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UNIVERSITY INTEGRATED INFORMATION SYSTEM DEVELOPMENT

Key words

Building management system, building automation system, building energy management system, integrated information system, monitoring, computer aided decision process, long-term forecasting.

Abstract

The article presents a case study of the integrated information system of University of Science and Technology in Bydgoszcz (UTP), the information about its present stage, the range of operation, and plans of further expansion. A significant part of the article has been devoted to various kinds of building management systems, their basic and advanced range, evolution, and the role they may play in the integrated information system of the university.

The other part of the article presents the concept and the first stage of the implementation of the university classrooms occupancy logging system based on the usage RFID key fobs, RFID readers and PC computers, and ARM microcontrollers in concierge desks in the university buildings. The simple system has been developed at the UTP in Bydgoszcz, Poland. It is now mainly used for logging and visualizing the occupancy of the lecture halls, but it will soon be linked to the UTP integrated information system and the BMS system of one of the UTP buildings.

Introduction

The modern university is a complex organism, functioning on many levels. Different tasks are performed there, such as didactic processes, knowledge management, research processes, intellectual property management, quality management, human resource management, the management of tangible and intangible assets, financial management, and risk management. Its computer systems are sometimes more complex than the systems of some companies. This is due to the diversity of the tasks of the university and the diverse and sometimes complex financial settlements. Universities are developing methods and procedures for solving problems related to their functioning and integrated information systems that support their activities related to teaching, research, EDI (electronic data interchange), etc.

In 28.02.2011 *High Education Research Centre*, *Jagiellonian University* published a document called *Final Report "Universities Management Models in Poland"* [1], which can be used by other universities in their individual computerization and organizational transformation, EDI, etc. This document contains ready-to-use patterns of solutions to many problems associated with the functioning of a modern university. The *Campus of the 600th Anniversary of the Jagiellonian University Revival* is one of the most modern university building complexes in Poland [2]. It has an advanced building automation system. The *Building Management System* (BMS) in this modern campus is an additional advantage to this university, facilitating the optimization of material resources management and maintaining the highest level of educational and research processes. This is one of the reasons why the patterns of solutions related to the management of universities proposed by the staff of this university are so valuable.

1. Project "New Quality in the UTP"

In 10.11.2011 The *National Centre for Research and Development*, *Department of Implementation of Human Capital Operational Programme* announced the competition number 1/POKL/4.1.1/2011 to subsidize projects concerning the development of universities [3]. *University of Science and Technology* (UTP – shortcut to polish name of the university: *Uniwersytet Technologiczno-Przyrodniczy*) in Bydgoszcz participated in this competition and received subsidies for a project called "*New Quality in the UTP*" [4]. The project was realized between 10.01.2012 and 30.09.2014. The project realization consisted of, among others, improving the efficiency of the university functioning, and improving the quality of education related to the needs of the business environment by implementing four modules: the quality

management training, human resource management, financial management, and physical asset management.

The individual modules consisted, among others, of the following:

- *Financial management* – automation of budgeting and controlling, enterprise resource planning (ERP), implementation of an electronic document interchange system (EDI);
- *HR management* – an application dedicated to a Human Resource Management;
- *Education quality management* – Deans' offices operating system, the principles of cooperation between UTP and the economic environment in terms of education quality, the implementation of the cost-absorption analysis of different fields of studies system in comparison with the needs of the economy; and,
- *Physical asset management* – computer tools for the planning and the management of physical assets, including an inventory system utilizing a barcode technology.

The university's physical asset management module is particularly interesting due to its potential integration with the BMS system, so it will be described in detail.

As part of the system such steps, among others, have been taken as follows:

- Elaboration "The UTP property management study" [5];
- Implementation of the *"Real estate and intangible assets management plans*" [6];
- The entire property of the UTP was marked with barcode labels, and inventory was conducted and settled in the new system;
- A summary was made of the real estate owned by the UTP, together with a description of their development;
- The sources of the UTP properties' funding and management were defined; and,
- The procedures for purchase of fixed assets and services were defined.

These actions were performed in order to analyse the current state of the real estate belonging to the UTP and for the purpose of its rational operation in respect of their usefulness for the Faculties, taking into account the analysis of the cost of their maintenance and modernization. These actions aim to support the optimization and rationalization of current costs and support the process of technical maintenance of the properties at a good technical level as follows:

- Monitoring maintenance, repair, troubleshooting and performing minor repairs by a computer system; and,
- Through the creation and management of the funding for modernization and renovation, designed to improve the aesthetics of classrooms, and reduce the cost of their maintenance through the modernization of classrooms' lighting,

integrated audio-visual systems in classrooms, the replacement of sanitary facilities, radiator valves, thermo-modernization of buildings, and implementation of regulation and monitoring systems for electricity and central heating.

The project *"New Quality in the UTP"* contributed to radical modernization of university management, but, of course, it does not exhaust all the issues related to functioning of the university, as it does not take the integration of the UTP *Integrated Information System* (IIS) with the BMS system and the university classrooms occupancy logging system into account. The proposal to complement the UTP IIS system, which is now in its second phase of implementation, is the main goal described in this paper. It consists of the following subgoals:

- The analysis of UTP hardware and software that can be used to manage building automation systems, BMS software licenses, its logging and visualization capabilities, building automation controllers, and so on;
- The inventory of modern and outmoded HVAC devices located in the UTP main campus objects;
- The analysis of the existing UTP integrated information system functionality, from the point of view of its potential integration with the BMS software and the university classrooms occupancy logging system; and,
- Searching for the best software, hardware and logistics solutions, allowing for the maximum BMS functionality, using existing UTP software and hardware, and limited funds for their maintenance and expansion.

