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Context-aware low power intelligent SmartHome based on the Internet of things[☆]

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ABSTRACT

Constructing a smart home is not a task without intricate challenges due to involvement of various tools and technologies. Therefore, this research work presents a concept of context-aware low power intelligent SmartHome (CLP*i*SmartHome). For CLP*i*SmartHome, we propose a communication model, which provides a common medium for communication, i.e., same communication language. Moreover, an architecture is also proposed that welcomes all the electronic devices to communicate with each other using a single platform service. The proposed architecture describes the application, analysis and visualization aspects of the CLP*i*SmartHome. Furthermore, the feasibility and efficiency of the proposed system are implemented on Hadoop single node setup on UBUNTU 14.04 LTS core™i5 machine with 3.2 GHz processor and 4 GB memory. Sample medical sensory data sets and fire detection datasets are tested on the proposed system. Finally, the results show that the proposed system architecture efficiently processes, analyzes, and integrates different datasets and triggers actions to provide safety measurements for elderly age people, patients, and others.

1. Introduction

The rapid growth of Wireless Sensor Network (WSN) enabled devices constitute IoT and may generate an enormous amount of data. Similarly, enabling seamless connectivity with existing networks and proactive operation based on different factors (context aware computation) are mandatory in IoT. Its goal is to let the computer identify information without human interaction. However, it depends on three factors i.e. 1) understanding users and its appliances 2) architecture and communication, and 3) analytical tools to support smart behavior. IoT and cloud computing can be considered as two major technologies which have been developed in order to extend ubiquitous computing. The ubiquitous computing integrates different technologies with the daily life. One example is of WSN whose nodes have the ability to act as ubiquitous-sensors

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using MEMS and wireless communication. Another example of Cloud computing that uses the internet to provide scalable, and reliable ubiquitous computing by acting as a receiver of data from ubiquitous sensors.

So far as the definition of IoT is concerned, it has been defined in multiple ways by various interest groups. From one perspective, IoT is a combination of middleware, sensors and knowledge [1]. While according to Radio-Frequency Identification (RFID) group, IoT is a network of objects accessible uniquely via standard protocols [2]. Another definition states that IoT's Things are participants who share information that is sensed from the environment with or without human interaction. Finally, the researchers define the IoT as an interconnection of devices, which share information among platforms via a unified framework. This can be achieved via ubiquitous sensing, data analytics, etc. Some of the major entities in an IoT environment are given below.

- *RFID:* It is a wireless microchips for wireless data communication. It allows automatic identification of thing that is attached to it.
- *WSN:* The shared sensor data are sent to a centralized or a distributed system for analytics. WSN hardware is a node with a sensor, which acts as the gateway to the WSN subnet and the Internet. WSN middleware provides access to different sensors by combining cyber infrastructure with Service Oriented Architecture (SOA) and sensor network. The reliable data collection and extending lifetime are ensured by secure data aggregation.
- *Addressing Schemes:* Every connected element needs to be identified uniquely. However, the variation of wireless nodes have worsened the problem even after using IPv6 addressing. WSN is on a stack except Internet, hence it uses subnet with a gateway having URN is used to uniquely identify within the network.
- *Data storage and analytics:* This forms the middle layer of IoT. These systems allow interoperability, integration, and adaptive communication. Centralized infrastructure is mandatory to support storage and analytics.
- *Visualization:* Provides interaction with environment and user. This holds both event detection and visualization of raw and modeled data.

IoT can be internet-centric or thing-centric. The conceptual framework was developed with the perspective of internet-centric by connecting ubiquites applications with sensor devices via the cloud. The cloud is responsible for storage, computing, visualization, and analytics. This is flexible in dividing costs logically, and highly scalable. The service providers can upload their tools such as analytical tools, data mining and machine learning tools, and visualization tools. So that, people can use them as a service on cloud. The cloud connects all endpoints of ubiquites computing. The framework describes the cloud platform using Aneka [3] and Azure [4]. The public and private cloud interaction is very important to bring sensed information, analytics and visualization to a single smooth framework. Developing IoT using low-level cloud programming is complex. To create IoT applications faster, the proposed framework was mapped to cloud APIs by Aneka platform. Similarly, every new framework should have following three characteristics; 1) Reads sensor data or fetch from database, 2) Process data transparently and in a scalable manner, and 3) Output if it detects any events of interest.

Other than that, to make the IoT more appealing, a traditional application can be considered i.e., the Smart Home where embedded devices, such as sensors and actuators are self-configurable and can be controlled remotely with the help of Web technology. Such kind of technology is used to enable a large variety of security, as well as monitoring applications. The involved devices sense user's activities and transmit these data to the remote station (any community services) where it can be processed, analyzed, and predicted or give response to the user for his/her convenience based on the received data. In the literature, extensive research work has been performed on the Smart Home technology [5] but their major focus is on individual homes. Similarly, the idea of smart home is also extended towards the smart community where home domain, community domain, and service domain are integrated to provide benefits to the mankind. However, such technology is lacking of various factors; how to connect vehicles, roadside units, Global Positioning System (GPS), and other to the same infrastructure, i.e., the central web.

The concept of Smart Home is further extended towards the Smart Community where a multi-hop network of smart homes is interconnected with the help of radio frequency [6]. Furthermore, it can also be noticed that the designed smart home (under the domain of IoT) work under multifunctional sensors, continuously monitoring physical environment (such as security, safety, healthcare, and emergency) for its improvement. However, given the variety of smart home and smart community contributions, several challenges need to be tackled in developing such systems.

Firstly, how to integrate various embedded systems under a single umbrella, i.e., requires a virtual or physical platform for the exploitation of the smart community. The next is how to integrate various systems since each specific system has its assumptions and strategies to control world physical variables without much knowledge of the other system. This generates conflict when these systems are integrated without careful consideration.

Having understood the feasibility and potential of the IoT, in this paper, we drive the concept of smart home to a further extent and introduce a notion of context-aware Low Power based intelligent Smart Home. The *CLPiSmartHome* is comprised of IoT and the community where they can share information using a same communication medium, i.e., the internet. The shared medium is supported by the web server where a variety of devices are interconnected with each other to form an *i*SmartHome. The nature of these devices is heterogeneous, which requires a unique platform to exchange useful information. Such a facility is provided by the proposed *CLPiSmartHome*. Moreover, *CLPiSmartHome* architecture is also proposed that could efficiently communicate with each other to assist users in a home based on the contextual information. It can be viewed that these devices (such as, smart watch, healthcare, KINECT XBOX 360, Internet of Vehicles, GPS, and so on so forth), continuously monitoring the physical entities, and when required, automatic or controlled physical system gives alert

