Designing Backend Servers for Mobile Applications in the Industrial Project Management

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Abstract. This paper describes the design challenges which everyone faces when a backend server for mobile applications is developed. For this particular research a backend server for mobile context-aware services for industrial process management was developed. The context information is gathered from the employees' smart phones and the industrial process management legacy information systems. The goal of the research was to utilize the gathered context information in order to improve the management and monitoring of the industrial processes, make the operations teams more efficient and taking the employee safety to a higher level. As a result of the research a prototype system was build and the defined use cases were tested. The build system is placed on top of the existing process control and management systems, acts like a gateway between these systems and the employees' smart phones and enables complete up to date information about the process state and monitoring of the vital parameters of the employees when they are working on some risky tasks. Based on the tests done, it was concluded that this type of design ensures: prompt information sending to it is users, security, scalability, reliability and enables easy addition of extra system components for gathering process data and content adaptation for mobile devices.

Keywords: backend server, industrial process management, operations and maintenance enterprise mobility, mobile phone application, context-aware services.

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1 Introduction

To enable continuous production, the production companies must ensure that all of the systems and machines which take part in the production process work properly. Machines' maintenance is very important because production outage means lower incomes or lost of clients due to unmet delivery deadlines. On the other hand if a malfunction or machine defect appears, the machine reparation may cost a lot or the restarting of the production line takes too long.

No matter how careful we are and what kind of precaution measurements we take the defects and production outages appear. If it's not a matter of a human error, the outages may appear because of machine's overloading or the machine parts simply abide due to machine's usage. Because the production outages can't be avoided the companies have various procedures and business processes which tend to make the outages less frequent and define employee's responsibilities in such situations. In case of production outage the most important thing is that every concerned employee, no matter what position he/she holds in the company's hierarchy has to be properly and timely informed about the situation. To ensure fast and quality intervention by the maintenance personnel, the employees who will be sent must be those who are physically closest to the place where the problem happened and they should have the relevant knowledge and experience in solving such problems.

To enable prompt and correct information delivery to all concerned parties in case of an emergency and production outage there must be a system which will monitor the current state of the whole production process and which will "know" the current state of each machine which is used in it. The role of such a system is to timely inform all concerned employees and to send only the information which is relevant to them.

With the development of the technology, the mobile devices and the smartphones are widely spread and they are becoming more and more powerful tools for accessing any kind of information in any format: audio, video, image or text. Because of that, they are perfect platform for displaying different kind of information. People are in constant movement and search for information, so it's very important to have the information available anywhere, anytime. Because of this and the various hardware accessories like: camera, compass, sensors for orientation, temperature, location etc. the smartphones enable us to detect the user's state so that we can send the most appropriate information in that particular moment in time. The other useful things which can help us to determine the state of the user are the way the user interacts with the smartphone and their habits when they are using the phone.

By using smarthones as a platform to which the relevant production process information is sent, the employees can have the exact state of the whole production process anywhere, anytime, so that they can timely react in that particular situation.

The goal of the research described in this paper was to make an overview of the problems which happen in the industrial process management, specifically the maintenance of the production lines and to give some pointers how these processes can be improved with using the modern mobile technologies, mobile devices and the services they offer. The idea was with minimal changes to the existing IT infrastructure to

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enable access to the production process and production line data, organize it in a meaningful way, and make it accessible to the employees' mobile devices anywhere, in order get the process maintenance on the higher level.

2 Related Work

2.1 General division of the systems

There are different systems available on the market which partly cover the area discussed in this paper, but there are only a few which make their data available on mobile devices.
These systems can be divided in three general categories:

1. ERP [1] (Enterprise Resource Planning) and BPM (Business Process Modeling) systems. They are used by the management teams to organize the activities and the business processes in the companies;
2. SCADA [2] (Supervisory Control and Data Acquisition) systems. They are used by the process engineers, process operators and the maintenance personnel to monitor the state of the production processes;
3. Various custom designed systems used by the maintenance personnel used in their daily tasks.

The ERP systems are usually used by the managers, but some of them have modules which are used by the warehouse or the maintenance personnel. These modules are usually used for tracking the state of machine parts, whole machines or tools owned by the company as well as for tracking the taken actions on the production line. Example of such module is the Plant Maintenance [3] (PM) module of SAP [4] and OpenERP [5]. These systems are great for tracking the company's processes, but in the field of plant maintenance they don't offer much except tracking the actions taken on the production line and parts replaced. Usually they lack the part which abstracts the current process state and presents data which are relevant to a specific user. Regarding the data access from mobile devices they offer limited or no access, but some of them, for an extra charge, offer APIs so that some third party companies or the users themselves can develop mobile clients.