2. Building management systems

Building management systems (BMS) or *Building automation systems* (BAS) are IT systems used to monitor, visualize, and control the operation of various systems of buildings. Generally, these IT systems are run using PC computer software that is linked to building controllers using special buses or just Ethernet cables. Usually, BMS or BAS systems can be programmed to include *heating*, *ventilation*, *and air conditioning* (HVAC). A BMS system controls fan coil units, air handling units (AHUs), boilers, chillers, and many other HVAC devices. The software allows building managers to visualize and inspect HVAC operations and to set temperature and humidity levels in many separate parts of the buildings using *graphic user interface* (GUI). In modern BMS systems, all of these operations can be performed using a web browser of a computer or a mobile phone or tablet. Additionally, a typical BMS allows controlling and adjusting light levels based on time of day, occupancy of a given area, or according to sunlight levels. More sophisticated BMS software includes a much wider range of subsystems and can use the interrelationships between

these subsystems and the HVAC and lighting control. Such software can monitor and control the following subsystems, among other things:

- Intruder alarm system, access control system;
- CCTV (closed circuit television);
- Fire alarm system, emergency voice alarm communication system (EVACS);
- Electrical installation monitoring and alarm system, central battery monitoring, and alarm system, energy monitoring and control system;
- Lift and escalator monitoring and alarm systems and other systems for the monitoring of electromechanical devices; and,
- Maintenance alarm system.

The advanced BMS software implemented in the buildings with various building subsystems allows building managers to perform the following: (a) remote diagnostics of various building devices (e.g. HVAC devices) or the entire subsystems, (b) control optimization, (c) preventive maintenance, (d) energy optimization and trending, (e) peak load management, (f) consumption reports for energy management, and many other things.

Taking into account high electricity and heat costs, the most important task to do for BMS and building managers is to maximize the building's energy efficiency by regulating ventilation system fan speeds, boilers, and chillers, to achieve good air quality in the buildings and proper ventilation with as low power consumption as possible.

The assessment of the impact automation systems for energy efficiency in buildings, in the light of the European Standard PN-EN 15232:2012 [12], has been widely described in the literature [13]. Therefore, these problems will not be further described in this paper.

In case of universities where faculties settle their costs of operation themselves, the next important thing is to integrate the work of BMS with enterprise resource planning, monitoring of media consumption, and monitoring the electrical installation.

Nowadays, BMS systems of leading companies allow the configuration of automatic notifications that are sent to specialized service companies in the case of a failure of individual components of the building automation. Thus, the evolution of monitoring and maintenance of the building automation systems is quite similar to the evolution of the monitoring and handling of information technology in enterprises, such as the following:

- In the past, monitoring and maintenance of building automation systems at a given facility were done mainly by the local staff, sometimes assisted by specialized external companies; the same type of work was performed in the case of small, local bank branches, small businesses and various institutions

that once employed computer engineers to administer local computer servers, other local resources and LAN network.

- Nowadays, monitoring the work of building automation systems is done more and more often remotely by specialized external companies; if one needs to service or repair any devices, these companies send their own technicians, and this is because the building automation systems are so reliable and labour costs so high that maintaining local service staff is in many cases inefficient and unprofitable; therefore, this type of service is most frequently left to outsourcing companies.

Several years ago, BMS systems were used very rarely, because of the following:

- There were fewer buildings equipped with complicated building automation systems.
- The cost of electricity and heat was relatively lower.
- Environmental awareness had just been born.
- BMS popularity on the market was small, and buildings with advanced BMS accounted for a small percentage of buildings in Poland.
- Due to their low popularity, BMS systems were expensive and difficult to implement and use.
- Servicing BMS systems required specialized knowledge.
- There were relatively few companies that offered mostly expensive and advanced systems, designed for very large commercial buildings.
- There was a relatively small amount of cheaper and simple applications, such as BAS, for small and medium-sized buildings.
- The Polish market of system manufacturers of the BAS/BMS systems was just being born.

Now, the situation has changed greatly, because of the strong competition among manufacturers and suppliers of BMS systems for small, medium, large, and very large buildings for the following reasons:

- Due to the strong competition and a large number of software vendors, prices of BMS systems designed for all market sectors were significantly reduced.
- More and more versatile systems are being created that can be scaled and adapted to most buildings – commercial, retail, service, office, educational, government, etc.
- BMS systems are still being produced by large corporations, such as *Honeywell*, *Johnson Controls*, *Schneider Electric*, *Siemens*, etc., but numerous manufacturers in many countries who offer their products in many languages have also appeared, and they distribute these products through networks of local vendors in many countries – in Poland, for example, *UniArt* system by an Israeli company *Control Applications*.

- Polish BMS manufacturers offering products tailored to the Polish financial realities have also appeared – system *Fibaro* by *Fibar Group*, system *Domatiq* by *SIM* Company, system *Vision BMS* by *APA* Company, and many others.
- Many systems with open source for remote control of different devices and systems have appeared, and these systems often have low hardware requirements and are distributed in different, often very liberal licenses, allowing the usage of a shared code for commercial purposes, without paying the authors of these systems. Such systems include, among others, *openHAB, openRemote, openSourceAutomation, HomeGenie, www.phpmydomo.org, www.pytomation.com, www.opensourceautomation.com, www.domoticz.com, www.agocontrol.com, www.freedomotic.com, wosh.sourceforge.net*, and many others.
- These open source projects are gathering a growing number of enthusiasts and businesses supporting their development, including developing commercial systems based on open source systems [7].
- The number of newly emerging BAS/BMS systems is growing at a very fast pace, and this is probably to the detriment of their development prospects, because the Internet community is divided as to which products to test and support and which to reject; it is like the famine of fertility, which affected the PLC controllers industry in the 1980s, which resulted in the creation of IEC 61131 norm (it was known as IEC 1131).
- There have been a lot of inexpensive hardware platforms that used ARM processors, based on various versions of *Linux, Android, OpenBSD* systems and others that allow tens of thousands of amateurs, students, and professionals around the world to integrate automation systems of homes and buildings and manage their work via the Internet. These platforms allow many of these open source systems for remote control of different systems and devices to run.

As you can see from the above examples, the situation on the BMS market during the last several years has changed dramatically. There are no technical, economic, or social arguments that would imply to refrain from installing BMS systems wherever it is economically justified. Nowadays, not only commercial BMS systems offered by big companies generate tangible savings in building supplies, directly proportional to the complexity of these systems, the level of their integration, and financial effort. Systems built on the less popular and much cheaper technologies also allow for significant operational savings while delivering much shorter payback time.

