Green Internet of Things (G-IoT) at engineering education institution: the classroom of tomorrow

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***Abstract*—Education, as almost every other aspect of our lives, has not been immune to advancements in Information and Communication Technology (ICT). With the evolution of the Internet of Things (IoT), the vision of completely smart classroom has never been closer to reality. However, despite diverse benefits of novel technology solutions, manufacturing, distribution, and utilization of IoT products and systems are energy and resource intensive and accompanied by escalating volumes of waste and toxic pollutions. Hence, in order to maximize benefits and minimize harm to people and the environment, Green IoT (G-IoT) appears as the adequate solution. This paper analyzes the possibilities of the G-IoT utilization in the engineering education. Therefore, the main benefits, as well as challenges for the appliance of G-IoT vision in a smart classroom, have been discussed.**

Keywords-Green Internet of Things (G-IoT); engineering; education; smart classroom

I. INTRODUCTION

The intensive technology advancements have dramatically changed the classroom in the last decade. The Internet of Things (IoT), which refers to the internetworking of Internet-aware devices, has played the significant role in transforming education processes. With the help of sensor technologies, radio frequency identification (RFID), Cloud computing technologies, big data analytics, and e-learning platforms, the vision of smart and interactive classroom, consisted of smart devices that have Internet capabilities and can be controlled and tracked through the Internet, becomes reality (Fig. 1). In the other words, smart technology and Internet connectivity have changed the approach of how the universities teach and students learn [1].

Figure 1. Smart and interactive environment at engineering education institution

With the IoT growth, more and more Internet-capable technologies are involved in educational practices. The IoT vision is based on the ability of everyday devices and appliances to communicate with each other and human by means of the Internet and Cloud computing. Large amounts of collected data can be easily quantified and stored. These facts prove that IoT has potential to significantly contribute to improving the processes of education systems [2]. With every year, more and more smart devices are presented in the classroom (tablets and electronic books (e-books), smart boards, smart tables, interactive whiteboards, cameras, 3D printers, student identification cards, etc.) together with appropriate software and applications (Fig. 1). As the smart devices are Internet capable and controlled, the IoT by means of smart devices creates a virtual, shared and intelligent experimental teaching environment [1]. Hence, the IoT has potential to transform the definition of knowledge delivery from "static classroom" to "anytime and anywhere" through remote access from any connected smart device (using smartphones, smart tablets, smart boards, and applications) [3].

Some of the possible drawbacks to a smart, IoT-enabled classroom are expensive equipment and labor, what is mostly the consequence of increased energy and resource usage in production, distribution, and utilization of smart devices and technologies. Furthermore, privacy, interoperability, student distraction and difficulty managing an IoT environment are stated as other challenges [4]. Increased amounts of electronic waste (e-waste) and hazardous emissions also must be taken into account. Perhaps the best answer to these challenges is in implementing the Green Information and Communication Technologies (ICTs), particularly G-IoT concept. Hence, this paper discusses the potential and implementation of the manners which are more energy and resource efficient, health and environment aware, in order to make anyone and anywhere, economically, socially and environmentally sustainable access to high-quality education.

The rest of this paper is structured as follows. The second section presents the G-IoT concepts and ideas. The possibilities of including G-IoT in an engineering education and potential benefits are discussed in the third section. The last section contains the closing remarks.

II. GOING GREEN WITH IOT - G-IOT

Despite the tremendous benefits that ICTs, especially IoT, provide, they are responsible for approximately 2% of global CO_2 emissions and consume incredible amounts of electricity, raw materials, chemicals, and water. Even ICTs are considered as a part of the environmental problem, they are at the same time seen as a part of the solution [5, 6]. Understandably, there is a demand to put a lot of efforts to reduce carbon production, energy, and other resource consumption. This is the reason for moving towards green ICTs, particularly G-IoT. Governments, companies, designers, manufacturers and consumers all have an important role in greening our future – creating a sustainable place for living.

The greening ICT process includes the economically and environmentally responsible ways of design, fabrication, and use of ICT devices and infrastructures (Fig. 2) [7].

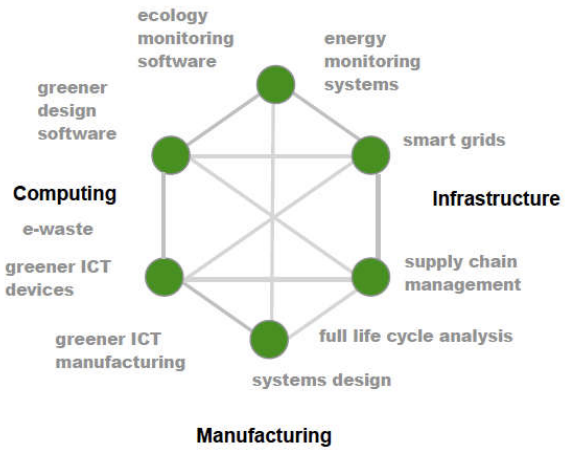

Figure 2. A map of green ICT activity [7]

From the technical perspective, green ICT is a broad concept, which includes numerous technologies, such as supercomputers, e-commerce, virtualization, telecommuting, IoT, smart grids and Cloud computing [8]. In other words, green ICTs, as well as G-IoT, are based on [9]:

- Green communication technology;
- Green computing technology; and
- Smart grid and applications.

