Arthur Lenkiewicz

Measurement system in the wooden mid-rise apartment

SeAMK

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Thesis abstract

Faculty: School of Technology

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The purpose of this Bachelor´s thesis was to design an intelligent data acquisition system to a wooden mid-rise. This system acquires sensor data from structures of the high-rise and sends this data using cloud-technology for further analyzing. Designed data system is based on modern bus technology to achieve ecological and versatile network.

The theoretical part of this thesis includes basic theory about bus technology, Ethernet and cloud servers. Also the structural and ecological side of this project were reported, because these were the factors for choosing the equipment. In the practical part of this thesis solutions for the data system, cloud technology and the communication between them were studied. The practical part includes also reasons for choosing the particular applications and ideas for alternative solutions.

This thesis is a part of the "Wooden apartment house as a study environment, stage 1" – project, which aims to contribute to the ecology of construction technology and help to raise the status of timber building in Finland. The project was carried out in co-operation with Seinäjoki University of Applied Sciences, Tampere University of Technology and Lakea Oy.

SEINÄJOEN AMMATTIKORKEAKOULU

Opinnäytetyön tiivistelmä

Koulutusyksikkö: Tekniikan yksikkö

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Tämän opinnäytetyön tarkoituksena oli suunnitella älykäs tiedonkeruujärjestelmä puiseen kerrostaloon. Tämä järjestelmä kerää mittaustietoa puukerrostalon rakenteista ja siirtää tiedon pilvipalveluita käyttäen myöhempää analysointia varten. Suunniteltu järjestelmä perustuu nykyaikaiseen väyläteknologiaan, jonka avulla voimme saavuttaa ekologisen sekä mukautuvan verkoston.

Opinnäytetyön teoreettinen osa sisältää teoriaa väyläkaapeloinnista, Ethernetistä ja pilviteknologiasta. Työssä käsitellään myös rakenteellista ja ekologista puolta, koska nämä asiat vaikuttivat projektissa käytettyjen tuotteiden valintaan. Käytännön osa sisältää ratkaisut väylätekniikkaan, pilvi-palveluun sekä näiden osien väliseen kommunikaatioon. Käytäntö pitää sisällään myös perustelut valintoihin ja ideoita siitä, kuinka nämä ratkaisut voidaan tehdä eri tavalla.

Tämä työ on osa "Puukerrostalo tutkimusympäristönä, Vaihe 1" – projektia, jonka tarkoituksena on edistää rakennusteknisten ratkaisujen ekologisuutta ja parantaa puurakentamisen asemaa Suomessa. Projekti suoritettiin yhteistyössä Seinäjoen Ammattikorkeakoulun, Tampereen Teknillisen Yliopiston sekä Lakea Oy:n kanssa.

Avainsanat: kenttäväylä, Ethernet, mittaustieto, pilvipalvelut

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Abbreviations and terms

Building automation   Contains automatic functions, with the aid of which a building's HVAC-processes are controlled. (Piikkilä & Sahlstén 2006, 9)

CLT   Cross Laminated Timber. Construction material for buildings.

Ethernet   The cabling and data transfer solution used in local area networks (LANs) (Indiana University 2015).

Fieldbus   Digital interfaced data transfer solution, which connects intelligent measurement- and control devices. Transferring is bidirectional. (Piikkilä et al 2006, 32.)

IT   Information Technology

PLC   Programmable Logic Controller is used in automation systems to control and analyze real time processes.

Protocol   In building automation protocol is a unified way of communication between equipment.

Sensor   Equipment which indicates the variations in process, these variations can be physical or chemical.

Sub-distributive board

Connection point for field devices and signal processing. (Piikkilä et al 2012, 268).

Topology   Physical structure of the system, the way the equipment is connected together.

1 INTRODUCTION

Wood construction is a growing trend in Finland but the source of renewable wood is highly underestimated. Increasing ecological needs are demanding more from every action but especially from industry and construction. Because of the demand, solutions must be found.

Wooden apartment house as a study environment, stage 1 -project is researching the possibilities of wooden high-rises made from CLT-plates. Ecology during construction and use, cost-effectiveness and the properties of a wooden house are the main focus points in this project. A wooden mid-rise with intelligent and large-scale automation and measurement system will give information about different changes during a long period. This helps to indicate the building's properties in harsh weather conditions and thus to improve wooden constructions in the future.

1.1 Purpose

The purpose of this thesis is to determine the possibilities to create an intelligent measurement network. The factors affecting the planning are cost effectiveness, ecology, suitability for a wooden mid-rise and versatility.

This thesis and the related documents are planned to give instructions for planning a measurement network for wooden houses. It is also meant to be a guideline for standards and factors that are essential for building automation in wooden environment. This work package is included in the wooden apartment house as a study environment, stage 1 -project plan and is physically realized in phase two of this project.

1.2 Structure

Chapters 1, 2 and 3 give basic information about building automation. There it can be seen what kind of technology is used inside buildings and how these technologies are divided into different categories.

Chapter 4 presents the characteristics of bus technology and the different topologies how these systems can be built. The systems based on bus technologies are built by using certain hierarchy models and these models are also presented in chapter 4.

Chapters 5 and 6 tell about the data transferring and storing methods. These chapters contain information about OPC UA -protocol and cloud technologies.

Chapter 7 is about the measurement system that was designed for this project. This chapter includes information about the structure and equipment that were used to design the measurement system.

Chapter 8 contains information about the laboratory system which was built to prove the functionality of the main system. In this chapter there is information about the equipment used to build this laboratory system and how these pieces were connected together.

Next chapter, which is chapter 9, tells about how budget calculations can be made. This chapter is the final chapter to describe the work inside the project.

The last chapter summarizes the whole project. There are presented the things which were improved during the project, what was achieved and what kind of problems occurred.