The vast majority of today's BMS/BAS systems have an intuitive GUI that allows for quick implementation of the user or administrator of the system and

provides remote access to system resources, even from mobile devices – mobile phones and tablets.

It is not yet known what systems will gain the market advantage in the future. Today it is not possible to find out, as in the early 90s, it would have been impossible to predict the popularity of *Linux* system, which dominated the web servers and mainframes market, as well as the success of *Android* devices currently dominating the mobile market. Market analysis indicates a steady increase in the sales of BMS systems designed for large customers and doubling of this market every decade. Probably, the nearest future belongs to the systems that are currently rolling out around the leading commercial solutions – just like the operating systems – *MacOS* and *Windows* started out. In the near future, one of the most promising BMS open source system is likely to gain strong support of a large company such as *Google, IBM,* and *CISCO* and become the BMS system market leader on a scale comparable to the *Android* success on the mobile device market. Everything indicates that the technology of building automation management systems in the future will connect with a much wider stream of solutions, referred to as the *Internet of Things* (IoT) [14].

3. BMS system for a medium-sized university

Creating a BMS system for buildings belonging to a medium-sized university, such as UTP, is not an easy task. UTP has dozens of buildings in different parts of Bydgoszcz with various degrees of technological advancement and HVAC devices. The implementation process of the building management system does not change much in the operating costs of buildings where those buildings are devoid of building automation systems that can be managed, taking into account different scenarios, algorithms, and a variety of criteria.

Many UTP buildings, similarly to some other universities in Poland, still have buoyancy-driven natural ventilation, which often becomes ineffective after replacing old box-type windows and reducing infiltration. This forces the users of such buildings to ventilate by opening the windows. Such activities during the heating season are very energy consuming. On the occasion of repair work in such facilities, the possibility to use mechanical ventilation with heat recovery or re-circulation may be worth considering in accordance with the revised *Regulation of the Ministry of Transport, Construction, and Marine Economy on technical conditions that should be fulfilled by building objects and their location* [8].

In case of buildings equipped with mechanical ventilation, the situation is much more favourable. To make the operation of air-handling units in the university buildings even more economical, it requires adjusting the flow rate and making it subject to current needs. The flow rate in many of these objects is specified using time schedules that often do not take into account the

classroom's plan. In order to do otherwise, the university integrated information system would have to be connected to the BMS system. Therefore, a more effective solution for entering the flow rate of air handling units often is to take into account the data from carbon dioxide (CO_2) and volatile organic compound (VOC) sensors located in classrooms, because it is an accurate and reliable way of incorporating demand-controlled ventilation (DCV) [10, 11]. DCV management is available in almost all BMS/BAS systems.

The consideration of the use of a BMS system for college buildings should reflect whether it is cost effective to purchase one integrated BMS system for all university buildings or to apply a number of smaller systems BAS / BMS for individual buildings. Choosing the first option, significantly simplifies management and maintenance of BMS system, servicing, software updates, etc. It would only have one system of logging, visualization, and management of all the university buildings, only one company servicing software of all of the buildings, not potentially several companies, and one for each of BMS systems (Fig.1). Currently this is the case for UTP. This solution has one drawback, which not everyone perceives; the *EBI (Enterprise Buildings Integrator)* system by *Honeywell* installed in UTP is used in the teaching process as a living model, illustrating lectures, and laboratory exercises for students from selected courses of the *Faculty of Civil and Environmental Engineering* and selected courses of the *Faculty of Telecommunications, Computer Science and Electrical Engineering*. If we considered the second option, in which, e.g., different faculties of the university had different BMS systems to manage its facilities, the students would have more *"live models"* available. However, this solution would be more expensive and more cumbersome to maintain and service.

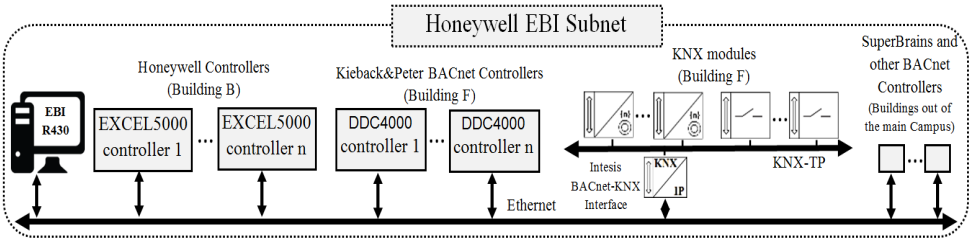

Fig. 1. A simplified diagram of one BMS concept of UTP buildings management

A question needs to be asked whether it is worth covering all of the buildings of the university with only one BMS system. Maybe it is better to focus on the implementation of such for the largest cluster of buildings of the university. In the case of UTP, this would be the university campus on Kaliskiego Street 7. Taking this concept into account, other clusters of

university buildings may be covered by a small budget, local BAS/BMS systems, offering the possibility of remote supervision, logging, and management of installed building automation systems. In this variant, we should also take into account the less popular BAS/BMS systems, which are used mainly to manage HVAC devices, but they also have the functionality to manage lighting, electrical installation, and many other systems, for example, the system by *UniArt* by *Control Applications* company, which does not require royalties for the number of points of BMS system (Fig. 2).

