State of the Art Literature Survey 2015 on Bluetooth

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ABSTRACT
Since the announcement of the digital India perspective, the creation of smart cities is being planned. The traditional methods will not suitably apply to smart cities. Hence innovative methods need to be established for the same. The existing mechanisms will need suitable upgrades for use in smart cities. For example the access control which is widely manual will need upgrades for automation; similarly other areas will also need suitable changes in approach for the same.

Bluetooth is a potential candidate and has a huge scope that is currently under-utilized. Bluetooth is widely available with all users, due to the increased popularity of smart phones. This is the most important aspect of Bluetooth that makes it a noteworthy technology of choice in smart cities**.**

General Terms
Bluetooth, Wireless Technology, Low Energy, Networking, SIG, Handsfree, Bluetooth Protocol Stack, Baseband, LMP, HCI, L2CAP, RFCOMM, SDP, TCS, PPP, UDP/TCP-IP, WAP, OBEX, Tethering, Radio Frequency.

Keywords
Bluetooth, Bluetooth Protocol Stack, Bluetooth Versions, Bluetooth Applications, Bluetooth Specifications.

1. INTRODUCTION
Bluetooth was invented by the telecom vendor Ericsson in 1994 as a wireless substitute to RS-232 data cables. Bluetooth is maintained by the Bluetooth Special Interest Group (SIG), which has more than 25,000 associate companies in fields such as telecommunication, computing, networking, and consumer electronics [1]. The heart of the Bluetooth brand identity is the name, which denotes the Danish king Harald "Bluetooth" Blaatand who united Denmark and Norway. This is largely because in the beginning of the Bluetooth wireless technology era, Bluetooth was intended to unite the telecom and computing industries. Bluetooth can be used to wirelessly sync and transfer data between devices. Bluetooth can be perceived as a cable replacement technology. General use includes automatically synchronizing contact and calendar information among desktop, notebook and palmtop computers without using the cables. Bluetooth can also be used to access a network or the Internet with a notebook computer by connecting wirelessly to a cellular phone [2].

Bluetooth is a potential candidate of becoming the optimal technology for ad hoc networks in the future. Its low power consumption and potential low cost make it a feasible solution for the standard mobile devices used in ad hoc networks. Bluetooth is a specification for Wireless Personal Area Network. It is a means of connecting and exchanging information and data between devices like mobile phones, laptops, desktops, etc. The data/information exchange is wireless and has the range of up to 10 meters. Bluetooth can be used to transfer files, photos, and songs between two Bluetooth devices. Bluetooth headsets can be used for receiving/making handsfree calls on the go [2].

2. BLUETOOTH PROTOCOL STACK
Bluetooth comprises of a layered architecture that includes core protocols, cable replacement protocols, telephony control protocols and adopted protocols. Both Bluetooth specific protocols and non-Bluetooth specific protocols (shaded in Figure) comprise the protocol stack.

The Bluetooth protocol stack comprises:

Baseband: Baseband and Link Control Layer enable a physical RF link between Bluetooth units that form a piconet. It manages a Bluetooth unit's synchronization and transmission frequency hopping sequence. It also manages two different types of links in Bluetooth, Synchronous Connection Oriented (SCO) and Asynchronous Connectionless (ACL). Both links can be multiplexed to use same RF link.

Link Manager Protocol (LMP): LMP handles link setup, control and negotiation of packet sizes when transmitting data, management of power modes and power consumption; and the generation, exchange and control of link and encryption keys for authentication and encryption.

Host Controller Interface (HCI): HCI provides a uniform interface method for enabling access to Bluetooth hardware capabilities. It contains control registers, event registers, command interface to Bluetooth controller and link manager and status of hardware.

Logical Link Control and Adaptation Protocol (L2CAP): The L2CAP layer provides connection-oriented and connectionless data services to upper layers. It performs multiplexing, segmentation and reassembly for packets exceeding Maximum Transmission Unit (MTU), Quality of service information exchange, group abstraction for mapping on piconet.

RFCOMM: RFCOMM is a serial port emulation protocol that emulates RS-232 control and data signals over Bluetooth baseband. It also provides transport capabilities to upper level services (e.g. OBEX) that use serial lines as a transport mechanism.

Service Discovery Protocol (SDP): For a Bluetooth client to discover available Bluetooth servers' services, SDP is used. It provides means for a client to discovering new services becoming available when it enters a Bluetooth server operating area. It defines how a client can search for a service

