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Internet of Things (IoT) Framework for Smart Real Estate Monitoring

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ABSTRACT

Real estate management of either residential, industrial or commercial land is a daunting and enormous task covering operations, control, oversight and maintenance of the physical properties.Unlike the existing automation systems specific to a building such as Building automation system (BAS) or Building automation and control network (BACnet)*, this study proposes a 3-tier architectural framework that utilizes* Open Services Gateway Initiative *(OSGi} layesr to communicate, analyze, and monitor real estate's data in a secure and nonintrusive manner.*

Keywords: Real estate, smart city, smart real estate, IoT in smart building, real estate monitoring, smart building monitoring.

1. INTRODUCTION

Modern information technologies enable realtors or clients to obtain enormous real estates data and process them for decision making. Since IoT technology enables prompt response to issues, and pre-empt advance adverse conditions such as hurricanes, floods and tornadoes requiring proactive preparedness and resilience. Since resources are scarce, inadequate housing, ecological, and financial incapacitation have made realtors to have to monitor, protect and enhance the value of their properties when data emanating from each real estate is extracted, stored and processed.

Real estate management entails activities such as operation, control, oversight and maintenance of physical properties. The real estate could be either residential, industrial or commercial land. The United nations human settlement programme [UN Habitat] (2018) reported that city dwellers are set to double in size over the next 25 years as people move to find work and other opportunities. Similarly, Jin, Gubbi, Marusic, and Palaniswami (2014) observed that 70% of the world's population of more than six billion will have to live in cities and neighboring regions by 2050. With increasing population, many more devices would have to communicate and exchange data, thus generating huge big data. Therefore, when population increases, realtors will be overwhelmed with day-to-day activities involved in real estate management, such as property offerings, service delivery, dynamic clients demand and business requirements, control, oversights and maintenance. This study focuses on the monitoring of physical structures of residential and industrial estates. Existing solutions dealt more about smart individual homes, cities or infrastructure rather than a group of buildings and their infrastructures (Theodoridis, Mylonas, & Chatzigiannakis, 2013), (Strohbach, Ziekow, Gazis, & Akiva, 2011) and (Zhang, Gu, & Zhu, 2008). The current trend in corporate real estate (CRE) is the innovation and redevelopment of the existing real estate sector frameworks (Battisti, Shams, Sakka, & Miglietta, (2019). Advances in communications technology and the integration in the real estate sector have enabled seamless connections of all types of internet protocol (IP) enabled devices and appliances, which are driving the vision to create intelligent, smart buildings and homes ecosystem. This concept is often termed PropTech (Property technology) (Pyle, Grunewald, and Wright (2017); Alam, Dixit, and Prasad, (2007); Baum, 2017; Shaw 2018)). Undoubtedly, IoT is changing how real estate is acquired and how to interact with the structures we live and work (Suresh, Nandagopal, Raj, Neeba, & Lin, 2020).

