How Bluetooth Works

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Introduction

This report addresses the functionality of Bluetooth as communication technology specifically in the case of the Indoor Navigation for the Visually Impaired capstone project. The project is to create a system for those with low vision such that they can navigate autonomously throughout a building. Low power Bluetooth could be used effectively for both locating a person within a building and sending location information to and from the user. While applicable to this project, Bluetooth is a useful tool that can be utilized in many different projects and technologies, and having a basis of knowledge in Bluetooth will add a strong tool for use in other work. Moreover, having knowledge of Bluetooth as well as the basics of communications protocols is helpful not only for those looking to understand more of the world around them, but also for those looking to create wireless or ad hoc networks. This report will address the definition of Bluetooth and uses for Bluetooth, and the functionality of Bluetooth.

History of Bluetooth

Bluetooth was created as an alternative to cables and wires to create a network. It was built to connect the telecommunications protocol under one universal standard. It is used for short range wireless communications and transmissions. Bluetooth enabled devices create ad hoc networks (networks with only one purpose) with each other to exchange or broadcast information. While Bluetooth was originally aimed at becoming a replacement for cables, it is now widely used because it creates a dynamic Personal Area Network (PAN). **[1]** This PAN allows users to connect and disconnect dynamically as they enter and exit the effective area of the Bluetooth device. An example of this is shown in Figure 1. Nowadays, Bluetooth is used in everything from hands-free phone connections to speakers, to connecting computers and electrical components.

Figure 1: Phones, computers and other devices can be connected through a Bluetooth PAN

Bluetooth Functionality

Bluetooth operates at either Basic Rate (BR) or Low Energy (LE), but one system can switch between the two for robustness. Basic Rate has the optional Enhanced Data Rate (EDR) as well as many other options that allow for higher data transfer rates as well as higher complexity, but at a higher cost. For the capstone project, we will be focusing on Bluetooth Low Energy as it is lower cost and the complexity and amount of data required for the project is relatively low. **[1]**

Bluetooth BR and EDR operate between the frequencies of 2.4 GHz and 2.4835 GHz. Each band is 1MHz wide and each band is spaced by 1MHz. There are 79 bands in standard Bluetooth and there are guard bands of 2MHz at the bottom of the frequency spectrum and 3.5MHz at the top of the frequency spectrum. **[1]**

The process for discovery in a Bluetooth device is relatively quick and simple. One device, hoping to make connections sends out inquiry "packets" into the different channels at a specific rate. The second device, which is considered discoverable, scans the channels at a different rate looking for inquiry packets. When the second device receives an inquiry packet, it responds with a Frequency Hopping Synchronization (FHS) packet which contains the information required to set up a connection. The first device receives the FHS packet when it returns to the proper channel and connects the devices. Once connected, the devices may communicate and synchronously hop to different channels to enable efficient bandwidth usage. **[1, 2]**

Standard Bluetooth uses frequency hopping and "packet switching" to get the information from one end user to another. "Packet Switching" is a communication method in which the sender transmits its data in many small packets with an order number. Each packet finds the fastest way to the receiver and the receiver re-orders the packets once they all arrive. An example of packet switching is seen below in Figure 2.

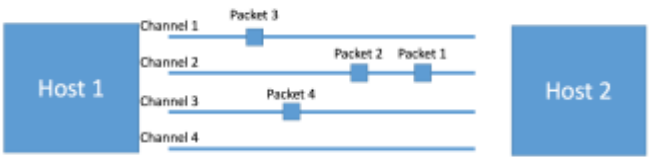

Figure 2: Host 1 sends four packets to Host 2 through packet switching. Host 2 will then reorder the packets once they arrive

For synchronization, there is one device that is the master that dictates the synchronization clock and the all the other devices follow the master clock and frequency hopping pattern to communicate. **[1]** The method of frequency hopping and packet switching means that the data from the sender is put into packages of a prescribed number of bytes and each package is sent over one of the 79 bands. **[1]** The process of frequency hopping ensures effective bandwidth usage and spreads the traffic out over the whole band.

Bluetooth Low Energy

Bluetooth LE operates within the same frequency band as BR and EDR, but there are only 40 channels with 2MHz in between each instead of the 79 from BR. **[1, 2]** Three of the forty channels are used as "advertising channels". Devices that want to connect and send information will transmit packets to the advertising channels and devices will receive the packets from the channels. The former are known as advertisers while the latter are scanners. When an advertiser sends a packet, it initiates an advertising event. **[1]** During an advertising event, the scanner may request information from the advertiser over the advertising channel. The advertiser may respond to scanner requests as well as end the advertising event at any time. For broadcasting or one-way communication, the advertiser-scanner method is enough.

However, for two-way communication, a device implementing LE must become an "initiator". An initiator will listen on the advertising channel for specific connectable packets and initiate a connection with the advertiser. **[1]** The initiator and the advertiser begin a connection event where the initiator is the master and the advertiser is the slave. The initiator may end the connection event at any time and the initiator and advertiser use the frequency hopping method from BR and EDR to transmit efficiently. **[1]** Note that for Bluetooth LE there are only 3 channels in use for broadcasting as well as for connecting devices. All other channels are used for communication during a connection event.

Bluetooth LE allows for quick and easy one-way communication without requiring too much power. This method can be more than enough for many implementations of Bluetooth, and Bluetooth LE also has the versatility to switch over to a two-way communication similar to BR while maintaining lower power consumption. A big drawback of Bluetooth LE is fewer channels, which results in slower transmission time. Additionally, Bluetooth BR and Bluetooth LE can be used for determining location in a method similar to the one used by Ultra-Wideband Signals **[3, 4, 5]**. More information on wireless triangulation for location is in Brian O'Keefe's Tech Note entitled ___.

Conclusion

All in all, Bluetooth technology is easy to use, easy to set up, and relatively cheap. Using Bluetooth may be a viable option for the Indoor Navigation for the Visually Impaired Project for communication and location data if the location accuracy can be precise enough for navigation.

Bluetooth is a flexible tool that can be utilized in many different solutions and projects. For more examples of the uses and implementations of Bluetooth, check out these other capstone projects: Link to other projects.

References

All images were either taken from Pixabay or created.

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