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Bluetooth and Ad Hoc Networking

Poonam Ahuja[*1]
Department of Computer Science
Aitm, Palwal
Email: ahujapoonam19@gmail.com

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Abstract- This paper is written to give introduction of the usage of the Bluetooth technology in ad hoc networking. Most common ad hoc networking applications for Bluetooth technology are introduced and current status of the Bluetooth technology suitability for ad hoc networks is examined. Also different protocols and functions, which are integral part of Bluetooth specification and used for ad hoc networking purposes, are discussed. Finally there are some recent studies shortly evaluated concerning Bluetooth scatternet formation and routing protocols performance.

Key Words- Bluetooth, LAN, TCP/IP, Protocol, MANET, Service Discovery Protocol

1. INTRODUCTION

An ad hoc network is a network with temporary plug-in connections, in which the network devices are part of the network only for the duration of a communications session or, in the case of mobile or portable devices, while in some close proximity to the rest of the network.
Ad hoc network is often local area network or other small area network formed by wireless devices. In Latin, ad hoc literally means "for this," further meaning "for this purpose only," and thus usually temporary. The term has been applied to future office, home and personal area networks in which new network nodes can be quickly added and removed. [1] The area of ad hoc networking has gathered much research interests in the past years. Many studies have concentrated on the routing issues of
ad hoc networking [2].

Bluetooth is one of the technologies that can be used for ad hoc networking. Bluetooth specification is a computing and telecommunications industry specification that describes how e.g. mobile phones, computers, and personal digital assistants (PDAs) can easily interconnect and communicate with each other by using wireless transmission in a short-range. The goal of the specification is to eliminate the need for any cable connectivity and promote ad hoc networking. By using this technology, users of cellular phones, laptops, PDAs, etc. portable devices can quickly share information with each other, for example, in a conference room using adhoc networking. [1]

The key features of the Bluetooth specification include robustness, low complexity, low power, and low cost. The transceiver transmits and receives in unlicensed IMS (Industrial, Scientific and Medical) frequency band of 2.4 GHz that is available globally. The technology is a combination of circuit switching and packet switching thereby supporting both synchronous voice channels and asynchronous data channels. Connections can be point to-point or multipoint. The maximum usage range is between 10 to 100 meters with three output power classes of 1, 2.5 and 100 mW. In theory, data can be exchanged at a rate of 1 megabit per second. However, the actual maximum data exchange rate is 723 kbps. A frequency hop scheme allows devices to communicate even in areas with a great deal of electromagnetic interference within 2.4 GHz IMS band. [3]

The original idea of Bluetooth concept was that of cable replacement between portable and/or fixed electronic device. According to the specification, when two Bluetooth devices come into each other's communication range, one of them assumes the role of master of the communication and the other becomes the slave. This simple "one hop" network is called a piconet, and may include up to seven active slaves connected to one master. As a matter of fact, there is no limit on the maximum number of slaves connected to one master but only seven of them can be active at time, others have to be in so called parked state. [5] See Figure 1 for basic piconet topologies introduced.

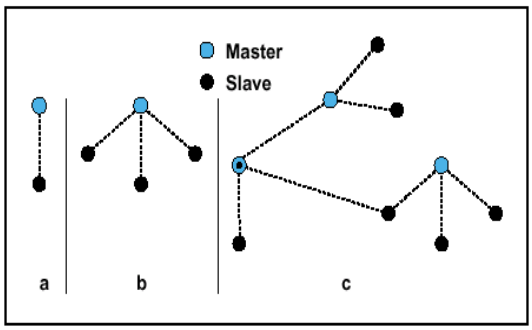

Figure 1: Piconets with single slave operation (a),

multi-slave operation (b) and scatternet operation (c).
The specification also allows multiple roles for the same device, i.e. a node can be a master in one piconet and a slave in another. This permits the connection of several piconets as the nodes functioning in master/slave mode act gateways between piconets. In the Bluetooth concept
the network topology resulting by the connection of piconets is called a scatternet. A node can be active in only one piconet at time, and to operate as a member of another piconet, a node must switch to the hopping frequency sequence of the other piconet. [5]

2. NETWORK TOPOLOGIES

This chapter examines in more detail the basic Bluetooth network topologies and their usability in real life applications. There is also some comparison made against other solutions available in market and evaluated the competitiveness of the Bluetooth topologies against the other solutions.

