TAMPEREEN TEKNILLINEN YLIOPISTO
TAMPERE UNIVERSITY OF TECHNOLOGY

TONI YLITALO

TESTING AND DEVELOPING A REMOTE CONTROLLED AND SUPERVISED CONTAINER HANDLING EQUIPMENT

Master of Science thesis

Examiner: professor Jose Martinez Lastra
Examiner and topic approved by the Faculty Council of the Faculty of Engineering Science
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ABSTRACT

TONI YLITALO: Testing and developing remote controlled and supervised container handling equipment
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The introduction of Automation is gaining speed in many application fields due the latest technological, social and economic developments. The field of harbour terminals is not an exception, with up to 500 large scale terminals searching for new automation systems.

This MSc thesis was carried out at Kalmar and it is taking into consideration company policies and procedures in order to provide a realistic scenario. However, the literature review was not limited to Kalmar solutions and is taking into consideration other practices, especially those related to networks and video and audio protocols.

The main objective of this MSc thesis is the development of an automatic rubber tyred gantry crane. Special consideration is provided on how the crane can remotely be controlled and supervised within a specific area. The supervision is desired because by safety reasons the operator supervises the automatic movements of the gantry direction in X coordinate and the Y trolley coordinate for a potential "dead man´s" switch. The hoist direction along Z and the truck lane operation are remotely controlled by the operator.

As an engineering requirement, Kalmar´s Software Architecture, and its reconfiguration features, play an important role at the time of configuring and installing the system. The Thesis pays special attention on how to solve network issues due the increase of crane´s load. The final approach is complemented by the development of a User Interface in order to host the increased amount of information due the new automation system. The Thesis also presents the results for testing the new solution on Cargotec final product, and outline the main issues reported during the testing period. The resulting solution is a market ready product.

TIIVISTELMÄ

TONI YLITALO: Etäohjatun ja valvotun kontinkäsittelynosturin testaus ja kehittäminen
Tampereen teknillinen yliopisto
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Avainsanat: automaatio, valvottu, konfigurointi, verkko, nosturi, testaus

Maailmalla on 500 suurta satamaa ja tämän hetkinen automatisoinnin tarve satamissa kasvattaa automaation merkitystä hurjaa vauhtia, samalla tavalla kuin jokaisella teollisuuden alalla. Kaikki satamat tullaan automatisoimaan lopulta täysin, joka johtaa siihen, että on entistä tärkeämpää saada uusia automatisoituja tuotevaihtoehtoja markkinoille.

Diplomityön teoriaosuus koostuu suurimmaksi osaksi Kalmarin sisäisessä käytössä olevasta materiaalista. Lopputyössä on kuitenkin haettu apua sähköisistä kirjoista ja julkaisuista, jotka suurimmaksi osaksi liittyvät verkon, videon ja audio protokolliin.

Tämän diplomityön aihe käsittelee manuaalisen koneen kehitysvaiheita kohti automaattista kumipyöräkonttinosturia. Työ keskittyy siihen, miten nosturi saadaan toimimaan valvotusti sille suunnitellulla alueella. Valvotuilla liikkeellä tarkoitetaan liikettä, jossa konesuunta X ja nosturin kärrynsuunta Y ovat valvottuja, mutta kuskin täytyy käyttää kuolleenmiehenkytkintä kahdessa edellä mainitulle suunnalle. Tarttujasuunta Z ja rekkakaista operointi ovat etäohjattua liikettä operaattorin toimesta.

Työssä käydään läpi Kalmarin omien ohjelmien konfigurointeja, sekä uusien laitteiden konfiguroinnit ja asennukset. Työssä esitetään myös millä tavalla verkko ongelmat on ratkaistu, jotka ovat ilmestyneet kuormituksen lisäännyttyä. Uusien käyttöliittymä sivujen luominen on myös osa projektia, koska automaation lisäännyttyä tarvitaan myös enemmän informaatiota nosturista. Työn lopussa käydään selkeästi läpi, miten tuotetta on lopulta testattu ja miten työssä käsitellyt asiat on raportoitu. Työn lopputuloksena on toimiva ja markkinoille valmis nosturi, joka sisältää valvotut ja etäohjatut liikkeet.

PREFACE

This Master's thesis was part of Master's Degree Programme in Automation Engineering and it was made for Cargotec Finland Oy, Tampere. This Master of Science thesis' main purpose was to develop Automated Rubber Tyred Gantry crane, which includes supervised and remote controlled releases. I would like to thank Dr. Jari Hämäläinen from Kalmar for offering me this master's thesis and also for supervising the thesis project. The project was very important, if thinking about my future careers, because theoretical part has taught me a lot about configuration, software, protocols and much more.

I want to thank Dr. Jani Jokinen who supervised the master's thesis. I also want to thank Dr. Jose Martinez Lastra who supervised the end of my master's thesis.

The greatest thanks belongs to my girlfriend Sara, you pushed me forward in my university studies when my own faith began to end. I also want to thank my family for supporting and pushing me through to this process.

Tampere, 23th of August 2017

Toni Ylitalo

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LIST OF SYMBOLS AND ABBREVIATIONS

AAC	Advanced Audio Coding
AGV	Automated guided vehicle
ASC	Automatic stacking crane
CHE	Container handling Equipment
CS	Control System
DAQ	Data Acquisition
DTDs	Document Type Definitions
EIS	External Interface Service
EMS	Equipment Monitoring Systems
FPS	Frames Per Second
GPS	Global Positioning Systems
GUI	Graphical User Interface
HD	High-Definition
HTTP	Hypertext Transfer Protocol
IP	Internet Protocol
LAN	Local Area Network
NAT	Network Address Translation
NMEA	National Marine Electronics Association
NTP	Network Time Protocol
OSI	Open Systems Interconnection
PLC	Programmable logic control
PN-IO	Profinet Input/Output
QoS	Quality of Service
Qt	A software framework, used in creating GUI
RC	Remote Controlled
RCC	Remote Control Center
RMG	Rail Mounted Gantry crane
RTG	Rubber Tyred Gantry crane
RTP	Real-time Transport Protocol
RTSP	Real Time Streaming Protocol
SHC	Shuttle Carrier
SC	Straddle Carrier
STS	Ship-to-shore crane
TCC	Technology and Competence Centre
TCP	Transmission Control Protocol
TLCS	Terminal Logical Coordination System
TLS	Terminal Logistic System
TOS	Terminal Operation System
TT	Terminal truck
UDP	User Datagram Protocol
UniQ	Internal communication platform
UI	User Interface
VS	Vehicle System
WAN	Wide Area Network
W3C	World Wide Web Consortium
XML	Extensible Markup Language
XSD	XML schema definitions

1. INTRODUCTION

This Thesis targets the transformation of a Rubber Tyred Gantry (RTG) crane into a Remote Controlled (RC) and Supervised Crane, and stresses the software configuration testing associated to the crane.

This chapter provides an introduction to the thesis and its background. It also outlines the motivation for the topic, and provides the scope of work, and the utilized methods. The chapter finishes with the structure of the remaining document.

1.1 Background and Motivation

In nowadays, automation is very important in many different industry sectors. The port industry is no exception. The main target of automation within this application field is to increase the efficiency of the movement of containers within the ports. Within this context, the safety issues related to the presence of humans plays an important role for the resulting automated system. These safety issues are reduced by limiting the presence of humans within the area, therefore the transformation of cranes into a RC system are a potential solution for both to increase the efficiency of the operations and reduce safety related problems.

There is a clear potential business opportunity associated to the proposed solution, and it was expressed by the current pool of clients of traditional cranes.

Terminal itself and its purpose is very important to understand because it concerns everyone more or less. It is global activity and every country has their own terminals, some of them are bigger and other smaller. Every country has foreign trade so they transport products overseas. Products travel to destination, for example, in a container. Same happens when you order something from the internet; it has to be transported somehow and one example is shipping the containers.

As it has been said before, terminal automation is not an exception when talking about automation. The automatic cranes are not new in terminals and these cranes have experienced automation in recent decades. There are two different types of terminal projects where automation cranes can be sold:

Brownfield Terminal where there are already installed cranes, buildings and production in the field. These legacy cranes require update and the updating can also be called to retrofit. Therefore, the new automation system needs to be flexible providing and easy update. Because of this the new system, including new hardware and software, needs to be easy to implement in the legacy cranes. There is also an option that the brownfield terminals sometimes choose the new cranes if the legacy cranes are obsolete.

Greenfield Terminals, there terminals are not having any activity. This type of terminal projects starts with the construction from a clean table. These projects are having less limitations from a technological viewpoint, however, the projects are larger and therefore, size is introducing a significant risk.

From a business perspective both, Brownfield and Greenfield are very important projects. In order to easy the commissioning stage of the project at the customer site, Cargotec built a large Testing field at its Tampere premises, where this thesis was carried out.

1.2 Scope of thesis

The site testing and commissioning documentation is the main part of my everyday work. That role requires expertise and full understanding of automatic RTG and Terminal Logistics System (TLS) architecture functionalities which are handled in this master's thesis.

The thesis started in working and learning about crane to be automated. Theoretical part was started about learning Kalmar's TLS software architecture and understanding about the development of the crane future automation levels. The practical work started about one week later than the theoretical part starts and first part was to make the remote control room at Technology and Competence Centre (TCC) test field.

During the master's thesis, RTG has evolved from a manual crane to a supervised crane and it has been verified operational. Full understanding of the whole product and its' journey to an automatic crane developed slowly until the end of the master's thesis. The crane included problems which had to be solved, such as crane network problems which had to be solved when devices and more data increased in the crane network. The project had to define certain functions which the crane must implement and the testing was a very big part of the project. Hardware's installation and configuration were also a big part of the project. Understanding the TLS software and their development process have been included in the thesis in order to make testing and software configuration possible. When the combination about TLS software are ready and configured then testing can be achieved.

Development of the new UI pages was also a part of the project. Latest part was documentation because when creating something new, everything has to be written down as clearly as possible. When all of the above were completed, a well-functioning product has been achieved.

1.3 Limitations and Methods

While the presented proposal is applicable to other areas, the thesis relays heavily on the Remote control room facility at Cargotec Test Field in Tampere. Also, initial directions are provided by the current and future pool of Cargotec customers base, and the own companies industrial practices. Therefore, the thesis follows Inductive Research methods.

The general problem and proposed solution were earlier introduced in this chapter, the following list provides a clear description of the main components of that approach solved by this thesis.

- TLS software configuration and testing
- Hardware configuration and testing
- Measuring the entire internal network data
- Camera system testing and possible redesign
- Camera streaming protocol testing and the final choice
- Collecting and analyzing the camera data
- Macro creation for alarms and tags lists
- New UI pages design
- Commissioning document and checklist creation
- Testing the environment

All the above aspects have been implemented in same way. There are three sections which have to be done before the object is on target. These different stages are illustrated in Figure 1. First one is theory, because every object requires understanding. When the theoretical part concerning objects is clear then it is easier to start working on the object. Second part is implementation, this stage also includes planning because it is the first time when each object is made. Third part is the testing, because when implementation is clear then testing can be started. This stage tells the implementation results and if it needs changes. When all these stages are done then the target has been achieved.

The implementation of the proposed solution is an important component of this thesis, however, a large literature and best industrial practices review was carried out. This review was targeting the following objectives:

- To get familiar with the terminal operation for better understanding of automated RTG functions and benefits of automation level increase
- To understand the Crane network standards and protocols
- To master the UI files developing process and get to know the software framework used at Kalmar
- To understand the easiest way for analyzing and collecting data, including how to filter and search the correct data
- Better understanding of the configuration and the software which require the configuration

As a consequence of this review, the following components were defined:

- Which TLS software need a configuration
- Qt creator better known
- Hardware and camera system plan

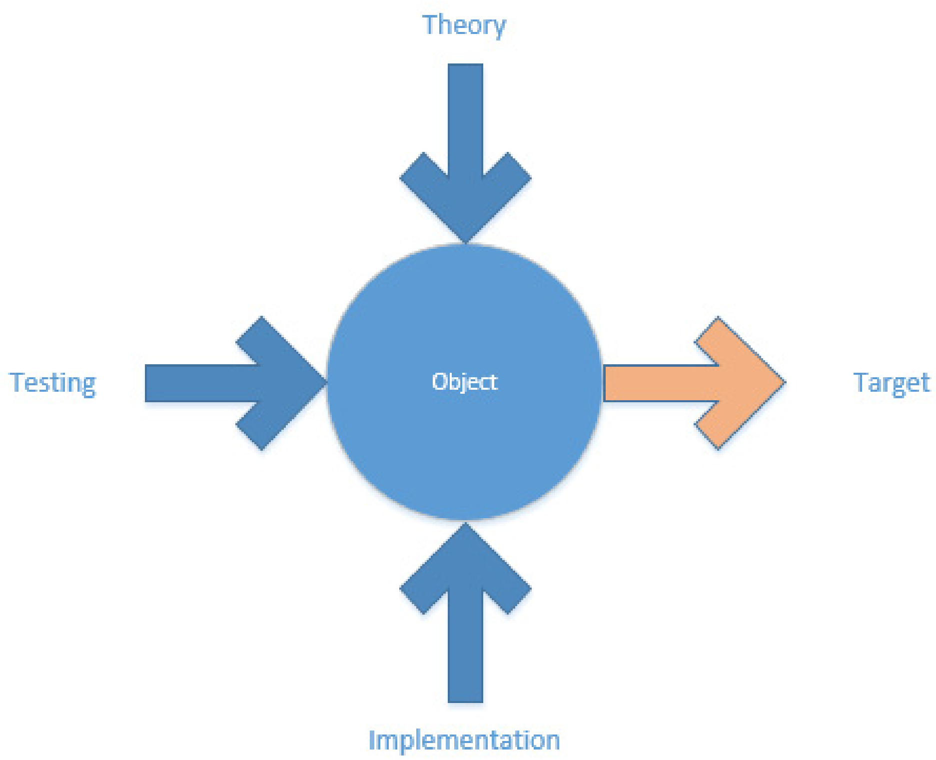


Figure 1. *Implementation methods*

1.4 Structure of the thesis

This thesis is structured in five chapters. Chapter 1 includes the introduction of the thesis and lists main research steps.

Chapter 2 presents the literature research of the thesis. Section 2.1 introduces the terminal background, which illustrates different equipment at terminal and also leads to better understanding of the RTG. Section 2.2 handles the crane internal network and how to design it. Section 2.3 presents the GUI planning and how to evaluate the UI file. Section 2.4 gives better approach on how to collect the network data. Section 2.5 illustrates the hardware and software configuration.

Chapter 3 presents problem solving and different phases during the thesis. Section 3.2 illustrates different TLS software which has to configured. Section 3.3 introduces the Qt creator software which is used to create new UI files. Section 3.4 discusses the hardware and measurement systems, but focuses on camera design.

Chapter 4 presents the implementation of the above chapters. Section 4.1 illustrates which kind of remote control room is build when remote control stage starts and also remote control desk functions. Section 4.2 handles the macro which is created to make thousands of alarms and tags easier to apply, also how to generate it. Section 4.3 includes the Liveview configuration and which kind of protocol is the best to this solution. Section 4.4 describes the main configuration files of Fleetview and it also includes the new UI files which were created during the thesis. Section 4.5 includes switches configuration on crane internal network. Section 4.6 solves the zoom camera levels configuration which is used on the trolley. Other cameras configuration and data analysis are also described. Section 4.7 handles the GPS which makes the positioning possible. Section 4.8 illustrates the audio device and its configuration style by browser. Chapter 4.9 illustrates the test methods which were used during the project. The chapter describes the test cases and how the testing is implemented. It also handles the commissioning checklist and it tells the meaning of the checklist. The section also introduces the commissioning reporting so the commissioning is easier to implement in customers site.

Chapter 5 is the conclusion of all chapters above. It ends the thesis and lists the conclusions which were made. Chapter 5.1 will give the discussion to the future work and improvements.

2. LITERATURE RESEARCH

This chapter handles literature research, which needs to be done before other chapters are ready to perform. The chapter handles issues which were mentioned before in chapter 1.

First, it is important to understand the wider entity and the fundamental reason for terminal and RTG. When the old product is understood then it is easier to understand the reasons of necessary for automation changes. After basics, from manual work to automation gives a better picture of the remote controlling and TLS architecture. Every automation level increases more TLS software and hardware. When full understanding of automation levels is achieved the benefits of crane automation can be defined.

It's important to understand the machine network before full software and hardware understanding is possible. The crane network has been created by using different protocols such as TCP, User Datagram Protocol (UDP) and Profinet.

2.1 Terminal background

Harbor layout is built on few main groups of container handling equipment (CHE). Equipment may be listed in order when container will be loaded from the ship and those are Ship-To-Shore cranes (STS), SHuttle Carriers (SHC), Straddle Carriers (SC), Terminal Tractors (TT), Rail Mounted Gantry crane (RMG), RTG crane and Automatic Stacking Cranes (ASC).

After a container has been loaded to ground by SHC, SC or TT pick it up and start to carry the container to a defined block, which depends on which of the container the machine block container gets. If the container is moved to ASC block then shuttle or TT carry it to water side, but if the container moves to RTG block then probably TT carries it to a truck lane.

ASC and RTG promise to do the same, they storage containers on block and move containers to a truck when needed, but those cranes are however totally different. ASC has water side and land side. Water side means that Automated Guided Vehicle (AGV) or shuttle bring containers from STS and land side means that a truck comes to retrieve a container to transport. RTG has only a truck lane on diesel opposite side and TT brings to containers in there.

Finally external trucks retrieve containers from landside in ASC and from a truck lane in RTG. External trucks start to carry containers to the next destination.

In below Figure 2 defines a simple harbor layout. When ship arrives in harbor it's placed under the STS cranes. At least one STS for each ship starts to load the containers from ship to ground.

