as MIDs (Mobile Internet Device), e-book readers, and even STBs (Set-Top Box). The first commercial devices were released in 2009, and more manufacturers are introducing their own devices every month.

However, not all corporations in the industry seem to believe in Android's potential. In an interview with Computerworld in June 2009, Kerry McGuire, an executive at ARM, stated that Android is optimized for smartphones and would need more work before it could be feasibly used in other devices. Certain software developers are also doubtful about Android's capabilities. Rishi Mathew, a director at Real Inc., cites Android's inability to run multiple applications simultaneously and the lack of drivers for plugged-in devices as limiting factors for Android's usefulness. [6].

Despite these doubts Android platform has made an advent on new types of devices. It therefore becomes necessary for telcos, software developers, and other companies involved in the industry to evaluate Android's potential for these new devices. The companies need to determine whether or not they should begin to offer products and services tailored for Android on devices other than mobile phones. This thesis was written to help with the decision process.

The goal of this thesis is to map out the feasibility and capabilities of Android platform on non-mobile multimedia devices. "Non-mobile", within the context of this thesis, is defined as devices other than smartphones and mobile handsets. The question that this thesis seeks to answer is two-fold:

- *What kind of devices is Android platform used for?* In order for companies to anticipate what kind of products and services they might have to offer for these devices, it is necessary to know how manufacturers are using the Android platform. What are most common features in the devices currently in the market? What seem to be the most common weaknesses?
- *What is the user-experience like on Android platform?* Whether or not consumers find a device pleasing to use is an important factor for the device's popularity and commercial success. Android OS has been optimized for smartphones, but how suitable is it for non-mobile devices?

This thesis has a Chapter dedicated to examining and answering each of these questions. The findings of these questions are then drawn together to give two perspectives on Android platform: how functional its capabilities are likely to be on non-mobile device and what the user-experience is like on them.

This thesis has been divided into the following chapters:

Chapter 2 introduces the Android platform. The platform's version history, primary features, and basic architecture are explained. Screen resolutions and multimedia formats supported by Android are listed. Finally, the Chapter takes a brief

look at Android Market, an online applications store that is one of the primary channels used to distribute software developed for Android platform.

Chapter 3 is dedicated to answering the first question presented above, that is, what kind of devices Android platform is being used for. This was accomplished by collecting information on as many Android-based non-mobile devices as could be found at the time of writing. Ten of these devices are presented in further detail. Each of the devices is examined in three parts. First, the technical specifications and notable features are listed. Second, third-party reviewers' responses to the device and its possible good and bad features are presented. Thirdly, the author of this thesis presents a small analysis, pointing out notable trends and possible problems. The Chapter concludes in a summarizing analysis that collects and discusses the trends, most common features, and most common problems that were noticed during the survey.

Chapter 4 answers to the second question presented above, what the user-experience on Android is like. This is accomplished by introducing a use case where Archos 5 Internet Tablet is examined as an example for what using an Android-based device could be like. The basic theory of good usability is first described and Jacob Nielsen's Heuristic Evaluation of usability is introduced. Archos 5's interface is then described in greater detail. The device is then evaluated using Jacob Nielsen's heuristics. Finally, the Chapter concludes by the listing of the findings and analysis on what the results would indicate about Android's usability.

Chapter 5 draws together the findings from Chapters 3 and Chapter 4. The results are discussed, conclusions are drawn for what they would mean for companies related to the field, and the results' overall reliability is estimated.

Chapter 6 is the conclusion. The thesis and its findings are briefly summarized. Recommendations for further studies are made.

Since this thesis covers a broad area, it is not feasible to examine any single detail too deeply. The reader is assumed to have a basic working knowledge on what today's multimedia devices are like, as well as familiarity with the abbreviations and file formats of today's multimedia standards.

2. ANDROID PLATFORM

This chapter introduces the Android platform and describes its capabilities. First, a brief history of Android and its developers, Open Handset Alliance, is given. Next, Android's version history and features are described. The architecture of Android software stack is explored in detail. After this the screen resolutions and media file formats supported by Android are listed. Finally, the online Android application store Android Market is described.

2.1. Introduction to Android

Android is an open source software platform for mobile devices [7]. It was first developed by a small, California-based firm called Android. In July 2005 the firm was acquired by Google, who continued the platform's development. In November 2007 Google publicly announced the Android platform, which had been developed by the team of the former company. At the same time it founded Open Handset Alliance, a group of companies from fields of hardware, software, and telecommunications who had been collaborating on the development of Android Platform. [8].

Open Handset Alliance states its purpose to be to "*accelerate innovation in mobile and offer consumers a richer, less expensive, and better mobile experience.*" This is primarily achieved through the development and application of Android platform. Members are committed to deploy Android platform in their respective products and make it a commercial success. Some members of OHA have helped to develop the platform. Others contribute by making sure that the platform is supported by the chipsets they produce. OHA was originally founded with 47 members. However, it is relatively easy for companies to join the alliance and many have discovered a membership to be advantageous for them. At the time of writing OHA consists of 65 members, including mobile operators, handset manufacturers, semiconductor companies, software companies, and commercialization companies. [7].

Majority of the Android platform is released under Apache 2.0 license. The Android project prefers to adhere to Apache 2.0 license as much as it can, but some parts of the project also have to be released under difference licenses – for example, Linux kernel patches are released under GPLv2 license. [9].

Apache 2.0 license means that the software released under it can be freely downloaded and used for personal, company internal, and commercial purposes. It allows the user to make modifications to the original software without having to contribute the changes back to the open source community. It forbids the user from redistributing any part of the software protected by the license without proper attribution

to the original community – in this case, it means that developers of Android platform are not allowed to release the source code as their own without giving Android any credit of it. [10].

2.2. Android versions and features

A preview version of Android SDK (Software Development Kit) was released in November 2007 [11]. The first full version, Android SDK 1.0, was released in September 2008 [2]. A month later, the source code of Android platform was released by OHA under Apache 2.0 license, as mentioned in Chapter 2.1 [12].

Android and its SDK have continued to evolve and new versions have been released every few months, honing out bugs and adding to the platform's features. *Table 2.1* displays the version history for the Android SDK, including release dates, supported Linux kernel version, and highlights of the new features in each release. The most notable releases have been assigned specific nicknames by Google. The unnamed versions between them are considered to be a part of the previously released "nicknamed" update. At the time of writing the latest version is Android 2.1. It was released in January 2010. [13].

According to Erick Tseng, senior product manager of Android, the next notable release will be nicknamed "Froyo" [14].

Table 2.1 *Version history of Android platform* [1; 13]

Version	Date	Linux Kernel	Highlights
Android 1.0	September 2008	Version 2.6	Initial release.
Android 1.1	February 2009		Enable applications to broadcast SMS or WAP push messages.
Android 1.5 *Cupcake*	April 2009	Version 2.6.27	On-screen soft keyboard, Bluetooth support, video recording & playback, copy & paste in browser, SIM Application toolkit 1.0, upload videos to Youtube, upload photos to Picasa, animations between the switching of screens.
Android 1.6 *Donut*	September 2009		Ability to integrate with Quick Search Box, support for additional screen resolutions (from QVGA to WVGA), framework for gestures, text-to-speech engine, support for CDMA telephony, improvements on Android market.
Android 2.0 *Éclair*	October 2009	Version 2.6.29	Bluetooth 2.1, built-in Flash support for the camera, support for HTML5, support for Microsoft Exchange, support for multiple user accounts, support for synchronization with external data sources, give applications better scalability between screen sizes.

Table 2.1 (continued) *Version history of Android platform* [1; 13]

Version	Date	Linux Kernel	Highlights
Android 2.0.1	December 2009		Minor bug fixes and API changes.
Android 2.1	January 2010		Minor bug fixes and API changes. Enable animated wallpapers. APIs for determining phone signal strength, additional WebKit tools for manipulating web storage databases.

Most of the Android updates are additive in nature, supplementing existing APIs (Application Programming Interface) with new features and functions. Existing features are only rarely removed from the APIs. This means that applications developed for older versions of the platform are for the most part forward compatible with newer versions of Android. There are relatively few cases where an application uses a feature that has been removed from newer versions and is thus rendered incompatible. Correspondingly, most of the applications developed on newer Android versions are usually not backwards compatible with older versions. [15].

2.3. Android architecture

The Android platform is a complete software stack for mobile phones. It contains an operating system, middleware layer with libraries that supply the platform with most of its functionality, and a selection of key applications that are typically found in a mobile phone. [16].

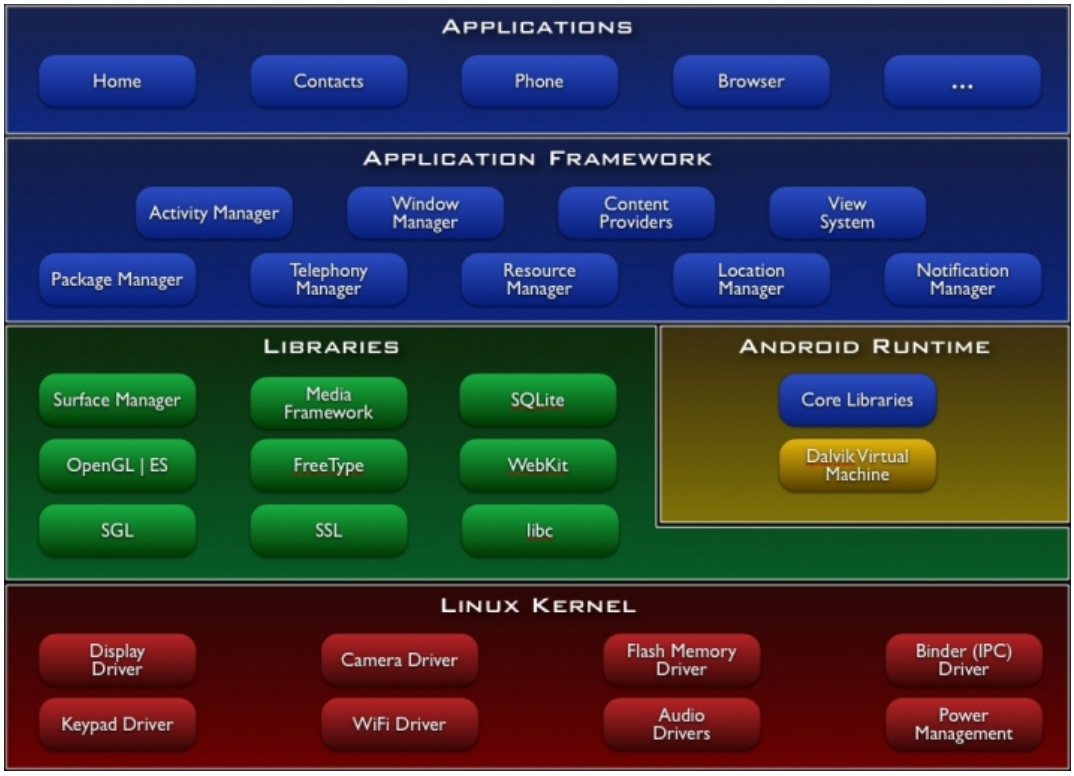

Figure 2.1 *Architecture of Android software stack* [16; 17]

Figure 2.1 displays the major elements of the Android software stack. It consists of five layers: Linux Kernel, Android Libraries, Android Runtime, Application Framework, and Applications. The sections of the architecture that are marked green, that is, the Libraries layer, have been written with C and C++ programming languages. Java language was used for the blue sections, which consist of the Core Libraries of the Android Runtime as well as the Application Framework and Application layers.

Linux kernel acts as an abstraction layer between device hardware and the rest of the software stack. As mentioned before, Android is based on Linux v2.6. The exact version supported by Android has been updated with the release of new platform versions, as could be seen in *Table 2.1*. The latest released version, Android 2.1, supports Linux 2.6.29. Linux kernel offers core system services for Android: security, memory management, process management, network stack, power management, and driver model. In today's industry Linux kernel is considered to be a commodity in the mobile software stack. It has been increasingly adopted by silicon and handset vendors [1].

Libraries layer is the core that provides much of Android's functionality. This layer contains various components that are used by the Android applications on the layer above it. All of the libraries are implemented natively in C/C++ and are fully accessible to third-party developers creating applications for the platform. Android's core libraries include the following components:

Surface manager manages access to the device's display subsystem. It is responsible for composing drawing surfaces onto the screen and making certain that the graphics from multiple applications are all displayed in the proper order.

OpenGL/ES is a 3D graphics API based on royalty-free OpenGL standard. Open GL ES is a version of the more general OpenGL that has been specifically designed for embedded devices [18]. Android supports OpenGL ES version 1.0, which is roughly equivalent to OpenGL v.1.3. The API comes with a 3D software rasterizer, but it can also make use of a 3D accelerator chip if such is available in the device's hardware.

SGL is a 2D graphics API that handles most of the drawing for the applications. Android graphics platform is able to use both 2D and 3D graphics on the same application simultaneously.

Android's fonts are rendered with *FreeType,* which is an open source font rendering engine [19].

Media Framework contains all the media codecs supported by Android. It was provided by PacketVideo, which is a member of OHA. Chapter 2.5 contains the full list of media formats supported by Android.

SSL (Secure Socket Layer) provides Internet security [20], and *WebKit* is an open source browser engine that is used as a core for Android's integrated web browser.

SQLite is a lightweight database available for all applications. It is used as the core of most of Android's data storage. Android uses a custom implementation of the standard C system library *libc*. It has been tuned for embedded Linux-based devices.

Android Runtime is the main component of Android platform. It was designed to meet the needs of running applications in an embedded environment with limited resources for battery, memory, and CPU (Central Processing Unit). Runtime's *Core Libraries* contain the collection classes, utilities, IO, and other resources, making it capable of providing most the functionalities available in the core libraries of the Java programming language. However, although the APIs are derived from Java, they are not based on the certified Java standards. According to Ovum, porting existing Java code for the platform might be complicated because of this [1].

The primary component of Android Runtime is the *Dalvik Virtual Machine* (Dalvik VM or DVM), which is used to run every application on the platform. Every Android application runs within its own process and each of these processes has its own instance of Dalvik VM. The Android platform is capable of running several Dalvik VMs simultaneously, which allows for a number of simultaneous processes and, therefore, a number of simultaneous applications.

