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Analysis of the Electric Energy Consumption in Teaching Centers and the Issue of the Environment Protection

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1. General information

The most important elements of higher schools/universities infrastructure are IT resources and related to them tele-information and electric installations. They are of strategic meaning if the profile of schools/universities is technical. In such cases computers and specialized software are used during most of classes, practical exercises and in laboratories. A didactic plan of a school / university requires using computer classrooms but they are also used to teach students how to work with applications and hardware.

Protection of correct, safe and reliable computers' operation at a school/university is a challenge for the IT team. The most important identified problems in this area are the following:

1. Administrators of the IT infrastructure must manage large groups of computers. This situation enforces automation of tasks in order to accelerate their execution and prevent human errors when carrying out arduous and repetitive operations.
2. Computers at the university are used by students intensively. Hence, it means frequent maintenance operations. Computers are also used by lecturers/teachers expecting that software used during classes is available at the computers.

3. Type of tasks carried out by students affects work quality of the operating systems which requires their frequent refreshing or changes of configuration. At the same time, these operations require great authorizations assigned to the administrator team.
4. Computers are generally used by a large group of persons, who frequently do not shut down the machine making extensive consumption of energy.

Except security of computer rooms, it is also significant to control and to reduce operation costs. Main costs of a school/university are generated by lecturers/teachers and the hardware used by students. In case of IT classes, a computer is a main tool and it consists of a monitor and a central (processing) unit. Both devices demand great quantity of power. Taking into consideration variety of IT classes, varied range of specialized software applied: graphics, programming, analysis and similar it's possible to say that computers in a computer room are used very intensively and they consume serious quantity of the electric energy.

The paper was developed on the ground of experiences' analysis and needs of an administrator team working and offering general classes at the IT university (Intel). Despite these analyses and consequent conclusions regard a higher school, they can be translated into reality of every single teaching center (Hłobił 2010, Schelly et al. 2010), where IT equipment is used during classes. Because of a wide range of applications, problem of habits' modification among students in IT class rooms may substantially affect decrease the cost of the electric energy (Attari et al. 2010). The next important reason to write this paper was that decision as for equipment acquisition must be based on knowledge of new technologies, not necessarily related to the daily use equipment, but permitting also to increase safety and efficiency of the equipment. It is also important that purchase decisions in the IT field may substantially decrease expenses concerning consumption of the electric energy.

2. Analysis of students' behavior in a computer room

Recently the successive change of personal computer has been taking place. Starting from 80's and first 20 years of the twenty first century a personal computer was built as a module system comprising the central processing unit and a monitor as well as peripheral devices such as a mouse and a keyboard. The computer of this shape was the most frequently stored in rooms, houses, offices and schools. Modular structure computer was considered to be a static unit and it did not move along with a user as it takes place nowadays. What is important, every user had to face such a configuration. It made that behaviors in terms of use were the same, among others, it concerned the startup procedure and shut down one. Every user remembered to shut down the computer when operation had been completed and any deviations were rather rare.

Since approx. 10 years new computer types have been appearing: laptops, netbooks, tablets or smart phones. Computers converted themselves into mobile ones and they became a significant part of our life. Apart from the operating system, also the way of use of computers has changed. The most frequently they use batteries and they do not require constant connection to a socket. They are designed and carried out in order to assure quick and simple access, hence, frequently they are not shut down but hibernated instead. It takes place after the cover has been closed or automatically, after expiration of a particular time. New possibilities made that users of mobile computers stopped paying attention whether or not their computers were on and they consumed energy – it is natural and universal. Since these are relatively energy saving electric devices they use a few dozen Watts only and compared to previous solutions these are small values. Moreover their users do not care whether they operate even if this operation is pointless.

The situation is different in case of modular computers still dominating in IT classrooms. Average computer set is equipped with a central unit with a power supply unit 350 W (average) and 50 W monitor. Even in the standby mode both, the unit and the monitor consume electric energy. It is not so much – approx. 5 W, but when number of computers in IT classrooms is serious, this value in question becomes serious as well (Gawłowski et al. 2010).

In order to determine behaviors regarding use of computers in a typical computer room, there was conducted a questionnaire survey among 57 students, who were divided into four lab groups attending classes: programming, computer graphics, databases and numerical computations. Despite the classes were very varied in the field of content, they required intensive work with the computer.

