International Research Journal of Engineering and Technology (IRJET) e-ISSN: 2395-0056
Volume: 07 Issue: 10 | Oct 2020 www.irjet.net p-ISSN: 2395-0072

A Study on Integrating Wireless Mesh Networking in IoT Systems

Ms. Manvi[1], Mr. Sunil Kr. Maakar[2]

[1]M.Tech. Scholar, Dept. of Computer Science Engineering, B.R.C.M.C.E.T., Bahal, Haryana, India
[2]Assistant Professor, Dept. of Computer Science Engineering, B.R.C.M.C.E.T., Bahal, Haryana, India

---

Abstract - *Here in this paper a study was carried out to gather the knowledge about wireless mesh network topology and how one can integrate this networking technique with the IoT systems. Mesh networking with its characteristics and limitations were discussed here in this paper. Also a comparative analysis was done here between the mesh networking and cellular networking. For implementing a wireless mesh with IoT systems a Wi-Fi powered high performance computational platform was required. Wi-Fi protocol was considered here for establishing connection between multiple nodes. Here it was found that as these nodes were to connect in a mesh network, there was no central node or parent node in this system instead here each node involved in data sharing with every other node available. Also multiple nodes were to connect using same Wi-Fi credentials.*

Key Words: WLAN, NodeMCU, Mesh Network, WiFi, IoT, etc.

1. INTRODUCTION

1.1 Internet of Things (IoT)

The IoT can be described as an extension of the internet and other network connections to different sensors and devices — or "things" — affording even simple objects, such as lightbulbs, locks, and vents, a higher degree of computing and analytical capabilities. Interoperability is one of the key aspects of the IoT that contribute to its growing popularity. Connected or "smart" devices — as "things" in the IoT are often called — have the ability to gather and share data from their environments with other devices and networks. Through the analysis and processing of the data, devices can perform their functions with little or no need for human interaction. Manufacturers are adding sensors to the components of their products so that they can transmit data back about how they are performing. This can help companies spot when a component is likely to fail and to swap it out before it causes damage. Companies can also use the data generated by these sensors to make their systems and their supply chains more efficient, because they will have much more accurate data about what's really going on. With the introduction of comprehensive, real-time data collection and analysis, production systems can become dramatically more responsive. The "things" that make up the IoT can be anything from a wearable fitness tracker to an autonomous vehicle. No matter what function they serve for users, these devices must have the following components for them to properly operate as parts of their respective IoT systems.

1.2 Mesh Networking

A mesh network allows you to extend the reach of the IoT device network by allowing each device or node on that network to act as a router. It allows the data to hop from device to device so that the radios too far apart to hear each other directly can still communicate. Here each device is connected to all other devices in the network. If the total number of devices in the mesh network are 'n' then each device must be connected to 'n-1' number of devices and total number of links can be calculated by using the formulae provided below:

Total no. of links, L = [n*(n-1)] / 2

In a mesh network the routing is taken care by the protocol itself. In mesh networking the networks can form and fix themselves automatically. In a non-mesh network or point-to-point network the data can be passed between nodes that can hear each other but never to the devices that are out of direct range. Similarly, in a point-to-multipoint network the communication is usually simpler and faster. However, it is limited to the reach of individual radio nodes. In a Mesh Network there is no single point of failure and every radio node can communicate with every other radio node on the network, no matter how far away they are as long as there is a valid route. If one route becomes disabled, the network will automatically rebuild a route through another radio node so that the information can still reach its destination. But there is a trade-off of greater latency. In other words, there is a longer delay between the sending and receiving information in some cases and added complexity in putting the network together.

Characteristics of Mesh Network Topology

- The dedicated link in mesh network topology guarantees that each connection can carry its own data load. Each device or node is dedicatedly connected point-to-point to every other node in the network.
- It is robust and eliminate the traffic congestion problem in networks
- In mesh networking the failure in one link does not harm other links
- There is privacy and security
- Fault identification and fault isolation is easy in mesh network topology

Limitations of Mesh Network Topology

- In mesh network topology there are more number of links, more cables and i/o ports are required and hence proved to be an expensive
- The connections and maintenance is complicated in case of mesh networking
- Installation and reconnection are difficult
- Hardware required to connect each link is expensive

Mesh Networking vs Cellular Networking for IoT

Mesh networking allows you to extend the reach of an IoT device network by allowing data to hop from device to device so that the radios too far apart to hear each other directly can still communicate while in a cellular technology each device communicates through the cellular network but never directly with each other

