Master Thesis

Commercial mobile platforms in an industrial environment

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Abstract

As commercial mobile devices grow more powerful their field of application expands. A mobile device that looks more and more like a computer can also be used like one, even in a industrial context. There are many different commercial mobile software and hardware platforms on the market today. Companies in the process of incorporating such mobile platforms in their systems stand before a difficult decision. This thesis evaluates the most popular platforms today from a case companies industrial point of view and shine light on the most important questions that arise in the platform decision process. This entails defining an industrial context, identifying relevant user scenarios and compiling a requirement specification that evidently leads to a platform recommendation.

The first step in doing this is to determine company-specific requirements, gather data by conducting interviews and examine the existing company specific systems. This is followed by evaluation of the available mobile platforms on the market today; Android, Symbian, IPhone, Blackberry and Windows Mobile. The purpose of this thesis is primarily to guide the company in this platform-decision process, but it can also be used as reference in future mobile development processes.

Android is pointed out as the most suitable platform for future development and two prototypes are implemented fulfilling the most relevant user scenarios. The company is recommended to place as much functionality as possible in web solutions, since they are portable and often accessible from any platform.

Contents

1 Introduction

1.1 Context and purpose

Tetra Pak Processing Systems AB is seeking to further improve their existing automation platform by incorporation of commercial mobile components, such as mobile phones and pads. The first step in doing so is to determine company-specific requirements, gather data by conducting interviews and examine the existing Tetra Pak systems. This is followed by evaluation of the available mobile platforms on the market today; Android, Symbian, IPhone, Blackberry and Windows Mobile[9]. The purpose of this thesis is primarily to guide the company in this platform-decision process, but it can also be used as reference in future mobile development processes.

1.2 Problem description

As commercial mobile devices grow more powerful their field of application expands. A mobile device that looks more and more like a computer can also be used like one, even in a industrial context. There are many different commercial mobile software and hardware platforms on the market today. Companies in the process of incorporating such mobile platforms in their systems stand before a difficult decision. This thesis evaluates the most popular platforms today from a case companies industrial point of view and shine light on the most important questions that arise in the platform decision process. This entails defining an industrial context, identifying relevant user scenarios and compiling a requirement specification that evidently leads to a platform recommendation. As part of the problem description four main questions are posted:

Which existing commercial mobile devices and software platforms possess the necessary and desired traits for this mobile, industrial development?

How can a commercial handheld device be utilized for communication with industrial equipment, for example controlling or monitoring a PLC, and what kind of opportunities and problems will arise from this?

Which mobile platform is best suited for the case company and why?

How can a mobile solution be used to simplify and/or increase the efficiency of a existing automation-system workflow or solve an existing problem in the company?

1.3 The company

The case company, Tetra Pak, was founded year 1951 in Lund by Ruben Rausing and Erik Wallenberg and is one of the world's leading food processing and packaging solutions companies. It is currently the only international company in the world able to provide integrated processing, packaging, and distribution line and plant solutions for food manufacturing. Tetra Pak provides processing solutions within five food categories: dairy, cheese, ice cream, beverage and prepared food. The thesis is conducted at the Tetra Pak Processing Systems AB offices in the department for Automation Solutions in Lund. This department constructs and maintains profitable and customer specific automation solutions for processing equipment. [17].

1.4 Abbreviations

- PLC - Programmable Logical Circuit
- IP Rating - Ingress Protection Rating or International Protection Rating
- ODBC - Open DataBase Connectivity
- OPC - OLE for Process Control
- OLE - Object Linking and Embedding
- OEM - Original Equipment Manufacturer
- OS - Operating System
- API - Application Programming Interface
- SCM - Software Configuration Management
- XP - Extreme Programming
- HMI - Human Machine Interface
- QR code - Quick Response code

1.5 Outline of the report

The report is divided in to the following main sections:

- 1. Introduction: In this section the purpose, context, basic theory, case company, delimitations and outline of the thesis is explained.;
- 2. Methodology: This section describes the methodology and workflow of the thesis.;
- 3. First Evaluation - Basic demands: The different software and hardware platforms are discussed in relation to a industrial environment.;
- 4. Second Evaluation - Use cases and Work zones: This section describes different scenarios where a mobile solution could be used in Tetra Pak's industrial context.;
- 5. Third Evaluation and prototyping: The prototyping and implementation of a few use cases is described. Existing solutions are examined and factors like security and forecasts are explored.;
- 6. Conclusions: This section contains recommendations, advise and offers guidance regarding the future implementation of mobile solutions in Tetra Pak, based on the previous evaluations.;
- A1. Requirement specification: The requirements describing what kind of software and hardware platform that is required for each use case;
- A2. Interview questionnaire: The survey handed out during the interviews.;

1.6 Underlying theory

1.6.1 Requirements

The thesis produces hardware, software and feature requirements related to the use of mobile platforms. These requirements are constructed as a result of literary mobile platform research and user scenarios relevant to Tetra Pak Processing Systems, and are meant to be used as guidelines for future mobile platform discussions.

1.6.2 Existing systems

Tetra Pak's systems include a entire production line, from the processing of raw material all the way to packaging of a final product. The processing part of the production line consists of several modules and components such as pasteurizers, holding-tanks, blenders and homogenizers. These are all integrated, monitored and controlled by a supervising computer system, or control room solution, via a OPC client/server solutions that communicates with the different module PLC:s. Each module has a separate PLC that handles the internal analog/digital signal exchange between for example valves, pumps, flow and pressure indicators. These PLC:s are in some cases coordinated and handled by a plant PLC. Important values and historical data is logged in a MSSQL database that can be accessed via different web services. Besides from the control room solution that integrates the entire production line, almost every module has its own HMI physically mounted on it, communicating with its PLC. As seen in **Figure 1.1** there are many different ways for a new device to interact and integrate itself with a module in this system. **Figure 1.2** illustrates the system from a plant PLC:s point of view.

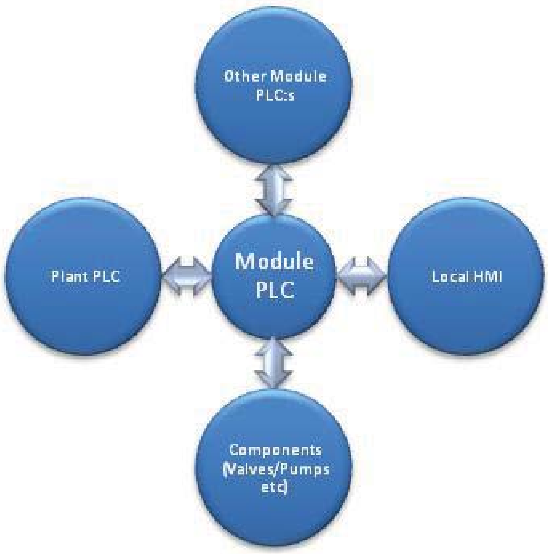

Figure 1.1 Existing system structure from a module perspective

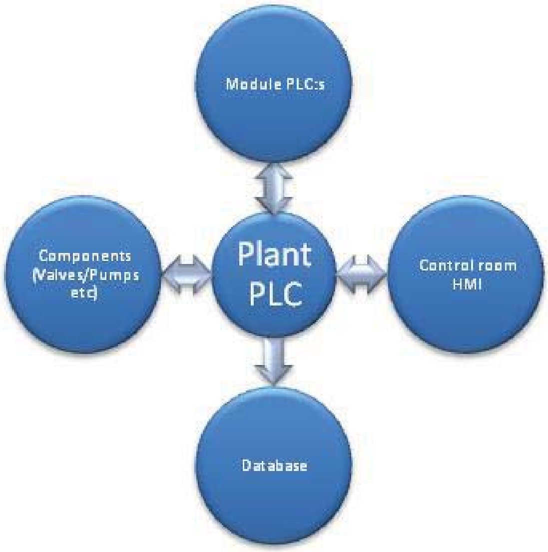

Figure 1.2 Existing system structure from a plant perspective

1.7 Delimitations

The thesis is limited to commercial mobile devices and platforms, thus no custom-made industrial mobile devices are taken into account. Furthermore, the thesis focuses on the use of mobile devices in the industrial environment at the case company, not industrial environments in general. However conclusions can be used as references for companies with similar interests, with these delimitations in mind.

