UNDERSTANDING THE VIABILITY OF INTEGRATING WSN WITH IOT USING CLOUD INFRASTRUCTURE

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ABSTRACT

IEEE 802.15.4, Wireless Sensor Networks, have increasingly become an important part of many sustainable development applications. However, due to the energy expenditure restrictions of Wireless Sensor Networks, it has become imperative to optimize its usage and reach ability through a amalgam of nature inspired techniques, Internet of things and cloud. In our study, we have used CupCarbon simulator to first establish the workability of such a model and to see if nature inspired algorithms technique may be used to develop and optimization wireless sensor network integrated Internet of Things cloud based modals as efficient solutions to modern problems. A resultant application was designed to handle healthcare facilities through the specified infrastructure. On the basis of the feedback from the usage of application, the study was able to infer that despite the challenges, Internet of Things, wireless sensor networks and cloud, although separate technologies, may be used together to deliver 'smart' applications in the field of smart town, smart residences and smart security.

KEYWORDS

Internet of Things, Cloud, Wireless Sensor Networks, Nature Inspired Algorithm, Coverage Optimization.

1. INTRODUCTION

Nature inspired mechanism of novelty with focuses on attaining sustainable solutions to human tests by emulating nature's time-tested patterns (Mead & Jeanrenaud, 2017), thus, it is a fact that this approach is applied to ideologies that maximizes the promising capabilities. It also refers to copying the models, processes and features found in natural environment to deal with complicated problems. This has even brought changes to how we view our surroundings and the kind of relationship we share with the Nature. The knowledge extracted from our surroundings is being used to develop modern technology, including the cutting-edge engineering skills that have contributed to an easy and smooth lifestyle. However, if we truly wish to control our natural surroundings, we first must get ready to follow its rules. In other words, to execute the natural processes, we should follow those processes (Kellert, Heerwagen, Mador, 2011). The more advanced our society is getting; the more we are finding ourselves looking at Nature for inspiration. Earlier, the technological advancement was only process-driven and not considered from sustainability point of view. This, however, proved limited in handling complex situations and has thus pushed professionals from all quarters to turn to Nature for searching novel solutions. The ability to redesign solutions that are increasingly more efficient and useful has been the key factor that has proved biomimetics advantageous. There is no dearth of practical examples of how business organizations have employed nature-based algorithms to execute many of the organizational functions and tasks. A significant difference between our earlier engineering solutions and Nature is that latter follows a bottom-upward structure, such that the elements are created in coherence with their functionality instead of first creating the element and then attempt at adapting it to the required needs. Technology like 3D printing work on this principle, and is the latest approach to gain momentum in the emerging 4th industrial revolution that includes creation of Internet of Things (IoT) and evolution of manufacturing processes (Katiyar, Goel, & Hawi, 2021).

So the IoT has been verified via the use of Wireless Sensor Networks (WSNs) and the biomimetics have seen exponential growth as WSNs has been also employed in a great variety of practical problem areas

https://doi.org/10.17993/3ctic.2022.111.269-289

which need a common means to share data over the Internet Borges (Neto, *et al*, 2015). The important of nature inspired algorithms used in WSN model is discussed detail in recent work (Mahapatra, Payal, & Chopra, 2020).

Every living being, in order to survive, searches for resources and upon finding it analyse it to make the best use of it as appropriate to it. The Nature's organisms follow their resources rather than acting dormant and inadaptable. A number of examples can illustrate this fact; for instance, a sunflower bends in accordance to the sun rays for its nourishment and growth. Similarly, a plant modifies its leaves to either capture more sunlight or prevent loss of moisture. For copying this kind of behaviour; there is a need to create such ubiquitous sensors that will relay the information without interruption and bias. As many inputs come in, there should be broadcasting of information simultaneously. However, such an approach could be successful with 'cloud' technology where virtual networks are established in a manner that facilitates broadcasting of information through every channel in contrast to one-way route. Application of biomimetics on a wider scale has the capacity to deal with universal challenges and intrinsically change the modern infrastructures too (Khanh etl. 2020). As energy from sunlight triggers a chain of reaction that drives a flower petal to open up or a plant to shift its location, we can likewise harness the same energy through solar panels to run a motor that can move the blinds on a window automatically.

