Implementation and Comparison of Low Power Wireless Protocols in a Mesh Topology

Amani Nafkha[1] and Paulo Matos[1]

Research Centre of Digitalization and Intelligent Robotics (CeDRI), Instituto Politécnico de Bragança, Bragança, Portugal
amani.na.nafkha@alunos.ipb.pt,pmatos@ipb.pt

Abstract. The Internet of Things is one of the upcoming networking that helps bridge the gap between the real world and the virtual world by enabling monitoring and control of certain elements.

The critical point for the future is the design with low power wireless technologies based on mesh topologies because it is very attractive due to their reliability and scalability of failures. In this report, we provide an overview of the most popular short-range wireless communication standards, such as BLE, Zigbee, and Thread technologies, comparing their key features and behaviors in terms of various metrics, network topology, security, quality of service, and power consumption.

This study presented in this work will be useful to the application in selecting the best technology for a concrete use of the low power wireless protocol.

Keywords: IoT , BLE , Zigbee, Thread.

1 Introduction

The combination of advances in hardware and networking has given rise to the Internet of Things (IoT), which aims to enable everyday objects to collect and exchange data over the Internet through small sensing devices.

Millions, if not billions, of Internet sensors embedded around the world provide an incredibly rich set of data that companies can use to collect data on the safety of their operations, track their assets and create new business opportunities. These objects have a variety of computing and sensory capabilities and offer complex interactions with their environment or users. The scope of IoT applications is vast. By installing sensors on objects such as lamps, refrigerators, heaters, fans, it is possible to monitor and control them remotely in a wide variety of applications that fall into two categories as shown in Figure 1 : short-range applications such as smart home, healthcare, and personal applications, and long-range applications such as smart cities, transportation, and industries.

This work focuses on short-range wireless technology: BLE, Zigbee and Thread that support mesh networks to extend applications that provide long distances with low transmission power and can achieve high reliability. We compare them based on their characteristics and behaviors in terms of various metrics, network topology, security, quality of service, and energy consumption.

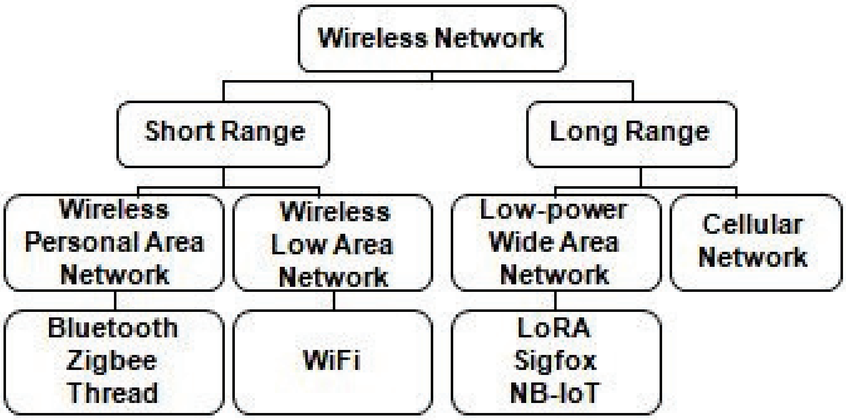


Fig. 1: A Wireless Network.

2 Mesh protocol analysis

2.1 Zigbee

Zigbee's technology is a wireless communication standard that defines a set of protocols for use in low-power, short and medium-range wireless networking devices such as sensors and control networks. It operates in unlicensed bands such as 2.4 GHz. There are also devices that use a different set of frequency bands such as 784 MHz, 868 MHz and 915 MHz in China, Europe and the United States [3].

Zigbee relies on the physical layer and medium access control defined in IEEE 802.15.4 to create a wireless mesh network. The Zigbee specification defines the network layer and the application layers. Each network must have a coordinator device and multiple routers to extend network-level communication.

2.2 Thread

Thread is an IPv6-based mesh networking protocol developed to directly and securely connect products around the home to each other. It was developed to run on low-power, low-cost. The Thread network, from the application layer to the physical layer, is not a new standard, but a combination of existing standards. Thread uses a combination of standards, including CoAP, UDP, DTLS, 6LowPan, vector routing and LR-WPAN [2]. Each network must have a leader device and multiple routers to extend network-level communication, additionally the role of a leader in a Thread network can be reassigned to another router if the original leader becomes unavailable.

2.3 Bluetooth Low Energy

The Bluetooth mesh network is based on Bluetooth Low Energy (BLE) technology operating at 2.4GHz. BLE mesh networks use scanning and advertising to achieve communications in the same way as BLE technology. It contains 3 advertising channels and 37 data channels. Bluetooth mesh uses managed flooding to transmit messages through the network [1].The Bluetooth mesh network defines its own application layer, called the mesh model, which is identified by the model ID.

2.4 Comparison of three wireless protocols

Table 1: Physical layer parameters of BLE, Zigbee, and Thread.