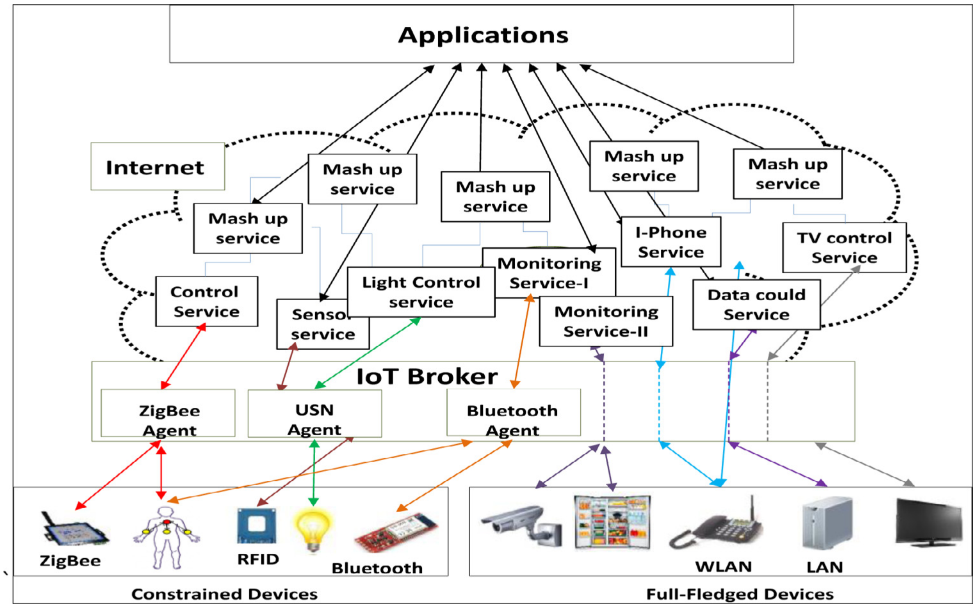

Fig. 1. Overview of the proposed system.

to the specific event to improve healthcare, security, accidents, fire brigade system, and so on. This system is connected to the Internet with the help of Wi-Fi (IEEE 802.11) and the third generation (3 G) of mobile telephone.

The remainder of this paper is organized as follows. Section 2 presents a detailed description of the background and related studies. In Section 3, some of the IoT characteristics are described. Section 4 presents the proposed system architecture for *CLPiSmartHome*. Detailed analytical and simulation analysis is given in Section 5. Finally, Section 6 concludes the presented work.

2. Background and related studies

In this section, we provide the background of WoT that could be integrated with the IoT along with the related study in the field of IoT and smart home.

2.1. Background

Several research proposals are submitted for introducing the scheduling services of temperature, and electronic devices at homes to make them smarter and to be furnished with Heating, Ventilating, and Air Conditioning (HVAC) system. A rich literature on intelligent control mechansims for HVAC system is available to the research community. Among those, [7,8], and [9] are few. For example, in [7], an underfloor air distribution system has been proposed based on a feedback control strategy. A similar scheme is developed for a central air-conditioning system that adaptively adjusts the Proportional-Integral-Derivative (PID) gain using cascade controller [8]. Also, a scheme for HVAC system is proposed that combines Cerebellar Model Articulation Controller (CMAC), Neural Network, and general PID control. Whereas, to regulate the indoor temperature, a model based on the design of embedded controllers for the integration of building system is presented in [9].

Although, IoT has been extensively studied so for, but a complete architecture of controlling home devices with the help of WoT technology is still need of the day. Therefore, a related work for controlling room temperature is available in [10], in which two actuators are used for air conditioning and window. However, the extension of the said work suggests the use of another actuator for curtains. Interested readers are referred to article [11–13] for more details. The overview of the proposed *i*SmartHome is shown in Fig. 1.

The constrained devices in the proposed iSmartHome such as mobile phones, sensors, etc. are using the technologies such as Bluetooth, and ZigBee to communicate with the IoT broker. The IoT broker acts as proxy and it obtains the information from the communication agents and transfer it to different services. These services are then connected to the Mesh up services, which help intransferring the information to different applications via Internet. This scenario is depicted in Fig. 1.

The WoT can be used based on unique IDs for different devices, which can further help in enabling an integration between the devices, infrastructure, and the physical environment [14]. However, the recent research study consists of various applications based on the M2M and Machine-to-Infrastructure (M2I) communications. Also, various data mining techniques for different people can also be incorporated into the same technology, which generate valuable information for supplementary information such as frequency of using a cell phone, car, etc, in each month. One of the major advantages of

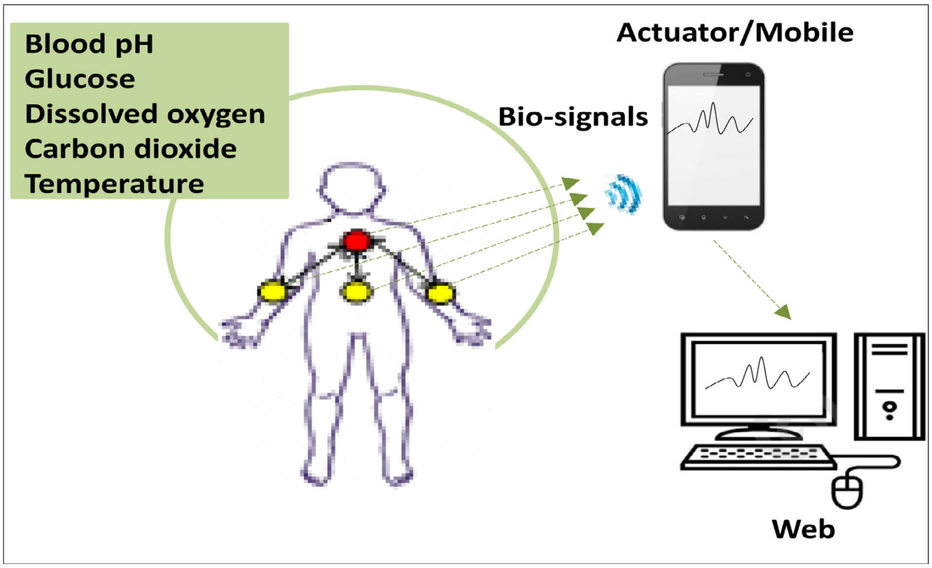

Fig. 2. Remote patient monitoring using IoT and WoT.

such technologies is that they can enable local computing and thus it reduces the communication delay and increases the performance up to some significant extent [15].

One of the fascinating areas of the research is the context-aware automation and decision optimization, which refers to monitoring unknown factors, such as physical environment, M2M, and M2I, etc. The purpose of decision modeling is used to integrate the capabilities of 'human-like' into machines [15]. In order to represent this claim in a better way, we are considering a remote patient monitoring system as shown in Fig. 2. In this Figure, sensor nodes sense the human object and transmit the bio-signals to the remote station with the help of IoT and WoT. Thus integrating the bio-sensor with the patient body that helps in reducing the data collection time and processing of sending the information to the actuator. Moreover, the Body Area Network (BAN) can also be used to efficiently control the data collection and transfer it for further assistance with less possible time.