Nevertheless, a critical requirement for successful application of biomimetics (Wagh & Escobar, 2019) in IoT is the availability of necessary infrastructure to not only handle the vast amount of data but to store them in an efficient way that results in minimum chances of redundancy. For example, the efficiency of any network is limited by its redundant or defective nodes that continue to occupy space and cause obstruction. Such nodes should follow the Nature's rule of extermination upon uselessness. The nodes should be obliterated from the current ecosystem' and employed elsewhere thus reducing the redundancy in network. This process can be exemplified through trees' shedding of leaves in winter. The dry autumn wind causes the redundant leaves to detach from the branch and fall onto the soil

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where it decays and increases its nutrient composition (Plessis, 2019). Thus, the redundant component is transformed into a useful entity. For IoT implementations, we can draw upon Nature's myriad examples for creating processes, sharing resources and storing vital information. The crucial knowledge of how various ecological cycles function can provide a fundamental base for building solutions in IoT, thus acting as biomimetics. Next section discusses the literature review related to our study, section 3 discusses the methodology employed for our research, section 4 outlines the inferences drawn from the design and usage of our application for healthcare and section 5 contains the conclusion of our study.

2. REVIEW OF LITERATURE

(Dhivyaprabha, Manjutha and Subashini, 2012) examined the latest development in the usage of metaheuristic algorithms for solving problems related to classification, edge detection and denoising. The authors list out many of the universally used optimization algorithms for Smart city applications like logistics, transport, sustainability and mobility etc. These algorithms are evaluated on certain fitness functions and parameters for deep investigation.

(Gill and Buyya, 2021) reviewed nature-inspired algorithms for analysis of big data. The chosen studies were examined on the basis of taxonomy, topic of research and stated limitations. The authors divided the algorithms into three separate categories, ecological, swarm-based and evolutionary and studied their demerits in details to help readers choose the most-desired algorithm as per the requirements.

(Hildmann *et al*, 2018) described optimization of energy- and cost-efficient wireless access network infrastructure. A Particle Swarm Optimization technique is also proposed to optimize design decisions with respect to Distributed Antenna Systems. The authors focused their work on two main targets, namely, reducing the total cost of hardware employed, and to increase the energy efficiency.

(Kimovski, *et al*, 2018) introduced a novel and promising Fog Computing framework called SmartFog that demonstrated the capability of adjusting and scaling whenever there are unpredictable patterns of

https://doi.org/10.17993/3ctic.2022.111.269-289

load due to the distributed IoT applications. The authors devised nature-inspired algorithms based on concepts of decision-making, graph theory and machine learning to create the intelligent processing system. The evaluation results showed a dramatic reduction of 13% in network load and 8% in latency.

(Li *et al*, 2018) proposed a new Hybrid Enhanced Particle Swarm Optimization (EHPSO) algorithm based on two Nature Inspired hybrid alogirithms, Novel Particle Swarm Optimization (NPSO) and Hybrid Particle Swarm Optimization (HPSO). Simulation results clearly show EHPSO as the winner as it outperforms HPSO and NPSO in evaluating localizing node positions and improves convergence by avoiding being trapped into local optima and hence eliminating pre mature results.

(Channe *et al*, 2015) proposed a multidisciplinary model for smart agriculture in Soil based on the key technologies: Internet-of-Things (IoT), Sensors, Cloud-Computing, Mobile Computing, Big-Data analysis.

(Malik and Dimple, 2017) proposed an Ant Colony Optimization technique for IoT network that was inspired from Nature. The technique was used to find the shortest path possible between the source and the destination node. A number of iterations were performed and after many trials the best path was demonstrated.

(Khattab *et al*, 2015) presented an IoT and cloud based architecture customized for precision agriculture applications. In this built a prototype of the proposed architecture and the accuracy metric demonstrates its performance advantages.