2 Methodology

2.1 Basic methodology

The method used in this document consists of 4 phases, as seen in **Figure 2**. Initially a startup phase describes the company interests and the purpose of this report. The phase also comprises the initial decision on what platforms to include in the evaluations, as well as identifying basic demands for integration in the existing systems. The second phase includes an first evaluation of the software and hardware-components available for each platform, resulting in a initial conclusion concluding the most promising platforms to continue with. Phase three provides a detailed second evaluation of the chosen platforms based on different use cases, environments and requirements. The environments are divided into different work zones with different attributes. Use cases describing different work scenarios create a link between work zones and fundamental requirements. Interviews with relevant employees at the case company filter out the best use cases.The next phase of this report offers discussion on the results of the different evaluations, summary and the conclusions one can draw taking different aspects into account. The requirement specification is formed in parallel with the evaluation process and the evaluation process produces a decision regarding the platform to be used for prototyping. In the prototyping phase the chosen platform will be put to the test by solving at least one of the use cases. The final phase will take the prototyping into account when making final conclusion and recommendations.

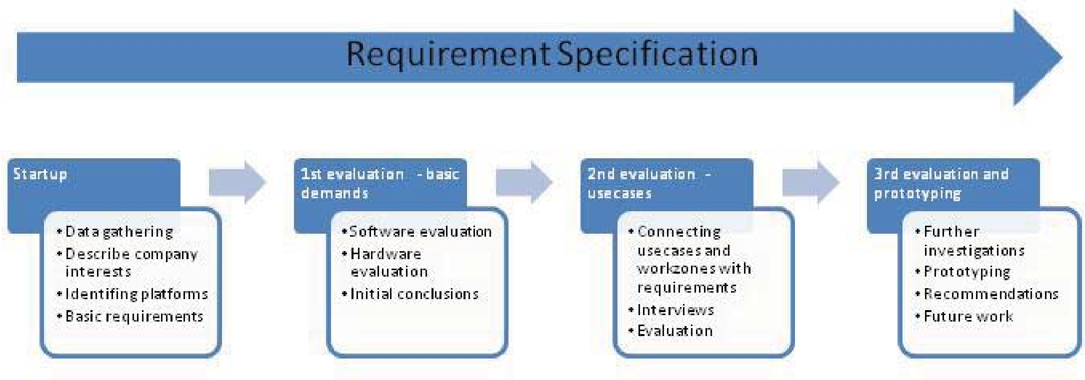

Figure 2. Illustrates the work process

2.2 Interviews

Employee interviews were conducted to validate various company-specific facts and ideas, such as different use cases [1]. The interviews were conducted individually, both in written and verbal form. The participants were selected with regard to their experience and responsibilities within the case company. The written interview-form can be found attached to the thesis as an appendix. The main goal of the interviews was to get feedback and suggestions for realistic use case scenarios where a mobile solution could be deployed to increase efficiency and/or solve a existing problem. This feedback is utilized when selecting a scenario for prototyping.

3 First evaluation - basic demands

3.1 Software

This section provides an initial comparison between the different software platforms, highlighting key differences and similarities. The basic software features that are needed to communicate with the existing Tetra Pak systems in a satisfying manner, as shown in **Figure1** above, are combined with the platforms illustrated in **Figure 3**. The different entry points are the database via ODBC, the PLC via an OPC client or any of the systems via a web-server,

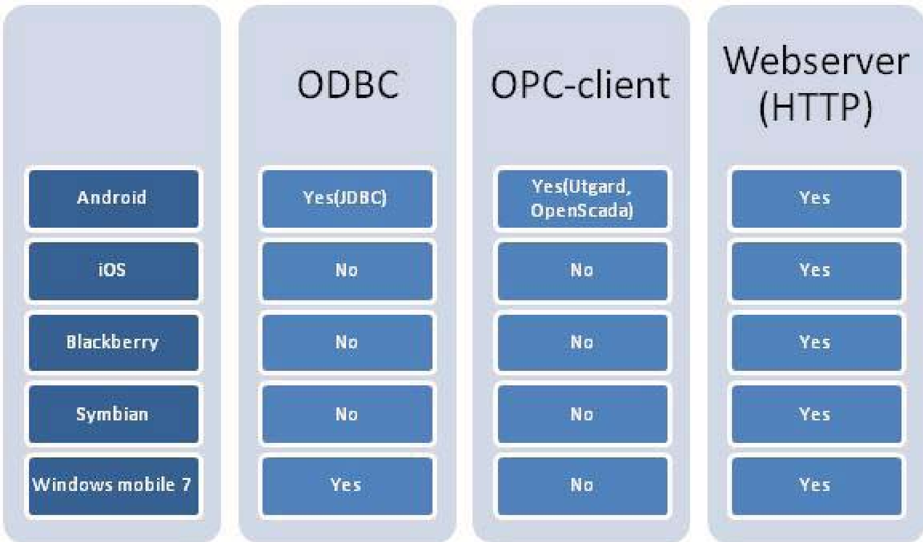

Figure 3. Relevant platform functionality for communication [3] [11] [18] [15] [14]

Judging by the results in the chart above it becomes apparent that a web-server solution in combination with a platform dependent application that can communicate with a PLC via Ethernet is a possibility for every examined platform. It is also clear that Android is most suitable for future development and incorporation into Tetra Pak's existing system, in the sense that it offers the most relevant functionality. The only other platform, besides from Android, that offers a ODBC feature for communication with external databases is Windows Mobile 7. However the current praxis for communicating with a database from a mobile device suggests wrapping it in a web server, adding extra security and eliminating the need for ODBC in the device. Neither iOS, Blackberry, Symbian nor Windows Mobile 7 offers OPC client functionality for integration in their developer environment.

A solution with a web-server leaves the door open for future actors on the mobile market. This is very beneficial in a longterm mobile development process. A web-server can be used as part of a tailor-made platform dependent application, if there is a need to access device-specific hardware functionality through local API:s. If one

decides not to use a web-server and develop a completely local platform dependent solution the road becomes very narrow. One potentially faces a large amount of work if API:s are updated or the application needs to be ported to another platform. The best solution for a online application is consequently to place most of the functionality in a web-server. If the need for local API functions appear one can write a smaller application that uses the web-server functionality as well as the extra local API functions, without any greater effort. In addition, a web-server also adds a extra layer of security between the device and database.
According to **Figure 3** all platforms can communicate with a web-server i.e. communicate via HTTP. The desired solution should build the most solid foundation for future development even in other platform directions. Therefore the platform should have access to as many relevant functionalities as possible.

With regard to the first column in **Figure 4** the platforms: Android, iOS, Blackberry, Symbian and Windows mobile 7 offer different possibilities to modify different layers of their OS. This is a crucial factor in the sense that it often determines whether third-party developers will adopt the platform.The most open platforms of the five examined are Android and Symbian [13]. But a closed platform also has its advantages, in that there is an added layer of security since no unauthorized developers can change system functionality. Another aspect is that closed platforms, in many cases, only can be used with specific, provided hardware. When using an open platform one has the freedom to choose which hardware to use, a possibility providing option to customize and optimize hardware to reach different goals in a cost-effective manner. The second column in **Figure 4** evaluates development costs in the sense that there would be a fee for the developer to access tools and API:s. In this aspect iOS is the only OS that will not let the developer test an application on the actual device unless a developer license is purchased. The third and fourth column determine whether a developer can choose how to distribute applications and which possibilities a user has to install these.