Various research challenges have been presented in the design of IoT that handles the real-time hybrid structural testing [16]. In such environment, the real-life testing could not be performed and verified prior to on-site deployment, and hence deprived of using caustic testing. Such a problem is tried to solve by the authors by proposing a middleware architecture that welcomes cyber as well as physical components. In order to use this framework, the researchers could get an intuition into real-time structural analysis, i.e., easiness towards the timing constraints as well as effects of the integration of the cyber and physical systems upon the system features. The designed approach could also be extended towards the non-destructive testing power systems before the actual use. Similarly, another hierarchical approach has been developed for designing the IoT, which combines the estimation methods with the data mining methods to apprehend the composite behavior of system at various levels of abstraction [17]. In this technique, the usage of green transportation has been employed, which focuses on fuel consumption and carbon footprint of the vehicles. In this method, vehicles are moving on the roads under diverse traffic conditions. Whereas, the routing optimization software has been used for cars, streets, and traffic conditions to empower green transportation. The results show that the designed system delivers significant improvements in the fuel consumptions predictions.

Many researchers are still working on smart home as individually and also with the coordination of some organization. Haidong Wang et al. [18] describe a new concept of interface in a home environment. They use a smart robot with a smartphone as the brain and a robot car like the body. With this system, a person is allowed to carry the robot's brain when he is out of his home. Thus, the brain monitors different parameters such as the temperature at home. On the other hand, when the person is at home, he is allowed to put his phone on the robot car. By invoking the system, he has an assist-robot. This assist-robot acts as a new interface in the smart home by following the person and recognizing the individual's voice commands for taking notes, reading notes and controlling smart home devices. The authors provide a high-level design and use Google voice recognition for user voice recognition. To invoke the Google Voice search itself, they developed a method by implementing Haarcascade from the OpenCV on Android phone and face recognition web service is developed by implementing the Eigenfaces algorithm.

Nektarios Papadopoulos et al. [19] present a connected home platform and development framework for easy deployment, development, and user friendly enviroment for smart home services. They offer a wealth of new exciting smart home experience on top of existing broadband service bundles. The connectivity between the homes' devices is made possible with the help of a home controller using different home technologies for communications. Most of these technologies use short range communication services; Bluetooth, ZigBee, etc. The service platform embeds the use of Open Services Gateway initiative (OSGi) technology in the home controller that enables the OSG engineer to develop quickly and deploy home services utilizing the widely adopted automation technologies. The network adaptation layer is used to interface and jointly link different home network subsystems using a new component known as ROCob. Following the ROCob API specification, a developer can build various applications, such as the applications for presentation layer (e.g., a web-based user interface), monitoring applications that collect data and send them to a backbone server, and other home control and pervasive applications.

Han and Lim [20] address a new smart home control system based on sensor networks to make home networks more intelligent and automatic. They design smart home device descriptions and standard practices for demand response and load management *'Smart Energy'* applications that are needed for intelligent energy based residential or light commercial environment. The control application domains that are included in this initial version are sensing device control, pricing, demand response, and load control applications. This paper also introduces smart home interfaces and device definitions to allow interoperability among ZigBee devices produced by various manufacturers of electrical equipment, meters, and smart energy enabling products. They propose a home energy control system design that provides intelligent services for users. This work is implemented using a real test bed environment.

Xiaojing Ye and Junwei Huang [21] present a theoretical framework for a cloud-based smart home for enabling home automation, household mobility, and interconnection. They claimed that the system was easily extensible and fit for future demands. They mainly focus on the overall smart home framework, features, architecture of smart home's components, and the interaction and cooperation between them in detail. The proposed architecture in the said work does not provide the real implementation of the system. They suggest the use of cloud computing, and web services for six smart home application; home entertainment, security, environment, health, communication, and domestic appliances.

Yang Song et al. [22] propose an IoT based model and simulation scenario for next generation based Smart Home. They discuss the family networking technology and propose several typical smart home system solutions. Basic networking mode and primary communications technology of smart home is also introduced. Also, a related modeling and simulation study is carried out for Wi-Fi and LTE coexistence scenario.

2.2. Problems and limitations in previous research

The IETF standard is followed to propose the architecture, since it is free and open. This allows to develop IoT as a web service, while ensuring flexibility and interoperable system. IoT services adheres to ReST paradigm. Hence, it supports both user and the developer to adopt and to use IoT, enabling the reuse of available knowledge. Two protocol stacks have been defined such as, constrained and unconstrained. The unconstrained stack contains common standards i.e. XML, HTTP, IPv4. Similarly, the constrained stack holds same protocols replaced with those that are less complex namely, EXI, CoAP, 6LoWPAN. The standards and less complex transcoding between two stacks ensure ease of access and interoperability between IoT nodes and Internet. There are three functional layers need to be considered, while transcoding between constrained and unconstrained protocol stacks.

- Application Layer and Transport Layer: Communication of IoT devices via HTTP is not suitable due to the wordiness (too much overhead) and complexity. On the other hand, Transmission control protocol (TCP) is not aligned for constrained devices. Hence, the architecture uses CoAP to transfer binary format over UDP. Strategically, it can easily work with HTTP as well due to:
  - Use rest method (get, put, post, delete)
  - Correspondence with response code
  - Support wider HTTP usage scenarios
- Similarly, cross proxy is responsible for translating requests and responses between the two protocols. However, still many limitations exist in the current architecture to make it suitable for the IoT environments.
- Network Layer: Due to the saturation of IPv4, IPv6 has been considered as a solution to address myriads of IoT devices. Yet, it creates overhead that is not compatible with constrained devices. 6LoWPAN has identified as a solution, which is a compression of IPv6 and UDP headers. Border router in a 6LoWPAN network performs translation from and to IPv6 and 6LoWPAN. Although, the problem arises when it is necessary to communicate with an IPv4 host. The solution outline to address the issue as mentioned below.
  - V4/V6 Port address translation: Maps random pairs of IPv4 and TCP/UDP ports to IPv6 and TCP/UDP ports. This is similar to NAPT and easier when the connection initiated from an IPv6 node. Complex architecture and DNS are necessary, if the initiating node is IP V44.
  - V4/V6 Domain name conversion: This allows virtual hosting like in HTTP 1.1. Similarly, can use DNS to get the domain name of the requested web service. The DNS will provide IPv4 address of the HTTP-CoAP cross proxy to access the IoT node. The process is similar in IPv6 DNS server as well.
  - URI mapping: This has HTTP-CoAP cross proxy and reverse cross proxy. Proxy acts as the final web server to the HTTP/IPv4 client. In contrast, act as the original client to CoAP/IPv6 web server. IPv4/IPv6 conversion is internally resolved.

