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A BLUETOOTH MOBILE AD HOC NETWORK COMMUNICATION TOPOLOGIES

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Abstract: Bluetooth is short range wireless mobile ad hoc network communication environment in which network is formed spontaneously. Mobility of ad hoc network can lead to frequent and unpredictable topology changes. In this paper, various communication topologies of Bluetooth ad hoc network are mentioned and their suitability of ad hoc networks is examined. Finally this article presents how these topologies are constructed and their challenges and compatibility with mobile applications.

Keywords — Ad hoc network, Bluetooth, Piconet, Scatternet

INTRODUCTION

Recently, wireless ad hoc networks or a mobile multi-hop wireless network has gained an unprecedented growth. Further, an increasing number of devices such as laptops, Personal Digital Assistants (PDAs), pocket PCs, tablet PCs, smart phones, MP3 players, digital cameras, etc. are provided with short-range wireless interfaces. In addition, these devices are getting smaller, cheaper, more user friendly and more powerful. This evolution is driving a new alternative way for mobile communication, in which mobile devices form a self creating, self-organizing and self-administering wireless network, called a *mobile ad hoc network* [2].

Short-range *ad hoc* networks can simplify intercommunication between various mobile devices by forming a Personal Area Network (PAN), and thereby eliminate the tedious need for cables. This could also extend the mobility provided by the fixed network (that is, mobile IP) to nodes further out in an *ad hoc* network domain. The Bluetooth system is perhaps the most promising technology in the context of Mobile ad hoc networking [8].

In Latin, ad hoc literally means “for this”, further means “for this purpose only”, and thus means temporary. The term has been applied to networks in which new nodes can be quickly added and removed [3]. The area of ad hoc networking has gathered much research interests in the past decades. Many studies have concentrated on the routing issues of ad hoc networking. Mobile *ad hoc* networks have been the focus of many recent research and development efforts [3].
The goal of mobile ad hoc networking is to extend mobility into the realm of autonomous, mobile, wireless domains, where a set of nodes--which may be combined routers and hosts--they form the network routing infrastructure in an ad hoc fashion. Also, ad hoc networks do not need to operate in a stand-alone fashion, but can be attached to the Internet, thereby integrating many different devices and making their services available to other users.

Furthermore, capacity, range and energy arguments promote their use with existing cellular infrastructures as they can extend coverage and interconnectivity. As a consequence, mobile ad hoc networks are expected to become an important part of the future 4G architecture, which aims to provide pervasive computer environments that support users in accomplishing their tasks, accessing information and communicating anytime, anywhere and from any device.

Bluetooth is one of the technologies that can be used for ad hoc networking. Bluetooth wireless technology is a short-range communications system intended to replace the cable(s) connecting portable and/or fixed electronic devices. Key features are robustness, low power, and low cost. Many features of the core specification are optional, allowing product differentiation. The Bluetooth core system consists of an RF transceiver, base band, and protocol stack. The system offers services that enable the connection of devices and the exchange of a variety of classes of data between these devices [1][3].

The paper is structured as follows. Section 2 gives overview of Bluetooth technology. In section 3, various communication topologies of Bluetooth are presented. Finally, Section 4 concludes the paper.

BLUETOOTH TECHNOLOGY

Bluetooth is a short range wireless communication radio technology, operates at 2.4 GHz unlicensed ISM (Industrial-Scientific-Medical) band that is available globally. It supports both synchronous voice channels and asynchronous IP-based data channels because of circuit switching and packet

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switching. The maximum usage range is between 10 to 100 meters. The Bluetooth radio link is based on Frequency Hopping Spread Spectrum (FHSS), multiple channels can co-exist in the same wide band without interfering with each other. The hop frequency is up to 1600 hops per second, the frequency spectrum is divided into 79 channels of 1 MHz bandwidth each.