	Open Source	License cost	Free distrubution	Can install third party applications
Android	Yes	No	Yes	Yes
iOS	No	Yes	No	Only via ApStore
Blackberry	No	No	Yes	Yes
Symbian	Yes/No	No	Yes/No	Yes (if signed)
Windows mobile 7	No	No	Yes	Only via MS Marketplace

Figure 4. Evaluates the targeted platforms: Android, iOS, Blackberry, Symbian and Windows mobile 7 in terms of openness, license cost, distribution rights and third party applications. [3] [11] [18] [15] [14]

3.2 Hardware

3.2.1 Comparison

To just compare hardware specifications in terms of CPU-speed, RAM and so on would be pointless since the hardware needs will vary greatly in different situations and seldom act as a bottleneck. However, if a software platform is compatible with a wide range of devices it offers a costumer more hardware customization options. Apple's iOS is for example only compatible with iPhone and iPad, whilst Android, Windows Mobile and Symbian are compatible with a wide range of devices that vary in for example speed, screen size and price. This customization aspect can cut costs in terms of cutting back on unnecessary, sometimes expensive, functionality. The functionality-cutback can also be dangerous as one would want to avoid upgrading hardware as a consequence of upgrading software with new features in the future. Naturally, there are benefits and drawbacks with every platform.

Construction, ruggedness and sturdiness are some of the most significant differences between commercial and industrial devices. Different commercial devices are optimized for different environments, but none of the commercial smart-phones or pads are made to be used in a industrial environment. The industrial devices use IP ratings to specify which environments a device is constructed for, and can be used in, to compare the ruggedness of different devices. The IP rating commonly consists of two numbers, the first rating its protection from solid objects and the second rating its resistance to moisture. [8]

To be able to get a perspective on what IP ratings that are suitable in Tetra Pak's industrial environment a commonly used stationary touch panel is examined. The panel, in this case a Siemens MP377 panel, is mounted in a stainless steel cabinet in such a way that only the front is exposed. The front has a IP rating of 65 while the protected backside only has a IP rating of 20 [20]. The outside of the MP377 panel is the interesting part since it is exposed to the industrial environment. By looking at **Figure 5** one can conclude that a device with the IP rating 65 is dust tight and protected against water jets. In order to approach these values a commercial device would have to be equipped with some sort of water and shock resistant casing or extra protection. The manufacturers of the investigated commercial devices have not bothered to assign their products any IP rating, and they are not required to since the devices are not intended for industrial use.

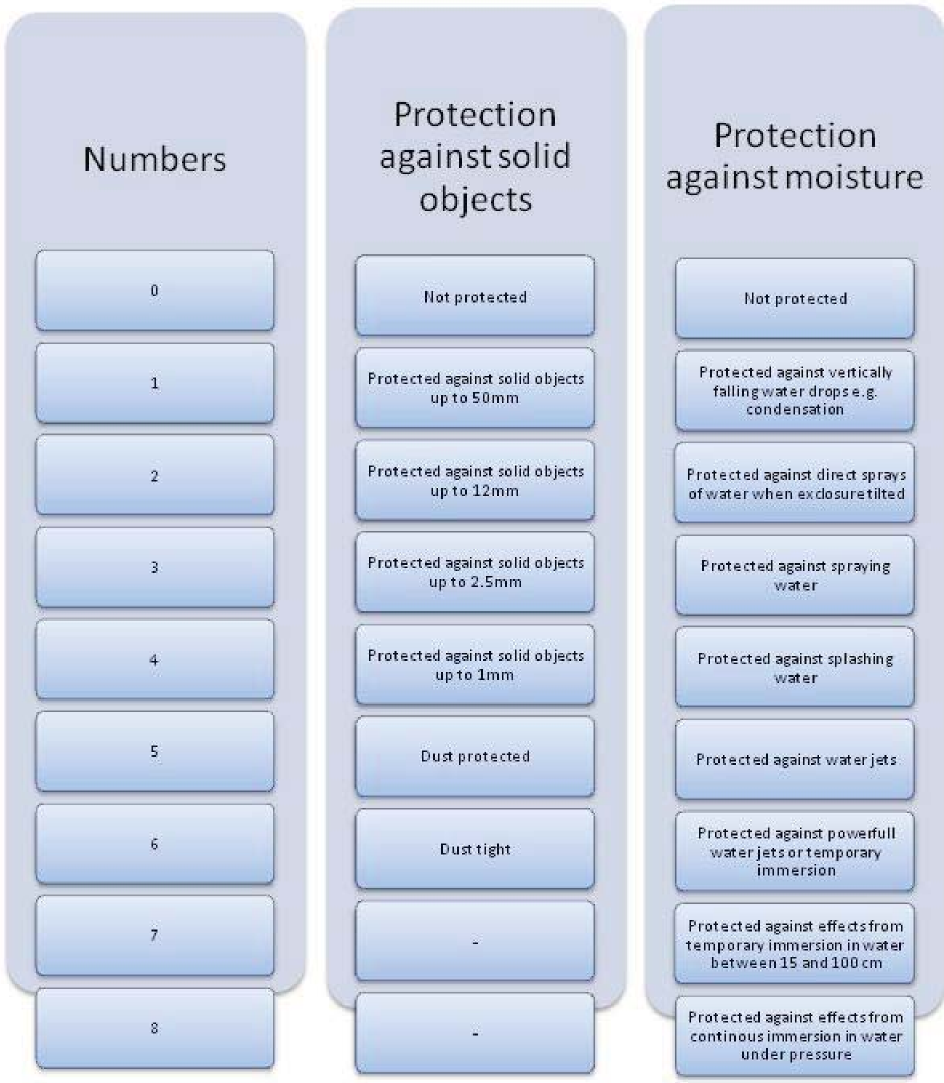

Figure 5. IP ratings[8]

3.2.2 Connectivity

If a mobile device is to be used in a industrial environment and successfully connect to and interact with industrial equipment, there are several parameters to take into account. To make a connection the device must have the ability to identify the targeted equipment and a reliable method to send and receive data. This is no trivial task since there are many different industrial communication standards. The wireless communication technique that is used in almost all modern mobile devices today is WLAN via the IEEE 802.11 standard. This Ethernet networking technique is used in almost all WiFi routers, most commonly for interaction with commercial devices. In industrial environments, wired Ethernet networking cables are often used because of their reliability, as opposed to WiFi that can be subject to interference. There are many obvious reasons to use the IEEE protocol suites. They are rich of features, well known, proved, widely accepted and cheap. If possible, to attempt to overcome possible weaknesses, like wireless interference, in order to achieve the required performances by minor extensions, is more reasonable than to adopt other techniques i.e. bluetooth. It has been proven that properly configured commercial wireless routers can be used, even in the presence of industrial interference, without compromising the network security. [6]

3.3 Product lifecycle

When selecting a platform it is important to estimate future maintenance costs as well as possibilities to upgrade and change applications. Since this thesis focuses on existing commercial mobile hardware, the upgrading possibilities of hardware components will be limited. The storage memory is, in most cases, the only thing a user can modify without voiding the warrantie. The software can on the other hand be modified and upgraded in many different ways. All examined platforms are compatible with some kind of agile development method and development environments often provide tools for agile purposes. A in-house development of platform dependent software can easily be maintained, upgraded and tested with the use of SCM methods such as XP or Scrum . However, the different platform-providers offer different possibilities to customize or alter the existing operating systems in their mobile devices. Apple does not allow any kind of reprogramming or altering of their OS without approval, applications can only be distributed either inside the company or via App-Store [3]. In other words, legally one can not develop and sell a application for iOS outside App-Store. When distributing via App-Store Apple receives 30 percent of the consumer price and the application is openly available to everyone. In contrast, there is more freedom when developing for an open platform like Android. The Android OS can be altered and rebuilt to any extent. The applications developed for Android OS can be distributed without restrictions and are therefore easier to maintain, update and customize [11]. With a open system such as Android it is easier to predict future conditions, and make forecasts, since the developer have complete ownership and legal rights to the software. Apple can at any time without warning remove a application from their App-Store. [3]

