# Bluetooth and ZigBee: A Network Layer Architecture Gateway

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***Abstract* – Deployment of Wireless Sensor Network (WSN) plays a key role in the efficient development of solutions for many domains like home automation, disaster management, healthcare, environment monitoring, etc. Improvement in technology has resulted in a major focus on smart and energy efficient buildings wherein one of the major concerns is efficient power management. On-line, "any place any time", monitoring of the power status of various equipment in large buildings using smartphones/tablets requires remote communication between local sensor networks and remote user which may be operating on diverse network protocols like zigbee and Bluetooth. There is a need for an efficient Gateway for mediating communication between sensor networks, which work generally using IEEE 802.15.4 based zigbee and the users, who normally use equipment with support for either IEEE 802.15.1 or IEEE 802.11. The architecture of an efficient Gateway between IEEE 802.15.4 & IEEE 802.15.1 is presented in this paper with details of the data flow mechanism between the Bluetooth and zigbee gateway. The proposed gateway mechanism is capable of converting IEEE 802.15.4 protocol data to IEEE 802.15.1 protocol data and vice-versa and is flexible enough that it can be used in any network that has Bluetooth enabled facility at its sink node.**

***Keywords - Gateway, Home Automation, WSN, IEEE 802.15.1 (Bluetooth), IEEE 802.15.4 (ZigBee).***

## I. INTRODUCTION

With the rapid development of network and communication technology, a smart home is becoming a realistic option as more and more people crave for smarter and more comfortable life. A depth study of the previously reported work indicates that significant research has been done in the field of building/home automation systems for making efficient systems. There is an enormous change in the living standards due to the rapid change in science and technology and home ambiance has seen a fast implementation of systems that are based on digital techniques. This innovation offers new and energizing chances to extend the networking of gadgets inside the house with an aim for efficient home automation. With the rapid growth of the Internet system, there is a massive future for remote controlling and monitoring of network empowered appliances. Thus efficient connectivity between various devices within the home and the external world is paramount. There are number of emerging wireless network technologies such as ZigBee, Wavenis, INSTEON, Z-Waves, and IP-based technologies that can be used for home automation [1].

One of the major aspects of building automation is that of power management in large buildings to successfully implement the concept of smart and energy efficient buildings. The smart phones, smart tablets, etc. are easy-to-use but normally support either IEEE 802.15.1 (Bluetooth) or IEEE 802.11 (Wi-Fi) at a time only. Moreover, all smart phones and tablets have web browser which can also be used to monitor the power of the electrical appliances in home [2].

The Wireless Sensor and Actuator Network (WSAN) communication schemes are defined in IEEE 802.15.4 standard. The protocols provide simple, cost effective, low rate and low power that is targeted toward automation and remote control applications. It is designed to provide connectivity for number of equipment that will operate for several years. Standard takes full benefit of IEEE 802.15.4 PHY-Radio specification. The ZigBee protocol gets benefitted from IEEE 802.15.4 protocol with added networking functionality [3].The low price makes technology to be deployed widely in wireless management and observation applications. Additionally, the low power permits longer life with smaller batteries; hence the ZigBee sensing element network can offer higher reliability and larger coverage range [4]. ZigBee Alliance is dedicated to developing standardized application software on top of the IEEE 802.15.4 wireless standard [5].

The ZigBee based sensor network is becoming much popular in wireless communication society. Also, the web-sensor enabled gateway research works are getting attention [6]. Recently, more research article on the Internet-Bluetooth and Internet-ZigBee are getting produced. To the best knowledge of this work, the Bluetooth-ZigBee gateway for smart home automation is the first kind of study in the literature which allows seamless data flow between IEEE 802.15.4 and IEEE 802.15.1 network. This paper aims to describe the gateway architecture for carrying out flawless data communication between Bluetooth and ZigBee network. The conceptual overview of smart home through

Bluetooth-ZigBee Gateway has been drawn in Fig 1. In this ZigBee network based Smart home automation system, various power appliances are connected to the ZigBee sensor node which senses power status of attached devices and can be remotely controlled by local users (having Bluetooth enabled devices) through Bluetooth-ZigBee Gateway. This network can further be extended for long distance remote users by using Web-Gateways.