Network Type	Number of Devices	Network Coverage	Device Communication	Communication Frequency
Mesh	Many in the same location	Cellular network coverage not available	Devices talk a lot to their neighbors	More Frequent
Cellular	10 or less at one location	Cellular network coverage available	Devices mostly talk to the Cloud	Less Frequent

Table-1: Mesh Networking vs Cellular Networking

Mesh networking is a good solution when you have many devices in the same location or anytime cellular coverage is not available. It is good for network where devices talk a lot to their local neighboring devices and when communication between these devices is frequent. For example, mesh networking is a popular choice for municipal street lighting control. Street lights are typically placed very close to each other so there are many in the same location. They may interact locally. Let us suppose, if one street light goes out its two neighboring street lights may want to sense that and turn up their brightness levels to compensate. Automated joining and self-healing help keep the street light network stable. Cellular networks are good choice when there are relatively few devices per location, generally, 5 to 10 on each local site. It's great when devices are mostly talking to the cloud and have little need to talk to each other. Of course, the cellular network has to be available. As the cellular data plan is paid and not free thus the user prefers to keep the communication short and to the point. Cellular network is a popular choice for applications like tank monitoring. For example, diesel fuel tanks for emergency generators. The user may want to know the current condition and fuel levels of each tank. There are typically few nodes per location and they only need to communicate once in a while to state the current fuel level or to send an alarm if there is some other critical issue. As these devices are remotely located Wi-Fi and Wired Ethernet typically is not available and as each device talks directly to the cloud, no interactions between the devices themselves is required.

2. OBJECTIVE

The objective behind this work was to integrate wireless mesh networking topology with that of an IoT network. The purpose was to demonstrate the practical aspects of integrating these two networks by implementing a system around ESP-32 devices with some sensors and other input/ output devices. The proposed work was to establish a wireless communication between three Wi-Fi enabled ESP-32 nodes sharing the same Wi-Fi credentials (ssid, password and port) for the transfer of data between them without using internet and without using any router. The Wi-Fi credentials used here in this mesh network must be arbitrarily chosen by the user and it should not entail user's mobile Wi-Fi hotspot credentials for its operation. The system should be able to connect automatically with all the nodes. Each node connected in this wireless mesh network should be able to talk and hear from other two nodes in real-time. The experimental set-up should validate the work.

3. PROBLEM FORMULATION

- To choose and acquire knowledge about the computational platform with integrated Wi-Fi SoC for the implementation of proposed work
- To gather information about the basic characteristics of wireless mesh network topology and its implementation so that the remotely deployed nodes in the system could be able to communicate with each other remotely without any internet or router in between
- To design an architecture of the proposed system with all the components properly organized
- To study about some sensors, relay, push buttons, OLED display and LED deployed here in the hardware experimental set-up for the demonstration
- To design the schematic and develop the hardware for all three nodes centered around the NodeMCU boards along with input/ output devices
- To design algorithm and write firmware for every individual node in the Arduino IDE (Integrated Development Environment)
- To calibrate the system for the desired results by performing multiple iterations of testing and debugging the source code and finally uploading it in each node
- To observe the response of experimental set-up and validate the work with desired experimental results

4. PROPOSED WORK

An IoT system was proposed here that embraces design and development of three individual Wi-Fi enabled nodes around the NodeMCU ESP8266 boards. The three nodes were to

interface with input/ output peripherals and sensors so as to interact with each other. To establish communication between these nodes the mesh network topology was required to be integrated with this IoT network. All the nodes were to connect in a Wi-Fi network. To implement this mesh network user was required to choose its own Wi-Fi credentials to establish a wireless adhoc network and also it should be taken care of that all the nodes must share the same Wi-Fi credentials in their source code, otherwise the communication between those would never be possible.