3.4 Summary of first evaluation and initial conclusions

There is no apparent superior platform emerging from this first evaluation, but from a developers point of view Android provides the most appealing characteristics. The platform is open source, free to distribute, not bound to a specific device and has the most relevant functionality. This points to Android as a solid platform for developing a mobile system. On the other hand Windows Mobile is a platform developed by Microsoft, the same company that develops and provides TetraPak's database. This promises good compatibility between the platform and the database, however Windows Mobile received negative criticism from the mobile community regarding usability and the fact that it's API:s are OEM dependant[12] [13], with risk of limitations for developers. iOS is a remarkably closed and restricted platform from a developers point of view. There are strict rules regarding which API:s that can be used and a formal auditing process when distributing applications via the only allowed distribution channel, App-Store. However, iOS offers superior distribution capabilities with the widely used App-Store [3], which allows licensed developers to reach a huge audience. This is a desired trait when making applications for promotional purposes. Symbian is widely known for its complicated development tools and have been abandoned by many developers. The negative consequences of this are discussed in the Market shares and forecasts section of this thesis. Blackberry is known as the most robust platform, but lacking in features [16].

4 Second evaluation - Use cases and Work zones

This section provides a set of use cases which describe probable series of events and relate them to requirements and environments. The requirements are not all predetermined, they emerge as the use cases develop and together with relevant work zones they serve as a basis for choosing a platform. Work zones are classifications of different industrial environments and variables within an organization, validated through interviews held with relevant employees [1].

4.1 Work zones

The work environment has been divided into four zones to aid the requirement specification: 1 - Production, 2 - Factory environment, 3 - Office, 4 - Home or traveling, each evaluated in detail in the **Figure 6** below. The risks of controlling a machine from a handheld device, when the person controlling doesn't have visual or physical access to the machine, are to great [1]. Only personnel in zone 1 and in some cases zone 2 should be able to remote control machines in a factory. Zone 1 and 2 assigns greater hardware requirements to the device compared to zone 3 and 4. However, there are no hardware requirements by european law unless the mobile device is equipped with a emergency stop button [7]. The security demands increase remarkably when the device is used outside the companies local network.

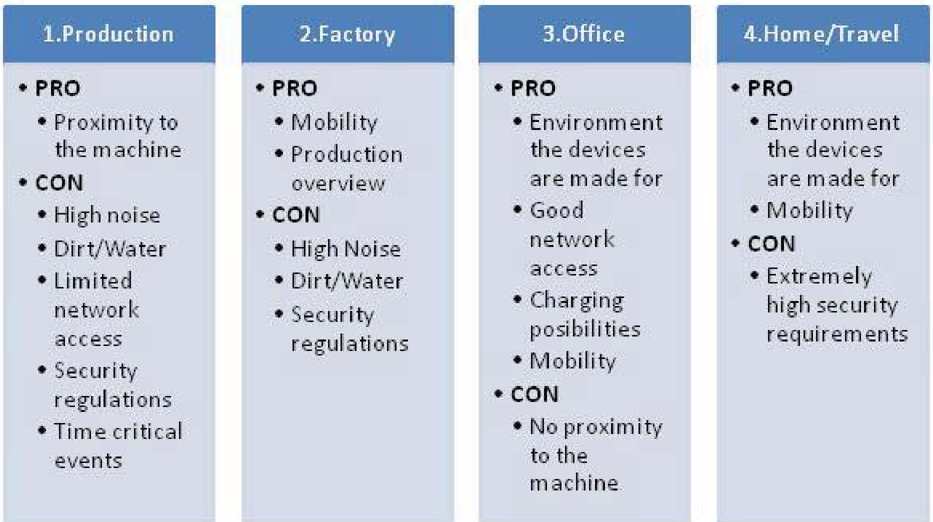

Figure 6. Illustrates pros and cons in different work zones. [1]

Employees have access to different industrial work zones, see example below.

	1.Production	2.Factory	3.Office	4.Home/Travel
Production personel	Yes	Yes	No	No
Support engineer	Yes	Yes	No	Yes
Production-site manager	No	Yes	Yes	Yes
Sales/finance personel	No	No	Yes	Yes
Office manager	No	No	Yes	Yes

Figure 7. Illustrates personel in different zones [1].

The work zones are paired with different user scenarios, or use cases. Use case corresponding employee groups and work environments can be derived from each use case. These use cases aim to describe relevant scenarios that occur in Tetra Pak or at a Tetra Pak customer company. They have been formulated and processed in collaboration with relevant employees at Tetra Pak [1]. The selected employees were interviewed and amongst other things asked to comment on the relevance of the different scenarios. The result of the interviews was 10 use cases that can be implemented separately or as part of a larger system.

4.2 UseCase 1 - Alarm

Online

Events
A customer encounter a problem with a pasteurizer. The production personnel on site can not solve the problem. Currently, this would be handled by the personnel on site. If a mobile solution would have been implemented the service engineer responsible for the machine would get a instant alarm sent to his handheld device. He/she can read the alarm description and choose to either turn the alarm of or contact the production personnel on site with instructions on how to solve the problem.

Required features
Network connection
Push notification
Fetch data from the database

Zones
1,2,3 and 4.

Relevant requirements
H2, H3, H4, F1, F2, S1

4.3 UseCase 2 - Monitoring

Online

Events
A employee at a costumer company is responsible for a specific product. He/she wants to make sure that everything is working and progressing according to plan, even when he/she is at home, that the production flow is at a good level and no serious errors have occurred. Currently he/she have no way of knowing this. If a mobile solution is implemented the scenario becomes different. He/she can start a application on his handheld device, log in with his/her credentials and input the time interval that he/she is interested in. The program then displays relevant historical production data in diagram and text form on the screen.

Required features
Network connection
Database access
Fetch data from the database

Zones
3 and 4.

Relevant requirements
H2, H3, H4, F1, F4, S1

4.4 UseCase 3 - Controlling

Online

Events
A engineer is interacting with a machine in a factory. He wants to test the phases, recipes and valve/motor activations on the machine. To do this, currently he/she will have to stand in front of the operating panel mounted on the machine, or in a control room. With a mobile solution he/she can log in to a handheld device and connect to the machine in question. A overview of the machines components is displayed and the engineer can start/stop phases and force activations. This makes testing more dynamic and can in some cases eliminate the need for extra personnel. A log showing the actions taken is created to improve traceability in the service process.

Required features
Network connection
Location sensing
Fetch real time data
Write data to the PLC

Zones
1 and 2.

Relevant requirements
H1, H2, H3, H4, F1, F2, F4, S1, S2, S3

4.5 UseCase 4 - Maintenance

Online

Events
A service engineer wants to check the maintenance needs, or time left in maintenance intervals, for different machines in a factory. As he/she walks through the factory physically inspecting each machine, he wants to access and maybe update maintenance information to optimize the maintenance intervals. Currently this is not possible, maintenance information is never updated until the components are replaced. In this mobile scenario he/she utilizes his handheld device, connected to the local Wifi, to access a database and fetch/change maintenance data for the different machines.

