2020 2nd International Conference on Advanced Information and Communication Technology (ICAICT) | 978-0-7381-2323-3/20/$31.00 ©2020 IEEE | DOI: 10.1109/ICAICT51780.2020.9333483

6LoWPAN Based Futuristic Smart Architecture for Home Automation

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***Abstract*—IPv6 over Low Power Wireless Personal Area Network (6LoWPAN) is an emerging area of research. It helps to extend network architecture for Wireless Sensor Network (WSN) which allows end-to-end connectivity between a 6LoWPAN node and any IP devices of the network. To make a low powered mesh network, 6LoWPAN is a promising solution on a simple embedded system. It's target is to carry IPv6 packets efficiently within a small link layer of IEEE 802.15.4 frame. Currently the absence of IP address hinders the process of accessing sensors directly. To overcome the problem, IP supporting sensors are necessary. According to 6LoWPAN technology each sensor will have a unique IPv6 address that will be auto-configured. So, the user can easily access the sensors data directly from the Internet without any gateway. In our proposed home automation, we have implemented it through COOJA simulator which is basically designed for wireless sensor network. It is exceptionally helpful for performing various and versatile tasks. It works in framework Contiki. In this proposed system a Contiki-based 6LoWPAN gateway is designed to interconnect with 6LoWPAN nodes through the Internet.Our home automation has found a better end to end communication, mobility, scalability and lower overhead which makes the system more convenient compare to other technology based automated system.**

***Index Terms*—6LoWPAN, IPv6, IEEE 802.15.4, Embedded System, Contiki, Home Automation**

I. Introduction

In this modern world, the smart objects are interconnected with one another and share essential communication towards them by using Internet of Things (IoT) [1] [2] [3] so that People have the choice of making their own smart functionality for example smart homes, smart agricultural systems, smart product management systems,ecological observing systems etc. So we can define the smart home as a global computing environment which is able to provide user context-aware automated services in the form of ambient intelligence. Nowadays, smart home's demand is increasing for living and security. Research found various technologies used in home automation are Bluetooth, Wi-Fi, ZigBee, X10, Z-Wave etc [4].

Currently available home automation models are designed with the help of supporting internet modules. All the sensors are connected with that supporting module. Without the module one will not be able to connect with the remote device from which they have control over the IoT system. Though those are very effective and advantageous, some limitations also arise like coverage in closed and specific area, difficulty in re-organizing room, wired connection creates complexity, incapable of providing the benefit of remote access over internet, short life span of battery and so on. Those limitations end up with the result of high overhead and incompetence of time.

To shorten the puzzle we come up with the idea of modernized technology called 6LoWPAN [5] [6] [7]. It has a large address space by which an extensive number of devices could be integrated to the network. 6LoWPAN convention empowers home computerization gadgets dependent on 802.15.4 remote sensor network measures to be perfect with IPv6 [8]. Here our concept is to make a smart home system based on 6LoWPAN where sensors will be constructed along with home structure. As a result, users will be able to access them from anywhere by using a mobile phone or any remote device. In such a way our attempt help the modern world.

Right now we have faced difficulties to arrange hardware components. That is why we move to implement software simulation. Most devices consume less energy and memory in IoT. Previously designed gateways are not convenient for the demand of lightweight gateways. Regarding that Swedish Institute of Computer Science has come out with the new lightweight embedded OS [8] that is built using the C language, Contiki. A Contiki-based 6LoWPAN gateway has been designed to interconnect nodes to the Internet [9], [10]. Here we have implemented a 6LoWPAN based Home automation by using Contiki.

The main contributions of this paper are as follows:

- Establish a system by which the end user will be allowed to send or collect data from the sensors node.
- The model will have a better lifetime compared to other existing wireless home automation models e.g. Bluetooth, ZigBee etc.
- It will have the ability to be connected with the same or different kind of network.
- It will have the best end to end communication facility which will make the system more functional and beneficial for the user in compare to other models
- If user wants to expand its network with more sensors or want to add new sensors, they will be easily connected with the existing network.

II. Proposed System With Architecture

Figure: 1 represents the architecture of the proposed system. Placement of the sensors are also shown in the figure.