2.1 Point to point applications

Point to point connection is the very basic functionality of the Bluetooth technology. It is not exactly the main interest of us when talking about Bluetooth ad hoc networks, indeed it can said that it is more like ad hoc connection than network. However, some key issues of Bluetooth usability in piconets with a single slave should be noted to understand how it is performing in the area where it is originally plant to be used. This helps us to understand the future availability of Bluetooth enabled devices in general. Point to point connectivity with Bluetooth is obviously an alternative for cable connectivity. However, it is clearly not an option as replacement of every type of cable connections. The data transmission rates that Bluetooth is currently designed to support are not suitable for high capacity connections. Connections using over 723 kbps data transmission rates will most probably not be replaced by Bluetooth simply for the sake of having a wireless connection. Computer industry is today widely supporting the Universal Serial Bus (USB) cabling standard for chaining peripherals together. Currently USB is enabling data transmission rates up to 12 Mbps. Any peripheral whose performance is less than satisfactory over such a connection is probably not going to benefit from a wireless link running at less than a tenth of this capacity.
The next version of USB is expected to run at 480 Mbps with the aim of being able to support digital video. After this there is clearly even less ground for Bluetooth technology to work as a USB replacement. [6]

2.2 Point to multipoint applications

Although Bluetooth supports a point to multipoint topology only two profiles in the version 1.1 of the Profiles Specification of the Bluetooth System [9] actually implement it; Cordless telephony and LAN access. [6] Of these LAN access is by far the most widely implemented. There are also a number of issues
connected to the point to multi-point topology that need to be borne in mind when designing applications. One application of the LAN access profile is the scenario where a number of laptops (or other devices) are connected to an access point as the access point works as the master and the connected devices as slaves. More interestingly, from the ad hoc networking point of view, the profile could also be used to support a group networking situation to network up to eight laptops with one as the master and the other seven as slaves as shown in Figure 2. The most obvious problem with this is that there is no facility for slave-to-slave communication supported by the LAN profile. Of course, there is an option that two slaves form a further piconet, thus creating a scatternet and generating the problems discussed in next chapter considering scatternets.

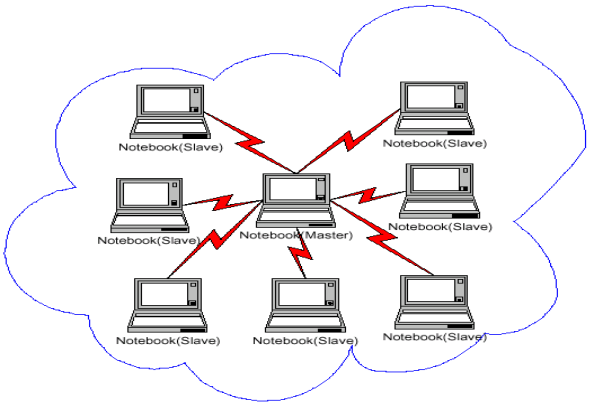

Figure 2: Single piconet ad hoc network.

The new Bluetooth Personal Area Networking Profile [10] is addressing this limitation in ways that will allow peer-to-peer communication and forwarding of packets between two slaves by the master working as a router.

As conclusion of Bluetooth usage for a simple, piconet size, ad hoc networking it can be noted that there are few problems that are not currently solved and that effect to performance of Bluetooth specification to work as ad hoc networking technology. The presented problems are not however showstoppers for Bluetooth usage in simple, e.g. meeting kind of, ad hoc networking
application.

2.3 Scatternet applications

The concept of the scatternet is integral part of Bluetooth specification and has been under a remarkable research interest since first introduced. Anyone new to Bluetooth will be introduced to the concept of the scatternet almost immediately; the topology employed by Bluetooth is that of a master and slave forming a piconet and piconets in turn can be linked to create a scatternet covering a much wider area. Indeed, scatternets are suggested as being preferential

Corresponding Author: *Poonam Ahuja*

to a point to multipoint piconet as the AU System's Bluetooth White paper [16] suggests; "if a mobile user wants to connect a number of Bluetooth units to his mobile phone, the best way to get high data transmission capacity is to form as many piconets as possible in one scatternet. Every connection is using a piconet's maximum capacity (721 kbps)."

3. PERSONAL AREA NETWORKING PROFILE

The LAN access point profile as it is specified today enables an access point to act as a bridge between a Bluetooth device and a local area network, by running multiple PPP (Point to Point Protocol) connections, with up to seven Bluetooth devices. RFCOMM runs on top of PPP, which in turn runs on either TCP/IP or UDP/IP. [4]. This allows basic services such as file access, printing, intranet or Internet access, synchronization and more advanced services such as cordless telephony and voice over IP. Although PPP allows LAN access for multiple.