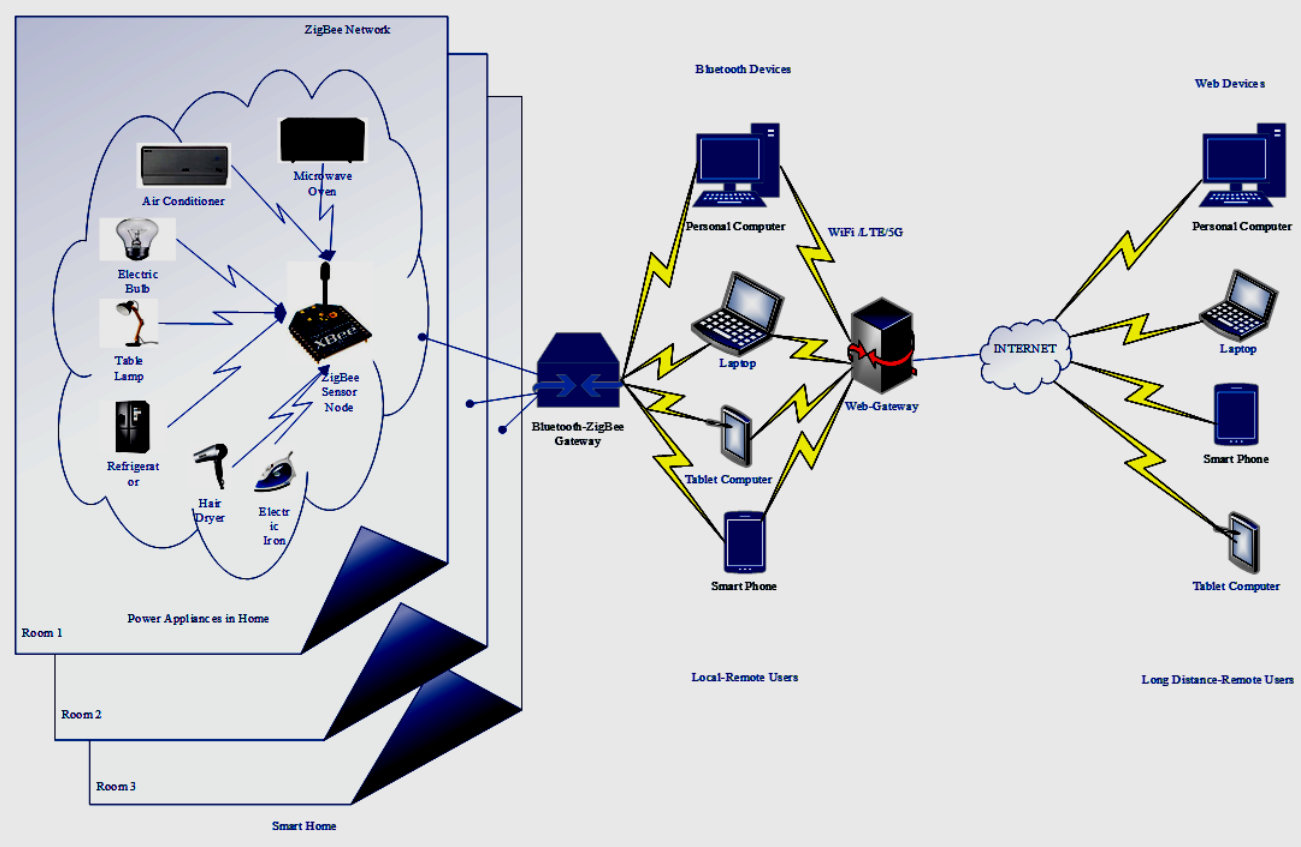


Fig.1. Conceptual Overview of Smart Home through Bluetooth-ZigBee Gateway

*A. Why Gateway is Needed?*

A gateway is an intermediate network device that connects two dissimilar networks and uses diverse protocols. A gateway can be in various forms such as computers, routers, etc. and can perform several tasks. These vary from passing traffic on to subsequent mount its path to giving complicated traffic filtering, protocol or proxies conversions at many network layers. The utmost common gateway is the Internet gateway that associates enterprise or home networking to the Internet. The gateway is needed to provide bridging between different data standards, specifications and middleware, etc. Internet of Things (IoT) gateway provides interoperability between sensing region and network region. IoT gateways can be used to connect different devices or different communication technologies together [7]. In IoT devices for different application layer protocols like Message Queuing Telemetry Transport (MQTT) and Extensible Messaging and Presence Protocol (XMPP), it uses different Communication technologies like Bluetooth and ZigBee. Therefore, in order to bridge different technologies together, gateways are required that can be a function embedded in the firmware of various intelligent devices such as computer or Human-Machine Interface (HMI), Programmable Logic Controller (PLC), or it can be a dedicated hardware [8]. As WSN has been a key factor in the growth of various areas such as home automation, health care monitoring, environmental monitoring, industrial monitoring, etc. To monitor all the data collected by WSN and disseminate these collected data through the Internet there is need of gateways. So gateway basically maps the different protocols. And, once these data are available then it can easily be stored and monitored. To the best knowledge of this paper, till now there is a nonexistence of Bluetooth low energy gateway in the literature, and in the coming age of IoT, it will be one of the main contenders. In the race of IoT, Bluetooth and ZigBee are lacking for direct connectivity but they are optimized for low power consumptions. Hence, there is an essential requirement of gateways between both.

### *B. Motivation and Principle Contribution*

The trend in the control system in any domain is shifting toward wireless based control. A small localized network comprising of IEEE 802.15.4 based devices can be created but the mentioned protocol lacks the support of IEEE 802.15.1 (i.e. device control from IEEE 802.15.1 is not possible).For a seamless operation, a strong need of some sort of gateway so that IEEE 802.15.4 based existing network could be connected with IEEE 802.15.1 network without any modification in the device. This paper proposed a theoretical architecture gateway between Bluetooth and ZigBee based home automation network. Architecture is supposed to allow homeowners to remotely monitor and control various connected power devices. The proposed gateway can provide interoperability between heterogeneous network technologies like Bluetooth and ZigBee. The remainder of this paper is organized as follows: Section II discusses the literature survey that is carried out in this field and comparative study of various gateways. Section III describes the prerequisite requirement and technologies. The proposed network gateway architecture between IEEE 802.15.4 and 802.15.1 protocol standard are presented in Section IV. And finally, Section V comes up with the conclusion and future directives.

## II. REPORTED LITRATURE SURVEY

The field of automation is being increased day by day and nowadays, becoming an integral part of the home, offices, hospitals, industries, etc. The home automation system has been changing from very old telephone-based to advanced IoT based system. In [9], authors have developed and designed the telephone-based remote controller to control the power supply in home and office. The system was based on Dual Tone Multiple Frequency (DTMF) and the circuit was designed using Turkish telephone standard. Here, telephone keypad act as the remote controller from where input command and instructions can be given to control the remote devices. Now, this system is obsolete because it has almost become static after the introduction of packet switching based system in the market. Because of the emergence of Bluetooth, a Bluetooth based home automation system along with its application in networking has been presented [10].