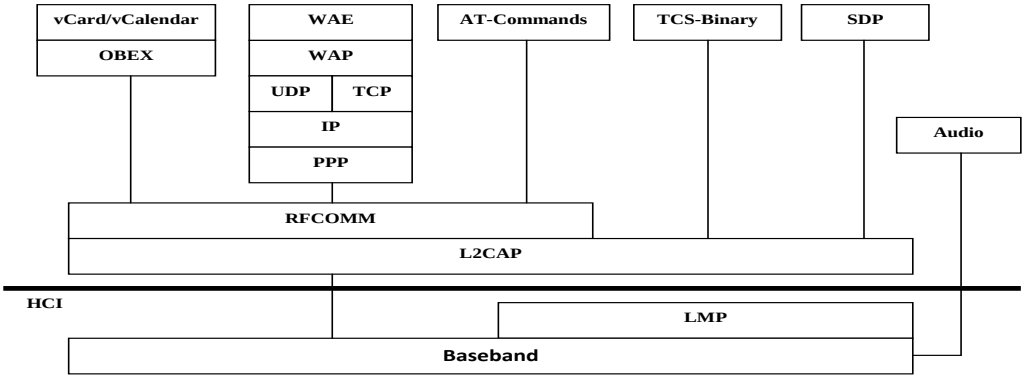

Fig. 1. The Bluetooth Protocol Stack

and detect when service is no longer available, without knowing anything of available services.

Telephony Control – Binary (TCS Binary): To define a call control signaling for establishing and releasing speech and data calls between Bluetooth units, TCS Binary is used. It is a bit-oriented protocol that provides functionality to exchange information that is unrelated to the ongoing call.

Audio: Audio data transmission between Bluetooth units does not travel via the L2CAP layer, but directly after link establishment and straightforward setup between the units [3].

Specific Protocols without Bluetooth:

These are protocols adopted from other standards making organizations and incorporated as part of the Bluetooth protocol stack. Protocols such as OBEX and UDP have been included in the protocol architecture to facilitate the adaptation of applications using such existing protocols.

Telephony Control – AT Commands: A number of AT command are supported by Bluetooth for transmitting control signals for telephony control through serial port emulation (RFCOMM).

Point-to-Point Protocol (PPP): The PPP is a packet-oriented protocol that runs over RFCOMM. It uses serial mechanisms and converts the packet data stream into a serial data stream.

UDP/TCP – IP Protocols: The UDP/TCP and IP standards allow Bluetooth to act as a bridge to the Internet and a transport configuration to WAP.

Wireless Application Protocol (WAP): Bluetooth can be used with WAP wireless protocol specification, to provide a bearer to transport data across a WAP Client and corresponding WAP server. Bluetooth can also be used for distributing information to hand-held devices on location basis, using server push capability of WAP. For example, shops can advertise special offers to WAP clients in Bluetooth proximity.

OBEX Protocol: OBEX allows infrared communication for exchanging a wide variety of data and commands. It is an optional application layer protocol that uses client-server model and is independent of transport mechanism/ API, using RFCOMM as the main transport layer [3].

2.1 Bluetooth Specifications

It defines a set of requirements to ensure interoperability between Bluetooth devices from different manufacturers. Due to the wide variety of possible Bluetooth devices, different sets of requirements are needed. The goal of the Specifications compliance section is to ensure that any device wearing a Bluetooth logo should support a minimum set of benefits for its user [4].

2.1.1 Bluetooth Radio Parameters

Bluetooth units operate on the 2.45 GHz ISM band. The transmitting power is between 1 and 100 mW. The maximum Bluetooth range is 10 m, with a possibility to extend it to 100 m. The maximum bit rate is 1 Mbps. Estimates have indicated data transfer rates up to 720 kbps [3].

2.1.2 Frequency Hopping

In Bluetooth, frequency- hopping (FH) spread spectrum technology is used to avoid interference. The Bluetooth specification defines a high hop rate of 1600 hops per second. The frequency band is divided into a number of hop channels. Every channel is used for 625 µs (one slot) followed by a hop in a pseudo-random order to another channel for another 625 µs and so on. Since traffic is spread over the entire ISM band, a good interference protection is achieved [3].

3. THE BLUETOOTH VERSIONS

There are number of Bluetooth versions which were developed to meet the particular requirements of the time. All versions support backward compatibility with the previous versions. The Versions of Bluetooth are as follows [1]:

3.1 Bluetooth 1.0, 1.0B AND 1.1[5]

- Earliest versions of Bluetooth
- Typical range upto 2m
- These had numerous problems and manufacturers had great difficulties in making their products interoperable.
- These versions had mandatory Bluetooth Hardware Device Address (BD_ADDR) transmission in the handshaking process, rendering anonymity impossible.
- In version 1.1 errors found in the 1.0B specifications were rectified and introduced support for non-encrypted channels.
- Received signal strength indicator added in version 1.1.

3.2 Bluetooth 1.2[5]

- Backward compatible with v1.1, faster connection and discovery.
- Introduction of Adaptive Frequency Hopping (AFH), which improved resistance to radio

interference by avoiding using crowded frequencies in the hopping sequence spectrum.

- Higher transmission speeds.
- Extended Synchronous Connections (ESCO) allowed retransmission of corrupt packets improving audio quality.
- Host Controller Interface (HCI) support for 3-wire UART.
- Data transmission speed up to 721 kbit / s.

3.3 Bluetooth 2.0[6]

- Non-hopping narrowband channel(s) introduced.
- Bluetooth 2.0 security is based on cryptography.
- Enhanced Data Rate (EDR) of 2.1 Mbit /s.
- Built-in QoS.
- Enhanced response time.
- Power consumption reduced to half due to shorter duty cycles.