In connection with the operation of the *EBI (Enterprise Buildings Integrator) R301* by *Honeywell* in the UTP since 2008 in building B at Kaliskiego Street 7, the upgrade of the building automation systems around the BMS system chosen a few years ago should be considered. This choice seems all the more justified due to the fact that Building B operated without a BMS system for the first year and the consumption of electricity, especially in the summer months, had cost the university up to 8500 PLN a month more than after the BMS system was installed. Thus, the payback time was just a few months. The decision to cover the entire university with *EBI* system, however, would require the *EBI* to migrate to the latest version - the *R430* and to buy a license for a several thousand new points, since the current license amounts to only 250 points and is now fully exploited. The *EBI* system license extension would allow to take full advantage of till now unused opportunities, available in this BMS system, and the possibility of its integration with an access control system, an intruder alarm system, CCTV, ERP, the UTP *Integrated Information System*, etc. However, one should bear in mind the need to implement planned purchases of additional equipment compatible with the established BMS system. When choosing *EBI* system as a system for the entire university, one should also remember about the future costs associated with the need to migrate to the future versions of BMS software, proportional to the number of licensed points. In this context, some competitive solutions seem very interesting, because although they do not have such a wide functionality and integration capabilities, they would allow the system to fit in with a smaller budget and migrate to newer versions at a lower cost.

In the *Stage 2 of the Regional Centre of Innovativeness Project* [9], the UTP has purchased controllers and equipment for the building automation system by *Kieback & Peter* Company and equipment by the *JUNG* Company working in the KNX standard. *Kieback & Peter* equipment allows conducting research on building automation systems, through the implementation of this company's BMS system called *Neutrino-GLT*. *Kieback & Peter* company's controllers can also be managed using several other BMS systems. There is the ability to manage these controllers using *Neutrino-GLT* or *EBI* BMS system, and additionally control KNX *JUNG* equipment using communication interfaces such as BACnet-KNX interface (Fig.1). The *Neutrino-GLT* is a very stable and

efficient BMS system, running on the *QNX* operating system. Therefore, this BMS should also be taken into account when selecting a global BMS for the whole university.

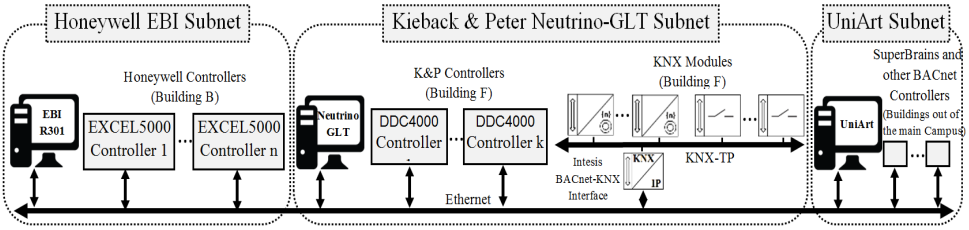

Fig. 2. A simplified diagram of three BMS concept of UTP buildings management

When considering further embodiments of the BMS system for the whole university, one should not forget about other popular, recognized, and dynamically developed BAS/BMS systems, for example *TAC Vista* by *Schneider Electric*, *METASYS* by *Johnson Controls*, or *enteliWEB* by *Delta Control*.

Searching for a BMS system for a university, where each of the faculties has its own financial settlement, and the BMS system is also used for educational purposes, one has to consider BEMS system *(Building energy management system)*, because it is a BMS system that is also used to conserve energy by data collection and analysis of the process or conditions being controlled. This system allows energy visualization and energy analytics to provide basic dashboard views and recommendations regarding potential energy conservation measures.

4. BMS system in one of the UTP buildings

The *Regional Centre of Innovativeness* (Building B, Fig. 10) was built in 2005-2007. It is a part of UTP campus on Kaliskiego 7 Street in Bydgoszcz. The exploitation of classrooms in this building is economical, because it is a building with very good wall insulation, airtight window frames, mechanical ventilation with heat recovery, an efficient BMS system, and modern and energy-efficient equipment. Relatively lower energy consumption in this building is achieved, inter alia, by the following:

- It uses modern equipment with reduced energy intensity, including energy efficient pumps, fans with energy efficient motors and multi-stage or continuously adjustable air flow, energy-efficient lighting, although it lacks the use of techniques to maintain a constant level of illumination, and it

lacks blind control system, which allows one to adjust the maximum inflow of daylight in bright sunlight.

- It reduces the runtime of devices by turning them on when they are needed, optimizing the start-stop time of devices, and the use of natural phenomena to save energy, e.g. night ventilation, etc.
- It turns various devices on or off in association with a variety of events.

Fig. 3 presents a simplified diagram of selected modules of the BMS system in Building B. Figs. 4, 5, and 6 are the selected screenshots of the simple, friendly, intuitive GUI for quick orientation in the operation of the HVAC devices and easy diagnosis of any failure.

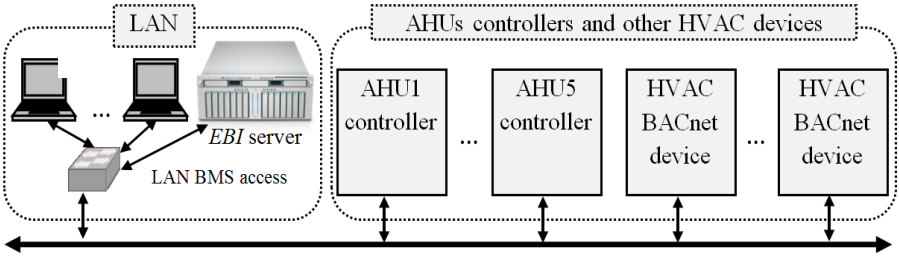

Fig. 3. Simplified diagram of selected modules of the *EBI* building management system

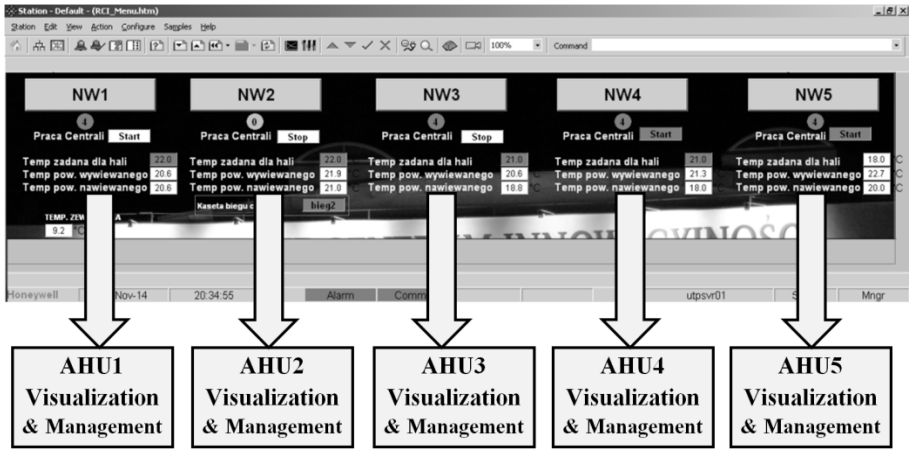

Fig. 4. A screenshot of a home page of *EBI* application (building B)