The concept of smart building offered by IoT technology led to smart real estate monitoring. A smart building is one that uses different types of sensors to collect data to manage its physical assets, resources and services efficiently. Smart real estate (SRE) is more sustainable and augmented by technology, hence a building "smartness" is borne out of intelligence harped on telecommunication networks, sensors, tags (sensory organs) and application software (Ullah, Sepasgozar, & Wang, 2018; Theodoridis et al., 2013). There are many metrics and issues a building management system (BMS) needs to track, therefore, internet of things (IoT) technologies can allow realtors to collect data and process the data for decision making. For example, realtors can monitor utilities consumption to effect an efficient energy consumption pattern and predict accurately maintenance schedules. Clients can also shop online for a desirable real estate. These are in a way making real estate functions smarter. Other smart real estate advantages include enhanced home search and buying experience; tracking and improves energy consumption; enhanced security; adds value to the property; and maintenance could be readily predicted. The continuous monitoring and predictive capability of smart buildings are enough to pre-empt an issue as well as alleviate security concerns to bolster internal security. Further, specialized sensors are capable of providing advance adverse weather warnings such as hurricanes, floods and tornadoes culminating in proactive preparedness and resilience. Smart building monitoring lowers the asset risk that enhances its management. For instance, the monitoring will enable the building manager to analyze the users behavior and learn their space usage patterns in order to prepare for peak space usage hours. Hence, controlling cost, maintenance and security are essential on real estates. Consider a multi-storey building with over one hundred floors or more such as the Empire state building (New York, USA), Jin Mao Tower (Shanghai, China), Petronas Twin Towers (Kuala Lumpur, Malaysia), etc. monitoring these facilities and the associated personnel in each floor could be daunting, apart from monitoring utilities and safety. Lately, Building automation system (BAS) is being used by real estate managers to keep lower utility cost and to ensure safety of everyone including the property with SNMP-based network protocols (Control Services. (n.d.)). A building controlled by a BAS is said to be a smart or intelligent building. Though BAS consists of several multi-protocol heterogeneous, intelligent nodes connected by networks (Hesse, Vasyutynskyy, Nadoveza, & Kiritsis., 2013), to control lighting, access, fire protection, etc. resulting in a minimal cost of buildings maintenance. Depending on the installed smart systems, BAS sensors collects a variety of data on a smart building, such as temperature, pressure or water leakage to track mechanical aspects of the building. The security system relays data that can indicate the presence of intruders. Alarms can be triggered when power supply is interrupted or elevators malfunctions. Monitor occupants behavior and learn their space usage patterns. The figure 1, shows many sensors polling several data via controllers and actuators of many smart equipment in smart buildings. De Bonis and Vinciarelli (2014) said an IoT communication platform is based on clusters of technologies with different bandwidths, hence a huge amount of data is generated and analyzed in real time, thereby requiring efficient infrastructure and storage for the information.

IoT for real estate monitoring can be viewed as a subset of the smart-city concept with broader infrastructures to manage and cater for services such as utilities (gas, electricity, and water), traffic flow, transportation systems, power supply, water supply, waste management and crime detection as well as other community monuments such as schools, library, hospitals, etc. that have to be obtained and managed (Minoli, Sohraby, & Kours, 2017). A smart-city that employs artificial intelligence, data analytics as well as assorted electronic IoT sensors to detect and collect data, learn the data and use the knowledge gained to manage, support, respond and improving the assets and services. Innovations in the telecommunication industry have reshaped the way devices communicate, especially with more pervasive connectivity, increased bandwidth, more services, and more scalability. This is a technology for driving a digitized real estate management system by connecting available physical structures resources. Also, IoT devices can be used to monitor remote real estates and emergency notification as well as its intervention services. This paper proposes a 3-tier architecture smart real estate framework which allows real estate managers to interact directly with the property in order to monitor the status of their valuable asset. This way, overhead cost is minimized in terms of maintenance and utilities consumption, then the surveillance performance is enhanced.

IoT technology-based data are processed to manage, make decisions and to monitor events or changes in the buildings especially during emergency situations or other conditions that can compromise safety and/or risk of the building. The degree of accuracy of intelligent buildings and its environments depends on the task they are set to accomplish. However, smart buildings could gather data necessary to predict hazards, such as fire, floods, intruders, erosion or even inclement weather such as typhoon. IoT technology can activate and notify the necessary organs when suspicious activity is detected within the real estate environment (Wright & Steventon, 2004), thereby adding value to the real estate. Presently, smart or intelligent building, is sustainable and realizable as long as fitted devices can communicate with each other using a peer-to-peer manner to gather data. The related computing devices must have the means to transfer data over a network, provided each device, or object has a unique IP identifier (Ullah, et al., 2019; Gray & Salber, 2001). Hence, the capability of this framework increases as new sensitive devices are invented and are network-enabled. Smart physical structures need to relay a problem or other information to the real estate managers, or to some third party agents such as police, medical services, or utility providers as the case might be. Figure 1 shows a generic smart building monitoring and control system.

Smart buildings technologies are being implemented in many places around the world such as in Singapore, India, Dubai, Amsterdam, Madrid, China, Southampton and New York where IoT data are used to manage the buildings as well as other infrastructures like transportation, urban flows, parking space and environmental monitoring, etc. (Komninos, 2013). Presently, as part of its initiative towards smart city, Dubai municipality launched a digital city initiative whereby each building has a unique code, indicating information about the building, plot and location (Mason, 2015).