2 Building automation

The level of automation has risen steadily over the years because of increasing demand for comfort and convenience. Building automation should be designed to be updatable to meet the changing regulations and practical needs. (Merz, Hansemann & Hübner 2009, 1.) In building automation HVAC-processes are controlled by automatic survey, control and adjustment operations. Better conditions, reduced financial and personnel risks, reduced need for routine work and energy saving are the benefits gained through building automation. (Piikkilä et al 2006, 9.)

2.1 Private residential buildings and building automation

Most common examples of building automation in private buildings are heating and light control. It should also be noticed that heat control includes not only sophisticated combustion controllers but also room temperature regulations. Exterior light control is usually connected to motion sensors and when combined with a brightness sensor, the result is a comfortable and energy saving solution. The main points where building automation focuses in the private sector are comfort and convenience, security, cost effectiveness and saving energy. (Merz et al 2009, 2.)

2.2 Commercial buildings and building automation

There is a variety of automation systems for ventilation, air conditioning and heating. These systems are interconnected via field buses and networks to ensure smoothness and economy of automation control. (Merz et al 2009, 2.)

Flexibility is a key factor in the systems of commercial buildings. If a company is planning to change the layout of a room and divide it into several smaller rooms, automation network must adapt to the new situation and allow these changes. (Merz et al 2009, 3.). The main points where building automation focuses in the commercial sector are comfort and convenience, communication via bus systems and networks, flexibility, cost effectiveness and saving energy. (Merz et al 2009, 3.)

3 Structure and technology of building automation

Present building automation systems contain different hierarchical layers. In the hierarchy picture (Figure 1.) it is shown that there are usually 3 - 4 layers which are an administrative system layer, a monitoring layer, a sub-distributive layer and a field layer. The central monitor and the field network are connected by an administrative system. The administrative network can combine PCs and can transfer reports and measurement data. (Piikkilä et al 2006, 10.)

The field network can be constructed in two ways: each field component is connected to a sub-distributive system with a separate, individual cabling or they can be connected via a serial interface. Sub-distributive systems are called traditional systems and serial interface connection is called a scattered system, also known as a fieldbus. (Piikkilä et al 2006, 11.)

The controlling and surveying of building automations is realized with a monitoring layer. This layer is capable of printing reports and alarm data. The sub-distributive layer contains input and output points, a processor and memory. For example, adjustment and control are operated by a user interface and adjustment programs. (Piikkilä et al 2006, 11.)

Building automation can also be integrated with other fields of building technology. The most common example of integrated systems is a building security system. Cameras, fire-alarms and passing survey can be integrated into the same system with the building automation so that everything can be managed from the same control system. Also data exchange and network are common. This integrated system greatly reduces the total cost of the building system. (Piikkilä et al 2012, 268.)
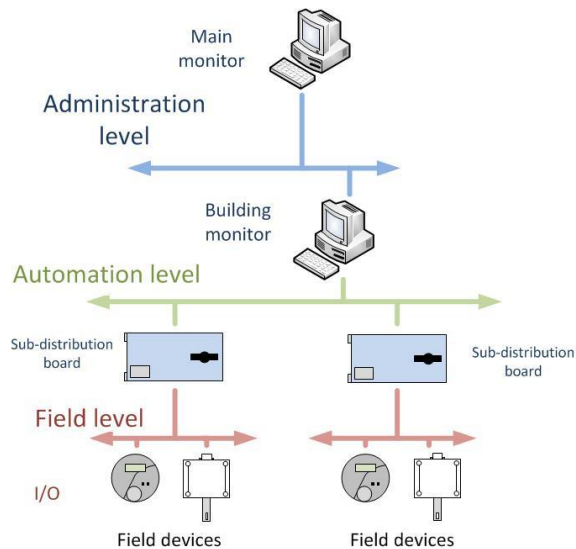
Figure 1. Hierarchy of automation systems

Field devices can be divided into two groups: sensors and actuators. Sensors are the inspectors of the process and actuators are the doers. Sensors are used to indicate the status and changes of a process. Usual targets of the inspection are movement, temperature and flow. Typical sensors used in building automation are humidity sensors and temperature sensors.

3.1   Fieldbus

Technology is evolving fast and demands for quality and controllability are getting higher. Needs for larger spaces in buildings are pushing building automation to a more effective direction which is really hard to reach with older technology. The theory of designing larger systems is clear but the physical implementation is very expensive and energy inefficient. Also the complexity of automation structures and data transfer gives own challenges for planning.

Fieldbus technology offers a simple and reliable solution for users. Supervision and complete control of network makes process and control automation easily manageable and versatile. Bidirectional data transfer reduces the space needed for cabling and lowers the costs. Reliability is one of the most important aspects in process automation, so supervising the process gives steady quality and longer

lifespan. (Piikkilä et al 2006, 33.) Fieldbus is a communicational channel that combines field devices and controlling devices. (Piikkilä et al 2006, 257.)

Bus technology is really different compared to the older systems which started to take place in the 1960s. The biggest difference is that in bus systems intelligence is located inside sensors and actuators. Intelligence means processors, memory and protocol programs that are located inside field devices. (Piikkilä et al 2006, 12.)

As seen in the system picture (Figure 2.), traditional automation system is constructed so that each sensor is controlling an actuator and all this data traffic is allocated and analyzed in sub-distributive boards. This limits versatility of the system.
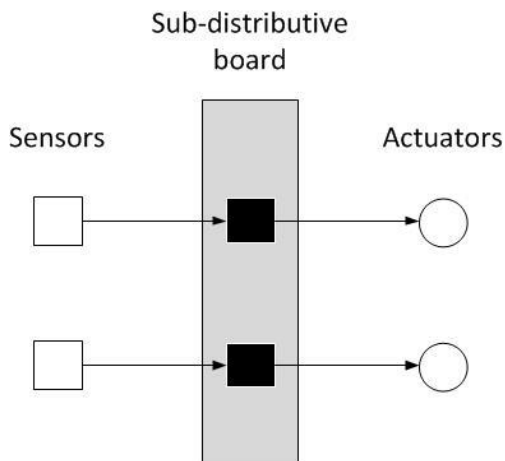
Figure 2. Traditional sub-distributive system

Fieldbus system is based on versatility, reliability and simplicity. All the data is transferred through one cable and the equipment is connected together. The pieces of equipment are communicating with each other using a certain protocol. As shown in the picture of the scattered system (Figure 3.), this gives the possibility to change and reallocate signals and create completely new ways of control. Bus network is simple, and it allows the scattered network. As a result the sub-distributive solution is not needed anymore.