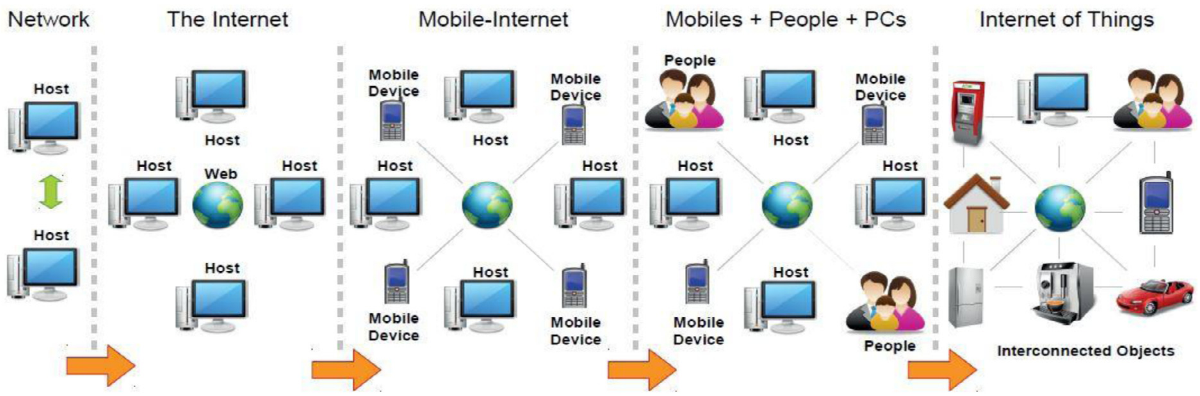

Fig. 3. Five phases of the evolution of the Internet.

Apart from the technology perspective, the current research work presented for smart home design still have several limitations. For example, the proposed technique by Haidong Wang et al. [23] has only 72.5% successful rate of one step forward detection. However, there is still a need to add more sensors to the robot car to avoid obstacles. Secondly, the robot body should lack most of the critical behaviors of a human, such as to move upstairs and downstairs. Similarly, a system is proposed in [20] to solve this problem but it can not provide support for location services, so there is a need for IEEE 802.15 standard implementation with Location Based Service (LBS) using GPS, etc. A theoretical framework for cloud-based smart home has been proposed in [21]. However, a practical implementation of such system is still needed.

Therefore, to cater these problems, a stronger emphasis needs to be set on device adaptation, usability and scalability, which can seamlessly accommodate new smart home services. Moreover, we need a system that resolves the issues of interoperability problems of different interacting hardware and software components, the complexity of configuration, lack of universal service consideration, and weak smart home security.

3. IoT characteristics

In this section, we briefly overview the characteristics of the IoT as well as the ongoing research in the IoT paradigm. As we know, IoT combines different technologies such as sensors, cell phones, cloud technologies, mesh networking, etc. Therefore, the characteristics of the IoT is different in every dimension. The IoT can be called a revolution of the internet that we already have. If we divide the evolution of the internet, it has five different phases [29] as is depicted in Fig. 3.

In the last couple of years, the IoT systems gain significant attention and therefore it is developed and designed by many IT companies and software firms. The ultimate goal of IoT is to combine these technologies together and form a single network where everything is connected with each other over the internet. Several characteristics have been identified in different research studies that made the IoT differ from other networks and technologies. For example, the IoT structure mainly consists of middleware, frameworks, and APIs, but on the other hand, the sensor network has firmware, sensors, and actuators. These characteristics can be classified into following parts.

(a) **Architecture:** As stated before, the IoT architecture is different from other technologies such as sensor network, etc. IoT systems communicate with more than one object at a time, therefore, the IoT architecture supports hybrid functionalities. Unlike the sensor technology that support either event or time driven architecture, the IoT system supports both the time and event driven architecture and specifically in most cases it supports event driven architecture [30].
(b) **Processing of Information:** The IoT systems are very complex due to their communication with millions of objects. Similarly, a large number of nodes are joining and leaving an IoT system instantaneously. There is enormous number of nodes that are already deployed around the world, and hence most of them are continuously generating the data. Thus, to control such systems, IoT requires a complex communication system [31].
(c) **Number of things:** It is estimated that at the end of 2020, around 100 billion objects will be connected to the internet. Thus, connecting, collecting, and processing of data of this much number of objects would be a difficult task to accomplish.
(d) **Communication between objects:** The IoT will consist of billions of objects at one stage and thus controlling the communication between these objects would result in different issues. Thus, the IoT systems should be strong enough to hold this much communication, and indeed the real-time processing must be made essential in such systems.
(e) **Uniform distribution of objects:** Except the mobile nodes, the rest of the objects should be uniformly distributed to make it easier for an IoT system to handle this large amount of continuous data generation.
(f) **Services:** Another important characteristic of the IoT systems should be providing every service to every IoT user. This could be possible by either integrating the IoT system to the cloud or to other IoT system. The everything-as-a-service model is one of the solutions in this regard [32].

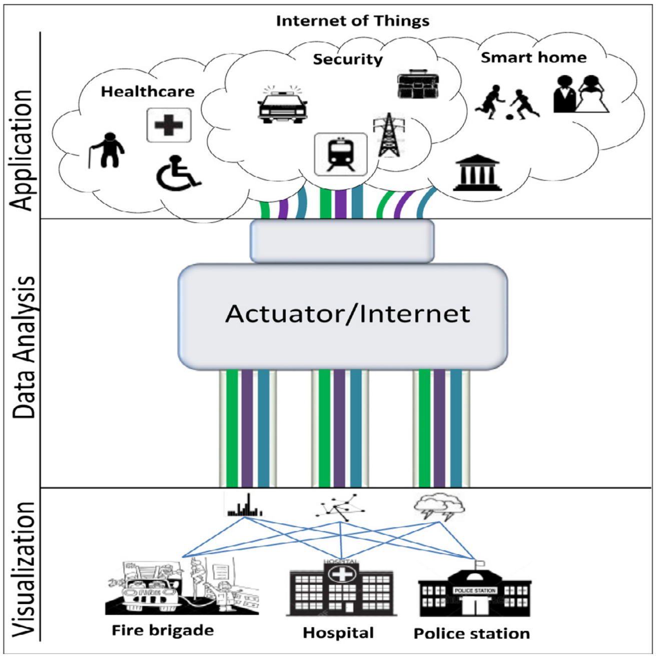

Fig. 4. Skeleton of the CLPiSmartHome.

4. Context aware low power based intelligent Smarthome

In this section, we discuss the breakdown of proposed system into two parts, i.e. communication model and the architecture for *CLPiSmartHome*. Before moving towards architecture for *CLPiSmartHome*, it is worth presenting the overview of the proposed architecture.

4.1. Overview

The proposed *CLPiSmartHome* consists of three major units namely application unit, data analysis unit, and visualization unit as are shown in Fig. 4. The application unit is comprised of healthcare system, home security system, and SmartHome system. In healthcare system, we have employed source ID/location-based 6LoWPAN wireless body area network mobility management scheme as shown in Fig. 5. In the architecture, we consider a group of 6LoWPAN sensors that are attached to human body, and one of them acts as coordinator and only the coordinator can exchange the control signaling messages with Primary Mobile Device (PMD). In the proposed scheme, each sensor and PMDs have a 128-bit Global Unique Device Identifier (GDID) [33], which is used in end to end communication and the link-layer addresses can be used as the Access IDentifier (AID).

The GDID contains the information about its home domain. As for locators, the location of PMDs is identified by Local LOCators (LLOC) and Global LOCators (GLOC). The LLOCs are the AIDs of PMDs, and it is used within the home domain. Because the GLOC represent the IP address of Access GateWays (AGW) and it is used for inter-domain communication. Each AGW keeps Home GDID Register (HGR) and Visiting GDID Register (VGR). HGR keeps track of the GDID-LOC mapping information for PMDs and VGR maintain the list of GDID-LLOC mapping information for the visited PMDs.