In 2008, CISCO reported that the number of objects connected to the Internet surpassed the number of humans on earth, whereas, in 2020, IP-enabled devices are expected to touch the limit of 50 billion. As the growth in smart buildings awareness increases, Figure 2 shows the potential growth in IoT sensor deployment. With the dwindling cost of sensors, data storage, and connectivity, smart buildings are projected to be on the increase by 78.8% between 2015 and 2020, according to Deloitte financial services [Deloitte] (2016) report, see figure 2.

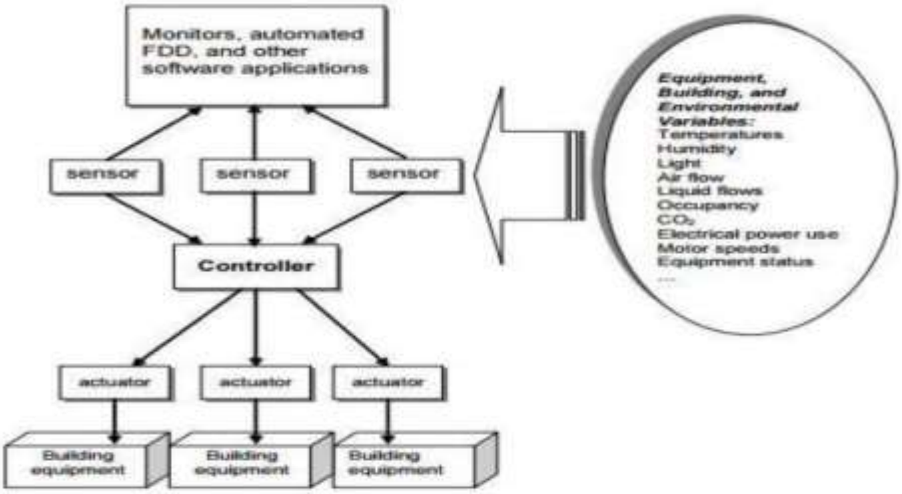

Figure 1: A generic smart building monitoring and control system (Source: Mullaserry, 2016).

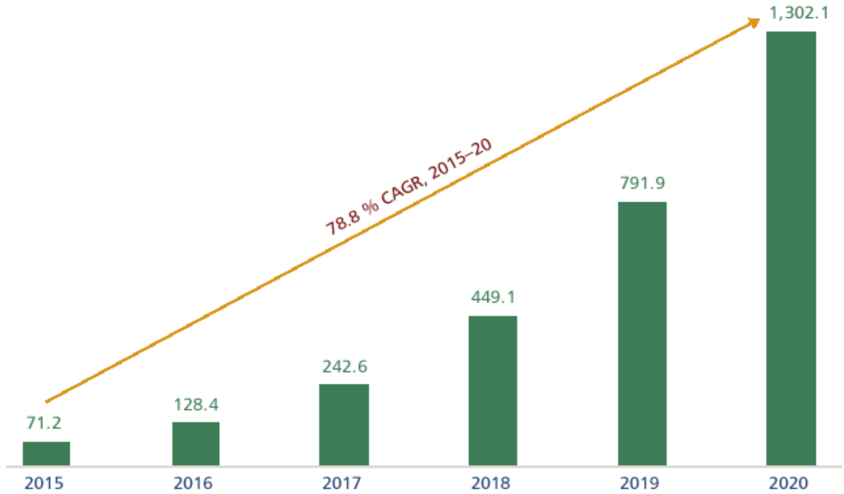

Figure 2: Potential global IoT growth and sensor deployments for commercial real estates (2015–20) (Source: Deloitte, 2016)

Deloitte (2017) reported that in addition to reducing smart buildings maintenance or repair costs, IoT has propelled a fundamental changes in corporate real estate sector with strong discontinuity from the traditional cultural, social and demographic frameworks, whereby the full potential motivates a series of activities by which values are created from the information generated from IoT-enabled buildings in terms of desirability and profitability, especially in industrial zones, large malls, airports and seaports. Similarly

In this study, the researchers provide an architectural framework to securely accumulate data from concurrently monitored real estates for the purpose of reducing the real estates utility cost, associated risks and enhance the real estates' value by making the estates smart. A Real estate becomes smart when it is fitted with sensors, actuators and other IP-enabled devices in a communication network.

