Bluetooth: A Viable Solution for IoT?

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Introduction

The news that Qualcomm is buying the dominant Bluetooth chip vendor, CSR, is creating speculation in the industry that Qualcomm is betting Bluetooth for Internet of Things (IoT) applications. Bluetooth, the technology once pronounced dead by a trade magazine journalist in 2003 [1], has enjoyed popularity and prosperity in the last 10 years for audio communications and stereo streaming. ABI Research predicts that over 3 billion Bluetooth enabled devices will be shipped in 2014, and over 10 billion Bluetooth enabled devices will be on the market by 2018. With the maturity of the technology and its strong presence in the marketplace, the Bluetooth industry is working on expanding the applications of the technology to short-range wireless communication markets other than audio and stereo communications, such as the Internet of Things (IoT) and machine-to-machine (M2M) communications. Currently, it is being used for M2M applications such as credit card readers [2]. For Bluetooth to be suitable for M2M and IoT applications, it needs to reduce power consumption so that it can be used in battery-powered devices for a longer period of time or even the lifetime of the device. To achieve that, the Bluetooth Special Interest Group (SIG) introduced Bluetooth Low Energy (BLE), which was first specified in Bluetooth 4.0 [3] and further improved in Bluetooth 4.1 [4]. In addition, the Bluetooth stakeholders also expanded work on it, with the Internet Engineering Task Force (IETF) working on the standardization effort of facilitating Bluetooth in exchanging IP packets.

Bluetooth Low-Energy Basics

BLE (also called Bluetooth Smart) was first introduced in 2010 with the goal of expanding the application of Bluetooth for use in power-constrained devices such as wireless sensors and wireless controls. Not only does application in sensors and controls require low power consumption, but the amount of data transmission is small and communication happens infrequently. This is different from conventional Bluetooth application, such as audio and data streaming, with large amounts of data transmission and frequent interaction between two communication devices. In addition, device cost is more important for wireless sensor controls than for audio streaming. To address these application requirements, BLE introduces a new radio, which is a derivative of the conventional Bluetooth (called Bluetooth Classic to differentiate from Bluetooth Smart), and new interfaces. In Bluetooth Classic, there are 79 channels, each with a channel bandwidth of 1 MHz and a raw symbol rate of 1 Msymbol/s. The modulation scheme could be Gaussian frequency shift keying (GFSK), quadrature phase shift keying (4PSK), or 8PSK. For BLE, the modulation scheme is GFSK with raw data rate of 1 Msymbols/s with 2 MHz channel bandwidth, which is double that of Bluetooth Classic. While frequency hopping is still used in BLE to mitigate interference, the dwell time in BLE is longer than Bluetooth Classic, so the timing requirements in BLE can be relaxed [5]. Due to the increase in channel bandwidth, there are a total of 40 channels in BLE, three of them advertising channels and 37 of them data channels. The channel plan for BLE is shown in Fig. 1 [2]. The advertising channels facilitate discovering devices and establishing initial communication between two devices, which includes required parameter exchanges. Once two devices are connected, data communication occurs through data channels. Since the robustness of the advertising channels is very important for setting up initial communications, they are chosen from channels that have less interference from Wi-Fi communications. BLE is also designed such that two devices can quickly be connected. Since most transactions in wireless sensor networks only require a small amount of data exchange, the transmitted packets for BLE have 1 byte of preamble, 4 bytes of access codes, 3 bytes of cyclic redundancy code (CRC), and a protocol data unit (PDU) size of 2 to 39 bytes. With this packet size, a shortest packet can be transmitted within 80 μs and a longest packet can be transmitted within 300 μs [5]. With a short packet size, BLE fulfills low-duty-cycle requirements, which is very important for wireless sensor network applications.

Besides radio, another important piece of BLE is the protocol stack, which is shown in Fig. 2 [6]. The BLE protocol stack is well layered to facilitate IP communications. In addition, the protocol stack is also designed to reduce power consumption. Similar to Bluetooth Classic, the host controller interface (HCI) separates the controller part (link and physical layers) from the host part (Logical Link Control and Adaptation Protocol (L2CAP), Attribute Protocol (ATT), Generic Attribute Profile (GATT), and Generic Access Profile (GAP). Due to the fact that IPv6 packets are much larger than BLE packets, to transmit IPv6 packets using BLE requires fragmentation before transmission and reassembly after receiving. The packet fragmentation and reassembly is done in L2CAP. GAP defines the generic procedures for discovering BLE devices and managing connections between LE devices [5]. The security manager (SM) takes care of device pairing and key distribution, and is designed to minimize resource requirements for slave devices by shifting workload to more powerful master devices. ATT is optimized for small packet sizes, and allows an attribute server to expose attributes and their associated values to an attribute client. GATT describes a service framework using ATT for discovering services, and reading and writing characteristic values on a peer device. GATT-