Bluetooth devices in a 'star' topology it is only allowing communication by serial cable emulation and is not a true networking protocol. It does not support any slave to- slave communication and its prospects for scalability in terms of the number of devices that can be networked are very limited. In addition no facility for hand-off between access points, to allow seamless mobility between access points, is provided. For this Bluetooth needs to support true networking protocols, most notably IP, which means running TCP/IP over L2CAP which in turn requires a new profile to be defined. This is the charter of the Bluetooth PAN Working Group that has been tasked with: [10]

- Enabling IPv4, IPv6 and other common networking protocols to run over Bluetooth whilst allowing existing networking applications to work.
- Supporting slave to slave communication
- Allowing both the above to work in both ad hoc mode (device to device) and infrastructure mode (in which access points are connected to the fixed infrastructure).

To achieve this PAN WG has proposed a new protocol, Bluetooth Networking Encapsulation Protocol (BNEP), which is described as providing an Ethernet like networking framework. It supports IPv4, IPv6, all IETF (Internet Engineering Task Force) protocols and also packet header compression to minimize transmission overheads. It is claimed that it will lead to greater ease of Bluetooth use as it will allow existing networking applications designed for these protocols to interface to Bluetooth and also supports ISO layer 2 bridging, similar to other wireless LANs and which is the foundation of access point hand-off. [6] It will enable devices to operate in more of a peer-to peer fashion rather than the usual master-slave topology and so help enable peer-to-peer applications such as gaming. The profile defines three different operational roles: [10]

- Pan User (PANU) in which a device acts as a client of either of the following two cases.
- Group Network (GN) in which devices are networked together but with no access point supporting communication with a wider infrastructure.
- Network Access Point (NAP) which supports the infrastructure case and connects devices via an access point to another network.

4. SERVICE DISCOVERY

As shown already, Bluetooth specification is a part of a new generation of much more fluid networks in which devices and services are not part of the fixed infrastructure but are continually leaving and joining different networks in an ad hoc fashion. Networks have traditionally been defined simply by the connections they provide but in future the ability to connect with a network and its devices will be taken for granted. The real value will lie in finding out what the capabilities of other devices are, what services the network can provide, how a device can access these services, e.g. what protocols and drivers are required. Also promoting a device's own services to the network and possibly even billing for services is almost essential functionality. All this is called service discovery, a facility that is supported by Bluetooth via the Service Discovery Protocol (SDP).

A key aspect of service discovery is the support it provides for self-configuration of devices. In static networks configuration is not such a big issue as it is usually done once, at installation, and the details of the various available services on the network and where to find them are held in a central directory.

5. PERFORMANCE STUDIES

In this chapter our main interest is Bluetooth ad hoc scatternets' formation and performance aspects. There are several studies made about optimizing scatternet formations. These studies try to overcome the problem of arranging scatternets in the most efficient way for routing between nodes. In Performance Aspects of Bluetooth Scatternet Formation [7] study by Miklós et al it was noted by using a statistical approach that two characteristics seem to be valid in performance of scatternet formation. First the amount of bridging overhead and secondly the number of established Bluetooth links. By bridging overhead is meant the number of nodes participating in more than one piconet i.e. working as both master and slave. Increasing the number of links first allows more traffic to be carried by the network, but this trend is later reversed due to the increased overhead of a node being a member of more and more piconets. So, there is a link number when the throughput is maximized.

6. CONCLUSIONS

In this paper we discussed about different aspects of Bluetooth technology suitability for ad hoc networking. As result is was shown that there are several issues limiting the functionality of Bluetooth technology in ad hoc environment. Most of these issues are connected to loose specification of scatternet formation. As result there are several research papers published proposing different scatternet formation protocols to correct this issue. Evaluations of these papers show that there is some good propositions available to address this issue efficiently. Still there is no widely utilized scatternet formation protocol implemented in current Bluetooth devices that would enable uniform, and efficient, ad hoc scatternet formation. Also the pending Bluetooth Personal Area Networking Profile [10] is hoped to address in many expectations to correct issues concerning Bluetooth ad hoc networking functionality. The PAN profile is extending Bluetooth to provide true IP-based personal area networking capability by allowing peer-to-peer communication and forwarding of packets between two slaves by the master working as a router. The PAN profile is the first Bluetooth profile fully supporting scatternet topology. As final conclusion it seems that today Bluetooth is not yet a commercial solution for seamlessly providing ad hoc networking capability to portable devices such as laptops and PDA's. However, the first commercial product implementations of the new PAN profile will soon show if Bluetooth is up to this task as being able to utilize it's scatternets efficiently to form ad hoc networks. The possibilities are there, we just have to wait and see markets response.

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