2. RELATED WORKS

As IoT research activities gathered momentum around the world in Europe, China, Japan, Korean and the USA with a view to study technologies and industry standards, Building automation and control network (BACnet) evolved (Erbes, 2008). Though, BACnet does not provide controls, rather it is the best practice for building data communication protocols

(Contemporary Controls, 2020). Lately, BACnet over IP permits cloud-enabled software in a secure environment (Control Solutions, 2020). It was noted that smart building is a subset of smart city since buildings and other infrastructures make up a city. There are growing number of devices that are making objects and buildings smart lately. Therefore, a lot of research efforts and technological advances were directed towards smart city and how IoT can be used to manage and monitor real estate.

According to Than (2013) report, the number of interconnected devices is predicted to be on the increase in the range of over 50 billion in the next 10 years. A fully integrated system containing sensing, storage, analytics, and interpretation is required for a smart building (Jin et al., 2014). In addition, Mullassery (2016) stated that energy consumption efficiency in smart buildings and real estates contribute up to 40% of global energy consumption. Strohbach, Ziekow, Gazis, and Akiva (2011) reviewed the relationship between Big data, IoT technologies and the challenges associated with the accompanying data velocity. The authors proposed an initial framework for pooling smart city massive volume of data together using streaming infrastructures. Also, Deloitte (2016) enumerated how smart buildings add value to corporate real estates and how it augments occupiers' experiences. Paul, Mai, Gulgulia, Srivastava, and Chowdary (2018) proposed an open source GIS environment for generating spatial data to monitor real estate property through its dynamic information such as Owner or tenant name, land description, rent amount, due amount etc. in an efficient manner as in Figure 3. Hence, for every land space or plots detail relevant information can be learned, stored and processed (Wyatt & Ralphs, 2003). .

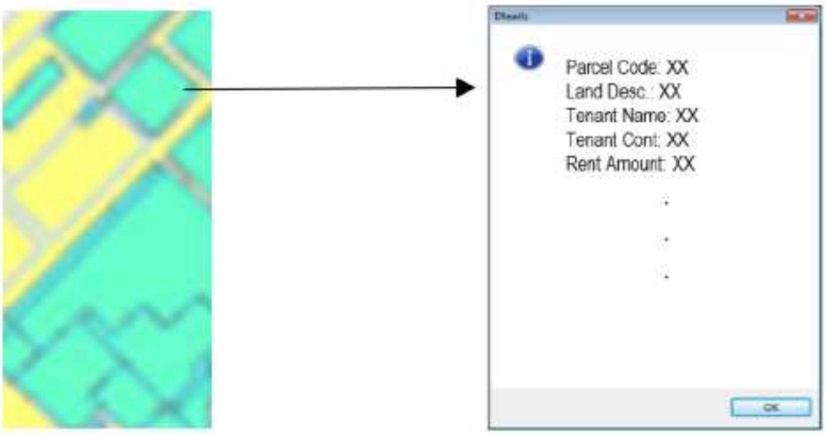

Figure 3: Using geographic information system (GIS) to generate spatial data. (Source: Paul et al., 2018)

Presently, as part of its smart city initiative, Dubai municipality launched a digital city initiative that identifies every building with a unique code, consisting of useful information about the building, such as the plot and location (Mason, 2015). Similarly, Sauter and Soucek (2011), proposed a centralized monitoring approach to real estates, which relies on the system's ability to observe a whole network segment. The monitor can either collect information by polling messages actively. In this way, active monitoring increases the network load and prone to instabilities.

Rathore, Paul, Ahmad, and Rho (2016) used Hadoop with Spark by specificity to process the disparate and distributed data in a 4-tier architecture for urban planning and building smart cities. Helal et al (2008) proposed a home residential gateway, an IP-based device to enable a service provider to offer enhanced set of home network services with quality of service (QoS), device and service discovery, security firewall, provisioning and management whereby a broadband connection is share through LAN in order to provide solutions for automation in homes, buildings, and assisting people in their immediate environments. They stated further that the functionality of a smart home is diverse with the following requirements:

i. Energy management
ii. Surveillance or environmental monitoring
iii. Access control
iv. Emergency detection (fire, flood, typhoon, etc.)

In most of the reviewed smart building frameworks, they were found to be lacking in the security as of their data communication. Therefore, this study proposes a 3-tier architecture framework that utilizes the Internet backbone with firewall security filter for data transfer among different sensors and IP-enabled building management systems to communicate, analyze, and monitor real estates in a secure and nonintrusive manner. The framework is open for exchange of data across many smart buildings. Data exchange security is fortified with data encoding protocols.