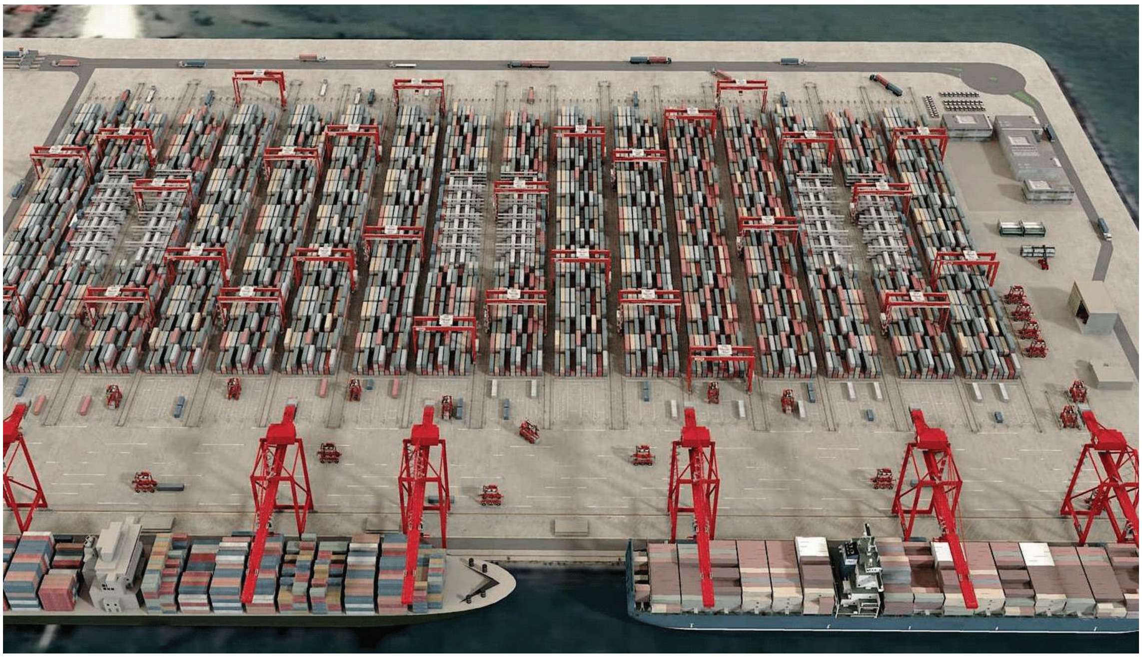


Figure 2. *Harbor example layout [1]*

2.1.1 Test field layout

Figure 3 presents Tampere's TCC test field layout. In Tampere's TCC the test field includes five different test areas. Some of those test areas are fenced, because safety must always come first when crane is an automatic.

RTG and ASC are both stacking cranes. Their main purpose is to store the container in their block. ASC block has its' own fenced area which is a so-called Access Control System (ACS). ASC is a fully automatic 5+1 high crane and it operates on rails. In test field ASC can operate both water side and land side. In land side ASC can pick or ground a container for TT's trailer and water side is straight connected to automatic SHC. Automatic SHC operates automatically and its' maximum operation tier is 2. Automated SHC observed TLS or Terminal Operation System (TOS) commands the same way as RTG and ASC. Front side of the field is reserved for manual SHC or SC testing which are electric machines. Last part of the test field is reserved for AGV testing and its' development.

Test field's idea is to test the real cranes and try out new ideas. Tampere's TCC is the best place for testing equipment before Kalmar delivers solutions for the customers.

External and internal training happens in the test field, also while customers visit the test field when they are interested to see Kalmar's new products. When customers visit the test field some demonstrations are always booked with a machine they are interested in.

Figure 3. *Test field layout*

2.1.2 RTG crane

RTG crane is a wheeled crane which main purpose is to store containers in the terminal until the containers are ready to leave by vessel or by internal truck. The storage area is called the block. It contains containers and may be controlled by one or more cranes.

The cranes have different sizes in width and height. The size depends entirely on terminal capacity and how much containers they have to storage. Cranes are also available for different weight classes, but the most common maximum lift weight is 50 tons. Three different direction of movements have been designated to move containers. Hoist direction (Z) for picking and grounding containers, trolley direction (Y) for moving above traverse direction to lanes and gantry direction (X) for moving in the longitudinal direction to bays.

Figure 4. *RTG picking container in Tampere TCC [21]*

Stacking area means a place where cranes stack the containers in order to store them. Stacking area consists of three different directions which are lane, bay and tier. Lane means gantry direction in stack and the number of these stacks depends on how large stacking each terminal can handle. Bay means trolley direction in stack and it's determined by the width of the crane. Tier means hoist direction in stack and it's determined by the height of the crane. So if a terminal can handle 30 lanes, crane width is 5 bay and crane height is 5 tier, the maximum the crane can stack is 30x5x5 20 feet containers which is 750 containers, but in normal situation that maximum amount of containers in one stack never happens. Normally RTG tier high increases when driving to trolley direction, so first lane's maximum tier is 2 and last lane contain tier 5.

RTG truck lane is located in rear frame and its' used by trucks to bring and pick containers. The trucks' drivers drive in the right bay when it brings or picks the container from RTG, because when RTG carries the container it does not normally make gantry movements but there are always exceptions. The truck driver and the RTG driver communicate to each other with an audio device. The Audio device is normally located near of the truck lane and the other audio device locates in the RTG cabin or remote operation table which depends about RTG model.

2.1.3 The benefits of RTG automation

Every automation level gives more efficiency to crane system. Automation provides more benefits to customers which want to increase their automation.

Reduced cost: A single operator can control multiple RTGs at the same time, depending on the automation level and the terminal structure. GPS and laser measurement system makes operation faster, so the container is always in the correct place.

Safer and more secure: Crane operator can operate the crane from an office, so less personnel is located in the field. Anti-collision system and safety system avoid material/person accidents.

Upgrade path to automation: RTG requires low initial investment cost, because infrastructure costs are lower than rail-mounted cranes and the manual RTG cranes may be retrofitted.

The reliability of proven technology: RTG automation system uses the same software, technology and components than the other Kalmar CHE. [38]

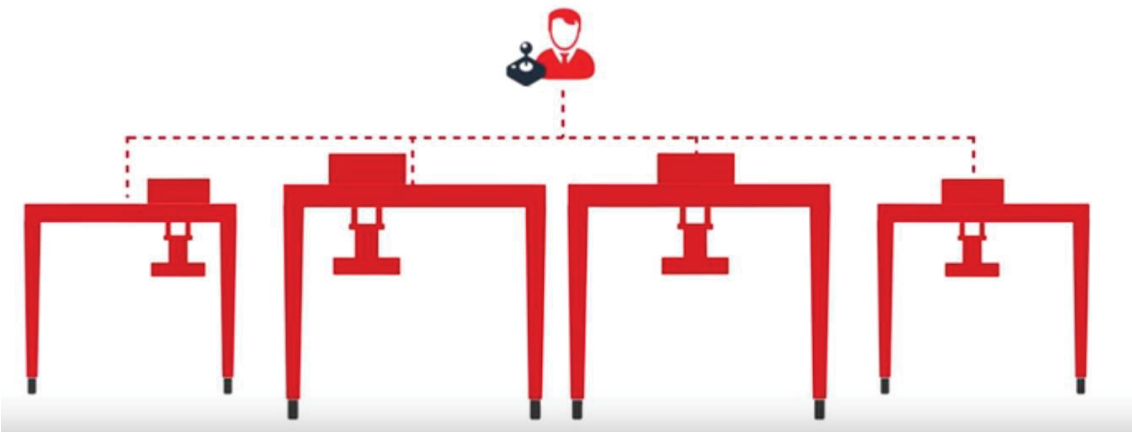


Figure 5. *One operator to operate several RTGs [36]*

2.2 Crane network

The internal network, which is a part of Local Area Network (LAN), is often used for example industrial purposes or offices. Probably the biggest reason to use internal network is reliability and speed. In this case RTG crane has its own internal network which including multiple devices, such as cameras and sensors. These devices can communicate with each other permanently and are connected to switches with Ethernet or fibre cables. Wireless communication is also possible in internal network and it's not mandatory, but it's used to facilitate the testing.

2.2.1 OSI-model

Purpose of Open Systems Interconnection (OSI)-model is to standardize the communication architecture so that it can be divided into different layers. OSI-model includes seven layers which each can communicate to one layer upper or lower level. First two layers include both hardware and software, but upper five layers are typically used in software only. [15]

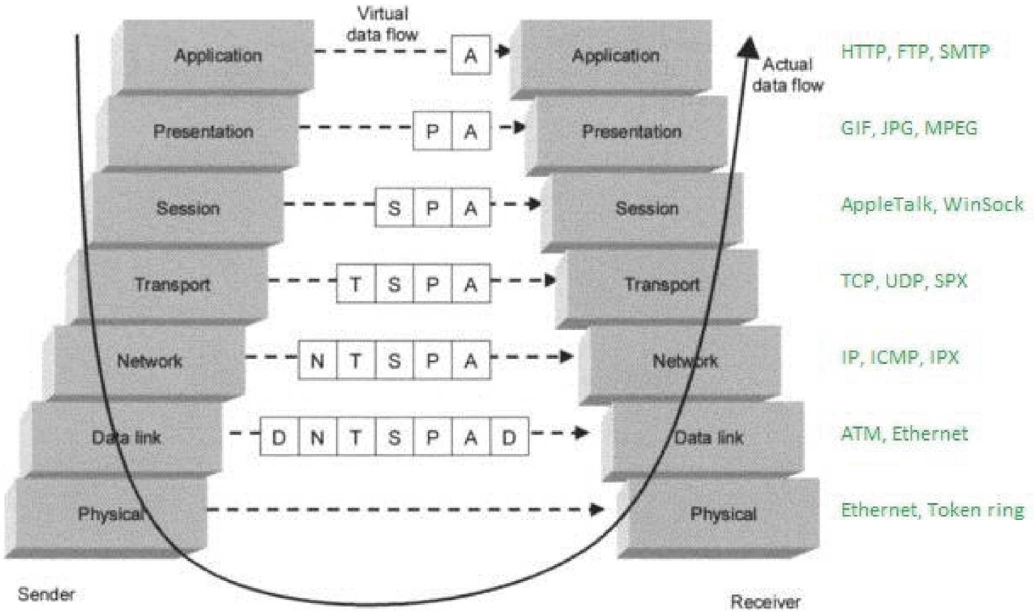


Figure 6. *OSI-model [16]*

1. Physical – Layer defines the physical characteristics, such as cabling and connections
2. Data link – Makes sure that no errors occur in the physical layer of the data and corrects data if needed
3. Network – Provides the connection to upper layers
4. Transport – Provides the actual communications link so the upper levels can transfer any data
5. Session – Connects over the network to the machine, maintains it and finally closes the connection at the same time freeing up resources
6. Presentation – Provides so that the application data is obtained to the correct format
7. Application - Provides the actual interface for applications, which they can use for network communication [17]

2.2.2 Network topology

Network topology can be imagined as a network's virtual shape or structure. However, the shape does not fully reflect the physical appearance of the network devices. If the system is complex then network topology can be built as hybrids and then it's a combination about two or more topologies. [22] Network topologies can be also categorized into five following basic types:

- Bus
- Ring
- Star
- Tree
- Mesh

The network topology creation was one important part when building the complex network. Manual RTG already includes some network devices, but when development project went ahead the network topology creation came as an essential. The network topology status is needed when the number of network devices increased and when a network topology was created it was easier to start solving network problems.

2.2.3 UDP

UDP belongs to OSI-model fourth layer which is a transport layer. In UPD messages the response is not always expected for example in cases when streaming video or audio. In Table 1 five major results when UDP request has sended. [10]

Action	Condition	Outcome
UDP request sent to server	Server available	Sender gets UDP reply from server
UDP request sent to server	Port is closed on server	Sender gets ICMP "Port unreachable" message
UDP request sent to server	Server host does not exist	Sender gets ICMP "Host unreachable" message
UDP request sent to server	Port is blocked by firewall/router	Sender gets ICMP "Port unreachable—Administrative prohibited"message
UDP request sent to server	Port is blocked by silent firewall/router	(timeout)
UDP request sent to server	Reply is lost on way back	(timeout)

Table 1. *UDP requests [10]*

Basically UDP uses a connectionless transmission model, which has a minimum of protocol mechanism. When UPD is used the computer applications can send messages to other hosts over Internet Protocol (IP) without prior communications to set up special transmissions channel or any data paths. Time-sensitive applications normally use UDP because it’s better to drop some packets than wait for the delayed packets, which probably would not be an option in a real-time system. [27]

2.2.4 TCP

Transmission Control Protocol (TCP) belongs also to transport layer. Most part of the internet traffic is based on TCP. It's a more reliable companion of UDP, but both protocols ports usually run from 0 to 65 535. TCP is also connection-oriented, which makes these protocols different. TCP is also more complex than UDP. [10]

TCP needs to know about the logical relationship connection between two endpoints (two different host). TCP connection can be a permanent or on demand. In permanent connection the other host is always there to receive the connection, but in that way communication can happen only in these two endpoints. In demand connection the communication can happens in any host, but the answer is mandatory so that information sharing is possible. [10]

2.2.5 Profinet

Profinet is an open standard industrial Ethernet and a real-time Ethernet protocol. Industrial solution requires reliability, real-time solution and highly robust system which Profinet can offer. Profinet also can resolve the issues of cycle time and jitter when talking about switching and routing. [8] The first two versions of Profinet jitter and cycle time were not as good as nowadays. In current version of Profinet cycle time can provided less than 1 ms and jitter less than 1 μs. [7]

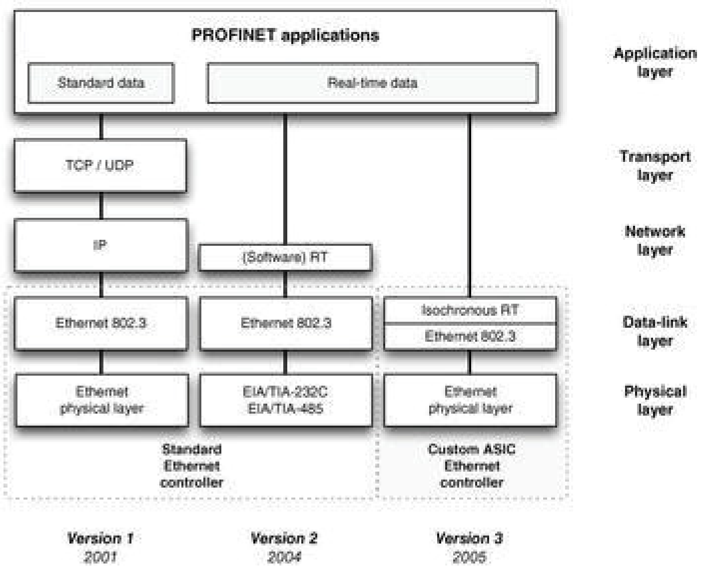


Figure 7. *Profinet development over the years [7]*

Profinet is Ethernet based, so it can use line, ring or star topology and can use both copper or fiber cable solution. Profinet also provides different diagnostic tools for network and field devices. Tools provide information about devices' status and health and it can also provide a display of the network topology. [8]

Old RTGs used Profibus standard. Profibus is still very widely used, but most of the users already move forward. The Ethernet based Profinet is next generation technology and it not require Profibus connectors anymore, so it's easier to apply any kind of applications to Profinet.

Deterministic performance can be achieved by Profinet, when Ethernet switches uses the IP's Profinet uses MAC addresses to communicate with other Ethernet devices locally. Because Profinet doesn't use IP address, it can reduce latency and jitter significantly. [8] Therefore, Profinet is still susceptible to any of vulnerabilities of Ethernet because it's real-time Ethernet protocol. [7]

2.2.6 GPS message

National Marine Electronics Association (NMEA) has been developed in 1975 and the latest version NMEA 0183 standard has been developed in 1983. The NMEA message is used in GPS and messages are data streams in the ASCII format. The data information can include for example position or datum, and each NMEA message starting with a dollar sign "$". After the dollar sign NMEA sentences can be announced and after that comes more relevant informations. [23]

NMEA Sentence	Description
ALM	GPS almanac data
GBS	GNSS satellite fault detection
GGA	GPS fix data
GMP	GNSS map projection fix data
GNS	GNSS fix data
GRS	GNSS range residuals
GSA	GNSS DOP and active satellites
GST	GNSS pseudorange error statistics
GSV	GNSS satellites in view

Table 2. *NMEA sentences [23]*

In supervised RTG solution and subsequent products GGA message is in use. According to the example in Table 3, the message is delivered as a form *$GPGGA, 170834, 4123.8963,N,08151.6838,W,1,05,1.5,280.2,M,-34.0,M,,75.* Using Table 3 it can easily parse the code into a format that can be set on to the GPS device. The most important parts used in GGA messages are latitude, longitude and altitude. This is the reason why to use NMEA message. NMEA provides most relevant information from GPS which are easy to decode.

Name	Example Data	Description
Sentence Identifier	$GPGGA	Global Positioning System Fix Data
Time	170834	17:08:34 Z
Latitude	4124.8963, N	41d 24.8963' N or 41d 24' 54" N
Longitude	08151.6838, W	81d 51.6838' W or 81d 51' 41" W
Fix Quality: - 0 = Invalid - 1 = GPS fix - 2 = DGPS fix	1	Data is from a GPS fix
Number of Satellites	05	5 Satellites are in view
Horizontal Dilution of Precision (HDOP)	1.5	Relative accuracy of horizontal position
Altitude	280.2, M	280.2 meters above mean sea level
Height of geoid above WGS84 ellipsoid	-34.0, M	-34.0 meters
Time since last DGPS update	blank	No last update
DGPS reference station id	blank	No station id
Checksum	*75	Used by program to check for transmission errors

Table 3. *GGA message fix data example [24]*

2.2.7 Audio protocols

Advanced Audio Coding (AAC) is a standard which is desired in order to give a better sound quality than MP3 gives with the same bit rate. AAC also allows bigger sampling frequency than MP3 and it also supports 48 different channels. [29] This standard is normally used in audio devices.

There are also other standards which can be used in audio device. Those are G.711 u-law, G.726 24 kbit/s and G.726 32 kbits/s. Those protocols are also older than AAC and not in use as much as before.