Network architecture consists of client modules (home appliances), mobile host controller and remote equipment. It uses the Home Automation Protocol (HAP) to provide communication between various home appliances (microcontroller based temperature sensor/fan controller, etc.) and host controller (implemented on a personal computer). Programming was done by using simple assembly and C language. Error detection and correction facility were only implemented at the Bluetooth level, not at application level. [11] Authors presented the implementation and design of Java-based home automation system that connects home appliances to the embedded system board (E-board 8-bit microcontroller) which is further connected to the Internet system. Home system can be controlled and monitored locally by E-board and remotely anywhere in the world by the web browser. It uses a dual multiplexer (MUX) so that users can switch between remote and local mode. The system was secured from unauthorized users by having a password protection concept. But, in case of unavailability of Internet connection or un-response of the server, it is failed to provide remote control. An intelligent and dynamic home gateway (using an Android phone) was proposed [12].

The system is intelligent because it predicting the behavior of users. When it founds that devices are not in use then it automatically turns off it and thus saves the energy as well as cost. On the basis of users predicted behavior, it establishes seven libraries corresponding to each day of week. Due to its dynamic behavior, it needs proper synchronization between user's behavior and default mobile gateway. Mobile WSN networking is not a newer thought and is suggested to solve the number of inherent problems including network operational lifetime, data collection, connectivity, etc. For connecting WSNs to the web through mobile phones has been explored [13]. A Bluetooth module (RN-41, Revolving Networks) is associated with the destination (TelosB, Crossbow Technology, Inc.) through a direct connection to serial transmission (TX) line of receiver node. A pairing of mobile phones and other devices are handled by the Bluetooth module as they enter in close proximity.

A dedicated JavaME application or midlet was written to links the mobile phone over Bluetooth module (compiled application (DataGetter.jar) and source code are available in online archive).Once pairing of a phone with Bluetooth module (default pass key "1234" for RN-41) is done then mobile users can run an application and choose RN-41 from a list of searchable Bluetooth devices. Likewise, the issue of interaction between mobile devices and sensor nodes is presented by Lifton [14] and Ringwald [15].However, the solution is closely tied to individual technologies in each case. S. H. Kim et al proposed UPnP-ZigBee networking architecture consisting of an UPnP-ZigBee gateway (UZG) and ZigBee network topology monitoring functions [16]. In this, UZG is implemented using C/C++. RS232 (baud rate: 115200) is used to connect ZigBee base station to the ZigBee gateway.

Application Object (APO) is added to the application framework to forward all messages from ZigBee nodes to the UZG and vice versa. In addition to this message converter for home control lightening is also implemented which is based on profile [17], where profile includes certain devices such as Light Sensor Monochrome (LSM), Switch Load Controller (SLC) and Switch Remote Controller (SRC). UZG is hosted on the desktop & UPnP control points were used to evaluate interoperability of the

gateway. Implementation of network topology monitoring function is done by introducing an agent and local manager.

Many academic and industry researchers have considered their study to provide compatibility between IEEE 802.15.4 and IP-based networks. Some of them are Meshlium and Waspmote by Libelium [18], DIGI XBEE/RF solutions by Digi-Family [19], IEEE802.15.4 Gateways by Jennic [20] and wireless LAN Gateway by Coalessenses, etc. The mobile gateway described here is generic solution supporting ZigBee that is most common protocol supported by WSNs and Bluetooth. Table I illustrates comparative study of various gateway.

TABLE I. VARIOUS GATEWAY'S COMPARATIVE STUDY

| Gateway Reference | Methodology and Contribution | Remarks |
|---|---|---|
| [21] Home Gateway | ZigBee home automation system (coordinator, routers & many end devices) and 802.11a/g ADSL modem router integrated through common home gateway. Proposed system reduced complexity & expenses of existing one & eliminated lack of interoperability. Further, virtual home concept inclusion offers security & safety continuously. | Interoperability; local ZigBee, Wi-Fi and Internet system. Moreover supports simple & flexible user interface and remote access to home automation systems. |
| [22] Bluetooth-based Mobile Gateway | Gateway consists: Bluetooth (BTManager discovers devices & services), Data (DBManager store collected data to a centralized database firstly locally & then remotely over the Internet systems) & User Interface module (to receive user commands & plot real time graph of monitor data). In proposed U-healthcare system, gateway establishes relay between BAN & remote server using Bluetooth, ZigBee, Wi-Fi/3G comm. Channels. | Gateway integrates Bluetooth &ZigBee based BAN and solves problem of data aggregation & slow transmission that was faced in previous Ubiquitous health care system. Cross layer design & genetic algorithm can lead optimal solution in terms of energy consumption & node deployment. |
| [23] Smart e-Health Gateway = UT- Gateway | UT-GATE co-operates with a remote server, clients & sensor nodes. In healthcare applications, it is able to enhance IoT architectures in view of reliability, performance energy efficiency, interoperability, etc. Gateway mainly bridges medical sensors and automated hospital building to cloud computing & IP based network. | Gateway offers efficient e-health monitoring services like local repository, signal processing, compression, data mining, notification, etc. However, scalability, energy efficiency, reliability are challenging task. |
| [24] Light weight Smart Gateway | Smart gateway that is lightweight software plug-in connects the Internet systems to home network for providing services like data collection, reporting and awareness. Cloud controller controls policies & assign task to each gateway. To achieve accurate data awareness a multi-dimensional awareness (MDA) frame is also proposed. | The proposed scheme & MDA achieves the accurate awareness, collection and reporting of data. |
| [8] Interoperability between IoT Platforms | Existing schemes are categorized based on their interoperability techniques like gateways, Open API & standards, web technology, virtual network, SOA etc. Survey on interoperability between different IoT platforms & future research directions including research issues challenges are pointed out. | Classification of existing techniques are reported based on their networking technologies, open standards, virtual networks, Gateway, open API, semantic web based interoperability handling. |