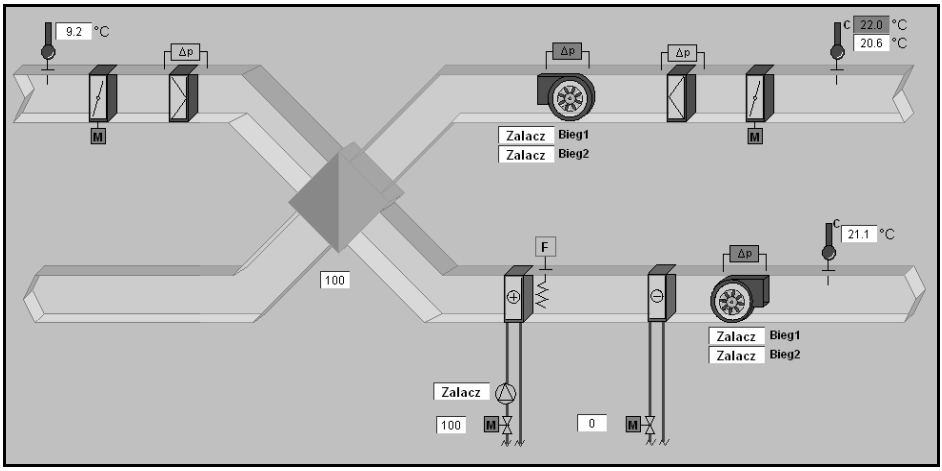

Fig. 5. A screenshot of *EBI* application visualizing the work of AHU1, AHU2 and AHU3

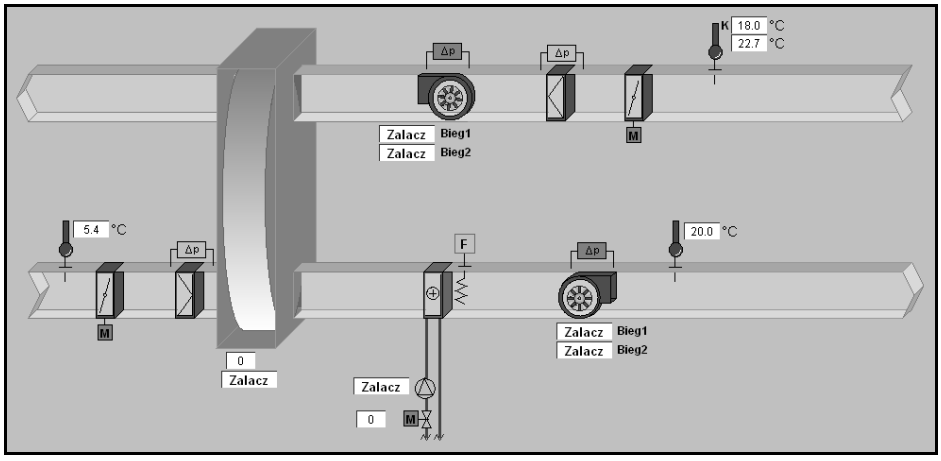

Fig. 6. A screenshot of *EBI* application visualizing the work of AHU4 and AHU5

Capabilities of the BMS system: The *EBI* applications used in Building B are not fully utilized due to the number of points being limited to 250. Therefore, this system is mainly used for the following:

- The visualization of HVAC equipment work,
- Monitoring the proper operation of HVAC equipment,
- The modification and optimization of HVAC work schedules, and
- The optimization of the equipment work to reduce energy consumption.

5. Implementation of the university classrooms occupancy logging system

Classrooms in universities are primarily used for the tasks of teaching. In theory, the availability of individual classrooms can be read from the occupancy that results from the schedule of all the faculties that use certain classrooms. However, in practice, particularly large lecture halls are also used during conferences, congresses, meetings, speeches, celebrations, and other events sometimes organized ad hoc.

Therefore, the use of occupancy logging system is justified, and there is a continuous need for visualization and logging of classrooms occupancy for current needs related to the activities of teaching, research, and other tasks of the university.

In addition, information collected in such a system can also be used for other purposes. Faculties of many universities are self-financing and information about the use of shared resources and associated costs can be useful to support the mutual financial settlements.

In addition, further development of such a system can allow the monitoring of the consumption of electricity and heat in the classrooms covered by that system. Such a system would enable monitoring most of the operating costs of facilities, including the cost of lighting, ventilation, heating and cooling, costs associated with maintenance of cleanliness and service work, repairs, and capital costs associated with the modernization of the system of lighting, sound, multimedia equipment, etc.

Information about what costs are associated with operation of large lecture halls is very useful in the scale of the university, because these rooms offer various comfort of work and science, and they have lighting systems and HVAC systems with varying quality, efficiency, and effectiveness. This implies a higher or lower quality of service and cost of operation. This data should be used when deciding on the plans to use individual rooms, to minimize the use of sub-standard rooms and the rooms most expensive to operate. In contrast, fully comfortable and less expensive rooms to operate should be used 100%. At the same time, realistic and continuously updated operating costs of individual large lecture halls should be used as an aid to determine which rooms must be upgraded first. What system should be modernized – HVAC, lighting? The use of information concerning the operation of large lecture halls after modernization should be used to calculate the real payback time of this upgrade and will help to develop optimal models of such modernization for other buildings.