Required features

Network connection
Database access
Write to database

Zones

1 and 2.
Relevant requirements
H1, H2, H3, H4, F1, F4, S1

4.6 UseCase 5 - Manual addition

Online

Events
A production worker wants to manually add ingredients in a mixer tank. Currently this has to be registered in a supervisory computer system or in the machines local HMI. By deploying a mobile solution he/she gets access to the system through his/her mobile device. The system displays the currently active mixer tanks and he chooses the

targeted one. He/she inputs the material ID, thus saving this information in the system, and physically adds the material.

Required features

Network connection
Database access
Write to database
PLC communication

Zones

1 and 2.

Relevant requirements
H1-H5, F1, F4, F5, S1

4.7 UseCase 6 - Quality assurance

Online

Events
A employee works in a quality assurance laboratory, testing different samples and logging the values in a online web server tool. Every product-sample is identified with a unique ID number. Instead of inputing this number manually, a mobile device can be utilized. The employee logs in to the device and uses the built-in camera to scan a barcode on the sample. The barcode containing the product unique ID is then sent to a database and displayed in the online-tool on the device. Thus minimizing the possibility of a human error. To document a specific sample, pictures can be taken. These pictures are then uploaded to a database and associated with the samples unique ID number.

Required features
Network connection
Database access
Write to database
Scanning functionality

Zones
2 and 3.

Relevant requirements
H2, H5, F4, F5

4.8 UseCase 7 - Service instructions

Offline

Events

A maintenance engineer arrives at a customer site. He/she identifies all the components, valves and motors, subject to service in a production line. He inputs the component ID:s in his mobile device. The mobile device contains a local database with service instructions and composes a list according to the given ID:s. The engineer can overview, copy or export the service instructions in a convenient way. The list of components is saved in the mobile device and associated with the production line for future reference.

Required features
Local database

Zones
1, 2, 3 and 4.

Relevant requirements
H1, H3, H4, F6

4.9 Summary of second evaluation and further conclusions

This report utilizes a dynamic requirement specification process, illustrated in **Figure 8**. A clear vision of what an ideal mobile system would be able to achieve is created using actual work scenarios. The outer margins are set by the possibilities within the mobile platforms and the case company's existing operating environment and systems. From this, various use cases are defined, creating software and hardware requirements. The mobile platforms are then evaluated for these scenarios.

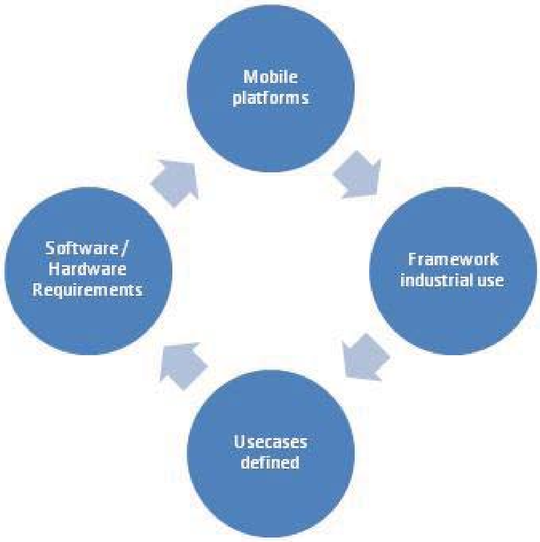

Figure 8. Requirement process

The use case interviews filtered out use case 3 and 7 as the most relevant and, hence, the most desirable scenarios to continue with [1]. These use cases will serve as a foundation for the following prototyping phase. Use case 3 describes a scenario where industrial equipment can be controlled wirelessly via a mobile device. The currently used testing process includes two automation engineers communicating via walkie-talkies. One positioned in the control room and the other positioned by the specific module or component being controlled and tested. This is most common when Tetra Pak is installing and starting up equipment at a customer site for the first time, then the functionality of every component has to be thoroughly tested. Enabling mobile control of the machine will in this case scale down the manpower requirements to only one engineer. The engineer testing a machine can stand in front of the targeted component with a mobile version of its control panel in his hands. A scenario like this also minimizes the errors that can occur from misunderstandings and other human factors. Use case 7 is a offline scenario where a mobile device is used a information source in a maintenance situation. When a machine is subject to maintenance Tetra Pak sends a engineer to the customer site in question. The engineer identifies which specific components within the plant that should be subject to maintenance and accesses service instructions for each of them. These instructions are currently located on a DVD and therefore needs a computer to be accessed. It is obvious that making information access mobile and to provide fast searchable retrieving saves time for the users. This is only one example of information that can be accessible on the go. The third most relevant scenario is Use case 4, which can be combined with use case 7. Use case 4 describes a dynamic maintenance scenario where a engineer can identify and optimize a components individual service interval. The use cases includes features like reading and writing to a database and scanning QR-codes with a built-in camera, amongst other things. The camera functionality can only be accessed from a local application, which points to at least a partially local application. If you utilize a local database you could even operate such a solution in a offline-state and synchronize the data when opportunity is given. There is a need for more dynamic maintenance systems since the real maintenance needs often differ from the existing, predefined static models, that are currently being used. [21]

5 Third evaluation and prototyping

5.1 Overview of Existing mobile solutions

There are several existing mobile solutions for commercial devices that control and monitor industrial equipment. To mention some of them I have selected three relevant examples.

ScadaMobile is a PLC monitoring application for Apples iOS developed by Sweet-Williams. It can be configured to monitor registers and alarms from any PLC, independent of vendor, without the need of any other equipment [4]. This kind of application could for example be used to solve use case number 1.

Antoher application that differs from the others in many ways is the Virtual factory. It is a complete automation monitoring and controlling system with a virtual factory environment built on top. The user can virtually walk around in the factory and inspect equipment while getting real time data from the actual physical machines. This could be a interesting way to realize use case number 4, but maybe not as practical as a simple remote control. [5]

The last application is SmartGlance, a reporting tool currently available for Apple and Blackberry. It simply communicates with a existing database and displays the data on a mobile device in a number of different ways. [2] This works with a subscription service where you pay a monthly fee depending on how many devices you will use. When you make a request from your company database the "SmartGlance Business Report Generator" prepares it and sends it to your device via internet. This could be a way to implement use case number 2 since it relies on retrieving data from the existing database.

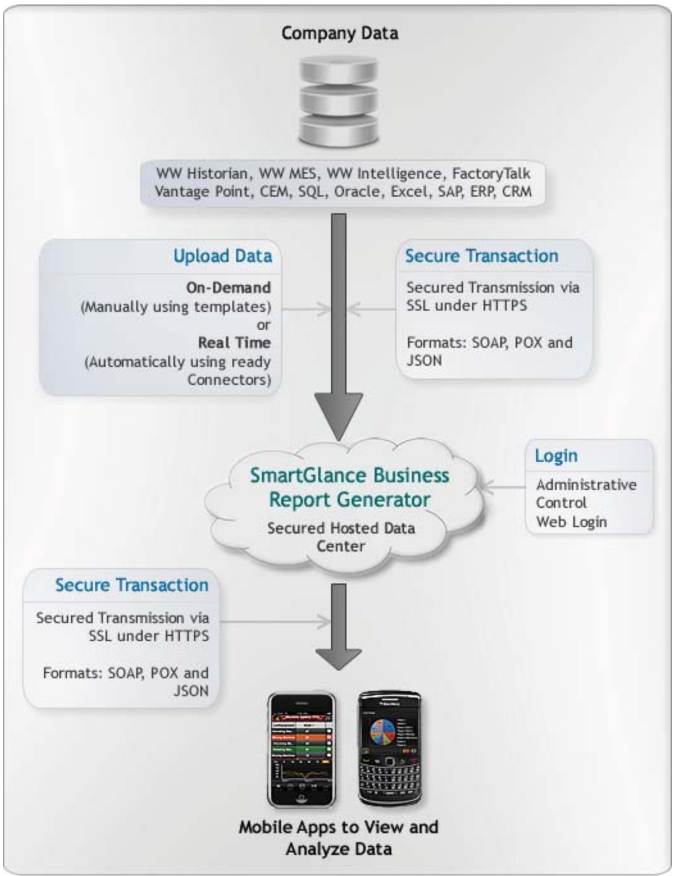

Figure 9. SmartGlance Architecture [2]

To summarize, there are some commercial mobile solutions that can be useful in a industrial context such as Tetra Pak, available on the market today. However, no application is perfect, since they have been developed for a wide range of purposes. But with these possibilities in mind one could, without any greater effort, develop customized systems targeting Tetra Pak's existing systems that can be marketed and sold in combination with existing systems as well as used internally.