2.2.8 Streaming protocols

Real Time streaming Protocol (RTSP) is the control protocol, which delivers multimedia packets over the IP network. In a normal situation the actual multimedia content is not typically sent over the RTSP connection. In default it is based on TCP traffic and it includes very similar syntax than Hypertext Transfer Protocol (HTTP). UDP traffic is also possible in RTSP, also both multicast and unicast are in use in RTSP. [37]

Real time Transport Protocol (RTP) is the protocol which is used to deliver and transport the actual real-time audio and video traffic. Audio and video data delivery is typically very delay sensitive. UDP protocol makes this sensitive delivery possible and UDP data is always steady when using RTP. Also TCP protocol also can be used, but it suffers higher packet loss. [37]

There are four different streaming types which can be used in Liveview transmission methods. They are different combination for RTP, RTSP and HTTP. First one is multicast RTP. It is suitable when same stream needs to be used in many different sources. It can handle the large number of clients without the bandwidth usage increase. Multicast RTP also requires multicast IP address. Second option is the unicast RTP. Unicast basically means that each media stream is sent independently to each user so the required bandwidth is normally greater than multicast. If there are several simultaneous users their streams are on at the same time. That increases the data amount on internal network and if many clients are connecting at the same time it needs to be considered. Unicast and multicast RTP are also not suitable networks when Network Address Translation (NAT) firewall is used. They both are based on UDP which can reduce performance of the steam delivery. [39]

RTP over RTSP and RTP over RTSP over HTTP are also unicast. RTP over RTSP is more suitable when firewall is used. When over HTTP is involved it can be used when the firewall need to pass between the camera and the client. Both transmission methods use TCP for media delivery. [39]

2.3 Graphical user interface

GUI offers more intuitive and informative user interface that text based command line. GUI normally uses different icons like buttons, menus and moving objects. Normal way to operate GUI is to use mouse or a keyboard, but also in modern touch screen. GUI operating system is much more comfortable to use and learn, because commands don’t need to be memorized. Also users don’t need to understand any programming languages and that’s why GUI operating system is most likely used in nowadays. [40]

2.3.1 Planning approach

New tabs are required when automation level increase. The GUI is Fleetview and it requires more tabs which can be visible for end users. Every tab is created by using Qt creator program.

Every new tab has a surface where the graphical elements and UI widgets can be added. In this case these surfaces are a so-called frame. When the frame is created, a name has to be chosen, and the name is the main title of the UI file. Below the frame there can be the tab widgets which work as a slider, so the different tabs can be chosen. Every tab widgets includes certain amount of group boxes, which depend on how many categories each tab widgets has. [41]

GUI widgets are elements which represent a common functionality like push button, label or led. Those widgets can be found on Kalmars own Qt creator library and each widgets has its own intended use. Different widgets can be added straight on group box, but the easiest way is to use different layouts. Layouts define how the widgets are set on group box. The most used is a grid layout, but also vertical and horizontal layouts are useful. When the whole GUI file is created, it must be defined on how these element react when the file is opened by different resolution. For that reason there are so-called vertical and horizontal spacers. These spacers resize the elements so the UI file always shows in its best size. Every widget can also be set to define their maximum and minimum sizes which also react when the resolution change. [41]

2.3.2 Evaluation of the UI file

When evaluating the UI there are four important stages which have to be considered during the design:

- Ease of use
- Operationality
- Efficiency
- Generality [41]

During the UI design these mentioned stages have to be on the mind. All of them are very strictly linked to each other. When the end user operates the crane there is no room for misunderstanding. These UI files evaluation requires checking rounds when other developers give some feedback about UI files. That way the evaluation goes to the right direction and the end users will receive better UI file, because the designer is sometimes blind to his own mistakes.

2.4 Data collection and analysis

There are various sources of data in the automation system, for example detection systems, sensors, cameras and computers. The raw data is not so informatic and that's why it needs to analyze and collect the data. [44] The data can be analyzed in different ways in different software. When the whole system data have to be analyzed, searching the right data source is important. When a certain time of data collection is over then the data should be analyzed. The easiest way is to create a graph from different sources which have to analyzed.

2.4.1 Network analysis with Wireshark and Iperf

Wireshark is a software which is used to capture and inspect different protocol data and it can also be called a packet capture tool or a network analysis tool. Nowadays computer network carry lot of data, voice and video traffic and that's why many network users as engineers use Wireshark to solve their data problems in the above mentioned entities. [11]

Wireshark can be used to design network capacity, network optimization and also to solve network communication problems. Wireshark can capture all the traffic which moves across your network, packet by packet. Wireshark also decodes the data and makes it easier to understand and it also interprets the different protocols in use. When data is already decoded and more detailed information will need to be found then it could be filtered. Filtering is a one of selected criteria which matches a filter, example specified protocol and its data amount. [11] Wireshark analyses the following capabilities:

- Captures network data and decodes data
- Network activity which includes different protocols
- Generates and shows specific details about network activity
- Wireshark can create pattern which illustrates network activity [11]

The iperf is an open source software which provides measurement TCP and UDP bandwidth performance. It also provides different parameters which reports datagram loss, delay jitter and bandwidth. Iperf provides client and server functionality which measures data from two point in both direction. [42]

2.5 Hardware and Software

Mostly word hardware refers to computer components, but in container handling industry it has also other meaning, like audio device, camera and industrial PC. Most of the cases a new program for hardware make it work entirely in a new way. Hardware also includes some configuration so the main purpose is still the same, but usability changes somehow. [45] Software is a general term of programs, which run in computers and related devices. If thinking about computers it can be said that software is a variable part and hardware is an invariable part. [46]

2.5.1 TLS architecture increase the software control

The TLS platform is Kalmar's own automation software architecture. The purpose of TLS is the same in all CHE, but there are different configurations in the deployment. The focus is on safety and efficient container moves by using CHE. TLS communicates with TOS and the container moves orders come from TOS. Before TOS works perfectly, it needs for example following information from TLS [1]:

- The planned works and execution order
- Correct crane which is best-placed to do that job
- Correct crane route and traffic in the field
- Crane can move safety to truck lane
- Crane can react correctly if there are obstacles in stacking area
- Crane mode/state
- Crane alarms

TLS architecture provides functionalities for different problems. For example TLS provides extensive tools for maintenance, remote operation, diagnostics, historical reporting tools, scheduling possibilities, safety functionalities, crane software which are related to controlling and GUI. TLS is therefore straightly connected to terminal's TOS and its' equipment. [1]

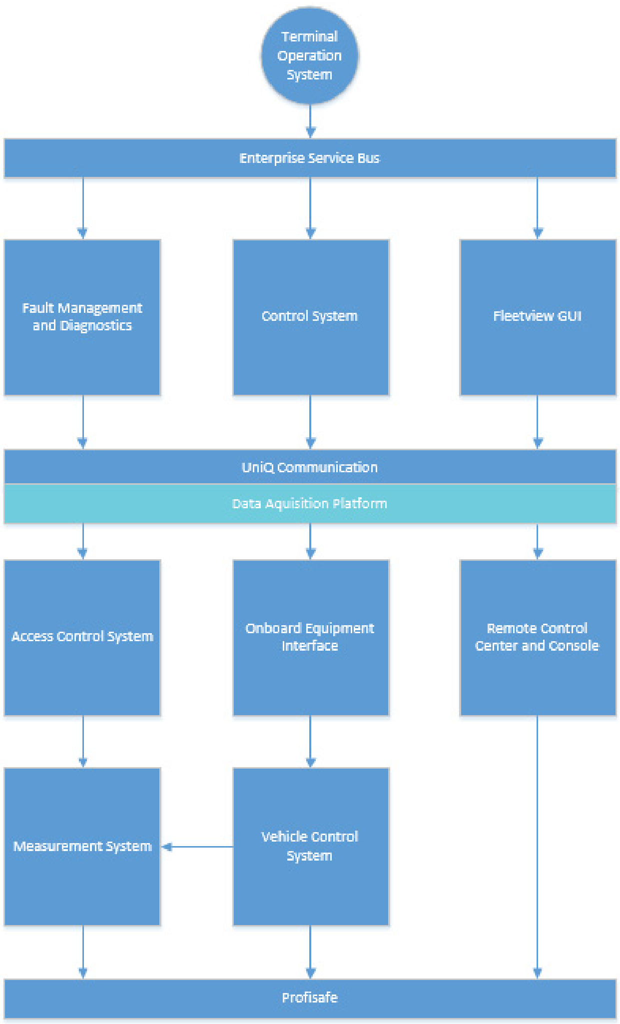


Figure 8. *TLS architecture*

First automation level is the so-called RC RTG which is illustrated in Figure 9. Crane cabin is no more needed in this operational phase, so the driver controls RTG crane fully in office and whole operation is fully operator controlled. When a job arrives from TOS, then operator connects the RC desk to the RTG. Operator selects the correct job from Fleetview. Operator starts to execute the job and uses desk joysticks to operate the crane. Operator picks container from the stack and moves it to the truck lane and after that the operator starts to ground the container to the truck. When the RTG operator controls the crane then the operator is viewing Liveview monitors and Fleetview in order to execute the job. After the job is done the operator reports the job completed and moves to the next job, which may be for another crane. [13]

In Figure 9 the RC RTG architecture has been presented. GUI and camera views are normally included in every RC crane. Also Remote Control Centre (RCC) and central safety Programmable Logic Control (PLC) are a part of RC RTG. All of those are included in TLS architecture. Crane control PLC is part of manual RTG, but PLC program has been changed in the RC RTG. Onboard safety PLC is a new part of software and the role of it is to control all safety functionalities in the crane.

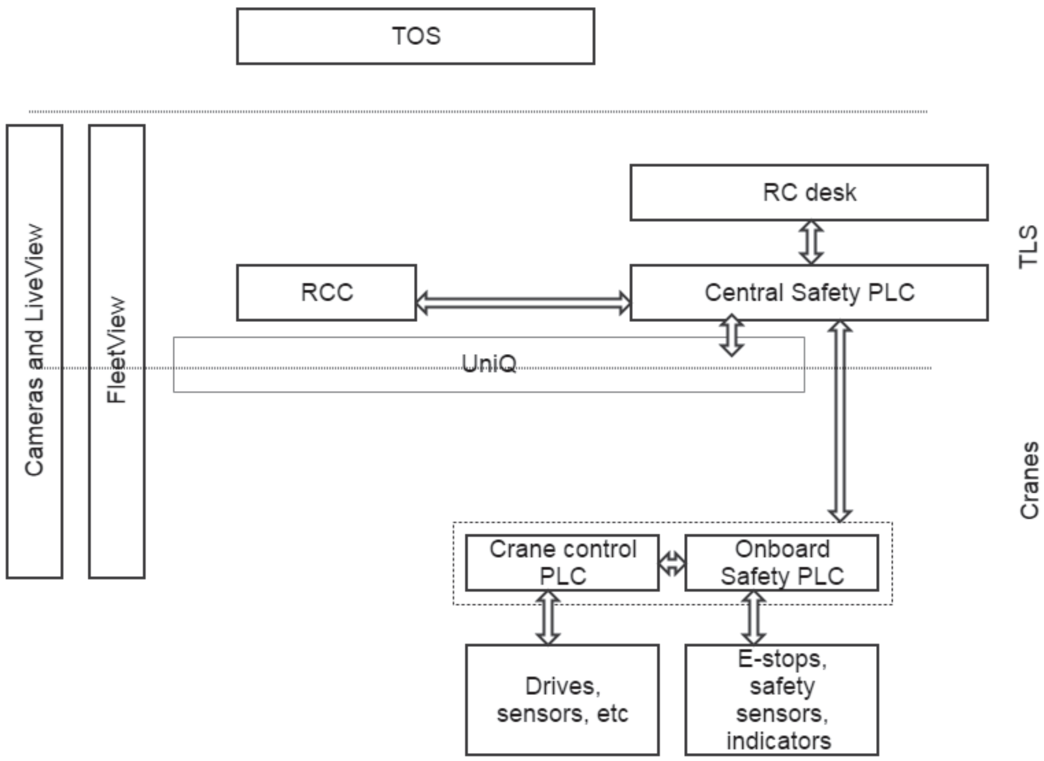


Figure 9. *RC RTG architecture [12]*

Second automation level is the so-called Supervised RTG which is illustrated in Figure 10. As in RC RTG, supervised RTG is also based on RC operation, but the difference is that the operator has an assistive semi-automatic functionality available. When job arrives from TOS, then the operator connects to RC desk. Operator starts the supervised move by activating the dead man's switch. Operating in stack happens in supervised mode, except hoisting down movements when a crane is in remote operation mode. Truck lane operation is done almost fully in remote operation mode. When safety height is reached after truck handling the supervised mode can be activated. If for some reason the operation needs to stop, the operator just releases the dead man's switch and when operation needs to continue the operator just enables the switch. When the whole transfer job is ready the operator can move to the next job. [13]

The architecture in Figure 10 is almost the same as in the RC RTG, but more software activities are in use. For example Vehicle System (VS), Control System (CS) and External Interface Service (EIS) which are Kalmar's own designed software. Measurement systems are a really important part of the supervised RTG because for example global positioning systems (GPS) gives a crane positions and VS/CS can use them to create the real position of the crane.

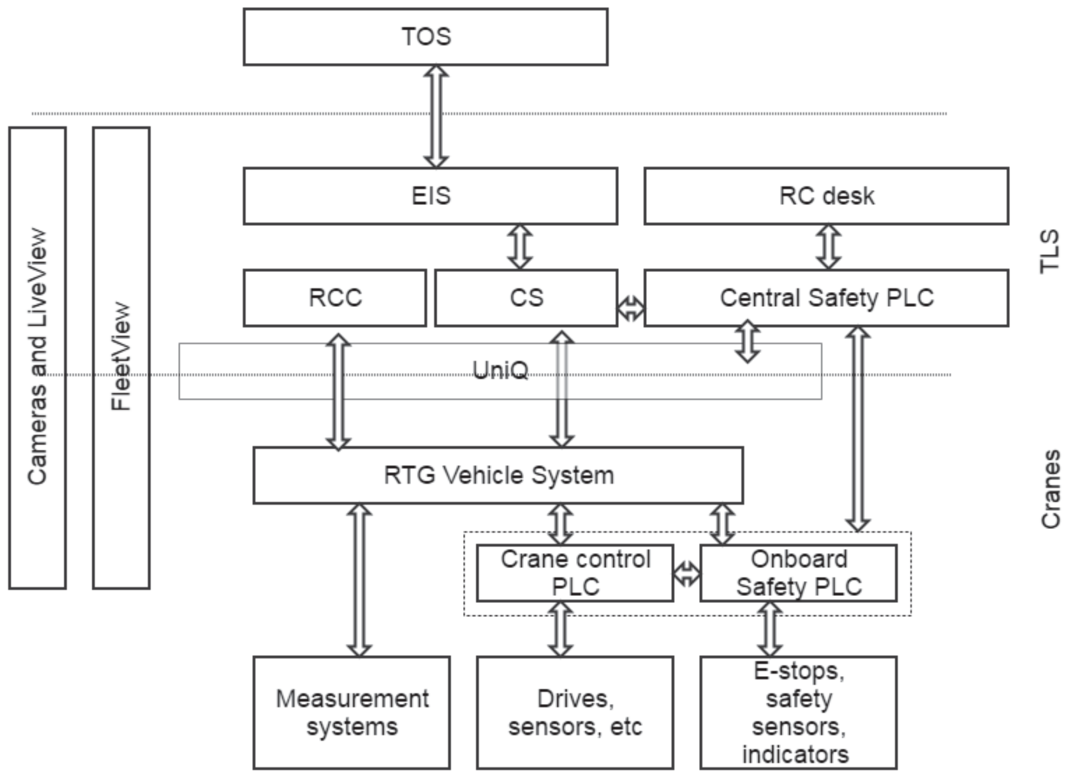


Figure 10. *Supervised RTG architecture [12]*

2.5.2 Configuration

The software development process requires actions so the software solution is tailored to the need of the user. That's why the configuration possibility is an important thing when developing the software. [43]

Configuration has many meanings and many purposes. Developers can easily change configuration file setting without having to change the software. In a normal situation there are many different configuration files which can be changed. When software starts it reads configuration file settings and shows the changes when software is started.

Otherwise the configuration can mean hardware configuration. These hardware configurations can normally be done straight on a browser or a command line. The changes are on when configuration changes are being saved or otherwise the hardware needs to be rebooted.

3. RESEARCH METHODOLOGY AND MATERIALS

This chapter gives better approach on how the problems may be solved. The relevant research steps are mentioned in chapter 1. This chapter is continuation to chapter 2 literature research.

Software is important part of the RTG product and the TLS architecture makes the crane workable entity. This chapter provides better approach to Kalmar software solution and different hardware which have to be configured before testing can be possible. The software and hardware have needed a lot of development work and testing before the system works. Kalmar software includes configuration files which are Extensible Markup Language (XML) format files, but the main functionalities are hard coded.

3.1 Research phases

The research phases include the different categories. There was a lot of reading and then testing how the implementation works. Sometimes it goes well and sometimes doing requires more research work. Planning and theoretical part was both hard and easy. It was easy because Kalmar internal materials help a lot. Someone else already in Kalmar was thinking the same kind of problems and documented it well to the database. It was also hard because there are many articles, reports and so on which handle same kind of problems which I have.

The problem identifications were very hard at the beginning but it becomes easier during the thesis. When knowledge increased then the problem identification was easier. It was easier to collect the information when I knew what to look for.

When the problems were listed and the theoretical part was handled, the implementation could be started. Therefore, the theoretical part followed the work for the entire time. Data needed to be analyzed and collected with different software. Hardware needed to be installed, configured and tested so the workable entity was achieved. Developing work needed to be done when something didn’t work as planned. Software also needed to be configured and tested before the final phase could be started.

The final phase was testing and documentation. Testing was also a part of every phase when implementation part was stared. Testing circulation was illustrated well in chapter 4.9. The final testing provided the product to be ready for marketing. When system was tested then documentation phase could be completed. The documentation part was started during the process.

3.2 TLS software configuration phases

All TLS software needs more or less configuration so the whole architecture is workable entity. Some of the software already includes some kind of commissioning guide, because other CHE types include same software. Anyway, CHE are implemented in different solutions. That is why every CHE requires its own specific configurations. Every configuration changes need to be tested after the change. The purpose is to clarify the change to go to the right direction and it to work like it should. It is easy to move backwards when only one change has been made, before doing other configuration changes.