Green communications and networking are the practice of choosing energy-efficient, environmentally friendly and sustainable communications and networking technologies and products. Communications and networking practices which enable remote conferencing and online collaboration environments, remote administration and work from home and other remote locations, as well as usage of new and more energy-efficient products significantly contribute to cost-efficiency and reduced energy usage.

The environmentally responsible use of ICT equipment and related resources is known as green computing technology. This includes the usage of energy-efficient ICT equipment (computers, servers, printers and other peripherals) alongside reduced resource consumption and proper disposal of e-waste.

Smart grids are sets of hardware and software tools that manage energy flows, supply and demand in a sustainable, reliable and economic manner.

Hence, to satisfy general principles of G-IoT, it is necessary to [10, 11]:

- Reduce energy consumption of facilities with appropriate hardware design or with the assistance of software;
- Transmit information only when is needed/required using the minimized data path length and applying advanced communication techniques;
- Design G-IoT components in an eco-friendly manner;
- Use renewable green power sources (e.g., usage of solar, wind, water).

III. G-IoT IN ENGINEERING EDUCATION

Traditionally, engineering education has been content-centered and design-oriented. Students attend classes on a full-time basis and carry out the laboratory experiments at the universities [1]. Therefore, until recently, an online teaching of engineering subjects was the most difficult because of the need for laboratories and equation manipulation [12]. However, even enabling online delivering traditional course content, it is still just information. Thus, besides the delivery method, the content of the delivery is even more significant [13]. With the IoT development, which provides a virtual space where objects are represented, the quality of online courses is not just comparable, but often better than the traditional classroom. In this way, a broad spectrum of engineering disciplines is available and accessible from anywhere [14].

Even connected devices are already in the classroom, the IoT lead to new levels of connectivity and learning approaches, especially in the science, technology, engineering, and mathematics areas [15]. With the IoT utilization in education students take an active role, they have access to their courses or laboratory exercises at any time, from anywhere they can log on. In addition, they are able to choose how to generate, obtain, manipulate, or display information as well as to evaluate their progress at the same time. In this manner, students are supplied with high quality and engaging lessons, the online training is quick, cost efficient and easily affordable while students' success depends on their ability to focus and to effectively use their time [1]. To bring students real-world experience with products and systems, next four areas of concentration should be addressed: open source computing projects, communication protocols, sensors, and messaging [15]. Hence, the adoption of IoT vision in engineering education requires [16]: low costs, scalable manufacturing, extremely simple tool chains and long-term future of used equipment. To realize multidisciplinary engineering practice, a model-based design approach, as well as modeling and analysis of multidisciplinary dynamic engineering systems' skills, are essential [13]. Using the IoT architecture, students have the ability to interact with a set of physical objects in the environment and to interact with executed applications. Each of used objects in particular course has associated one (or more) the virtual object which provides information that allows the student to learn how they work, how it can be used and so on. Hence, students are able to manipulate the objects (either virtually in a computer simulation or physically with an actual hardware system) in order to increase their understanding of the subject [17]. The possibilities of making various DIY (Do It Yourself) solutions based on the IoT architecture [1], implementing Cloud computing and data collection, processing and analyzing systems [18, 19], contribute to improved students' experience through critically thinking, better understanding and solving a real-world problem, and consequently transform the experience both for students and teachers.

Smart HVAC (Heating, Ventilation and Air Conditioning), electric lightning, temperature sensors, attendance tracking or wireless door locks save teachers' precious time, making teachers free from classroom procedures, and help them to spend more time to organize and present learning materials. The IoT in education gives the teachers the role of facilitators in setting project goals and providing guidelines, resources, and support in students' problem-solving efforts [1]. Thus, they are able to produce more efficient learning methods through tailoring content to students' demands and continuing their teaching beyond the classroom, join forces with other instructors, offer more appealing ways of transmitting and delivering information, as well as successfully implement the students' evaluation through online assessment tools [3].

Evidently, the IoT will play a significant role in transforming educational processes. Bringing out new methods and strategies of teaching and learning will raise the quality of the education, guaranteeing the delivery of long-lasting knowledge and sciences that are applicable to real-world problems solving [1]. The vision of future education, supported by IoT vision, is presented in Fig. 3.