Figure 3. Bus network, the scattered system

3.2 Standards

Standards are designed to merge devices from different manufacturers together and helping maintenance routines. Building automation does 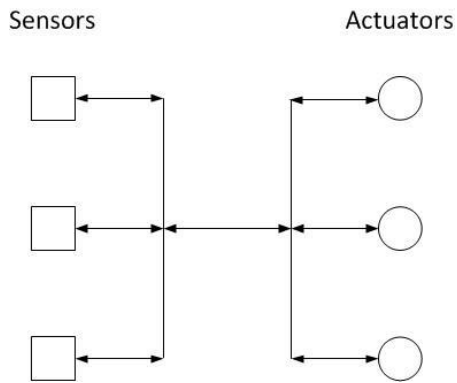not have many official specifications but you can find helpful and straight references from different explanatory notes. There are not straight regulations for functionality either, but regulations for indoor climate and energy efficiency can be achieved only with a certain level of building automation. (Piikkilä et al 2006, 25.)

The signals used in automation are standardized. For example, an analog signal has the following standards: IEC 60381-1 for current signal, IEC 60381-2 for voltage signal, IEC 60929 for 1-10 V control and IEC 60946 for the binary signal based on voltage. (Piikkilä et al 2006, 28.)

3.3 Communication and cabling in building automation

Cables are used to transfer data between stations using electrical or optical technology. Data can be transferred analogically or digitally and the maximum size of data package is not defined. (Piikkilä et al 2006, 98.)

Communication can be divided to two groups: wired and wireless communication. Wired communication can be implemented for example with different twisted twin cables, optical fibers or coaxial cables. Wired solution needs solid material for

moving data. Cables are in crucial position in quality of the communication when using wired network. Wireless communication can be implemented with satellite, optical sensors or free signals which are moving through air. Satellites are in crucial position in quality of communication when using wireless network. (Piikkilä et al 2006, 98.)

Sub-distributive boards are usually constructed with RS-485. This physical cabling can use open protocols or closed protocols. IT-technology is growing rapidly so TCP/IP is more frequently used in sub-distributive boards. (Piikkilä et al 2012, 135.)

When choosing a cabling for field network, there are few things that have to be considered: what kind of measurements are done, how big is the supply voltage and what are working principles of field devices. To choose the right cabling, all decisions should be based on supplier´s instructions. (Piikkilä et al 2012, 134.)

Common cables used in building automation:
   − 230 VAC controls, cable for example MMJ/MMO n x 1,5
   − measurement transmitters, protected cable NOMAK 2 x 2 x 0,5 + 0,5
   − alarms and indications, protected cable NOMAK n x 2 x 0,5 + 0,5
   − actuators, 230 VAC, MMJ 4 x 1,5S
   − actuators, 24 VAC, protected cable NOMAK 2 x 2 x 0,5
   − + 0,5
   − passive sensors, protected cable NOMAK 2 x 2 x 0,5
   − + 0,5 or KLMA n x 0,8 + 0,8.
      (Piikkilä et al 2012, 134.)

4 Bus technology

Sensor and actuators are located at the field level so they can be called field devices. Field devices are used to measure, report and switch different values and actions in automation systems. In order to perform actions at the right time and report the results, the communication between field devices and control devices has to be effective and versatile. Field devices used on field bus are able to communicate straight with each other using built-in microcontrollers. This gives the reason to think field devices as intelligent devices. (Merz et al 2009, 27).

Bus technology was first developed in 1980s. The idea was to replace analog transfer signals with digital signals and parallel connection systems with serial interface. Depending of requirements there is various field bus systems that can be implemented on the field. Field bus is really versatile, but the amount of data can hinder the use of bus technology because field bus can process only a small amount of data in short time. (Merz et al 2009, 27 – 28).

Major difference between field bus and typical network is the size of communication. In typical network only two stations are talking with each other but in bus cabling system data is sent to all stations.

4.1 Topologies

To achieve an effective network, cabling should be as minimal and straight as possible. This physical structure of network is called topology. There are various topologies to choose from, but there are few conditions for choosing the right topology. To implement the right topology, the amount of data and the properties of equipment have to be known. (Piikkilä et al 2006, 71).

There are two kinds of topology head topics. Physical topology means the structure that can be figured out by the physical layout of the network. For example circle topology means, that equipment is connected together so that starting from point A and continuing the cabling you will eventually come to point A. (Piikkilä et al 2006, 71).

Logical topology tells the way of communication. Logical and physical topology can be differently shaped. For example physical topology is star shaped, but the message is sent like in circle shaped topology.

4.2 Bus topology

Picture of the bus topology (Figure 4.) shows that all stations are connected to one main cable that can be coaxial cable, twisted twin cable or optical fiber. Heads of main cable are not connected together but the heads have to be ended with terminating resistors. This way we can reduce disrupting signals. (Piikkilä et al 2006, 72.)

In bus topology all the stations can interact with each other. Message has to be sent one at a time. Messages are sent in small packages and are transferred for all stations at same time. Stations have their own network addresses and that way it is possible to see which of the stations send the message, on the other words recognize and individualize the stations. Advantages of bus topology are reliability, simplicity, versatility and commonness. (Piikkilä et al 2006, 73.)
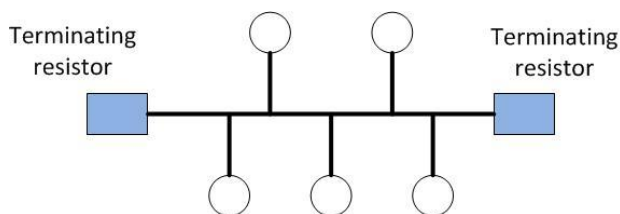
Figure 4. Bus topology

4.3 Circle topology

Heads of the main cable are connected together and forming a circle as shown in the picture (Figure 5.). Twin cable, coaxial cable and optical fiber can be used as main cable. Circle topology is really common in industry automation. (Piikkilä et al 2006, 73–74).