Communication of Bluetooth devices follows a master-slave configuration. When two or more Bluetooth devices come into each other's communication range, one of them act as master controlling the communication and others become slaves. This type of single-hop network is referred as *piconet* that includes up to seven active slaves connected to one master. There is no limit on the maximum number of slaves connected to one master but only seven of them can be active at time. A master defines the timing and hop patter, slaves have to say synchronized to master while participating in the piconet.

A set of several piconets in the same geographic area form a *scatternet*, which is multi hop Bluetooth network. A device can participate in two or more piconets (but active in only one piconet at a time), on a time-sharing basis, and even change its role when moving from one piconet to another. Such device is called as Bridge which can be master in one piconet and a slave in another piconet but cannot be a master in more than one piconet [7].

COMMUNICATION TOPOLOGIES

Communication topology is a physical communication scheme used by the devices which are connected to make a communication. In this section, Topology formed by the Bluetooth devices while communicating with each other is presented in detail.

Point-to-Point Communication

Communication with two endpoints is called Point-to-point Communication. It is the simple functionality of Bluetooth technology. Piconets with a single master and single slave forms point-to-point communication in Bluetooth as shown in Figure 1. Point-to-point connection using Bluetooth is alternative approach for cable connection. However, it is not an absolute solution for replacing all types of cable connection.

Figure 1. Point-to-Point communication

Currently, Bluetooth is designed to support data transmission up to 26 Mbps. Connections over 26 Mbps data transmission rates will most probably not replaced by Bluetooth.
The most common wireless point-to-point communication standard for Wireless Local Area Networks (WLAN) is the IEEE 802.11 standards by IEEE. IEEE 802.11n standard enables point-to-point connection up to 600 Mbps. These standards are essentially high speed but also mainly unidirectional, as they allow only very limited bandwidth.

However, Bluetooth is not an alternative for other technologies (cable, USB, IEEE 802.11x), it supports much greater degree of interactivity and will be best deployed where this two-way capability is required such as voice and data retrieval applications [3][4].

Bluetooth is well appropriate for point-to-point applications demanding, or highly benefiting of, wireless connectivity. Good examples of this kind of applications are mobile terminal headsets and dial-up networking between laptop and mobile terminal. Bluetooth technology suits also well in applications where there is only moderate demands for data transfer rate. Bluetooth is not the technology to fully eliminate need for cable connectivity but it definitely has some good applications and possibility to take piece of the market [3][4].

Piconet Topology

Any time a Bluetooth link is formed it is within the context of a piconet. A piconet consists of two or more devices that occupy the same physical channel (which means that they are synchronized to a common clock and hopping sequence.) The common (piconet) clock is identical to the Bluetooth clock of one of the devices in the piconet, known as the master of the piconet, and the hopping sequence is derived from the master's clock and the master's Bluetooth device address. (See Figure 2) All other synchronized devices are referred to as slaves in the piconet. The terms master and slave are only used when describing these roles in a piconet [1].

Within a piconet a Bluetooth unit can be either master or slave. Within each piconet there may be only one master (and there must always be one) and up to seven active slaves. Any Bluetooth unit can become a master in a piconet [9].

Figure 2: Piconet with one master and three Slaves

Within a common location a number of independent piconets may exist. Each piconet has a different physical channel that is a different master device and an independent piconet clock and hopping sequence [1].
The Bluetooth Specification defines various modes for Bluetooth devices. Four modes are described below, three of them (hold, park and sniff mode) are power saving modes which are used to reduce the duty cycle of devices.

Connected mode - After a successful connection procedure, the devices are physically connected to each other within a piconet. This means that there is a piconet physical channel to which they are both connected; there is a physical link between the devices [1].

Hold Mode – A slave is inactive in the piconet for an agreed period. At the end of the period the salve becomes active and can be

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addressed by the master. The period is called hold timeout and its length is negotiated between the master and slave [1][7].

