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Is BLE Most Suitable for IoT Applications?

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The Road to 50 Billion Smart-things

In 1999, eminent journalist Neil Gross stated, “In the next century, planet earth will don an electronic skin. It will use the Internet as a scaffold to support and transmit its sensations. This skin is already being stitched together.” True to Mr. Gross’s expectations, today we are standing face to face with the ultimate possibility of a continuous skin: The Internet of Things.

The Internet of Things (IoT) is often defined as a scenario in which objects, animals, and/or people are provided with unique identifiers and the ability to transfer data over a network without requiring human-to-human or human-to-computer interaction. Cisco’s IBSG (Internet Business Solutions Group) predicts (2) that by the year 2020, 50-billion “things” will be connected by the Internet of Things. The IoT is driven by a combination of sensors (or actuators), connectivity, and the Internet. All the “things” that are to be connected to the network are fitted with sensors or actuators. The sensors talk to the master devices (e.g. computers, phones, etc.) using a communication mode that is commonly understood and detectable by the master.

One of the most celebrated achievements of the entire IoT revolution is the “cattle-sensors” invented by a Dutch startup called Sparked. These sensors, when connected to the ears of cattle, can track an animal’s vitals and message farmers when illness or pregnancy is detected. As a result, farmers can better control the health of their livestock. Similar breakthroughs have happened in other domains such as healthcare (wireless cardiac monitor), apparel (smart shoes), and consumer electronics (smart refrigerators).

The concept of the IoT, while straightforward, leads to innumerable possibilities. Take anything and fit a sensor/actuator to it (the thing now becomes a “smart-thing”). The sensor detects and measures certain parameters (example: heart rate, speed of running /walking, where your pet is heading). This data is wirelessly communicated to a master (example: a phone or a PC). Thus, the IoT is all about detecting, measuring, and communicating.

For a successful IoT environment to flourish, we need efficient and cost-effective intercommunication between masters and slaves as well as between slaves themselves. Communication is possible only when:

1. “Things” are active and transmitting data
2. They are within the communication range
3. There is interoperability (i.e. the transmitted message is understood by the receiver)
4. The data is relevant to the master

At the same time, it is important to ensure that the communication process is quick and doesn’t drain device batteries.

Wireless Communication systems

Connectivity within the IoT often utilizes wireless communication. There are quite a few wireless communication systems available to choose from. Which communication technology is the best fit depends on the application type and its requirement. Based on application needs, we can segment IoT communication requirements as follows:

1. Short range and long range: How far can a device be from the master or another device and still communicate reliably? The previously mentioned cattle example illustrates a long-range application. On the other hand, there are numerous life-style, home automation, PC peripheral, and health applications where the need is for short-range communication only.

2. Need for low-power communication: When it comes to industrial applications, there is a chance that devices are wired to a power source (or using a powerful battery) and thus low-power communication may not be required. However, for applications like wearable electronics that typically run on coin cell batteries, the need for low-power communication is acute. Such applications are a major growth area for the IoT in the coming years.

3. Short burst or continuous data transfer: Some devices need to communicate continuously while some devices need to send data in short bursts periodically. The metric used to describe these transfer methods is duty cycle (= % of one period when the signal is active). Thus, devices can be segmented in terms of low or high duty cycle.

4. Need for proprietary or standard communication: There are many proprietary (invented and owned by a single company) and standard (specifications defined by an industry body and multiple vendors complying to the definition) communication technologies available. One limitation with proprietary communication is the fact that both parties (master-slave, master-master, or slave-slave) need to be similarly equipped to acknowledge and interpret the data. This can usually happen when the transmitter device and receptor device are both manufactured by the same company or by companies that have co-developed a solution (e.g., a PC by company X can talk to wireless mice by company X using a particular proprietary communication technology).

However, with more and more new IoT devices entering the market, the scope of proprietary communication technology begins to limit the marketability of devices. To understand this better, let’s consider the wearable technology segment. There are many companies focused on creating innovative smart wearable devices. Most of these companies do not manufacture master devices such as PCs or smart phones. These companies would thus prefer that their devices can talk to maximum number of masters. For this they would use a standard communication that most master devices can understand.