Each station can send the message for other stations. The big difference is that in circle topology message moves through each station and only one station can hear the message at a time. This means if an error occurs in one of the stations, the whole network can be disabled. Circle needs one terminating resistor and it can be connected to any part of the circle. (Piikkilä et al 2006, 73 – 74.)
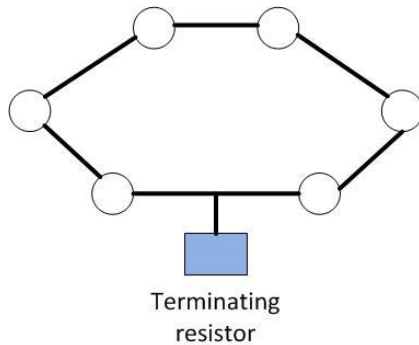
Terminating
resistor

Figure 5. Circle topology

4.4 Star topology

Coupling boards acts as a center of a star system. Each station is connected to the board and all the signals go through the center. Cabling can be made with a pair cabling, a coaxial cabling or optical fibers. In the optical fiber systems the star topology is the most effective system. (Piikkilä et al 2006, 75.)

One of the biggest weaknesses of the start topology is the central board. Systems vulnerability is much higher than in other topologies because even small errors in the center can disrupt the whole system. Also versatility of the system is highly depending of central board´s properties. Well planned star system can be really versatile and changeable. (Piikkilä et al 2006, 75.) The picture of star topology (Figure 6.) shows the structure used in star topology.
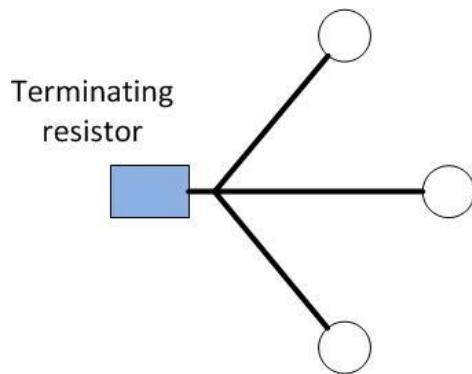
Figure 6. Star topology

4.5 Tree topology

Like other topologies, tree system has to be ended with terminating resistor. Tree topology can be really effective in saving cabling costs, but the role of planning is more important. High versatility is an advantage compared to other topologies. (Piikkilä et al 2006, 75.) The structure can be seen in Figure 7.
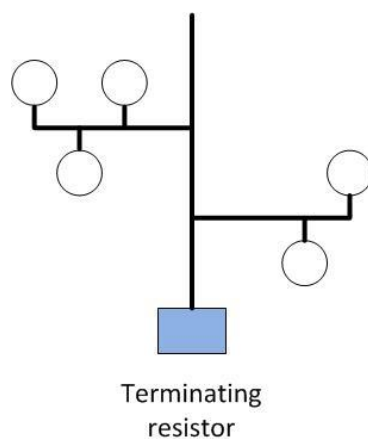
Figure 7. Tree topology

4.6 Free topology

Free topology is a versatile system, which is easy to assemble and reduces the cable costs. Need of the cable can be reduced to half compared to the bus topology. Benefits are easy assembling and designing. The termination resistor is also needed. (Piikkilä et al 2006, 76.) The structure can be seen in Figure 8.

Figure 8. Free Topology

4.7   Hybrid topology

Hybrid topology is a combination of other topologies and is often created during renovation. This topology has many difficulties. Hybrid topology is vulnerable for disrupting signals. Also implementing and controlling the system can be challenging. The termination resistor is needed. (Piikkilä et al 2006, 77.) The structure can be seen in Figure 9.

Figure 9. Hybrid Topology

5 OPC Unified Architecture
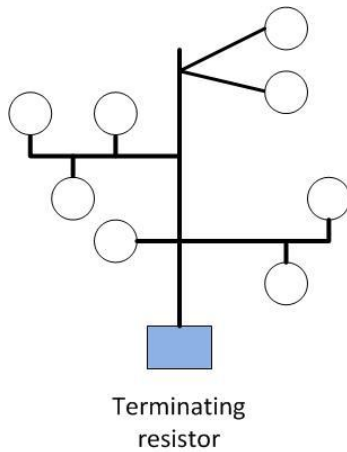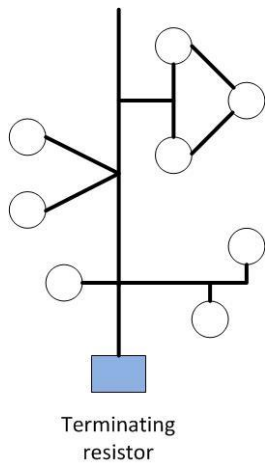
One area in automation is a communication between devices. When a device is sending data, this message is always formed in certain way and the structure of the message is depending on talking device. To ensure a general understanding between two devices, a unified language is needed.

In bus technology, there are a plenty of choices for communication protocol. For example in industry you need to build a large network with high-speed reaction for variations, Ethernet-based protocol EtherCAT is used. If the protocol for wireless network is needed, for example EnOcean can be used.

Automation technology is going forward all the time and new protocols are developed for new and different solutions. Many companies are involved in designing new communication possibilities, but they all have the same goal: to produce universal language.

OPC UA (Unified Architecture) is an Ethernet based communication protocol. It is usually used in systems which demands high versatility and security. OPC UA is developed by the OPC Foundation. (OPC Foundation 2014.)