Configuration files are created by XML. XML was created by the World Wide Web Consortium (W3C) and the first development version was published in 1996, but only two years later they published a better structured XML version. In the beginning of XML markup language wasn't really used and it found slowly people's consciousness. When the developers fixed more weak points in XML and made improvements, interest started to grow in the software and information technology world. Nowadays XML has a stable place in information technology systems and many applications use it to configuration or data somehow. [9]

```xml
<?xml version="1.0" encoding="UTF-8"?>
<ui version="4.0">
  <property name="geometry">
    <rect>
      <x>0</x>
      <y>0</y>
      <width>1230</width>
      <height>557</height>
    </rect>
  </property>
</ui>
```

Program 1. *XML example*

Program 1 above illustrates that if there is no XML format, then it is much more difficult to understand and understanding of texts is only based on people's own knowledge. But immediately it is easier to understand the individual parts of data if it is specified to pieces. Of course every size of the file increases because there are much more characters than only in a standard text file. [9]

XML schema is used for to check the XML file format and vocabularies are much more detailed than in applications' own XML syntax checker. XML schema definitions (XSD) and Document Type Definitions (DTDs) are probably most used schema languages. Checking of the schema is an important part of quality assurance. [5] A schema can be used for example these cases:

- To combine different types, such as integer or string
- XML document is readable and computer can handle the document
- Define list of elements and attributes
- Define where elements and attributes can be visible
- To provide formal description to documents [5]

3.2.1 Internal communication platform

The internal communication platform is called a UniQ communication platform. It's a cross-platform data distribution layer and it provides common ways of communication between UniQ services. The most important thing which a platform tries to solve is reliability and scalable issues in heterogeneous network. It also tries to handle the diversity of communication media, equipment and hardware interfaces. [1]

The UniQ communication consists of independent services and each service include different peers which act as consumers, publishers or subscribers. [1] Each peer can communicate with each other and communication can be a two-way connection. [25]

3.2.2 Data acquisition platform

The UniQ Data Acquisition (DAQ) platform offers different UniQ services to access the crane. DAQ includes different individual components which can communicate with the actual UniQ DAQ service application and each component shares the same diagnostics and centralizes configuration management. [1]

Each component uses the DAQ platform and there are two different types of data handling DAQ components. Interface components handle connections and communication of external devices, example PLC and sensors. Handler components are another way to data handling and they refine and combine data provided by the interface components. [1]

3.2.3 Zoom handler

Zoom handler was originally created in RTG's, but it can also be used in other application. Zoom handler is created to calculate cameras zoom value which depend on RTG's hoist height value. Normally there are several zoom cameras installed which have the same zoom level and these cameras are also pointing down. When hoist moves up and down, zoom handler controls cameras' zoom level and zooming on the right camera zoom value. Also spreader length can affect the zoom value, but hoist height is normally in use. [4]

3.2.4 Vehicle system platform

VS main task is to control vehicle movements like accelerating, braking, steering, hoisting and work movements. [35] VS is a so-called soft PLC and it basically makes all automation movements possible. VS is created by using Codesys software which uses IEC 61131-3 open standard for PLC. The standard includes different programming languages which are:

- Ladder diagram
- Function block diagram
- Structure text
- Instruction list
- Sequential function chart

The VS includes many configuration files and one configuration file includes GPS parameters. GPS configuration file includes different information about GPS, such as information about reference point position.

3.2.5 Control system platform

The CS provides different software components which can control many cranes or just a single. It controls common functionalities for semi-automatic or automatic crane and it manages continuity and safe operation when crane moves. CS is also responsible about jobs which arrive from TLS or TOS. [1]

CS also creates a virtual container map and terminal layout on Fleetview which should match real world terminal. [25] It's also responsible to know machine movements so if a machine is near to collision then it sends information which stops the crane and sends a message to GUI. Program 2 illustrates one configuration possibility about Cs configuration of the crane's smallest and largest travel height on crane block.

```xml
<?xml version="1.0" encoding="utf-8"?>
<appSettings file="App.config">
    <add key="Artgcs.Small.MinTravelHeightMm" value="18000" />
    <add key="Artgcs.Small.MaxTravelHeightMm" value="18000" />
    <add key="Artgcs.Large.MinTravelHeightMm" value="5000" />
    <add key="Artgcs.Large.MaxTravelHeightMm" value="20000" />
</appSettings>
```

Program 2. *CS configuration file example*

3.2.6 Remote control center

RCCs purpose is to handle all connection and disconnection requests which arrive to the cranes and it also includes console selection to available consoles. When connection request arrives to the crane, the RCC confirms request which connects directly to

Liveview and central safety PLC, but still video and control signal use connection peers between remote desk and crane. [1]

RCC configuration needs to be done before a connection to RC desk is possible. One example about configuration is that which kind of communication RCC promises for RC table. In this case RCC must get pass through to video and audio connection, which has configured to RCC.

3.2.7 Crane PLC

Crane PLC has been built to use Siemens Simatic Step 7 software. Siemens software was also included in manual RTG, but it has been developed to work in RC products. Crane PLC defines some basic functions such as:

- Hoist overspeed prevention – Stops hoist motion if speed is higher than nominal speed
- Gantry overspeed prevention - Stops gantry motion if speed is higher than nominal speed
- Trolley overspeed prevention - Stops trolley motion if speed is higher than nominal speed
- Hoist overload detection – Stops hoist up motion if load weight is over limit
- Crane out of rail – Slows down or stops gantry motion if crane is leaving the operation range [26]

Crane PLC also includes onboard safety called software component which runs in the same PLC device. Onboard safety defines safety functions which are needed when RCor supervised RTG are operated, and for example, it defines truck lane operation speed limits when hoist is near for a truck.

3.2.8 Fleetview

Fleetview is part of TLS and it is Kalmar's own GUI software. Fleetview offers customizable layouts and widgets which can easily be modified according to the needs. Fleetview also provides customers with enhanced visibility and greater flexibility over common operational and maintenance tasks. [1]

Fleetview functionality changes are easy to define because biggest configuration changes can be defined in xml file. If a new UI file is created and it needs to be attached in Fleetview, it can easily be attached in Fleetview folder structure, after next Fleetview reboot new UI file is visible in GUI. Biggest functionalities are still hard coded by using C++ as the primary programming languages and those changes are project specific.

3.2.9 Liveview

An application/decoder is for the live video signal switching. The application supports simultaneous decoding of multiple video signals from the connected CHE and allows different display configurations based on the CHE type (single, split, quad). Standard IP video encoding protocols are supported and no hardware provider specific components are required. The image quality can be adjusted according to the network throughput by adjusting the signal compression level or by combining video signals at the CHE with an additional hardware quad splitter together with the video encoder. [2]

3.3 User interface files created with Qt creator

Qt creator is a integrated development environment which can be used to create an application for multiple platforms such as mobile devices or computers. [19] An application is possible to design by using C++ code or a so-called designer which is a graphical way to implement the application. [20]

Fleetview includes UIs' pages which can’t be modified and which are hard coded in software, but it includes a lot of subpages which can be add and modified to Fleetview GUI. These pages are so called Equipment Monitoring system (EMS) pages. Fleetview subpages have been designed for Qt creator program, which provides easy edit to UI environment. Kalmar has created its own widget library in Qt creator editor and it provides a similar appearance in all files which are created to Fleetview. Pages should be easy to understand, because they go directly for customer use and end-user is a crane operator.

All values which come to Qt creator are in different platforms, such as PLC and soft PLC programs. Example if there is a push button which is defined in PLC program, a tag can be read in Qt creator interface. When GUI is running and the push button is pushed then it should work like it is programmed to.

3.4 Hardware and measurement system configuration phases

Table testing is the normal situations first part, which has to be done before installing the hardware in a real environment. It gives better understanding for hardware and some configuration mistakes are normal when trying to get the hardware as it should be. If something goes wrong it does not confuse the real environment, it only happens to the hardware on the table. The reset of the hardware and starting from the beginning is the easiest way. When knowledge has increased and hardware works like it should then hardware can be installed on the real environment. Normally some configuration changes need to be added after table testing, but these are not very critical changes.

3.4.1 Camera study

Twelve cameras are installed in RTG and these video cameras are designed to see all around the RTG. Four of these cameras are installed in a trolley which is above to the spreader. These cameras also include a program called Zoom handler, which zoom the cameras stream in right height, closer and further when changing the height. The purpose of trolley cameras is to make picking and grounding easier, when operator handles the container. Also four of these cameras are installed in gantry direction in every corner of the crane and its purpose is to see possible obstacles in the gantry direction. Two cameras are installed high in both side of a side frame. These are so-called overview cameras used to see obstacles when trolley position is in stacking area. Two last cameras are installed in diesel opposite side frame and these cameras are only visible in Liveview when trolley is in the truck lane. These cameras are so-called lane cameras and those make operations easier when lowered or raised container from the truck.

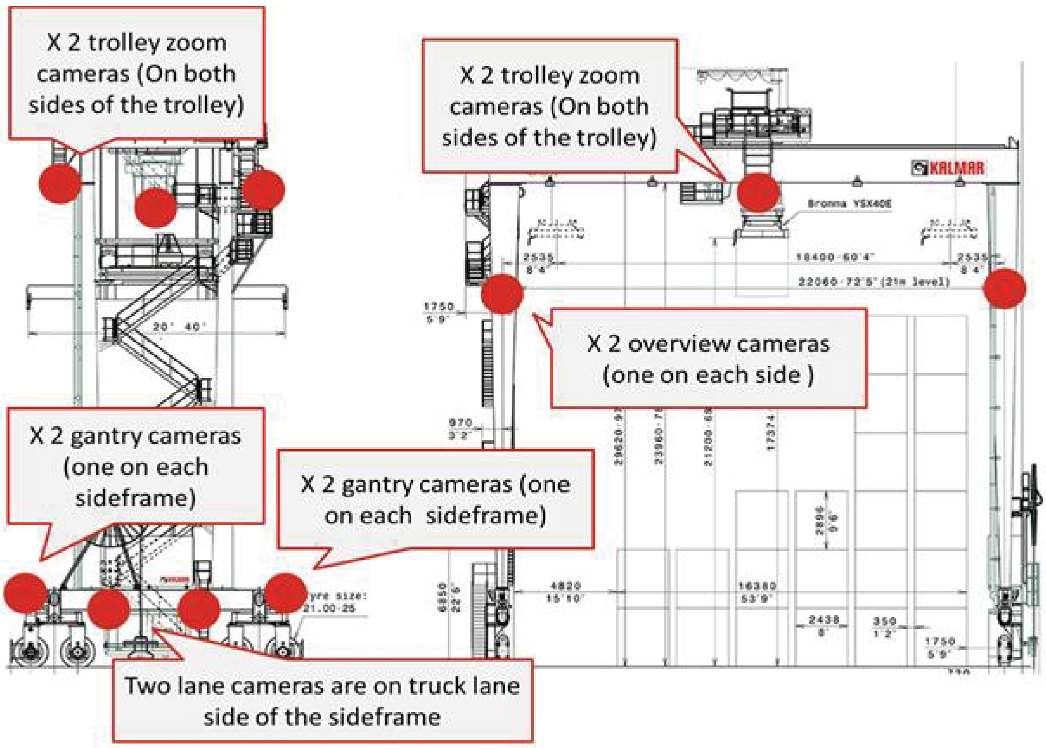


Figure 11. *RTG camera setup*

RTG sends twelve real time video streams to Liveview and ten of these video images are turned on at the same time. These cameras will be sent to Liveview PC which is connected to three displays. These screens are located in remote operation table which is located in Kalmar's TCC test field. Camera views and displays are optimized/designed to give the best possible view to remote operator.

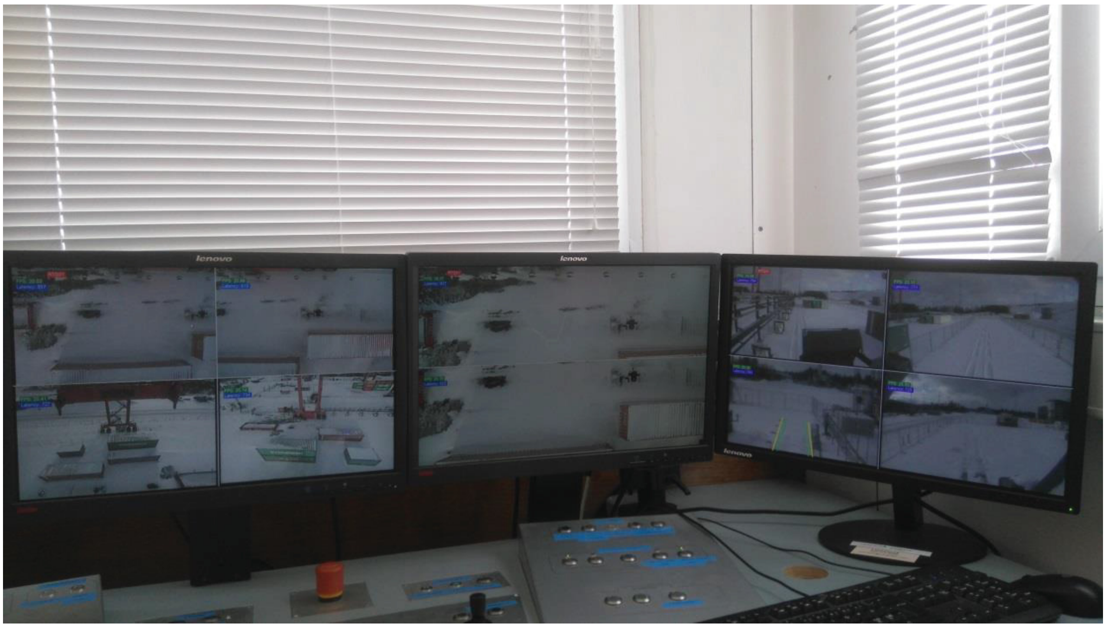


Figure 12. *Liveview screens at test field*

Eight of these cameras are connected to video encoder. That means these eight cameras are analogic cameras. One video encoder includes four different channels and one channel creates an IP address to one analogy camera. These cameras data amount need to be collected and analyzed.

When these cameras data are collected, then it's needed to install new cameras with better quality. These cameras are so-called IP cameras which can transmit High-Definition (HD) stream. After camera replacement this new camera setup data also needs to be measured and analyzed on how much the data amount is increased.

4. IMPLEMENTATION

This chapter closes and illustrates the research steps which mentioned in chapter 1. In this chapter software and hardware configurations are used in RC and supervised RTG becomes more familiar. Configuration makes software and hardware more flexible and controllable for each customers deployment. In this chapter largest configurations of the software, which is already mentioned in chapter 3, are handled.

This chapter also explains different hardware and measurement system components which are installed in these two project releases. The chapter also includes different configurations which have to be done when hardware or measurement system is added to the crane. Some of these changes or additions are very important if thinking about functionality of the crane network.

4.1 Remote control test room at test field

The RC test room has been built at Kalmar Tampere TCC test field at the beginning of summer 2016 and the RTG RC system was moved to the test container in autumn 2016, when the RC step started completely. The RC test container is approximately 14 square meters (2,45 m x 6,05 m) and it is in the dimensions of a 20 feet container.

The test container includes one single door and four windows. The windows are designed to provide better visibility to the crane which is to be tested in test field. The windows also allow customers to see better the test crane movements when they follow the operation from the test room. The room is furnished with three tables which are under the windows towards the test crane. One of these tables includes RC table and the other two are used when software developers are testing newest software versions on the crane.

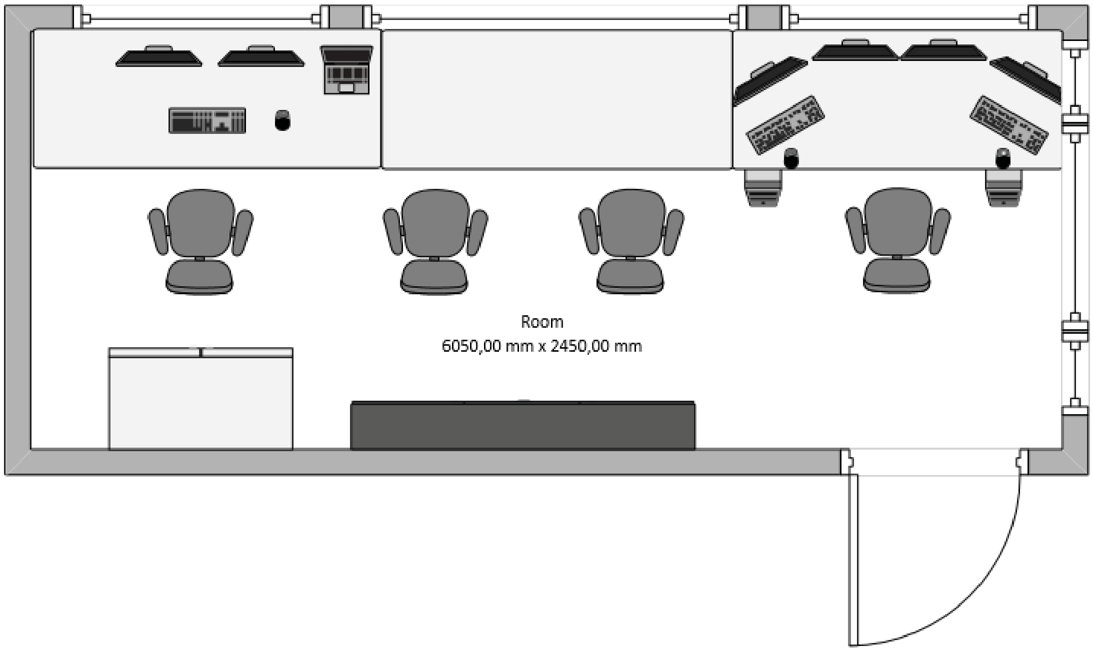


Figure 13. *Test container layout*

4.1.1 Remote control desk

RC desk plays a very important role in all products after manual RTG. The RC table includes joysticks, push buttons and indication lights. Without joysticks and push buttons movements and functions would not be possible. Desk control components are able to work with PLC, which inputs and outputs are connected to the desk. The RC desk is also connected to central safety PLC, which is attached to every crane.

RCC makes the connection to the desk possible. When the control is taken to the RC desk, then the desk components are in use. The desk also includes four different displays which include software that is used for RC. When control place is selected then video streams appear on the three screens where Liveview program is running. One display shows Fleetview GUI and it illustrates all relevant information about the crane control, for example job information and terminal layout.