In the survey in question students answered questions included in the Table 1. We imposed a one question - one answer rule. From preliminary analysis of the questionnaires it results that all of them were filled out correctly and they could be used.

Table 1. Question and answers in the questionnaires
Tabela 1. Pytanie i odpowiedzi udzielone w badaniu ankietowym

Question	Number of answers	%
1. After you have come into a computer classroom and taken your seat you start up the computer:	57	100
per request of a lecturer / teacher	46	81
I chose the time	11	19
2. During scheduled classes you use a computer in a classroom:	57	100
only to perform scheduled exercises	44	77
to perform scheduled exercises, but in a free time I use a computer for personal needs	9	16
I do not perform exercises, I use computer at university in order to spend time of the class	1	2
other: e.g. for personal job	3	5
3. at the time of classes, in the computer room, free electric sockets:	57	100
are used by me for private needs such as: mobile charging, charging of private computer, power bank	13	23
I do not use it for private goals	44	77
4. When classes in the computer room are ended:	57	100
I shut down the computer instinctively, without request of the lecturer / teacher	24	42
I shut down the computer per request of the lecturer / teacher	16	28
I do not shut down the computer even in case of a request of the lecturer / teacher	7	12
I shut down the central unit only	2	4
I shut down the monitor only	8	14

Source: own work.

On the basic analysis of the questionnaires it can be concluded that more and more loosening concerning the use of computers has been observed. It was proved by answers to the point 1 and subsequent ones. Students frequently start their computers without a clear command, they bring own computers into the computer room and at the end of class they do not shut down a computer despite a command of the teacher.

From the first point of the questionnaire one can conclude that as many as 19% students want to use a computer when they can see it. It can be a result of the fact they use private computers daily for different goals. This is also confirmed by answers to the second question since 23% of students during IT classes use the university's computer for private or professional purposes at their free time.

At desks at computer rooms there are frequently available power strips with free electric sockets. As the results of the questionnaires prove, the sockets in question are used by students for varied goals. It concerns approx. 23% of answers and means connection of private computers, charging of mobiles and tablets or power banks (Panasiuk & Panasiuk 2015).

In the light of the energy saving habit, the most crucial answers are the ones to the last question. Answers to this question show that less than 50% students normally shut down their computers. The main role is assigned to the lecturer/teacher. In case he/she asks for it, additionally 28% students shut down computers. It is unquestionably effect of certain weakening of behaviors. It is disturbing that more than 30% of students do not shut down the entire computer set or its particular elements. Such a behavior may be a result of a casual contrariness (Gizowski et al. 2016), but it also could be a habit arising from use of mobiles, which are rarely shut down normally (Sikora 2012).

Such survey is an argument to develop a system, which could autonomously shut down computers after the end of classes and play additional functions such as: protect them from theft, inform on failures or non-authorized intervention into parts of a computer.

3. Introduction of Intel AMT

Recent years we have been observing giving up classic solutions that is maintenance of IT infrastructure in organizations. There appeared revolutionary technologies which enabled making the infrastructure and software available in form of services (e.g. PaaS, SaaS, DbaaS). AMT is one of many technologies, which enables automation of work with the computer infrastructure. Technology Intel® Active Management (Intel® AMT) enables to manage the computer infrastructure via TCP/IP when the machine connected to the power grid and the network is shut off. It is *firmware* manufactured by Intel and installed at main boards equipped with chipsets (PCH) and processors *Core vPro* and *Xeon for workstation*.

Solution offered by Intel operates at a low level – it assures management of power supply and the hardware, it also enables configuration of BIOS and UEFI settings, that is operations which are unavailable and barely available from the operating system level.

The most important and the largest area where AMT is applied is final user support. Access to KVM (*Keyboard Video Mouse*) enables remote procedures and provision of the help desk type services which are much more extensive compared to RDP (*Remote Desktop Protocol*) or VNC (*Virtual Network Computing*) (Tan et al. 2007, Kumar 2009).

This technology is not hardware only, but also varied software. The technology comprises inbuilt systems, controllers for the operating system, web applications, BIOS or UEFI or tool packs for programmers.

At the market a few programs are available enabling application of the Intel AMT technology. Exemplary programs are: *Intel® vPro™ Platform Solution Manager*, *Intel Open Manageability Developer Tool Kit*, *Microsoft System Center*, IPMI and *SuperMicro IPMI View*. In the following part of the paper the most important attributes of the applications are described. On the basis of their capabilities and own experiences certain functional requirements were defined for the suggested interface TUI (*Text User Interface*).

