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CSRMesh Bluetooth technology for speedy automation

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ABSTRACT

The Project aims to employ “CSRMesh Bluetooth Low Energy technology” to design Wireless Switch Panels and Controller Units for speedy installation of home automation solution. Wireless Panels are powered by a battery which would last for years unlike daily charging needed by most of the Wireless devices. These switch panels communicate on low power CSRMesh Low Energy protocol. Similarly, a Controller unit which will be connected at the load side to control the lamps, TV, fans and various other appliances use CSRMesh to communicate with switch panel thereby simplifying cabling in order to achieve speedy installation. Using Bluetooth low energy MESH technology it is possible to establish a powerful wireless network which is prerequisite of wireless connectivity. On successful completion of the above project, wiring complexity in homes should come down by about 80%, turnaround time by 90%, cost of the conduiting and wiring by 60%.

Keywords: CSRMesh, PIC18F28K22, RERA act, Bluetooth module, Touch Controller, MESH service layer, Surface Mounting, BLE characteristics.

1. INTRODUCTION

Under the RERA act, each state is mandated to set up regulatory bodies to protect homebuyers from exploiting practices prevalent in this sector. Such appellate tribunals are going to redress the disputes between buyer and builder within 120 days. Developers will have to put 70% of the money collected from a buyer in a separate account to meet the construction cost of the project. RERA also seeks to impose strict regulations on the promoter and ensure that construction is completed on time. The bill provides for penalty up to 10 per cent of the total project cost or even imprisonment, if builders do not honor their commitment or fail to register themselves with the regulator. Presently, Home Automation deployed homes is good selling proposition and can generate huge business. Besides this builders can reduce costs and efforts by using new and upcoming technology. In light of the above act, home automation systems that are wireless and have fast turnaround time are a boon to the builders as well as the end users. The project aims to achieve installation of speedy automation by using emerging technology.

The project is an embedded system that incorporates Bluetooth module CSR1010 which will be programmed through a microcontroller. The Bluetooth module and microcontroller are together developed by circuit designing, PCB designing and programming using Embedded C. The network will relay its messages using Mesh Networking. The system includes various concepts revolving around Computer Networking, Electronic product Designing and Microcontrollers. The project is an embedded system that incorporates Bluetooth module CSR1010 which will be programmed through a microcontroller. The Bluetooth module and microcontroller are together developed by circuit designing, PCB designing and programming using Embedded C. The network will relay its messages using Mesh Networking. The system includes various concepts revolving around Computer Networking, Electronic product Designing and Microcontrollers. Complexity in the deployment of automation solution - The wiring of smart user interface needs CAT6 cabling whereas wiring of electrical devices - lamps, fans & appliances - AC, TV requires 230V cabling. The problem gets further complicated due to the need for separate conduits to lay the cables.

It is not only time consuming but cost prohibitive also; Lack of skilled installer who can deploy automation solution. The CSRMesh extends the range of Bluetooth by repeating messages (with a minimal propagation delay of 15ms). These messages can be sent to either an individual node or to a group of nodes, in which case the message is relayed until it reaches the right node. Hence there is no single point of failure within the system. Every device will be configured with a unique Device ID which will allow for easy and secure communication between the devices. This could be either done automatically through settings that you have pre-programmed or done on the fly using voice command.

1.1. Objective

- To reduce wiring complexity in homes by about 80%
- To improve the turnaround time of automation deployment by 80%.
- To reduce the cost of conducting and wiring by about 70%
- To reduce dependability on automation expert.
- To control appliances within the house through Bluetooth switch panel which can work on low power.

1.2. Abbreviations and Acronyms

CU	Controller unit
UI	User Interface
Ns	No. of secondary windings
Np	No. of primary windings
Vdc av	Average DC voltage
Vp	Peak voltage
CSR	Cambridge Silicon Radio
BLE	Bluetooth Low Energy

1.3. Equations

Assuming that the transfer rate of device-to-device decreases after a specific distance, d, as a half-normal distribution, we model the transfer rate by the following function.

