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BLUETOOTH MESH IN IOT

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В работе будет рассмотрен стандарт Bluetooth Mesh, который широко применяется в такой сфере, как Internet of Things (интернет вещей). Будут освещены моменты, присущие Bluetooth Mesh: архитектура, топологии, принцип наводнения, передача сообщений, подход к коммуникации (использующийся паттерн).

Ключевые слова: bluetooth low energy, IoT, mesh-сети

BLUETOOTH MESH IN IOT

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This paper will discuss the Bluetooth Mesh standard, which is widely used in an area such as the Internet of Things. It will cover the intrinsic aspects of Bluetooth Mesh: architecture, topologies, flooding principle, messaging, communication approach (pattern used).

Keywords: bluetooth low energy, IoT, mesh-networks

Bluetooth Mesh - a system built on the concept of mesh networking, in addition to technologies related to Bluetooth, namely traditional Bluetooth and Bluetooth Low Energy, the basics of mesh networks and communication technologies in the IoT will also be discussed.

Comparison of communication technologies for the IoT.

Currently, the number of devices related to the IoT is constantly growing, hence the ways of their communication is developing. Used as the usual Wi-Fi, LTE, and more specific, such as BLE, ZigBee, etc. All of them have different speed, power consumption, topologies, and accordingly different applications [5].

Table 1 shows the main characteristics of technologies that can be applied in the Internet of Things. Comparing the indicators and the ratio of power consumption, speed and range, we can say that BLE and ZigBee technologies are among the most promising in this direction.

Table 1 – Comparison of technologies applicable in the IoT [6]

Technology	**Стандарт**	**Frequency range**	**Data transfer rate**	**Operating range with external antenna**	**Power consumption of the module during transmission**	**Topology**
Wi-Fi	IEEE 802.11	2.4/5/60 GHz	Over 300 Mbps	up to 100 m	High	"Star," sometimes a mesh network used to extend the range
BLE	Bluetooth 5.0	2.4 GHz	Up to 3Mbps	>100 м	About 250mA per channel	"Point-to-point," mesh network
HaLow	IEEE 802.11ah	900 MHz	50 kbit/s to 18Mbit/s	> 1 km	Low	Mesh network
ZigBee	IEEE 802.15.4	915 MHz /2.4 GHz	250 kbit/s	100 м	BLE-13mA, v4.0- 40mA	Mesh network
Z-Wave	Z-Wave	433/800/900 MHz	10-100 kbit/s	30 м	Low 120mA	Mesh network
Lora	LoRaWAN	less than 1 GHz	0.3-50 kbit/s	2-5 km in the city, up to 45 km outside the city	Low About 50mA	Star
Thread	IEEE 802.15.4	2.4 GHz	250 kbit/s	30 м	Low	Mesh
LTE	LTE	All cellular bands	Up to 300	3 to 20 km, depending on frequency	2.5 mA	Star
NB-IoT	NB-IoT	800/	Mbps	From 13 to 20 km	Low 45 mA	Star

1. Mesh-network

A mesh network is a network in which devices or nodes are interconnected by branching off from other devices or nodes. Such networks are created to efficiently route data between devices and clients. They help organizations to provide consistent connectivity across the physical space [9].

Mesh network topologies create multiple routes to transmit information between connected nodes. This approach increases network resilience in the event of node or connection failure. Large mesh networks may include multiple routers, switches, and other devices that act as nodes. A mesh network can include hundreds of wireless mesh nodes, allowing it to cover a large area (Figure 1) [1, 10].