The SCADA systems are the basic information systems in every control and monitoring of industrial processes. They visually show the process state, the values of the process parameters and alarm the operators in case of some abnormal state. The process state is acquired by reading various sensors or local controlling loops made with PLC (Programmable Logic Controllers). The alarms are usually made with sound (blowing a horn) but there are some systems which can send SMS or email messages. Regarding the mobile data access the things written for ERP systems are also valid. Many times these systems are built to specifically satisfy the needs of a

particular industrial process and they use a specific proprietary hardware which makes upgrades and data retrieval hard.

The third group of systems comprises the systems which help the maintenance personnel. These systems improve the communication between the maintenance personnel, give better overview of the parameters of interest, give overview or the environment in which the work is done or even follow the vital functions of the employees. These systems are usually closely coupled with the monitored industrial process and have different implementations. The common thing about all of them is that they use some specialized hardware which the users are wearing on them, so called wearable computers [6][7][8].

2.2 Similar systems

The systems similar to the one discussed in this paper, usually use location based services, wearable computers and augmented reality.

Google made an interesting system called Google Maps Coordinate [9]. The system is build on top of few Google services like Google Maps and Google Latitude and it's intended to be used for coordination of the field work done by the maintenance teams. The team coordination is done on a central place and the field worker positions and the jobs done are shown on a map in real time. The maintenance personnel can add write messages and update the job status reassign the jobs to some other worker etc. The system is quite new and is build on top of proven Google technologies. The difference between this system and the one discussed in this paper is that the data and the jobs are inserted manually and they are not taken out automatically from some production process.

The other systems are made by some industry giants like SAP and Siemens. SAP has more general ERP solutions which are customized to the needs of a specific implementation. On the other hand Siemens has some solutions which are completely closed and made from their own hardware and software. This is good in terms of system integration, everything is from single vendor and can be easily integrated, but in case some hardware needs to be bought from some other vendor, there can be problems integrating it or maybe some extra charges for customization.

The rest of the systems are developed mostly by some research institutions and are targeting electrical and nuclear plants and waste water facilities [10][11][12][13]. They use location based services for outdoor localizing and QR Codes or barcodes for indoor localizing or object detection. They also use augmented reality to show the users how to get to the place where the problem is. To read some process parameter when the users are standing in front of some machine augmented reality, barcodes and image processing on the mobile device are used. These systems are good, but they are made specifically for some particular plant and a particular process.

3 System Overview

3.1 General overview of backend servers for mobile applications

The general block diagram of a backend server for mobile applications is shown on figure 1. It can be seen that the content which has to be delivered to the mobile devices is retrieved and processed so that it can be manipulated by the rest of the system. After this the contents are adapted so that they are suitable for displaying and delivery to the mobile devices. At the end the content is being delivered to the mobile devices.

Fig. 1. Backend server for mobile applications block diagram

The content retrieval and the initial data processing depends on the content sources and the form and amount of data which they are serving. Depending on the content sources the connectors for retrieval can use different mechanisms for data retrieval like content polling, some notification messages when there is data that the system is interested in etc. The retrieved data can be in various formats as well.

The content adaptation is done depending on the number of different devices to which the data should be delivered and the format in which the data should be delivered. If we have some devices which are connecting via web service we would probably use JSON or SOAP messages and if we are delivering to a mobile phone browser we'll have to adjust the HTML layouts and image sizes so that they will be appropriate for a given device.

The content delivery is made based on the way the content should be delivered. This depends on the way the communication between the backend server and the mobile application goes.

The crucial thing that must be done is to move all the heavy processing on the server side so that the client mobile applications will act just like a thin terminal. The other thing that must be done is to optimize the power consumption on mobile device because the battery life is limited. The whole communication and the mobile device sensor readings have to be carefully designed so that the mobile device can handle all the data sent from the server without losing any of its parts. We should also be careful with the amount of data that the server sends to the mobile phones so that we do not affect the data plan and cause extra expenses for the users. If the mobile application uses the sensors, than we must optimize how we use them so that our app will not kill the battery in a short time interval after we started it.

Speaking in general, the design of the backend server depends from the application in which it is used but we should always have in mind that the mobile devices have limited hardware resources and battery life, we must optimize and secure the data transfer and we should adapt the content so that it suits the best to the mobile device.

3.2 System block diagram and system requirements

Before we set the system requirements for our backend server for mobile applications for the industrial project management we will give a short overview of the context-aware data which can be acquired from the process and from the employee's smartphones. Context is a set of information which describes some object or a person in some particular situation.