5.1 Basics of OPC

OPC (Open Connectivity via Open Standards) is a standard for data exchange which relies on security and reliability. It was developed to be platform independent and to offer a solution for industrial needs. OPC contains a series of specification which were developed by end-users, software developers and industry vendors. These specifications define the access to real-time data and historical data, monitoring of alarms and other applications. (OPC Foundation 2014.)

5.2 History

First OPC standard was released in 1996. OPC UA was released in 2008 by the OPC Foundation. While it is based heavily on previous OPC Classic, OPC Foundation wanted to develop something new that surpasses protocols in freedom and security. OPC Classic was based on Windows-platform but OPC UA was created to run on the most popular platforms. (OPC Foundation 2014.)

5.3 Structure

OPC UA is used through two different protocols: OPC TCP (Transmission Control Protocol) and SOAP/HTTP (Hyper Text Protocol). Difference between these two is that HTTP sends data in characters and TCP sends data in binary numbers. Because character data is slower than binary data, HTTP is usually used for data transfer on upper level and TCP is used between devices. (OPC Foundation 2014.)

5.4 Security

One of the biggest benefits of OPC UA is security. OPC Classic relies on complicated COM/DCOM technology which demanded a lot of knowledge to operate. This feature can cause the lack of good protection. OPC UA relies on common and powerful web technologies to protect application from unwanted traffic. This web technology includes both authentication and encryption. (National Instruments 2014.)

OPC server and client communicate with each other using x.509 Web standard certificates. Authentication occurs with private and public key which are used and compared by server and client. (National Instruments 2014.)

6 Cloud computing

When we are living in the world of mobility, demand of continuous access to data is growing. Everything started with a need of communication between two humans while ignoring the location in the moment of word exchange.

After development of telephones and internet it was possible to see potential also from longer distances, not only from things that are around you. This leads to spreading of professionals around the world. This step gives a new question: how can I keep all the knowledge and material with me and share it with others while ignoring the location in the moment of data acquisition? Cloud computing enables the handling of data, no matter where you are. Sharing a data with others and running programs with any device is possible. Service is completely scalable for the needs. It is possible to use the cloud as a simple storage or as a platform for bigger projects and programs.

6.1 Cloud computing as a term

A term "cloud computing" can be used in situations, where computing resources are offered over a network. These services are using an external space of physical or virtual resources and does not require to setup personal software or hardware. (Interoute 2014a.)

6.2 Characteristics of cloud computing

One of the biggest benefits of the cloud computing is flexibility. Services are scalable and client can customize their services. Cloud computing is also secure, because these services are provided by IT – professionals with diverse equipment. (Interoute 2014a.)

Cloud computing is divided to 3 groups: private cloud, public cloud and hybrid cloud. Private cloud offers a secure and reliability service for software and hardware which can be accessed only by one client. This ensures that the whole capacity and power

of the cloud is dedicated for single usage. Private clouding is more expensive than public cloud. (Interoute 2014a.)

Public cloud is suitable for larger networks. Access is allowed for multiple clients and this way public cloud is more versatile. It is a cost-effective solution, but multi-accessible system also means shared capacity and power. (Interoute 2014a.)

Hybrid cloud is the most versatile option of all clouds. Client can verify, which material can be accessed only by the client and which material are open for other users. Client can gain the benefits of both public and private options. Hybrid cloud is the most expensive cloud service. (Interoute 2014a.)

6.3   Fundamental service models

There are three service models in cloud computing: Infrastructure as a Service (IaaS), Platform as a Service (PaaS) and Software as a Service (SaaS). These services occur in daily life, even without noticing. (Interoute 2014a.)

Software as a Service is the most common form of service provided for users. This term is used, when an application is provided for users usually through the network and hosted or maintained by the provider. Software is often rented rather than bought and can be named as usage-on-demand-software. Because of the versatility, SaaS is used in many applications from business software to daily-life applications. Good examples are Facebook and Gmail. (Interoute 2014d.)

Platform as a Service provides a virtual platform and tools for users to build their own applications or use the platform as data storage. Application and infrastructure is maintained by provider. Existing services are updated constantly and new services are available at any time. Platform is accessible through the internet. (Interoute 2014c.) Infrastructure as a Service provides a whole virtualized computing environment. This includes for example virtual hardware, IP – addresses and network connections. Also the customer receives tools to construct their own IT infrastructure, which is accessible for all clients at any time via internet. IaaS is cost effective and easy way to create own structures without maintaining. (Interoute 2014a.)

7 Designed measurement system

The Wooden apartment house as a study environment, stage 1 – project is aiming to observe characteristics of the wooden high-rise. In one year, change between the highest and the lowest temperature can be 60 degrees and therefore Finland is an ideal environment for testing.

The most effecting variables in the wooden structures are humidity and temperature. While measuring these variables it is possible to observe and predict the characteristics and possible changes in a CLT – structures.

7.1 Structure of the measurement system

Structure of the designed system is based on bus communication. Bus controller is placed into 4th level in the wooden high-rise. Controller is connected to the main PC where controlling of the data is carried out. Main PC is located in the technical room on the base level.