(Shah *et al*, 2019) conducted a detailed literature survey to study the techniques that have been used in Smart homes for optimisation of energy consumption and scheduling. Many factors like temperature regulation, visibility and air quality were investigated thoroughly. Latest developments, like fog and edge computing techniques have also been reviewed.

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(Zedadra *et al*, 2018) described the technical aspects of swarm intelligence algorithms and their possible utility in IoT based applications. The authors first reviewed SI algorithms with their major applications, followed by current IoT system that is using these algorithms. In the last section, authors discussed how main features of SI can be constructively employed in IoT-based system.

(Zedadra *et al*, 2018) presented a framework for the Smart city based on swarm intelligence. Besides describing the scope of SI algorithms and existing use of them in IoT based system, the chapter described trends on how flexibility and scalability can be achieved in Smart Cities through the SI paradigm.

(Singh *et al*, 2017) introduced a newly hybrid nature-inspired approach (MGBPSO-GSA) is developed with a combination of Mean Gbest Particle Swarm Optimization (MGBPSO) and Gravitational Search Algorithm (GSA).

3. METHODOLOGY

The Internet of Things (IoT) is a new revolution of the Internet (Abraham, 2016). Objects make themselves recognizable and they obtain intelligence by making or enabling context related decisions.

Sensor networks are a crucial element of IoT ecosystem as they can assist other systems like RFID to track a status, locate position of an object, determine movement pattern or ascertain temperature and likewise. A large number of sensor nodes inter-communicating in a wireless multi-hop fashion form a sensor network. There are special nodes called sinks that function primarily to collect results. Application of WSN (Qian & Wang, 2014) can be found in sectors like healthcare, military surveillance, defense strategies, environmental programmes, governmental services, disaster prevention, geographical exploration and such. Still, there are many challenges in sensor networks with respect to communications and resources. Communication issues could be extent of area covered, robust data security, and protection of privacy, reliability and mobility. On the other hand, addressing matters about backup power, ample storage capacity, sufficient processing power, availability of required bandwidth etc. come

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under the purview of resource management. In addition to this, there are WSN-specific limitations in regards to resources and design, which in turn are influenced by application and settings, and can be modulated as per the monitoring environment. However, evidence reflects that many of the concerns like efficient energy expenditure, consistency, sturdiness, accessibility and soon have been deeply studied by the scientific community.

With wireless technologies like Wi-Fi and RFID, there is massive transformation of the internet by IoT framework. While people to people connections increased through internet evolution, there has been a surge in object to object connectivity creating Smart environment. For this to be successful, the most important requirement is to distinguish an object unique from other ones and thus identify different number of devices that are connected through internet. This scheme of uniquely addressing each object is governed by factors like dependability, tenacity, exclusivity and scalability. IPv4 can help solve the challenge of unique identification to a limited extent by geographically identifying a set of shared sensor devices but not single ones. While IPv6 due to its internet mobility characteristics is expected to better address the issue. Due to diversity of the member objects with respect to their storage capabilities and processing skills, and due to a number of varied applications associated with it, there is a need for middleware between the application layer and things. Middleware helps in extraction of the functionalities and communication capacity of the involved devices. This middleware can be in turn divided into further layers of "Object Abstraction, Service management, Service Composition, and Application" (Kosmatos, Tselikas & Boucouvalas, 2011)

Cloud computing (Sadeeq *et al.*, 2021) is not a new term, denoting a framework that enables universal access to shared group of computation resources like servers, applications and networks with minimum disturbance and interaction between the user and the provider. However, it became popular over the last few years especially with Google cloud services that have increased the storage capacity to virtually unlimited extent. Further, there is increased processing power at minimum cost and availability of resources on-demand. Major companies like Amazon and Facebook are the popular success stories that

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have utilized cloud for delivering their services and becoming market pioneers. technical challenges that needs to be addressed in cloud computing. Many of the times, users are apprehensive of the privacy of their data, how secure the network is for private transactions and how will their data be used by the service provider. The service level agreements may not be approved by many potential users resulting in loss of business (Alouffi *et al.*, 2021).