We can divide the context information gathered from the process in three general groups:

- The place where the information is gathered;
- The employee profile which need information of a specific type;
- The meaning which the information has to the set production process goals and how it affects them.

The information can be gathered in various places: the current state of the production process, the state of the machines on the production line, the history of failures, etc... This is the information in its raw state and it is used by the process engineers, process operators and the maintenance personnel.

The second group contains the same information as the first one, but it is filtered and grouped so that the each employee gets only the information which is relevant to him/her.

The third group gives some interesting information based on abstraction. The process parameters are analyzed and based on their values or correlation to other parameters a conclusion is made and presented to a particular group of employees. For example if there are few parameters whose values observed together means that some machine is broken, the managers won't get the parameter values, but will get a message saying that the machine is broken.

The employee context information can be the employee's job position, current tasks, latest completed tasks and sensor readings from his /hers mobile device (location, orientation, environmental temperature, vital functions – pulse, blood pressure...). All these information can help us to determine which data is relevant for the employee in a specific situation.

Based on the available context information and goals which are set for the backend server we can set the system requirements:

- Reading of the process parameters in real time from various sources;
- History of the process parameter values fluctuation;
- Statistical analysis of the process parameter values and prediction of possible defects;
- Prompt delivery of the relevant information about the current process state and predicted failures to all concerned parties;
- Support for various mobile devices;
- Remote view and help for the maintenance personnel in the field;

- Tracking of the employee's vital parameters if they are working in some bad conditions;
- Tracking employee's performance on the reparation task and proposing the most appropriate person for a specific problem.

According to the written above, we have designed the system whose block diagram is shown on figure 2.

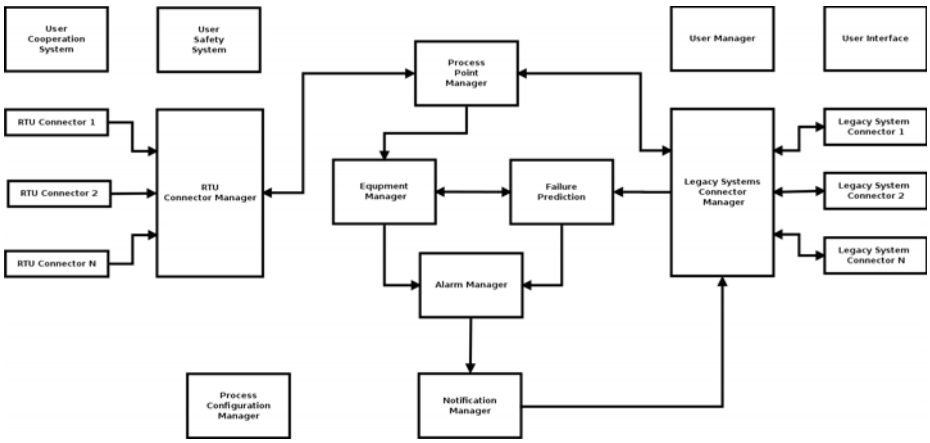

Fig. 2. Block diagram of the designed system

On the block diagram few major groups can be seen:

- Remote terminal unit manager and connectors – these are used to connect to sensors and data sources apart from the legacy systems;
- Legacy systems manager and connectors – used to connect to the existing systems ;
- Process point and notification manager – management of process point parameters and their values as well as definition and sending of notifications;
- User management – management of user rights, grouping the users by their position in the company and data relevant to their working tasks;
- Employee communication system and vital parameters monitoring – a sub-system which enables communication between the maintenance personnel while they are working and monitoring of employee's vital parameters.

The designed system has modular component design which enables easy addition or replacement of various components. It is build on top of the existing IT infrastructure and process control circuits. This way without any problems it can be implemented for various process control applications.

4 Implementation Details

The system is designed to be implemented with standard well proven software technologies. Because the process control IT infrastructure can have many different legacy control systems produced by various manufacturers, we have decided to use messaging bus and interfaces to connect the control systems to it.

The message bus is implemented with 0MQ [14] a high-performance asynchronous messaging library aimed at use in scalable distributed or concurrent applications. This library was chosen because it Open Source, it works under the most of the major operating systems, it supports various types of messages and network topologies and supports many programming languages. The capability of developing messaging clients in various programming languages enables the developers and system integrators to write the interfaces in the language the legacy system is build. The other basic system components such as the process point, notification, service discovery, message loggers are written in Java with the Spring [15] framework. The mobile application used in the testing was written for Android [16]. The component diagram can be seen on figure 3. This kind of system organization enables scalability, reliability and easy system component replacement in case of problems.