Main PC contains the user interface, which indicates changing variables inside the structures. This interface is accessible through the internet and allows the real-time surveillance through mobile devices. Structure picture (Figure 10.) shows the fundamental structure of the measurement system.
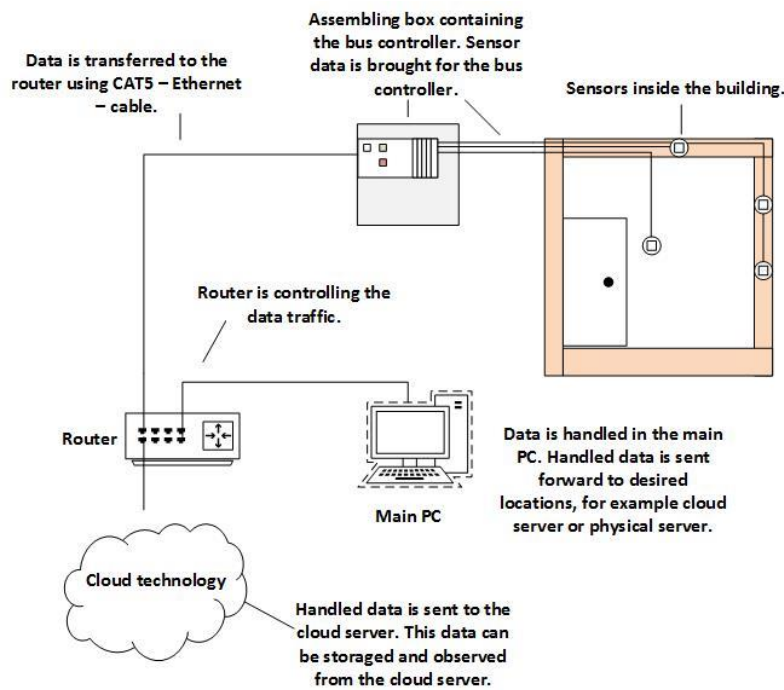
Figure 10. Fundamental structure of the measurement system.

To measure variables inside the high-rise, sensors have to be assembled. The sensor is a hybrid sensor, which can measure both temperature and humidity at the same time. These sensors are located inside the structures and rooms. Cables from each sensor are brought to bus controller.

Weather station is located on top of the high-rise apartment. Station gives the possibility to observe the changes in weather.

7.2 Equipment

Beckhoff CX8091 embedded pc were chosen to this system to receive the data from the sensors. CX8091 is a programmable controller with 32-bit ARM-based CPU and it is used for process the PLC-programs. It is possible to use CX8091 in different topologies and this controller is capable to integrate with various bus systems such as PROFINET, CANOpen and Profibus. CX8091 is supplied with 24 V DC / 3 A. This is enough to power up the CPU and the connected I/O – cards. Supply is carried out with the ABB supply converter. Input cards are KL858 analog input cards that are capable to measure signals from 4 to 20 mA. (Beckhoff 2015.)

In order to communicate with the controller, CX8091 has to be connected to main-PC with Ethernet-cable. Programming is done by using Beckhoff TwinCAT 2. Data transfer between the bus controller and the main PC is carried out with OPC UA – protocol. (Beckhoff 2015.)

Vaisala HMP110 sensors were chosen to measure variables inside the structures. HMP110 sensor can measure both temperature and humidity. Measurement ranges are from 0 to 100 %RH and from –40 to +80 °C. Output signals from HMP110 sensors are from 0 to 5 V DC or optionally from 0 to 20 mA. (Vaisala 2015c.)

Humidities, temperatures and carbon dioxides are measured inside the rooms. For this purpose, two different sensors are needed.

Vaisala HMW92 sensor is capable to measure both temperature and humidity. Because of the smaller temperature range and plastic case, HMW92 sensor is used inside houses and rooms. Measurement ranges are from 0 to 100 %RH and from -5 to +50 °C. Output current is from 0 to 20 mA. (Vaisala 2015d.)

Vaisala GMW86P sensors were chosen to measure carbon dioxides inside the rooms. Measurement range is from 0 to 22000 ppm. Output current is from 0 to 20 mA. (Vaisala 2015a.)

Weather station on the roof contains five different sensors. For measuring global and straight effects of the sun, four different Kipp & Zone sensors were chosen. Sensors are a pyranometer, a pyrgeometer, a pyrheliometer and a sun tracking sensor. All sensors are giving an output current from 0 to 20 mA. Vaisala WXT520 sensor is used to measure the rain and wind conditions. WXT520 – sensors output signal is from 0 to 10 V or optionally from 0 to 20 mA. (Vaisala 2015e.)

One variable to measure is oblique rain. Measuring this variable gives possibility to observe and predict detritions on the outer walls of the wooden mid-rise apartment. Because there is no proper sensors in the markets, oblique rain sensors are under planning.

7.3   Placement of the equipment

Sensors are located inside the structures and rooms. To ease the observation of sensors location, placements are divided into sensor groups. Groups are scattered around the 4th floor therefore different data is acquired. More accurate placement of the sensors are seen in the layout of the 4th floor (Attachment 2.).

One sensor group inside the room is containing one Vaisala HMW92 hybrid sensor and one Vaisala GMW86P carbon dioxide sensor. There are four room groups scattered on each corner of the floor.

Structures contains five sensor groups. There are six groups inside the walls. Each of them contains three HMP-110 hybrid sensors. Because of the layers of the CLT – wall, it is possible to measure accurately the changes of variables inside the wall. There are also two sensor groups inside the ceiling layer. Each group contains four Vaisala HMP-110 hybrid sensors.

8 Laboratory of The Measurement System

In order to approve functionality of the designed project, the testing system was built. The test laboratory was set up to correspond the major system, but in smaller scale. Equipment are from the same companies and measured variables are temperature and humidity.

Bus controller, power supply, temperature sensors and assembling box were provided by Seinäjoki University of Applied Sciences. Humidity sensors were ordered from Vaisala Ltd. Data from the sensors were not analyzed. Main focus was to observe and improve the designed system.