Bluetooth Low Energy (BLE)

Bluetooth Low Energy or BLE (marketed as Bluetooth smart) is a wireless communication technology designed and marketed by the Bluetooth SIG. BLE is targeting applications that have the following requirements:

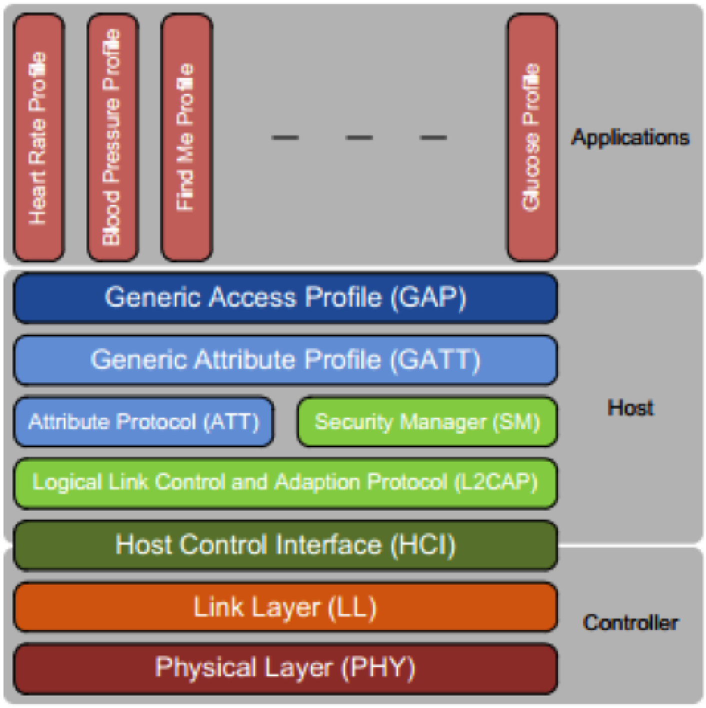
1. Range of up to 100m: However, as per the SIG website, the specification does not limit range. This means manufacturers can possibly create devices that have range higher than 100m.

2. Need to run on coin cell battery for significant time: Many IoT devices need to be able to run on standard coin cell batteries for years. BLE enables ultra-low peak, average, and idle mode power consumption. In addition, devices with a lower duty cycle will save more power.

3. Multi-vendor interoperability: As a standard, BLE, like the previous versions of Bluetooth, enjoys a high level of adoption by master-device manufacturing companies. Many IOT slave devices also support BLE. Key operating systems like Android, iOS, Windows 8, and Linux natively support BLE. The SIG predicts that by 2018, 90% of smart phones will support BLE. This ecosystem helps achieve multi-vendor interoperability.

4. Data transfer up to 1Mbps:

A BLE stack (Fig 1: Stack diagram) comprises 3 sub-groups:



A. Controller: The actual device that encodes the data packet and transmits it as a radio signal. The controller is also capable of receiving radio signals and decoding them for data.

B. Host: It is the software stack, consisting of protocols and profiles (a collection of services and their behavior that together perform a particular end application), that manages the communication between two devices.

C. Application: A use case that utilizes the controller and host to implement a particular function.

The application layer is a great advantage of Bluetooth. For developers, it means that along with the generic set of protocols and services, they have access to many application-specific protocols. The Bluetooth SIG has defined several profiles (i.e., a specification of how a device would function in a particular application) for BLE devices. An example would be HRP or heart rate profile. This profile enables a collector (say a smart phone) to connect and interact with a Heart Rate sensor placed on a user's body. The profile specifications released by the SIG state the profile dependencies (e.g. HRP requires a generic attribute profile or GATT), sensor role requirements, collector (data) role requirements, connection establishment procedure, and security considerations, among others. Adhering to the profile specs makes the process of qualifying BLE for an application seamless and easy. The SIG webpage lists all the available profiles. A device may make use of multiple profiles.

BLE against the rest (for IoT applications)

Today the top competitors to BLE are ZigBee, Wi-Fi, Ant+ and a wide range of proprietary protocols. Let's understand the competition briefly before getting into a formal comparison:
ZigBee: ZigBee is a wireless communication specification developed by the ZigBee alliance, a non-profit association with close to 400 members. ZigBee supports a large network with multiple low power chipsets operating at a lower data rate than BLE. ZigBee primarily targets home automation and industrial automation systems.

Wi-Fi: Wi-Fi is a wireless networking technology that uses radio waves to provide high speed internet and network connectivity. It is based on IEEE 802.11 standards and consumes much more power than ZigBee or BLE.

ANT+: ANT+ is an interoperable open-access wireless sensor network technology designed and marketed by ANT Wireless (a subsidiary of Garmin since 2006). Low power is one of the key USPs of ANT. Typically, ANT-enabled devices are expected to be in sleep mode for long periods, wake up briefly to send data, then return to sleep mode again. It targets sports and fitness applications.

Comparing BLE with proprietary protocols would be unfair. Any application that intends to use a standard communication technology would abstain from using a proprietary protocol. Thus, the comparison will be limited to four standard players only: BLE, ZigBee, Wi-Fi and ANT+.