Dalvik VM runs applications in .dex file format, which is a bytecode that has been converted at build-time from Java's .class and .jar file formats. .dex files have been optimized for memory efficiency and can be expected to run well on small processors. The data structures used in the virtual machine are also designed to be shared across processes whenever possible.

Dalvik is a register-based virtual machine. It relies on the underlying Linux kernel layer for background functionalities such as threading and low-level memory management.

Application Framework is the toolkit used by all Android applications, both the standard core applications that are shipped with the platform and the applications written by third-party developers. The toolkit has been written in Java and includes the following components:

Activity manager manages the life cycle of applications that are run on the platform. It also maintains a common backstack that enables applications running in different processes to have a smoothly integrated navigation experience.

Package manager keeps track of the applications that have been installed onto the device.

Windows manager manages windows. It provides abstraction to the graphics services offered by surface manager in Library layer.

Telephony manager provides the APIs needed to build phone applications central to most phones.

Content providers is a framework that allows applications to share their data with other applications. For example, a Contacts application contains all the information on the user's contacts, details such as phone numbers, home addresses, and names. Through content provides it can make this information available for other applications as well.

Resource manager provides storage for iStrings, bitmaps, layout file descriptions, and other external parts of an application that are not actual code.

View system provides building components such as buttons and lists that can be used to construct user interfaces. It also handles layout drawing and event dispatching.

Notification manager is an API that allows any application to put up a notification onto the Android's status bar. The status bar is normally used to display notifications of SMS, voice messages, and other similar functions, but notification manager allows any program to access it. The developer may also assign certain conditions and events that will trigger an application to post a notification to the status bar. For example a location application can be set to dispatch a notification if it detects that there is a friend near by.

Finally, as the name indicates, **Application** layer is where the Android applications are located. Android platform comes preinstalled with a number of applications, including a home application, a contacts application, and a web browser. This is the layer where the applications provided by third-party developers are also located.

2.4. Screen resolutions on Android

Up to Android version 1.5 the platform supported only one screen resolution for its devices. This was HVGA (320x480) on a 3.2'' screen, a configuration that was well

suited for the mobile phones that used Android at the time. The HVGA resolution is still used as a baseline to which the other screen sizes are compared.

Android 1.6 added support for multiple screen sizes and resolutions, to reflect the different types and sizes of the devices on which the platform can be run. The screen sizes, defined by how many pixels there are in each dimension of the screen, are roughly divided into three categories: *small*, *normal*, and *large*. Screen pixel densities are also divided into three categories: *low (ldpi)*, *medium (mdpi)*, and *high (hdpi)*. Together these two factors can form a number of screen sizes supported by Android platform, as displayed on *Table 2.2*.

Table 2.2 *Screen resolutions and pixel densities supported by Android* [21]

	Low density (120), *ldpi*	Medium density (160), *mdpi*	High density (240), *hdpi*
Small screen	QVGA (240x320), 2.6"-3.0" diagonal		
Normal screen	WQVGA (240x400), 3.2"-3.5" diagonal FWQVGA (240x432), 3.5"-3.8" diagonal	**HVGA (320x480), 3.0"-3.5" diagonal**	WVGA (480x800), 3.3"-4.0" diagonal FWVGA (480x854), 3.5"-4.0" diagonal
Large screen		WVGA (480x800), 4.8"-5.5" diagonal FWVGA (480x854), 5.0"-5.8" diagonal	

Android has a number of options for how views of different resolutions are displayed on the screen. The platform can scale the graphics to the appropriate resolution before displaying them. Alternatively it can display the view onto a larger screen in a so-called “postage-stamp” mode, where the view is shown in its original resolution against a blank background.

In order to place the resolutions listed in *Table 2.2* in perspective, it becomes necessary to define a few standard resolutions used on today’s multimedia displays. The baseline resolution for Android, HVGA (320x480), is among the most common screen resolutions used by modern touchscreen mobile phones. The same resolution is also used by iPhone, which is Android phone’s most notable competitor [22].

For large-screen multimedia, the two categories that need to be defined are High Definition (HD) and Standard Definition (SD). The Standard Definition used for regular broadcast TV in Europe is Phase Alternate Line (PAL), which has the resolution of 720x576. This is also the largest resolution that can be considered SD. Anything larger than this is categorized as HD. HD quality generally has the resolution of either 1920x1080 or 1280x720. [23].

2.5. Media formats supported by Android

Android platform has an in-built support for a variety of media formats. These are listed in *Table 2.3*. Android can also make use of additional media formats if they are supported by the device running the platform.

Table 2.3 *Media formats supported by Android* [24]

Type	Format	File type(s)
Audio	3GPP	.3gp
	MPEG-4	.mp4, .m4a
	MP3	.mp3
	MIDI	.mif, .cmg, .mvmf, .rtttl, .rtx, .ota, .imy
	Ogg Vorbis	.ogg
	WAVE	.wav
Image	JPEG	.jpg
	GIF	.gif
	PNG	.png
	BMP	.bmp
Video	H.263	.3gp, .mp4
	H.264	.3gp, .mp4
	MPEG-4 SP	.3gp

Android platform can also make use of separate images as graphics in applications. When images are used in this manner, PNG format is preferred for graphics, but JPG is also acceptable. GIF format is discouraged for this, likely because Android platform is incapable of running GIF animations, displaying only the first frame of them.

2.6. Android Market

Android Market is an online software store, also called “appstore”, developed by Google for Android devices. It provides users with various applications that can be downloaded and installed to Android-compatible devices. Some of these are available for free, while others need to be purchased. Android Market was first launched in August 2008. [25]. It is one of the methods for software developers to distribute their own Android applications to consumers.

The Android Market can be accessed via Internet, but its website has only a handful of featured applications on display. In order to fully make use of the Market’s selection it has be accessed via an Android device. Many Android devices have a preinstalled application called AppStore that allows the user to connect directly to the Market. [26].

The number of applications offered on Android Market has been climbing with increasing speed. According to T-Mobile's Chief Technical Officer Cole Brodman there were 2,300 applications on Android Market in March 2009 [27].

Although Google itself does not disclose public information on how many applications Android has available, there is a website titled Androlib.com that keeps track of free and paid applications. According to Robin Wauters of MobileCrunch, in September 2009 Androlib.com estimated the number of Android applications to be approximately 10,072. 64% of these were free applications, while the remaining 36% had to be paid for. The number of applications broke 20,000 in December 2009. By March 2010, their number had risen to over 34,000. 61.7% of these were free, while 38.3% must be paid for. [28; 29].

To provide contrast, in January 2010 Apple's iStore was stated to contain 133,979 applications. [30].

Android Market allows developers to submit third-party applications into the store. The developer can choose to either sell the application for a fee in the store, or allow it to be distributed for free. Should the developer choose to sell the application, Android Market will require a transaction fee equivalent to 30% of the application price for each sale, leaving the developer with 70% of the selling price. Applications that are being distributed for free do not have a transaction fee. Android Market has a return policy that allows the customer to request a full refund within 48 hours from the purchase. [26].

3. ANDROID ON NON-MOBILE MULTIMEDIA DEVICES

This Chapter examines the various non-mobile multimedia devices that are using the Android platform.

In order to determine what is happening on today's Android device market, it is important to have a good understanding of what kind of devices manufacturers have been making with the platform. What are the common features among them? What seem to be their most common problems? This thesis attempts to answer to these questions by conducting a survey on as many Android-based non-mobile devices as is feasible and analyzing the common trends among them. Although new Android-based devices are being introduced to the market almost monthly, there are still few enough of them that examining most of them is manageable within this thesis.

The greatest obstacle for the survey was acquiring reliable first-hand information on the devices. Manufacturers tend to treat in-depth information on their devices as confidential material, so it became necessary to rely on whatever information they were willing to release publicly. Furthermore, at the time of writing many of the devices examined in this Chapter have not yet been released to the market, so there is not much information available on them.

The survey conducted for this thesis examined 21 non-mobile Android-based devices. Most of the information listed in this Chapter was collected in the beginning of year 2010. However, constant change and development on the market means that this list is by no means comprehensive and is likely to become outdated within a few months. Information was collected primarily from the manufacturers' official websites and press releases, as well as from reviews and hands-on evaluations found on professional electronic magazines and websites. This information was then used to analyze the trends related to the Android-based devices. The full list of the analyzed devices can be found in *Appendix 1* and *Appendix 2*. Ten of these devices were picked for more in-depth analysis and will be introduced in detail in the following sub-chapters.

Each of the devices in this list is examined in three parts:

- **Technical evaluation**. Here the device is introduced, its features described and technical specifications listed.
- **Third-party evaluation**. Since it is impossible to acquire first-hand experience on all of the listed devices, other sources have to be used to evaluate what using the device is like. The best source for such information is professional reviewers employed by technical magazines, websites, and other journalists related to this field.

- **Analysis**. The information discovered in the two previous parts is examined further. Highlights are pointed out and conjectures are drawn.

The exception for the layout above is Creative Zii EGG in Chapter 3.10. This device is not a consumer device but a development platform meant for industrial use. It is also the only one of the examined devices to have its platform architecture available for public. Therefore, in place of third-party evaluations the device's platform was examined instead.

3.1. Archos 5 Internet Tablet

Archos 5 Internet Tablet (*Figure 3.1*) is a PMP (Portable Media Player) with Internet connectivity. It is manufactured and marketed by a French consumer electronics company Archos. "Internet Tablet" is a term coined by the company itself for these devices – in more general terms, Archos 5 can be classified as something between a MID (Mobile Internet Device) and a PMP. It was one of the first non-mobile devices with a dedicated Android platform to be released to consumer market. *Table 3.1* lists the primary technical specifications of Archos 5.

Figure 3.1 *Archos 5 Internet Tablet* [31]

Table 3.1 *Archos 5 Internet Tablet technical specifications* [31]

Name	Archos 5 Internet Tablet
Manufacturer	Archos
Release Date	September 15, 2009
Android version	1.5, updatable to 2.1
Price	199.98 € for 8GB, 349.99€ for 160GB, 399.99€ for 500GB
Display	4,8'' LCD touchscreen, 800x480 resolution
Connectivity	802.11 b/g/n WiFi, 3G via Bluetooth connection
Storage	8 to 500GB flash memory + Micro SD slot
Supported files	
Video	MPEG. H.264 (Up to HD quality 720p), WMV, MKV, MJPEG
Audio	MP3, WMA, WAV, AAC, OGG, Flac
Image	JPEG, BMP, PNG, GIF

Table 3.1 (continued) *Archos 5 Internet Tablet technical specifications* [31]

Supported files	
E-book	PDF
Primary features Watch multimedia on the device or by connecting it to larger TV, or stream media content from home PC into the device. Read PDFs and Office documents. Browse Internet on Opera browser with Flash support. GPS. Numerous small applications from email to web radio, Wikipedia access and LinkedIn. Many of the features are available only as add-ons purchased separately.	

Archos 5 was primarily designed as an Internet device with multimedia playing capabilities. As such, its features include an in-built Internet browser and a number of web-related functions such as web radio, web-TV, and email. The device's connectivity is handled wirelessly, either by connecting to a WiFi network or by a Bluetooth tether to a 3G phone.

As a media player Archos 5 is able to play most of the common video and audio formats. However, the highest-quality media is not immediately available - in order to play HD quality 720p video with the device, the user must purchase a separate High-Definition plugin from Archos. Archos 5 can be connected to a TV via a separately purchasable TV dock accessory. This enables the user to view the multimedia stored on the device on TV screen and to record TV programs onto Archos 5 for later viewing. The device includes an in-built GPS navigator.

Archos 5 also features a number of smaller applications for various purposes, including versions of Facebook, Wikipedia, and Twitter. More applications can be downloaded either for free or for a price from a service called Appslib. This service is similar to, but separate from Android Market. It is closely connected to Archos and is currently inviting developers to create and submit more applications for them. [32].

Archos has opened Archos 5 for third-party developers to make their own software. However, in order to make this happen, the Android platform on the device has to be replaced by another OS, the Ångström Linux distribution. Therefore, studying this feature falls outside the scope of this project. [33].

3.1.1. Third-party evaluation

Archos 5 seems to have received fairly good, but not excellent ratings from expert reviewers. ZDNet, a webzine on technology and IT, has collected 39 reviews from various sources on the device and has calculated the average rating from them to be 7.5 out of 10 points. [34].

Hubert Nguye of Ubergizmo is impressed by the device's performance power, although he also states that the perceived performance of the user interface is equal to that of an Android phone such as HTC Magic. This makes the responsiveness seem slower than that of iPhone 3G. Hubert feels that accessing Internet via a 3G phone seems impractical. However, he also praises the solution as it means that the user

wouldn't have to pay for another wireless subscription, which would be the case had Archos 5 supported 3G directly. Hubert also mentions that Android applications should work on the device, but expresses worry that there is no Android Market installed. [35].

The sentiment is also shared by the Crunchgear reviewer Doug Aamoth, who would like to see Android applications available for the device. On the other hand, he also mentions that the primary complaint about the previous Archos devices was their unstable OS. Switching over to Android was considered a major improvement over this. According to him, early versions of Archos 5 software seemed unfinished and many of its features did not work, but the overall performance seems to have improved after several software updates. [36].

3.1.2. Analysis

As one of the first non-mobile Android devices on the market, it is only natural that Archos 5 Internet Tablet would come across numerous software incompatibility problems. The repeated need for software updates might be an indication of this, although one cannot say for certain. After all, it seems to be common practice among manufacturers to release a product with functional yet incomplete software, which is then optimized and complemented with updates later on.

Beyond this, Archos 5 Internet Tablet can be thought of as the basic example of what a non-mobile multimedia device running Android platform could be like. It is essentially a smartphone with a larger-than-normal touchscreen, powerful media-playing capabilities, and no telephony.

The Archos company seems to be attempting to maintain distance to Google, as Archos 5 does not seem to include any of the built-in Google features typically associated with Android platform, such as Gmail and Google Talk. Archos also seems to be unwilling to allow their device to access the applications on Android Market. Instead they offer an applications service of their own, Appslib, with a much smaller selection than what is available on Android Market. This would indicate a possibility that ordinary Android applications are not readily compatible with the device, or that Archos wishes to control the applications available on its device, or both.