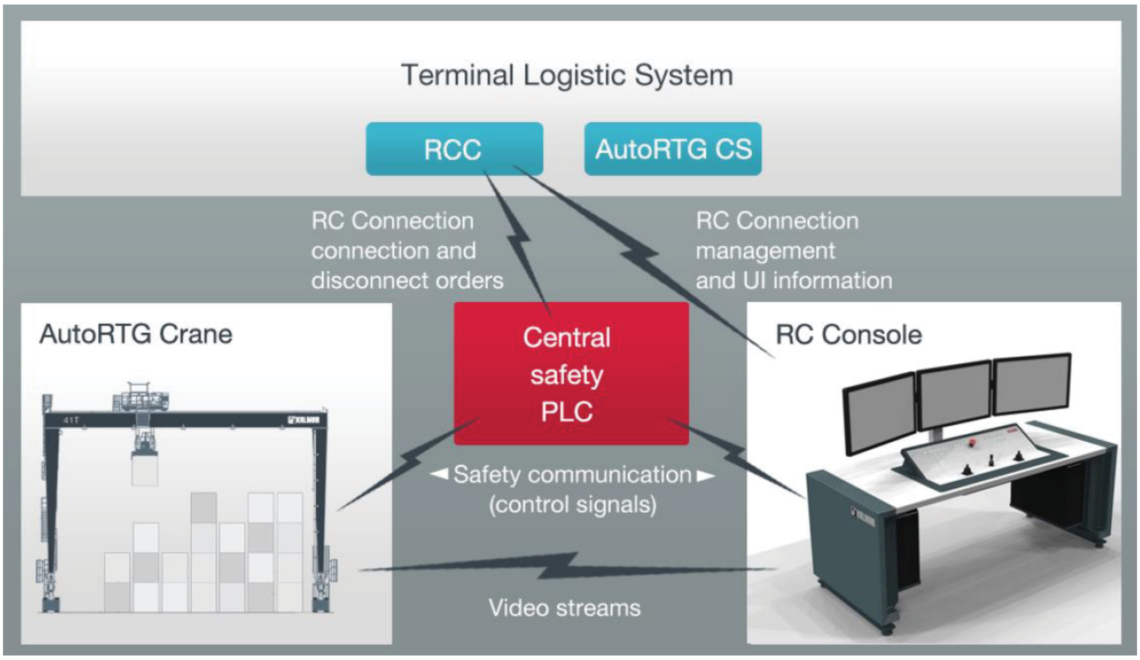


Figure 14. RC desk communications in RTG operation [13]

4.2 Creating excel macros

Creating a macro about alarm list, tag map and data source map facilitates the creation of XML files and it's also makes XML creation faster than without macro. Each alarm or tag has been created by using Microsoft excel and macro itself has been created by using visual basic language.

At first macro needs a global variables which are columns in excel and each excel sheet, from which values are read, must also be defined. The macro reads each row and makes them an according XML schema alert or tag. The macro reads each row and changes the sheet when previous sheet has been read in the last row. After every row has been read, the macro requests to save the XML file to the hard drive.

4.2.1 Alarmlist, tagmap, datasourcemap configuration files

Alarm list is part of each software which are used in RC and supervised RTG. Program 3 describes an alarm according to XML schema. Each alarm includes important information about the alarm such as alarm class which gives different notice depending about the alarm states, some class gives just notice about crane states and some class interlock the crane and stops the movements.

```
<alarm index="53029">
    <interface>CCU_softPLCSHM_if</interface>
    <ref>EXTPLCALARM30</ref>
    <desc>Hoist prevent by-pass used</desc>
    <source>0</source>
    <code>53029</code>
    <class>2</class>
    <detection>0</detection>
    <cause>Bypass Switch on Left-Console </cause>
    <reaction>0</reaction>
    <instructions> Release switch </instructions>
    <version timestamp="2016-09-01T00:00:00.000" author="JNi"/>
</alarm>
```

Program 3. *Alarm example in XML format*

Tag map and data source map are in same the excel because some attributes are the same. Tag map's purpose is to give a specific tag for defined software. Tag gives the specified component a function such as a push button or an indication light. Data source map's meaning is to define which part of a message or data block is used to get data for tag.

```
<tag id="60001">
    <name>COMMAND.AREA.ID</n
    <desc>Area number </desc
    <quantity/>
    <unit/>
    <struct>uint</struct>
    <length>4</length>
    <mod>444</mod>
</tag>
```

Program 4. *Tag example in XML format*

4.3 Liveview configuration

Liveview includes two main configuration files which can be configured easily if the projects require it. These two files are xml format files, as many others on Kalmar software.

First file is a so-called Liveview Settings file. Communication modules include three types of interface and each module needs to be defined in a configuration file and also all these three communication modes purpose are handled in this thesis. Monitors command means camera screen displays which define how many monitor current project includes. Audio is just optional, but in this project audio setting and devices are being tested. Labels define for example frame rate or latency on Liveview software and these are also needed to define Axis camera settings. Icon type is important because it is connected straight to the hardware monitor system which recognizes, if Liveview screens are frozen and then PLC program can command crane to stop. [6]

Figure 15. *Liveview settings structure [6]*

Liveview mappings file defines everything which are include in camera settings and displays. These setting which needed to define in streams settings are:

- Provider ID
- Video or audio device
- Camera or encoder channel IP addresses
- Username
- Password
- Compression
- Transmit type
- Crop (optional)
- View rotation (optional)

Mappings file also determines the view layout which means the order of transmitted images on the screens. These configurations can be easily made when settings file and stream definitions are made. If camera screen needs to be changed to some different positions in RTG block then it's needed to tags definitions from tag map and two camera views can replace two other camera views in different position. [6]

Transmit type is one of the most important part if thinking about the performance of the network. There are four different transmit types witch work fine the in crane environment. If only one transmission of each camera is in use then unicast RTP protocol or RTP over RTSP is a good choice. After a lot of testing the RTP over RTSP is the better option, because it is not lagging as much than unicast RTP. All the cameras are on internal network. That means the NAT firewall disrupts the camera data and unicast RTP is not suitable in this case. When cameras are not behind the NAT firewall, then unicast RTP works better because it uses UDP.

Secondly if more than one video transmission is needed then multicast RTP has to be used, but that also need to do without NAT. For example, if video footage has to be storaged because terminal would like to see if something unexpected happens at the crane.

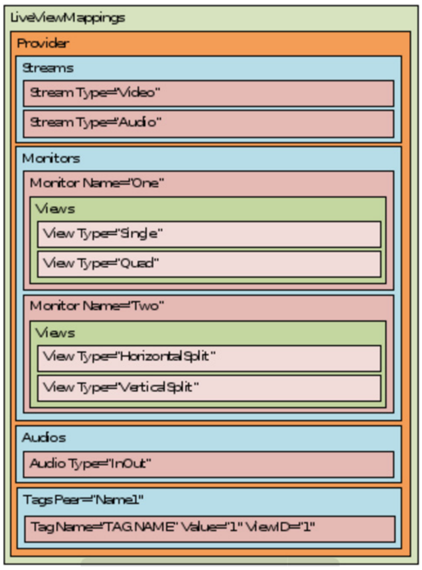


Figure 16. *LiveView mappings structure [6]*

4.4 Fleetview configuration

Fleetview includes different configuration files which have to be defined project-specifically. The most important ones, if thinking about configuration, are probably terminal_layout.xml and machines.xml because these two need the most configurations.

Fleetview includes already defined components which have different shapes and meaning. Program 5 configuration files example presents Figure 17 terminal layout. First are defined terminal width and height, which consider whole layout size which is defined in Figure 17. RTG rails and fences are defined next which also presents in Figure 17. Rails' and fences' definition needs four different points so that they can be determined. Building can be defined in different shapes and that’s why it needs eight points to be determined.

```
<?xml version="1.0" encoding="UTF-8"?>
<Terminal width="110" height="35">
    <Rail left="5" top="5" right="108.18" bottom="5"/>
    <Rail left="5" top="28.55" right="108.18" bottom="28.55"/>
    <Fence points="10.284,9.582 108.18,9.582"/>
    <Fence points="10.284,33.582 108.18,33.582"/>
    <Building points="31.476,31.582 31.476,30.582 101.476,30.582 101.476,31.476" text="Busbar"/>
    <Building points="22.464,30.241 22.464,29.641 24.464,29.641 24.464,30.241" text="Cable Drum"/>
</Terminal>
```

Program 5. *Terminal_layout.xml example*

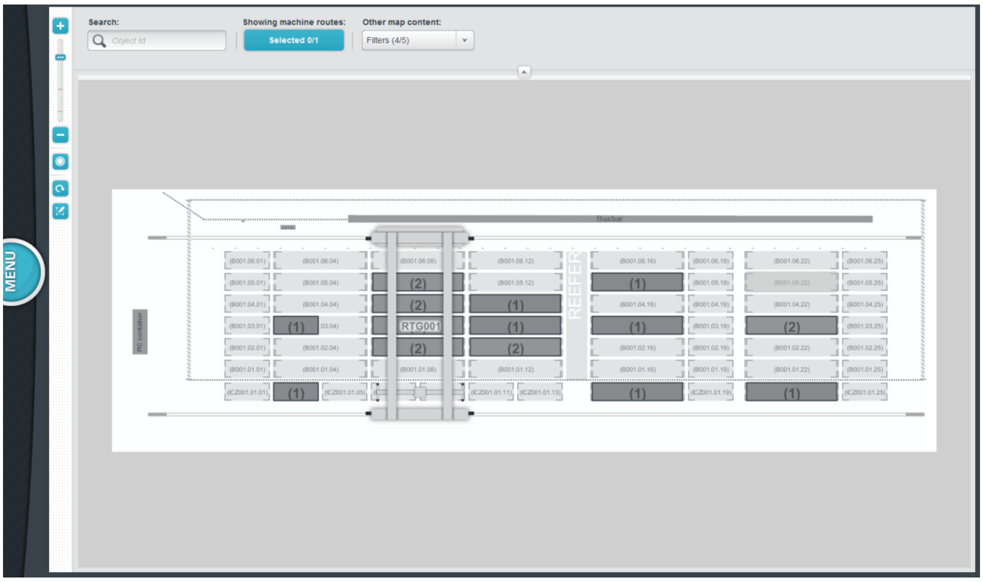


Figure 17. *Terminal layout from RTG Fleetview when only one RTG is visible*

Program 6 presents machine configuration file. It defines different software functionalities which Fleetview has to use so that a crane is visible as presented in Figure 17 and Figure 18. Different tags also have to be defined so that crane trolley and gantry has correct positions.

```
<machines>
    <machine name="EIS" peerName="EIS" type="EIS"/>
    <machine name="RCC" peerName="RCC" type="RCC"/>
    <machine name="CSPLC" peerName="CSPLC" type="CSPLC"/>
    <machine name="RTGCS" peerName="RTGCS" type="RTGCS"
        blockName="A01" zeroPos="5,5" heading="0" railwidth="23.550"/>
    <machine name="RTG1" peerName="RTG1" type="AutoRTG"
        controlPeerName="RTGCS" behalfPeerName="RTG1B"/>
</machines>
```

Program 6. *Machines.xml example*

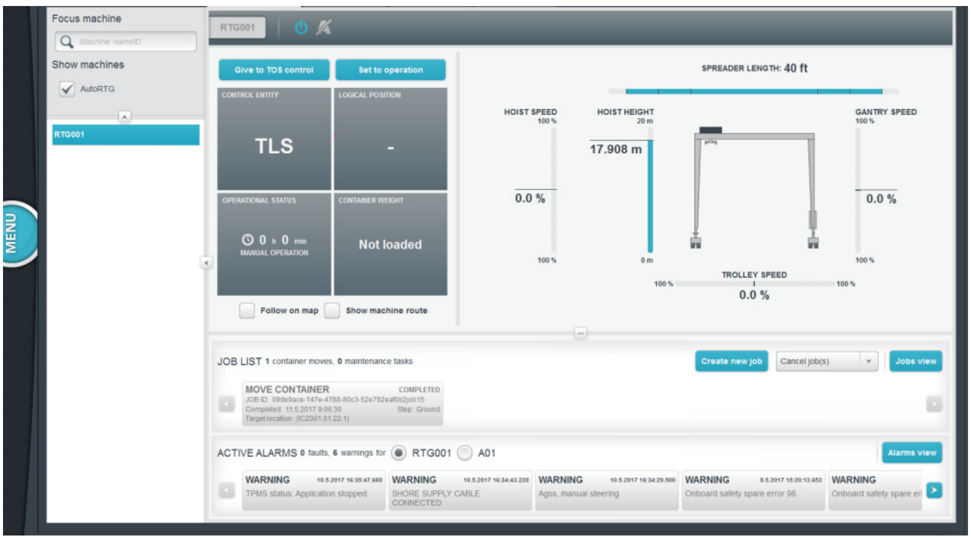


Figure 18. *Machines view from RTG Fleetview*

4.4.1 Virtual desk view

Virtual desk view is a new UI page. It shows the user all the virtual buttons which are missing from the RC table. These buttons are rarely used, but they need to be somewhere visible and the perfect place for them is the virtual view. Virtual desk view is created because the RC desk has a limited amount of space and some functions still need to be visible.

Virtual desk view depends entirely on the product, for example RC-only and automated RTG includes different amount of virtual buttons. Figure 19 shows a virtual desk view which can be easily modified according to the needs, but which is a valid in several implementations.

In the Figure 19 skew & flippers section illustrates the spreader and the necessary functionalities. Both sides of the spreader include a meter which illustrates the spreader skew between the center points of the spreader. At each corner of the spreader there are also a flipper button and indication lights added. Flippers purpose is a centralized spreader to the container and make centralization assisted. In gantry modes section it's only possible to choose the crane mode and that means the position of the wheels. The last section only manages the spreader and hoist commands.

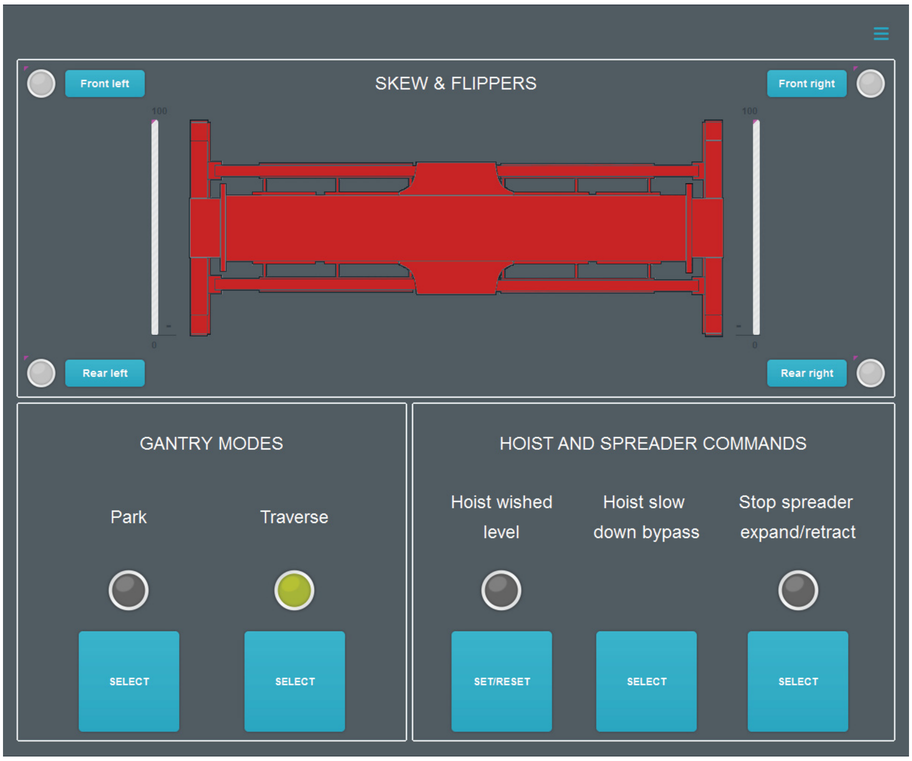


Figure 19. *Virtual desk view in Fleetview*

4.4.2 GPS view

GPS view shows all relevant information about GPS. Some of this information is also found in receiver, but shown in Fleetview. Latitudinal and longitudinal tells the crane's real position. Terminal Logical Coordination System (TLCS) origin position is in test field, it tells X and Y position between TLSC origin. Block origin position is located in AutoRTG's block, it tells X and Y position between Block origin.

AutoRTG GPS view illustrates heading/pitch/roll meaning. Heading is vertical axis, Roll is longitudinal axis and Pitch is Lateral axis. Also Heading/Roll/Pitch includes rotation around the axis. These angles are already calculated in VS and real-time information is constantly updated in Fleetview.

4.4.3 Job information view

Job information view illustrates job variable and latest container report. When CS calculates route from the starting point to the end point, information will also be visible in Fleetview and Gantry/Trolley/Hoist distance to target value displayed in the field. Latest container report presents Gantry/Trolley/Hoist current position and also shows other relevant information like weight which comes from Siemens PLC. The trace also figures every direction about current job deviation between target direction and current direction.

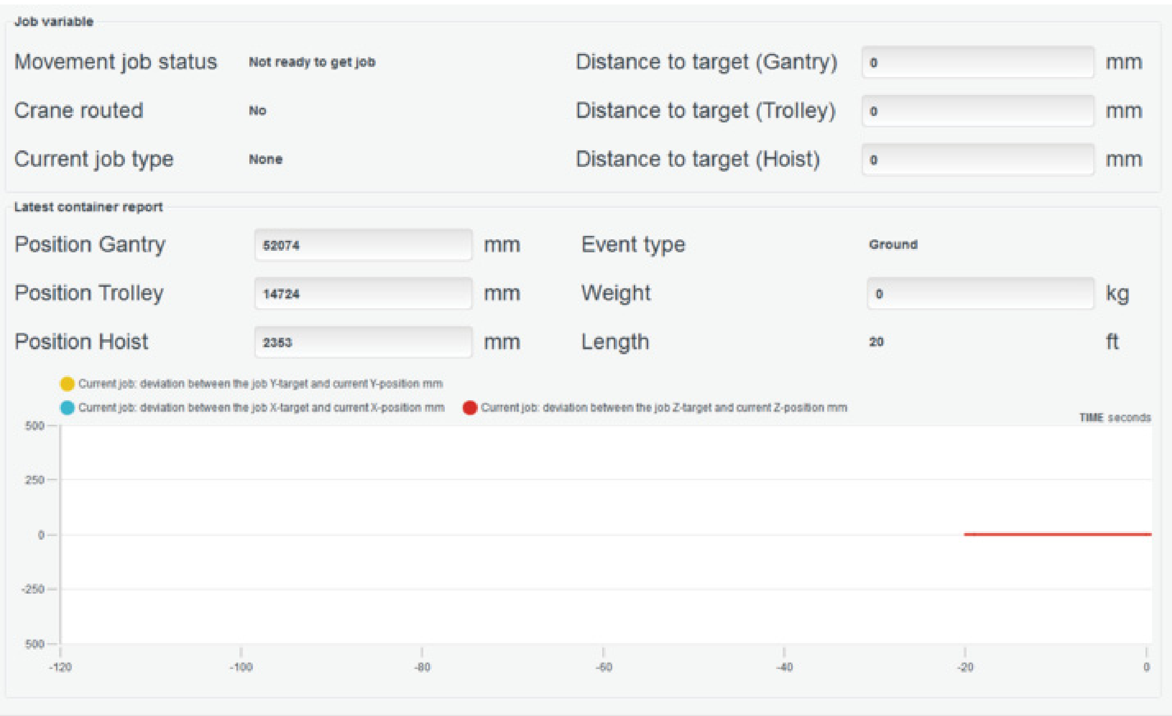


Figure 20. *Job information view in AutoRTG tab in Fleetview*

4.5 Switches in crane network

Switch is a device which main purpose is to communicate with multiple devices which are connected to same LAN with Ethernet or Fibre cable. Switches include different capabilities such as 100 Mbps, 1 Gbps and 10 Gbps. Normally high-performance switches are used in corporate network which have higher capabilities. [30] If switches are used in corporate network then one switch can support between 32 to 128 network device connections, but if they're used for example in crane internal network then switches support normally between 8 to 16 network device connections.