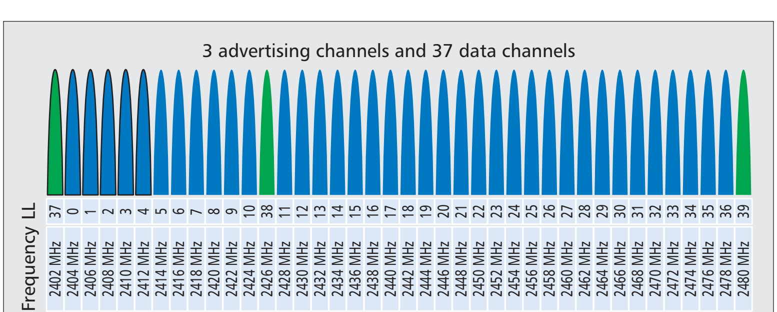

Figure 1. The channel plan of Bluetooth Low Energy.

based profiles are simple and efficient, so they can minimize the size of the data exchange between devices and hence reduce power consumption.

BLE has two GAP roles: the BLE central role and the BLE peripheral role [6]. The central role can manage multiple simultaneous connections with a number of devices in the peripheral role. Normally, a peripheral is connected to a single central, but it is modified to be able to connect to multiple centrals in Bluetooth 4.1. This change is needed if Bluetooth wants to support mesh networks.

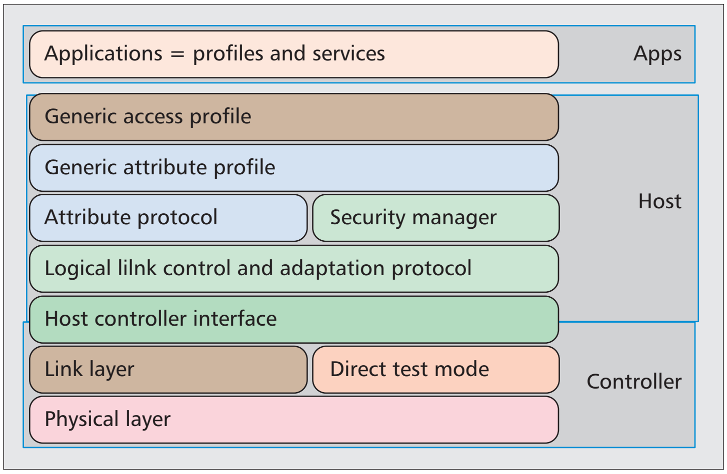

Figure 2. Bluetooth Low Energy protocol stack.

CHALLENGES

Bluetooth stakeholders are making great efforts to support IP so that the technology can serve IoT applications well. As part of these efforts, Bluetooth SIG published the Internet Protocol Support Profile (IPSP) to enable discovering IP-enabled devices and establishing link-layer connections for transporting IPv6 packets. However, at this point in time BLE only supports star networks and cannot support mesh networks. In addition, the BLE link layer cannot support multicast, which is an important function for low-power and lossy networks. If a LoWPAN border router (LBR) wants to multicast a packet to LoWPAN nodes (LNs) it needs to unicast the packet to each LN sequentially, which is quite cumbersome. For Bluetooth to be a viable solution for IoT, these are some of the challenges the Bluetooth stakeholders need to overcome. As we speak, these stakeholders are working to address these challenges. The Bluetooth SIG is leading the effort to standardize BLE mesh networks. Figure 3 is a network architecture that shows how BLE can be used in a home environment for sensing and control, where the upper portion of the network shows a conventional star network, and the lower portion shows how the start network can work in conjunction with a mesh network. The BLE mesh network standardization effort is expected to be completed in 2015.

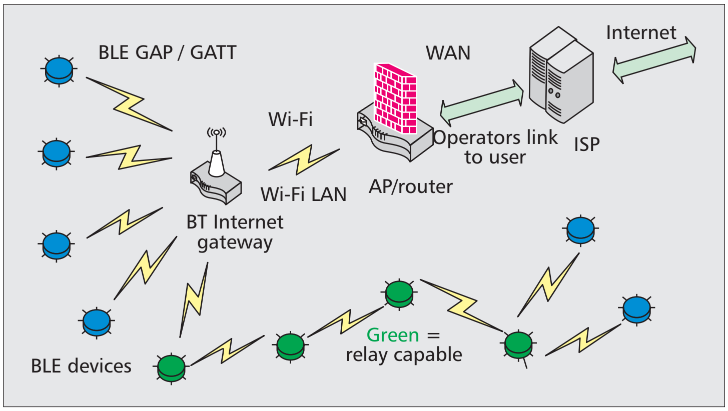

Figure 3. A BLE home network.

SUMMARY

Since IoT applications are broad and diverse, it is certain that the market requires various wireless technologies. However, in the end there will be market winners and losers for a specific application domain. Since Bluetooth is pervasive in smartphones and personal computers, it is gaining ground in home automation applications even though the effort to be a *truly* low-power technology is still in progress. However, whether Bluetooth Low Energy or Smart, or whatever you call it, will be a dominant technology for applications that only require small amounts of data communications is yet to be seen over time.

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