Archos 5 Internet Tablet is further studied in Chapter 4, which contains a heuristic usability analysis on the device's user interface.

3.2. Barnes & Noble nook

Nook (*Figure 3.2*) is an electronic book (e-book) reader developed and marketed by Barnes & Noble, a book retailer in United States. It was developed to compete with devices such as Amazon Kindle, which is an e-book reader developed by another book retailer, Amazon.com. According to Barnes & Noble, it is the first electronic book reader based on Android platform. Nook's technical specifications are listed in *Table 3.2*.

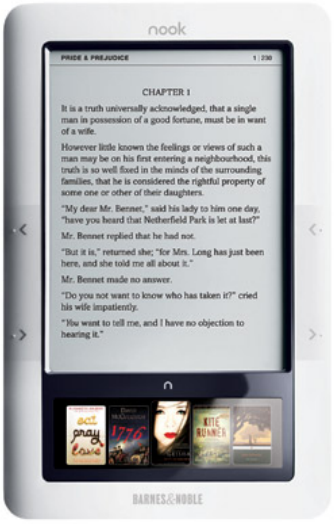

Figure 3.2 *Barnes & Noble nook* [37]

Table 3.2 *Barnes & Noble nook technical specifications* [37; 38]

Name	Nook
Manufacturer	Barnes & Noble
Release Date	November 30, 2009
Android version	1.5
Price	$259 (approximately 190.9 €)
Display	6'' grayscale E Ink screen, 600x800 resolution 3,5'' touchscreen, 480x144 resolution
Connectivity	802.11 b/g/n WiFi, 3G by AT&T
Storage	2GB internal storage + MicroSD expansion up to 16GBs
Supported files	
Video	-
Audio	MP3
Image	JPG, GIF, PNG, BMP
E-book	EPUB, PDB, PDF
Primary features Display e-books, display images as a screensaver, play MP3 music (has in-built mono speakers). Purchase and download books from Barnes & Hobble bookstore either by wireless connection or direct connection to PC. Subscribe to magazines that are automatically downloaded into the device. Lend e-books to friends up to 14 days via e-mail. In-built dictionary.	

Nook's most notable feature is its dual screen. The larger of these is a grey-scale E ink screen typically found on e-book readers. Below it is a color touchscreen that serves as the device's user interface.

As an e-book reader, nook's primary purpose is to serve as a portable storage and viewing device for electronic documents. It is capable of displaying most common

standard formats used with e-book documents. In addition to this, the device comes with an in-built WiFi connectivity as well as a 3G capability provided by AT&T, which is an American teleoperator. These features turn nook into a portable access point for Barnes & Noble online book store, which allows the user to purchase and download books wirelessly. The device also enables the user to "lend" his or her books to another user via email for up to 14 days.

Nook's secondary features are few. It is able to display some of the most common image standards, but only as a slideshow screensaver. The device also serves as an audio player, but is able to play only MP3s.

According to IT website The Register, the president of Barnes & Noble, William J. Lynch, has expressed a possibility that Android platform might enable the company to open the nook for third-party application development at some point in the future. [39].

Other parties are also interested in developing on nook. There is at least one unofficial development community called nookDevs that is dedicated to developing additional applications for the device. [38].

3.2.1. Third-party evaluation

ZDNet.Com has four reviews for nook, which give the device an average rating of 7.7 out of 10 [40].

Joshua Topolsky of Engadget praises the user friendliness of nook's book-purchasing functions, but states that the device has a sluggish speed. He adds that there is a distinct difference between the refreshing speeds of E Ink- and touchscreen, with the latter loading much faster and leaving the former trailing behind. He also states that Android software seems unstable at times because loading some parts of the software occasionally brings up Android's standard Force Close error message. [41].

Gizmodo's reviewer Wilson Rothman also finds nook's software to be work-in-progress and believes that it needs heavy updating. He also mentions that it would be important that this sort of device would have more software features, especially because the Android touchscreen would seem like a promising ground for it. [42].

David Carnoy of CNet writes that the color touchscreen adds some of the much-needed "wow-factor" that e-book readers generally seem to be lacking. However, he believes that rather than the touchscreen, it will be the services, WiFi feature, and book lending capabilities that might give nook advantage over its competition. [43].

3.2.2. Analysis

Barnes & Noble nook is an example of how much Android platform can be tailored for the needs of a specific device. The user interface is very different from the norm. Where standard Android interface has a selection of icons against a wallpaper background, nook has a close row of buttons, each of which opens up menus containing the device's features. An E Ink screen is also something that is not normally related to Android.

Modifying the platform so heavily also has its downsides. Nook is almost completely bare of the applications and other features offered by many of the other Android-based devices. Many of the reviewers cite the device to have sluggish refreshing speed. One reviewer even mentioned an occasional error message when attempting to launch some particular feature. However, nook's software is still in its early versions, so the performance can be expected to improve with optimization and bug fixes.

Nook lacks downloadable applications, but the president of Barnes & Noble seems to acknowledge the potential here and has mentioned the possibility that the device might be opened for third parties in the future. Developers certainly are interested, as can be seen from the unofficial community that has already been established.

Since Barnes & Noble is an American company and nook features 3G connection provided by an American telco, it is unlikely that the device will be exported to Europe in the near future. In order to do so, they would have to negotiate treaties with European telcos. This would likely be a time-consuming process.

3.3. Camangi WebStation

WebStation (*Figure 3.3*) is an Internet Tablet developed and marketed by Camangi, a Taiwanese company specializing in Internet communications. The company states WebStation to be the first device with 7-inch screen to feature Android platform. WebStation's technical specifications can be seen in *Table 3.3*.

Figure 3.3 *Camangi WebStation* [44]

Table 3.3 *Camangi WebStation technical specifications* [44]

Name	WebStation
Manufacturer	Camangi
Release Date	December 2009
Android version	1.5
Price	$275 (approximately 202.7 €)

Table 3.3 (continued) *Camangi WebStation technical specifications* [44]

Display	7'' touchsreen, 800x480 resolution
Connectivity	802.11 b/g/n WiFi, support for 3G via USB dongle
Storage	256MB flash memory, slot for MicroSD card slot for 1-16GB
Supported files	
Video	3GP, MP4
Audio	3GP, MP3, MP4, OGG, MID, WAV
Image	JPG, GIF, PNG, BMP
E-book	EPUB
Primary features Browse Internet, read email. View images, listen to music, and read e-books. GPS. Numerous smaller services, including calendar, calculator, weather forecast, etc. More applications can be purchased from Camangi's own market (currently at beta stage).	

WebStation specializes in wireless Internet connectivity. It allows the reader to browse Internet and read email. The device has a built-in WiFi connectivity and support for 3G via an USB dongle. It also features a GPS module.

WebStation also functions as a multimedia player. It is capable of playing several of the common audio formats and has a gallery that can display standard image formats. There is also support for a basic e-book format. The device is able to play video, although its video format support is very narrow when compared to that of Archos 5 Internet Tablet. The device comes with a stand that allows it to function as a digital photo frame.

Camangi provides an application market of its own, titled Camangi Market, from which users can purchase and download applications for WebStation [45]. The device comes with a number of basic applications preinstalled, including features such as weather reports, alarm clock and calculator.

3.3.1. Third-party evaluation

Reviews of WebStation have been primarily negative. Laptop magazine's K. T. Bradford writes that Android platform runs sluggishly on Camangi's hardware. He cites lack of Android Market as a notable flaw for the device, as Camangi's own market is small and confined by comparison. [46]

Michael Smith from Gizmodo agrees about the device's sluggish speed. According to him, even videos designed to be playable on iPod played very slowly on WebStation, with the image lagging well behind the sound. He also mentions that Flash does not function in the web browser, thus limiting the Internet experience on the device. In a summary Camangi WebStation is, to quote Mr. Smith,"*basically a digital picture frame loaded with a cell phone version of Google Android with a touch screen.*" [47].

3.3.2. Analysis

At first glance WebStation seems like something of a crossbreed of Archos 5 and Barnes & Noble nook: an Internet tablet with video-playing capabilities and ability to read e-book formats. However, a closer look at the device's user interface (*Figure 3.3*) indicates that this is a rather straightforward scaling of Android platform onto a larger screen. The device features several of Google's applications that have been built into the Android platform, most notably Gmail.

WebStation's primary problem is likely to be the screen size compared to the hardware inside. Large resolutions tend to be heavy for a device to run properly, especially when required to play high-quality video, as Gizmodo's Michael Smith could attest. Optimizing software updates could perhaps help to make the device run smoother, but if the operating system indeed is a straightforward scaling of Google Android, it is uncertain how much the software can be optimized.

Again, Android Market is not available for the device. In its place Camangi offers a market of their own, with a handful of applications and an invitation for developers to create more.

3.4. enTourage eDGe

enTourage eDGe (*Figure 3.4*) is a dualbook, a combination of e-book reader and notepad with Internet connectivity and media-playing capabilities. It is developed and marketed by Entourage Systems, a small USA-based company that was founded to create this device. enTourage eDGe's technical specifications are listed in *Table 3.4.*

Figure 3.4 *enTourage eDGe* [48]

Table 3.4 *enTourage eDGe technical specifications* [48; 49]

Name	enTourage eDGe
Manufacturer	Entourage Systems
Release Date	February 2010
Android version	1.6, upgrade to 2.1 coming in April 2010
Price	$499 (approximately 367 €)
Display	9.7'' E Ink display, 1200x825 resolution 10.1'' LCD touchscreen display, 1024x600 resolution
Connectivity	802.11 b/g/n WiFi, Bluetooth, optional 3G (version available in March 2010)
Storage	3GB internal storage, SD card slot
Supported files	
Video	3GP, MP4, Adobe Flash Lite (H.264)
Audio	MP3, WAV, 3GPP, MP4, AMR, AAC, OGG, M4A
Image	BMP, GIF
E-book	EPUB, PDF
Primary features Purchase, download and read e-books. Play music and videos, display images. Record audio and images. Browse Internet. A number of small applications, including email, contacts, calculator, alarm clock, library function.	

enTourage eDGe consists of two screens that are joined together on a hinge, allowing them to be opened and closed like the covers of a notebook. One of the screens is an E Ink display, while the other is a touchscreen. enTourage eDGe was created to assist in schoolwork and studies. It combines the functionalities of e-book reader, multimedia player, Internet browser, and video- and audio recorder. The device connects wirelessly via WiFi and features Bluetooth. A version with an option for 3G is stated to become available in March 2010.

enTourage eDGe is capable of playing a number of audio formats and a few video formats, as well as displaying a narrow selection of image formats. It is capable of reading basic e-book formats and includes a service for purchasing and downloading e-books from Entourage Systems' own online service.

A built-in video camera allows enTourage eDGe to be used to take still images. The device also has a microphone for audio recordings. In addition to the major features enTourage eDGe also has a number of smaller applications, including email client, calculator, and alarm clock.

At the time of writing Entourage Systems does not offer any services for purchasing new applications, but they state that Android OS was specifically chosen for the device so that new applications could be added as necessary.

3.4.1. Third-party evaluation

At the time of writing enTourage eDGe is a very new device and few experts have had the opportunity to review it. There are, however, a few hands-on articles about the device, which can give some idea of what using it could be like in practice.

The staff at Electronista praise enTourage eDGe for its e-book reading capabilities, but points out that the device is bulky and slightly difficult to use [50].
At Gizmodo Kat Hannaford also mentions about the large size and suggests that potential customers should wait until a smaller version becomes available. However, she also commends the device for the large number of features available in it and notes that the software runs fairly fast on the device. [51].

3.4.2. Analysis

enTourage eDGe can no longer be called merely a multimedia device. It can play video and audio, and it can display images and e-books, but the way all of the features come together makes it different from most of the other multimedia devices. enTourage eDGe was designed from the start as a device for schoolwork and studies. All of its features are fitted together for this goal. Judging by the images (*Figure 3.4*) and preview videos of the device, this was accomplished without having to change the basic Android user interface very much.

Beyond this, enTourage eDGe is at the time of writing too new and there is not yet enough information to analyze it further. It should be noted, however, that Entourage Systems has stated that they chose Android OS for their device in order to allow new applications to be added into the system as necessary. This would indicate a possibility for applications store or even Android Market in the future.

3.5. GiiNii Movit Mini

Movit Mini (*Figure 3.5*) is a mobile Internet device developed by GiiNii, a consumer electronics company based on USA. The device was first veiled in CES-2009, where it gained attention for its Android platform. *Table 3.5* lists Movit Mini's technical specifications.

Figure 3.5 *GiiNii Movit Mini* [52]

Table 3.5 *GiiNii Movit Mini technical specifications* [52; 53]

Name	Movit Mini
Manufacturer	GiiNii
Release Date	Upcoming, release date unknown (first introduced at CES-2009)
Android version	Unknown
Price	Unknown
Display	4.3'' touchscreen, 480x272 resolution
Connectivity	802.11 b/g/n WiFi, Bluetooth
Storage	256MB internal, microSD slot
Supported files	
Video	Unknown
Audio	Unknown
Image	Unknown
E-book	Unknown
Primary features Skype-enabled device, make calls for free to other Skype users. Browse Internet. Play music and video (details unknown). Works with Facebook, Google, and Yahoo. Includes smaller applications such as camera, calculator, address book and alarm.	

Movit Mini's development was delayed and its release was moved from 2009 to somewhere in 2010. At the time of writing Movit Mini has not yet been released and there is not much technical information on its capabilities. According to GiiNii, Movit Mini is an Internet device for social networking. It allows the user to browse Internet and make Skype calls with the help of a built-in mic and camera. The device is also compatible with social networking services from Facebook, Google, and Yahoo. Its connectivity includes WiFi and Bluetooth, but not 3G.

Movit Mini is also able to play video and audio, but there is no information on what formats is supports. The device includes a number of smaller applications and features such as camera, calculator, and alarm clock. There is no information on whether or not Movit Mini will support downloading and installing new applications.

Movit Mini also has a sister device, Movit Maxx, which is a larger, tablet-like device with a 7'' screen. At the time of writing there is no actual information on Movit Maxx's features or capabilities. However, according to GiiNii website, Movit Mini has all the features of Movit Maxx, only in a smaller frame.