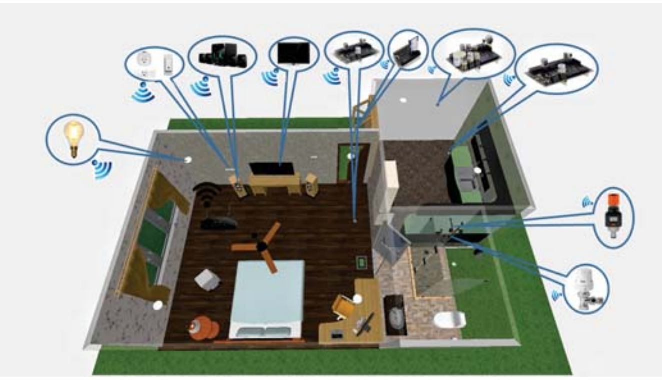

Fig. 1. Proposed Home Automation System

III. Implementation Details

The proposed system is going to solve the issue of transferring data from sensor to device. Considering the software solution, Cooja is going to be used. Cooja is a simulation tool which runs in the Contiki operating system. In the contiki different notes are present in which sky mote is ipv6 supported. So sky mote used to create different nodes of implementation. The Home Automation model has been executed with the help of COOJA simulation software which is shown in Fig. 2. We have tested that model over IEEE 802.15.4 and IPv6. Here, the router establishes the communication between sensor nodes and the Internet. The router is connected on the internet through a public IPv6 address. The sensor nodes are actually the end devices which only send data to its neighbor sensors and routers. On the simulator, the background grid is 10m. Each node has TX range of 50m and INT range of 100m where TX range refers that the transmitted packet can be received easily by any node which are inside of the range while INT range is the range where the transmission of packets can be heard but cannot receive the transmitted packet.

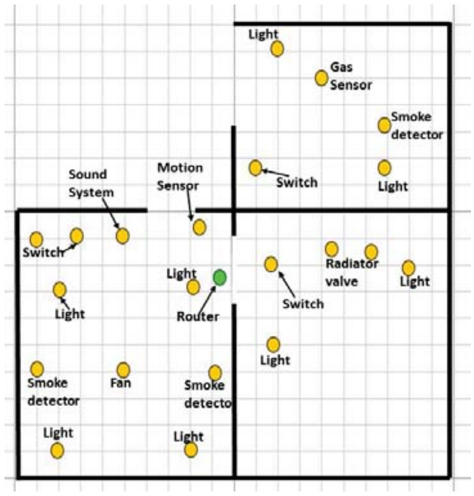

Fig. 2. Proposed model in Contiki

After starting the simulation each node follows some steps to get connected with each other. From Fig. 3 we see the node starts transmitting or receiving data.

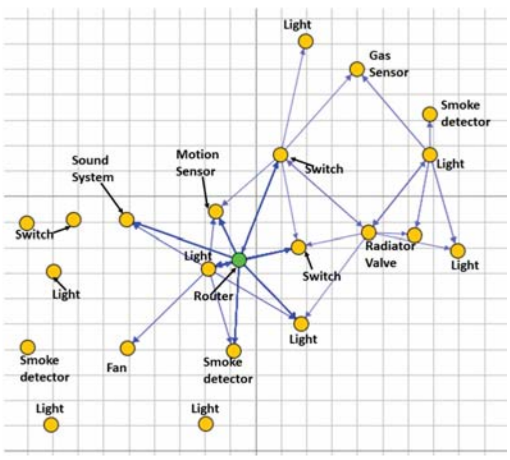

Fig. 3. Data transmission

Now the sensors of that model can be accessed from the internet where the router's neighbors and routes are seen.

IV. Comparative Study

Here we have shown a comparative discussion between 6LoWPAN [11], Bluetooth [12] and ZigBee [11] [12].

Technology	Proposed architecture	Bluetooth architecture	ZigBee architecture
Supported frequency	668 MHz, 915 MHz, 2.4 GHz	2.4 GHz	2.4 GHz
Data rate	250 kbps	1000 kbps	20-250 kbps
Distance	10-200 meters	8-100 meters	10-75 meters
Topology	Star or Mesh	Star or Bus	Star, Tree, Mesh
Certification	IETF/open source	Bluetooth SIG	ZigBee Alliance
IPv6 support	Yes	No	Yes
Packet Size	127 octets	Up to 251 bytes	128 bytes
Peak consumption	TX:12-25 mA, RX:20-35 mA	TX: 15 - 30 mA, RX: 15 - 30 mA	TX:20-30 mA, RX:20-35 mA
Application	Monitoring and control	Data and voice transmission	Monitoring and control
Supporting device for Internet	Router	-	ZigBee gateway

TABLE I
Comparison of 6LoWPAN, Bluetooth and ZigBee

According to the analysis, ZigBee and 6LoWPAN perform much better rather than Bluetooth in terms of monitoring and controlling home devices because Bluetooth modules do not have access over the internet. So it has the ability only to retrieve data. Now in between ZigBee and 6LoWPAN network, 6LoWPAN shows better results on end-to-end delays with authenticity [13].