## III. PREREQUISITE

Wireless Personal Area Network (WPAN) is used to transfer information over short distances among a private intimate group of participating devices. A WPAN is generally low range networking concept that conveyed information between nodes like personal computers, mobile phones, and digital assistants etc. The communication between the personal digital assistants themselves or to connect to a higher level network and the Internet (Uplink) can be done by using of PANs. WPAN is a PAN carried over wireless network technologies like Wireless USB, Infrared, Z-Waves, Bluetooth, ZigBee, etc.

### *A. IEEE 802.15.1*

IEEE 802.15.1 standard defines PHY and MAC specifications for wireless connectivity with fixed, portable and moving devices within Personal Operating Space (POS). The original goal of IEEE 802.15.1 Task Group was to achieve a level of interoperability that could allow the transfer of data between a WPAN device and IEEE 802.11 device. This standard is based upon technology originally developed by the Bluetooth Special Group (SIG). This standard describes the functions and services required by an IEEE 802.15.1-2005 device to operate within ad hoc network [25]. The RF (PHY) operates in the unlicensed ISM band at 2.4 GHz. The system employs a frequency transceiver to combat interference and fading and provide much frequency hopping spread spectrum (FHSS) carriers. It supports the bit rate of 1 Mbps. This standard provides the effect of full duplex transmission through the use of Time-Division Duplex (TDD) scheme.

*A1. Bluetooth Overview:* Bluetooth is a low-cost, low power wireless networking technology, mainly intended to be a cable replacement between portable and/or fixed electronic devices. Lately, the true potential of the technology begins to reveal itself when it supports low-cost solutions to creating ad-hoc mobile PAN [26]. The idea was born in 1994 when Ericsson mobile communications decide to investigate the feasibility of a cheap radio interface between mobile phones and their accessories (laptops, PDAs, headphones etc). In 1998 Ericsson, Nokia, IBM, Toshiba and Intel formed the Bluetooth SIG. Their intention was to produce a global and open specification to make it possible for everyone to develop Bluetooth products and promote it on the market.

*B. IEEE 802.15.4*

IEEE 802.15.4 is a wireless technology standard to address unique needs of low-cost, low-power wireless networks. It operates in unlicensed bands including 2.4 GHz, 900 MHz and 868 MHz. At 2.4 GHz, it supports total 16 different channels & maximum 250 kbps data rate. For 915 MHz, ten channels are available &supports a maximum data rate of 40 kbps, while at 868 MHz there is only one channel and this can support data transfer at up to 20 kbps. The modulation techniques also vary according to the band in use. Direct sequence spread spectrum (DSSS) is used in all cases. However, for 868 and 915 MHz bands the actual form of modulation is Binary Phase Shift Keying (BPSK). For the 2.4 GHz band, offset Quadrature Phase Shift Keying (O-QPSK) is employed.

The 802.15.2 specification protocol gained ratification by the IEEE in 2003 and currently maintained by the IEEE 802.15 working group. The specification is a packet-based radio protocol intended for low-cost, battery-operated devices. The protocol allows devices to communicate in a variety of network topologies and can have battery life lasting several years. The protocol is designed to communicate data through hostile RF environments that are common in commercial and industrial applications [27].

Standard supports 64 bit IEEE addresses as well as 16 bit short addresses. The 64 bit addresses uniquely identify every device in the same way that devices have a unique IP address. Once a network is set up, the short addresses can be used and this enables over 65K nodes to be supported.

The protocol intend to offer fundamental lower network layers of a type of WPAN, which focuses on low-cost, low speed ubiquitous communication between devices. The emphasis is on very low cost communication of nearby devices with little to no underlying infrastructure, intending to exploit this to lower power consumption even more. The basic framework conceives a 10 meter communications range with transfer rate of 250 Kbps. Tradeoffs are possible to favors more radically embedded devices with even lower power requirements, through the definition of not one, but several physical layers. Lower transfer rates of 20 and 40 Kbps were initially defined, with the 100 Kbps rate being added in the current revision. Even lower rates can be considered with the resulting effect on power consumption. As already mentioned, the main identifying feature of IEEE 802.15.4 among WPAN is the importance of achieving extremely low manufacturing and operation costs and technological simplicity, without sacrificing flexibility or generality. Important features include real-time suitability by reservation of guaranteed time slots, collision avoidance through CSMA/CA and integrated support for secure communications. Devices also include power management functions such as link quality and energy detection.

*B1. ZigBee Overview:* It is the most popular wireless mesh networking standard for connecting sensors, control systems and instrumentation. ZigBee is a specification for communication in a WPAN and it has been called as the "Internet of things". It is an open, global, packet-based protocol designed to provide an easy-to-use architecture for reliable, secure and low power wireless networks. ZigBee and IEEE 802.15.4 are low data rate wireless networking standards that can eliminate the costly and damage prone wiring in industrial control applications. Flow or process control equipment can be place anywhere and still communicate with the rest of the system. It can also be moved, since the network does not care about the physical location of a sensor, pump or valve. The comparative study table between Bluetooth and ZigBee is tabulated in Table II.

