Enhancing Security of Smart Buildings using Internet of Things

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Abstract— **Because of the low and affordable prices of central processing units (CPUs), in the new computer processing era, using the CPU-based technologies is a must in today world. In this regard, enhancement of smart buildings' security using the agent-based approaches is analyzed in this paper. This approach considers all the potentials of devices in the smart environment and utilizes them in order to provide the building's security.**

Keywords: Internet of things; Sensor networks; Smart building; Security; Agent-based design.

I. INTRODUCTION

Many years ago, a processor like I486, was as expensive as a car, but nowadays, a small powerful processor is as cheap as a chocolate bar. Because of the affordable prices and flexible dimensions of processors, nowadays the new technologies are developed based on them. In fact, they can be easily embedded in small devices such as the measurement tools, lighting systems, telephones, etc. Therefore, we can rely on these small chips to facilitate our lives, save more energy, decrease the operational costs, and enhance the productivity [1], [2]. In this papers, we have focused on the advantages and particular benefits of deploying the Internet of Things (IoT) solutions in smart building's security and safety.

The rest of the paper is organized as follows. Section II describes the Internet of Things definition and its components in details. Section III introduces the smart building and its components. The next section presents the smart building design and implementation with Internet of Things solutions. Section V talk about the IoT layers. The next section illustrate our agent-based smart building design based on IoT. And, eventually section VII contains the conclusions and discusses future research.

II. INTERNET OF THINGS DEFINITION AND ITS COMPONENTS

To begin with, we want to explain the Internet of Things as some simple scenarios. (1) your alarm clock starts ringing 5 minutes later than your scheduled time, because for instance the train schedule is delayed for 5 minutes and you had 5 more minutes to sleep more. (2) The patient a health care system at home that automatically notifies him/her to have his/her pills, and if the patient does not do so, it will send emails to the patient's doctor to let him/her know that his/her patient did not follow the prescriptions. (3) When the resident wants to leave the apartment, the umbrella's light turns on, meaning that the weather forecasting website predicted it is going to be rainy today and the resident needs to get his/her umbrella with him/her.

The aforementioned scenarios are being implemented in today smart buildings [3-7] or as prototypes in the smart building laboratories for research purposes [8]; in particular smart residential buildings. All the IoT components are in connection with the Internet network; they transfer information to or receive from it. All the things connected in this environment are called the things. Internet of Things is a World Wide Web of objects with unique addresses, which can communicate through the specific standard communication protocols. All the aforementioned purposes can be accomplished through the Internet or the smart phones; for instance, the delayed train schedule can be looked up through the smart phone, or the weather forecast data can be accessed through the Internet or smart phone. However, the most important advantage of the IoT technology in today world is the time savings [4], [5]. In other words, the smart building (or smart city as a whole) residents can save a huge amount of time as well as enhance their productivity using the new IoT-based technologies.

The things in a IoT network can be virtual or physical, dynamic or static, however, all of them have something in common; that is they all are active objects in communication with other objects through the IoT network. The communications between the things/objects is called the thing-to-thing communications. If an object communicates with a human, it is known as a thing-to-human communication. So the concept of Internet of Things is not only limited to the powerful tools such as smart phones, laptops, or music players, it is expandable to the regular and personal tools and devices such as an umbrella, mirror, bracelet, refrigerator, shoes, etc. Fig. 1 shows a general illustration of the Internet of Things and its applications [9].

One might get confused in distinguishing the comprehensive computing from the Internet of Things. The most important difference between IoT with all other Internet-based technologies is that the virtual of physical objects have communications through the IoT-based technology. For instance, a freshener can be programmed to act when a person enters a place; this components does not need to be connected to other devices to perform, it can perform individually only based on a flag that represents the existence of a resident (which is activated by a sensor, such as a PIR sensor). The technologies based on pervasive computing assist the humans to control the objects based on the decisions that are generated based on the inputs of real-world, and they on't need to be under the network communications. Although the IoT-based technologies assist humans in the way that the pervasive computing approaches are not capable of.

The Internet of Things network is composed of the control units, sensors, and actuators. All these components are explained here in details.