V. Result Analysis

In our proposed model we have used 21 sensors. Here Fig 4 shows the basic power calculation of our home automation model. As we mentioned earlier in our simulation process, we take 21 sensor nodes where some nodes are directly connected with the router and others have not any direct connection but they can communicate through other nodes. In the figure. We see that every sensor node power consumption has four partitions where the yellow part shows the power consumption of Radio Transmission. It normally produces because of alternative current of radio frequency which may be applied in its antenna. Secondly, the green part shows the power consumption of Radio Listening, the blue part shows the power consumption of CPU and the red part shows the power consumption of LPM.

Fig. 5 shows the routing metrics of sensor nodes. In the COOJA simulator, the routing metrics are calculated by ETX [14]. ETX means Expected Transmission Count. It measures the expected number of data transmission from source node to destination node. Whenever any source node sends a data packet, the destination node sends an acknowledgment that it receives the packet. Otherwise it represents packet loss. If we consider that *df* is the forward ratio and *dr* is the reverse ratio then the formula of ETX will be $ETX=1/df*dr$ [15] [16].
In Fig. 6, the ETX rate decreases with respect to time. It only decreases if the value of *dr* and *df* increases. So it is convenient to get the decreasing value of ETX.

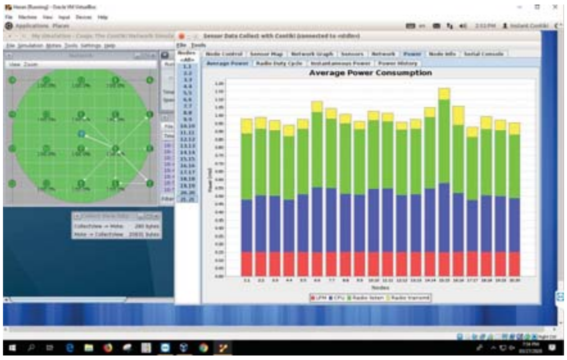

Fig. 4. Average power consumption

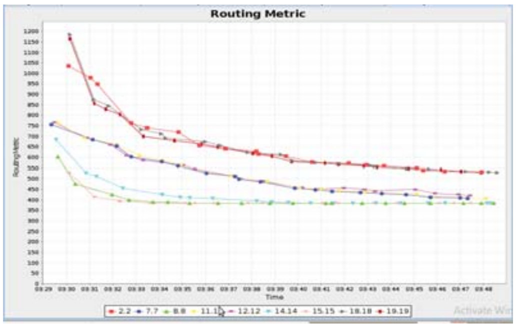

Fig. 5. Routing metrics

Fig. 6. ETX to next hop

VI. Performance Evaluation

Research finds the following benefits comparing to the existing home automation systems:

A. Mobility, Scalability and Connectivity

In our proposed model, the sensors consist of individual IP addresses [17]. Thus the users can access directly to transfer or receive data. For wireless connectivity an Inter-media Gateway (*IG*) has been used between the end devices and the Sensor Nodes (*SN*) [18]. The *IG* authenticates the end devices once they request for connection. So, When we move or add our sensors according to our need, it recreates the connection to the end devices and for that the mobility [19] and the scalability cost of sensors (C_{wsn}) is derived below.

Here,
U = $C_{EN \cdot IG} + C_{IG \cdot 0IG} + C_{IG \cdot SN}$
$V = 3 \times a_{IG} + a_{0IG} + a_{SN}$
$$C_{wsn} = N(2 \times U + V) \quad (1)$$
where,
C_{wsn}= The total mobility cost for our proposed model
$C_{EN.IG}$= The cost of authentication for end devices
$C_{IG.OIG}$ = The cost of sending acknowledgement to the end devices and sensor node
$C_{IG.SN}$ = The cost of authentication for sensor nodes
a_{IG}= Number of IG request
a_{OIG}= Number of IG acknowledgement
a_{SN} = Number of SN request
N= Number of end devices request

When we establish a wire connection of the sensor and get the sensor data from end devices. So when we move our sensor we have to consider the sensor node connection cost C_{SN}, the router connection cost C_{RG}, the internet connection cost C_{GIG} So the total connection cost is

$$C_{wrd} = M \times C_{SN} + N \times C_{GIG} + P \times C_{RG}h \quad (2)$$

Where,
M = is total number of sensor node
N= total number of internet connection
P= total number of router connection
Here we see that when we establish the wireless connection like our proposed model, we need not to consider the extra connection cost of C_{RG} and C_{GIG} where this cost is extra for every time when we move any sensor and add any sensor [5], [20].

B. Battery Life

6LoWPAN home automation node has additives to the battery energy [21]. It can escalate the lifetime and thoroughly run for a maximum chunk of time.Therefore periodical replacement of batteries is not necessary. Through our research [22], [11] we have found that the lifetime of Bluetooth based model is 16.82 days and ZigBee based model is 58.50 days whereas 6LoWPAN based systems get 79.70 days. So, visibly our proposed 6LoWPAN model provides the highest life time from other two models.

