BUILDING-UP AN AUTOMATED DATA COLLECTION SYSTEM

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ABSTRACT
The need for gathering real-time information in building and industrial environments has increased in recent years. In the building environment, along with automatic utility meter reading, other information is increasingly needed e.g. room temperatures or device conditions. In the industrial environment, for instance in the paper industry, information on paper reel locations is essential when developing logistics and supply chain management. This paper presents a particular system definition of the automated data collection system and clarifies management issues. The study is based on the automated data collection system (ADCS). ADCS is an open and advanced platform e.g. for building control and monitoring systems. This study also analyzes ADCS data loads, quality of transmission, and error sensibility in different system parties. By using ADCS infrastructure, the usually inconvenient attachment and registration of new devices can be solved.

Keywords: Data collection, information, automatization, meter reading

1 INTRODUCTION

Device-independent and open data collection in different kind of applications is a very important area under current consideration. An open architecture consisting of actuators, sensors, transmission media, secure data transmission, compact messages, and message types presents a big challenge in designing the whole system and needs comprehensive study before implementation procedure.

ADCS is a common name for an open data collection system, it is planned to be suitable for applications such as automatic meter reading (AMR/AMS) [1], RFID-systems [2], and for building automation sensor networks [3]–[6]. In AMR systems, for instance, the amount of transferred data is small. Thus, an ADCS offers a varied choice and the features required to manage the data transmission. As Figure 1 in chapter 3 will show, the advantage of ADCS is in its versatile options for public utilities and their customers. Many of these features suggest the desirability of real-time processing and methodology which is one of the main motivations behind this paper.

This paper is organized as follows: chapter 2 clarifies the basis of the automated data collection. Chapter 3 presents a solution for ADCS data collection system on the basis from chapter 2. Chapter 4 presents a case study for ADCS data collection and chapter 5 concludes the study and takes a look at future work.

2 BASIS OF THE AUTOMATED DATA COLLECTION

This chapter presents a common overview for an automated collection system. The basic building-up procedure for an automated data collection system consists of phases such as new device attachment, operations during maintenance and system operations. In the attachment phase, new device attachment activities are presented, and in the second phase, operations during ADCS maintenance are explained. In the last phase, the functions of system operation are clarified.

2.1 Attaching

One of the main goals of the device attachment procedure is to be “Plug & Play”. As discussed in [7], home-networking solutions should be easy to install, providing PnP and/or autoconfiguration features, and should enable remote maintenance from the service, network, or manufacturer site. Reliability and robustness are also considered mandatory, as residential users will have difficulty identifying and handling problems and home-networking products need to operate all day and night long [7].

When an actuating device is installed, the concentrator automatically updates itself with the values from the device registers, for example device number- and energy consumption values. The exception is a pulse reading technique that cannot be read via the device register.
The information is sent to the main system to ensure that a new device is connected to the system. The same information is supplied to all relevant subsystems. This should minimize the occurrence of human mistakes in the information flow [8], [9], [10].

Basically, most of today’s AMR consumption meter registration is not based on entirely self-configurable or automatic updating methods and these systems are not generally open-based. Therefore difficulties often arise in the case of software updates when vendor support is needed to solve the problems. In addition to this, some software conflicts cannot be solved or can take a long time to be found. Even a vendor can come up against software conflicts that cannot be solved without the help of external software consultations [19]. Also the lack of plug & play standards is an obvious disadvantage.

A new AMR consumption meter installation and configuration is normally handled by an electrician visiting the building and reconfiguring the main system. Commonly, the consumption meter is pre-configured by a vendor according to the requirements of a utility company. After a meter is installed in a building whose energy consumption is to be metered, the rules of communication between the meter and main system are established by the means of main system tools. In the last phase, the metering information (for example meter ID number, energy consumption, type of meter, meter location or property information) is stored in the meter value database.

In [11], the biggest challenge in all symmetric security systems is how to exchange the initial encryption key safely. In many communication protocols, this is carried out without any security procedure or the challenge has been left to the application developer to solve [12], [13], and [14]. If an adversary receives this first insecure message, the security of the whole network is threatened. One solution to this problem is to exchange the primary key through physical contact [11].