Layer 3 switches are normally used in large LAN's like corporate network and layer 3 name comes from OSI model, because it operates at layer 3 when normal switch operates at layer 2. A layer 3 switch is normally used in network routing, but it uses same routing protocols than a normal switch. [31]

Switches normally use some popular features such as port monitoring, link aggregation and Quality of Service (QoS). [30] Switches also include some basic functions like Network Time Protocol (NTP) or security settings configuration, but next two sub chapters handle the main configuration about switches.

4.5.1 NAT

NAT is a common way to change IP address when the user wants to change Wide Area Network (WAN) IP address to LAN IP address and hide the WAN address. [33] NAT is highly used in home and corporation network, because NAT functionality is usually found in basic routers. [32]

Normally NAT is used to set all private IP addresses to one public IP address. [32] In RTG solution 1-to-1 NAT is used, because some internal devices need to communicate with external devices. Figure 21 visualizes how easy 1-to-1 NAT can be and of course some other configurations have to be done first, for example correct gateway needs to be defined before it works correctly.

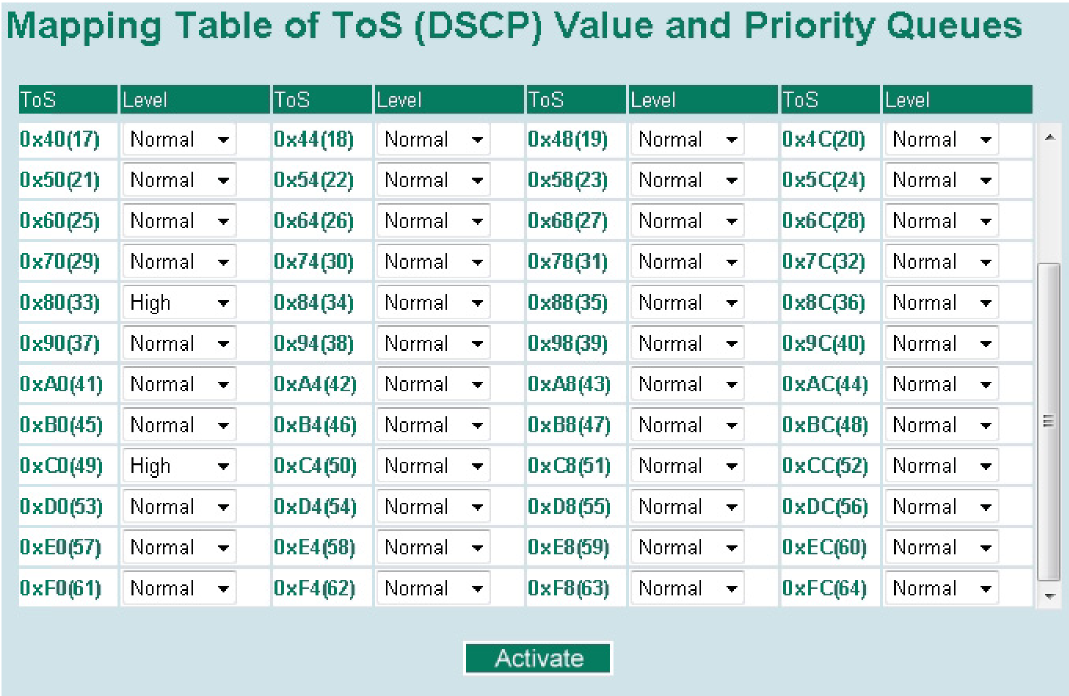
NAT List (2/128)

Enable	Index	Protocol	Local IP	Local Port	WAN IP	WAN Port
✓	1	--	192.168.100.1	--	10.10.1.1	--
✓	2	--	192.168.100.2	--	10.10.1.2	--

Figure 21. *NAT configuration example [33]*

4.5.2 Profinet prioritization with QoS

Profinet prioritization is an important when using automation network based on Profinet. Prioritization happens by using a Wireshark program and the Wireshark captures the data which passes through in internal network. The Wireshark also decodes the data which can be storaged in data capturing PC. A couple minutes of data capturing is enough and then data can be analysed. The easiest way to find right data is to use filtering. Wireshark offers a different filtering type and only correct filter needs to be defined. Profinet Input/Output (PN-IO) is the right filter when it's needed to find Profinet data. Appendix A it's illustrates how PN-IO data can be read in Wireshark and which is the right value in Wireshark. When a correct frame ID has been found from Wireshark then it needs to be set in every switch in internal network as shown in Figure 22 and then defining corrects PN-IO frame ID’s to highest priority.



ToS	Level	ToS	Level	ToS	Level	ToS	Level
0x40(17)	Normal	0x44(18)	Normal	0x48(19)	Normal	0x4C(20)	Normal
0x50(21)	Normal	0x54(22)	Normal	0x58(23)	Normal	0x5C(24)	Normal
0x60(25)	Normal	0x64(26)	Normal	0x68(27)	Normal	0x6C(28)	Normal
0x70(29)	Normal	0x74(30)	Normal	0x78(31)	Normal	0x7C(32)	Normal
0x80(33)	High	0x84(34)	Normal	0x88(35)	Normal	0x8C(36)	Normal
0x90(37)	Normal	0x94(38)	Normal	0x98(39)	Normal	0x9C(40)	Normal
0xA0(41)	Normal	0xA4(42)	Normal	0xA8(43)	Normal	0xAC(44)	Normal
0xB0(45)	Normal	0xB4(46)	Normal	0xB8(47)	Normal	0xBC(48)	Normal
0xC0(49)	High	0xC4(50)	Normal	0xC8(51)	Normal	0xCC(52)	Normal
0xD0(53)	Normal	0xD4(54)	Normal	0xD8(55)	Normal	0xDC(56)	Normal
0xE0(57)	Normal	0xE4(58)	Normal	0xE8(59)	Normal	0xEC(60)	Normal
0xF0(61)	Normal	0xF4(62)	Normal	0xF8(63)	Normal	0xFC(64)	Normal

Figure 22. *Profinet data prioritization and setting the frame ID to the crane’s network*

4.6 Camera configuration

When cameras are installed to the crane, cameras must be configured right, before Liveview connection is possible. Before camera settings changes are possible, camera needs to correct IP address. Best way to IP address changes is to use Axis own software which is a so-called IP utility. Software shows all Axis devices which are in the same network than IP utility computer.

NTP configuration is also very important part when two different devices need to be set at the same time. NTP is a protocol which allows network devices' clocks to synchronize time to distributed clients and servers. NTP can keep these devices time within ten of microseconds and NTP does this in a robust and scalable. The most common way to implement this is a client-to-server configuration. [14]

Figure 23 presents Axis camera video stream settings which can be changed easily by using the browser. The most important settings are resolution and Frames Per Second (FPS) and also compression. Resolution defines width and height pixels which are displayed in video screen and FPS illustrates the number of images displayed per second in a row on the screen.

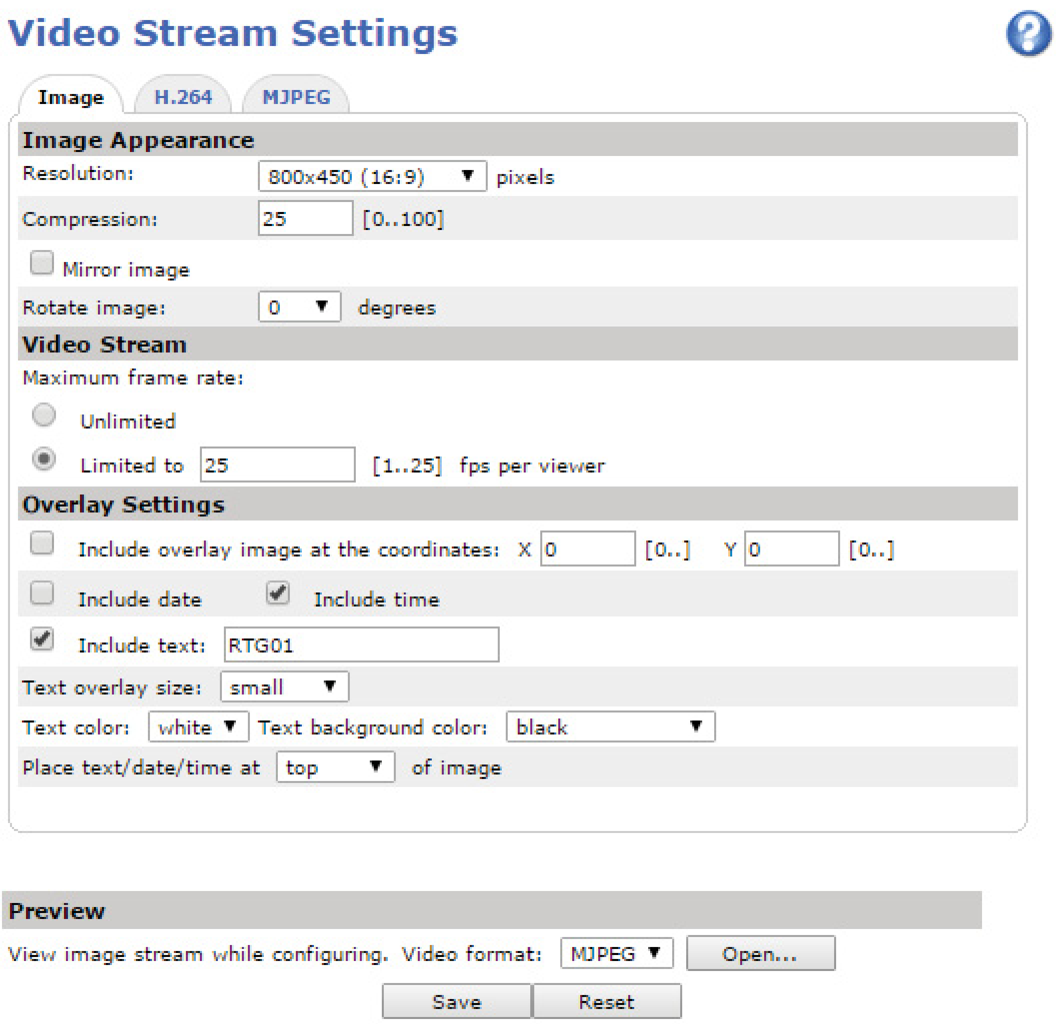


Figure 23. *Video settings example in Axis camera*

4.6.1 Spreader camera testing

In RC and supervised RTG product doesn't include spreader cameras as part of the RC concept. It's still good to perform spreader camera testing and look at what kind of outcome it provides. Spreader camera setup needs the following components:

- Four spreader camera
- Video splitter
- Wireless transmitter
- Wireless receiver
- Video monitor

Four spreader cameras are mounted in the spreader and these cameras are connected to the video splitter channels. Video splitter is connected to a wireless transmitter, 24VDC is also wired to transmitter and it shares the power to the cameras. Transmitter send camera view to the receiver and then it shows camera views in video monitor. 24VDC is also wired to the video monitor and it makes receiver's and monitor's power possible. Video stream is configured to show a squad view in monitor and camera views need to be aligned correctly so that the squad view is aligned when the spreader is touching the container.

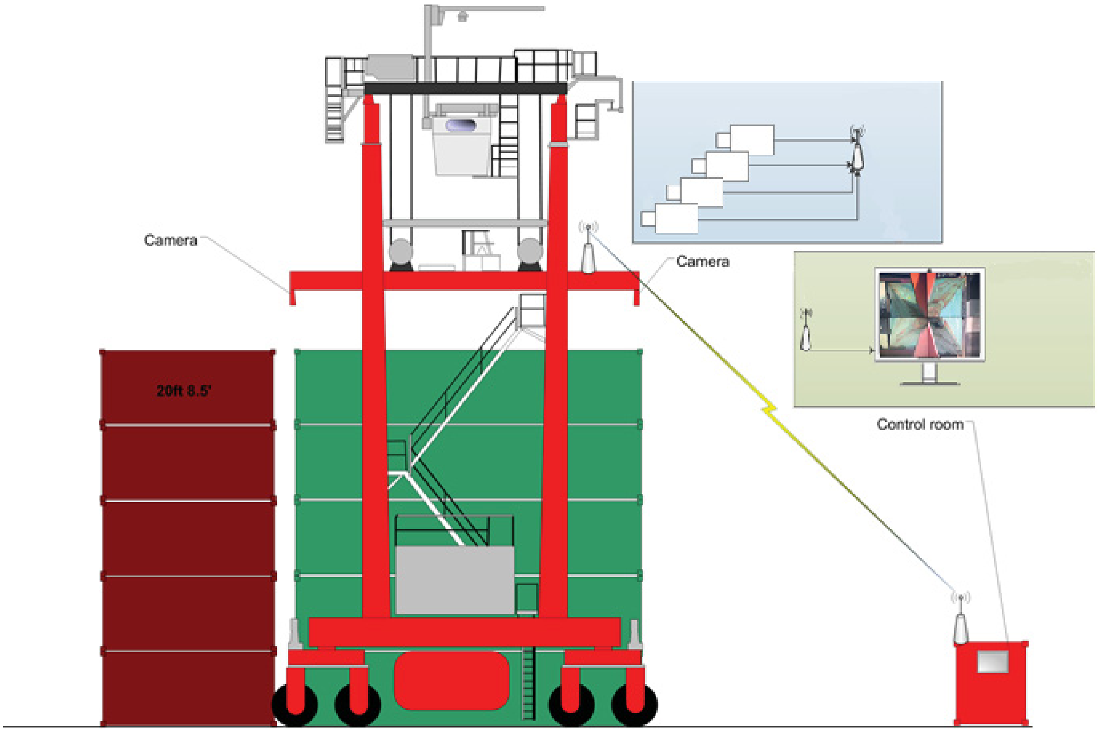


Figure 24. *Wireless communication between the crane and the control room [18]*

4.6.2 Zoom handler configuration

As seen below in Program 7 zoom handler file is in xml format and therefore it is very easy to configure. It includes different tier levels which are defined in millimeters. Every zoom camera includes its own configuration and in each zoom level different zoom height is included. Zoom handler configuration can also handle different spreader size configuration and zoom value can be different in every spreader size.

```
<?xml version="1.0" encoding="utf-8"?>
<zoomhand>
    <tiers border="200">
        <tier name="ground" height="1550"/>
        <tier name="1" height="3400"/>
        <tier name="2" height="4650"/>
        <tier name="3" height="5900"/>
        <tier name="4" height="7150"/>
        <tier name="5" height="8350"/>
        <tier name="6" height="9600"/>
        <tier name="7" height="10850"/>
        <tier name="8" height="12100"/>
        <tier name="9" height="13350"/>
        <tier name="10" height="14600"/>
        <tier name="11" height="15850"/>
        <tier name="12" height="17100"/>
    </tiers>
    <cameras>
        <camera server_name="192.168.xxx.xxx">
            <tier name="ground" zoom20="470" zoom40="390" />
            <tier name="1" zoom20="410" zoom40="350" />
            <tier name="2" zoom20="350" zoom40="280" />
            <tier name="3" zoom20="325" zoom40="210"/>
            <tier name="4" zoom20="300" zoom40="190"/>
            <tier name="5" zoom20="275" zoom40="175"/>
            <tier name="6" zoom20="250" zoom40="165"/>
            <tier name="7" zoom20="225" zoom40="155"/>
            <tier name="8" zoom20="200" zoom40="145"/>
            <tier name="9" zoom20="180" zoom40="135"/>
            <tier name="10" zoom20="160" zoom40="130"/>
            <tier name="11" zoom20="110" zoom40="120"/>
            <tier name="12" zoom20="50" zoom40="100"/>
        </camera>
```

Program 7. *Zoomhand.xml configuration file*

4.6.3 Overlay image

An overlay image means that another image is placed over another image. The best example for the overlay image is a park assist video on car. Video image is moving when driving a car and other image is added to the video view. The image, which is added to another image, shows danger or not-desirable area. In RTG crane overlay image does almost the same thing than a car park assist. When driving a crane to the gantry direction, then overlay images are added to gantry cameras. If crane is skewed, it can be seen in the overlay image and then operator knows that the crane is out of rail. Trolley and overview camera works a bit different than gantry cameras. Overlay images purpose in these cameras is to show the crane the correct position between containers which are to be lifted. When overlay image line is a middle position then operator know that the crane is at its correct logical position.

4.6.4 Camera data optimization

Data can be captured by using a laptop in internal network or external network, but the easiest way to capture data is data capturing PC in crane internal network. PC is installed to switch port which can analyse all possible data in internal network.

Camera data optimization is one part of camera configuration and Wireshark software was good assistance when starting optimization. Figure 25 and Figure 26 illustrate two different test cases. Yellow line illustrates whole data amount which passes through the switch gate in which PC was connected. The biggest data amount change becomes the resolutions and FPS.

In Figure 25 test case included settings which include optimal resolution and optimal FPS settings. Smaller resolution leads to lower data amount and doesn't cause network problems. FPS is limited to 25 so FPS is correctly optimized, but when FPS is higher then data amount is a bit more than lower FPS.