Then, if the system has N devices, the transfer rate of the signal from the first device to the last device can be described as follows:

$$f(x) = \begin{cases} 1 & 0 < x < d \\ e^{-(x-d)^2/\sigma^2} & d < x \end{cases}$$

Then, if the system has N devices, the transfer rate of the signal from the first device to the last device can be described as follows:

$$h(x) = f_1(x) \cdot f_2(x) \cdot f_3(x) \cdot \dots \cdot f_k(x)$$

Where $f_k(x)$ is the transfer rate from the k-th device to (k+1)-the device.

1.4. Background

Under the RERA act, each state is mandated to set up regulatory bodies to protect homebuyers from exploiting practices prevalent in this sector. Such appellate tribunals are going to redress the disputes between buyer and builder within 120 days. Developers will have to put 70% of the money collected from a buyer in a separate account to meet the construction cost of the project. RERA also seeks to impose strict regulations on the promoter and ensure that construction is completed on time. The bill provides for penalty up to 10 per cent of the total project cost or even imprisonment, if builders do not honor their commitment or fail to register themselves with the regulator. Presently, Home Automation deployed homes is good selling proposition and can generate huge business. Besides this builders can reduce costs and efforts by using new and upcoming technology. In light of the above act, home automation systems that are wireless and have fast turnaround time are a boon to the builders as well as the end users. The project aims to achieve installation of speedy automation by using emerging technology. The project is an embedded system that incorporates Bluetooth module CSR1010 which will be programmed through a microcontroller. The Bluetooth module and microcontroller are together developed by circuit designing, PCB designing and programming using Embedded C. The network will relay its messages using Mesh Networking. The system includes various concepts revolving around Computer Networking, Electronic product Designing and Microcontrollers.

The CSR Mesh protocol allows Bluetooth to create a decentralized network of interconnected Bluetooth Smart devices. Most current, common Bluetooth applications allow for up to seven devices to be available for pairing and yet will allow only two to be active at any time and only within a 33ft/10 meter range. CSR Mesh technology allows each Bluetooth Smart device to communicate with all of the others in the network. Each added device will also extend the working range of the network. With CSR Mesh, you can control up to 65,000 devices in a single network! And if that wasn't enough, there is virtually no limit to the number of networks that can be setup in a given location. CSR is already currently working with a number of undisclosed companies that are building products based on CSR Mesh, set to be launched in the near future. This is going to be a quantum leap for all technology, not just wireless. We all knew it was coming, but CSR Mesh is helping make it today's reality. And if thinking about this has only led you to more questions, you are not alone. Extends the range of Bluetooth by repeating messages. Communicates directly with the phone when the network is robust. Devices are organized into secure networks. Networks are secured using a network key and all devices within the network are trusted devices. Authorization codes are used to prevent a man-in-the-middle attack.

1.5. CSR MESH TECHNOLOGY

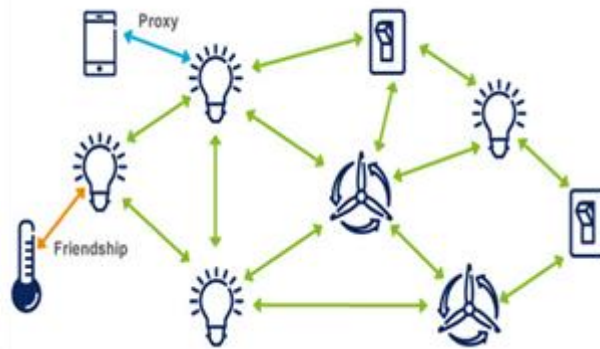


Fig. 1

Bluetooth is one of Wireless Personal Area Network (WPAN) for IoT. Bluetooth has many advantages such as collecting and controlling sensor data from devices due to its low-power consumption, and low latency. In addition, Bluetooth is mostly preinstalled in widely used smartphones. A solution to extend the Bluetooth range is a mesh network. A mesh network is one of the network topologies in which each node forwards data for the network. Bluetooth Mesh is a promising technology for mesh applications but additional effort is required during the ongoing standardization process to exploit its full potential. The demonstrated application has already shown promising results for the Smart Home sector. These results validated that the proposed method extended the available communication range over a range of general Bluetooth communication distance through the mesh network. However, the current work examined communication between devices without obstacles such as wall and furniture. It is necessary to test the system capacity of bypassing blocked obstacles on the paths between communicating devices.