TABLE II. COMPARISION BETWEEN BLUETOOTH AND ZIGBEE

| **Wireless parameter** | **Bluetooth** | **ZigBee** |
|---|---|---|
| Frequency band | 2.4 GHz | 2.4 GHz |
| Physical/MAC layers | IEEE 802.15.1 | IEEE 802.15.4 |
| Range | 10m | Indoor: up to 30m, Outdoor (LoS): up to 100m |
| Current Consumption | 60mA (Tx Mode) | 25-35mA (Tx mode) 3μA(standby mode) |
| Raw Data rate | 1Mbps | 250Kbps |
| Protocol stack size | 250 KB | 32 KB , 4 KB (for limited function end device) |
| Typical network join time | >3sec | 30ms typically |
| Interference avoidance method | FHSS | DSSS |
| Minimum quite bandwidth required | 15MHz (dynamic) | 3MHz (static) |
| Maximum number of nodes per network | 7 | 64K |
| Number of channels | 79 | 16 |

## IV. FLOW CHART OF THE PROPOSED GATEWAY SOFTWARE

The flowchart of the proposed gateway architecture is shown in Fig 2.When the gateway starts it will first initiate the Master Agent and listen for the new slave/client connections on the Bluetooth user side. And, at the same time on ZigBee side it gets the address of all ZigBee nodes in the network and stores it in the Data Queue Manager. If there is any request for the new slave connection then it will accept the connection. After that master agent will continuously listen for request from the slave client, if slave client wants to get the list of all ZigBee nodes in the network. It will pass the message command GETLIST to RF COMM Handler and this RF COMM Handler will get the list of all ZigBee nodes from the Data Queue Manager and pass it to interested slave client. If the slave client wants to get data then it passes the message command GETDATA to the RF COMM Handler. After receiving the GETDATA command it will first check whether Data Queue Out exists or not. If Data Queue Out exists then it will fetch the Object Handler and place the client file of the interested slave on the Object Handler and read Data from the Queue Out.

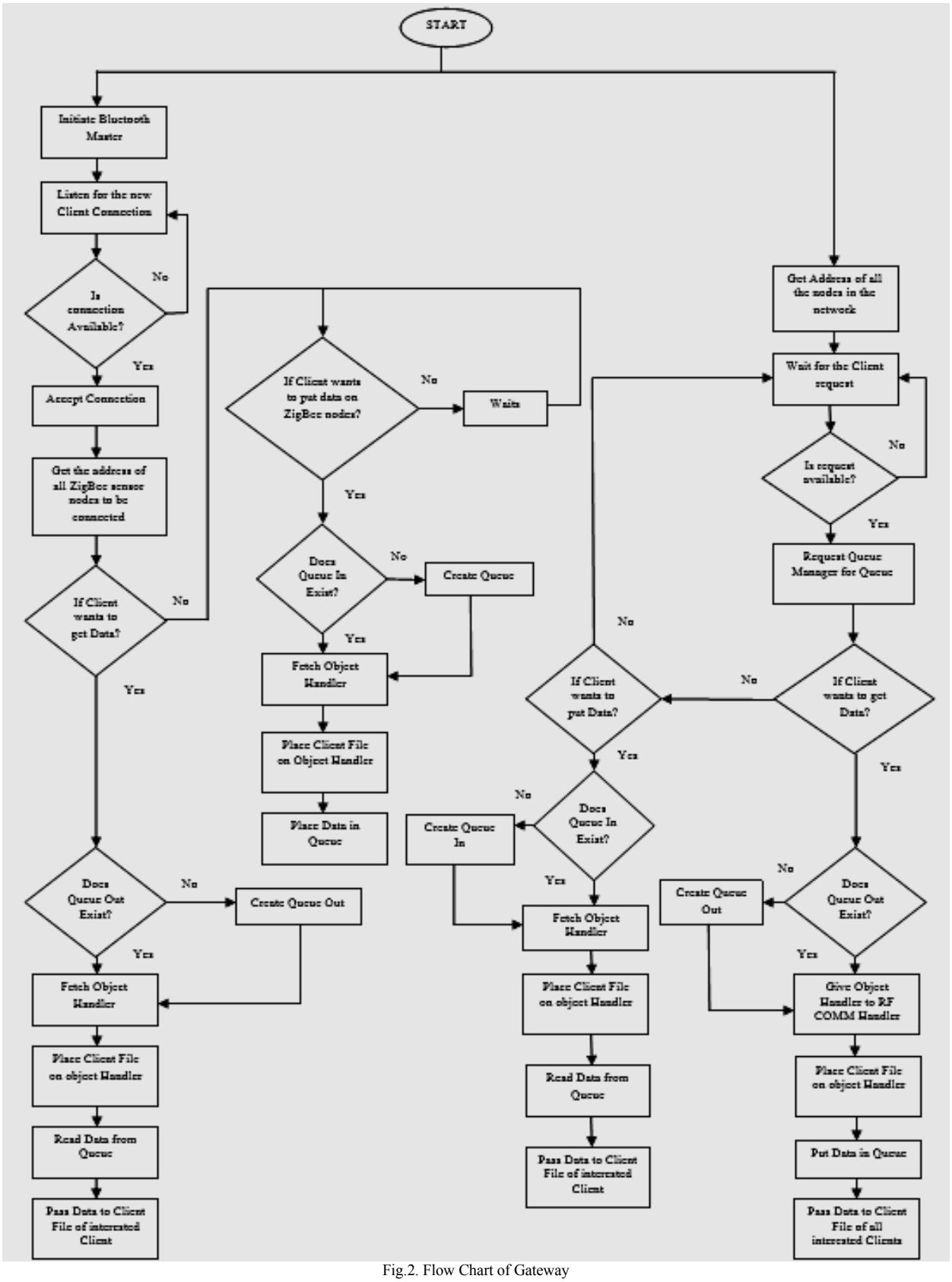


Fig.2. Flow Chart of Gateway

After reading data from the Queue it transmits the data to all the client files of the interested slave. If the Data Queue Out does not exist then it will create the Data Queue Out and then fetch Object Handler and do the same procedure.