3.5.1. Third-party evaluation

Because Movit Mini is still unreleased, third party reviewers have very little information on the device. Chris Crum from WebProNews believes that Movit Mini's ability to make Skype calls for free over WiFi hotspots might excite consumers, since it means that it does not need mobile phone contracts in order to make phone calls. [54].

3.5.2. Analysis

Movit Mini is a device using a platform that had originally been designed for mobile phones, but its phone capabilities have been replaced with Skype's Internet telephony. GiiNii has drawn much attention to how the device could allow consumers to sever ties to telecommunications operators and use free telephony instead. Should Movit Mini become popular, it could pose a threat to telcos. However, the device only supports WiFi connection. Since WiFi networks tend to be much smaller in scale when compared to mobile phone networks, this will limit the mobility and general usefulness of Movit Mini's phone call feature.

There is not enough information to analyze the device further.

3.6. Acer Aspire One D250

Aspire One D250 (*Figure 3.6*), or AOD250 for short, is a netbook manufactured and sold by PC vendor Acer. There are numerous different configurations of AOD250. Some of them run Microsoft Windows XP and others Microsoft Windows 7. One of these configurations, coded 1613, contains a dualboot system that allows the netbook to be used either on Windows XP or Android platform. The following analysis will discuss only this configuration. AOD250's technical specifications are listed in *Table 3.6.*

Figure 3.6 *Acer Aspire One D250* [55]

Table 3.6 *Acer Aspire One D250 technical specifications* [55]

Name	Aspire One D250 (configuration 1613)
Manufacturer	Acer
Release Date	October 2009
Android version	Most reviews state 1.0, though this seems to be updatable
Price	$334.99 (approximately 246.1€)

Table 3.6 (continued) *Acer Aspire One D250 technical specifications* [55]

Display	10.1'' screen, 1024x600 resolution
Connectivity	802.11b/g WiFi, Bluetooth, LAN
Storage	160GB hard drive
Supported files	
Video	-
Audio	-
Image	-
E-book	-
Primary features A dualboot netbook that can be started up either on Windows XP or Android. Numerous other configurations of this netbook exist, running either Windows XP or Windows 7. Configuration 1613 is the only one to run Android. Several preinstalled applications: Browse Internet, Google Talk, Google Calendar, and Gmail. Likely to support numerous video, audio and image files.	

Upon startup AOD250 gives the user a choice of booting the netbook either in Windows XP or Android platform mode. Describing AOD250's features when it is in Windows XP mode falls outside the scope of this study and therefore will not be discussed. Choosing the Android option causes the netbook to boot into a basic Android view, with a selection of pre-installed applications available. These include a number of basic Internet-related applications typically associated with Android: Internet browser, Google Talk, Google Calendar, and Gmail. The netbook's connectivity is handled either wirelessly by WiFi or via a LAN (Local Area Network).

According to a review by Cisco Cheng on PCMag, Android platform has a button that allows the user to instantly switch over to Windows XP mode. However, moving from Windows XP to Android requires the entire device to be rebooted. [56].

3.6.1. Third-party evaluation

Expert response to AOD250 has been mostly negative.

Chris Davis of Slashgear reports that the device seems "semi-finished", largely because of the Android platform. Acer does not seem to have significantly modified the standard Android mobile phone interface before installing it to the netbook. Chris Davis also adds that Android Market has been removed from the netbook's OS and that it is not possible to upload new applications to the device. This means that AOD250's Android has technically been turned into a closed OS. On the other hand, Chris Davis writes that the device has a large selection of pre-loaded Android applications available. He also says that the device boots into Android very quickly. It takes only 20 seconds for the OS to load from startup, and only one second for it to shut down. [57].

Paul Miller of Engadget also expresses his disappointment in AOD250's Android platform. According to him, Acer launched AOD250 without Google's support and states this to be the reason why the device cannot access Android Market. [58].

Joseph L. Flatley of Engadget further points out that using Android platform on a PC without a touchscreen can cause issues. Android was originally designed as a mobile phone OS. Therefore it might be troublesome to use the system without any designated “Android” keys. [59].

3.6.2. Analysis

Acer’s experiments with Android platform and the reviewers’ negative response to it indicate that the unmodified platform does not function very well in a full PC-type device. Most of the other devices studied in Chapter 3 feature touchscreens as their primary input method. AOD250 does not have a touchscreen and giving it instructions seems to be more complicated because of this.

Lack of Android Market heavily limits AOD250’s potential, particularly if new applications cannot be installed via any other means. A set of standard applications for Internet browsing, email, and others might be enough for casual Internet use, turning Android-mode AOD250 into something of an Internet Tablet with a keyboard.

3.7. Guangzhou Skytone Alpha 680

Alpha 680 (*Figure 3.7*) is a netbook with a rotating display. It was developed by Chinese Internet technology company Guangzhou Skytone. Alpha 680 is one of the first netbooks shipped with preinstalled Android platform. It is also one of the oldest Android products to be included into this study. *Table 3.7* lists technical specifications of Alpha 680.

Figure 3.7 *Guangzhou Skytone Alpha 680* [60]

Table 3.7 *Guangzhou Skytone Alpha 680 technical specifications* [60]

Name	Alpha 680
Manufacturer	Guangzhou Skytone
Release Date	April 2009 in China, US release unknown
Android version	Unknown
Price	$250 (approximately 184.2 €)
Display	7'' touchscreen, 800x480 resolution
Connectivity	802.11b/g WiFi (ADSL, GPRS, CDMA, EDGE, WCDMA under development), Ethernet
Storage	1GB flash memory, SD card slot
Supported files	
Video	MPEG1/2/4, H.263, H.264, WMV9
Audio	Unknown
Image	Unknown
E-book	Unknown
Primary features Netbook with Internet browsing capability. Includes numerous standard Android applications such as Gmail, Google Docs, Google Calendar, and video player.	

Alpha 680 was first released in China. It is unknown when it will be released in the western countries. Much like Acer's Aspire One D250 (see Chapter 3.6), Alpha 680 is a netbook running Android platform. Unlike AOD250, however, Android is Alpha 680's sole operating system. It has both a built-in keyboard and a touchscreen. The device also has a wide variety of connectivity options, including WiFi, ADSL and Ethernet. At the time of writing many of the connectivity protocols were still under development for the device.

As a netbook Alpha 680's primary feature is its Internet browsing capability. This is supplemented by a number of Android applications, including Gmail, Google Docs, and video player. Alpha 680 is able to play the most common video formats, but there is no information about its audio-playing or image-displaying capabilities.

3.7.1. Third-party evaluation

Expert response to Alpha 680 has been somewhat negative. Ross Miller of Engadget feels that the operating system's tendency to fill the entire screen with the running application makes it difficult to multitask on the device, something that a netbook is expected to be able to do. [61].

The staff at Rokland Technologies, which is an online retailer of wireless networking products, states that Alpha 680 is "*a fun toy for geeks who want to work on Android on a netbook*", but that the device still needs honing before it can be considered a mainstream product. They add that the device seems to use an almost unmodified version of the Android mobile phone interface, which does not always fit well with the device's hardware. However, Rokland staff adds that the large screen allows the Android to be easily used on the device. According to them, one of the primary complaints about netbooks is that they try to be fully qualified PCs and because of that

using them can be difficult. Android platform was designed for simplicity so that it could be used more easily on a smartphone. This would make a netbook running an Android platform something of a stepping stone between a smartphone and a netbook. [62].

According to Eric Laine of Computerworld, Alpha 680 is capable of downloading and installing new applications from Android Market. However, he adds, at least in April 2009 approximately 20% of the applications available on Market were not compatible with the device. [63].

3.7.2. Analysis

As mentioned in Chapter 3.7, Alpha 680 is similar to Acer's Aspire One D250 (Chapter 3.6), a netbook with Android platform. However, there are two primary differences between the devices. First, AOD250 runs also a Windows XP OS as an alternative should Android platform prove insufficient. Second, Alpha 680 has a touchscreen which, as was pointed out in Chapter 3.6.2, is something Android tends to rely on for input. This makes Alpha 680 a more suitable device for running Android when compared to AOD250.

Relying solely on Android platform has some weaknesses for Alpha 680. Android platform is not very suitable for multitasking, which is something that a netbook is expected to do.

3.8. ICD Vega

Vega (*Figure 3.8*) is a 15-inch tablet device developed by Innovative Converged Devices (ICD), a technology designer company based on United Kingdom. At the time of writing the Vega tablet is still unreleased, but ICD has promised that it would arrive during year 2010. The device is marketed as "a family hub" that is "designed primarily to sit in the kitchen." ICD has stated that it will release smaller, 7- and 11-inch versions of the device at some later, unconfirmed time. Vega's technical specifications are listed on *Table 3.8.*

Figure 3.8 *ICD Vega* [64]

Table 3.8 *ICD Vega technical specifications* [64; 65]

Name	Vega
Manufacturer	Innovative Converged Devices (ICD)
Release Date	Upcoming, April 2010
Android version	2.0
Price	Unknown
Display	15.6'' touchscreen, 1366x768 resolution
Connectivity	802.11 b/g/n WiFi, Bluetooth 2.1, options for 2G, 3G
Storage	512MB Flash, SD slot up to 32GB
Supported files	
Video	Unknown
Audio	Unknown
Image	Unknown
E-book	Unknown
Primary features Social networking. Numerous communications methods: chat, video chat, email, voice, SMS, and MMS. Microphones and video camera. Play music and videos (formats still unknown). Games. On demand web-TV, FM radio.	

Like with many of the still unreleased devices, there is not yet much information about Vega's capabilities. It is described to have an NVIDIA Tegra processor and a combined application / graphic accelerator, which promises powerful multimedia-playing capabilities. ICD has promised full-HD 1080p video-playing capability for the device. Supported video, audio, and image formats are still unknown. However, on-demand web-TV and FM radio are also included as features.

Vega's other primary features include social networking. It accomplishes this through a number of applications such as chat, video chat, email, and SMS / MMS-messaging. The family calendar can be set so that the device automatically sends SMS messages to family members at given dates and times. Vega's connectivity includes

WiFi and options for 2G and 3G connection. In the latter case the device can be used as a table phone with a microphone and loudspeakers.

3.8.1. Third-party evaluation

Experts have given Vega positive expectations. According to Laptop magazine's Kenneth Butler, the device's touchscreen responds quickly to commands, at least in demo environment. He also claims that the primary reasons for the enthusiasm for Vega are its large screen and powerful graphics processor. [66].

3.8.2. Analysis

With a large touchscreen and powerful hardware running one of the later versions of Android platform, Vega is an example of the next generation of tablet devices. Vega relies heavily on connectivity for many of its functions, and ICD has listed on-demand web-TV as one of the device's features. Therefore, it can be reasonably expected that the device would also have some kind of application for streaming media content either from Internet or from home computers. If ICD also fulfills its promise for full-HD quality video for this tablet, Vega could well become a very good multimedia device and a proof-of-concept for what is possible to accomplish with the Android platform.

3.9. Spring Design Alex

Alex (*Figure 3.9*) is an e-book reader developed by Spring Design, a company specializing in e-book reader solutions. The device's appearance and features make it very similar to Barnes & Noble nook e-book reader (see Chapter 3.2). In fact, in February 2010 Spring Design sued Barnes & Noble for stealing ideas and features from their device [67]. Alex's technical specifications are listed on *Table 3.9*.

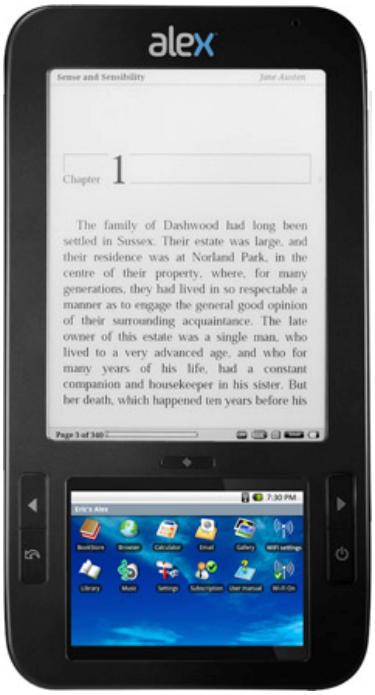

Figure 3.9 *Spring Design Alex* [68]

Table 3.9 *Spring Design Alex technical specifications* [68; 69]

Name	Alex
Manufacturer	Spring Design Inc.
Release Date	February 2010
Android version	1.5
Price	$399 (approximately 294 €)
Display	6'' E Ink display, 600x800 resolution 3.5'' touchscreen, 320x480 resolution
Connectivity	802.11b/g WiFi. (3G, EVCO/CDMA, and GSM claimed, but not in the technical specifications.)
Storage	2GB flash internal, slot for microSD up to 4GB
Supported files	
Video	MPEG2, MPEG4, 3GPP, Adobe Flash Lite
Audio	MP3, MIDI, WAV
Image	JPEG, GIF, GMP, PNG
E-book	ePUB, PDF, DRM, txt, HTML
Primary features Download and read e-books. Browse Internet on the touchscreen. Listen to music, watch videos. Gmail, Twitter. Android applications.	

Alex's most prominent feature is its dualscreen. The larger of the two screens is an E Ink display. Below it is located a smaller color touchscreen that is used to control the device.

Alex is capable of displaying a number of e-book formats. It allows the user to connect to online book retailer services such as Google Books to purchase and download e-book documents. The device's connectivity features include at least WiFi.

3G and GSM support are also claimed by Spring Design, but they are not present in the device's technical specifications.

In addition to e-books Alex can also play a number of the common video- and audio formats and display the most common image types. The device can also be used to browse Internet via the touchscreen and has access to Gmail and Twitter. Alex can also run Android applications. It cannot access Android Market, but Spring Design has a service of its own, titled Alex Marketplace. At the time of writing Alex Marketplace is not yet open, but it promises to have a number of applications available for the device. According to Spring Design Alex Marketplace is *"open to all registered Android application developers."*

3.9.1. Third-party evaluation

At the time of writing Alex is not yet released and there are not many reviews written about it. However, experts have described their first impressions of the device somewhat positively. Stuart Miles of Pocket-lint writes that the device is currently one of the most expensive e-book readers on the market. He describes the touchscreen interface to be very similar to an Android smartphone bolted to the bottom of the reader. He also mentions that both the touchscreen and the E Ink screen respond to commands and refresh faster than either of its competitors, Barnes & Noble nook and Amazon Kindle. [67].