Novel sensor registration should ensure security procedures to authenticate new devices safely into the system with easy and fast registration, for example as executed in [11]. In practice, this means that a new device receives a primary key from the registering device that is synchronized with the network master node. This means that communication in the new network is immediately secure [11].

2.2 Operations during Maintenance

An important and essential issue in future metering systems is the establishment of automatic configuration [15] and easy installation methods. So far there are many equipment suppliers whose systems are designed to operate automatically, but rarely are these systems based on an open infrastructure.

Automated configuration will simplify the system operator's task of building and maintaining the sensor network [16]. As in most novel AMR and ADCS systems, the new device attachment procedure is designed with easy management functions.

2.3 System Operation

From the system user’s point of view the ADCS is self-configurable after the registration procedure. The ADCS network is monitored and maintained by the DCU. Two-way communication allows network control and software updates to be controlled by the main system programming tools. For instance, meter reading intervals can be configured from a system management site, so there is no need for additional pre-configuration for the sensing or metering devices. Also all software updating is handled by the main system applications.

The necessity for data content is greatly dependent on device-based definitions. Table 1 outlines the basic information needed to complete the data transmission. Certainly, much more detailed information can be acquired, but at the same time it increases the amount of data transmission [17], [18]. The amount of data transfer should be kept as small as possible.

3 A SOLUTION

This chapter presents a solution for automated data collection system and clarifies the ADCS functions. Under subheading A, the data collection procedure is clarified. Below subheading B, system operation is presented and below subheading C, the DCU (Data Collection Unit) registration is determined. Under the subheading D, analysis of the ADCS solution is given.

3.1 Data Collection

For an ADCS, a metering device could be for instance a utility meter, actuator or sensor. The communication between a metering device and a master device is two-way based as seen in Figure 1. In this architecture model, the heart for data collection is the Master DCU (MDCU). The MDCU operates as a data server and data storage. All users can access the data through the MDCU. The Slave DCU (SDCU) can also store data but it also forwards the information to the MDCU. The SDCU includes database storage in case of data transmission errors (packet corruption or loss) or total blackouts. When a data transmission blackout or error occurs, the metering information is saved in the SDCU database and retrieved by the MDCU during the next MDCU
reading schedule. Thus, the metering information will not be lost. Further, the MDCU includes a database backup in case of power- and data transmission failures.

Figure 1: The main parts of ADCS data collection

The ADCS infrastructure is designed for automatic configuration. The basic procedure is that all network maintenance is configured by the MDCU. In this way, the SDCU is pre-configured at a new DCU attachment. This means that when a new metering device is within range of the MDCU, it updates all necessary information from the MDCU. After that, a new metering device is ready to collect the pre-defined metering data, for example, from an apartment building environment.

3.2 DCU Registration

One of the most common architectures in data collection systems is a centralized architecture. In this architecture, the MDCU manages registration, authentication, and device control and monitoring. Other general types are semi-distributed and distributed architectures, presented in [23]. In this paper, centralized architecture is selected because of its suitability for small systems where the amount of collected data is also relatively small [23].

First, the attaching of a new metering device to the ADCS system is defined. When a new DCU comes within the ADCS identification range, the MDCU wakes up and automatically sends a query message through the network to the new metering device. The other MDCU or SDCU works as a repeater to forward the query message to the destination MDCU. After that the MDCU verifies the message format and if the format is correct, the MDCU confirms that the message includes valid content for the data exchange.

If the MDCU somehow does not receive the message, then the Type C message is retransmitted until MDCU receives the message and sends the acknowledgement (Ack) message to complete the registration (message type B, see Table 1 for message types). A notification message from the new device attachment is then sent to the SDCU and stored in the database in the MDCU. This message consists of at least the new device’s ID number and name. After this is done, the user who is logged on to the system can view the stored metering data and information from the database to exploit, for example, a meter reading value or sensor data [11], [20].

Appropriate message types and descriptions in ADCS registration are presented in Table 1. The functionality of each message type is also described.