The project tries to incorporate technology that is both low power yet efficient so that a sustainable system can be developed. The system uses - microcontroller and CSR1010 Bluetooth module which operate on low power. The CSR1010 enables the various modules to form a mesh network which helps in the easy and fast relay of messages. This mesh networking also helps in connecting various devices over a long distance, thus increasing the coverage area of the entire network. The technical aspects used in the project help us form a sustainable, yet "speedy" network. Bluetooth Low Energy was first introduced in Bluetooth Specification 4.0 and is a more economical version of the classical Bluetooth Protocol. The main focus of BLE is to provide nodes with a low power consumption by exploiting extended sleep phases of the transceiver. The characteristic functionalities of BLE remain similar to those of the classical Bluetooth, with the biggest difference being the increase of its channel bandwidth, reducing the number of channels from 80 to 40. Out of the available 40 channels, 3 have been reserved to send broadcasts and advertisements, while the remaining 37 channels are used for the traditional frequency-hopping once the connection is established.

There are other technologies such as 802.11s or 802.15.4 that are capable to form mesh networks and can be applied to sensor networks as well. However, they were designed with different goals. Wi-Fi devices are usually not employed in low energy scenarios and rather focus on networks formed by smartphones, tablets, or notebooks in contrast to sensing or actuating devices. But 802.11s is interesting for applications that require high data rates or as backbone connection between different subnetworks. 802.15.4 Was designed for sensor networks with a fixed topology where many sensors try to forward messages to one sink. The design focus is on low data rates and low energy consumption.

BLE mesh can fill that gap since it uses multiple channels and provides better data rates than 802.15.4. Besides that, it is widely available in various devices allowing easy access to the network and thus enables new applications.

MESH Service Layer: Mesh node is an implementation of a node in the mesh networking topology. Mesh node is identified by the mesh instance Id. Mesh node decodes the received advertisement and data messages and acts upon mesh specific messages.

The CSRMesh extends the range of Bluetooth by repeating messages (with a minimal propagation delay of 15ms). These messages can be sent to either an individual node or to a group of nodes, in which case the message is relayed until it reaches the right node. Hence there is no single point of failure within the system.

Every device will be configured with a unique Device ID which will allow for easy and secure communication between the devices.

The messages that are sent by the device will be encrypted, thus preventing any eavesdropping on the network and making it secure. The system is simple: Use a Bluetooth-based mesh network to perform tasks remotely, such as monitoring and updating beacons or tracking and finding assets throughout a fleet of Bluetooth-enabled devices and nodes. Control and monitoring can be done directly on the network from a smartphone, and access is possible via a gateway. Heat maps, dwell times, and other useful data can be collected and passed to a back-end service for analyses. Whether finding lost items, pushing software updates to multiple beacons, or uncovering valuable analytical data, CSRmesh is designed to meet the growing needs of the IoT. The more devices or nodes in a mesh network, the stronger it becomes. If there were one hundred other people in the building, wherever you and I were, our phones would have countless routes through which they could send messages. If Tina's phone ran out of battery, the message would automatically be routed through a different series of nodes to reach you.

How will mesh technology help make the Internet of Things a reality and what is the role of Bluetooth Smart?

Mesh technology is a key enabling technology for the Internet of Things. It is important that things can have access to information from the Internet, and provide information to the Internet, regardless of how far they are from an access point. Also, these things must be very low energy consuming devices, so using Bluetooth Smart in these devices is obvious. By combining the low energy requirements of Bluetooth Smart and Mesh technology, we can create a more extensive network of things.

How will mesh networking enable smarter homes and buildings?