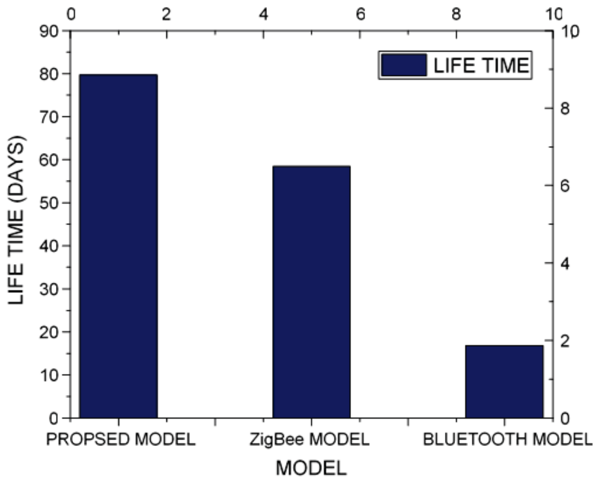

Fig. 7. Lifetime measure

C. Data Rate

Compared to the traditional Home automation model, 6LoWPAN adopts a different approach to the other low power wireless sensor network solutions. Here, the IP networking target for low-power radio communication and applications need wireless internet connectivity at lower data rates for devices with very limited form factor. As It works with the combination of IEEE 802.11 with IEEE 802.15.4 networks so 6LoWPAN makes the border router less complex. So, node to end device connectivity becomes faster because of low overhead. We can measure the overhead by throughput and here the higher throughput indicates the lower overhead.

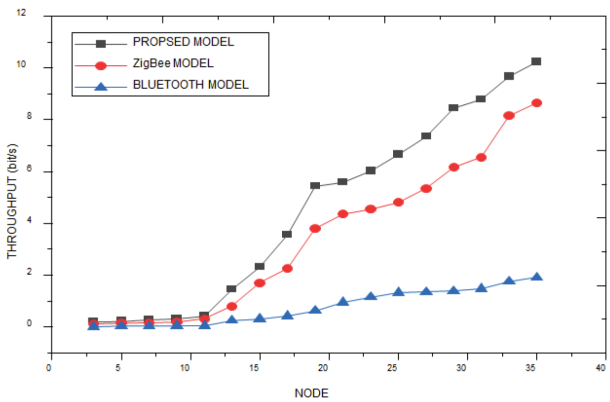

Fig. 8. Throughput of nodes

D. End To End Delay

Moreover, another significant parameter to evaluate our proposed model with others would be end-to-end delay measurement for different number of nodes. Here, end-to-end delay indicates the required time for a packet to travel from source node to destination node.From our proposed simulation model we have found the mean end-to-end delay is 114.9 ms and the ZigBee based model end-to-end delay is 627.9ms. From the value we see that our proposed model has 31 persent smaller delay than ZigBee based model. As a result, our proposed model has better end-to-end communication compare to ZigBee [23].

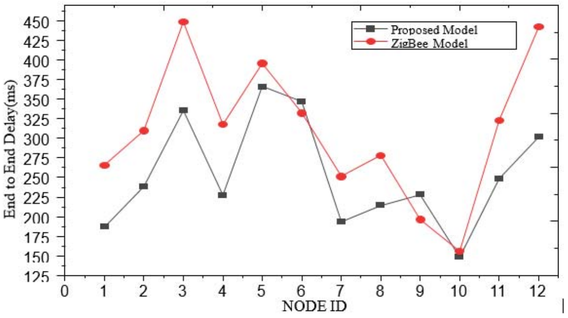

Fig. 9. End to End Delay

Here, in Fig. 9, we see that the end-to-end delay for different node id is different cause delay depends on the length of packet .

VII. Conclusion

In this present era of technology, it has been really easy for us to manage our comfort via the maximum use of technology. But it somehow remains unsorted because of their different drawbacks in different cases. In solution, we have come up with the idea of a state-of-the-art technology called 6LoWPAN that has tremendous scopes to empower the amalgamation of huge quantities of gadgets to the IP network. We have presented our work to develop a well founded arrangement that can dominate home automation devices using 6LoWPAN. Our proposed system facilitates users with the advantage of checking status of gadgets and controlling remotely by virtue of Internet. We have compared our proposed model with existing technology on the basis of mobility, scalability, power consumption and other important aspects. It shows that our proposed model is better than existing models considering those factors. Furthermore, the use of 6LoWPAN communication technology helps lower the expense of the system and the easier end-to-end communication. Finally, we have implemented the simulated Home Automation model. And Our future task will be implementing this simulated model into hardware setup where actual data will be transmitted by sensors and receive by end devices.

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