3. METHODOLOGY

The IoT implies that physical objects are able to explore the Internet backbone to transfer data about their sensor. Sensors can track physical data sources such as presence, motion, pressure, temperature, water flow, and other desirable properties. With the internet backbone IP-enabled devices, building management system (BMS) communicate, analyze, and act or react to people or other machines in a nonintrusive manner. Conceptually, this study proposes a generic reference architecture based on Open Services Gateway Initiative (OSGi) for smart buildings that consists of three layers whereby each buildings generate its data. See Figure 4.

OSGi consists of two components: a modular components (or plug-ins) specification and how they interact; and a Java virtual machine-level service registry component whereby plug-ins use to detect and bind to services in a service-oriented architecture (SOA). The OSGi service platform was used to develop applications that serves as services gateways for smart devices management, security, communication, and a number of other relevant services. OSGi is Java-based, open and it runs on most hardware, making it easy to deploy in a heterogeneous hardware environment such as real estate monitoring. The OSGi consists of three layers such as Physical, Service and Application layers.

3.1.1 Physical layer

The physical layer consists of disparate devices such as sensors, cameras, actuators, smoke detectors, fire alarms, heat ventilation and air conditioning (HVAC), boiler control, motion detectors, etc. Since these are smart devices, data can transmit through internet protocol (IP) to open services gateway initiative (OSGi) service layer.

3.1.2 OSGi Service Layer

The Open Services Gateway Initiative (OSGi) framework resides here to detect the presence of all activated services. OSGi framework aggregates and stores the service bundle definitions with functionality such as data pre-processing, repository and device configuration managers as well as secure cloud connectivity for any sensor or actuator present in the OSGi framework.

IoT data obtained in and around a building must lead to desired actions that are not in conflict with one another. The context processing and management protocol is responsible for resolving contextual conflicts. For instance, turning on the heater and the air conditioning system simultaneously might not be reasonable! Hence, a clear description of an actuator's intentional effect, is possible by determining the acceptable behaviors for a given context by examining all possible behaviors in the current state and identifying which intentional effects are mutually exclusive. OSGi context management ensures that the system will never invoke conflict actions like activating the air conditioning and heater systems simultaneously. There must be a standardized description of an actuator's behavior in relation to specific context, especially in determining an impermissible situation and how to avoid it. Also, the OSGi application can accept explicit input from the building occupier via a 'panic button', which forces an alert to be triggered. At the physical layer are the array of sensors and actuators which define the capturing or the presence of all smart objects present in a building. A sensor can communicate with a wide variety of devices, appliances, other sensors, and actuators.

3.1.3 Application Layer

In order to register contexts of interest, OSGi service is connected to wire application program interface (API) linking various sensors. The context model that is employed by a given context-aware application can be specified by the application developer for a certain domain. A context-aware application defines services to permit (activate) or deny (deactivate) for some requests and sends incident reports to the dashboard as necessary. In addition, the application incorporates algorithms that learn patterns of "normal" and "abnormal" behavior such as when an occupier remains motionless for a considerable long time and/or not switching lights off at the usual time, the application sends alerts to appropriate output devices, such as a family member's mobile phone. Finally, the application layer integrates with third-party devices and other enterprise applications. Also, OSGi layer obtains and provide information in a secure encrypted content to an authorized domain about the connected smart building through various sensors and can be linked by other real estate managers at different locations for update on regular basis. All transmissions between stations are encrypted with a unique, shared network encryption key based on Shared Wireless Access Protocol (SWAP) with firewalls fortification as outlined in Figure 5. Each building is fitted with BAS and linked to each other via an Open Service Gateway Initiative (OSGi) framework through a backbone connectivity. To systematically integrate the various devices, appliances, sensors, and actuators, an Open Service Gateway Initiative (OSGi) service bundle was created on a Java framework for developing and deploying modular software programs and libraries (Zhang et al., 2008). OSGi runs on most hardware, thus making it easy to deploy in a heterogeneous hardware environment.

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A list of all installed smart devices and other internet-enabled devices in the building can be viewed over wide-area networks or local networks since they are internet protocol (IP) based. Once powered on, a sensor registers itself on the OSGi service layer by sending its OSGi service bundle definition. When a user installs a new device, the system downloads each bundle and registers it in the OSGi framework.