Since most large classrooms are windowless in the UTP campus at Kaliskiego 7 Street, one should try to use other large classrooms, enabling the use of daylight. Knowledge of the real cost of the large lecture halls lighting can be used to calculate the payback time of installing properly designed, energy

efficient fixed windows in large windowless classrooms. Designing properly controlled shutters provides the appropriate amount of light for most of the day for teachers who use mainly blackboard and chalk, and is useful for teachers who often use multimedia projectors.

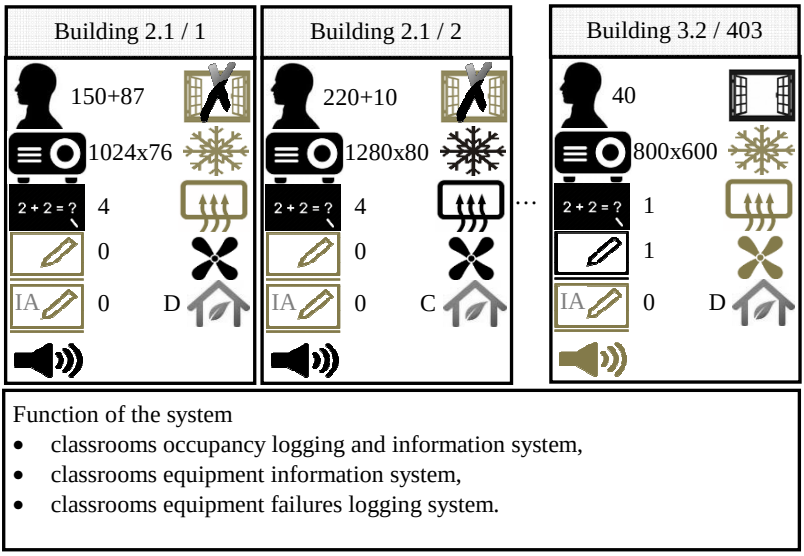

Fig. 7. A simplified diagram presenting some parameters of university classrooms and some functions of the proposed system: the number of standard and extra seats for students, multimedia projector resolution, the number of blackboards, whiteboards and interactive whiteboards, the existence of a sound system, windows, cooling, warming and ventilation system, and the Building Automation and Control Systems Energy performance Class of the given classroom

From a technical point of view, information on the occupancy of university classrooms can be collected, processed, and shared using database systems of advanced access control systems. However, installing such a system in the entire university would involve large financial effort associated with the following needs: (a) to install electromagnetic locks or door electric locks, RFID card readers in all classroom doors, the network of access control controllers with the power suppliers, the access control management system, (b) to distribute the appropriate RFID cards to all employees authorized to access the classrooms, and (c) to manage such cards, i.e. to grant and revoke access privileges, etc.

An alternative method of acquiring information about the classrooms occupancy is to use information from the intrusion detection system. Control units of such systems collect and process data concerning motion detection in

individual rooms within their range. In practice, the data can be retrieved from these control units in various ways, including using Ethernet interfaces or using hard-wire connection, i.e. by signalling the occupancy of each room on the digital outputs or expanders' digital outputs of such control units.

This paper describes the cheapest and easiest to implement, cost-effective system that is based on the system of logging of issued keys to university classrooms. RFID tags are permanently attached to individual keys. The university concierge, when issuing keys or collecting returned keys, encloses them in the RFID reader (USB RFID proximity contactless smart card reader 125kHz) and verifies the correctness of the operation on a computer screen (Fig. 9). The logging system is based on a popular development environment *Apache, PHP,* and *MySQL*. Information from this system can be easily exported to a variety of BMS systems in several ways, ranging from high-level methods, and ending with the low-level methods. That is, ranging from integration at the level of the database systems of classrooms occupancy logging system and of the BMS (Fig. 8), and ending with the method involving the use of application exporting data from the occupancy logging system to controllers with digital outputs, enabling integration with the BMS system using the hard-wire method.

Due to the number of buildings, concierge desks and classrooms, to which the keys are issued in UTP, a decision has been made that the occupancy logging system would be completed in a few steps:

- Step A1 is the installation of the system in the main concierge desk of the main UTP campus, Building C, for testing and optimization of the system. This step has been made using the simplified algorithm of university classrooms occupancy logging system that is presented in Fig. 9.
- Step A2 is the installation of the system in the concierge desk in Building B *(Regional Centre of Innovativeness),* and everything is prepared for implementation of this step.
- Step A3 is the installation of the system in Building A *(Auditorium Novum)* and testing of the system based on ARM Ethernet microcontroller instead of a PC.
- Step A4 is the installation of the system in other campus buildings at Kaliskiego 7 Street.
- Step A5 is the possible installation of the system in UTP buildings outside the main campus at Kaliskiego 7 Street.

At the time of writing this paper, the classrooms occupancy logging system runs on a standard PC using the database engine *MySQL 5.5.21, Apache 2.2.22* with *PHP 5.3.20* parser. For reasons of database safety and many others, the system will soon be moved to UTP servers.