First described program is *Intel® vPro™ Platform Solution Manager*. It enables to manage power supply simply, as well as to re-direct, read events from a platform or a configuration. It also enables to download entire list of platforms from XML (Tan et al. 2007).

The second of the mentioned programs assures the same functionality as the first one, but extends it to a great extent. Additional functions in the *Intel Open Manageability Developer Tool Kit*, are dozens of options and information on connected computers and AMT Discovery, which is scanning of set range of IP addresses in order to look for computers with active AMT service. Other interesting functionality is capability to carry out operations from many computers at the same time (Tan et al. 2007).

Microsoft System Center is not the Intel software and it is designed mainly to manage configuration and licenses in large grids based on solutions of the Microsoft company. One of functionalities of the application is provision of basic services by Intel AMT limited to certain versions of the Intel AMT (Tan et al. 2007).

IPMI is a different solution from the AMT and it is designed for server machines, but it also has the common functionality which is reading of physical parameters from sensors installed at a platform. It enables to manage the power supply. It directs the managing console which enables to commence BIOS remotely and to configure it. Additionally, it is capable to manage users (Tan et al. 2007).

Software, which is designed to manage remotely is e.g. *SuperMicro IPMI View*. The application operates also on Windows and Linux systems (developed in Java). It provides many information from physical sensors, rpm of fans, temp. in varied regions of a server, levels of voltages, valid consumption of the electric energy by particular power supply units. Information is helpful in case of operation with server machines. It enables to estimate load of the electric installation or quantity of produced warmth, as well as needs in the field of cooling e.g. increase in power of air conditioning units or other placement of servers in order to distribute warmth evenly (Tan et al. 2007).

The most important conclusion from the analysis of the aforementioned program is that these are frequently too extensive systems which require complicated configuration and usually they are developed for Windows. Additionally, migration of this software into other platform is impossible One of reasons to develop the application in a version with the TUI interface there was a chance to use this technology from the Linux level or OS X and to increase its productivity.

4. Architecture of the system and interfaces

Assumption of the system was to embed the application in an operating system, and to assure access to it from the Linux system or the Windows console in a computer network. Giving considerations to the requirements stipulated above, users are proposed the TUI type interface in form of a user text interface.