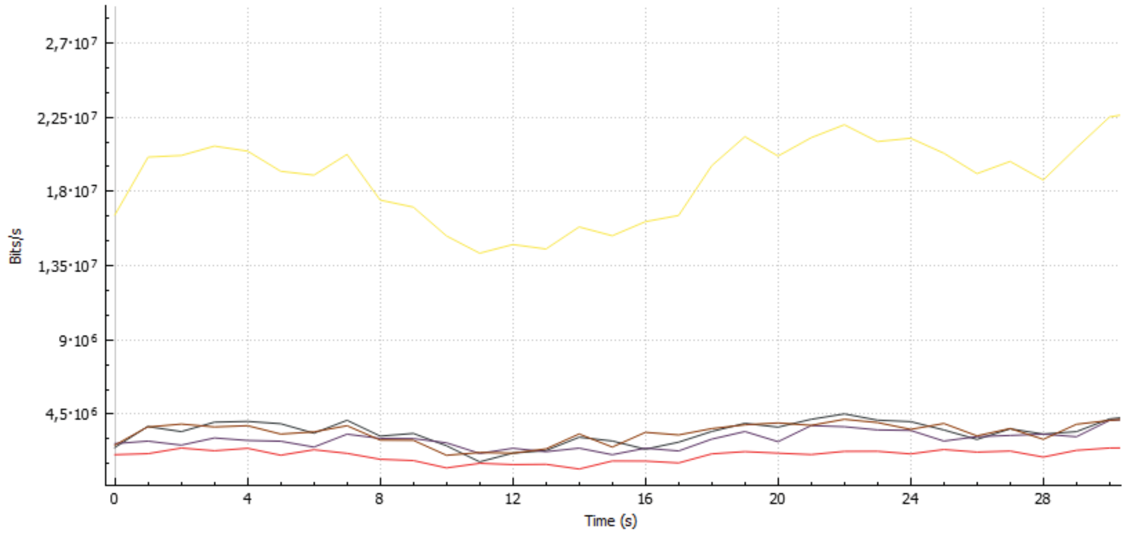


Figure 25. *Camera resolution 800x450 and 25 FPS*

In Figure 26 test case included settings which include too high resolution and optimal FPS settings. Too high resolution can lead to bigger data amount and may cause problems to internal network. FPS is limited to 25 so FPS is correct optimized, but when FPS is higher then data amount is a bit more lower than FPS.

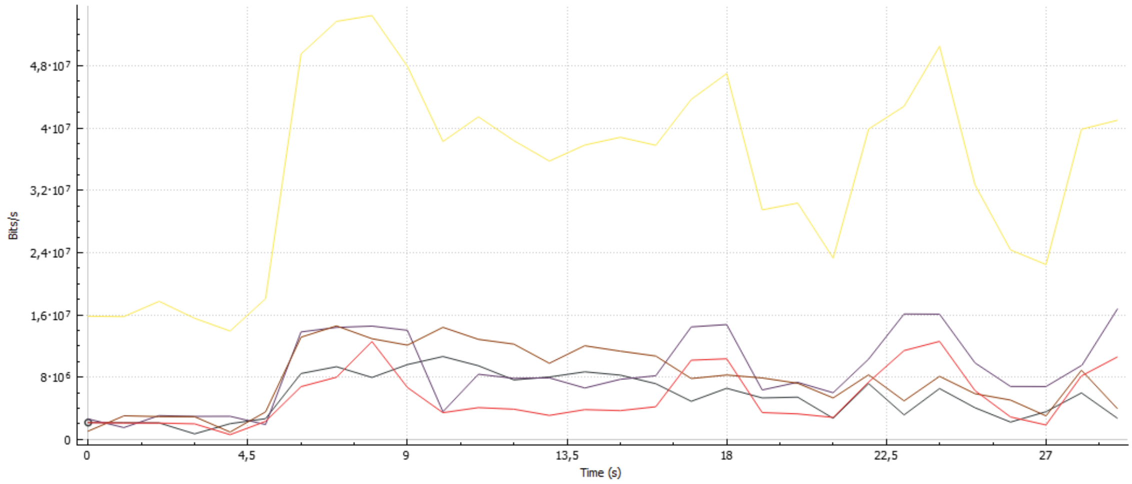


Figure 26. *Camera resolution 1280x800 and 25 FPS*

When analogy cameras are replaced to new IP cameras and correct resolution and FPS are set, these camera setup data amount is also measured. The analogy cameras and IP cameras difference is about 1 to 3 Mbit/s which depends the crane moves. If the crane stays on its place then data amount is smaller, but when crane moves gantry direction then data amount is higher. The total data amount is still not too high and 800x450 resolution and 25 FPS are good.

The camera optimization conclusion, the highest possible FPS is the best option for the optimal settings and resolution must be set to the lowest as possible, but camera view also needs to be clear.

4.7 Global positioning system

GPS is based on satellites which are called a radio positioning system. GPS provides every three dimension position, time and velocity information 24/7 to everyone and everywhere on the earth in regardless of weather. Every GPS satellite rotates the earth every 12 hours and sends continuously navigation signal. Consequently every device can receive location, time or velocity if the device includes some kind of receiver. [34]

Starting from supervised RTG the automation movements need GPS to measure crane's position. GPS solution is presented in Figure 27 which has one reference point which is the so-called GPS base. GPS base sends correction message to GPS receiver over NAT switch. GPS receiver is located on the crane and receiver communicates straight to the VS software.

The GPS configuration is possible to do for the manufacturers own software or to the browser. The configuration includes some basic parts like IP configuration and port settings. Most important configurations are already mentioned in chapter 2.2.6. Understanding these messages are very important so that the positioning is possible.

Before GPS commissioning is possible, the solution requires drawings, antennas installation and also crane position measurements. After above mentioned are done, GPS base, GPS receiver and VS configuration are possible.

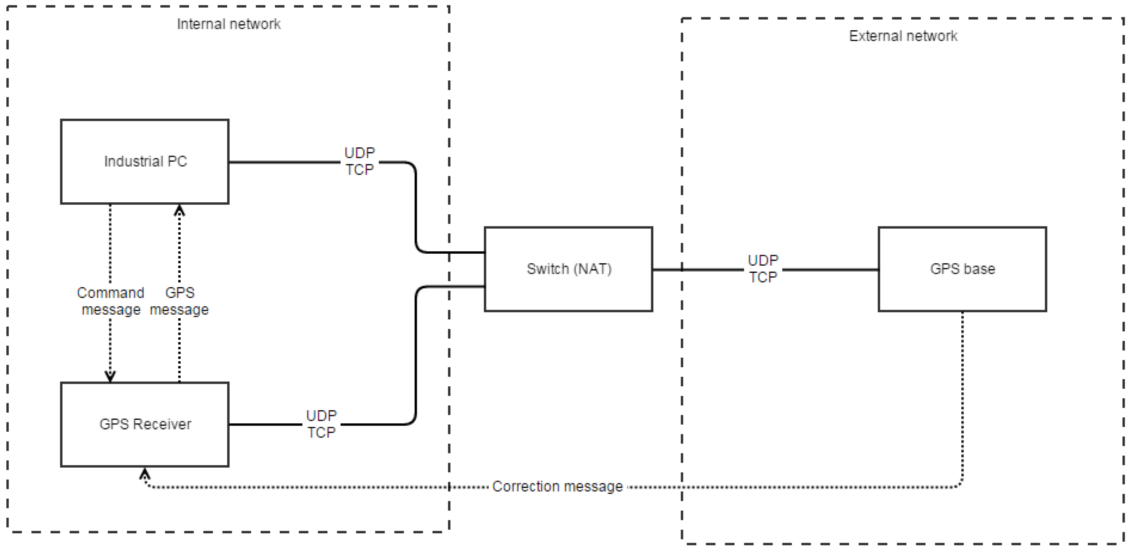


Figure 27. *Data movement in the GPS solution*

4.8 Audio device installation and configuration

The purpose of audio device is to make working easier and safer between truck driver and remote operator by enabling audio communication between them. A Call station in the crane is installed near of a truck lane which is in diesel opposite side. Microphone is activated by pressing the tangent key in call station and in RC table a push-to-talk button is required. RC table audio connection is available for each crane, but only in one crane at the time. That means when RC table is connected to crane, which needs operation, then audio connection is available between truck lane and RC table.

Audio connection is not as simple as the Figure 28 suggests. It needs different configurations changes in different software. RCC needs configuration changes if compared to only video connection and Liveview also needs changes to both configuration files which are already mentioned.

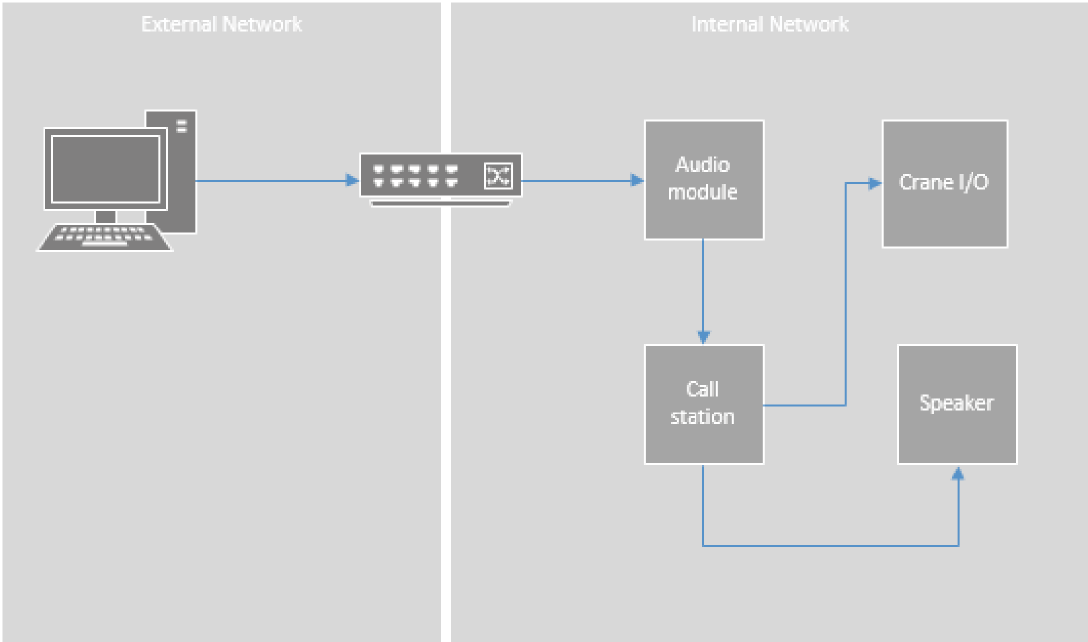


Figure 28. *Audio device simple coupling figure*

Audio module can be configured by browser and over Ethernet after correct IP address is set to device. The most important settings which have to be defined in Figure 29 are audio mode and encoding standard. Also correct input port has to be defined, so it depends on to which port speaker and microphone are connected.

Audio mode can be set to Half duplex or full duplex. Half duplex means when one device is transmitting and another device only receives information so communication happens alternately. Full duplex means that both devices can transmit and receive information simultaneously between each other. [28]

AAC coding standard also has to be defined in Liveview settings when audio device is connected to crane and RC table. AAC is also recommended to be used in this audio device and it is default in use when the audio device configuration starts.

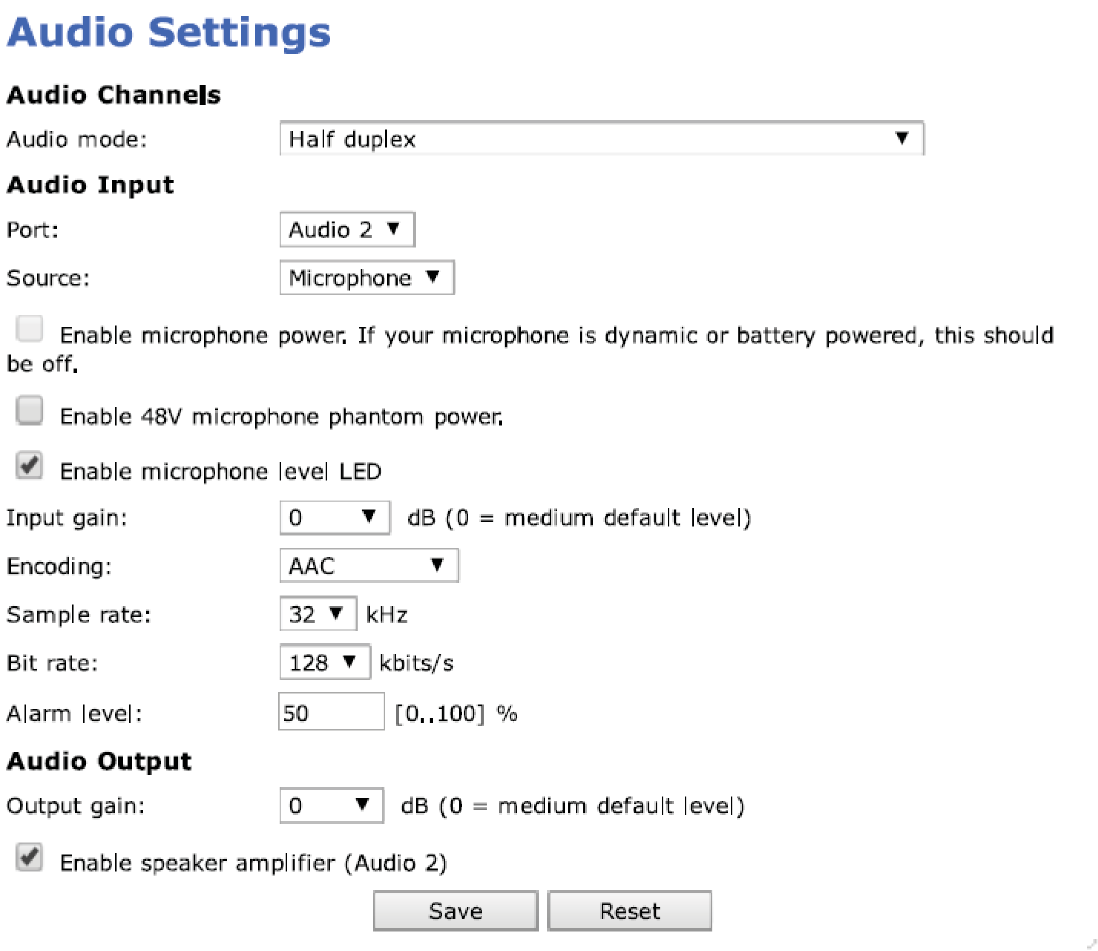


Figure 29. Audio module configuration in browser

4.9 Final testing and reporting

Testing is large part of the project when developing something new. Normally testing happens step by step, but the most significant testing is at the end of the project. Some of these tests happens firstly in virtual environment, but final tests happen in real environment where real machines are being used.

Reporting is done by the author who has implemented the planned solution. When reporting happens as soon as something is done then the document is also the best and the most detailed one. The reporting in this case means testing methods and cases, hardware's and software's configuration and installation which are included with the most specific details.

4.9.1 Test methods

Testing is important part when developing a new product for the market. Right test methods also have to be defined, because without a good plan and test environment the testing is hard. Probably in nowadays when testing large device and many software functionalities at same time, virtual environment or simulator is the right way to start testing. In Kalmar's case both have been implemented and are used for different purposes and different software functionalities enables. Virtual environment includes more specific tests before new software version will be released.

In normal situation when a new software is published and it has a test environment it can almost be classified as real. Then simulator environment can be used to test the new software before it will be installed to real crane. If the new software version works as it should, then it can be tested in a real crane. It should work in the same way as in simulator environment but there is always risk that it doesn't work the same way.

4.9.2 Test cases

Test cases have been created on the basis of defined the crane functionalities have been defined and software play a major role when defining the crane's functionalities. Every test case is somehow connected to a software and its activities. Some test cases can include very specific details about how something should work and they can include many different steps. Some tests can only contain one main instruction such as “Stack five 20 feet container on top of each other”, but probably it includes some operating procedures and so on. The last part of a new product is always an endurance test and it includes a test cycle which must be carried out for a specified time.

Simulated TOS environment is a part of test automation framework and in most cases it can be used in virtual machines. Simulated TOS is the sum of many factors and it needs many software components to work perfectly. Simulated TOS makes testing easier than without it, because it makes planned cycle possible.

Basically it can be used if the same test cycle has been repeated many times in a row. Every container's place needs to be known and container's size also. It speeds up the work, because each job does not have to be created separately.

Test cases are created in one place so that the states of all test cases can be detected at once and the percentage of tests can also be seen at the same time. When a test is started then it’s in progress state and if it passes it can signify as a passed state. Some test cases also require some illustrative figure about the test. For example if some safety issues are being tested, it would be nice to show an illustrative figure.

There are also failed tests cases which do not meet the requirements. When some test cases fail, the reason has to be reported. The report must be sent to the software development team which develops the software that failed the test. In a normal situation the report includes logs and an explanation of how the mistake was made. When software development team has fixed and closed the issue, then the test can be performed again and marked as passed.

4.9.3 Commissioning checklist

Commissioning checklist's purpose is to make a list for every new installation which have to be done in new project in customer sites. It has been collected for each part which include every release components. Example of detailed overview camera checklist:

- Overview camera installation
- Overview camera cabling
- Overview camera alignment
- Overview camera IP change
- Overview camera configuration

The more detailed the list is, the better it is for workers to remember to go through every part in the customers site in the right order. For every part, which is included in checklist, a more detailed document can be found in commissioning documentation.

4.9.4 Commissioning reporting

The purpose of commissioning documentation is to make installation, configuration and other tasks at the customer site as easy as possible. When a Kalmar's automation commissioning engineer works at customer site, they should not need to think what is the next step. Therefore, every smallest detail needs to be documented rather than jumping over a simple tasks which are in your own opinion very clear. If commissioning worker has to think for a long time which is the next step, then the documentary has failed.

When commissioning documentation happens, it’s very important to use pictures as much as possible, because one picture tells more than a thousand words. It’s always best to tell something and make cross-reference to some picture. Everything that is included in this master’s thesis are documented and some of them are handwritten by me, such as GPS documentation and camera configuration. The aim was to make the documents very clear and each point, which needs configuration changes, needs to be documented clearly and also the illustrative pictures taken.

5. CONCLUSION

This master’s thesis one goal was to create for a configuration for hardware and software which are installed to RC and supervised RTG. Network issues were also the problem for many months until they were finally solved. The biggest part was testing which was involved in almost every work day. The goal was completed and the end result was functional entity.

Network topology creation was an important part when starting to fix the crane network problems. Some old devices were removed to make the topology clearer. After topology creation began the problem solving. Profinet prioritization was the one part that effected performance of the network. Probably the biggest effect in network performance was the camera data optimization and video data transmission. While testing different camera options, correct settings were found which included suitable amount of data and still the visibility was good. Transmission type was tested because some packets were skipped which made some delays in camera views. The result in the end was a workable crane internal network which included an appropriate amount of data.

During the master’s thesis software and hardware installation and configuration was a part of everyday work. Some XML files had been done also if thinking about alarm list, tag map and data source map. Configuration's purpose was to create a workable entity where every device and software would work as it should. The configuration was not always so easy because some configuration introduction was missing sometimes so problem solving had to be done. Eventually when all testing was done, all software and hardware worked correctly.