If a slave wants to put data on a specific ZigBee node, then it will pass the message command PUTDATA. After that it will check whether Data_Queue_In exists or not. If it exists then fetch the Object Handler and place client file of desired client slave on a particular Object Handler and then puts data on the Data_Queue_In after reading data from client file. If the Data Queue In does not exist then it will first create the Data Queue In and then fetch the Object Handler and do the same procedure.

After getting the address of all the ZigBee sensor nodes in the ZigBee network on the ZigBee side, it will wait for slave client request if there is any slave client request then it will request data queue manager for the queue. After that, it will check whether the slave client wants to put data or the slave client wants to get data. If a slave client wants to get data it will first check whether Queue out exists or not, if it exists then it will give the Object Handler to RF COMM Handler and then place client file on the Object Handler.

After placing the client file on Object Handler, it will put the data in the queue and then pass the data to the client file of all the interested slave clients. If the Queue does not exist then it will first create the Data out queue and then give the Object Handler to RF COMM Handler. If the slave client wants to put data it will first check whether the Queue In exists or not, if it exists then it will give the Object Handler to RF COMM Handler and then place the client file on the object handler. After that, RF COMM Handler will read the data from the client file and then puts the data in the Object Handler. If the queue does not exist then it will first create the Data Queue In after that it will give the object handler to RF COMM Handler. In this way, data flows continuously between IEEE 802.15.1 device and IEEE 802.15.4 sensor node in the ZigBee network with the help of this gateway.

## V. PROPOSED NETWORK GATEWAY ARCHITECTURE BETWEEN IEEE 802.15.4 AND 802.15.1

The multiple threads are associated together in modular and layered fashion to form gateway software. Several modules present in the gateway are Master Agent, RF COMM Handler Agent, Data Collection Service Agent, Queue and Gateway Management. A Mal operation of one should not alter the operation of other modules. To counter this Master Agent, RF COMM Handler and Data collection Service Agent are provided with an individual and dedicated thread. Fig. 3 shows the gateway software architecture.

### *A. Master Agent*

The Master Agent takes the task of listening to the client/Bluetooth user (slave) connections (i.e. to listen if any new Bluetooth device is present or not?). And, when it founds a new Bluetooth device, then it tries to establish the connections and allot the assigned task to RF COMM Handler Agent. Also, a client file is created which is bound to address of that client so that no other client can use it. Once the master agent is initiated, it makes the RF COMM handler to do its work. Client connections are established in an infinite running loop. After establishing the connection, master agent assigns the job of actual information transfer to the RF COMM Handler Agent. There is a separate thread for every client connection that has its individual instance of RF COMM handler agent.

It is a crucial and complex portion of gateway software that has a dedicated thread, where Master Agent awards client file to RF COMM handler agent. RF COMM handler agent receives a message from the master while working inside a loop. This loop never stops until and unless it is disconnected. RF COMM handler is totally reliant on Queue manager hat is unique and created once at a time of gateway software beginning. The protocol for data flow between slave client (i.e. Bluetooth Device) and gateway are defined by RF COMM handler. These protocols consist of three codes namely; GETLIST, GETDATA, &PUTDATA.

GETLIST: It describes a way of carrying out the list of node IDs of various sensor nodes that are available in the ZigBee network of Smart Home. Gateway software stores sensor node IDs list during initialization and it retains updated list. To retrieve the node ID list from the gateway, the client establishes a new connection through the gateway and forwards the GETLIST code. When the gateway receives the GETLIST code then it responds by providing a packed node list, where a special character delimits each node ID. Once task is over, the gateway closes communication and exits thread.

GETDATA: This code represents a scheme to get data of the specific sensor node from IEEE802.15.4 network (ZigBee) (i.e. to get data from a particular power appliance connected to ZigBee sensor node). GETDATA: <NODE ID> is actually the whole syntax of the system. To get information of specific sensor node, client makes a fresh association with the gateway & transmits GETDATA: <NODE_ID> in basic ASCII set-up, where NODE ID is an address of a specified node. RF COMM Handler Agent gets GETDATA code and recovers NODE_ID and then sends a request to Queue manager for DATA_OUT_QUEUE. Whereas, if the data queue is absent, the Queue Manager creates a new DATA_OUT_QUEUE corresponds to NODE_ID. After DATA_OUT_QUEUE creation, Queue manager revising handle object of corresponding queue to the RF COMM Handler agent. Subsequently, the client's file of interested slave clients is stored in Queue handle

Object by RF COMM handler agent. RF COMM handler Agent transmits data to all client file available within the Queue handle object after reading data from the Queue. If information sending to any specific client file is not delivered, then the client file is eliminated from Queue handle Object assuming that slave client has closed the connection. The said method is beneficial in two ways: firstly, a single node can transmit data to multiple clients and secondly, any slave client can accept information from several nodes simultaneously.