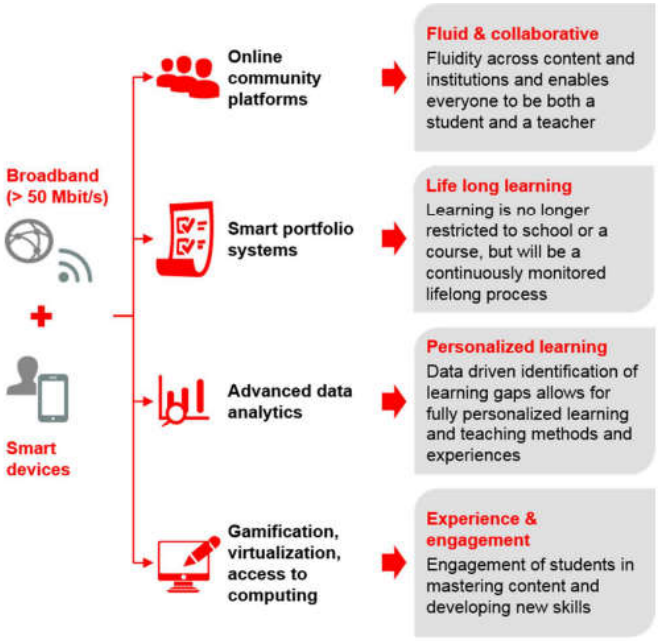

Figure 3. Technology vision in education for 2030 [3]

Compared to IoT, the G-IoT at education institutions ensures the sustainability of the ICT resources and encourages and supports greener behavior by the faculties, staff members, students and admin people [6]. Hence, to realize economically, socially and environmentally sustainable education with the help of G-IoT, it is necessary to perform the following tasks [6, 20]:

- Optimal utilization of resources - this can be done in various manners: shutting down personal computers, and ICT laboratory equipment when they are not used by students, teachers or other educational institution staffs; enabling the standby/sleep mode and power management settings for central processing unit, monitor, printer and peripherals; replacing desktop devices with thin client models; using the right-sized monitors and turn down the brightness settings on monitors; avoiding screensavers; using Cloud computing; implementing efficient hard drives; using multifunctional equipment (printer, copier, scanner,

fax); sharing printers, reducing printing and configuring low toner mode; sending documents as email attachments rather than printing or faxing; using e-learning approach, teleconferencing, video conferencing, web conferencing and online collaboration tools; enabling remote access to equipment; storage consolidations and optimization and virtualization of server resources; using smart grids and alternative renewable energy sources; using low-cost sensors to enable a more finely-tuned HVAC system, etc.

- Dispose, reuse and recycle ICT equipment – this can be performed via reassigning old IT devices when possible, reusing and repairing ICT equipment before replacing or donating it and recycling old ICT devices in an eco-friendly manner.
- Increase G-IoT practice awareness among all the stakeholders of education establishment like a staff, faculty, students and top management people. Following G-IoT practices, saving natural resources, minimal or no impact on the environment and cost reduction can be accomplished.

Clearly, G-IoT in education institution will lead to achieving cost effectiveness and sustenance of ICT in the future. Some of the forecasted benefits in education by 2030 are [3]: 5 billion liters of fuel saved from transportation, 91 million tons of paper saved thanks to e-books, 450 million e-learning participants, and 1,81 billion USD costs savings due to a decrease in expenditure per student. Still, challenges regarding data privacy and security issues, standardization and legislation must be seriously considered in order that G-IoT shows the full potential. However, the G-IoT will play a key role in the environmental, economic and social benefits of education of tomorrow.

IV. CONCLUDING REMARKS

The IoT progress already shows a positive influence on education, moving classroom from traditional to smart and interactive. Going green with IoT and implementing the G-IoT vision at educational institutions will completely transform ways of teaching and learning. In a vision of future educational practice, the students will be able to remotely access and control laboratory equipment, online collaborate and play an active role in obtaining knowledge. On the other side, a teacher will provide novel ways of teaching, support, and guidance. Enabling access to high-quality education to anyone, from anywhere and anyhow are the goals of IoT utilization in education. The G-IoT inclusion at educational institutions embraced with the taking care of energy and resource consumption, e-waste, hazardous emissions and toxic pollutions, holds the potential to create affordable, flexible and engaging educational practices. It is foreseen that the education of tomorrow will be economically, socially and environmentally sustainable. Based on performed study, it can be concluded that the G-IoT will play a key role in achieving this goal.

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Achieving interoperability among e-learning infrastructures is essential for the classroom of the future. However, the field of e-learning has grown without a clear vision on how heterogeneous e-learning systems should inter-relate, and interoperability remains a big challenge. We analyze relevant standardization approaches which in turn shapes an overview of enabling technologies for e-learning.Â @article{Chituc2019UnderstandingTI, title={Understanding the Importance of Interoperability Standards in the Classroom of the Future}, author={Claudia-Melania Chituc and Marc Rittberger}, journal={IECON 2019 - 45th Annual Conference of the IEEE Industrial Electronics Society}, year={2019}, volume={1}, pages={6801-6806} }. Claudia-Melania Chituc, Marc Rittberger. The Internet of things (IoT) is a system of interrelated computing devices, mechanical and digital machines provided with unique identifiers (UIDs) and the ability to transfer data over a network without requiring human-to-human or human-to-computer interaction. The definition of the Internet of things has evolved due to the convergence of multiple technologies, real-time analytics, machine learning, commodity sensors, and embedded systems. Traditional fields of embedded systems, wireless sensor