A successful cloud model has typical characteristics, a layered architecture and standard service models. The architecture is divided into four layers comprising of "hardware", "infrastructure", "platform" and "application" (Fig. 1). Each layer provides service to the below level layer and consumes services from the above level layer. Practically, three cloud services are available, namely IaaS, PaaS and SaaS. Infrastructure as a Software (IaaS) has been of utmost interest as it provides storage, processing capabilities and network resources thus making the user a better controller of operating system. Support for operating system and frameworks for development come under Platform as a Service. Software as a Service involves applications running on clouds that are accessible through a web browser. Cloud Computing Technology solves the deadlock condition by providing a elasticide environment of resource allocation and processing. This infrastructure is not only highly reliable in terms of storage but also a very efficient computing provider to its users (Mo, 2019).

Although cloud and IoT are independent technologies, they share a number of features that act complementary to each other. Much research has been directed towards merging of these two to extract maximum advantages. The limitations of IoT, like storage, communication range and processing capabilities, gets countered by unlimited virtual space and availability of resources in cloud. For instance, cloud can be very effective to manage IoT services and to execute the applications that run on things.

In return, cloud can extend its service delivery in a distributed manner to the real world through IoT. Quite often, cloud helps in creating a middle layer between things and applications to compensate any limitation in running the latter. It holds a future significance when multi-cloud system will exist, and it will become imperative to search for novel ways of collecting, processing and broadcasting information

https://doi.org/10.17993/3ctic.2022.111.269-289

(Prabhu, 2017). A typical IoT framework is heterogeneous in character with various devices and their protocols. The lack of extendibility, elasticity, dependability and efficiency is compensated by cloud features that are known as Cloud-IoT drivers.

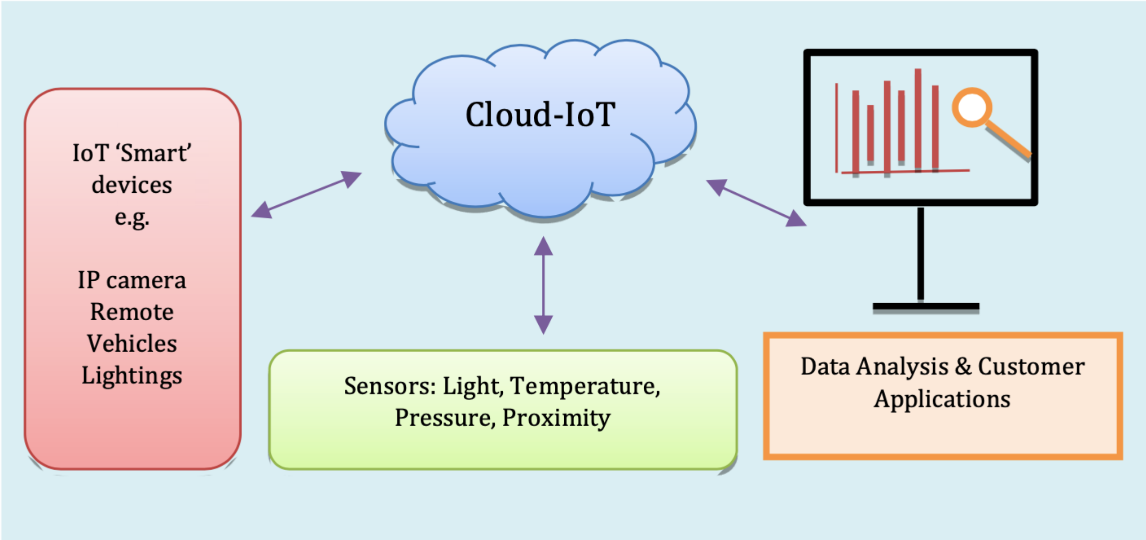

Figure 1. Cloud and IoT paradigm.
Source: own elaboration.

It leads to smooth operations between data gathering and it's processing, thereby facilitating quick integration with reduced costs of deployment, and prompts analyses of complex data through better decision support system and predictive algorithms. Through cloud-IoT, customized applications can be accessed by the users without much trouble. Moreover, through personalized portals and applications, it is easy to track or connect anything anywhere.