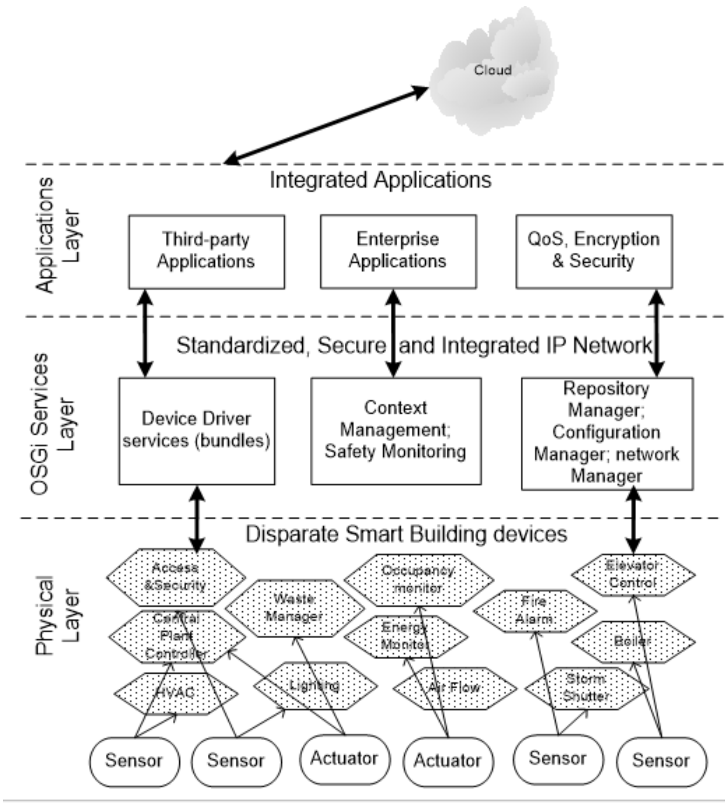

Figure 4: Smart building OSGi architecture.

3.2 Basic requirements for IoT data collection:

The following devices are necessary requirements for IoT data collection and monitoring:

i. Sensors
ii. Controllers
iii. Actuators or output devices
iv. Communication protocols
v. Data analytics
vi. Dashboard

i. *Sensors:* different sensors are used to read variable analog quantities such as temperature, humidity, number of people in and around a building. Sensors transmit these information to the controllers.

ii. *Controllers*: This component coordinates the collected data from the sensors and sends command to the concerned devices. Controllers are small purpose-built devices to control devices in the building and other sub-networks of controllers. The controllers are either programmable logic controllers (PLC), system or network controllers. Terminal unit controllers are used to control simpler devices such as lighting, rooftop unit, heat pump, fan coil, etc.

iii. *Actuators or Output devices*: Once the controller issues a command, actuators and relays performs the required action such as to reduce or increase the heating in a particular part of a building, dim lights in unused offices, etc.

iv. *Communication protocols*: A specific language is used to communicate with the user over the network, Java in this case over TCP/IP.

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v. *Data analytics:* This is where the data produced by the sensors can be accessed to enable users interact with the BAS such that the information presented can be monitored or overridden manually. This data analytics interface provide the necessary access or analysis that the facility manager requires to understand the system's performance.

vi. *Dashboard:* This is where notifications, alerts and alarms are displayed or sent as a result of the data analysis to enable the facility manager to take further action as necessary. Notification can be through computer email, SMS, voice call, audible alarm or all of these. However, some detectors or cameras trigger alarms when disconnected. Fire alarm overrides other alarms once it is activated.

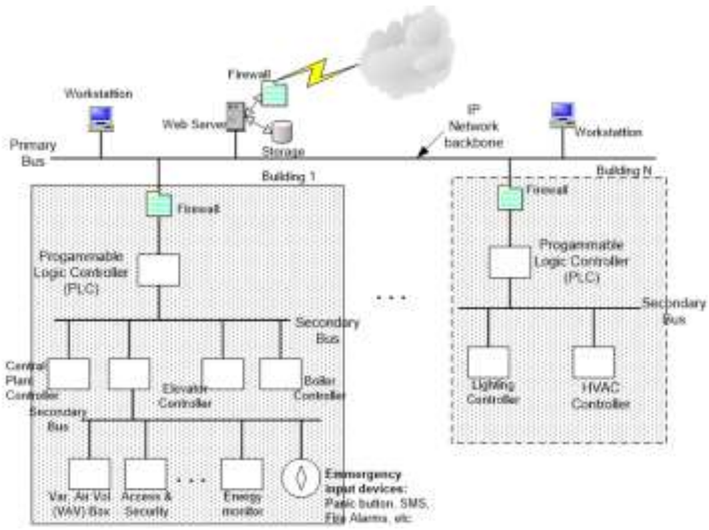

Figure 5: Architecture of an integrated smart buildings.