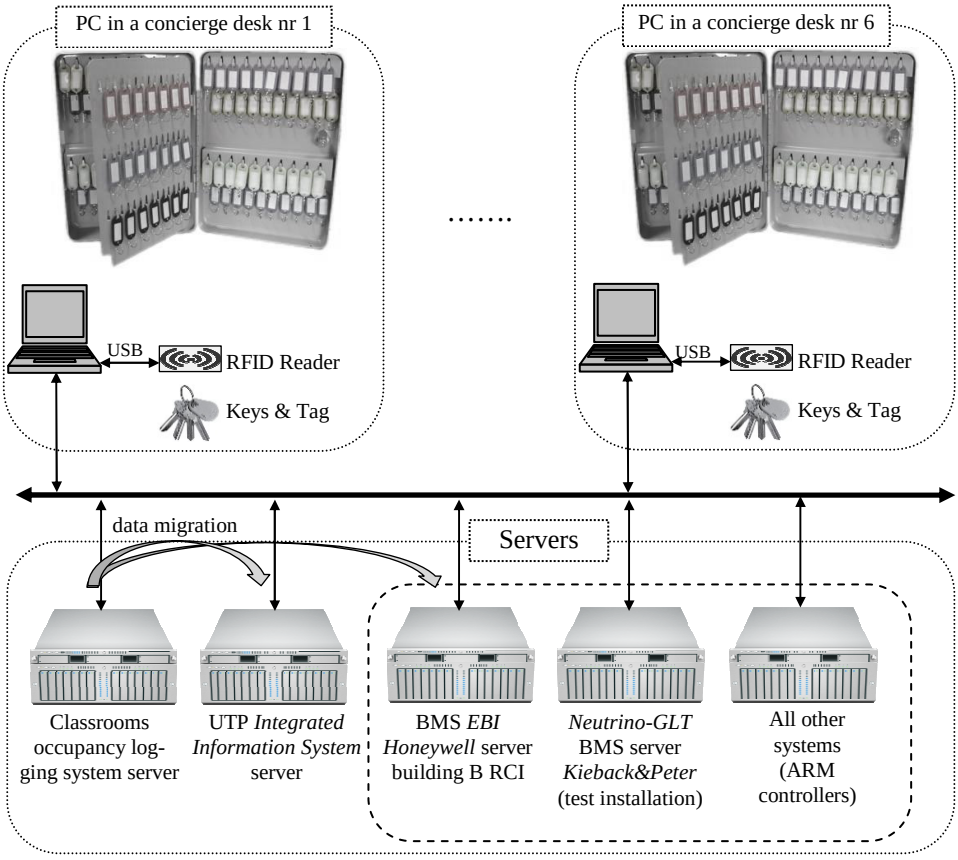

Fig. 8. A block diagram of the classrooms occupancy logging system

There is, among others, a UTP *Integrated Information System* on these servers. The system was created through the implementation of the project *"New Quality in the UTP."*

Therefore, the following steps are foreseen to integrate the classrooms occupancy logging system with the UTP *Integrated Information System*:

- Step B1 is the integration of the classrooms occupancy logging system with timetabling, scheduling and management software, and the functionality provided within this integration: (a) classrooms occupancy visualization and registration, (b) analysis of the compatibility of classrooms occupancy and the timetables of all faculties, (c) alerting and registration of the lack of classroom occupancy, when, according to the plan, there should be classes, (d) alerting and registration of the classroom occupancy, when, according to

the plan, there should be empty hall, (e) sharing the information about classrooms equipment and its characteristics, (f) logging the information about classrooms equipment failures.

- Step B2 is the collected and returned keys and employers receiving and returning keys logging system, based on RFID employee cards, which is used for cleaning and maintenance workers to the needs of settlements in the facility management system.
- Step B3 is the integration of the classroom-occupancy logging system and the BMS system – HVAC work management system based on classrooms usage.

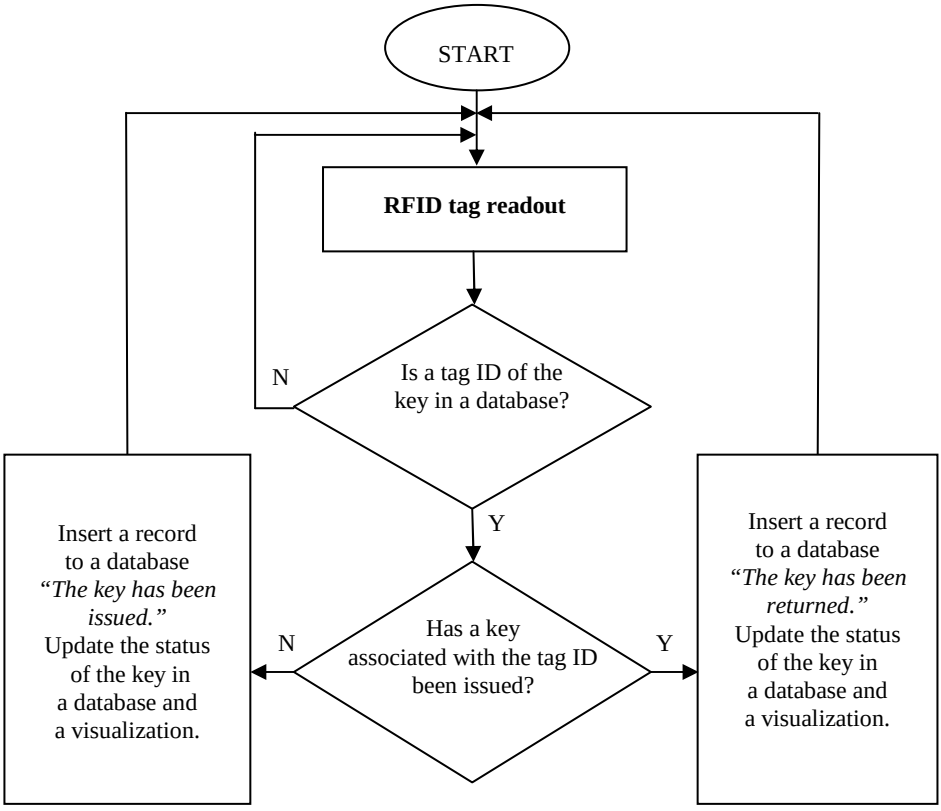

Fig. 9. The simplified algorithm of the university classrooms occupancy logging system