In the proposed architecture, only one time Router Solicitation (RS) and Router Advertisement (RA) messages are sent by the coordinator and thus reduce a lot of control messages. Initially, the PMD communicates with correspondent PMD (C-PMD) in the previous AGW (p-AGW) domain. Now, the PMD moves to a new AGW (n-AGW).

Moreover, the security system is equipped with the Xbox 360 KINECT camera throughout the home, particularly in the door entrance. The KINECT camera handles identifying the object, whether a home user or outside user. Such a system is connected to the internet, which further transmits its information to the required community, i.e., police station. Finally, the proposed iSmartHome is equipped with the electronic appliances, which are interconnected with each other with the help of Bluetooth and ZigBee technologies.

4.2. Communication model

We employ two different technologies in the proposed scheme for communications in the smart home. The ZigBee technologies are used to cover the entire house. Because, the ZigBee provides the LAN services better than the IEEE802.11n. The

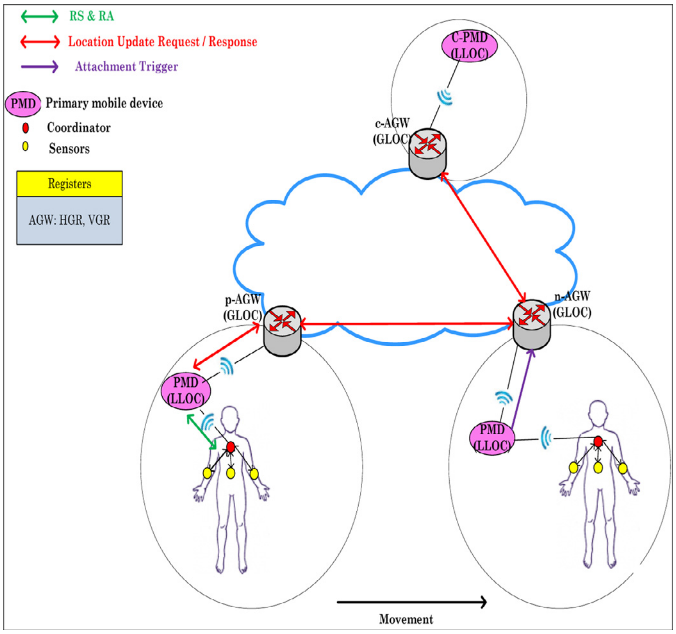

Fig. 5. Network Model for iHealtcare system.

advantages of the ZigBee over the IEEE802.11n includes the low power and low duty cycle embedded systems. Similarly, the Bluetooth Low Energy (BLE) is used to cover a room inside a smart home. The reason of using BLE in a room is that it works efficiently for Personal Area Network (PAN). Therefore, we present an overview of the communication model of both the technologies in following subsections.

4.3. Bluetooth low energy (BLE)

The BLE is one the latest version of the Bluetooth v4.0, which is specifically designed for the low power consumption devices such as sensors and wearable devices. The architecture of the BLE is consists of two type of layers i.e. upper and lower. The lower layers handle the transmission of bits over the physical medium while the upper layers are providing the functionality of flow control, error control, etc. Moreover, the upper layers are further divided into Logical Link Control and Adaptation Protocol (L2CAP), Generic Access Profile (GAP), and Generic Attribute Protocol (GAP). The L2CAP handles the fragmentation and reassembly of large packets, and the multiplexing of the data of channels from upper layers. The BLE is using Adaptive Frequency Hopping Spread spectrum (AFHSS), similar to the classical Bluetooth. However, the BLE uses 40 channels each of 2 MHz, bit rate of 1Mbit/s, and the transmit power equal to 10 mW. As BLE uses a bit rate of 1 MHz, therefore, it is unable to provide the voice capability. Because of these characteristics, the BLE is considered low energy devices such as mobile phones, wearable devices, etc.

The BLE consumes 90% (0.01 to 0.05 W) of the energy on the advertising and scanning process. Therefore, we discuss the advertising and scanning process in detail. The BLE operates in three different ways i.e. advertisement of the BLE devices, scanning of the available devices and initiating the connection. Unlike the classical Bluetooth, the BLE has three different channels for advertisement i.e. 37, 38, and 39. The BLE has total 40 channels out of which three channels are used for the advertisement purpose. Similarly, the BLE keep sending the advertisement messages using the ADV_IND packet data units over the three channels during the advertisement event. A random amount of delay is used between the advertisements of the channels to avoid the collision between two advertisers. The BLE standard define the advertisement interval for all three channel, and the advertisement should be between 20 and 10.24 ms having an integer multiple of 0.625 ms. Similarly, the delay should be less than 10 ms [34]. Once the advertisement phase over, the advertiser will listen to the responses from the available devices on the same channels. Thus, the device will enter into scanning mode after advertisement phase. The scanner sends a response to the received request against the advertisement message. The standard define a scanning window time of 10.24 s for scanning the available devices. Keeping these characteristics of BLE technology, we employ it in the proposed iSmartHome architecture.

4.4. ZigBee protocol

The ZigBee protocol is based on the IEEE802.15.4 standard. The ZigBee can be used to transfer data over a distance of 10 to 100 meters depending on the environmental conditions. The ZigBee protocol is considered for low power devices because

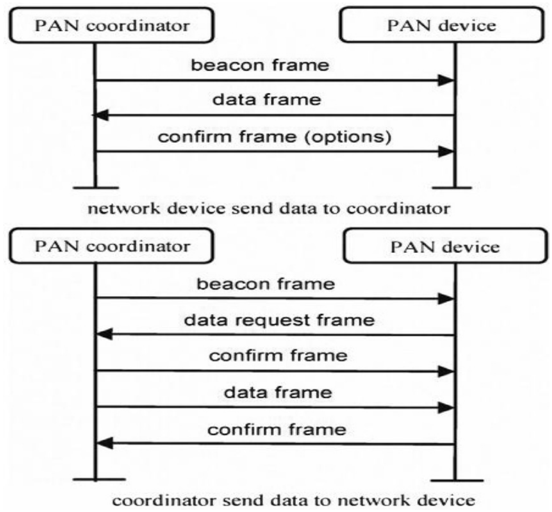

Fig. 6. Beacon-enabled communications in ZigBee protocol.