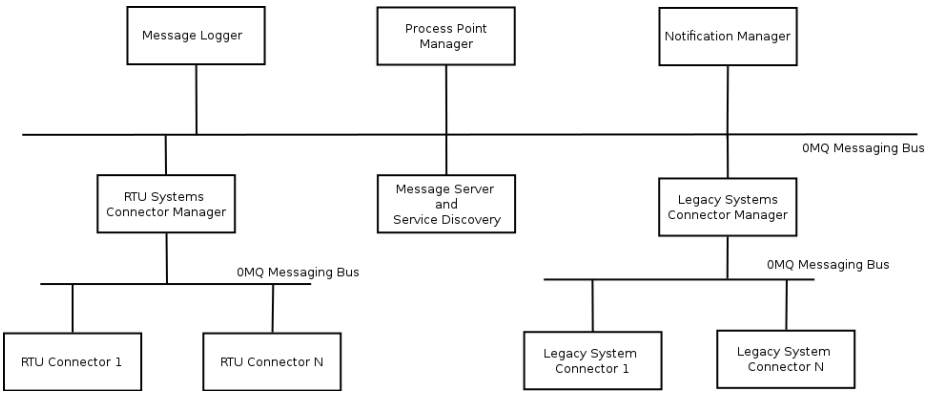

Fig. 3. System component diagram

On the system deployment diagram shown on figure 4 it is shown where and how the system is connected in the company's control systems IT infrastructure. It can easily connect to various systems on various levels of the IT network such as plant floor, operations network and business network.

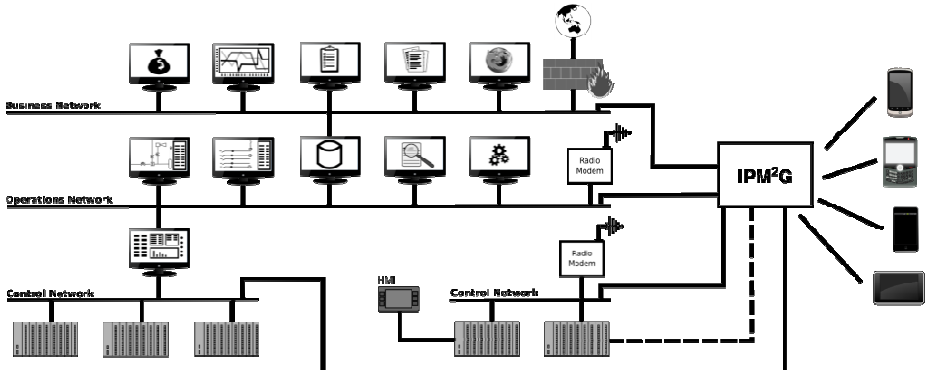

Fig. 4. System deployment diagram

5 Testing and discussion

Because the main goal of the research was system design and not its implementation, instead of building a complete system and testing its capabilities only a few components of the whole system were made. The main focus of the tests was to ensure that the components are communicating between themselves as it was designed and to check the processing of the process parameters and their delivery to the mobile devices.

The communication tests were made by examination of the messages passed in the system between its components. Basically the messages were monitored in a normal operation mode, their content was analyzed and was checked against the predefined use cases and communication rules of the defined communication protocol.

The processing of the process parameters values was tested in order to see if the messages are correctly interpreted on high level (to check the predefined rules by which few parameters together define some process state and the message is abstracted) and to see if the process parameter values are properly filtered and only the relevant information is sent to a specific employee.

The last conducted tests were system load tests which were performed by simulating few legacy system connections and few RTU connections sending data and the observation was made if the data is properly and timely processed.

All of the tests passed without any significant problems.

6 Conclusion

By the analysis of the system design and conducted test of the prototype system it can be concluded that the primary goals have been totally accomplished. If this kind of system needs to be implemented for a real industrial process, the whole system must be adjusted to that specific process. The build system can work out of the box for some small process, but for bigger processes there might have to be done some adjustments in order the system to handle all that big amount of data. Maybe just adding some extra system components to share the processing time will be enough. Maybe some adjustments of the data processing algorithms should be done. It all depends on the industrial process for which the system will be used. Besides the data processing adjustments, some changes in the content delivery components and the content adaptation components should be made in order to meet the requirements of the used mobile devices.

Generally speaking this system design is a good base for building real world back-end servers for mobile applications for industrial process.

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