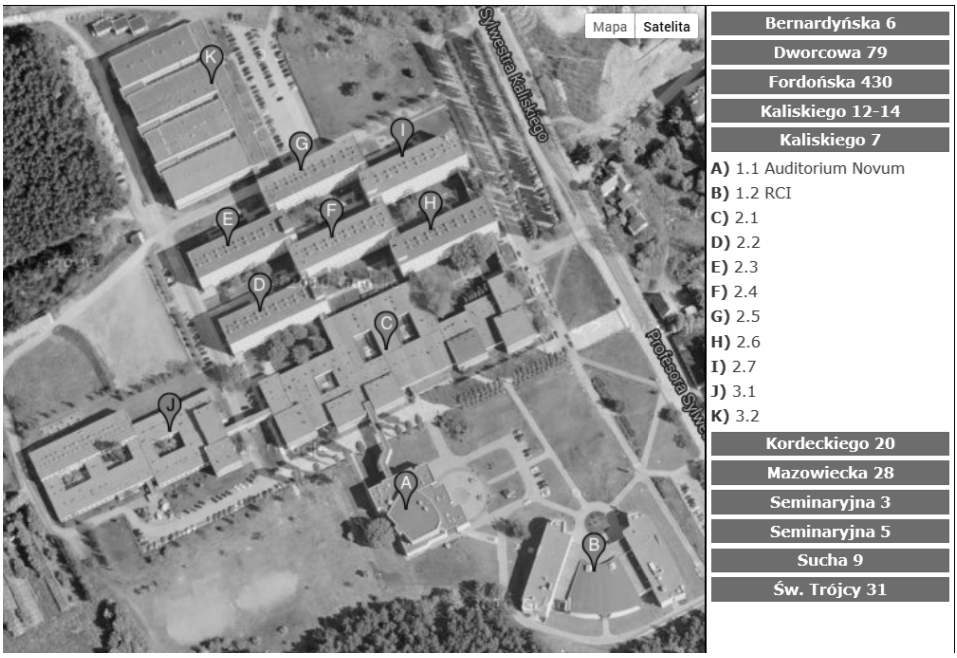

Fig. 10. A map of the main UTP campus on Kaliskiego 7 Street in Bydgoszcz

Figure 10 shows a map of the main UTP campus on Kaliskiego 7 Street in Bydgoszcz:

- Building A has an advanced HVAC system, but without any control of a BMS system.
- Building B has an advanced HVAC and *EBI* BMS system, and it will soon be covered by the occupancy logging system.
- Buildings C is a complex of buildings, mainly consisting of a set of big lecture halls, and it is now fully covered by the occupancy logging system.
- Buildings D, E, F, G, I, and H are the buildings in which only some classrooms are covered by the occupancy logging system.

To implement classrooms occupancy logging system, there is a need to install computers or microcontrollers in 6 concierge desks in the main campus of UTP buildings. These computers would work 24 h a day, 7 days a week. In the table below, there is information about the total power consumption per year of a single computer or microcontroller for 4 various configurations of the hardware.

Table 1. The proposed ways to implement the system and corresponding functionalities

	Hardware platform	Display	Power	Power a year	Functionality
1	ATmega128A, Ethernet module ENC28J60	LCD 20x4 chars, HD44780 compatible	1W	8,76 kWh	only sending a tag ID to a UTP server application, tag readout confirmation on a 2x16 char LCD display
2	Raspberry Pi Model B, SD card 4GB	4" 320*480 pix. LCD display with touch	1.8W	15,77 kWh	only sending a tag ID to a UTP server application, tag readout confirmation on a 4" LCD display
3	Raspberry Pi Model B, SD card 4GB, keyboard and mouse	HP 2310ei 23"	2W + 22W	210 kWh	sending a tag ID to a UTP server application, full functionality using web interface
4	PC Core2Duo 2.13GHz/4GB RAM	HP 2310ei 23"	110W + 22W	1156 kWh	sending a tag ID to a UTP server application, full functionality using web interface or working as the server and client of application, no additional resources needed

Summary

The creation of a holistic integrated information system for a medium-sized university and all of its buildings, covering all aspects of its operation, including BMS system and classrooms occupancy visualization and verification, is a complex, expensive, multi-step, and time-consuming task.

This process is part of the broader issue of the comprehensive computerization of universities and requires a number of strategic decisions, and the effects of which will be perceptible for many years. Therefore, they require a deep commitment from the university authorities. The authorities must decide which way to choose, taking various arguments into account and respecting all aspects of university development.

The final decision regarding selection of a specific BMS system is very difficult, because there is no strong leader regarding BMS technology that would also offer its system at an attractive price. When it comes to open source building automation software, there is no leading project in bringing together the majority of programmers looking for volunteer work in this field and focusing the interest and support from the largest commercial companies.

Owning an occupancy-aware BMS system to control and reduce the university's operation cost is necessary. If complete integration of the BMS system with the access control system is impossible due to the economic

situation of the given university, there are many other cost-effective ways to achieve operational savings in university buildings. A small step towards the implementation of such a system is building classrooms occupancy logging system, presented in this paper, and then integrating its database with the BMS system.

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Rozwój zintegrowanego systemu informatycznego uczelni

Słowa kluczowe

System zarządzania budynku, system automatyki budynku, system energetycznego zarządzania budynku, zintegrowany system informatyczny, monitorowanie, komputerowe wspomagania procesu decyzyjnego, długoterminowe prognozowanie.

Streszczenie

W artykule przedstawiono studium przypadku dotyczące Zintegrowanego Systemu Informatycznego Uniwersytetu Technologiczno-Przyrodniczego w Bydgoszczy (UTP). Przedstawiono w nim informacje o obecnym etapie realizacji systemu, jego zakresie działania i planach jego dalszego rozwoju. Znaczna część artykułu została poświęcona różnego rodzaju systemom zarządzania budynków BMS, podstawowym i zaawansowanym funkcjom tych systemów, ewolucji tych systemów i roli, jaką mogą one odegrać w ramach zintegrowanego systemu informatycznego uczelni.

Druga część artykułu przedstawia koncepcję i pierwszy etap wdrożenia systemu rejestracji zajętości uczelnianych sal dydaktycznych. Ten prosty system

jest oparty na wykorzystaniu breloków RFID trwale dołączonych do kluczy wydawanych przez portierów oraz czytników RFID połączonych z komputerami PC, umieszczonymi w portierniach budynków uniwersyteckich.

System został opracowany na potrzeby UTP w Bydgoszczy. W chwili obecnej system jest głównie wykorzystywany do rejestracji i wizualizacji zajętości sal wykładowych, ale wkrótce jego działanie będzie połączone ze Zintegrowanym Systemem Informatycznym UTP oraz systemem BMS jednego z budynków UTP.