Devices that are part of a mesh network have the ability to not only signal information to other devices within this mesh network but to also receive such signals. Because mesh networks connect every device to every other device, any device within the mesh network can receive all these messages, make inferences based off the content and timing of these messages, and then send out additional messages that are smart. For example, somebody walking down a hall or corridor would trigger occupancy sensors in a sequence, and other things like lights, door unlocking, and opening would be triggered based on this.

How does mesh technology overcome the limitations of other connectivity solutions?

Removing the single-hop topology restrictions of these connectivity solutions means that whole homes or whole buildings can be covered with a mesh network. Also, because the CSR Mesh is based on existing Bluetooth low energy wireless technology, known as Bluetooth Smart, it has the same excellent robustness and interference mitigation techniques that enable it to work seamlessly with existing Wi-Fi installations. The CSR Mesh also has the ability to overlay networks in the same building, so you could have a facilities network, an employee network, and individual room networks. To track the asset, CSRmesh uses the network to pass data collected from the moving object back through the mesh, to a back-end service where the data can be analyzed and acted upon. That asset can then be tracked, and movement heat maps and dwell times can be built to find out where the moving item is. CSRmesh is engineered to simplify the beacon management process by supporting standard Bluetooth beacons within the same mesh network to talk to each other. As long as each beacon is within the Bluetooth range of another, an entire building can be covered. CSR Mesh aims to place smartphones at the center of the Internet of Things (IoT), allowing for an almost unlimited number of Bluetooth Low Energy (BLE) enabled devices to be networked together and controlled directly from a single smartphone, tablet, or PC. Optimized for smart home and IoT applications, CSR Mesh doesn't have the limited range or required hub of similar technologies.

1.6. WORKING

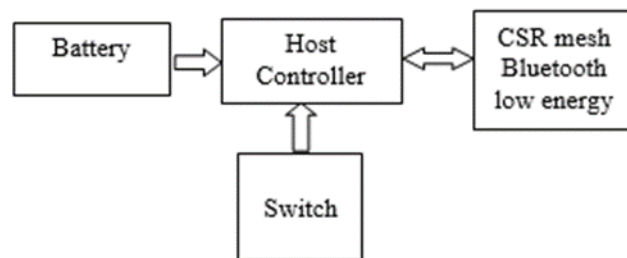


Fig. 2 User Interface Block

Microcontroller (PIC18F26K22): The microcontroller will be programmed using Embedded C and will communicate with the CSR1010 module through the UART. It uses two pins for communication, TX and RX. It interfaces switch in the Interface unit.