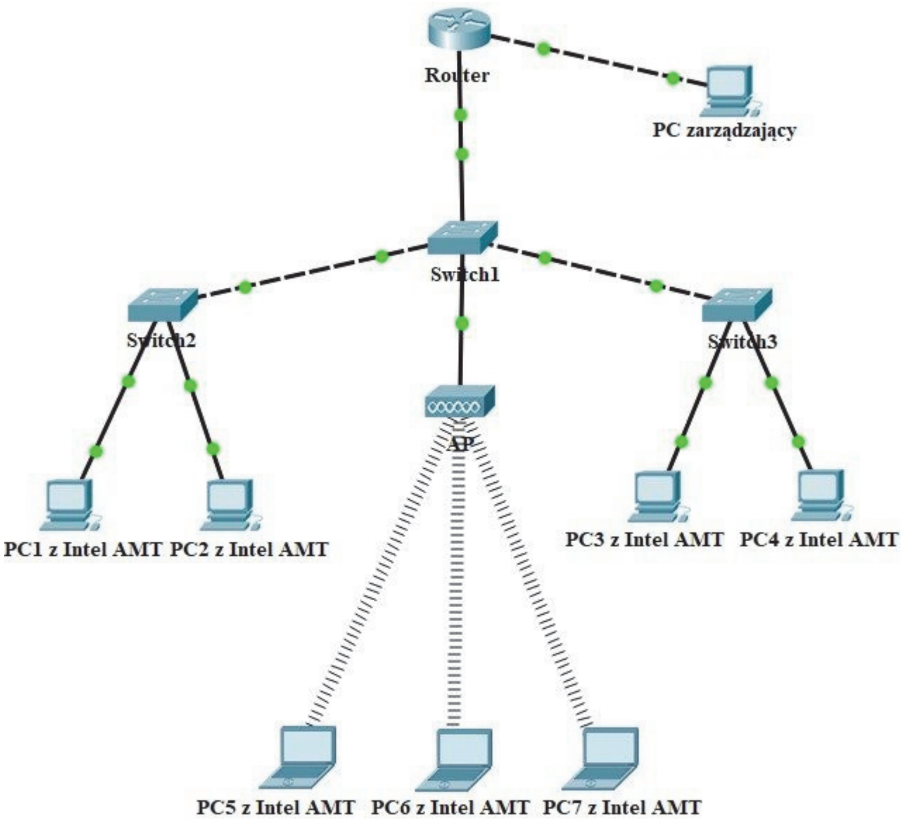

Fig. 1. Architecture of the computer network where there operates a system based on Intel AMT, and where: managing PC – computer, from which it is possible to manage other computers remotely, equipped with Intel AMT, marked accordingly: PC1-PC7

Rys. 1. Architektura sieci komputerowej, w której działa system oparty technologię Intel AMT, gdzie: PC zarządzający – komputer, z poziomu którego można zdalnie zarządzać pozostałymi komputerami wyposażonymi w Intel AMT oznaczonymi odpowiednio: PC1-PC7

Parts of the system are demonstrated in the Fig. 2. The application was developed in Java technology with application of object designing technologies. The most important libraries are supplied by the Intel company. These were two libraries, which simplified communication with the WS-Managment and SOAP: *Intel WS-Management Library* and *Intel RDK-SOAP*. Other libraries supporting development of the application were libraries in the Mavena repository: Google Guice, Log4j, TestNG, XStream.

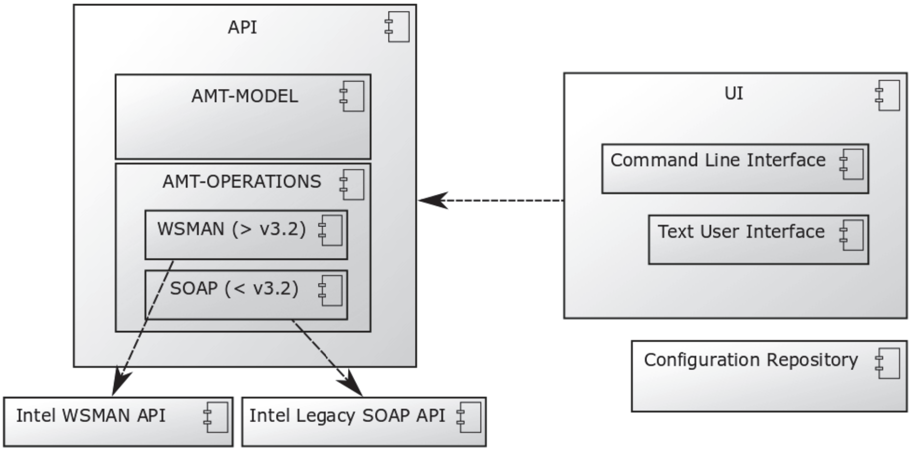

Fig. 2. Division of the system into individual parts (Saint-Hilaire & Ylian 2008), where: UI – comprises two user's interfaces Configuration Repository – responsible for configuration of modules in the system, AMT-Model – abstractive model of data used to carry out the operations, AMT-Operations – a pack including set of functions assuring relations between platforms, Intel WSMAN API – a pack comprising set of functions to communicate with AMT up to 2.9.X, IntelSOAP – a pack comprising set of functions AMT after 2.9.X
Rys. 2. Podział systemu na elementy składowe (Saint-Hilaire & Ylian 2008), gdzie: UI – zawiera dwa interfejsy użytkownika, Configuration Repository – odpowiada za konfigurację modułów w systemie, AMT-Model – abstrakcyjny model danych wykorzystywany do prowadzenia operacji, AMT-Operations – pakiet zawierający zestaw funkcji zapewniający połączenie z platformami, Intel WSMAN API – pakiet zawiera zestaw funkcji do komunikacji z AMT do wydania 2.9.X, IntelSOAP – pakiet zawiera zestaw funkcji do komunikacji z AMT powyżej 2.9.X

TUI interface is based on the CHARVA library which derives from the Java. It is used to present graphically the user's interface in traditional system terminals (*Character Cell Terminals*). Its operation consists in emulation of components of the AWT library and SWING into the form of terminal windows.

The application enables to perform essential functionalities in the area of management at a single computer or a group of them. User of the application can:

- manage the power supply that is to download information on the power supply and a present status of the computer and to change it,
- monitor computer configuration that is to read information on equipment configuration of an individual unit.