8.1 Equipment

Beckhoff CX1000 embedded pc was serving as a bus controller. CX1000 seen in the picture (Figure 11.) is an older model compared to CX8091 controller but even so CX1000 is capable to carry out the given measurement process. They are programmed with TwinCAT 2 and able to communicate using OPC UA (Beckhoff 2015). Buss controller is supplied with MURR Elektronik MPS3 power supply which converts 230 V AC to 24 V DC.
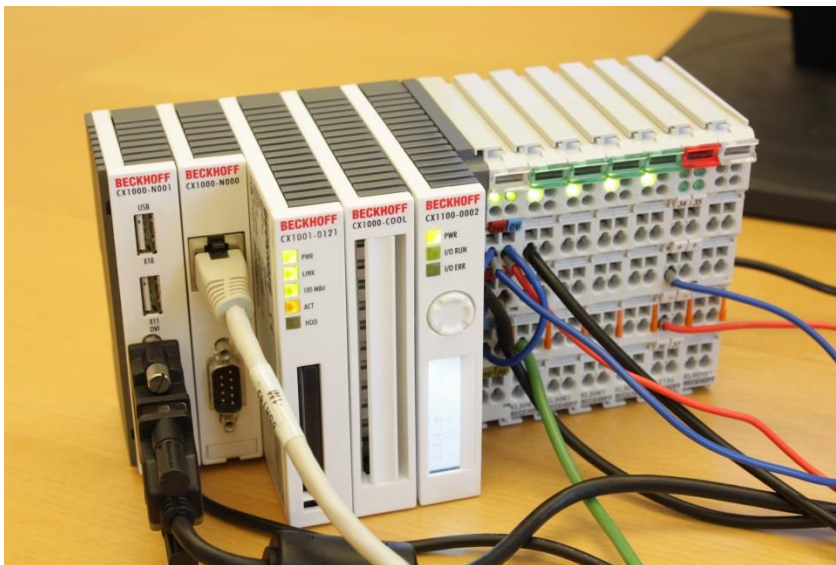
Figure 11. Beckhoff CX1000 and input cards

There are three different input cards: Beckhoff KL3061, Beckhoff KL2134 and Beckhoff KL3022. KL3061 is a 2-channeled analog input terminal card which is capable to measure from 0 to 10 V. They are supplied with 24 V DC from bus controller. (Beckhoff 2015.)

KL2134 is a 4 – channeled output terminal card. Output current is 0.5 A per channel. In laboratory system output cards were not used for controlling, but they were great indicators for showing the functionality of input signals. (Beckhoff 2015.) KL3022 is a 2-channeled analog input terminal card. KL3022 is capable to measure signals from 0 to 20 mA. (Beckhoff 2015.)

Two different sensors were used to measure temperatures in laboratory conditions. WIKA TSD-30 temperature sensor (Figure12.) is capable to measure from -20 to +80 °C. Output signal is from 0 to 10 V or optionally from 0 to 20 mA (WIKA, 2015.)

Figure 12. WIKA TSD - 30 (WIKA 2015.)

Siemens TS 500 (Figure 13.) is an analog temperature sensor. Measuring range is from -40 to +1000 °C. Output signal is from 0 to 20 mA. (Siemens, 2015.)

Figure 13. Siemens TS 500 – temperature sensor

Two Vaisala HMP 60 hybrid sensors (Figure 14.) were assembled to measure humidities in laboratory conditions. HMP 60 is capable to measure both humidity and temperature, therefore measurement ranges are from 0 to 100 %RH and from -40 to +60 °C. Output signal is from 0 to 5 V, which can be divided into 4 different output signals. (Vaisala, 2015b.)

Figure 14. Vaisala HMP 60 (Vaisala 2015a.)

8.2   Assembling and connections

Laboratory system was built into the assembling box to correspond the main system. As seen in the assembling picture (Figure 15.) system is really compact and there are numerous ways to re-assemble the system.
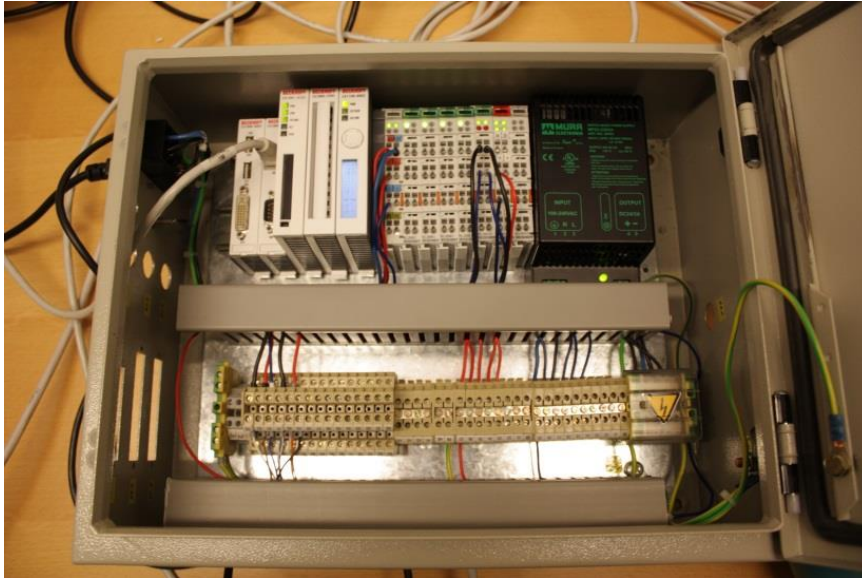
Figure 15. Measurement system inside the assembling box

The assembling box is connected to 230 V power supply. This supply is connected to MURR Elektronik MPS3 supply converter. After conversion 24 V is supplied to a supply rack and the bus controller and sensors are supplied from the same rack. Left-side rack is connecting sensors and input cards together. Ethernet – cable is connected between the bus controller and the router.

Assembling the measurement system is really simple. In the electrical circuit diagram (Attachment 1.) is shown connections between sensors and the bus controller.

8.3 Configurations of the bus controller

As mentioned before, CX1000 is programmed with TwinCAT 2 which is provided by Beckhoff. TwinCAT 2 supports all IEC 61131 – programming standards for example ladder (Ladder Diagram, LD), function blocks (Function Block Diagram, FBD) and text programming (Structural Text, ST). It has to be notified that TwinCAT 2 R3 program is supported only by 32 – bits user interface. Configurations for the bus controller are made by TwinCAT System Manager. (Beckhoff 2015.)

8.4   OPC Unified Architecture in bus controller

For setting up the OPC connection, UAExpert free client was downloaded for the main PC and the bus controller. UAExpert allows users to observe and handle data send from the desired controller.