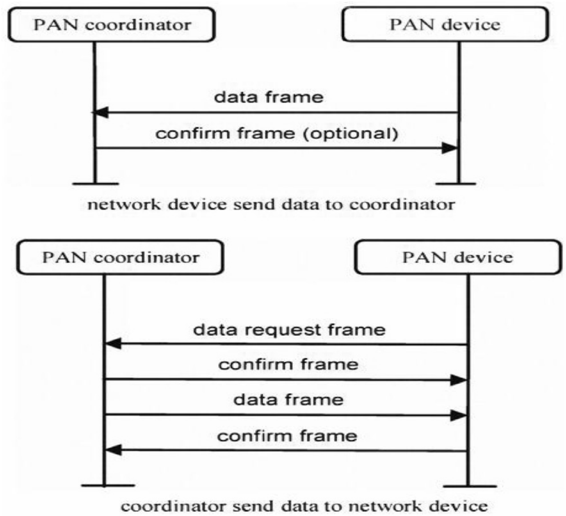

Fig. 7. Non-Beacon-enabled communications in ZigBee protocol.

it requires very limited energy to transmit and receive data. Similarly, it consumes most of the energy on the data transmission. The ZigBee uses three different type of devices i.e. coordinator, router, and end device. Similar to BLE, the ZigBee also operates on 2.5 GHz unlicensed band worldwide. It uses 16 channels with a 5 MHz space and 2 MHz bandwidth. The ZigBee uses direct-sequence spread spectrum (DSSS) coding technique. Moreover, there is two type of communication modes are present for data transmission i.e. beacon-enabled and non-beacon enabled. In the case of Beacon enabled approach, the network coordinator periodically broadcasting the beacon message in the PAN Network. The devices in the PAN network synchronized with the coordinator upon receiving the beacon messages. In the case of the non-beacon enabled communications, randomly broadcast the beacon messages. If a device want to send data it waits for a random amount of time and then sense (CSMA-CA) the channel, if the channel is available, it starts the data sending otherwise switch to waiting state. The framework of the beacon enabled, and non-beacon-enabled communication is shown in Figs. 6 and 7, respectively [35]. In case of beacon-enabled communications, the PAN coordinator periodically broad casts the beacon frames. However, in the case of non-beacon-enabled communication the PAN coordinator randomly sends beacon frame. The PAN device has to wait until the channel is available in idle state otherwise it waits for a random amount of time.

Whenever, a device is not sending data, the ZigBee protocol turn off its radio interface to save the energy. Similarly, a node can be in the active state whenever it is transmitting a beacon message. The beacon interval depends on the data rate, and it is usually ranging between 15.36 ms and 251.65 ms at 250kbits/s.

Keeping in view the communication model, we proposed that the BLE is an excellent choice for using it in the room coverage while the ZigBee for the entire house.

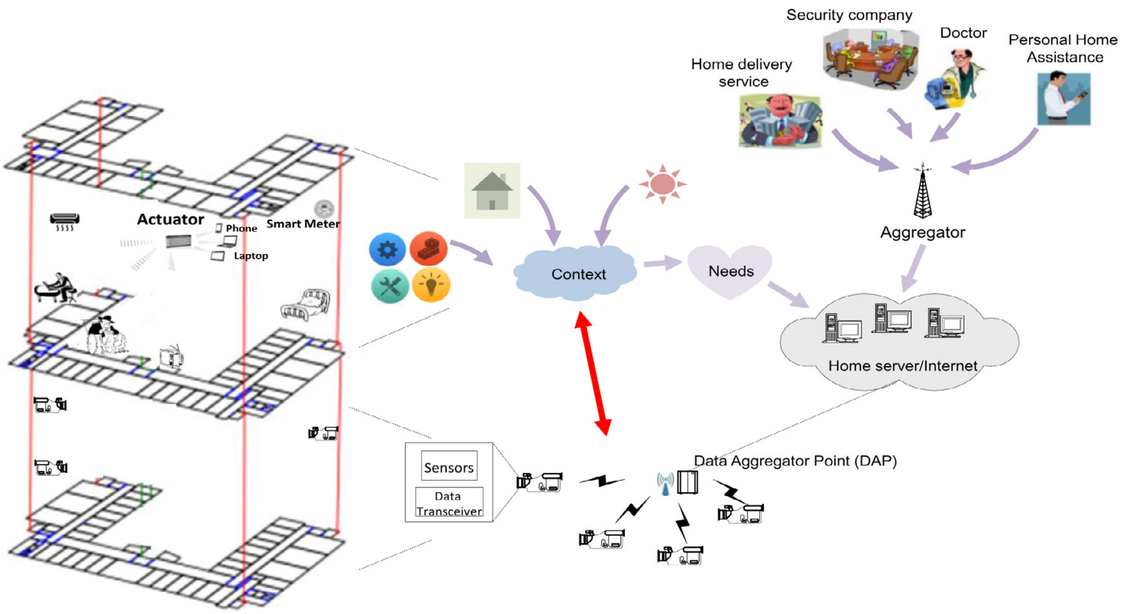

Fig. 8. Architecture for the *CLPiSmartHome.*

4.5. *CLPiSmartHome* architecture

A *CLPiSmartHome* is a virtual environment composed of network of various devices in different units, such as healthcare system, security system, and *i*SmartHome located in a large geographic area. These different units include smart homes, police stations, hospitals, fire brigade centers, and home servers. These homes are powered by the web application server that is used for integration of various electronic devices (wearable devices, healthcare devices, electric appliances, social networking, and so on, so forth) and provide a same communication medium either using short range communication technologies such as Bluetooth and ZigBee or long range technologies such as WLAN, cellular, etc. Architecture of a *CLPiSmartHome* is composed of three large parts i.e. application unit, an analysis unit, and visualization unit, as is depicted in Fig. 8.

A home network is equipped with different electronic appliances, which are interconnected with the help of Internet. Also, these devices are connected to the home server to store data for analysis purpose. These electronic appliances include a health care system for elderly age people, wearable devices, social network, and KINECT XBOX for security system. Such devices monitor real-time context monitoring of residents in the home environment. According to the architecture, these devices are connected to the actuator with the help of ZigBee where it can send signals to the web server for further actions. The actuator is a smart, and intelligent device responsible for sending instructions to other devices either using Zigbee or Bluetooth depending on the location of server. For instance, various electronic appliances, such as smart meter, water usage meter, and lights, etc. are connected to the actuator. These electronic devices perform accordingly when the user is at home or not. Moreover, also, it depicts the level of water that is used by each user in the home. Similarly, all the electronic appliances could be controlled remotely. For instance, if a user is not at home, the user can access home server with the help of 3 G/4 G data network, and can send instructions to the devices to perform a particular task. Moreover, a surveillance system is designed for elderly age people and small kids in the home. In the case of elderly age people, wearable devices are used that could detect the body gestures of the object, and could decide the position of the object using body area network in integration with BLE. Similarly, for small kids at home, our designed system could be used to find out the current location of the∗ kids. To elaborate the finding of small kids at home, the following technique could be applied, which shows the registration phase among coordinator, PMD, and AGW.

In Fig. 9, the coordinator is attached to the PMD. Afterward, the coordinator sends router solicitation (RS) message to PMD. The RS message contains coordinator ID (GDID) and link layer address (AIDs). On receiving the RS message, the PMD generates a response message to the coordinator and respond with the RA message again to the coordinator. Then, the Location Update Request (LUR) message is sent to AGW by PMD. Hence, the AGW updates HGR that maintains GDID-LOC mapping table as shown in Table 1.