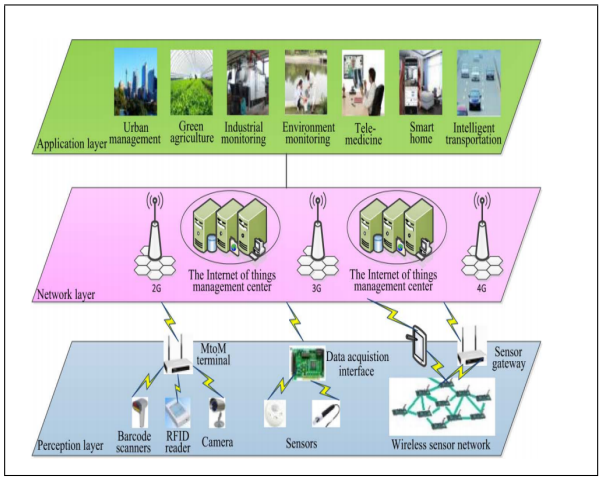

Fig. 1: Internet of Things configuration and its main applications

A. IoT Controller

The control unit in IoT is responsible to analyze the inputs from the sensors and generate commands based on specific control algorithms. These commands are then transferred to the actuators through the standard IoT communication protocols. The control framework can be developed based on various architectures; decentralized, distributed, centralized. Each of these architectures has its own advantages and disadvantages, and they should be selected based on the system architecture, and its components. Nowadays, the distributed control frameworks are under special attentions and many researchers utilize these architectures in designing controllers for smart buildings [8], smart traffic systems [10], smart parking [11], etc.

B. IoT Sensors

The sensor networks is a very important part of a IoT network. The sensors collect the sensed data (such as light exposure, heart rate, vehicle's speed, ...), store it, and send it to the decision making units in IoT. In this regard, the real-world inputs, such as the number of times a building resident sit on a chair, are collected and sent to other devices or processors through the Internet network.

C. IoT Actuators

The outputs are generated and sent to actuators to act. These outputs are the outcomes of the analyzed data on the Internet. For instance, a chair can be scheduled to vibrate when the resident sitting on it receives an email.

Therefore, all the aforementioned components can be addressed in the Internet environment and communicate through the network, under the standard IoT protocols. This network of connected things build the Internet of Things network.

III. Smart Building and Its Components

Smart building is a building structure in which a network of devices communicate with each other to manage and control the building system in the most optimum way. The first question is what is referred to smart devices in a smart building. Almost all the appliances and devices, that are connected to the building outlets, are considered as the smart devices; such as central controls for the lighting system, temperature control, ventilation controls, door locks, curtain and cover controls, surveillance system control, etc.

The advantages of a smart building can be categorized into three main aspects: comfort, security, efficiency.

Comfort: Smart buildings improve the residents comfort level significantly. They assist the residents in scheduling their plans, performing their everyday activities, and overall making the life easier for them.

Security: The security aspect is very important in a smart environment, because in an IoT network the residents' information can be abused in an insecure way anytime. The smart devices in the buildings can be utilized to protect the residents from natural disasters, like fire, floods, or gas leaks, . The sensors can be implemented in the doors, windows, elevators, such that they can detect an abnormal activity and notify the residents by alarms, hazard lights, sirens, and any other actuator.

Efficiency: Thanks to the new smart building technologies based on IoT solutions, the buildings' efficiency and flexibility have increased significantly. The residents can check their energy consumption every day and try to decrease their energy usage. Also, the smart technologies assist the residents save energy, for instance the smart lighting system turns off automatically when the residents leave the environment, or the smart technologies set the status of the curtains during the daylight and night in a way to use the natural lights in the maximum optimum way. The smart grids are also considered as the top-trend smart technologies which resulted in a lot of energy savings.

IV. Smart Building with Internet of Things Solutions

Internet of Things solutions can assist the designers to design more reliable, comfortable and secure smart structures. The mentioned aspects of smart building (mentioned above); comfort, security, and efficiency, are analyzed here in detail in smart buildings constructed based on IoT solutions.

Comfort: In a smart building, a thermostat not only controls the room temperature and ventilation system, but also communicates with the garage door opener to detect when the residents leave the place. Moreover, the dish washer machine communicates with the PIR sensors to detect when the residents leave to work. The lighting system can be facilitated with dimming technology, to help the residents wake up or sleep based on a schedule. The surveillance system can be connected to the police department in terms of an emergency or intrude. All the building appliances can

adapt themselves to the residents' activities, for instance, the lighting system will be set based on what activities the residents are engaged with; watching TV, studying, sleeping, listening to music,entering the room, leaving the building, etc. The residents also can meddle with the automatic system whenever they want. For example, the residents can set the temperature or the status of windows or curtains through their smart phones.

Security: The smart technologies allow the residents to have a more secure building; for instance the cameras are embedded all over the building to monitor the area whenever needed, through the phone or computer. Furthermore, the security cameras are connected with the other smart systems to manage the building more efficiently based on the occupancy status. Obviously, the residents can interact with the security system through their phones or smart interfaces. The safety system is in communications with the lighting system of the building, the buzzers, the locks, the police department center, etc. The security system will act when it detects an abnormal movement or motion, or recognizes intruders in the building. Thus, you can see that this smart security is a lot more efficient and professional than only an emergency siren. Furthermore, the appliances' maintenance schedule can be sent to the residents to make sure all the devices are performing securely and efficiently; for example if a refrigerator needs to be fixed, the message will be sent to the resident's phone to be aware of this issue and act as soon as he/she can. If a building appliance needs to be repaired and the resident is not around, the building can call the repair shop and schedule a time for the service, without any need for the resident to be there.