3.4 Bluetooth 2.1[7]

- Uses secure simple pairing (SSP) resulting a better pairing experience for Bluetooth devices.
- Uses sniff sub rating reducing the power consumption in low-power mode.
- Extended Inquiry Response (EIR) provides more information during the inquiry procedure to allow better filtering of devices before connection.

3.5 Bluetooth 3.0[8]

- Bluetooth 3.0 provides notional data transfer speeds of up to 24 Mbit/s.
- For high data rate traffic this version uses the adjacent 802.11 link.
- Enhanced Power Control
- Unicast Connectionless Data
- The principal difference between Bluetooth 3.0 and Bluetooth 2.1 is that Bluetooth 3.0 (HS, 802.11) can transmit large amounts of data, and Power consumption also is clearly higher, but due to idle time, the 802.11 module will automatically shut down, so power consumption can be greatly reduced

3.6 Bluetooth 4.0[9][10]

- Also called as Bluetooth Smart.
- Provides faster speed in data transmission than the earlier version.
- Reduces power consumption even further.
- Provides more security in data transmission than the earlier versions.
- The Apple iPhone 4S is the first phone to ship with this Bluetooth v4.0.
- It includes Classic Bluetooth, Bluetooth high speed and Bluetooth low energy protocols [10].
- Classic Bluetooth consists of legacy Bluetooth protocols and High speed Bluetooth is based on Wi-Fi.

3.7 Bluetooth Low Energy [11]

- Bluetooth low energy, previously known as Wibree, is a subset of Bluetooth v4.0 with a completely new protocol stack for fast build-up of simple links.
- As a substitute to the Bluetooth standard protocols that were introduced in Bluetooth v1.0 to v3.0, it is aimed at very low power running applications.

3.8 Bluetooth 4.1[12]

- Bluetooth v4.1 specification was adopted on 4 December 2013.
- This specification is an incremental software update to Bluetooth Specification v4.0, and not a hardware update.
- Mobile Wireless Service Coexistence Signalling, Train Nudging and Generalized Interlaced Scanning, Low Duty Cycle Directed Advertising, L2CAP Connection Oriented and Dedicated Channels with Credit Based Flow Control, Dual Mode and Topology, LE Link Layer Topology, 802.11nPAL, Audio Architecture Updates for Wide Band Speech, Fast Data Advertising Interval, Limited Discovery Time are some of the new features.

3.9 Bluetooth 4.2[12]

- Bluetooth v4.2 was released on December 2, 2014.
- It introduced key features for IoT such as Data Length Extension, privacy updates via firmware.
- LE Data Packet Length Extension, LE Secure Connections, Link Layer Privacy, Link Layer Extended Scanner Filter Policies, Bluetooth Smart, to support connected home and other IoT implementations are major areas of improvement.

4. BLUETOOTH APPLICATIONS

- The earliest application to become popular was the wireless control of and communication between a mobile phone and handsfree headset for receiving or making calls [13].
- Wireless control of car stereo system using Bluetooth enabled mobile.
- Mutual communication between Bluetooth enabled devices like iOS and Android.
- Headphones with wireless audio streaming capability.
- Modern all-in-one desktop computers use Bluetooth to replace cables and enable wireless access of keyboard and mouse.
- Transfer of files, contact details, calendar appointments, and reminders between devices with OBEX.
- Previously wired RS-232 serial communication can be replaced with Bluetooth in test equipment, GPS receivers, medical equipment, bar code scanners, and traffic control devices.

- Bluetooth advertisement broadcasting for discovery of special offers to nearby Bluetooth enabled devices.[14]
- Wireless bridge among two Industrial Ethernet (e.g., PROFINET) networks.
- Home video game consoles use Bluetooth for their wireless controllers like Nintendo's Wii.[15] and Sony's PlayStation 3.
- Tethering of mobile data to laptop or desktop to use or share the cellular data.
- Medical equipment can share/transmit the information or data back to paired mobile or receiver [16].
- Real-time location systems (RTLS), are used to track and identify the location of objects in real-time by embedding nodes or tags, and readers that receive and process the wireless signals from these tags to determine their locations [17].
- Personal security application on mobile phones for prevention of theft. A connection is established between phone and the protected item, raising an alarm if connection is broken.[18]
- Door unlocking using Bluetooth eliminating need of keys, entry way lights turn on, etc [19].
- Bluetooth Low Energy beacons can be used in a variety of different ways, for advertising, mobile commerce, mobile marketing and approximate indoor positioning [20].

5. CONCLUSION

Thus it can be inferred that Bluetooth has a very important role to play in the development of smart cities. Bluetooth is an emerging platform for future telecommunications and thus has a lot to offer. With all the wide applications and potential for more Bluetooth is really a trump card for the future of smart cities. In particular access controls for smart cities can be designed and built around Bluetooth in the future. The ability of Bluetooth to have an intermediate range between Radio Frequency Identifiers and Wi-Fi allows for a convenient personal communication or interfacing medium for advance applications.

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