The fast speed network has resulted in successful regulation and control of distant things for improved communication, inter-operability and synchronization (Figure 1). However, there can be certain situations where cloud may not be able to solve the limitations of IoT. For instance, though there has been enormous increase in the storage and processing capabilities, we cannot find such incremental

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surge in broadband capabilities. IoT through its many information sources generate a lot of organised and unorganised data that is similar to Big Data in terms of volume, variability, speed and complexity.

Our research aimed to study the effectiveness of WSN IoT network interlinked through the cloud infrastructure. For this we simulated our network on cupcake IoT simulator 5.0 – 2021 (Bounceur *et al*, 2018). The simulator is able to integrate IoTNode as well as IoTRNode together thus making it possible for them to communicate using MQTT Protocol. This feature allows us to record WSN behavior while interacting with IoT infrastructure through cloud and thus gaze out its effectiveness.

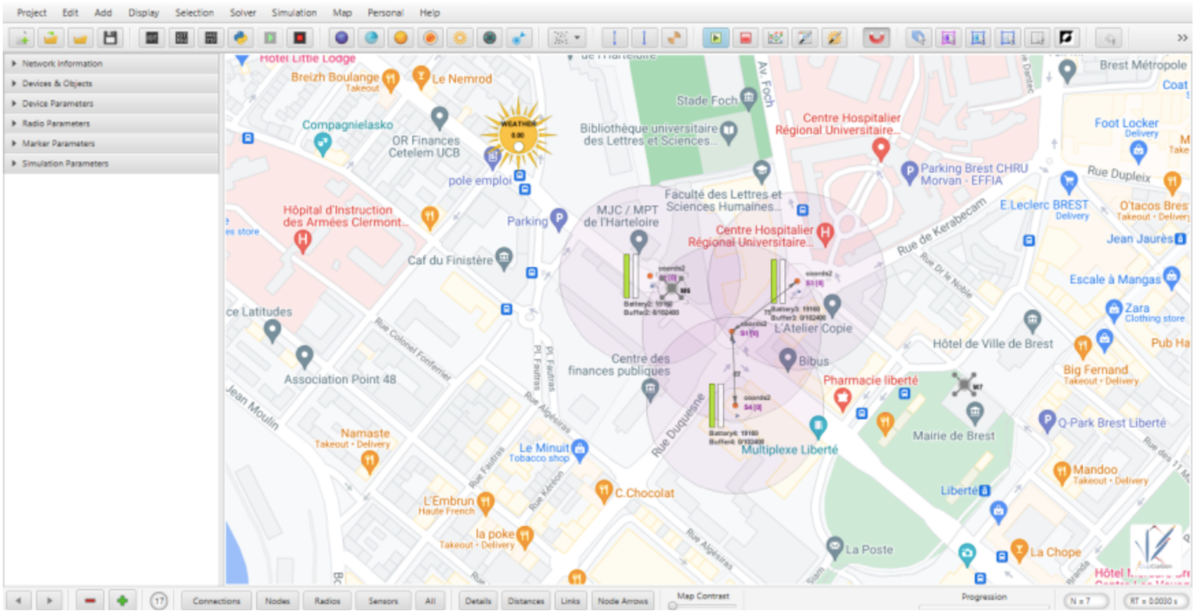

Figure 2. CupCarbon screenshot for node localization.
Source: own elaboration.

The simulator can easily be programmed using python, thus making it possible for us to check individualized algorithms and optimize the same. The power of the simulator can be gauged from the fact that a single sensor node can be configured at PHY level to work with 802.15.4, ZigBee, LoRa and

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WiFi mode. The simulator can be used to study mobile sensor nodes as well as static sensor nodes and their interaction and communication with base stations and other sensor nodes. The heterogeneous data is converted into homogenous by APIs and secured to be safely accessed from any remote location.