PUTDATA: This keyword describes a process for transmitting information to a specific node in the network (i.e. to transmit control message from the Bluetooth device to control a particular power appliance connected with a ZigBee node in the ZigBee network) PUTDTA: <NODE_ID> is actual complete syntax of the method. In order to transmit data to a specified node, a client has to create a fresh connection with the gateway and transmit keyword PUTDATA: <NODE_ID> in pure ASCII data format in which NODE_ID represents the address of a specific node. RF COMM handler agent gets PUTDATA code and re-backs NODE_ID and then sends request to Queue Manager for DATA_IN_QUEUE corresponds to this particular NODE_ID. When the data Queue is available, Queue manager instantly sends back handle object of corresponding DATA_IN_QUEUE. If the data queue is absent, the Queue manager creates a new DATA_IN_QUEUE corresponds to NODE_ID, after DATA_IN_QUEUE creation Queue manager reverts handle object of corresponding queue to the RF COMM handler Agent. Subsequently, the client file of a particular slave client is stored by RF COMM handler agent in Queue handle object. RF COMM handler now puts information in the DATA_IN_QUEUE after reading data from the client file. When there is no reception of data from the client file, the client file is removed from the queue handle object assuming that the slave client has terminated the connection. As against the GETDATA keyword, PUTDATA allows only one slave client to transmit information to a specific node at a particular interval, by doing this scrambling of information from various slave clients are avoided.

### *B. Data Collection Agent*

The work of data collection agent is to collect information from various power appliances which are connected to the ZigBee sensor node in the ZigBee network. All the data collected from the ZigBee sensor node is forwarded to the Data Collection Agent which is then stored in the Data Queue Manager. There is a dedicated thread for Data Collection Agent where it runs and receives packets from the ZigBee PAN Coordinator. After receiving packets from the ZigBee sensor nodes, it also collects the source address from them and asks the Queue manager for the DATA_OUT_QUEUE corresponds to source address (NODE_ID). When the queue is present, the Information packet is put in queue else it is rejected quietly.