### Table 1: Example message types in ADCS

<table>
<thead>
<tr>
<th>Message Type</th>
<th>Description</th>
<th>Function</th>
</tr>
</thead>
<tbody>
<tr>
<td>Type A</td>
<td>Request DCU</td>
<td>DCU attachment to MDCU</td>
</tr>
<tr>
<td>Type B</td>
<td>Acknowledgement</td>
<td>Ack to MDCU</td>
</tr>
<tr>
<td>Type C</td>
<td>Negative Ack</td>
<td>Retransmission to MDCU</td>
</tr>
<tr>
<td>Type D</td>
<td>Data content</td>
<td>Data content from meter/sensor</td>
</tr>
</tbody>
</table>

According to Table 1, four message types are proposed: Type A, Type B, Type C and Type D. These short messages do not need large data content and do not substantially increase the data packet length. Data packets include the pre-defined metering information such as energy usage, temperature, or moisture (see Table 2).

A new device authentication is carried out by user authentication when a new user enters his or her username and password. After logging on to the system the user can view the metering data. Because of minor secrecy demands and the nature of the collected data, a primary key exchange is not needed.

3.3 System Operation

The SDCU is pre-configured by the MDCU software tools before the attaching procedure. In all such procedures, the MDCU recognizes the device, executes the registration with the new device, updates the metering database, and maintains network operation. The network operation includes control and maintenance operations, operations under maintenance, and the metering interval changes and configurations.

When the aggregate of sent and received queries from the database is estimated, the data load can be checked with ADCS centralized architecture [23]. To simplify, the more queries made the more data transmission and load. Moreover lots of queries lead to larger network requirements where the main focus
is to enable sufficient data transmission, and to avoid congestion problems. So, this assumes that data packet size should be minimized or a network must have sufficient capacity to carry out the data transmission demands. The ADCS also supports integrated push- and pull based queries over the hierarchy.

In ADCS architecture, data load is optimized by cutting query requests and message lengths to a minimum. Hence, the query sequence is in such a form as to be suitable for any kind of data collection network type and is also self-configurable for network and device extensions. This paper discusses data load and network requirements only generated in the ADCS system itself.

Table 2 compares different metering characteristics and suitable environments for ACDS. Some less obvious differences are in need of different metering parameters between domestic and industrial building environments.

Table 2: Examples and comparison of different metering characteristics and suitable metering environments

<table>
<thead>
<tr>
<th>Value</th>
<th>Unit</th>
<th>A</th>
<th>B</th>
</tr>
</thead>
<tbody>
<tr>
<td>Electricity</td>
<td>kWh</td>
<td>x</td>
<td>x</td>
</tr>
<tr>
<td>Quality control</td>
<td>e.g. outages</td>
<td>x</td>
<td>x</td>
</tr>
<tr>
<td>Temperature</td>
<td>°C/K</td>
<td>x</td>
<td>x</td>
</tr>
<tr>
<td>Moisture</td>
<td>ppmv</td>
<td>x</td>
<td>x</td>
</tr>
<tr>
<td>Data load</td>
<td>kbs/Mbs</td>
<td>x</td>
<td>x</td>
</tr>
<tr>
<td>Humidity</td>
<td>%</td>
<td>x</td>
<td>x</td>
</tr>
<tr>
<td>Lighting conditions</td>
<td>lx</td>
<td>x</td>
<td>x</td>
</tr>
<tr>
<td>HVAC</td>
<td>°C/K</td>
<td>x</td>
<td>x</td>
</tr>
</tbody>
</table>

A=domestic building environment (apartment buildings, single-family houses, rented flats)
B=industrial building environment

Because of a small amount of transferred data, possible retransmission does not generate notable external traffic load on the transmission network. The ADCS also implies the requirement of supporting multihop networking and the flexibility of data transmission that can be used to quickly modify or exploit the infrastructure. A significant feature of ADCS network is the detection of data transmission failures that improve the quality of transmission. These networks are also inherently self-healing, so users do not have to worry about losing communication with control devices across the building automation system [22].