MICRO-CONTROLLER

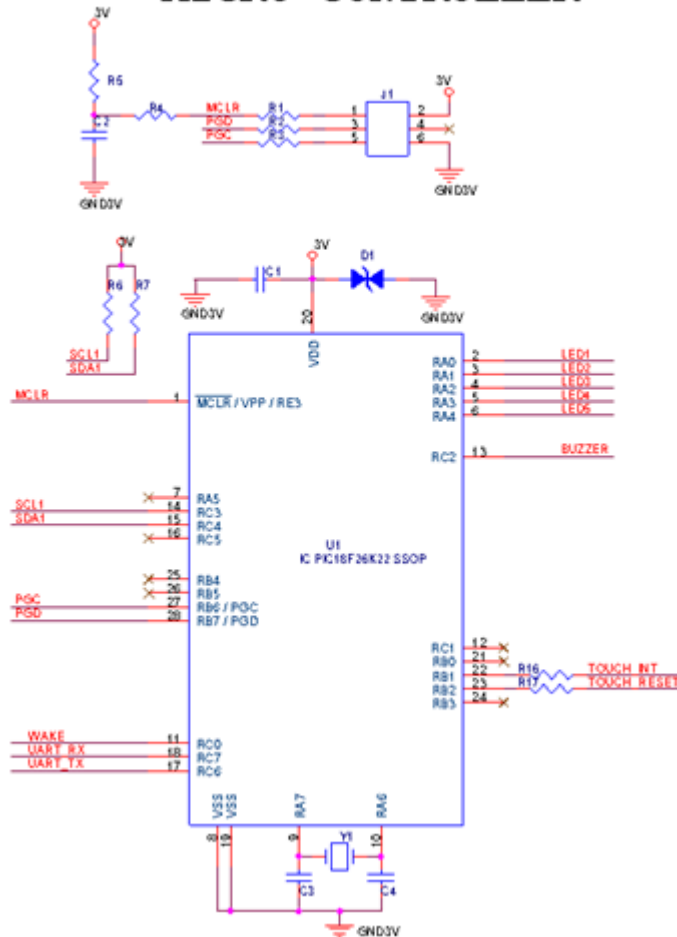


Fig. 3 Micro-Controller Module

CSR1010 (Bluetooth Module): The CSR1010 is a low powered, cost-efficient Bluetooth module that enables Mesh Networking, allowing the system to relay messages over long distances hence increasing the network area of the system. This module works on Bluetooth low energy enabling battery to last for many years.

The power supply is regulated to provide the required voltage for the working of the host controller and the CSR1010 Bluetooth module.

The CSR1010 will receive and decrypt the message and send it to the microcontroller. The microcontroller will process the message and take the appropriate action, e.g. switch on or off. If the message is not meant for that node, the message will be relayed on until it reaches the right node and the same process will be carried out there.

The battery supplies the required voltage for the working of the host controller, CSR1010 Bluetooth module, and the Touch Controller. Bluetooth low energy is an attractive proposition for manufacturers because of its compatibility and interoperability with standard Bluetooth. Unlike other technologies such as ZigBee, Bluetooth low energy can build on the existing billions of Bluetooth devices already in the market. Bluetooth low energy is being added to existing Bluetooth silicon for a negligible cost and with no need for redesign. Compared to alternative technologies this is a massive advantage. Low energy can also enable gateways from small devices such as weighing scales, out onto the internet via these same mobile phones. This not only increases data revenues for operators but also connects your devices to websites and the internet to your devices

When a touch is detected by the Touch Controller, it wakes up the microcontroller and CSR module. Corresponding to touch button, Touch Controller sends the touch button address to host microcontroller.

The microcontroller will process this request and send the appropriate commands to the CSR1010.

The CSR1010 will then encrypt and transmit the message to the other nodes, and these will relay the messages to the correct node. A resistive touch screen panel is coated with a metallic electrically resistive and conductive layer that can cause a change in the electrical current which is registered when touched and sent to the controller for processing.

A capacitive touch screen panel is coated with a material which stores electrical charges. When touched, a charge is drawn to the point of contact and circuits located in the panel measure that charge and then send the information to the controller to process it.