Sniff Mode – A slave is inactive for specific intervals called sniff intervals. At the beginning of every interval it becomes active for few slots, called sniff attempt, in which the master can address it. If the master addresses it, it becomes inactive until timeout expires. Otherwise, it becomes inactive until the beginning of next interval [1][7].
Parked mode - Used to connect more than seven slaves in piconet. A Slave is still synchronized to the piconet but does not participate in the piconet. Parked devices have given up their MAC address and listen to the traffic of the master to remain synchronized messages.[5]

However, Master unit of piconet supports several slaves; there are some of facts that should be considered when using the piconet applications.

First, even the slaves can come and go as they want, the application will handle these dynamics as expected and if the master leaves the piconet the whole networks drop down. It needs extra work from the users of the ad hoc network to decide a proper master that will be available for whole time. Second, Collisions occurred due to several devices paging the master at once lead to increase network formation time. Finally, method of forming piconet results in loss of bandwidth [3][4].

Bluetooth offers Enhanced Data Rate for data transmission. Even Simple Bluetooth piconet is well suited for ad hoc networking, still there are few problems should be noted and solved.

Scatternet Topology

To increase the Bluetooth networking capabilities, piconets are interconnected into Scatternets, Which requires some Bluetooth units participating in multiple piconets. These connecting devices work in time division manner i.e. inter –piconet unit will switch between the piconets. This unit is called as Bridge; it can act as slave in one piconet and master in another piconet. It can be salve in one or more piconets but master in only one piconet [6].

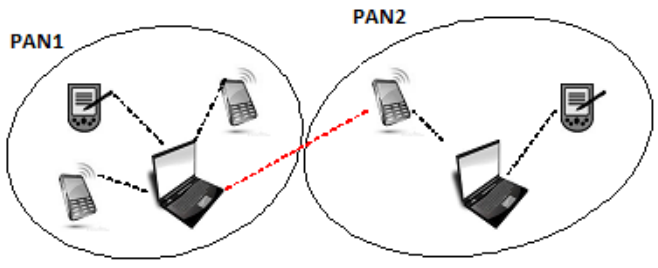

Figure 3. Scatternet with two interconnected piconet

Bridge may also act as gateways that forward traffic between the piconets. It cannot receive the information from more than one piconet at the time, so coordinating the presence of masters and bridges in each piconet is needed to attain a controlled performance. The scatternet is used to improve the performance of group of Bluetooth units that are either already part of a scatternet, or part of separate piconet [6].

Even the functionality of scatternet works well; there are some issues that makes scatternet application unreliable. First the bridge unit can change the role as either master or slave. If this switch occurs at the time as the ACL link is created this will be OK, but if the switch occurs after the creation of ACL link and a connection to the third device is created prior to the switch, a scatternet make ensue rather than to multipoint piconet. Second, when multiple profiles are being run simultaneously on one device, an issue that the Bluetooth specification does not dealing with [3][4].

Bluetooth scatternets will work efficiently at sometimes, but not in all cases because of a level of reliability. We anticipate that the most of the scatternets will not be used as the replacement to WLANs.

CONCLUSION

This paper presents basic characteristic of Mobile ad hoc networks. It specifies how Bluetooth technology extends the mobile ad hoc network into user domain. Then, different kinds of communication topologies for Bluetooth devices were given. The Bluetooth architecture is based on the piconet which is defined by two or more Bluetooth units that share the same frequency hopping channel. One Bluetooth unit is the master and other units are slaves. The piconet has one master and maximum of seven active slaves. The need for simplicity and low complexity has made Time Division Duplex (TDD) one of the promising methods in wireless systems having Master-Slave configuration.

The scatternet topology had mentioned and the characteristics of scatternet were shown. Multiple piconets which are interconnected by bridges are called scatternet. A device that is a member of more than one piconet must schedule its presence in all the piconets in which it is a member.

Then, the performance of Bluetooth ad hoc network communication topologies with other wireless ad hoc network communication technologies was identified. Finally, limitations and challenges of piconet and scatternet topologies have been highlighted and analyzed.

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