TUI interface enables to scan selected extents of network addresses in order to find computers with active AMT module. TUI interface is read by means of a reflection mechanism. It assures that the application can be extended easily since it does not require changes in the module logics during further development of application.

The application has been divided into modules. To erect them and to manage them the Apache Maven was applied. Modules were designed in such a way to follow assumptions of so called *loose coupling*. Loose coupling means that modules are much more independent on each other. They communicate with each other by means of interfaces or abstraction classes. Such structure of the system was guaranteed by use of a design sample under the name *dependency injection* (Panasiuk & Panasiuk 2015).

Text User Interface because of its specificity – the users do not have to know the commands and the interface is equipped with advices mechanism, is designed for users with less quantity of the experience in the area of Intel AMT. TUI interface window comprises a panel which makes system functionalities available. In the bottom part of the application window there is a console with results of made operations. TUI provides also guidelines enabling navigation within the interface.

There also available key shortcuts which enhance ergonomics and quickness of use of the system functions. In the Fig. 3 there has been presented a basic screen of the TUI interface. Functionality included there enables to catalog the equipment remotely and to mange power supplies for the platforms.

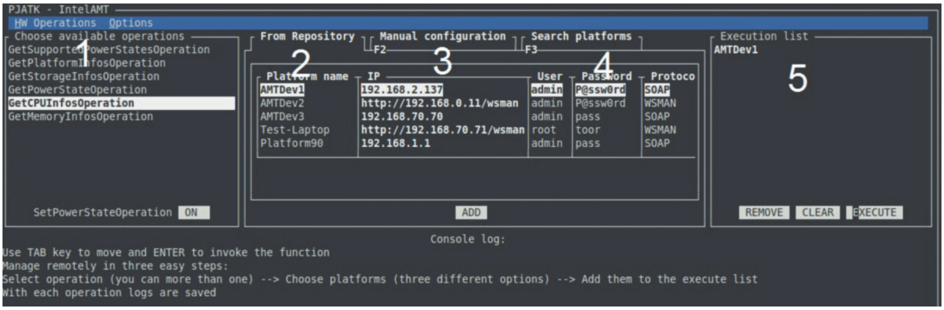

Fig. 3. Preliminary TUI interface window, where: 1 – choice of operations, 2 – display of all computers from the repository, 3 – manual configuration of computers' parameters, 4 – browser of computers in a network, 5 – list with selected computers. To adjust the list no. 5 the following buttons are designed: REMOVE (removes ticked item) and CLEAR (it clears the list). EXECUTE button performs certain operations at selected computers, informing a user on progress of operations in the console of the window

Rys. 3. Początkowe okno interfejsu TUI, gdzie: 1 – wybór operacji, 2 – wyświetlanie wszystkich komputerów z repozytorium, 3 – ręczne skonfigurowanie parametrów komputerów, 4 – wyszukiwarka komputerów w sieci, 5 – lista z wybranymi komputerami. Do korekty listy 5 służą przyciski: REMOVE (usuwa zaznaczoną pozycję) i CLEAR (czyści listę). Przycisk EXECUTE wykonuje wskazane operacje na wybranych komputerach, na bieżąco informując użytkowania o postępie prac w konsoli okna

5. Simulation test and measurement of the electric energy consumption in a computer classroom

In order to picture quantity changes of the electric energy consumption in a typical computer classroom certain simulations and measurements of the electric energy took place.

Simulations and the measurements were made for the computer classroom equipped with 16 stationary computers, IBM class, equipped with a central unit with a 400 W power supply unit and 50 W monitor. Also a multimedia projector was used in the room, 230 W and 600 W total lighting.

In the winter season 2017 during a week, that is from Monday to Sunday approx. 50 (45 minute) lessons took place. In particular, these were programming, computer graphics, software engineering, databases, engineering computations. Such diversity results in situation that computers in the classroom were loaded in different manner.

During simulation tests average electric energy consumption was accepted equal 225 W. In the Table 2 there is also comparison of results of the simulation test for a full week, where 16 computers are shut down after the end of classes that is just after 50 (45 minute) lessons, or after 38 full hours, and comparing this situation to situation where one, two, three and half of the computers are not shut down. As it was evidenced by analysis of the results in the Table 1, case of failure to shut down 8 of the computers is impossible in practice, but it was included since it was supposed to be used as the upper asymptote for carried out analysis.