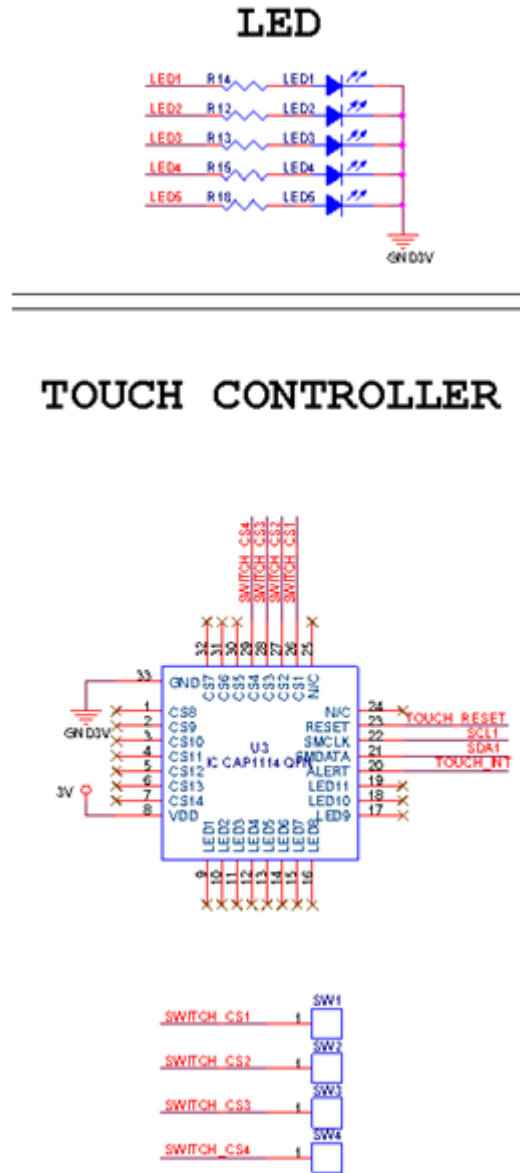


Fig. 4 Touch Controller and Led

This module allows you to wirelessly extend your serial interface, Hence any program running on your Laptop feels it's controlling a local serial port (which is over a wireless Bluetooth link). The 4 pins are +5V, GND, TXD, RXD. Supply voltage should be 3.3 - 6 V. Absolute maximum is 7 V. The maximum baud rate can be configured to 1382400bps, but 115200bps is recommended for reliability purposes.

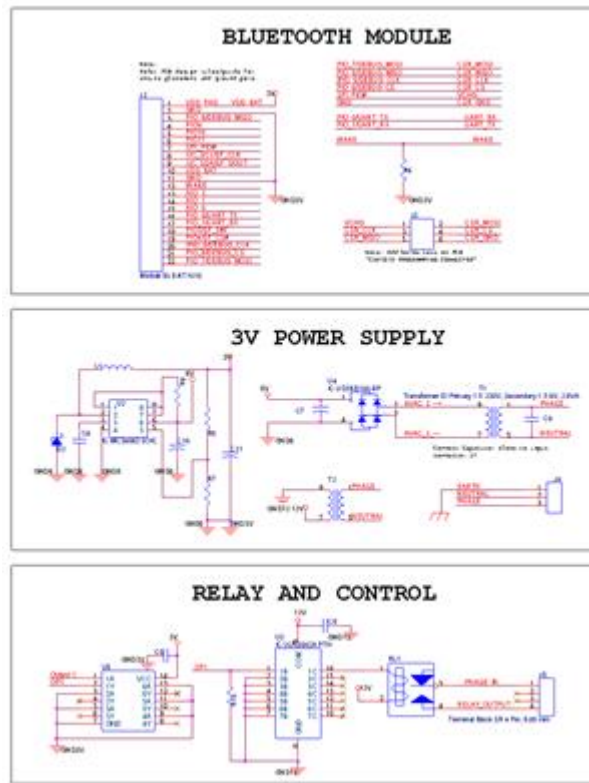


Fig. 5 Bluetooth Module, Power supply, and Relay Control

Automation System has two parts: User Interface (UI) and Controller Unit (CU). Where the UI is used for easy interaction between the user and device, the CU is the “brains” behind the operation of the system. Here, The CU is used to operate the lights or various appliances in the house. The CU has various functions including DC power supply, Microcontroller, Bluetooth module and relay circuitry to control lights and appliances.

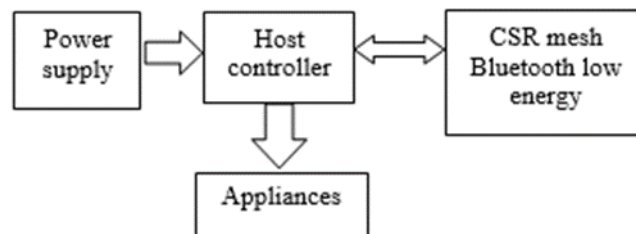


Fig. 6 Controller Unit Block

The input AC voltage (230 Volts Vrms), is given to a transformer. The transformer output will be a stepped down AC. The stepped down AC voltage is then given to a bridge rectifier to convert AC into DC. The filter removes AC ripples using ripple capacitor. The smoothed voltage is further processed using a regulating circuit, an LDO regulator, whose output will be a constant dc voltage. Relay controls phase given to lights or appliances depending on the signal flowing through its coil which is received from the microcontroller

BLE CHARACTERISTICS

Parameter	Value
frequency band	2.4 GHz
number of channels	40
reserved for broadcasts	3
data rate	1 Mbit/s
Range	10 – 100m

MESH Service Layer: Mesh node is an implementation of a node in the mesh networking topology. Mesh node is identified by the mesh instance Id. Mesh node decodes the received advertisement and data messages and acts upon mesh specific messages.