See figure 5, where each building has its own BAS with a unique IP address for each connected device. The building automated network consists of a primary bus and a secondary bus, connecting high-level programmable logic controllers (PLC), with lower-level controllers serving as input/output and a user interface.

When a sensor platform is on, data can be extracted from the sensor to provide the connected system (e.g., a network server or a PC) with the information required to interact with a specific device, appliance, sensor, or actuator. The data can be specified and accessed in a readable form, either as XML, text, or in a machine-readable form, specific for each application. Java bytecode is suitable for OSGi application.

Meanwhile, physical connectivity between devices is either through fibre optics or Ethernet or low bandwidth wireless network. Meanwhile, each controller monitors a specific device through its application, some of which are interoperable, while others are not. However, with the presence of OSGi gateway, it allows interoperability (at the application level) of different devices by different manufacturers and it provides compatibility with other control systems. The security enhancement distinguished the IoT framework for real estates monitoring from the OSGI architecture which is less secure.

3.3 Issues and Challenges

Sufficiently, the OSGi application provides monitoring activity for buildings, and generates alerts when abnormal circumstances arise. This entails remote communication using a variety of networking protocols, polling sensors at regular intervals, handling sensor errors, and interpreting sensor outputs.

A common problem in context management systems is the presence of imperfect context derived information such as sensor failures, power failure, noise in the environment, faulty sensor installation, or error in the algorithms used to abstract context data. Therefore, resilience is built in the context processing and management application to be able to function effectively even when the context information is incomplete, imprecise, ambiguous, or otherwise imperfect.

The added security feature enhances the OSGi application layer, since IoT and smart buildings are vulnerable to hackers or cyber-attacks by altering their environments (Wendzel, 2016), IoT security (IoTSec) which defines the importance of security in terms of supporting confidentiality, integrity and service provisioning were incorporated to circumvent these issues as stated earlier.

4. CONCLUSION

Unlike BAS specific to a real estate, this framework employs OSGi service layer to monitor smart real estates by sending OSGi service definition to detect new device and registers it in the OSGi framework. IoT data obtained in and around a real estate must activate desired actions devoid of conflict by using the context processing and management protocol included in the OSGi service. Similarly, OSGi platform obtains and provides information in a secure encrypted content to authorized domains. Also, the accumulated data can be linked by other authorized real estate managers at different locations. All installed smart devices in a real estate can be viewed over wide-area networks or local networks.

Energy infrastructure is at the base of smart environments as real estates consumes 40% of total energy supply (Clifford, 2015). Smart buildings should be designed with intelligent power and heat management with low-power consumption devices to provide significant energy savings, with a possibility of green or renewable energy sources like solar and wind energy. Next, IoT should accomplish three important things in smart buildings, namely: aggregate data in order to reduce cost, risks and improve the occupants' experience, all of which in turn adds value to the asset and enhance revenue.

Smart buildings tend to monitor the natural surroundings at a much higher precisions, due to access to a richer and more significant data. Data can be used in different phenomena to monitor and manage real estates such as coastal erosion, flooding, movement of glacial, etc. Real-time monitoring bolsters internal security, and specialized weather sensors provide advance warnings of possible adverse weather events (Deloitte, 2016). As the frequency and severity of emergencies such as hurricanes, floods, and tornadoes increase under a changing climate, so too does the value of disaster preparedness and resilience.

The network security is important as it relies on the corporate backbone. The stakeholders must incorporate the IoT platform into the overall IT infrastructure to ensure that there are at least firewalls, data encryption, authorization and authentication protocols in place. With increasing smart devices, IoT promises to turn smart object to information sources about its environment. Therefore, this framework is resilient to integrate emerging technologies as they are available.

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