Combined with wired- and wireless based transmission media, the ADCS offers a good solution for sparsely populated areas. Especially in novel meter reading systems, which support a wireless infrastructure, easy device installation and attachment, these multiform transmission media hybrids are extremely valuable.

3.4 Analysis

In this chapter, the analysis of the ADCS data load profile, system functionality and usability estimation is presented [21]. In the system application layer the ADCS is data load effective, self-configurable and useful in the building automation environment where changes in the environment are commonly predictable. Also the authentication can be executed without primary key exchange. Short messages and small data packets are the starting point in defining of ADCS data transmission. The number of messages is also small; only the required data is transmitted.

The basis for more accurate designing and specifying an application-specific automated data collection system is presented in [23].

4 Verification: A Case Study

This chapter presents a case study for the proposed ADCS data collection. The case study exploits a centralized network architecture model presented in [23]. The network architecture model is evaluated by a simulations procedure to verify the overall performance in different traffic conditions.

4.1 Data Collection- and Traffic Simulations

A method for system verification is determined under this subheading. First, the system architecture is presented and then verified with the simulation procedure presented under subheading 4.2. This simulation procedure concentrates on building automation activities. Figure 2 presents ADCS data collection features in a basic building automation environment.

Figure 2: The ADCS data collection features
To evaluate traffic load, the centralized architecture model and its usability for ADCS in practice, the information flow simulation was executed. The centralized data collection architecture of ADCS is shown in Figure 3.

![Figure 3: The ADCS network architecture](image)

The centralized architecture model for simulation consists of one MDCU that works as a server, and DCUs that work as data storage and forwarders. This centralized architecture model is comprehensively studied in [23]. In accordance of this study, the centralized architecture is suitable for ADCS where traffic loads are high, maintenance is remarkably easy, modifiability is very good and the number of DCUs is small.

Table 3 introduces some common selection parameters for ADCS establishment. By using varied parameters and case study results, utility personnel can achieve benefits for data transmission development of an automatic data collection system.

5 CONCLUSION AND FUTURE WORK

Accurate and reliable data collection is an important subject for the building environment and its development issues. Another big challenge is to form an open infrastructure which can be used in most buildings to meter and control different attributes of changes in living conditions.

This paper presented an open architecture to attain diversified control and a monitoring platform especially for the building environment. The platform can consist of a sensor, utility meter or other actuator. New device registration and attachment to a communication network is also defined. One of the biggest motivations of this study is to solve the problem of new device registration and attachment.

To make ADCS sufficiently versatile for common wired-based applications such as TCP/IP or future. This study does not commit itself to a specific network structures or parameters, and therefore, these appear likely to be the next major focus for future research projects.

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REFERENCES


Table 3: Some common directive system selection parameters for ADCS

<table>
<thead>
<tr>
<th>Parameter</th>
<th>PLC</th>
<th>RF</th>
<th>WLAN</th>
<th>WiMAX</th>
<th>TCP/IP</th>
<th>Twist&amp;pair optical fiber</th>
<th>WSN</th>
</tr>
</thead>
<tbody>
<tr>
<td>Max communication distance</td>
<td>100-150 m</td>
<td>~50 m (in building)</td>
<td>~200-500 m</td>
<td>Up to 10 km</td>
<td>Up to 100 m</td>
<td>~500 m</td>
<td>Up to 20 km</td>
</tr>
<tr>
<td>Suitability for AMR</td>
<td>Average</td>
<td>High</td>
<td>Average</td>
<td>High</td>
<td>High</td>
<td>Aver age</td>
<td>High</td>
</tr>
<tr>
<td>Data communication interface</td>
<td>Modem</td>
<td>Base station</td>
<td>Base station</td>
<td>Base station</td>
<td>Subscriber line</td>
<td>Ethernet</td>
<td>Line modem</td>
</tr>
<tr>
<td>Network communication principle</td>
<td>Power line wiring</td>
<td>Radio frequency</td>
<td>IEEE 802.11</td>
<td>IEEE 802.16</td>
<td>Protocol-based</td>
<td>IEEE 802.3i</td>
<td>IEEE 802.3j</td>
</tr>
</tbody>
</table>