A reviewer on Besttabletreview.com, writing under pseudonym "Tablet", claims to know the reason for why Alex screens respond so well. The device features Marvell Technology Group's ARMADA 166E application processor that has been built specifically for e-book devices. According to "Tablet", the processor triples the frame-rate of the usually slow-responding E Ink screens. [68].

3.9.2. Analysis

Alex is more expensive, but also more powerful than its competitors, Barnes & Noble nook and Amazon Kindle. The device's touchscreen is larger than that of nook, and it accommodates a user interface that is closer to standard Android. This gives Alex more flexibility for displaying its features and functions when compared to nook's row-of-buttons menu. However, smartphone-style interface might also be more complicated to use than nook's simple buttons.

Alex is another example of a manufacturer eschewing Android Market in favor of an application service of its own.

3.10. Creative Zii EGG

Zii EGG (*Figure 3.10*) is a hardware development platform by Creative Technology, a Singapore-based manufacturer of multimedia devices. Creative Technology markets Zii EGG not as a complete device, but as a basis on which integrators and developers can

create customized applications and devices of their own. Zii EGG's technical specifications are listed in *Table 3.10*.

Figure 3.10 *Creative Zii EGG* [71]

Table 3.10 *Creative Zii EGG technical specifications* [71]

Name	Zii EGG
Manufacturer	Creative Technology (Creative Labs)
Release Date	November, 2009
Android version	Optimized 1.6
Price	Not for consumer use
Display	3.5'' touchscreen, 320x480 resolution
Connectivity	820.11 b/g WiFi, Bluetooth
Storage	Up to 32GB Flash, SDHC slot for up to 32GB external
Supported files	
Video	MPEG4, DivX, Xvid, H.264, WMV, MJPEG
Audio	AAC, MP3, MIDI, Ogg, ADPCM, WMA, FLAC
Image	Unknown
E-book	Unknown
Primary features A development platform for integrators and developers to create customized applications and devices on. Not for consumer use. Runs Android and Creative's own Plaszma OS, both Linux-based. "Multi-format audio and video processing, web browsing, OpenGL ES 3D graphics, content streaming." Up to 1080p high-definition video output, either scaled down to the screen or via HDMI to TV. Hardware GPS receiver. Two cameras. Android applications are expected to work.	

Unlike the other devices described in Chapter 3, Zii EGG is not meant for consumer use. It is a development platform meant to allow the development of customized devices and is sold alongside a compatible SDK.

Zii EGG is a touchscreen device with a WiFi network connection. It runs either on Creative Technology's own Linux-based Plazma OS [72] or on a modified Android platform. The Android platform is optimized for graphic performance and Zii EGG's processor has technology that allows Android to run 3D graphics and high-definition video on the device. Android's applications are also expected to work normally on the device, but there is no information on whether or not Zii EGG is compatible with Android Market.

Zii EGG's primary features are described as video-and-audio processing, web browsing, content streaming, and 3D graphics. The device is able to play a number of advanced video and audio formats. Its video output quality can reach up to 1080p HD, either scaled down for the device or played via HDMI connection on TV.

Zii EGG comes with an in-built GPS receiver and two cameras, a VGA camera up front and a HD camera in the rear.

Creative Technology has also developed a consumer version of Zii EGG, which is called Creative Zii. However, at the time of writing Creative Zii is still unreleased. Its exact capabilities and differences from Zii EGG are not yet known.

3.10.1. Android on Zii EGG

Zii EGG uses a modified version of Android platform. Its architecture can be seen in *Figure 3.11*. [73].

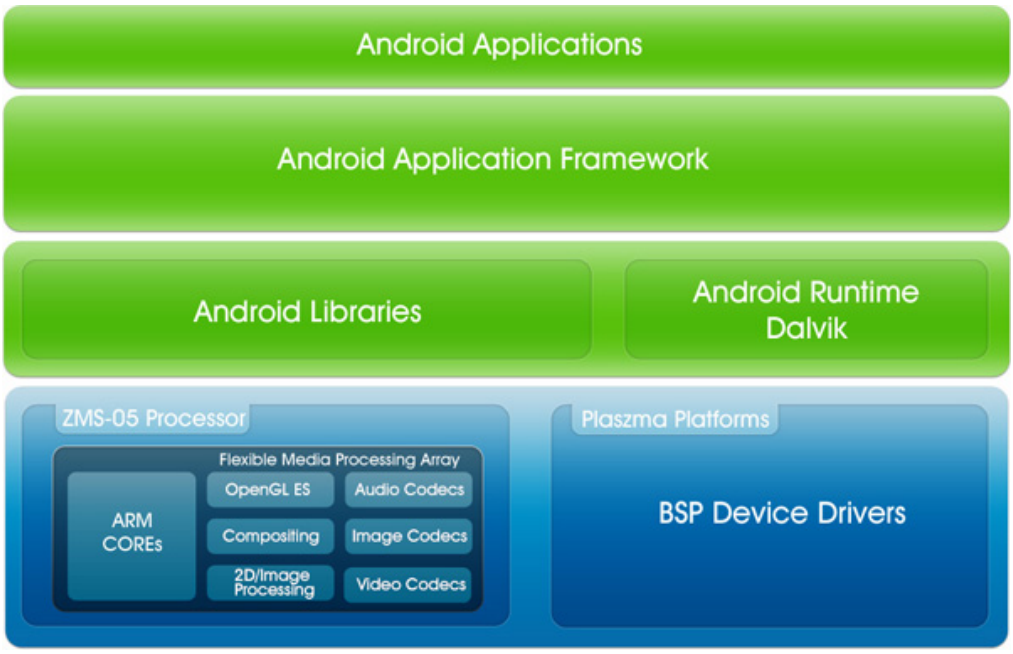

Figure 3.11 *Architecture of Android on Creative Zii EGG* [73]

It can be seen that the architecture is very similar to the standard Android architecture seen in *Figure 2.2*. The most notable difference is that the lowest layer of the architecture, Linux layer, is replaced with ZMS-05 processor and Plazma platform drivers. The device still runs on Linux, but it also makes use of additional graphics processors on ZMS-05 that help to enhance Android's graphical performance on Zii EGG. However, the modification has been done without changes to the Android architecture's upper layers. This means that the device can be installed with a standard open source Android 1.6 without need for assistance from Creative Technologies. It also means that Android applications can be expected to run as normal on the device.

3.10.2. Analysis

Zii EGG is a unique case among the devices introduced in Chapter 3. Instead of a finished device, it is a device platform for other manufacturers to develop on. As such, it serves as a proof of concept that this kind of arrangement indeed is possible for Android platform. Zii EGG also acts as an example of how existing Android architecture can be modified to better suit the needs of a specific device.

Zii EGG features enhancements that improve the device's graphical performance. Considering that graphics-heavy devices such as ICD Vega (see Chapter 3.8) also include similar enhancements, this might be a necessary feature for any Android-based device intended to have noteworthy visual capabilities.

3.11. Analysis of Android devices

As was mentioned in the beginning of Chapter 3, although only ten devices were introduced in Chapters 3.1 to 3.10, a total of 21 Android-based non-mobile devices were examined for the needs of this thesis. Studying the properties of these devices resulted in discovery of a number of trends that appear to be common in Android-based non-mobile device market of today. These trends are now presented in further detail.

The two most common device types among the studied devices were Internet Tablets and e-book readers. 7 out of 21 devices were Internet Tablets, a device type with a large touchscreen, usually featuring an Internet connection and multimedia-playing capabilities. 6 out of 21 devices were e-book readers, devices featuring an E Ink screen for reading electronic book formats. A dual-screen setup, with one E Ink screen and the other touchscreen was a particularly common type of e-book reader, combining electronic documents with more traditional Android-based applications. Together Internet Tablets and E-book readers consisted over half of the examined devices. This indicates a definite interest from manufacturers for making such device types for today's market.

Touchscreens dominate the Android device market. Only one device out of 21 did not have an integrated touchscreen as its primary means of user input. It should be noted that the device, Acer Aspire One D250 (see Chapter 3.6), suffered from poor usability because of this. This indicates that a touchscreen or a similarly simple means of input is crucial for Android platform to be used in a feasible manner.

Screen sizes and resolutions are variable. Although it was stated in Chapter 2.4 that Android platform supported only 320x480 screen resolution before the introduction of Android v.1.6, in practice devices can have a broader scope of resolutions even with earlier versions. For example, Camangi Webstation (see Chapter 3.3) was stated to run Android platform v.1.5, but it still managed to provide 800x480 screen resolution. The most common resolutions among the studied devices are listed in *Table 3.11*.

Table 3.11 *Layout of screen resolutions among the 21 examined devices.*

Resolution	*480x320*	*800x480*	*1024x600*	*Others*	*Unknown*
Devices	3	10	3	3	2

The most common screen resolution among examined devices was 800x480, which means non-mobile devices tend to be somewhat larger than most smartphones on today's market. According to *Table 2.2* in Chapter 2.4, 800x480 is the largest screen resolution that Android platform v.1.6 and onwards is currently capable of accomplishing. However, there are also devices that are capable of resolutions as high as 1024x600, which proves that it is possible to make even current versions of Android platform to reach the lower levels of HD resolution as it is defined in Chapter 2.4. The highest screen resolution encountered in this study was 1366x764. This was in ICD Vega (see Chapter 3.8), an Internet Tablet that is being advertised to have high-definition video-playing capabilities.

Almost every device is WiFi-capable, while roughly half support 3G. A typical Android-based non-mobile device relies heavily on wireless network for its connectivity. The layout of various forms of connectivity among the 21 examined devices can be found in *Table 3.12*.

Table 3.12 *Forms of connectivity supported by the 21 examined devices.*

Connectivity	*WiFi*	*LAN*	*3G*
Devices	20	4	10

As can be seen in Android architecture displayed in *Figure 2.1* in Chapter 2.3, the Android platform has ready-made drivers and APIs both for WiFi and telephony. It only makes sense that these features are exploited in Android-based non-mobile devices as well, so it is not surprising to see both WiFi and 3G prevalent among the studied devices. Only one device of the 21 did not feature WiFi. This was 1CrossTech's MIDhybrid, a combination of MID and e-book reader, which makes up for the lack of WiFi by featuring 3G connectivity. This device was not introduced in Chapter 3 due to lack of space, but its technical specifications can be found in *Appendix 1* and *Appendix 2*.

Roughly half of the devices supported 3G. Considering Android's origins as a platform for smartphones, the portion of 3G-supporting devices is smaller than expected. However, since most of the newer, still-unreleased devices in the study supported 3G, perhaps their share will increase in the future.

Most devices support Android applications, but many manufacturers eschew Android Market in favor of their own application store. Many manufacturers cited the availability of Android applications as one of the primary reasons for choosing Android platform for their devices. The layout of devices that support Android applications can be seen in *Table 3.13*.

Table 3.13 *Compatibility of Android applications among the 21 examined devices.*

Android applications	*Support*	*No support*	*Unknown*
Devices	16	2	3

Most of the studied devices had support for Android applications. Android Market is currently the best source of Android applications. However, the software used to connect to the Market is apparently available only on devices that have been launched in co-operation with Google. Many manufactures have chosen to not go via this route, and have introduced their own online application stores instead. The numbers of devices supporting Android Market, those that offer manufacturer's own appstore instead, and those that do not feature any appstore at all are listed in *Table 3.14*.

Table 3.24 *Support for Android application stores among the 21 examined devices.*

Appstore	*Android Market*	*Manufacturer's Appstore*	*No appstore*	*Unknown*
Devices	3	6	2	7

Only a small portion of the studied devices openly supported Android Market. By comparison a significant number of manufacturers chose to introduce their own appstores for their devices. However, at the time of writing most of these appstores were newly established and featured only a small number of applications, whereas Android Market (see Chapter 2.6) featured thousands of applications. It should be noted that a significant number of the devices were vague about whether or not they supported an application store. This number of unknown devices has potential to tilt the results on Table *3.14* in any direction.

Android-based devices are heavily multimedia-oriented, but Android platform needs additional enhancements before it can provide high-quality media. A good majority of the studied devices featured versatile media-playing capabilities, making good use of the base set of file formats provided by the Android platform (see Chapter 2.5). Some of the devices, such as e-book readers, had narrower media-playing capabilities due to device limitations, while others expanded on Android's base set by introducing additional file formats. A number of higher-end devices were capable of playing HD-quality video either on their own screens or when connected to a TV. Android architecture (see Chapter 2.3) does not support high resolutions by itself (see Chapter 2.4), so the platform needs extensions before it can provide HD quality video. Most of the HD-capable Android devices had either special hardware or graphics software to improve their visual performance. Creative Zii EGG (see Chapter 3.10) provides an example of how Android platform can be modified to accommodate high-quality media-playing capabilities. If the device does not have access to such enhancements, the video may lag heavily and the device might operate slowly in general, as happened in the case of Camangi WebStation (see Chapter 3.3).

Android UI (User Interface) can be tailored into various setups according to the needs of the device, though most manufacturers prefer to retain the basic Android UI. As was mentioned in Chapter 2.3, Android's architecture includes components that can be used to build custom user interfaces for the platform, allowing the manufacturers to construct new UIs to meet the needs of their devices. The resulting interfaces can be drastically different from the basic layout. This is evident in Barnes & Noble nook's row-of-buttons interface (see Chapter 3.2). Even dual-screen based setups are possible, as can be seen on Spring Design's Alex (see Chapter 3.9) or enTourage eDGe (see Chapter 3.4), to name just two. However, despite the interface's malleability a good majority of the devices seem to use a basic Android layout, which is similar to the one used on smartphones.

To summarize the findings of Chapter 3, Android platform can be employed in a variety of different devices. However, a touchscreen is a must for the device to have good usability. Most Android-based devices support Android applications, but many manufacturers have chosen to open their own application stores instead of using Google's Android Market. Android is capable of playing high-quality multimedia, but needs extensions to the basic platform to make this happen. Android UI can be tailored according to the device, but most manufacturers prefer to use the basic UI instead.