The UI files were created because new functionalities were added if compared to manual RTG. The new files included maintenance pages which were only used when commissioning happened in customer terminal. More relevant pages were created because end users have to see some information when operating the crane. The most important views were the virtual desk view which illustrates virtual buttons and information which doesn't fit in the physical RC table. GPS and job information pages include different information about crane position and movements. The pages became easy to use and design was easy to understand.

The testing part was the longest journey because the tests didn't just take place at the end of the project. When the new software release was published, tests had to be done in the simulator and after that it had to be tested how the software works in real environment. The crane functionalities also changed many times and the tests had to be done again. Software developers were also testing their software's in the real crane. The final tests were completed and there were almost 100 tests done with sub steps in every test cases. The crane functionalities were tested and also endurance tests was completed successfully.

5.1 Future work and automation level releases

In the future the new automation level arrives to the market. Automation increases and every automation level needs less operator control than previous automation levels. Biggest improvements are normally in software control, but when automation increases then safety becomes more important. When responsibility is transferred more from the operator to the automation then safety devices are more important. Every smallest safety issue needs to be noted and solved. Also better visibility from the camera makes the operating safe, when every smallest detail from the camera is clear.

5.1.1 Camera improvements

Every automation level required good visibility from the office to the crane block. It does not just make the operating safer, it makes the operating much more comfortable. Probably everyone tries to make the camera solution better and make it as human eyes. Until that is possible, cameras places and quality are important. The camera needs to be better than analogy camera resolution. When improving resolution, every smallest detail is clearer. At first, an analogy camera needs to upgraded to a better quality. At first a HD video is enough but probably after two years a full HD camera is required and so on.

There are different camera solutions which have to be considered, not only just in normal cameras in different opening angles. One worthy option is the 360 degree camera. There are already glasses which can already be put on. When glasses are on the operator can watch in every direction, even backwards. The 360 degree camera solution still needs to be improved and considered how to show other relevant information from the crane when glasses are on. Maybe this relevant information can be added for overlay image, but the overlay image must be a moving image.

5.1.2 Third automation level

Third automation level, so called Semi-Automated RTG is one of the future products and it is not yet for as a commercial, but the development starts in the summer 2017. Semi-automated RTG is the first level, which doesn't need any kind of supervision by the operator. The automated area (stacking area) is fenced and there are also safety systems in truck lane. When job arrives from TOS, then remote desk connects automatically and the crane starts to operate containers automatically if the crane is on automated area, but if operation happens in truck lane then the operator needs to finalize the job. [13]

The architecture is not so different from supervised RTG and the biggest update is new software functionality in PLC, VS and CS. Hardware include massive updates, because when automation increase then the crane needs more safety devices. The laser scanners in rear sill beam side (truck lane) are a good example, which are added in the crane when it is necessary to increase safety. Purpose of the laser scanner is to recognize the object and slow down the crane or completely stop it if the object is too close to the crane.

5.1.3 Fourth automation level

Fourth automation level, so called Automated RTG also includes automatic pick and place functionalities in stacking area, but in this level also gantry movements are automatic so the stacking area movements are fully automatic. All functionalities work same as a semi-automated RTG, but gantry movements increase in automation mode. The architecture is very close to semi-automated RTG and the biggest updates are in the software side. [13]

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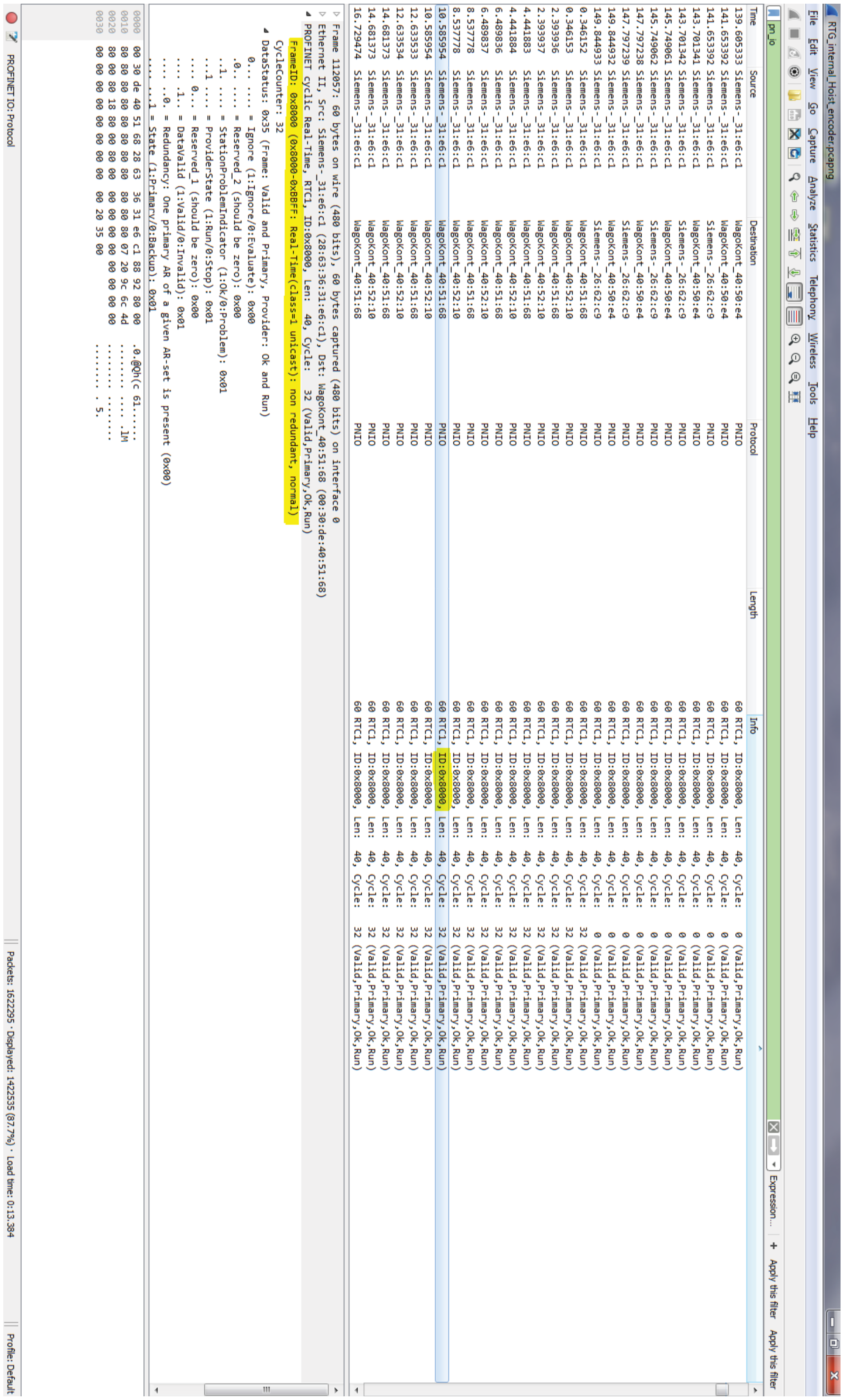
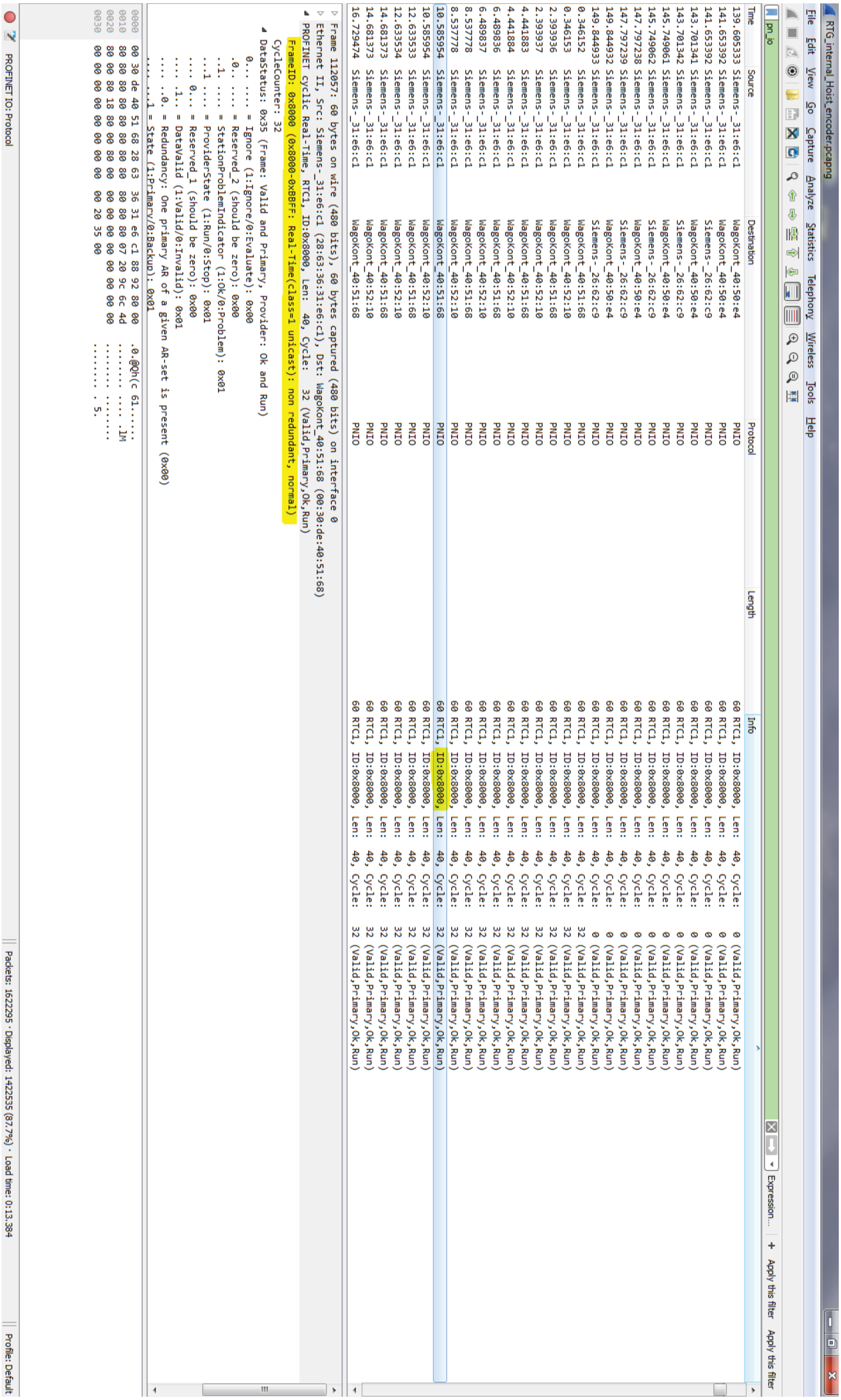
APPENDIX A: PROFINET FRAME ID'S IN WIRESHARK





RTG_internal_Hoist_encoder.pcapng
File Edit View Go Capture Analyze Statistics Telephony Wireless Tools Help
pn_io
Expression... + Apply this filter Apply this filter
Time Source Destination Protocol Length Info
139.605333 Siemens-_31:e6:c1 WagoKont_40:50:e4 PNIO 60 RTC1, ID:0x8000, Len: 40, Cycle: 0 (Valid,Primary,Ok,Run)
141.653392 Siemens-_31:e6:c1 WagoKont_40:50:e4 PNIO 60 RTC1, ID:0x8000, Len: 40, Cycle: 0 (Valid,Primary,Ok,Run)
141.653392 Siemens-_31:e6:c1 Siemens-_26:62:c9 PNIO 60 RTC1, ID:0x8000, Len: 40, Cycle: 0 (Valid,Primary,Ok,Run)
143.701341 Siemens-_31:e6:c1 WagoKont_40:50:e4 PNIO 60 RTC1, ID:0x8000, Len: 40, Cycle: 0 (Valid,Primary,Ok,Run)
143.701342 Siemens-_31:e6:c1 Siemens-_26:62:c9 PNIO 60 RTC1, ID:0x8000, Len: 40, Cycle: 0 (Valid,Primary,Ok,Run)
145.749061 Siemens-_31:e6:c1 WagoKont_40:50:e4 PNIO 60 RTC1, ID:0x8000, Len: 40, Cycle: 0 (Valid,Primary,Ok,Run)
145.749062 Siemens-_31:e6:c1 Siemens-_26:62:c9 PNIO 60 RTC1, ID:0x8000, Len: 40, Cycle: 0 (Valid,Primary,Ok,Run)
147.797238 Siemens-_31:e6:c1 WagoKont_40:50:e4 PNIO 60 RTC1, ID:0x8000, Len: 40, Cycle: 0 (Valid,Primary,Ok,Run)
147.797239 Siemens-_31:e6:c1 Siemens-_26:62:c9 PNIO 60 RTC1, ID:0x8000, Len: 40, Cycle: 0 (Valid,Primary,Ok,Run)
149.844932 Siemens-_31:e6:c1 WagoKont_40:50:e4 PNIO 60 RTC1, ID:0x8000, Len: 40, Cycle: 0 (Valid,Primary,Ok,Run)
149.844933 Siemens-_31:e6:c1 Siemens-_26:62:c9 PNIO 60 RTC1, ID:0x8000, Len: 40, Cycle: 0 (Valid,Primary,Ok,Run)
0.346152 Siemens-_31:e6:c1 WagoKont_40:51:68 PNIO 60 RTC1, ID:0x8000, Len: 40, Cycle: 32 (Valid,Primary,Ok,Run)
0.346153 Siemens-_31:e6:c1 WagoKont_40:52:10 PNIO 60 RTC1, ID:0x8000, Len: 40, Cycle: 32 (Valid,Primary,Ok,Run)
2.393936 Siemens-_31:e6:c1 WagoKont_40:51:68 PNIO 60 RTC1, ID:0x8000, Len: 40, Cycle: 32 (Valid,Primary,Ok,Run)
2.393937 Siemens-_31:e6:c1 WagoKont_40:52:10 PNIO 60 RTC1, ID:0x8000, Len: 40, Cycle: 32 (Valid,Primary,Ok,Run)
4.441883 Siemens-_31:e6:c1 WagoKont_40:51:68 PNIO 60 RTC1, ID:0x8000, Len: 40, Cycle: 32 (Valid,Primary,Ok,Run)
4.441884 Siemens-_31:e6:c1 WagoKont_40:52:10 PNIO 60 RTC1, ID:0x8000, Len: 40, Cycle: 32 (Valid,Primary,Ok,Run)
6.489836 Siemens-_31:e6:c1 WagoKont_40:51:68 PNIO 60 RTC1, ID:0x8000, Len: 40, Cycle: 32 (Valid,Primary,Ok,Run)
6.489837 Siemens-_31:e6:c1 WagoKont_40:52:10 PNIO 60 RTC1, ID:0x8000, Len: 40, Cycle: 32 (Valid,Primary,Ok,Run)
8.537778 Siemens-_31:e6:c1 WagoKont_40:51:68 PNIO 60 RTC1, ID:0x8000, Len: 40, Cycle: 32 (Valid,Primary,Ok,Run)
8.537778 Siemens-_31:e6:c1 WagoKont_40:52:10 PNIO 60 RTC1, ID:0x8000, Len: 40, Cycle: 32 (Valid,Primary,Ok,Run)
10.585954 Siemens-_31:e6:c1 WagoKont_40:51:68 PNIO 60 RTC1, ID:0x8000, Len: 40, Cycle: 32 (Valid,Primary,Ok,Run)
10.585954 Siemens-_31:e6:c1 WagoKont_40:52:10 PNIO 60 RTC1, ID:0x8000, Len: 40, Cycle: 32 (Valid,Primary,Ok,Run)
12.633533 Siemens-_31:e6:c1 WagoKont_40:51:68 PNIO 60 RTC1, ID:0x8000, Len: 40, Cycle: 32 (Valid,Primary,Ok,Run)
12.633534 Siemens-_31:e6:c1 WagoKont_40:52:10 PNIO 60 RTC1, ID:0x8000, Len: 40, Cycle: 32 (Valid,Primary,Ok,Run)
14.681373 Siemens-_31:e6:c1 WagoKont_40:51:68 PNIO 60 RTC1, ID:0x8000, Len: 40, Cycle: 32 (Valid,Primary,Ok,Run)
14.681373 Siemens-_31:e6:c1 WagoKont_40:52:10 PNIO 60 RTC1, ID:0x8000, Len: 40, Cycle: 32 (Valid,Primary,Ok,Run)
16.729474 Siemens-_31:e6:c1 WagoKont_40:51:68 PNIO 60 RTC1, ID:0x8000, Len: 40, Cycle: 32 (Valid,Primary,Ok,Run)
Frame 112057: 60 bytes on wire (480 bits), 60 bytes captured (480 bits) on interface 0
Ethernet II, Src: Siemens-_31:e6:c1 (28:63:36:31:e6:c1), Dst: WagoKont_40:51:68 (00:30:de:40:51:68)
PROFINET cyclic Real-Time, RTC1, ID:0x8000, Len: 40, Cycle: 32 (Valid,Primary,Ok,Run)
FrameID: 0x8000 (0x8000-0xBBFF: Real-Time(class=1 unicast): non redundant, normal)
CycleCounter: 32
DataStatus: 0x35 (Frame: Valid and Primary, Provider: Ok and Run)
0... .... = Ignore (1:Ignore/0:Evaluate): 0x00
.0.. .... = Reserved_2 (should be zero): 0x00
..1. .... = StationProblemIndicator (1:Ok/0:Problem): 0x01
...1 .... = ProviderState (1:Run/0:Stop): 0x01
.... 0... = Reserved_1 (should be zero): 0x00
.... .1.. = DataValid (1:Valid/0:Invalid): 0x01
.... ..0. = Redundancy: One primary AR of a given AR-set is present (0x00)
....1 = State (1:Primary/0:Backup): 0x01
0000 00 30 de 40 51 68 28 63 36 31 e6 c1 88 92 80 00 .0.@Qh(c 61......
0010 80 80 80 80 80 80 80 80 80 80 80 07 20 9c 6c 4d .... .lM
0020 80 00 80 18 80 00 80 00 00 00 00 00 00 00 00 00 ....
0030 00 00 00 00 00 00 00 00 00 20 35 00 .... 5.
PROFINET IO: Protocol
Packets: 1622295 · Displayed: 1422535 (87.7%) · Load time: 0:13.384
Profile: Default