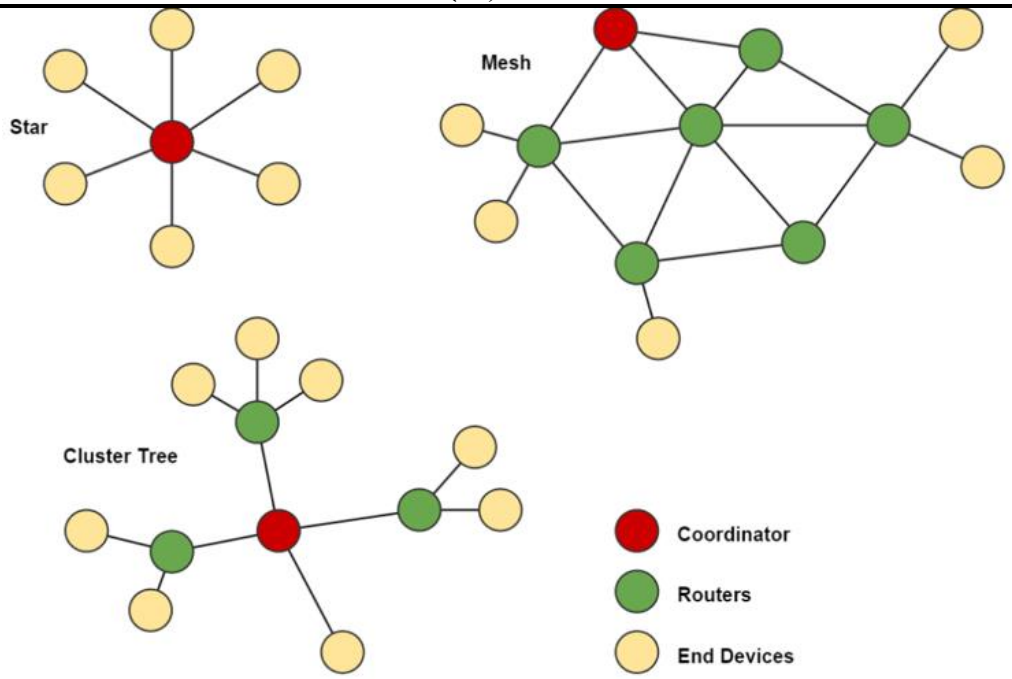

Figure 1 – An example of a mesh network (top right) [11].

2. Bluetooth and Bluetooth Low Energy

Bluetooth Low Energy is a low-power wireless personal network operating in the 2.4 GHz ISM band. Its purpose is to connect devices over a relatively short distance. BLE was created with IoT applications in mind, which has particular implications for its concept. For example, IoT devices tend to be limited and require long battery life, so BLE favors low power consumption over continuous data transfer. In other words: when a device is not in use, it goes into sleep mode to save energy [7].

Speaking of BLE-equipped devices, this is the architecture of the technology, especially its asymmetry. The device can operate in either a central or peripheral role. For example, take a smartphone and a smart bracelet: the more "advanced" and sophisticated smartphone is the central device, and a smart bracelet with limited functionality is the peripheral. Neither the two central nor the two peripheral devices can talk to each other. Communication is only possible between the central device and the peripheral device. To overcome this limitation, the device can be configured in both central and peripheral mode, as in many smartphones (Figure 2).

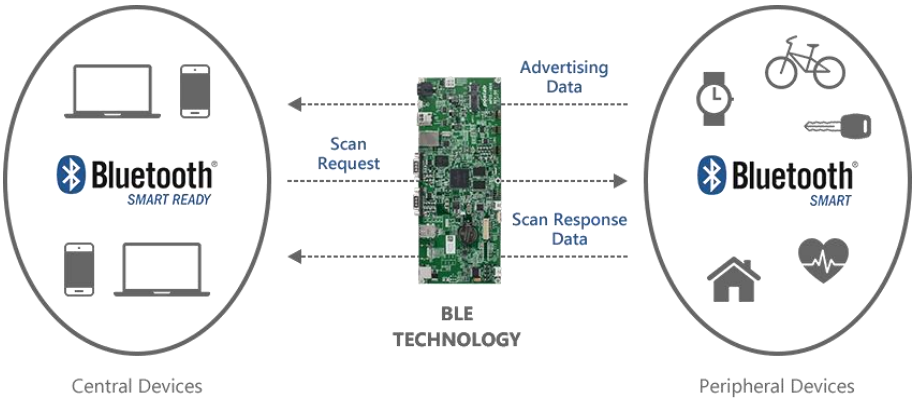

Figure 2 – BLE in IoT [12]

BLE is an independent standard, incompatible with "classic" Bluetooth. The latter was first introduced commercially more than 20 years ago and is now essentially no longer being developed by the Bluetooth Special Interest Group (SIG). However, it is often found in devices that require constant connectivity, mostly audio devices such as wireless speakers or headphones.