4. ANDROID USABILITY

This Chapter examines the usability and user experience of Android user interface on a non-mobile device. This is accomplished by the means of using Archos 5 Internet Tablet as an example of a typical Android-based non-mobile device and evaluating its usability.

Good usability is an important factor for the success of almost any device. Even if a device is efficient at what it does but is difficult and frustrating to use, it is not likely to become popular among consumers beyond a small circle of experts. By contrast, if the device is easy and pleasing to use, more consumers are likely to be satisfied with it. Widely-spread consumer satisfaction is in turn crucial for the commercial success of any manufacturer. Android platform and its user interface were originally designed for mobile phones. However, as could be seen in Chapter 3, manufacturers have installed the platform onto many different types of devices, with different kinds of capabilities and different kinds of displays. Most of these manufacturers have chosen to retain the basic Android user interface instead of designing an UI of their own. This means that most of the new devices introduced by these manufacturers are controlled by the same Android UI that is found in Android-based mobile phones. However, since the Android UI was not originally designed for non-mobile devices, this might give rise to usability problems that might hamper the consumer's user-experience. Therefore, it becomes necessary to study the Android UI on non-mobile devices to determine what kind of problems the consumer might encounter using it.

The most thorough method for examining the performance of Android UI on non-mobile devices would be to acquire a number of different kinds of devices introduced in Chapter 3 and perform a usability analysis on each. However, such a project would require vast resources and at the time of writing many of the new Android devices are not yet available on the market. Therefore, this method was deemed unrealistic for this thesis.

However, as was mentioned before, many of the manufacturers have chosen to incorporate the basic Android UI for their devices with minimal changes. The user experience is likely to not change much when moving from one similar device to another. Therefore, it becomes feasible to acquire one Android-based device and examine it as a use case in order to have a general idea of what user experience is like on Android UI. This thesis will use Archos 5 Internet Tablet (Chapter 3.1) for this purpose.

This chapter contains five parts. First the basic theory of usability will be discussed. Heuristic evaluation is introduced as a method for estimating usability in a

system. Next the test situation for the use case is given and Archos 5 Internet Tablet user interface is described to give an idea of what the device is like. Finally the Chapter will list the results of the heuristic evaluation of the system and discuss them in further detail.

4.1. Usability

Usability of a system is only a small part of a system's acceptability to the user. The acceptability of a system refers to the system's ability to satisfy all the needs and requirements of the user. The overall acceptability of a system can be further divided into social acceptability and practical acceptability. One of the aspects of practical acceptability is the system's usefulness, the question of whether the system can be used to achieve some desired goal. Usefulness can be further divided into two sections, utility and usability.

Utility refers to whether or not the system's functionality can perform the tasks required of it. *Usability* means how well the user can use that functionality.

Usability is a part of all aspects of a system with which a human might interact. It is rare to find a computer feature that does not have component that interacts with a human. Jacob Nielsen says in his book *Usability Engineering* that usability is not a one-dimensional property, but is rather formed from multiple components. According to Nielsen, a system with good usability is easy to learn, efficient to use, easy to remember, produces few errors, and finally is subjectively pleasing to use. [74].

4.1.1. Heuristic evaluation

Heuristic evaluation is a usability engineering method used to find problems in a user interface. It is performed by a number of evaluators who examine the interface in question and estimate its performance against a set of principles. These principles are called "heuristics". [75].

Nielsen lists ten general principles for user interface design. He calls them "heuristics" because they are more like rules of thumb rather than specific usability guidelines. Each of the heuristics describes features that are typical for an interface with good usability. [76].

1. **Visibility of system status** – The user should always be informed of what is going on in the system. The system should give the user appropriate feedback within reasonable time.
2. **Match between system and the real world** – The system should speak the user's language. It should use words, phrases and concepts familiar to the user. The information should appear in a natural and logical order, following real-world conventions.
3. **User control and freedom** – The user can be expected to frequently choose wrong functions. The system should anticipate this by offering the user a clearly

marked “emergency exit” to quickly leave the unwanted state. Undo and redo should be supported.

4. **Consistency and standards** – The user should not have to wonder whether or not different words, situations, or actions mean the same thing. Platform conventions should be followed.
5. **Error prevention** – Careful design can prevent a problem from occurring in the first place. Error-prone conditions should either be eliminated from the system or they should be checked and the user given a confirmation option before they commit to the action.
6. **Recognition rather than recall** – The user’s memory load should be minimized by making objects, actions, and options visible. The user should not have to remember information from one part of the system to another. Instructions for using the system should be visible or easy to retrieve.
7. **Flexibility and efficiency of use** – Expert users should be offered advanced methods to accelerate their use of the system. These shortcuts should be invisible to the novice users so that the system can cater both to the needs of experienced and inexperienced users. Users should be allowed to tailor their frequent actions.
8. **Aesthetic and minimalist design** – Dialogues should not contain irrelevant or rarely needed information. Every extra unit of information competes with the relevant units of information and diminishes their relative visibility.
9. **Help users recognize, diagnose, and recover from errors** – Error messages should be in plain language, without codes. They should precisely indicate the problem and suggest a constructive solution.
10. **Help and documentation** – While it would be better if the system can be used without documentation, it might be necessary provide the user with help. Any such documentation should be easy to search, focused on the user’s task, list concrete steps to be carried out, and not be too large.

It is usually good to have more than one evaluator to examine the interface because it is difficult for a single individual to come across every usability problem in the system. Different testers also tend to treat the same interface differently, allowing some evaluators to discover problems that would not become apparent to the others.

A heuristic evaluation session typically lasts for one or two hours. The evaluator goes through the interface several times and compares its functions with the aforementioned list of heuristics, making a note of the problems he or she perceives. These are then given grades according to their severity. The evaluator should go through the system at least twice. The first time is used to gain a feel of the interface and the flow of the interaction. This gives the evaluator the knowledge of how the different parts of the system work together as a whole. The second time can then be used to focus on specific elements and functions in the interface. The result of the evaluation should be a list of problems the evaluator perceived in the interface. [75].

The problems found during heuristic evaluation are given ratings according to their severity. According to Nielsen, the severity of a problem can be derived from three factors. The first of these is how **frequently** the problem appears. Is it common or does it occur only rarely? The second factor is the **impact** of the problem. Once it appears, will it be easy or troublesome for the user to overcome? The third and final factor is the **persistence** of the problem. Is it a one-time problem that can be easily avoided once the user knows about it, or is it something that has to be dealt with repeatedly? [77].

It should be noted that the rating an evaluator assigns to a problem is based on the evaluator's own perspective of the interface. As was mentioned before, a single evaluator is likely to find only a part of the problems in the interface. It is not until the findings of several evaluators are brought together and compared with each other that the severity of the problems can be placed into proper perspective. Therefore, the ratings assigned by a single evaluator are too unreliable to be trusted. However, as more evaluators assign ratings to the same problem, their ratings can be used to produce a more reliable mean severity rating. According to Nielsen, a mean severity rating produced by three evaluators is satisfactory for many purposes.

Nielsen suggests that the problems are assigned severity ratings on a scale of 0 to 4. The ratings are explained in *Table 4.1*.

Table 4.1 *Severity ratings of heuristic evaluation problems* [77].

Rating	Description
0	The evaluator does not agree that this is a usability problem at all.
1	Cosmetic problem. Does not need to be fixed unless there is extra time available for the project.
2	Minor usability problem. Fixing the problem should be assigned low priority.
3	Major usability problem. Important to fix.
4	Usability catastrophe. The interface should not be released for public before this problem is fixed.

4.2. Use case: evaluation of Archos 5 Internet Tablet

The examined device was Archos 5 Internet Tablet running Android 1.6 operating system and firmware version 1.7.33, which was the latest update available from Archos at the time of testing. The device's technical specifications and a list of its features can be found in Chapter 3.1.

The evaluation was performed both in home environment and at the Medialab of the Tampere office of TeliaSonera Finland. Medialab's wireless network was used to test the device's connectivity features.

The heuristic evaluation was performed following Jacob Nielsen's guidelines, as described in Chapter 4.1.1. The interface was examined several times and its features evaluated in the light of Jacob Nielsen's ten heuristics. Instead of merely attempting to find problems, however, the evaluation was expanded so that the heuristics were also used to determine what the system was doing well, to give a more balanced view of the

system's overall usability. The problems discovered during the evaluation were given severity ratings as they are defined in *Table 4.1*. It should be kept in mind that severity ratings given by a single evaluator can not be considered reliable, but they do help to give perspective of the severity of various problems in relation of each other.

The evaluation was performed by the writer of this thesis, who has education on usability testing and working experience on using and evaluating various handheld multimedia devices. Jacob Nielsen suggests that the number of evaluators for a single project should be three or more. However, this was not possible within the time frame and resources available for this thesis. In order to compensate for the lack of numbers the evaluation was performed several times over the course of a number of days. The length of an individual evaluation session was also longer than Nielsen's suggested 1-2 hours.

The following section gives a brief description of Archos 5 Internet Tablet's interface and how the user controls its functions. Describing every state and feature available in Archos 5 Internet Tablet would not be relevant to the needs of this study, so the focus of this section is to give a general understanding of the workings of the interface. The section after that will list the results of the heuristic evaluation, organized according to the heuristics mentioned in Chapter 4.1.1.

4.2.1. Archos 5 Internet Tablet user interface

Archos 5 Internet Tablet has two physical buttons in the frame, a volume controller and a power button, but the device is primarily controlled by the touchscreen. This is accomplished by tapping at the screen, holding a finger against it, or sliding a finger along the screen's surface. A tap is equivalent to a double mouse-click on a typical computer OS, while holding a finger against the screen can be compared to an alternative click similar to the right mouse button. A slide can be compared to a click-and-drag motion with a mouse. Touching icons and menu options is acknowledged throughout the system by orange highlighting.

Archos 5 Internet Tablet is started up by pressing the power button in its frame for a few seconds. The device takes approximately 50 seconds to fully boot up. During this time it displays Archos company's logo, followed later by an animated Android logo. The device will then bring up the main view, which can be seen in *Figure 4.1*.

Figure 4.1 *Archos 5 Internet Tablet User Interface* [31]

The main view has been divided into three primary sections. For the sake of clarity this study assigns names for these sections: **upper panel**, **desktop**, and **bottom row**. The sections will be referred to by these names from here onwards.

Upper panel is present in most views found in the system. Moving from left to right, it contains Home button, a broad, empty space that is used to display small icons of running processes and announcements, a battery symbol displaying the current battery charge, Back button, and Menu button.

Tapping the Home button takes the user to the main view from any section of the system. Tapping the Back button takes the user one step backwards in the system. Tapping the Menu button brings up a list of options, the exact contents of which varies depending on the current view. Pressing and holding a finger against the blank space between the Home and Back buttons displays the current date and time. Pulling the blank space downwards will pull out a menu that lists the currently running processes and notifications, and also serves as a short-cut menu to them.

Desktop takes up the largest section of the view. It houses the icons of the applications used by the device. Tapping an icon will start up the application. The icons can be moved around on the desktop. New icons for installed applications can be added to the desktop and existing icons can be removed. The desktop can also be used to display widgets, which are small programs that are running directly on the desktop itself. The analog clock displayed in the lower right corner of the device screen in *Figure 4.1* is one such widget. Pressing a finger against an empty space on the desktop and sliding it either left or right causes the desktop to slide either left or right, bringing more icon space into the view. The desktop has three screen widths of space available in total: one screen to the left from the center and one screen to the right.

Located in the right side of the desktop is a slider handle. Pulling it to the left will cause a slider tray to slide over the desktop. The slider tray contains a full list of all the applications installed onto the device. Their icons can be moved over onto the

desktop for quick access. Pushing the slider handle to the right will cause the slider tray to move back into its original position and reveal the desktop from underneath.

Bottom row contains direct access to the different types of media available on the device. Each of the icons launches a different media player. For example, Video icon brings up the video player, while Photo icon launches the picture viewer. Choosing one of the icons brings up a sub-menu that lists different functions related to the chosen player. For example, choosing Video icon brings up a sub-menu that allows the user to choose whether to play media from the device's internal storage or streamed across a network, or to use the device's TV-related features such as TV scheduler and video recorder.

4.2.2. Results of heuristic evaluation

The results of the heuristic evaluation of Archos 5 Internet Tablet are divided according to the heuristics described in Chapter 4.1.1. Each of the heuristics will have a brief evaluation of how well the device seems to be performing on that particular field. The problems that were discovered during the evaluation are listed under the most closely related heuristic.

1. Visibility of system status

For the most part the system keeps the user well informed of the system status. Whenever an icon or other object is activated, it is immediately highlighted in orange. Animated sliders and similar features help to give the user a sense of transition when moving from one section of the interface to another. Active processes such as the media player running in the background are marked with tiny symbols in the upper panel of the main view. When WiFi and Bluetooth connections are active, they are marked with a green V-symbol, which is a common symbol for correctness. Accessing videos and performing other such large operations are usually marked with animated loading symbols. The procedures of starting the device up and shutting it down are also marked with animations that indicate that something is happening within the device.

Error rating: 3 (Becomes infuriating in the long run)
The device occasionally loses its wireless connection when using Internet browser. The system simply ceases to work when this happens and gives no error message about it.

Error rating: 2 (Inconveniences using the system)
The device sometimes freezes after the user touches a virtual button, particularly when using the media player. One can assume this pause comes from the size of media files the system has to process. The device continues working normally after a moment, but not before the user has had time to impatiently tap the screen several times. The device remembers these taps and once the screen unfreezes, it reacts to all of them immediately, usually taking the user to unintended places.

Error rating: 3 (Heavily limits the device's usability)
The primary method of transferring files into the device is by connecting it onto a PC like USB memory storage. However, doing this on a PC running Windows XP operating system was not successful. The device offered an option to transfer files via Windows Media Player, but nothing happened when this was attempted. Transferring files between computer and the device worked normally when the PC was running Windows Vista. Apple Macbook did not detect the device at all.

2. Match between system and the real world

The interface is very visual. When an application icon is moved around on the desktop, it seems to rise above its surroundings as if the user had just pulled it up from the background. Animated sliders help the user to visualize the interface and the relation of various sections to each other. The virtual keyboard used to input writing is of fairly good size for human fingers to use. Each keystroke is marked with an orange highlight to indicate which key is being touched. However, writing on the keyboard has a much slower rhythm than writing on a physical keyboard. Typing mistakes are rather frequent.