5.2 Market shares and forecasts

How the consumers perceive and adapt a mobile platform has a huge impact on the platforms future development[13],. If a large group of consumers choose a specific platform then developers will automatically be drawn to it. This leads to improved functionality and consequently a rapidly improving platform. Forecasts predict that android will claim a larger share of the consumer market, taking shares mainly from Symbian and RIM's Blackberry, illustrated in **Figure 10** and **Figure 11** below. The figures also show that Apple's iOS will remain at it's current market percentage and that other competitors will surface and claim a significant share of the world market.

However this is a very dynamic and unpredictable field of technology where nothing is certain.

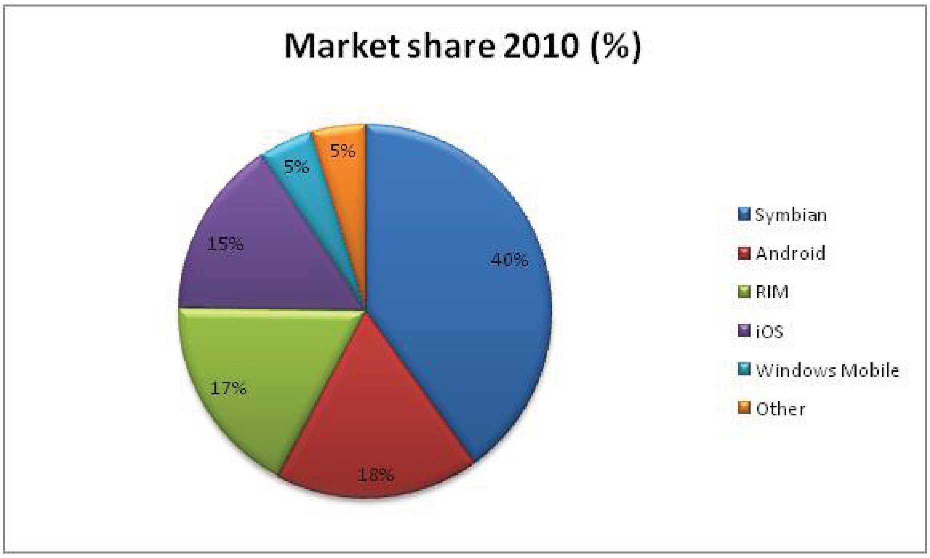

Figure 10. Market shares 2010 [9]

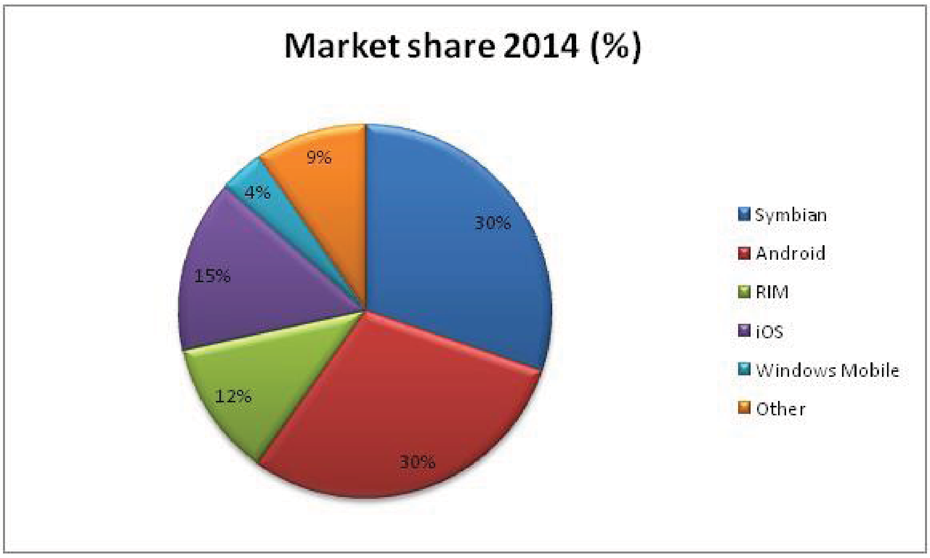

Figure 11. Market shares 2014 [9]

5.3 Mobile Security

If mobile devices are allowed access to enterprise systems the need for a good way to manage mobile security increases. Surveys are showing that 42 percent of organizations allow mobile phones to remotely connect to their enterprise networks and less than 50 percent of the companies that uses mobile devices have a specific documented mobile security policy. While at the same time 73 percent never backup data stored on their mobile devices. This is alarming numbers and the need for antivirus software and security procedures is increasing in parallel with the increasing mobile phone virus threat. [10]

5.4 Prototyping

This phase describes the implementation and deploying of a mobile solution, taking the previous software and hardware platform discussions into account, as well as forecasts, security aspects.

5.4.1 Platform

Android is the software platform used for prototyping in combination with a suitable hardware platform, in this case a Samsung galaxy pad GT-1000. The earlier platform analysis and forecasts points to Android as the best platform for implementing the selected use cases within Tetra Pak, as well as the best path to take for future in-house application development. One of the benefits with Android is the wide selection of compatible commercial hardware available. This particular mobile device has a 7 inch screen, cameras on the front and back as well as Wifi and 3G capabilities, see manufacturers specifications below.

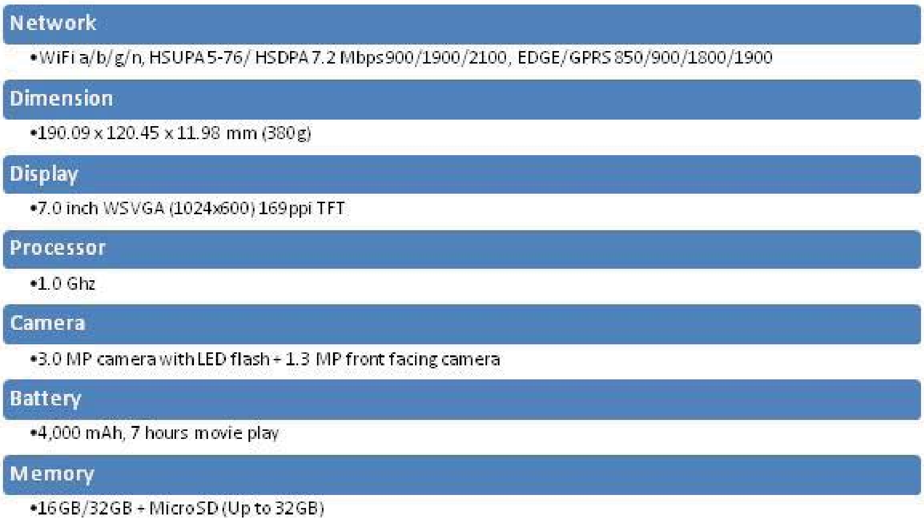

Figure 12. Samsung Galaxy tab GT-P1000 [19]

This hardware was selected primarily for it's suitable screen size in combination with the camera on the back. The size of the device allows it to be held firmly in one hand when operating it. It can also be transported in a jacket or pant pocket, in contrast to many other 10 inch devices. The resolution is similar to the one used in Tetra Pak module HMI:s, which opens up the possibility of remote desktop applications. A camera makes it possible to identify components by scanning barcodes, as well as taking pictures for documentation purposes. The mobile security aspect is satisfied by using a properly configured WPA encrypted Wifi router with a secure password, as well as routines for backing up the device mobile device.