The first parameter we need to consider while comparing the above communication technologies is the type of network our devices will join. IoT devices may connect to a PAN (Personal area network) or WLAN (wireless Local area network). When a device is connecting to the WLAN, Wi-Fi is definitely the best option in terms of cost. However, the power consumption of Wi-Fi is high and thus we cannot expect devices that need to run on coin-cell batteries to connect to a LAN using Wi-Fi (unless we have a plan in place to replace batteries periodically.) Thus, devices that are constrained in terms of power can only connect to a LAN indirectly. That is, they connect to a master (e.g., a smart phone or PC) and let the master connect to a LAN. In addition, one advantage of using a LAN is resource sharing (e.g. shared enterprise printers). However, most IoT devices don't actually need this advantage – a heart rate sensor needs to connect to only one master device.

Thus the ideal network for most battery-backed IoT devices that need to communicate with a single master is PAN. This reduces our choice for communication standard to BLE, Ant+ and ZigBee.

The competition between ANT+ and BLE is extremely interesting. ANT+ lists BLE as a competitor but BLE doesn't acknowledge ANT+ in its list of competitors. ANT's one-sided paranoia about BLE stems from the fact that BLE targets ANT's market almost to entirety. ANT+ and BLE are competitive in terms of key specs such as over the air data rate, application throughput, and range (50-100m). However BLE still corners ANT+ in terms of actual industry adoption. Please note, on their own BLE and ANT are nothing beyond protocols. Their real success depends on how much industry adoption they enjoy. Industry adoption is dependent on the number of chipmakers willing to invest in designing and manufacturing chips that support a protocol, the number of master devices supporting the protocol natively, and of course the number of slave manufacturers willing to take a bet on the technology.

As of today, there are only 3 manufacturers who are supplying chips with ANT+: Dynastream Innovation, Nordic Semiconductor, and Texas Instruments. In the case of BLE, there are planned or in-production chips from Broadcom, Freescale, Cypress, Microchip, Bluegiga, StMicro, Dialog Semiconductor and many others (including TI and Nordic). In fact, TI and Nordic are the only manufacturers whose portfolio has ANT+ enabled chips, BLE enabled chips, and chips with both technologies supported.

Currently, all the major mobile operating systems (iOS, Android, Windows, Blackberry) natively support BLE. In the case of ANT+, native support is limited. Windows8 and iOS both don't support ANT+ natively. Thus, to pair an ANT+ device with a Windows phone or an iPhone requires an additional ANT+ USB stick or dongle. In the case of Android, there are plug-ins available to run ANT+, if the phone manufacturer supports the same. As of now, Samsung and Sony are the major phone manufacturers supporting ANT+ across a wide product range. However, support for ANT+ doesn't rule out support for BLE. In fact, the update enabling ANT+ on the Samsung devices was a part of Android 4.3 update – the same update brought full Bluetooth smart compatibility to these devices as well.

ANT+ targets the sports, fitness, and lifestyle market primarily. The end goal of the technology would be to ensure that the maximum number of smart-device makers in this category choose it for communication. ANT+ was indeed successful till BLE was launched. Post the launch of BLE, the manufacturers of this category now had an alternate choice in terms of low-power communication protocols. Since BLE is backed more by the masters, it proved to be a safer bet. Thus, major wearable makers like Fitbit, Jawbone and Tom-tom have all chosen BLE. And, of course, the much-celebrated Apple watch will use BLE to pair with iPhones. Since BLE is expected to be a standard for almost all smartphones in the near future, smart devices are also expected to follow suit. However, ANT+ may survive as a niche protocol for applications where BLE cannot perform (e.g., point to multipoint communication or single slave to multiple master communication is not possible in BLE but can be done through ANT+).

The battle between BLE and ZigBee is on a different turf – home and industrial automation. BLE cannot displace ZigBee entirely. This is because ZigBee allows mesh networking while BLE is restricted to a star network topology (i.e., many slaves connecting to a single master). Also, ZigBee allows connection of more devices than BLE. These features make ZigBee a better choice when a bigger range network is required. On the other hand, to connect simple devices to a phone BLE would be more convenient due to its large existing installed base. In addition, the data rate and throughput of BLE is better than ZigBee. Setting up a ZigBee network requires connecting an additional ZigBee modem to a host device (preferably a PC) and thus it is less convenient and more expensive than setting up a BLE network.

In summary, BLE is the best choice when it comes to setting up a personal network by connecting a battery-backed smart device to a single phone or computer wirelessly. Thus, it is becoming the communication protocol of choice for an increasing number of smart wearables, PC/Phone peripherals, and health monitoring equipment. The Bluetooth SIG website lists the various Bluetooth Smart Ready products (host devices that support BLE) and Bluetooth Smart products (independent devices that communicate with the host using BLE). The list is ever increasing and is indicative of the bright future of BLE in IoT applications.

To learn more about BLE and get started with your own design, see the following application note: http://www.cypress.com/?docID=51385

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