Error rating: 2 (Unintuitive)
Filling out forms such as username/password queries on web browser is difficult on the virtual keyboard. The most intuitive act to submit the query would be to press the keyboard's Enter-key, but this only causes the keyboard to move on to a new row. In this case the only way to confirm the form and exit the keyboard seems to be by pressing the Back button, which is completely separate from the keyboard itself.

Error rating: 1 (Slightly unintuitive)
The top of the screen in the main view has tiny icons representing active processes and other matters the user should know about. It takes a while to realize that the user has to pull the row down to access the icons, not tap at them.

Error rating: 1 (Slightly unintuitive)
The device can shut itself down into a power-save mode automatically. The first impulse from the user wishing to use the device is to tap or flick the screen to wake it, but this does not work. The real method is to press and hold down the power button for several seconds. This is not intuitive.

3. User control and freedom

The Back and Home buttons are visible in almost every state, allowing the user to either backtrack one step or to go back all the way to the main view. There is no way to immediately undo or redo changes done to the system.

4. Consistency and standards

Icons used to signify the loading of a file and similar functions are generally the same throughout the system. There are several inconsistencies, but these seem to be cosmetic problems at best.

Error rating: 1 (Cosmetic inconsistency)
The battery icon representing remaining battery charge displays as a green icon in some views and as a white icon in others.

Error rating: 1 (Cosmetic inconsistency)
The device can be turned into a horizontal or a vertical position and most views change their orientation accordingly. The main view does not do this, remaining in horizontal configuration at all times.

Error rating: 1 (Cosmetic inconsistency)
The contents and location of the Settings menu change according to the view. Sometimes the resulting menu appears in the bottom of the screen, at others in the upper right corner of the screen.

Error rating: 1 (Cosmetic inconsistency)
The device bears some traces of Android platform's phone origins. The Settings menu lists an option for "Changing ringtones", even though this feature does not actually exist since Archos 5 has no phone capabilities.

5. Error prevention

The system seems to be designed in a manner that helps a casual user to avoid catastrophic mistakes. Files stored in the device can only be altered either by taking several clearly-marked steps from the Menu or by going into a separate File Manager application, so there is no danger of accidentally moving or deleting files while viewing them through the device's multimedia players. Archos 5 denies the user access to its file folders while the device is connected to a computer via USB. Such an arrangement helps to prevent possible conflict situations should the user attempt to access the files simultaneously on the computer and the device itself.

Error rating: 2 (Infuriating)
In the image gallery it is possible to set the currently viewed image as wallpaper for the desktop with a push of a button. It is very easy to do this by accident. The system does not prompt for confirmation when this happens and the change cannot be undone directly. The wallpaper has to be changed back manually from a separate wallpaper section, which can cause frustration.

Error rating: 3 (Difficult to use)
The images in the gallery can be rotated by drawing a circle on the touchscreen. However, the system has difficulties at recognizing the difference between the rotation command and a slide gesture used to indicate the command to turn over the next image. This frequently results in accidental rotations which then cannot be immediately undone.

6. Recognition rather than recall

For the most part the system is easy to recognize and easy to remember. Again the animated sliders help to visualize the movements within the system and help the user to backtrack when necessary. The system Settings lists the options in neat rows and also provides brief descriptions of what each option contains. The device's virtual keyboard has a row dedicated for displaying the word being written, so there is no risk of the writing being hidden behind the keyboard.

Error rating: 3 (Difficult to use)
The most confusing aspect of the system is the Menu button. It brings up different options depending on the state of the system and does not explain these options. The user is forced to remember what is possible to do in the Menu in which state.

7. Flexibility and efficiency of use

The device offers a number of shortcuts and tailoring options that will help the advanced user but will not get into the way of a novice. The device allows the user to change the contents of the desktop, including icons for new applications, widgets, and Internet bookmarks. Pressing and holding the Menu button for a few seconds brings up a quick search function. The device remembers used wireless network connections and automatically attempts to reconnect to them on start-up. Media players remember the last viewed file and offer an option to continue viewing from where it was last stopped.

8. Aesthetic and minimalist design

The interface is simple, clear, and visual. The system's sliders and buttons are mostly grey in color, allowing the brighter application icons to stand out from the interface. The File Manager feature is an exception to this. Its text-heavy appearance can be confusing, and there is no option for viewing files and folders as icons.

9. Help users recognize, diagnose, and recover from errors

For the most part applications give appropriate error messages. They inform the user of what is wrong and sometimes also give suggestions or information on how to fix the

problem. For example, attempting to open a web page without a network connection brings up an error message stating that the page will continue to load after the connection has been re-established. Another similar example comes from attempting to play video formats that are not supported by the device. In such a case the device may offer to take the user to Archos' webstore to purchase the appropriate plugin to play the content.

10. Help and documentation

Documentation for the device is not well marked. The documents are in PDF file format and are hidden away into a separate folder on the device's hard drive. The folder is titled "Info", which can be slightly misleading about the documentation's purpose. They can only be accessed via the device's Files Manager.

4.3. Analysis

Chapter 4 introduced a test case where Archos 5 internet Tablet was used as an example of a typical Android-based non-mobile device to evaluate the platform's usability. Judging by the findings presented in Chapter 4.2.2 above, it is clear that Archos 5 Internet Tablet and Android UI as a whole were designed with usability in mind. The UI fulfills well several of Nielsen's heuristics for good usability (see Chapter 4.1.1). Graphical interface, easily remembered symbols, minimalist use of colors, and animated transitions from one state to another all make the UI approachable to the casual user. A layman should be able to learn to use the device with relatively little trouble.

It was reasonable to expect that Android platform would function well on Archos 5 Internet Tablet. Android platform was originally designed for mobile phones, so it is natural to assume that small tablets, MIDs, PMPs, and other similar devices would take well to its UI. If the consumer has used Android-based mobile phones before picking up a device such as Archos 5, it is probable that the UI will seem familiar and thus easily approachable.

Android was designed around touchscreen, so it is natural that the UI functions well in a device controlled primarily by such. Most of the actions could be performed with simple taps and slides, with little need for the user to touch the screen in multiple spots at the same time. In fact, casual observation indicates that Android works better on larger-than-smartphone-sized touchscreens. With larger screens the icons and other critical components of the system are also larger. This makes manipulating them easier and lessens the probability of user mistakes.

Although Archos 5 Internet Tablet's overall usability performance was good, it nonetheless had a number of issues. Some of these problems may seem small at first, but prolonged use might make them frustrating. Some of the UI's features are located in unintuitive places and require some memorization before they can be used effectively. The device's image gallery is suffering from a usability problem caused by the

touchscreen's poor gesture recognition when attempting to browse the images. It is uncertain whether or not this is because of the software or Android's own touchscreen compatibility. If it is because of the latter, it might indicate a problem with the interface's fine control that the manufacturer needs to be prepared for when designing custom software for Android. Finally, there are a number of small, graphical inconsistencies throughout the system that do not actually hamper the usability of the device, but do convey the impression of a slightly unpolished whole.

Surprisingly, the two greatest problems encountered in Archos 5 Internet Tablet were technical. The device is supposed to be compatible with PCs for file transfer via USB connection. This was attempted with three computers: one running Windows XP, another running Windows Vista, and the last one running Mac OS. Of these three OS only Windows Vista performed as expected. Windows XP refused to display the contents of the device's hard drive while Mac OS did not acknowledge the device at all. USB connection is crucial for transferring multimedia files and other content to Archos 5, so any problems with it will greatly hamper the device's overall usability. If this compatibility issue extends to other Android-based devices as well, it might become an obstacle that manufacturers will have to deal with.

Another problem encountered in Archos 5 is the unreliability of the WiFi connection. While it is uncertain whether or not this is because of the device itself or the wireless network used for testing, the device relies heavily on WiFi for its connectivity and any problems with it will greatly impact the overall user experience. The problem was made worse by the fact that there was no error message when the connection was lost, forcing the user to guess when this happened. Since Android-based devices described in Chapter 3 made extensive use of WiFi, this might be another significant problem that manufacturers would have to anticipate when designing their own devices.

To summarize the findings of Chapter 4, the use case of Archos 5 Internet Tablet usability testing indicates that Android UI functions well in a touchscreen-based handheld device. The interface is graphical and approachable, but minor unintuitive features and cosmetic inconsistencies still make it seem slightly stiff and unpolished, especially next to its major competitor, Apple's iPhone UI. If the two major technical issues are a problem in other devices as well, they need to be seen to before Android UI's potential can be realized.

5. DISCUSSION

Chapters 3 and 4 examined Android platform on non-mobile multimedia devices from different points of view. Chapter 3 examined what kind of non-mobile multimedia devices there are on today's market and how the manufacturers are using Android platform on their devices. Chapter 4 studied the usability of Android platform's user interface via a heuristic evaluation where Archos 5 Internet Tablet represented a typical Android-based non-mobile multimedia device. Here, in Chapter 5, the results of Chapters 3 and 4 are drawn together and discussed. Conclusions are drawn from the results and displayed in italics for emphasis. Finally, this Chapter evaluates the reliability of the results and how well the thesis has managed to answer the questions first posed in Chapter 1.

It was seen in the studies of Chapter 3 and evaluation in Chapter 4 that Android is a malleable platform that can be fitted into a variety of different devices. It requires a touchscreen or a similar simple interface in order to have good usability. Android is particularly easy to use on a larger-than-smartphone touchscreen. Overall, it is a definite improvement from some of the older handheld devices that featured an ordinary Windows XP as operating system. As was pointed out in Chapter 3.11, Android can be set into a variety of different resolutions, even those outside the official specifications listed in Chapter 2.4. Likewise, Android platform can be expanded with external modules without greatly altering the platform's base capabilities. To summarize this, *Android platform has the potential to function well in a variety of different devices, but works best with a touchscreen.* From this it would follow that *software developers and content providers have to take into account a variety of different screen types, hardware, and context when developing Android applications and providing multimedia content for the devices. It is possible that compatibility of Android platform can fragment as manufacturers continue to expand the platform to meet the needs of their own devices.*

In theory, common platform means that a wide variety of very different devices could make use of the same pool of Android applications. Same applications could be compatible with different devices either straight away or after small modifications to better meet the device's screen resolution and other features. This seems to be true to an extent, but the distribution of the applications might give rise to a problem. Although most Android-based devices support Android applications, only a few have access to Android Market, the single largest source of Android applications. It seems that only those devices that have been launched in co-operation with Google have access to the software that connects to Android Market. However, many manufacturers have chosen

to not launch their devices with Google, and have set up their own application stores instead. It could be speculated that these manufacturers wish to control what kind of applications their devices have access to, or perhaps they are attempting to steer their devices away from under the influence of Google's Android Market. Whatever is the case, many of these individual online stores are very new affairs and their applications selection is very small when compared to Android Market. To summarize, *most Android-based devices support Android applications. Android Market is the single largest source of Android applications, but many device manufacturers have chosen to sell applications for their devices via their own online stores.* It can be concluded that *distributing Android applications to different devices will be complicated if they have to be submitted individually to different online stores. This gives rise to a possibility that soon applications offered in one online store will only be compatible with that store's device.*

Android-based devices tend to be heavily multimedia-centric. Android platform is capable of playing high-quality multimedia. However, in order to do so, it needs extensions to the basic platform and has to run on powerful hardware. Cheaper devices still attempt to run multimedia, but their performance is likely to be slow. At the time of writing high-definition video is in fashion and many manufacturers advertise HD-capability as a major selling point for their device. To summarize, *Android-based devices are multimedia-centric and some are capable of HD-quality video.* This means that *Android-based devices could expand the market for content-providers selling downloadable and streamed media. It is likely that consumers are willing to pay for HD-quality multimedia for their devices, but content-providers should also be prepared to sell lower-quality media for the less capable devices.*

Wireless network connectivity was nearly universal among the Android-based device examined in Chapter 3. Nearly all of the device featured WiFi connectivity, while roughly half featured 3G. However, usability tests in Chapter 4 indicated a possibility that Android's WiFi might be slightly unreliable. This might cause a problem, considering how critical wireless connectivity is for these devices. 3G-compatibility was not as common as what could be reasonably expected from a platform that was originally designed for mobile phones, but they might grow more common in the future. In short, *wireless connectivity is nearly universal among the Android-based devices.* This gives a reason to conclude that if Android-based devices grow more popular, *telcos and network providers could have a market for selling more network bandwidth and 3G connectivity.*

Android platform is a newcomer on non-mobile devices, and has yet to find its place. The devices examined in Chapter 3 are some of the early generations of Android-based non-mobile devices, the time when the manufacturers experiment with the platform and mistakes are made. The device category is still findings its shape. It remains to be seen whether or not the category will remain interesting after the first wave of novelty has worn off. The Android platform itself is still under development and new features are being introduced to it at a rapid pace. A new update can change

and expand what Android platform can be expected to do. Furthermore, usability testing performed in Chapter 4 indicated that although Android platform functions well, it is still slightly stiff and unpolished, especially next to its most notable competitor, Apple iPhone. In short, *Android platform is still new on non-mobile devices and is under rapid development.* This means that *large changes can still be expected.*

The last set of conclusions drawn above also represents the single greatest challenge encountered during the composition of this thesis. Android platform is still relatively new. Its arrival on non-mobile devices is even more recent, and many of the devices examined over the course of this thesis had not yet been released at the time of writing. Acquiring and studying those devices that were already on the market would have required unfeasible resources and time for this thesis. Therefore, nearly all of the information used for this thesis had to be collected from second-hand sources: press releases, professional reviews, and the similar. The only device that could be studied first-hand was Archos 5 Internet Tablet, which was used for usability evaluation in Chapter 4. However, this thesis lacked the manpower to make the heuristic evaluation of usability to meet the criteria of reliability as it was specified by Jacob Nielsen in Chapter 4.1.1. Other aspects of the evaluation process were changed to compensate for the lack of manpower, but this should nonetheless be taken into account when estimating the accuracy of the conclusions drawn above. Besides the second-hand information, it should also be kept in mind that the Android and the devices using it are all under rapid development at the time of writing. Much of the data provided in this thesis is likely to grow outdated within a few months.