Smart buildings based on IoT solutions are categorized into two aspects; physical aspect, and application aspect. IoT-based smart buildings study in a physical view is the study of what sorts of devices, protocols, networks, sensors, and actuators are being used in the project. In an application layer, we discuss what services, communications, commands, information are considered in the design.

V. Internet of Things Layers

In general, IoT is composed of three main layers; agent layer, middle-ware layer, and user layer; these layers are illustrated in Fig. 2 [12]. The physical layer includes all the sensors, actuators, networks, and devices. The middle-ware ease the complications of the hardware and the software, and allow the designer to better build the communications and connections between the devices through the network. The middle-ware can be of any of these kinds; event-based, service-oriented, VM (virtual machine)-based, Agent-based, Tuple-spaces, Database oriented, Application specific. In this paper the security system is developed through an agent-based approach [13].

In an agent-based middle-ware design, applications are developed modular, which allow the efficient and easy expansion and distribution over the network. In this design, the agents maintain their states while transiting from one node

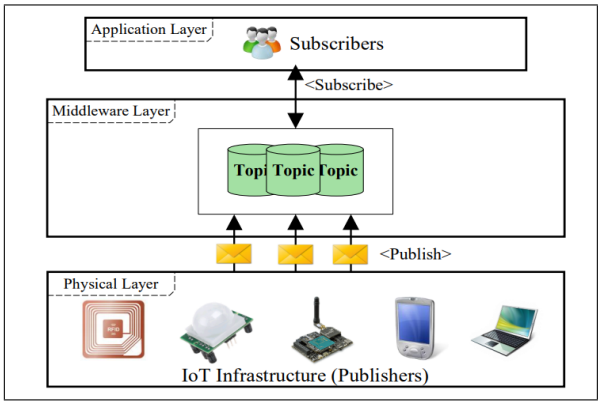

Fig. 2: Internet of Things layers

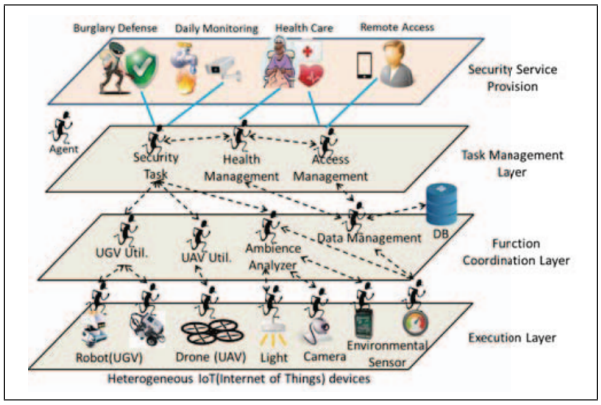

Fig. 3: Agent-based configuration

to another. Based on this architecture, a decentralized strategy can be built for the system. Through this approach, the agents can talk to each other and update only a part of the application, without modifying the whole program [13]. Moreover, the agent-based design does not require a lot of resources or tools.

VI. Secure System Design for Smart Buildings Based on Internet of Things Solutions

To design a reliable security platform for a smart building, we first need to consider two technical aspects; first, the coordination between the heterogeneous tools, and second, the management of tasks. The first technical issue can be solved by implementing an agent-based framework for the smart system. The second issue can be addressed by building a dynamic security system based on the tasks. Fig. 3 shows an agent-based infrastructure for the smart buildings based on IoT solutions [12]. The infrastructure is composed of four main layers; Execution layer, function coordination layer, task management layer, and security service provisioning.
In this paper, a scenario that an intruder comes to the building is considered. Several actuators and sensor are coordinating in this project. We assume that the resident has left the building. When the intruder enters the building, the door sensor detects it and sends the signal to other devices, particularly the lower layer devices to track the intruder. First the light turns on to

tape the intruder with a better image quality. Then, a UGV (MINDSTORM NXT Lego Kit) robot reaches to the door and recorde a video of the intruder. Once the signals from the sensor networks are received by the UAVs (with HD cameras), the intruder is tracked by these UAVs, while trying to escape from the area. In this project, the reliability and flexibility of security systems designed based on IoT is much evident.

VII. Conclusion

In an agent-based design, if any of the components cease working, other components continue performing and this helps the system to maintain its performance. Therefore, the Internet of Things solutions are considered as the most efficient solutions to be used in designing the security systems. The drones that are designed for the safety nowadays are designed based on IoT solutions. As time goes by, more and more IoT-based devices will be implemented in smart environments, smart cities, smart buildings, etc.

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