There are some critical differences between standard Bluetooth and BLE [4]:

1. Bluetooth Classic is designed for continuous two-way communication, whereas BLE transmits small packets of data for short periods of time;
2. As the name implies, Bluetooth Low Energy consumes much less power (100 times less than Bluetooth Classic);
3. Because Bluetooth Classic is not as limited, it has a longer range and higher throughput.

3. Bluetooth Mesh

Bluetooth mesh is a Bluetooth technology owned by the Bluetooth Special Interest Group (SIG). It was launched in July 2017. In general, it can be defined as a computer network that allows communication between many devices [8].

According to the Bluetooth SIG, Bluetooth mesh was created to optimally build automation and offer multiple solutions in the Internet of Things (IoT), where thousands of devices can communicate efficiently and securely.

This standard is based on Bluetooth Low Energy (BLE) technology [1]. The main goal was to create a protocol for wireless communication, which has low power consumption, easy scalability and high reliability.

The principle of Bluetooth Mesh flooding

Bluetooth Mesh technology works on the principle of a flood network. This means that when a node receives a message, it broadcasts it to all other nodes in range except the one from which it received the message. Each node in a Bluetooth Mesh network acts as a transmitter and as a receiver.

The flood method makes Bluetooth mesh networks more reliable than wireless mesh technology. The main advantage of the flood topology is that there is no need to assign special responsibility to certain devices, that is, to act as centralized routers, where the failure of one device can take out the entire network. With the flood method, there are usually multiple paths that a message can take to its destination. This makes Bluetooth Mesh technology very robust.

4. Topologies

To deliver a message in a Bluetooth Mesh, you can switch between two possible modes: Peer-to-Peer and Multipath (message relay) (variations: one-to-many, many-to-many) (Figure 3) [2]. A peer-to-peer (or "piconet") network involves direct communication between nodes without intermediaries such as routers. The second option builds on the retransmission of a managed message stream. It helps to easily deploy networks over large areas.

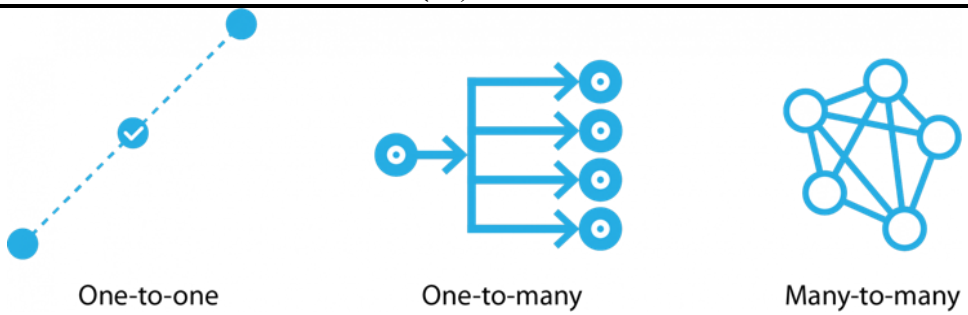

Figure 3 – BLE topologies [3]

In mesh networks it is possible to obfuscate packet headers, which protects data from passive attacks on the network [2].