This thesis made the best it could to answer the questions presented in Chapter from the limited material and second-hand information reasonably available on the topic at the time of writing. Care was taken to process the information in a critical and impartial manner and the conclusions were formed to not rely on too specific information. However, at least some of the data should be expected to be inaccurate or outdated and the conclusions based on this information should therefore be taken critically. It is suggested that instead of a scientific evaluation of what Android platform is capable of, this thesis is treated as a survey on what is taking place in the market of Android-based non-mobile multimedia devices at the time of writing. Perhaps this description could serve as a base for further studies concentrating on one or another detail mentioned in this thesis.

6. CONCLUSION

This Chapter provides a brief summary of the entire thesis, lists the most important findings and the conclusions drawn from them, and gives suggestions for further studies.

This thesis endeavored to map out the functionality and user-experience of Android platform on non-mobile multimedia devices. It was composed for companies related to software development, content-providing, telecommunications, and other fields relevant to Android-based multimedia devices. The goal was to help the said companies to decide whether or not it would be profitable for them to begin providing content and services aimed for Android-based non-mobile devices. This was accomplished by providing companies with information based on two questions:

- What kind of devices is Android platform used for?
- What is the user-experience like on Android platform?

Chapter 2 examined the Android platform itself, its history, architecture, and capabilities.

Chapter 3 was dedicated to answering the first of the questions. This was accomplished by examining a total of 21 different Android-based non-mobile multimedia devices from various manufacturers. Ten of these devices were examined in greater detail. Technical specifications for each device were presented and third-party reviews cited for various up- and downsides related to each. The Chapter concluded with an analysis on the most common trends discovered from the devices.

Chapter 4 answered to the second question by presenting a sample case of Archos 5 Internet Tablet. This device was used as an example of what can be expected of a typical Android-based non-mobile multimedia device and was given a heuristic evaluation to determine its usability. The Chapter was finished by providing an analysis on the good and bad sides of the device.

Chapter 5 drew together the findings of Chapter 3 and 4 and made further conclusions from them in an attempt to present information on the functionality and user-experience of Android-based devices, as well as what can be expected of them.

The results of Chapter 5 are summarized in the following eight points:

1. Android platform has the potential to function well in a variety of different devices, *but works best with a touchscreen.*
2. Different manufacturers have expanded on Android platform's capabilities to better meet the needs of their devices. *It is possible that the common*

compatibility of Android platform can fragment as manufacturers continue to expand the platform in their own direction.

3. Android-based devices are multimedia-centric and some are capable of HD-quality video. They might expand the market for content-providers selling downloadable and streamed media. *Consumers are likely willing to pay for HD-quality multimedia for their devices, but content-providers should also be prepared to sell lower-quality media for the less capable devices.*
4. Wireless connectivity is nearly universal among the Android-based devices. *Telecommunications operators and network providers could have a market for selling more network bandwidth and 3G connectivity*.
5. Most devices support Android applications. Common platform can allow same Android applications to be compatible with different types of devices. *Software developers and content providers have to take into account a variety of different screen types, hardware, and context when developing Android applications and providing multimedia content for the devices*.
6. Android Market online store is the single largest source of Android applications, but *many device manufacturers have chosen to sell applications for their devices via their own online stores*.
7. Distributing Android applications to different devices will be complicated if they have to be submitted individually to different online stores. This gives rise to a possibility that soon applications offered in one online store will only be compatible with that store's device.
8. Android platform is still new on non-mobile devices and is under rapid development. *Large changes can still be expected*.

Finally, it was noted that since the Android platform was new on non-mobile devices and many of the devices examined in this thesis were still unreleased at the time of writing, much of the information in this thesis had to be collected from second-hand sources. It should be assumed that the information provided herein will grow outdated within a few months from the time of writing.

The scope for this thesis was wide, and as a trade-off none of the subjects could be studied in great depth. Further studies should concentrate on either updating the provided information or examining one or more of the topics in greater detail. The next step would be to acquire several of the devices mentioned in Chapter 3 and examine them via performance tests and usability evaluation. It would also be important to have first-hand experience on what kind of differences there are between developing Android applications for non-mobile devices and mobile phones. This experience could be acquired by creating several demo applications and tailoring them to fit each of the different devices. Finally, it would also be important to make contact with Android software developer communities and examine what kind of effect different manufacturers having individual online application stores for their devices has on developing software for Android-based non-mobile devices.

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APPENDIX 1: LIST OF DEVICES PART 1

Name	Manufacturer	Device type	Release Date	Android versi	Price	Display	Screen resolution	Input	Processor	Memory	Storage	Connectivity
Adam	Notion Ink	E-book reader	Unreleased, June 2010	Unknown	Unknown	10.1"	1024x600	Touchscreen Trackpad	NVIDIA TEGRA 2 Dual Core Cortex A-9 ULP GPU	LP-DDR2/DDR2	16 / 32 GB MicroSD slot	802.11 b/g WiFi Bluetooth 2.1 A2DP WWAN – 3G HSPDA
Alex	Spring Design	E-book reader	February 2010	v. 1.5	294 €	Dual screen: 6" E Ink, 3.5"	600x800 E Ink, 320x480	Touchscreen	Monahan PXA303 624MHz	Unknown	2GB, MicroSD	802.11b/g WiFi. (3G, EVCO/CDMA, GSM claimed, but not in the tech specs.)
Alpha 680	Guangzhou Skytone	Laptop PC	April 2009 in China, US release unknown	Unknown	184.2 €	7"	800x480	Touchscreen, keyboard, mouse pad	ARM11 533MHz 32bit	128-258MB	1-4GB, SD	802.11b/g WiFi, Ethernet
Archos 5 Internet Tablet	Archos	Internet Tablet	2009 September	v. 1.5 Updatable to v. 2.1	199.98€ - 399.99€	4.88"	800x480	Touchscreen	ARM Cortex 800 MHz DSP @ 430 MHz	256MB	8-500GB Micro SD	802.11 b/g/n WiFi 3G via Bluetooth
Archos 7 Home Tablet	Archos	Internet Tablet	Unreleased	v. 1.5	134 €	7"	800x480	Touchscreen	ARM 9 600 MHz	128MB	2-8GB	WiFi
Archos 8 Home Tablet	Archos	Internet Tablet	Unreleased	v. 1.5	150.2 €	8"	Unknown	Touchscreen	ARM 9 600 MHz	128MB	4GB	WiFi
Aspire One D250	Acer	Laptop PC	October 2009	v. 1.0	251.6€	10.1"	1024x600	Keyboard, mouse touchpad	Intel® Atom™ Processor N280	1GB DDR2 533 SDRAM	160GB	802.11b/g WiFi, Bluetooth, LAN
Entourage eDGe	Entourage Systems	E-book reader	February 2010	v. 1.6. Updatable to v. 2.1	367€	Dual display, 9.7" E Ink, 10.1"	1200x825 E Ink, 1024x600	Touchscreen	Unknown	Unknown	3GB, SD	802.11 b/g WiFi, Bluetooth, optional 3G
GoGear Connect	Phillips	PMP	Unreleased, July 2010	v. 2.1	Unknown	3.2"	320x480	Touchscreen	Unknown	Unknown	8-64GB, MicroSD	WiFi, Bluetooth
MIDhydrid	1Cross Tech	E-book reader + MID	Unknown	v. 1.6	Unknown	Dual display, one E Ink	Unknown	Touchscreen	Unknown	Unknown	Unknown	3G, Bluetooth
Mini 5	Dell	Internet Tablet	Unreleased	v. 1.6+	Unknown	5"	480x800	Touchscreen	1GHz Qualcomm QSD 8250 Snapdragon ARM	405 MB DRAM	Flash memory 2 MicroSD slots	802.11b/g WiFi, Bluetooth, A-GPS, 3G
Movit Mini	GiiNii	MID	Unknown	Unknown	Unknown	4.3"	480x272	Touchscreen	Unknown	Unknown	256MB, MicroSD	802.11 b/g WiFi, Bluetooth
MyID	Astri	E-book reader	Unknown	Unknown	97€-113€	4.8" 5" E Ink	800x480	Touchscreen	Marvell	Unknown	Unknown	802.11b/g WiFi, Bluetooth
nook	Barnes & Noble	E-book reader	November 30, 2009	v. 1.5	190.9 €	Dual display, 6" E Ink, 3.5" color	600x800 E Ink, 480x144 color	Touchscreen	Unknown	Unknown	2GB, MicroSD	AT&T 3G, 802.11b/g WiFi
PWS700CA	Hivision	Laptop PC	Unknown	Unknown	75 €	7"	800x480	Mouse Touch Pad	Rockchip RK2808 600MHz, ARM 926	128MB	2G, SD slot	802.11b/g/WiFi, Ethernet
SpeedPad	Hivision	Internet Tablet	Unknown	v. 1.6	75€	7"	800x480	Touchscreen	Samsung ARM 11 800MHz	256MB	2GB	WiFi, Bluetooth, 3G
Sungworld MID	Sungworld	MID	Unknown	Unknown	Unknown	7"	800x480	Touchscreen	ARM926 CPU	512MB	2GB	WiFi
Vega	Innovative Converged Devices (ICD)	Internet Tablet	April 2010	v. 2.0	Unknown	15.6"	1366x768	Touchscreen	NVIDIA Tegra T20 1 GHZ	512B DDR / 512MBNAND	512MB Flash, SD	802.11 b/g/n WiFi, Bluetooth 2.1, optional: 2G, 3G
W7	RAmos	MID	Unknown in west September 2009 in China	v. 1.5	143€- 176€	4.8"	800x480	Touchscreen	600 MHz Rockchip	Unknown	8-16GB	WiFi, 3G optional
WebStation	Camangi	Internet Tablet	December 2009	v. 1.5	202.7 €	7"	800x480	Touchscreen	Marvell PXA303 624MHz	128MB Mobile DDR	256MB, MicroSD	802.11b/g WiFi, support for 3G USB dongle
Zii EGG	Creative Technology (Creative Labs)	PMP platform	November, 2009	Optimized v. 1.6	Not for consumer use	3.5"	320x480	Touchscreen	ZMS05	256MB RAM	Up to 32GB, SD	820.11 b/g WiFi, Bluetooth

APPENDIX 2: LIST OF DEVICES PART 2

Name	Video support	Audio support	Image support	Other support	Internet	Android Applications
Adam	Camera for photography & video. Full HD up to 1080p. File formats unknown	Audio support, file formats unknown	Unknown	All major e-book formats	Video streaming, browsing	Yes, Notion Ink's own app store
Alex	MPEG2, MPEG4, 3GPP, Adobe Flash Lite	MP3, MIDI, WAV	JPEG, GIF, GMP, PNG	ePUB, PDF, DRM, txt, HTML	Browse Internet, download e-books, email, Twitter	Yes, support for Android Market unknown
Alpha 680	MPEG1/2/4, H.263, H.264, WMV9	Unknown	Unknown	Unknown	Browse Internet	Yes, support for Android Market unknown
Archos 5 Internet Tablet	MPEG. H.264, WMV, MKV, MJPEG	MP3, WMA, WAV, AAC, OGG, Flac	JPEG, BMP, PNG, GIF	PDF viewer, Office documents	Browse Internet, GPS, email, webradio	Yes, Archos Appstore
Archos 7 Home Tablet	MPEG1/2/4, WMV, FLV, AVI, RM, RMVB, MKV, MOV	MP3, WMA, WAV, OGG, FLAC, APE, AAC	JPEG, BMP, GIF	Read text-files (TXT) and lyrics files (LRC)	Browse Internet	Yes, Archos Appstore
Archos 8 Home Tablet	Play multimedia, file formats unkown	Unknown	Unknown	Unknown	Browse Internet, email, calendar	Yes, Archos Appstore
Aspire One D250	Unknown, likely wide	Unknown, likely wide	Unknown, likely wide	Unknown, likely wide	Browse Internet, email, IM	Yes, but no support for Android Market
Entourage eDGe	3GP, MP4, Adobe Flash Lite (H.264)	MP3, WAV, 3GPP, MP4, AMR, AAC, OGG, M4A	BMP, GIF	E-book formats: ePub, PDF	Browse Internet, download e-books, email	Yes, support for Android Market unknown
GoGear Connect	Unknown	Play audio, file formats unknown	Unknown	Unknown	GPS locator	Yes, Android Market
MIDhydrid	Play multimedia, file formats unkown	Unknown	Unknown	E-book formats	Unknown	Yes, API extension for E Ink screen
Mini 5	Play multimedia, file formats unkown	Unknown	Unknown	Unknown	Browse Internet	Yes, AndroidMarket
Movit Mini	Play multimedia, file formats unkown	Unknown	Unknown	Unknown	Skype-enabled, browse Internet	Yes, support for Android Market unknown
MyID	Play multimedia, file formats unkown	Unknown	Unknown	E-book formats	Browse Internet	Unknown
nook	None	MP3	Display images only as screen saver: JPG, GIF, PNG, BMP	E-book formats: EPUB, PDB, PDF	Download books from Barnes & Noble	None, but possibility mentioned
PWS700CA	720p playback support, Xvid, Divx, MPEG-4, RMVB	Built-in mic and dual speakers, file formats unknown	Supports image sharing, file formats unknown	PDF viewer	Browse Internet, Flash, email, IM	Yes, support for Android Market unknown
SpeedPad	Play multimedia, file formats unkown	Unknown	Unknown	Unknown	Browse Internet, email, messaging	Unknown
Sungworld MID	1080p video, file formats unknown	Unknown	Unknown	Unknown	Unknown	Unknown
Vega	Play HD multimedia, supported formats unknown	Unknown	Unknown	Unknown	Browse Internet, social networking, IM	Yes, support for Android Market unknown
W7	Play multimedia. MKV, AVI, RMVB	Unknown	Unknown	Unknown	Browser Internet	No Android Market
WebStation	3GP, MP4	3GP, MP3, MP4, OGG, MID, WAV	JPG, GIF, PNG, BMP	E-book EPUB	Browse Internet, email, GPS	Yes, Camangi's own app store
Zii EGG	Optimized video processing, MPEG4, DivX, Xvid, H.264, WMV, MJPEG	AAC, MP3, MIDI, Ogg, ADPCM, WMA, FLAC	Unknown	Unknown	GPS	Yes, support for Android Market unknown