Furthermore, when the PMD establishes a communication link with the PMD, which is residing in the corresponding gateway as is shown in Fig. 10. The PMD generates a device ID request to the AGW. Afterward, the AGW checks whether the GDID belongs to the same domain or not. The AGW has the capability to find it based on GDID, since GDID contains the information about its home domain. Doing so, AGW sends location discovery message to c-AGW. The c-AGW has the capability to look for HGR mapping table with the reply that contains the location discovery message to AGW. After receiving

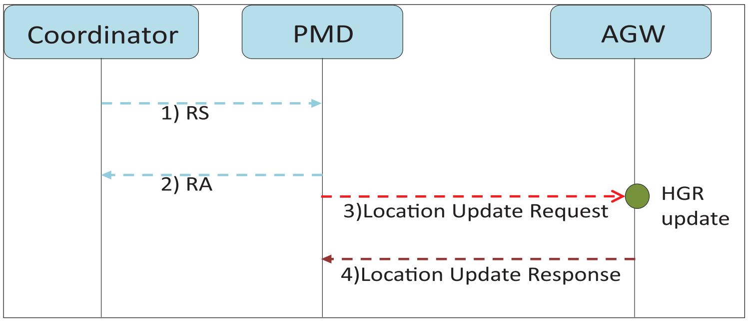

Fig. 9. Initial registration.

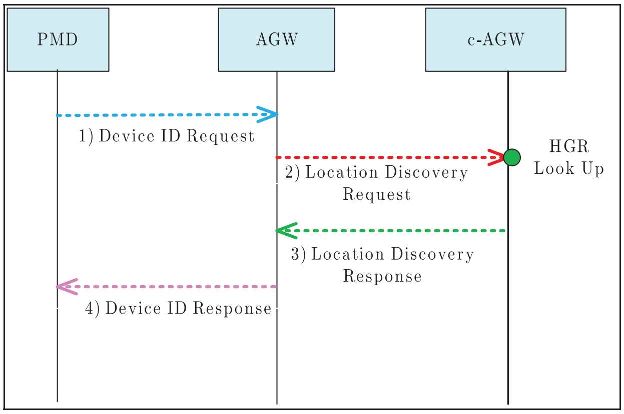

Fig. 10. Packet delivery operation.

Table 1
Home GDID register (HGR).

No.	ID	LOC	Domain
1	GDID1	LLOC (AID) of PMD,	Home
2	GDID2	GLOC of AGW	Visiting
3	…..	……	……

location discovery response message, the AGW adds such information to its mapping table. Afterward, the AGW responds with the device ID response message to PMD. Hence, the data packets are forwarded to C-PMD through AGW and c-AGW.

Moreover, *i*SmartHome provides the facility of security. For this purpose, the KINECT camera is mounted at the door entrance and is linked to the actuator using ZigBee. The home server has the database of all the users at smart home. In case, a non-user is entering the home, it compares the characteristics of a new user with the entries in the database. If it does not match with the database, it sends instructions to the actuator. The actuator is then responsible to inform the appropriate user at home and displays its result as is depicted in Fig. 11. Nowadays, due to the traffic intensity on the roads and the intensive population growth make it difficult to bring elderly people to hospitals for everyday medical checkup. However, a system can be designed which enables remote communication to the physician home, etc. to discuss the patient conditions. However, it is not much simple because of the various involved issues, such as getting an appointment, vacations, etc. Thus, to overcome such problems in the existing systems or in designing a new system for a routine checkup of the elderly people can be a beneficial step in eHealth systems. Therefore, we designed a system keeping all the issues in the existing systems and providing a user-friendly environment to the patients. Various sensors are attached to the patient body that monitor different health conditions such as a patient is suffering from diabetics is attached to a sensor that periodically measure the diabetics level of a patient. Moreover, a system is proposed which is based on different thresholds on various conditions of the patient. For example, a patient condition is dropping or elevating than a defined threshold, the system generates alerts and warning messages. These messages and alerts are sent to home server that sends the data to the concerned department via Internet link. The sensors attached to the Patient's body communicate locally using the BLE technology. Moreover, the communication with the home server is done using ZigBee. Similarly, the data from the home server is sent to the remote department using WiFi or Cellular technology. The concerned department initiates the emergency conditions upon receiving the alert and sends the ambulance or doctor to the patient's location. Similarly, other emergency conditions such as in case

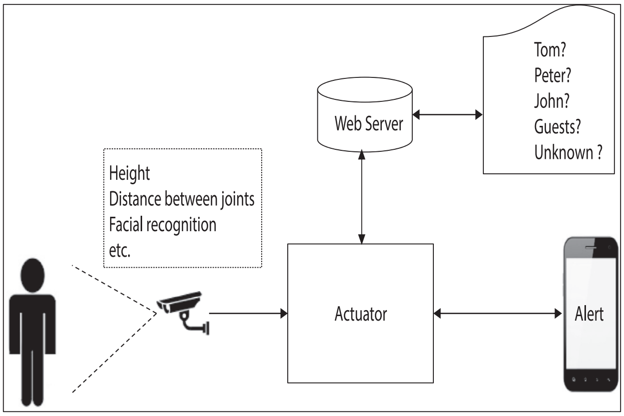

Fig. 11. Typical scenario for identifying objects.

Algorithm 1
Fire detection and patient monitoring.

1. For each (Temperature readings) do
IF (Temp > A_{STemp} && Flush_light > A_{FL})
Fire: Detected;
Else IF: (Temp > A_{NTemp})
Fire = Analyze ($\bar{x}_{Temp}$, σ^2_{Temp}, Max_val_{Temp})
Else
Next();
Alert();
2. For each (Heart_Rate) Do
//Define Thresholds
Assign A_{NR} and A_{SR} using following table

Age	A_{NR}	A_{SR}	Age	A_{NR}	A_{SR}
<20)	170	200	<50	145	175
<30	162	190	<60	136	170
<40	153	185	>60	128	150

//Decision
IF: (Hear_Rate > A_{SR})
Alert();
Else IF: (Hear_Rate > A_{NR})
Analyze (Heart_Rate)
Else:
Next();

of fire, gas leakage, water pipe leakage, etc can be controlled using same architecture. The web server plays a vital role in this situation by sending the information to other web servers for more efficient recovery and timely services.

5. Analytical results and discussion

To check the accuracy and efficiency of the proposed scheme, we design an algorithm that monitors the fire level in the home. Similarly, the system also monitor the heartbeat rate of a patient at home. The system is loaded with the initial information of flashlight and temperature. Because, we want to set a threshold on the intensity of fire for eliminating false alarm generation. Similarly, the intensity of fire is elevated than the threshold, and we check whether the system can generate the alarm or not. The system generates alarm as the fire level exceeds the threshold. Similarly, the system is tested many times, and we have noticed almost zero-degree false alarm rate. Moreover, if the system is taking measurements and it is within the limits for a longer time, then the system calculate the mean, standard deviation, and maximum value readings. Similarly, the action is taken while considering the above values. The same analytical results have been measured in case of chronic patient. The thresholds are set on the lower and upper limits of the blood pressure. If the measurements drop below any level, the alarm is generated and sent to the concerned department. A pseudo code is given as Algorithm 1.