5. Bluetooth Mesh architecture

Bluetooth Mesh is an add-on to BLE. It makes special use of the state of the BLE device's advertisement. Devices in a Bluetooth Mesh network do not connect to others the way classic BLE devices do. Instead, they use the override and scan states to relay messages from one device to another. There is only one exception to this rule, the proxy device, which can be part of a mesh network. The Bluetooth Mesh architecture is shown in Figure 4 [3].

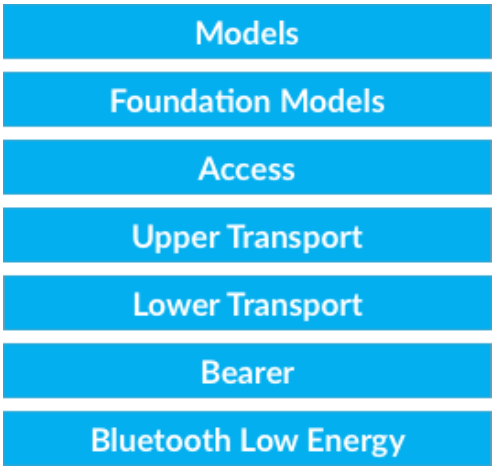

Figure 4 – Bluetooth Mesh architecture [3]

6. Messages in Bluetooth Mesh

The way nodes communicate with each other is known as messaging. Message exchange in a Bluetooth mesh network is done using a publish-subscribe mechanism.

Messages. Nodes on a mesh network send messages to control and/or transmit information to each other. There are three types of messages:

- GET: Request a state from one or more nodes.
- SET: Change the value of a given state
- STATUS: Report the state of an item [3].

Bluetooth Mesh Message Template

Bluetooth mesh implements a publisher-subscriber pattern approach to communication to ensure that different users coexist on the network without disturbing them with messages from

devices they do not need to listen to. The publisher node sends messages only to nodes that have subscribed to it and will act on those messages. An example of how this works is using the network in different rooms of the same house. Each room can subscribe to messages from specific light switches for that room. In addition, messages can be unicast, multicast, and/or broadcast, meaning that the message can reach one, several, or all nodes in the network [8].

The figure below (Figure 5) shows an example of a home mesh network consisting of 6 switches and 9 lights. The network uses a publisher-subscriber pattern to allow nodes to send messages to each other.

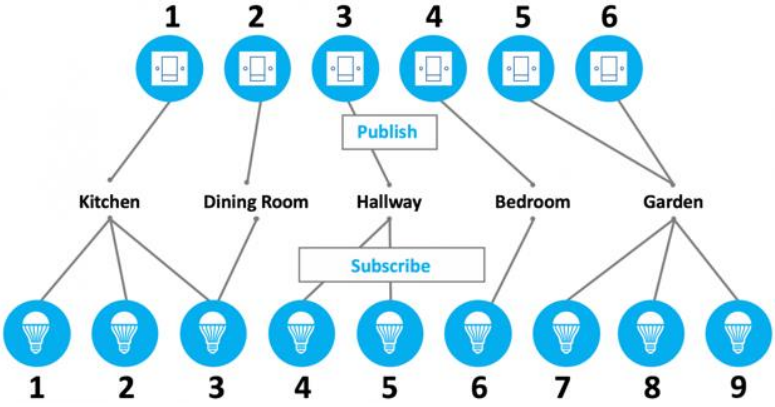

Figure 5 – Example of a "publisher-subscriber" template [3]

Conclusion

Bluetooth Mesh technology has enormous potential in the Internet of Things, especially when there are multiple node devices. These nodes can self-organize and act together, putting into practice some swarm intelligence approaches, exchanging data with each other, so that each node knows relevant information about its environment, which will help it to better configure its configuration (for example, the smart home thing on which it runs).

Already, BLE technology (on which the Bluetooth mesh network is built) makes it easier to share data with wearable devices and solves the problem of the need for constant active connectivity.

Bluetooth Mesh is the next step that will allow portable devices, smart home devices, wearable electronics, and other devices to communicate more coherently, faster, blurring the boundaries between different devices, transforming many isolated devices into one big ecosystem.

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