Table 2. Analysis of consumption of the energy in a computer room during a week, for 16 computers shut down after classes
Tabela 2. Analiza zużycia energii w pracowni komputerowej przez okres tygodnia dla 16 komputerów wyłączonych po zajęciach

Number of computers not shut down after the class	Energy consumptions [MWh/month]	%
0	0,54	–
1	0,54 + 0,05 = 0,59	10
2	0,54 + 0,09 = 0,63	15
3	0,54 + 0,11 = 0,65	18
8	0,54+ 0,47 = 1,01	47

Source: own work.

Analysis of the results presented in the Table 1 proves that failure to shut down the computer after the class in a computer classroom during the week causes increase in consumption of the electric energy. That increase comprises additional 10% of the electric energy in relation to total consumption by all of the 16 computers operating only during classes at the time of the tested week. Increasing number of not shut down computers during the week in question up to 2 or 3 makes an increase in the energy accordingly by 15% and 18%.

In the Fig. 4 there is demonstrated distribution of the electric energy consumption for two months (October, November). The measurement was carried out by an energy meter and the reading took place after each week. Results of the measurement demonstrated in the Fig. 4 were placed at the background of results entered into the Table 2.

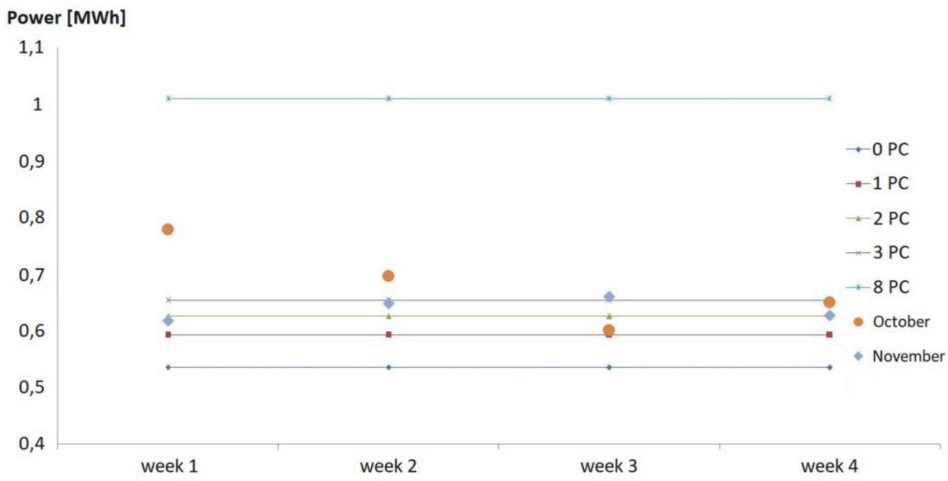

Fig. 4. Recorded consumption of the electric energy by 16 computers during 2 month period in the background of results from Table 2
Rys. 4. Zarejestrowane zużycie energii elektrycznej przez 16 komputerów przez okres dwóch miesięcy na tle wyników z tabeli 2

Presented distribution of the energy consumption shows decreasing tendency and then controlled smoothing of it. According to the Fig. 4 it results that the largest consumption of the energy was noted in October, and much lower was observed in November. At every higher school this is time, when students start attending labs and relatively frequently attend them. Large consumption of the electric energy after the first week, and then its successive drop can be explained by the fact that students were taught on how to deal (shut down) with the computer equipment. After some time for most of them it has become something normal. It confirms the results acquired in the questionnaire survey, according to which it results that, if admonished, 28% students shut down the computers while 18% of them shut down only certain parts of computers. Comparing results of the measurements and simulation tests one can conclude that the bottom asymptote of consumption of the energy may arise from the fact, that averagely one or two computers are not shut down although students have been asked to do so.

6. Conclusions

IT system developed for a higher school enables simple and effective management of its computer infrastructure. The most substantial added value arising from developed software is automation of IT administrators' duties from level of any system and possibility to control and to monitor condition and operation of the computer infrastructure. Due to high level of automation the product must enable more effective management of the electric energy and quicker reaction in case of a failure. The system can be also applied in order to make periodic cataloging of the computer equipment or other reports on IT infrastructure of a university. Proposed solution has been adjusted to the environment where it was to function and it met requirements of the final user. Even if the proposed system cannot be implemented, still the conclusion is that at the time of planning the technical infrastructure one needs to invest into new technologies since they enable improvement of the work quality and they also enable reduction of the energy consumption contributing consequently to promotion of the environment protection.