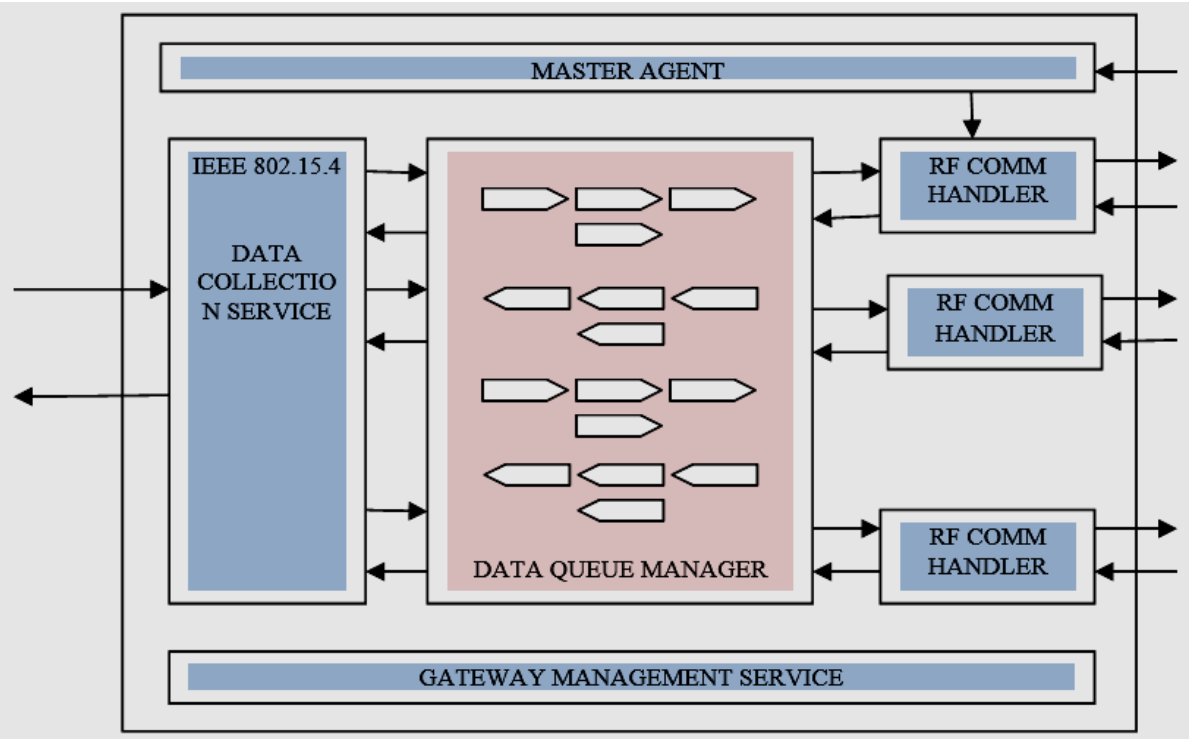


Fig.3. Gateway Software Architecture

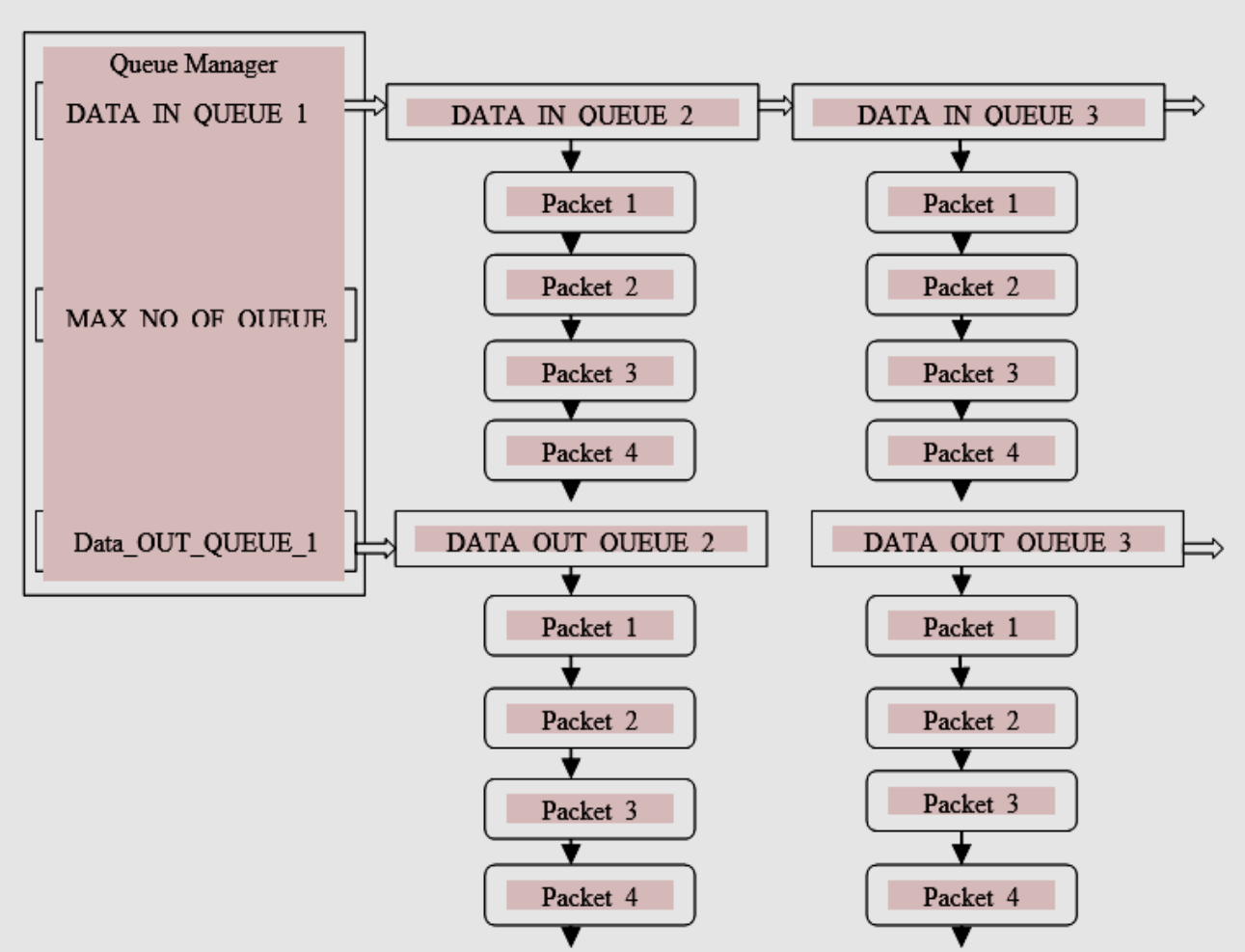


Fig.4. Queue Management Architecture

The DATA_OUT_QUEUE is generated once single or more requests are received from the slave client and if there is no request from the salve client, then there are no requirement of data storage in DATA_OUT_QUEUE. Also, the purpose of Data Collection Agent is to look for vacant DATA_IN_QUEUE; when there is a presence of any information in a queue then it sends that information to a client associated with that DATA_IN_QUEUE.

*C. Queue Management*

Queue Management consists of globally unique object known as Queue Manager Object which operates once at a time of booting. Queue manager generates DATA_IN_QUEUE and DATA_OUT_QUEUE after obtaining NODE_ID from slave client. These generated queues are updated in the list of queues of which handles are stored in Queue Manager Object. Queue manager sends back the handle of these created queues when other slave client requests for data receiving or sending to the corresponding node. This help to maintain data cohesiveness during gateway operation. There is usually front & rear pointer of DATA PACKET in each queue handle. Queue handle also has a pointer to the next queue which in turn forms a linked list of queues and their fronts are kept in Queue Manager Object. The updating of the rear pointer is done by Data Collection Service. Due to overflow and underflow constraints, the front pointer is updated by RF COMM handler agent. Fig 4 shows the Queue management architecture.

*D. Gateway Management*

It monitors the inactivity of any agent with the help of certain time services. When a certain queue is not occupied by the Data Collection Service at any given time interval, then service request queue manager removes the particular queue from the queue list assuming there is no communication. Whereas if the connected slave client is not transmitting any command, the service request RF COMM handler terminates connection and exit thread on which RF COMM handler agent is running.

## VI. CONCLUSION AND FUTURE WORK

The design and architecture of software gateway between IEEE 802.15.4 and IEEE 802.15.1 have been proposed for smart home automation systems that support bi-directional data exchange between IEEE 802.15.4 to IEEE 802.15.1. The proposed software architecture will find use in various circumstances apart from home automation. Furthermore, it can also interact with conventional mobile devices and will be suitable for real-time controlling and monitoring applications as well. In this paper, theoretical model of the gateway is presented. The future direction of our proposed gateway architecture is to practical implementation in the real benchmark. For that appropriate selection of hardware and software with latest Bluetooth and ZigBee version that will support this gateway architecture is needed. For hardware, it requires proper selection of hardware like the microprocessor, Bluetooth controller and IEEE 802.15.4 complaint modules and memory. And for software, selection of an appropriate Linux Kernel, adding suitable device drivers and selection of programming language is needed.

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