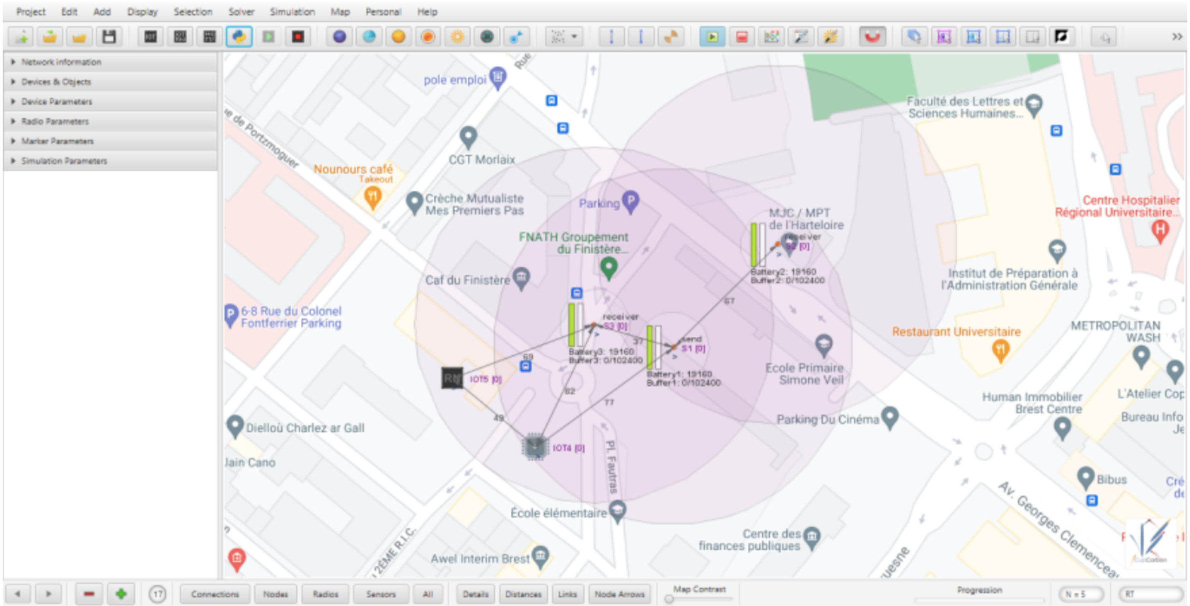

Figure 3. CupCarbon screenshot depicting message transfer between WSN and IoTNodes.
Source: own elaboration.

4. RESULTS

Thus, the cloud-IoT paradigm has resulted in more people connections and greater flow of information, creating billions of new networks and Internet of Everything (IoE). This facilitates availability of new 'smart' services and applications (Kumar & Chand, 2020) such as WSenHealthcare MoniDoc App.

WSenHealthcare MoniDoc App is a cloud based IoT + WSN integrated resultant app for optimizing usage, of most important infrastructure of the hospitals and nursing Home ie. nurses and patient live

https://doi.org/10.17993/3ctic.2022.111.269-289

data. The App has been conceived to capture a wearable sensor worn by every nurse and the access points (AP) laid inside the healthcare facility are able to localize the position of the nurse so that incase of emergency the nearest nurse (s) can be sent to the effected patient site. The patients themselves shall wear a sensor band which not only relays there location inside the healthcare facility but also transmits patients health status to AP(s) for processing in the cloud through IoT. All processing and storage is done on cloud infrastructure thus providing a affordable, fast and elastic backbone to the WSN, what's more, a robot nature inspired algorithm may be used to further optimize the App. Below are the screen shots of the prototype App and the layout of Healthcare Facility:

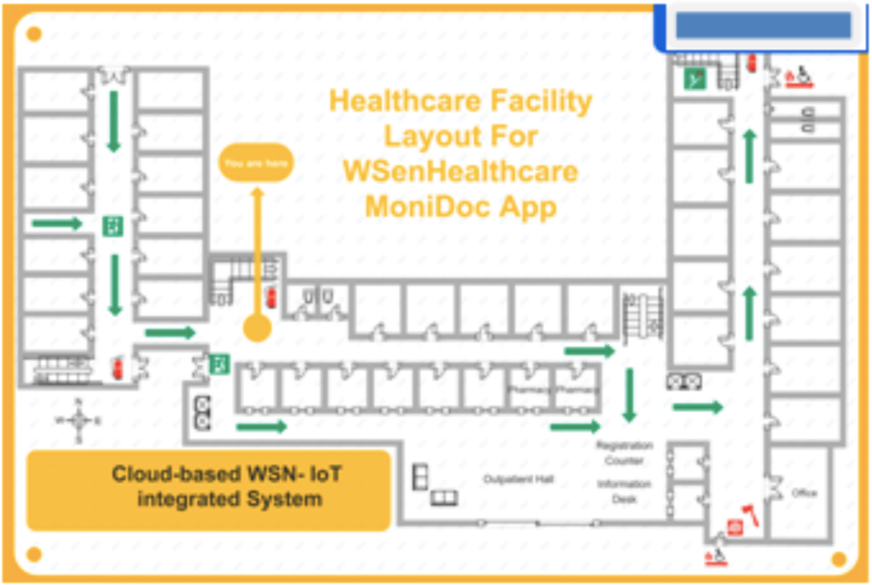

Figure 4. Healthcare Facility Layout For WSN + IoT + Cloud Setup.
Source: own elaboration.

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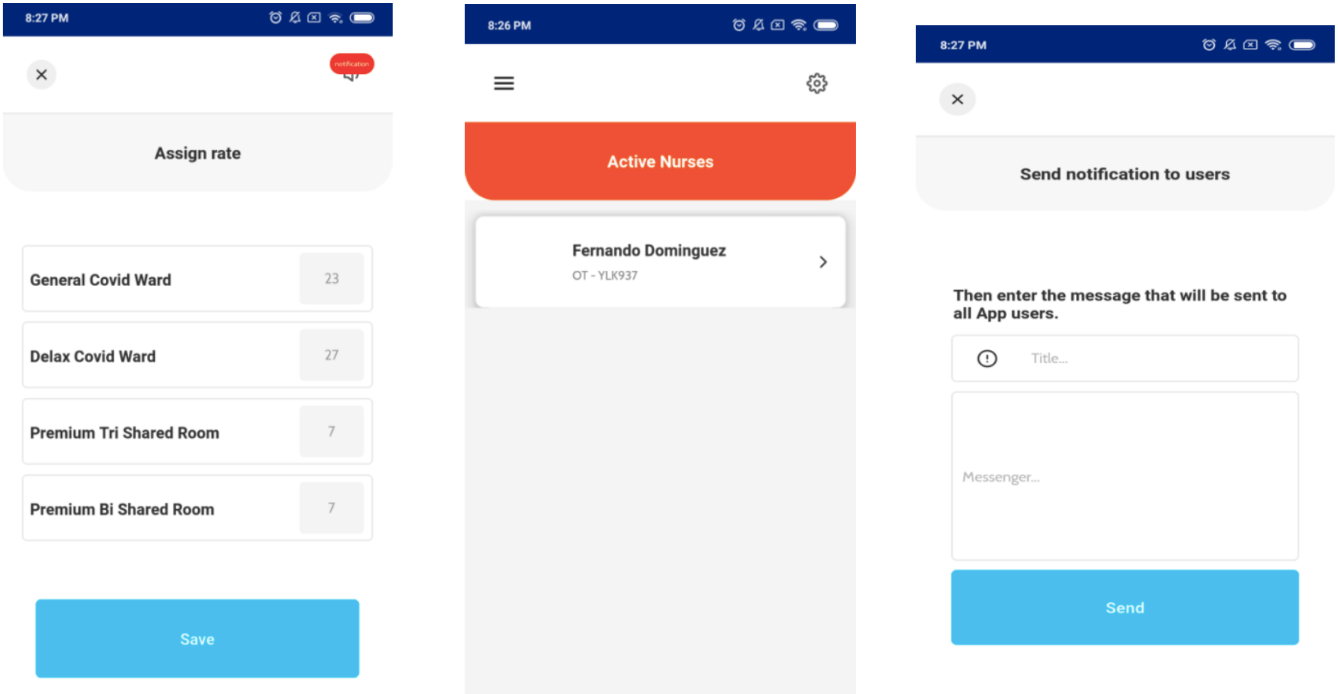

Figure 5. Screen Shots of the Prototype App.
Source: own elaboration.