A substantial conclusion arising from conducted questionnaire survey and measurements of the electric energy consumption is that, to the some extent, it is possible to promote pro-eco approach among youths in terms of use of electric devices. Cultural changes in this field are significant and hence, trends must be controlled and watched.

When planning the IT infrastructure in an organization, especially a large one such as higher school/university, technologies similar to Intel AMT are worth of attention since due to them management and maintenance of proper technical condition of computers is much more simple and effective. At the technological process one should take into account all operations regarding ecology and environment protection. The issues refereed herein are of significant meaning for the ecological awareness growth.

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Analiza zużycia energii elektrycznej w ośrodkach dydaktycznych a ochrona środowiska

Streszczenie

Nowoczesne programy studiów prowadzone w szczególności na kierunkach technicznych, obejmują przedmioty, które w części praktycznej realizowane są w pracowniach komputerowych. Takich przedmiotów jest szczególnie dużo na uczelniach technicznych, a kierunkiem, który wiedzie prym w tym zakresie jest informatyka. W pracy przedstawiono czynniki, które mają istotny wpływ na zużycie energii eklektycznej w pracowni komputerowej. Analiza ta pokazuje, że zmiana nawyków zachowania studentów korzystających z pracowni komputerowych jest istotna ze względu na relatywnie duże oszczędności w zużyciu energii elektrycznej i w obniżeniu kosztów utrzymania pracowni. Przeprowadzono badanie ankietowe, w którym rozpoznano nawyki użytkowników pracowni komputerowych. Następnie przedstawiono oprogramowanie, które umożliwia zdalne i efektywne zarządzanie stanem platform komputerowych. System ten oparty został na technologii sprzętowej „Intel Active Management Technology", która również została scharakteryzowana w pracy. Funkcjonalność systemu opracowano na podstawienie doświadczenia i wymagań zespołu administratorów sieci komputerowej i prowadzących zajęcia informatyczne. Do najważniejszych funkcjonalności systemu należy pobieranie informacji o stanie zasilania platform i zmienianie go, pobieranie informacji o podzespołach komputera, skanowanie adresów IP maszyn i archiwizowanie ich. Powstałe oprogramowanie wyposażone zostało w dwa typy interfejsów. W stosunku do znanych rozwiązań komercyjnych stworzone interfejsy wpłynęły na poprawienie wydajności systemu oraz zwiększyły jego ergonomię w zarządzaniu platformami. Jako podsumowanie przedstawiono analizę zużycia energii elektrycznej w pracowni komputerowej bez zastosowania systemu i po jego implementacji. W artykule pokazano występującą problematykę ochrony środowiska, którą obejmuje przeprowadzona analiza zużycia energii elektrycznej w ośrodkach dydaktycznych.

Abstract

Modern programs of studies, in particular for technical majors, include classes which take place in computer rooms. Such subjects are numerous in particular at technical schools / universities and the major which is leading one is the IT. In the paper authors presented factors which have a significant impact on consumption of the electric energy in a computer room. The analysis in question shows that change of habits of students using computer rooms is important because of relatively large savings in consumption of the electric energy and lower costs of maintenance of computer rooms. Survey was carried out in order to learn habits of users of computer rooms. Then software was demonstrated enabling remote and effective management of computer platforms. The system was based on equipment technology “Intel Active Management Technology” which also is characterized in the paper. The system functionality was developed on the basis of experience and administrators’ requirements of the computer network and IT class teachers. The most important functionalities of the system comprise collection of information on power supply of the platforms, as well as changing this state, collection of information on sub assemblies of a computer, scanning of machines IPs and archiving them. Elaborated software was equipped with two types of interfaces. In relation to known commercial solutions, developed interfaces improved efficiency of the system and enhanced ergonomics of platforms management. As a conclusion the analysis of the electric energy consumption in a computer room has been presented - the consumption without application of the system and after it has been implemented. Also the environment protection is part of this paper since it is a part of made analysis of the electric energy consumption in teaching centers.

Słowa kluczowe:
oszczędzanie energii, energia elektryczna, sieć komputerowa,
technologia Intel AMT, oprogramowanie

Keywords:
energy saving, electric energy, computer network, Intel AMT technology,
software