OPCExpert is provided by Unified Architecture and it contains many solutions that helps users to handle and indicate the data. Along with simple observing, it is also possible to observe historical data, indicate the data with graphical pictures and collect the data into the bigger data bank.

9 Budget calculation

The last phase of this project was to estimate the budget of the measurement system. When trying to estimate the budget, two variables are in a central position in the calculations: the price of the equipment and the price of work.

The calculation on the equipment were relatively easy. The prices of the equipment were obtained in close co-operation with the companies. It is also possible to find the prices in public catalogs but these prices are usually given only for consumer products.

For the bus controllers the products of three different companies were compared. The three companies were Beckhoff, Siemens and National Instruments. As Beckhoff's bus controllers had the best price-performance ratio they were chosen for the system. Vaisala's sensors were chosen by Tampere University of Applied Sciences. The price of the sensors was also added to the measurement systems' budget calculations. Vaisala is offering many sensors for various applications so Vaisala was the most potential company.

The calculations on the work price can be done in three ways: by experience, using calculation tools or ask consultation from price calculation companies. In this project the calculation tools were used.

10 Summary

The main goal of this project was realized to the end. The measurement system was designed and tested successfully. This work provided also an opportunity to learn about social and technical skills.

Working in a project which contains several parties, always demands versatility and flexibility in working phases. Changes in one design affect also other designs. These changes were the most negative strain in this project. Also communication problems were delaying some of the work phases, but there were no critical delays, however.

The budget calculation was a relatively new area to work with. Good support and tools were helping with the calculations and good estimation of the measurement system was produced.

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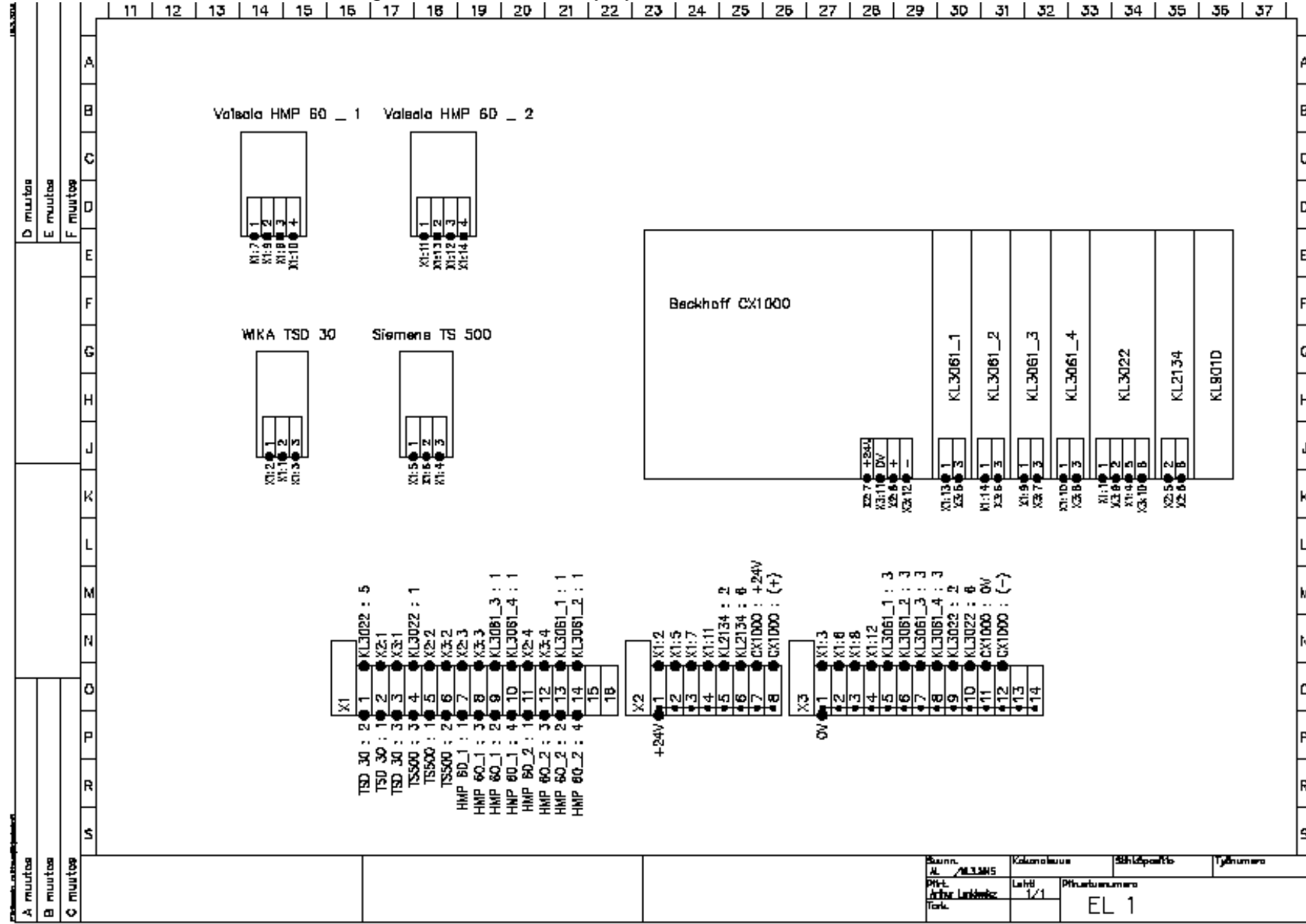http://www.vaisala.com/en/products/multiweathersensors/Pages/WXT520.aspx

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Attachments

Attachment 1. Electrical circuit diagram of CX1000

Attachment 2. Locations of sensor groups

Attachment 1. Electrical circuit diagram of the laboratory system

Attachment 2. Locations of sensor groups.

Room - sensor group

Oblique rain - sensor

Structure - sensor group

Bus controller