5.4.2 Implementation of Use case 3

For this scenario I integrated existing open source remote desktop and barcode scanning functions in my own local application. The scanning is used to identify the component to be controlled and triggers the remote desktop function with the information in the scanned barcode. One possible target of the application is the remote desktop server integrated in every machines local HMI. To communicate with the HMI a wireless router is attached to the panels Ethernet port. The connection could off-course have been established by inputing the HMI:s IP:address manually instead of scanning. This will not be made possible since I want to make sure that the user is physically present, at least when initiating the remote control. Without this security measure the machine could be remote controlled by someone not aware of the activities at site, a potentially dangerous scenario since the personnel at site may be tampering with it, thinking it is not running. Tetra Pak's existing system is very safe and prevents the user from operating a module if anything is missing, broken or at the wrong level. This application is intended to be used primarily by automation and commissioning engineers while starting up or testing processing equipment. The time and resources spent on training and testing when introducing a new application are important variables. This application uses Tetra Pak's existing user interface, a huge advantage with building a remote desktop application as opposed to building a application with a completely new user interface. Engineers can continue working as usual, but from anywhere in the factory. The solution is not limited to controlling single modules. The supervisory system, or control room solution that connects the entire factory in a single user interface, can also be controlled by a remote desktop application. When starting up or testing a new system at a customer site, this user interface also has to be tested. This usually means that one engineer has to be stationed in the control room while another is on the factory floor observing whats really happening. By using this remote desktop application only one engineer is required, as he can access the control room solution while observing the targeted components and modules himself. At the some time, this allows the engineer to test the actual control room system, as opposed to a application with its own customized user interface.

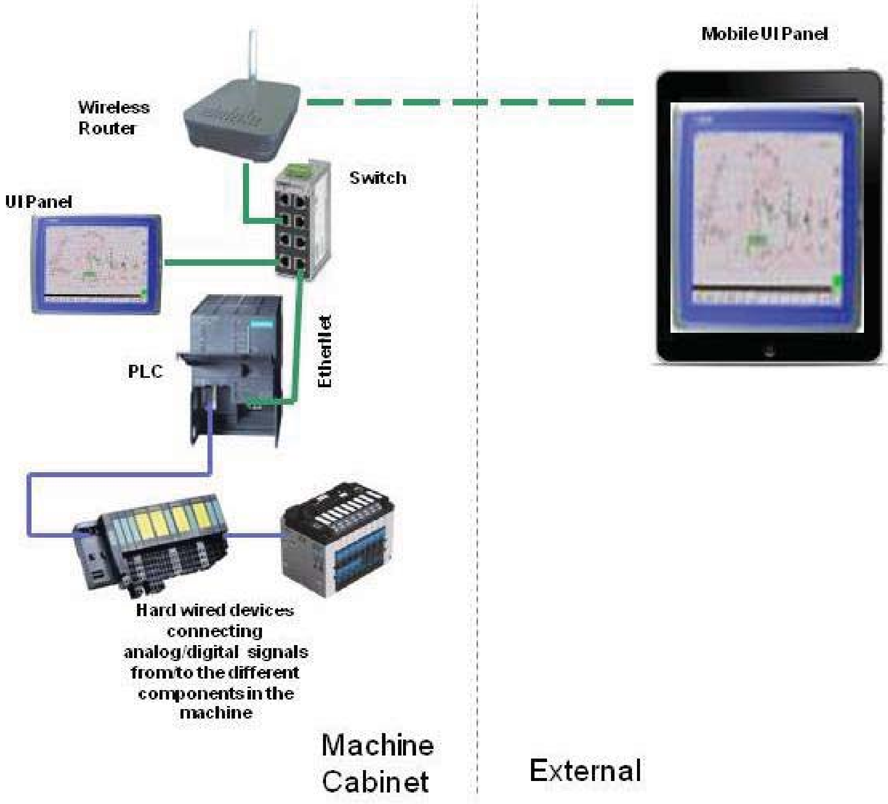

Figure 13. System communication overview

The panel i used for testing had a 15 inch screen that display the user interface with a resolution of 1024 x 768 pixels. When using my remote desktop application this translates very well to the 7 inch screen with the similar display resolution of 1024 x 600 pixels. Another positive aspect is that the user interface used in the panel is tailor-made for a touch application.

5.4.3 Implementation of Use case 7

This application makes use of the embedded SQLite database library integrated in the Android development environment for fast and efficient access to service instructions. The components article-numbers, the same as the file names of the instructions, are associated with different categories in the database. One can search for a component category and receive a list of relevant components, select one, and be forwarded to the correct file. The files containing service instructions are copied from their current location, a DVD, to a folder on the device. The application is totally network and location independent as this solution only uses information located on the actual device. This increases the reliability and minimizes the security risks, as opposed to a online solution with information in a web server.

This application is primarily intended for use by maintenance or service engineers interacting with processing equipment.

6 Conclusions

6.1 Recommendations

After investigating the different mobile platforms, in combination with existing Tetra Pak systems, taking interviews and prototyping into account, I make the following recommendations.

I recommend Android, for the development of advanced in-house applications. Android is rapidly taking more and more market shares from competing platforms. When the number of users increase developers are drawn to the platform, and it grows sturdier and more advanced in a rapid pace. Another big advantage with this platform is the open source aspect which grants developers complete rights to modify and distribute code and applications. This makes the development and testing of new applications easy and fast since a lot of complex functionality is available for integration.

For marketing or promotional applications that is intended to reach as many people as possible I recommend iOS primarily for it's currently superior application distribution channel App-Store.

This thesis focuses on integrating a mobile solution without having to customize the existing systems to any greater extent. Communication with the different components, like the database, PLC or web server can be established via wireless Ethernet. Android offers the possibility to easily construct applications with integrated OPC-clients for communication with PLC:s, and ODBC drivers or web server support for communication with databases. Establishing a wireless network is the only modification needed to make the existing systems compatible with a mobile solution. This is accomplished in a factory by connecting a wireless router to the wired Ethernet network that is already in place.

Placing as much functionality as possible in a web server solution is advised, since the existing systems are available as web content via a network. Additionally, this leaves the door open for adaptation of other platforms in the future. Which is a desirable trait since the mobile platform industry is such a dynamic, rapidly evolving arena.

The greatest challenge for Tetra Pak, when deploying a mobile solution like in use case 3, is to establish a reliable wireless network in the customer factory. According to the interviews, the time and effort required to do this will be acceptable, compared to the resources that can be saved when cutting down on manpower.

6.2 Future work

I recommend Tetra Pak to continue development and research in the mobile technology field. The first step in this direction would be to test and implement more use cases and applications, and to continue with further evaluations and optimizations. The two already implemented use cases should be tested and evaluated by Tetra Pak automation or commissioning engineers in the field. The commercial hardware platform, without a IP-rating, is a crucial aspect that needs extra attention and testing. Integration of mobile devices can by itself promote innovation, and stimulate engineers to work in new creative ways. Finally, one should always be agile, screen the market for new technology, techniques and trends in order to be successful in the dynamic mobile arena.

A Appendix 1. Requirement specification

A.1 Hardware requirements

A.1.1 Water and Shock resistance

Description
The device is sufficiently water and shock resistant.
Reason/Gain/Advantage
This requirement opens up the possibility to use the device in a industrial factory environment in the food processing industry.
Risk/Limitations
The risk is that this requirement leads to bad mobility, low battery time and an unpleasant user experience.
Reference No.
H1.