5. SYSTEM ARCHITECTURE

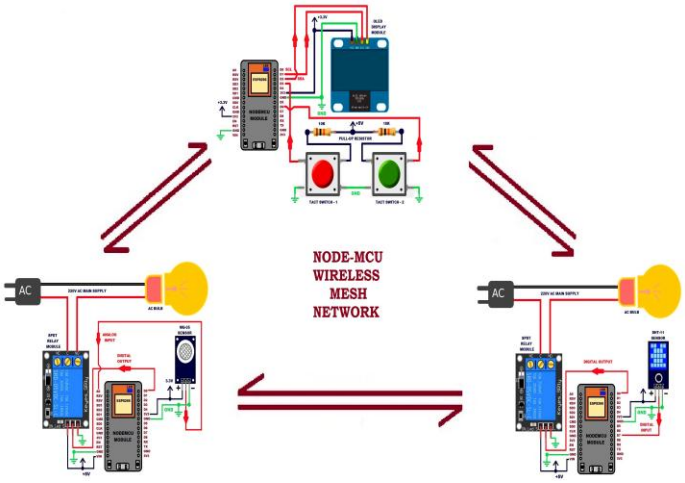

FIG 1: System Architecture

In this system architecture, three individual nodes were developed and centered around three ESP32 NodeMCU Modules as shown in figure below. The three nodes of this IoT network were interfaced to some trigger and action devices and also with some sensors to measure environmental parameters and acquire data for monitoring purpose here.

NodeMCU 1 module was interfaced to:

- Input Device: Two tactile Push Buttons
- Output Device: OLED Display Module

NodeMCU 2 module was interfaced to:

- Input Device: MQ-135 Sensor Module
- Output Device: Relay Switch Module

NodeMCU 3 module was interfaced to:

- Input Device: DHT-11 Sensor Module
- Output Device: LED Indicator Module

All these nodes were connected in a mesh network topology and establish wireless connectivity to interact with each other using the Wi-Fi protocol. Each node was transmitting as well as receiving the data from other two nodes within this network without using any internet and router in between.

6. CONCLUSIONS

Here it could be easily observed and verified that to establish communication between multiple nodes in a wireless network could be through a router if it were a traditional Wi-Fi network which has its own set of limitations or it could be attained without using any router in between via a mesh network topology which has its own set of benefits. Here it was successfully demonstrated that a local wireless local area network could be established between multiple nodes without even using the internet. The number of nodes could increase to a significant level using this mesh network topology as here the nodes are mutually responsible for relaying each other's transmissions and these interconnected nodes resulted in a much larger coverage area.

REFERENCES

[1] Emanuele Di Pascale; Irene Macaluso; Avishek Nag; Mark Kelly; Linda Doyle, "The Network as a Computer: A Framework for Distributed Computing Over IoT Mesh Networks", IEEE Internet of Things Journal, 2018, Volume: 5, Issue: 3, Journal Article, Publisher: IEEE

[2] Khalid Haseeb; Ikram Ud Din; Ahmad Almogren; Naveed Islam; Ayman Altameem, "RTS: A Robust and Trusted Scheme for IoT-Based Mobile Wireless Mesh Networks", IEEE Access, 2020, Volume: 8, Journal Article, Publisher: IEEE

[3] Xiaofan Jiang; Heng Zhang; Edgardo Alberto Barsallo Yi; Nithin Raghunathan; Charilaos Mousoulis; Somali Chaterji; Dimitrios Peroulis; Ali Shakouri; Saurabh Bagchi, "Hybrid Low-Power Wide-Area Mesh Network for IoT Applications", IEEE Internet of Things Journal, 2020, Early Access Article, Publisher: IEEE

[4] Hamid Al-Hamadi; Mohammad Saoud; Ing-Ray Chen; Jin-Hee Cho, "Optimizing the Lifetime of IoT-Based Star and Mesh Networks", IEEE Access, 2020, Volume: 8, Journal Article, Publisher: IEEE

[5] Rajiv Kashyap; Mohamed Azma ; Jithu G. Panicker, "Ubiquitous Mesh: A Wireless Mesh Network for IoT Systems in Smart Homes and Smart Cities", IEEE International Conference on Electrical, Computer and Communication Technologies (ICECCT), 2019, Publisher: IEEE

[6] Muhammad Usman Qadeer; Sheroze Liaquat; Muhammad Ali Shafique; Abdul Rahman Kashif, "Implementation of Wireless Mesh Network for IoT based Smart Homes", International Symposium on Recent Advances in Electrical Engineering (RAEE), 2019, Volume: 4, Publisher: IEEE

[7] Kanitkorn Khanchuea; Rawat Siripokarpirom, "A Multi-Protocol IoT Gateway and WiFi/BLE Sensor Nodes for Smart Home and Building Automation: Design and Implementation", 10th International Conference of Information and Communication Technology for Embedded Systems (IC-ICTES), 2019, Publisher: IEEE