Application Layer: This can have various mesh applications like chat application, torch light sensor activation, and file sharing in a group. The application layer will be used for light activation.

BLE Connection: A BLE Logical Link Control and Adaptation (L2CAP) channel is a logical connection between two endpoints of peer devices.

Advertisement Manager: The advertisement manager transfers the advertisement messages from mesh service layer to BLE framework layer.

Surface-mount technology (SMT) is a method for producing electronic circuits in which the components are mounted or placed directly onto the surface of printed circuit boards (PCBs). An electronic device so made is called a surface-mount device (SMD). In industry, it has largely replaced the through-hole technology construction method of fitting components with wire leads into holes in the circuit board. Both technologies can be used on the same board, with the through-hole technology used for components not suitable for surface mounting such as large transformers and heat-sinker power semiconductors. By employing SMT, the production process speeds up, but the risk of defects also increase due to component miniaturization and to the denser packing of boards. In those conditions, detection of failures has become critical for any SMT manufacturing process. An SMT component is usually smaller than its through-hole counterpart because it has either smaller leads or no leads at all. Mass produced electronic circuit boards need to be manufactured in a highly mechanized manner to ensure the lowest cost of manufacture. The traditional leaded electronic components do not lend themselves to this approach. Although some mechanization was possible, component leads needed to be pre-formed. Also when the leads were inserted into boards automatically problems were often encountered as wires would often not fit properly slowing production rates considerably.

It was reasoned that the wires that had traditionally been used for connections were not actually needed for printed circuit board construction. Rather than having leads placed through holes, the components could be soldered onto pads on the board instead. This also saved creating the lead holes in the boards which added cost to the production of the bare PCBs.

SMT is used almost exclusively for the manufacture of electronic circuit boards these days. They are smaller, often offer a better level of performance and they can be used with automated pick and place machine that in many cases all bit eliminate the need for manual intervention in the assembly process.

1.7. Figures and Tables

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2. CONCLUSION

Since CSRMESH Bluetooth Low Energy is an emerging technology, the economy of scale is extremely unfavorable and it is understandable. For example CSR module for the quantity of 1 costs 8\$, where else for the quantity of 1000 it costs 3\$. When such modules are used in 100's of 1000's then it will cost about a 1\$. So we expect around 3 year's Gestation time for this technology to be affordable to masses. If the development of the solar technology it is possible to power the switch panel by the solar cell. As automation has become a necessity of modern life, it is essential to have such solutions being rolled out by industries. It is just a matter of time that such solution is widely accepted by many manufacturers. Mesh technology is a key enabling technology for the Internet of Things. It is important that things can have access to information from the Internet, and provide information to the Internet, regardless of how far they are from an access point. Also, these things must be very low energy consuming devices, so using Bluetooth Smart in these devices is obvious. By combining the low energy requirements of Bluetooth Smart and Mesh technology, we can create a more extensive network of things.Devices that are part of a mesh network have the ability to not only signal information to other devices within this mesh network but to also receive such signals. Because mesh networks connect every

device to every other device, any device within the mesh network can receive all these messages, make inferences based off the content and timing of these messages, and then send out additional messages that are smart. For example, somebody walking down a hall or corridor would trigger occupancy sensors in a sequence, and other things like lights, door unlocking, and opening would be triggered based on this.

Qualcomm Bluetooth Mesh is designed to allow Bluetooth Low Energy devices to send and receive messages, act on received messages, and repeat those messages to nearby devices. Qualcomm Bluetooth Mesh extends the range of Bluetooth wireless technology by turning Bluetooth-enabled devices into a security-rich mesh network for the Internet of Things (IOT).

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