A.1.2 WIFI

Description
The device will communicate with a web-server via local WIFI.
Reason/Gain/Advantage
Without the ability to communicate over a local network via WIFI a device would have to have 3G reception at all times when interacting with industrial equipment.
Risk/Limitations
Communication can only be conducted over secure networks, by using provided log-in credentials.
Reference No.
H2.

A.1.3 Battery-life

Description
The device must have a battery-life that allows a reasonable time of usage without charging, for example a average working day, 8-10 hours.
Reason/Gain/Advantage
The requirement is important in order to make the device completely mobile.
Risk/Limitations
This can make the device big and heavy or lacking in performance.
Reference No.
H3.

A.1.4 Portability

Description
The device has a appropriate weight, size and form to be ergonomically compatible with a average worker.
Reason/Gain/Advantage
The requirement is important in order to make the device universal and usable by everyone.
Risk/Limitations
Applications that require large screens affect the portability in a negative way.
Reference No.
H4.

A.1.5 Camera

Description
The device has a integrated camera for taking pictures and possibly making movies.
Reason/Gain/Advantage
With a integrated camera the device can for example scan barcodes and take pictures for quality assurance purposes.
Risk/Limitations
Many integrated cameras are limited in terms of pixel rate, resolution, frames per second, flash and zoom-functionality.
Reference No.
H5.

A.2 Feature requirements

A.2.1 Database access

Description
The application can fetch data from Tetra Pak's database, direct or indirect.
Reason/Gain/Advantage
This is a basic requirement that allows retrieving of historical data from Tetra Pak's existing system.
Risk/Limitations
The user must have access to the local network or be routed in via a web-server.
Reference No.
F1.

A.2.2 Controlling

Description
The application can change values in the PLC via the local network.
Reason/Gain/Advantage
Opens up the possibility to test or operate a machine controlled by a PLC.
Risk/Limitations
This feature will only be available in zone 1 and 2, for security reasons.
Reference No.
F2.

A.2.3 Distribution

Description
The application can easily be distributed through a suitable channel.
Reason/Gain/Advantage
Allows the application to reach a wide audience for promotional purposes.
Risk/Limitations
Applications distributed to a large group via an open distribution channel may not have access to any sensitive information.
Reference No.
F3.

A.2.4 Web browsing

Description
The application can browse web content.
Reason/Gain/Advantage
This is a basic requirement that allows interaction with a web-server or other HTTP content.
Risk/Limitations
The user must have access to internet or the local network in question. This exposes the device to external security threats.
Reference No.
F4.

A.2.5 Barcode scanning

Description
The application can scan barcodes.
Reason/Gain/Advantage

Allows the application to identify objects in a convenient and reliable way.
Risk/Limitations
The device executing the software must have a integrated or attached camera.
Reference No.
F5.

A.2.6 Local database

Description
The application can access and maintain a local database, for example SQLite.
Reason/Gain/Advantage
Allows the application to store and search between objects locally, without a network connection.
Risk/Limitations
There needs to be a backup of the stored data in case of data loss or accident.
Reference No.
F6.

A.3 Software requirements

A.3.1 Database

Description
The application can interact with a MSSQL database directly via an ODBC.
Reason/Gain/Advantage
A requirement for directly monitoring historical data from a database.
Risk/Limitations
Giving a application direct access to a database exposes it to security risks.
Reference No.
S1.

A.3.2 OPC

Description
The application can interact with a OPC server via a OPC client.
Reason/Gain/Advantage
Opens up the possibility to control a PLC or retrieve real-time data without using a external database or web server.
Risk/Limitations
- .
Reference No.

S2.

A.3.3 TCP/IP

Description
The application can use TCP/IP protocols to send/receive data over a network.
Reason/Gain/Advantage
Opens up the possibility to talk to the PLC, for example via PLCPump.
Risk/Limitations
.
Reference No.
S3.

A.3.4 Maintenance

Description
The application should be easy to maintain and update.
Reason/Gain/Advantage
When bug-fixing and feature updating this is a necessity.
Risk/Limitations
If the platforms development tools and API:s are subject to frequent changes that affects the application-code this will increase the maintenance time and costs.
Reference No.
S4.

B Appendix 2. Interview questionnaire

Nedan följer användarscenarion där en mobil lösning kan tänkas användbar. Kommentera dessa, är de realistiska, relevanta, behöver de förändras på något sätt?

UseCase 1
Events
A customer encounters a problem with a filling-machine. The production personnel on site doesnÕt know how to solve the problem. The service engineer responsible for the machine gets an instant alarm sent to his handheld device. He reads the alarm description and chooses to either turn the alarm of or contact the production personnel on site with instructions on how to solve the problem.
Required features Network connection Push notification Fetch data from the database

UseCase 2
Events
A employee at a costumer company is responsible for a specific product. He wants to make sure that everything is working and progressing according to plan, even when he is at home. He wants to know that the production flow is at a good level and no serious errors have occurred. He starts a application on his handheld device, log in with his credentials and input the time interval that he is interested in. The program then displays relevant historical production data in diagram and text form on the screen.
Required features Network connection Fetch data from the database

UseCase 3
Events
A service engineer is interacting with a machine in a factory. He wants to test the phases, recipes and valve/motor activations on the machine. He logs in to his handheld device with his credentials and connects to the machine in question. A overview of the machines components is displayed and the engineer can start/stop phases and force activations. A log showing the actions taken is created to improve traceability in the service process.
Required features Network connection Location sensing Fetch real time data Write data to the PLC

UseCase 4
Events
A employee in Tetra PakÕs marketing division developed a promotional application, wanting to highlight the launch of a new product. He logs in to his developer account and submits the application for distribution, reaching a wide audience.
Required features Access to a good distribution channel.

UseCase 5
Events
A service engineer wants to check the maintenance needs, or time left in maintenance intervals, for different machines in a factory. As he walks through the factory physically inspecting each machine, he wants to access and maybe update maintenance

information. He utilizes his handheld device, connected to the local Wifi, to access a database and fetch/change maintenance data for the different machines.
Required features Network connection Fetch data from database Write to database

UseCase 6
Events
A production worker wants to manually add ingredients in a filling machine. He inputs his credentials in his mobile device and gets access to the system. The system displays the currently active filling machines and he chooses the targeted one. He scans the barcode on the material, thus saving this information in the system, and then physically adds the material.
Required features Network connection Database access Write to database Scanning functionality

Har du förslag på några egna scenarion där en mobil lösning kan vara användbar?

Ett företag inom livsmedelsindustrin har delats upp i olika miljöer och ett antal olika roller har specificerats. Rollerna och miljöerna kombineras i matrisen nedan utefter vilka personer som arbetar i vilka miljöer. Stämmer detta överens med din bild av hur en typisk Tetra Pak Ð kund är strukturerad? Skulle du vilja dela in en verksamhet i fler/färre roller?

	1.Production	2.Factory	3.Office	4.Home/Travel
Production personel	Yes	Yes	No	No
Support engineer	Yes	Yes	No	Yes
Production-site manager	No	Yes	Yes	Yes
Sales/finance personel	No	No	Yes	Yes
Office manager	No	No	Yes	Yes

Behöver verksamheten delas upp i fler/färre miljöer?

Vilka fysiska krav skulle du ställa på en mobil enhet i de olika miljöerna ovan?

Vilka säkerhetsrisker ser du med användandet av en mobil enhet för styrning och övervakning av en process?

Det finns en bifogad kravspecifikation indelad i hårdvarukrav, mjukvarukrav och funktionskrav. Vilka krav tycker du skall plockas bort eller förändras och vilka bör läggas till?

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