Specifications	**BLE**	**Zigbee**	**Thread**
IEEE Standard	802.15.1	802.15.4	802.15.4
Frequency Band	2.4GHz	2.4GHz,868 MHz,915MHz	2.4GHz
Bandwidth	1mbps	250kbps	250kbps
Range	10m	1-100m	30m
Routing	Managed Flooding	Full Routing	Full Routing
Protocol layering	Network and Application	Network and Application	Network
Cloud connectivity	Gateways	Smartphone /Gateways	Border Router/Gateway

2.5 Results and Discussion

The nRF52 SoC comes with the Thread, Zigbee and Bluetooth Low Energy protocol stack.Thus, to compile and run software on nRF52840 devices, Segger's Embedded Studio IDE, nRF connect, and J-link are used to debug and run code on the devices. On the host device PUTTY, a serial terminal, is used.

a. Thread

The table 1 shows the result of creating the mesh network with different configurations. The network was created with 5 devices, including a leader, 3 routers and a child, each device having its own IP address. For example, the following addresses are those of the leader, whose first address is used to route traffic and identify the location of interfaces and the second address is created when the device is connected to the network; the third address is used to communicate with other interfaces on the same network; and the fourth one is created with the mac.

- Leader Anycast Locator(ALOC): fdde:ad00:beef:0:0:ff:fe00:fc00
- Routing Locator(RLOC): fdde:ad00:beef:0:0:ff:fe00:dc00
- Mesh-Local EID(ML-EID): fdde:ad00:beef:0:f633:979d:cf70:c041
- Link-Local Address(LLA): fe80:0:0:0:b458:45c4:7753:8182

User	COM13	COM11	COM12	COM14
PAN ID	0X1234	0X1234	0X1234	0X1234
State	Leader	Router 1	Router 2	Router 3
EXT Mac	b65845c477538182	3fe4c90dbe2be0c0	36a7aeca27b83e6f	46c5dde91469ddf4
Master key	00112233445566778899aabbccddeeff			
EXT PAN	dead00beef00cafe			
Channel	11			

Fig. 2: Characteristics of joining devices.

The figure 2 above concludes all the characteristics of each device of the network.

The routing table is established when the mesh network is created as shows the figure below the leader routing table, which is populated with a compressed form of a local mesh address for each router and the appropriate next hop. It also contains the path cost and age, which define the number of nodes to traverse when sending data from the current node to a destination node. The routing table is established when the mesh network is created.

Also get the neighbor table for each device that contains the average of the RSSI and each extended Mac.

✓ **COM13 : LEADER**

ID	RLOC	Next hop	Path Cost	LQ In	LQ Out	Age	Extended Mac
11	0x2c00	15	1	3	3	15	3ef4c90dbe2be0c0
15	0x3c00	11	1	3	3	4	46c5dde91469ddf4
26	0x6800	11	1	3	3	13	36a7aeca27b83e6f

Fig. 3: Network leader routing table

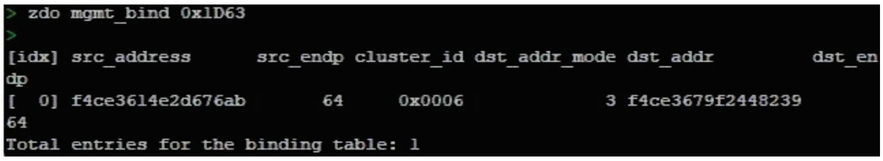
b. Zigbee

The following table explain the operations and commands performed by coordinators, routers to form or join a network. The coordinator is the only device that can start a network, so every Zigbee network must have a coordinator. It is responsible for selecting an unused operating channel, PAN ID, security and stack profile for a network that, routers must discover and join a valid Zigbee network. When a router joins a network, it receives a 16-bit address randomly chosen by the device that authorized the connection.

Also in Zigbee, the Ping command is used to show the time between sending and receiving a packet, and as shown in Figure 5 get a binding table that defines the relationships between two devices at the application layer. Figure 4 below concludes all the characteristics of each device in the network.

Username	COM17	COM16	COM18	COM19
PAN ID	9943	9943	9943	9943
Role	Coordinator	Router 1	Router 2	Router 3
Short address	0000	7059	5E85	5Dc4
Eui64 address	f4ce36e27cf78d03	4ce3679f2448239	f4ce36b34448da7b	f4ce3614e2d676ab
Network key	00112233445566778899aabbccddeeff			
Channel	16			

Fig. 4: Network leader routing table



```
> zdo mgmt_bind 0x1D63
>
[idx] src_address      src_endp cluster_id dst_addr_mode dst_addr         dst_en
dp
[  0] f4ce3614e2d676ab       64     0x0006             3 f4ce3679f2448239
64
Total entries for the binding table: 1
```

Fig. 5: Network leader routing table

c. BLE

For the BLE, five devices are connected so that each device can send data to any other, and these are received in the "nrf connect" application. For example, after connecting the devices to the mesh network, to change the status of the LED of one device, all other devices are notified in the same way. Also, access to the characteristic value of a device to all other devices, and each device can get the characteristic value in BLE.

3 Conclusion

Through the mesh, a node can communicate efficiently with another node by sending messages along a specific route. This has a positive effect on mesh throughput and can reduce latency, so a routing mesh is better than a flooding mesh because it provides more efficient communications and predictable performance.Finally, the Thread network is an optimal choice because it was easier to control IoT products and systems from personal devices such as cell phones or tablets, and this technology is expected to grow significantly over the next few years.Thread has great potential and has the added benefits of Wi-Fi like functionality.

References

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