To test and analyze the proposed system in terms of efficiency for processing larger datasets, Hadoop stores data in different blocks using HDSF file system. Such a facility provides parallel processing on datasets in each server. Therefore, a considerable amount of increase in efficiency could be achieved as compared to different existing scheme that uses other technology. For our analysis, the temperature datasets (Size: 118 MB), ECG datasets (Size: 227 MB), and heartbeat rate datasets (Size: 1.7 GB) are considered [24–28]. Various other parameters including activity parameters and medical health parameters are taken into account in single dataset. To validate the proposed scheme, we have analyzed the given datasets

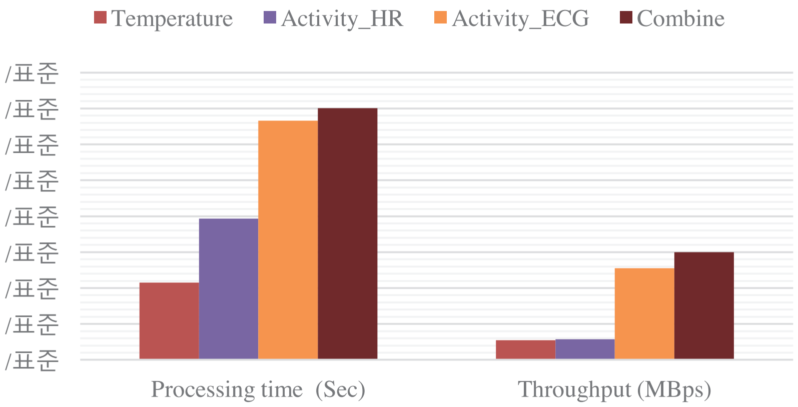

Fig. 12. Efficiency of proposed system.

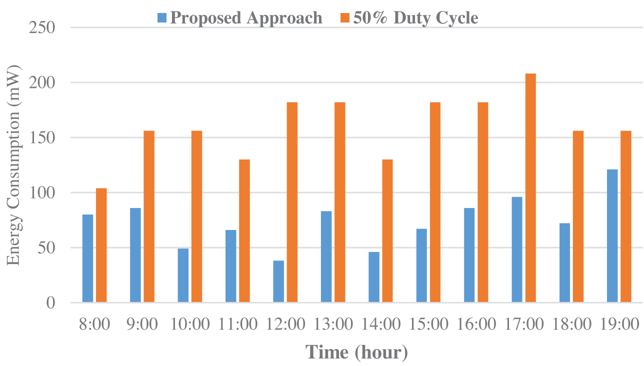

Fig. 13. Energy consumption while the sensors operate at 50% duty cycle.

to check the throughput and processing time. In Fig. 12, the temperature dataset takes less time to process since the size of the datasets is smaller. However, throughput is noticed as greater. To combine all the datasets (2.1 GB), the proposed system take a longer time to process it, however, throughput is less. The processing time and throughput for various datasets are given in Fig. 12. It can be seen that if we increase the size of the datasets, it results in decreasing the throughput.

We also consider a scenario of a house with five members. The average energy consumption by the BLE and ZigBee sensors attached to different appliances is calculated for a duration of 12 h time. Where the duty cycle is 100% i.e. the time in which the radio interface remains in active state. The energy efficient communication stack has a duty cycle less than 1%. However, we want to utilize the effect of both the technologies in full, therefore we keep the radio interface always in ON state. The sensor embedded in each device is considered of operating on a pair of AA batteries (3000 mAh). The BLE enabled sensor consume an amount of 6 mA in active state. Similarly, the ZigBee is consuming an amount of 13 mA. The member of house randomly moves around the house and randomly switching ON/OFF the device available in the house. The BLE is only used in the room environment while the ZigBee is used in the entire house. The security system and door opening and closing are also controlled through remote control operating via ZigBee. Similarly, different appliances like TV, refrigerator, washing machine, light bulbs, microwave oven, etc. are also controlled through sensors by using both ZigBee and BLE (only rooms). The communication in the range of 50 m is carried out by using BLE and more than 100 m by using ZigBee. The average energy consumption values of both the technologies for 12 hours' time (50% duty cycle) are graphed in Fig. 13. Similarly, the total energy consumption of both the technologies for 12 hours' time (100% duty cycle) is also computed as shown in Fig. 14.

Various sensors are installed at different locations such as in rooms, kitchen, body of the patient, and security services. The energy consumption of the sensors are calculated as shown in Fig. 15. The sensors used in the rooms consume high energy as compared to other sensors. In general, the energy in consume by the sensors during morning, afternoon, and in evening is relatively higher. Similarly, the energy consumption of some the sensors is zero at some particular hours because the sensors were remain in sleep state. Moreover, the overall energy consumption of the sensors is within the acceptable limits.

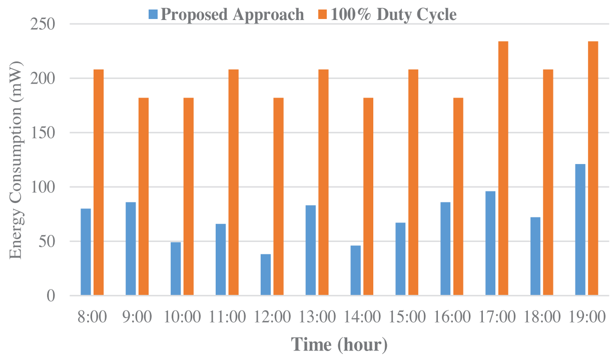

Fig. 14. Energy consumption while the sensors operate at 50% duty cycle.

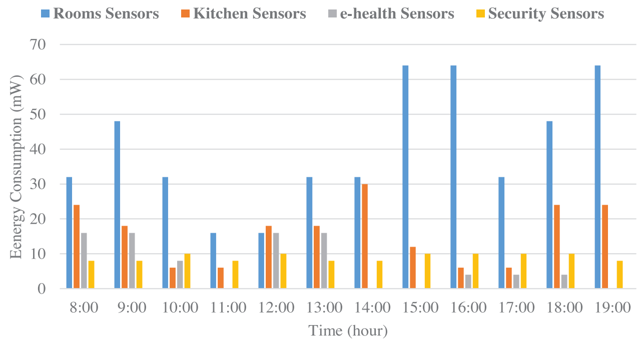

Fig. 15. Total energy consumption of the sensors during 12 hours' time Period.

6. Conclusion

In this paper, we provide a new concept of intelligent smart home that integrates the concept of IoT based on a web application. Furthermore, we define a communication model for sharing data using the same medium. The communication model provides a common medium for the communication of all the heterogeneous devices. Furthermore, a system architecture is also proposed based on web application. The web application concept is used to send or receive action messages over the network. The proposed architecture provides the application, analysis, and visualization aspects where various devices are integrating with various electronic devices. The performance of the system architecture is tested on Hadoop using UBUNTU 14.04 LTS core^{TM}i5 machine with 3.2 GHz processor and 4 GB memory. Similarly, the energy consumption of the sensors installed in the proposed smart home is also computed. The energy consumption of the sensors using the proposed architecture is significantly reduced. The final evaluations show that the performance of the proposed network architecture fulfills the required desires of the users connected to it, whether the input data is real-time or offline while taking actions at real time.

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