The IoT + WSN cloud based applications have grown tremendously in the market nowadays. Drawing inference from our study, we suggest that the IoT + WSN + Cloud based applications can be successful in following given areas: **Smart Towns** – Modern society suffer from the lack of awareness regarding the need to have sustainable development with efficient and skilful technologies and services. Through the vast network of people and their inter-exchange of information and sensors, a collective intelligence can be drawn to modify the communal behaviours. Cloud-IoT provides opportunity to access information from the heterogeneous objects, including the geo-location, context and 3D representations, to present in a detailed map. The structure comprises of a sensor platform and a cloud platform that work in

https://doi.org/10.17993/3ctic.2022.111.269-289

coordination. The sensors are actuated by APIs in the platform while cloud provides a scalable storage for processing the information generated by sensing devices. Literature presents many examples, like "Sensing as a Service" framework (Munirathinam, 2020), or a paradigm for mobile devices. The application developers are under immense pressure to deal with the extremely heterogeneous environment of IoT which can be managed by sensor virtualization that enables communication at different sensor layers. Architecture that supports detection, linking and addition of sensors can help create universal connectivity and success of smart cities. Moreover, IoT plug-ins can be created by third party to enable connectivity of any device to the cloud thus removing the issue of heterogeneity. The challenges are associated with privacy, scalability, heterogeneity, storage and computing abilities.

Smart Residences–Through application of cloud and heterogeneous devices, many domestic activities can be automated creating smart homes. The inanimate objects are transformed into information generating devices that are connected to internet due to presence of sensors. The wireless networks of these intelligent devices are used to control the appliances from a remote location. For instance, controlling the cooling temperature of an air conditioner, or switching off smart fan and lights. Such endeavors can have major impact on environmental concerns, as for example, saving power energy by switching off lights can reduce greenhouse gases' emissions. Home automation is relatively an easy task through cloud by enabling easy interaction between users and sensors, along with critical prerequisites of inter-appliance connection, intelligent control from remote places, and automation. In addition, cloud-based infrastructure provides a universal space that allows individual access of all devices in a fixed manner and also delivers synchronized functionality among many users. However, to meet the challenge of different devices and their communication among themselves as well as with the cloud, potent computing devices should be installed as mediators between IoT objects and cloud, and to execute the complex functions. Furthermore, issues related to establishment of standards and making home devices reliable should be addressed to deal with failed or unreachable devices (Chan, 2008).

https://doi.org/10.17993/3ctic.2022.111.269-289

Smart Security: The surveillance video produced from IP cameras are effectively stored, processed and handled by Cloud-IoT. The information is generated by the video sensors on the camera and transmitted to various registered devices through the internet. The task of processing is distributed over the server in a methodical manner to balance the load. There have been specific cloud-based options like SaaS (Prati, 2013) to satisfy the necessities of storing files at a central place with facilities of on-demand, scalability and availability, and further processing through specific algorithms and pattern-recognition software. The notable challenges in this application are incompatibility issues with different cameras which arise due to ill-defined standards and service framework.

5. CONCLUSIONS

This paper discuss about the details of cloud computing environment, Internet of Things (IoT) which is applied to Wireless Sensor Network (WSN) and optimized by nature inspired algorithm. Initially they discuss about the importance of IoT in WSN, then review work related to IoT with WSN, cloud computing are clearly discussed with each other. After that how the cloud computing is integrated to IoT is clearly discussed. Finally, the applications used for applying the technologies are clearly discussed. From the review work it concludes that the importance of IoT in WSN is mostly used by several authors in the recent work. Hence, the study establishes the future of WSN integrated IoT cloud platform, which shall encourage the researchers to work having to focus on the application of IoT in WSN in healthcare facility.

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