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Applications Transforming Technology of future Bluetooth

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Abstract: ***Bluetooth is a new short-range wireless technology designed to enable wireless communication between diverse devices. It is gaining increasing popularity and acceptance in the world today. There is a growing body of research on the subject, but very few, if any of the analyses, provide a balanced view of the technology, which describe its pros and cons and implications for businesses. This paper attempts to critically analyze the Bluetooth technology from a various perspectives. It begins with a description of the technology in terms of its hardware, software, and network infrastructure. Then it addresses the related issues of interference, security, and reliability. This microanalysis is followed by a larger macroanalytical view, which includes the advantages of this technology, its role in the global third generation (3G) wireless scheme, health/safety issues, and business implications. It concludes with the applications of Bluetooth and its future potential. Bluetooth technology unplugs our digital peripherals and makes a cable clutter a thing of the past. In short, it is a wireless replacement for many of the cables we currently use to transmit voice and data signals. It is the result of the joint achievements of nine leading companies: 3COM, Lucent Technologies, IBM, Intel, Microsoft, Motorola, Nokia, Toshiba, Ericsson, altogether known as the Blue Tooth Special Interest Group (SIG). The idea is to create a single wireless protocol to address the end-user problems arising from proliferation of various mobile devices. It aims at low power consumption and provides security for both stationary and mobile devices. A Bluetooth chip (9mm x 9mm) takes the information normally carried by the cable, and transmits it at a special frequency to a receiver. Bluetooth radio modules use Gaussian Frequency Shift Keying (GFSK) for modulation.***

Keywords: Communications Devices,Usage, Economical Solution , Network Topology, Frequency-Hopping , Long Term Applications **Transforming technology of future Bluetooth**

I. Introduction:

A look around at the moment! Keyboard connected to the computer, as well as a printer, mouse, monitor and so on. What (literally) joins all of these together? They are connected by cables. Cables have become the bane of many offices, homes etc. That is what the Bluetooth technology aims at – a cable replacement technology!

Bluetooth is a short-range wireless technology designed to enable such communication without the need for Companies that manufacture computers, entertainment systems, and other electronic devices have realized that the incredible array of cables and connectors involved in their products make it difficult for even expert technicians to correctly set up a complete system on the first try.

II. Bluetooth - In detail:

One of the most significant recent developments in wireless technologies is the emergence of Wireless personal area networking (WPAN). Developed in 1998, WPAN is based on a new technology called Bluetooth, which uses short-range radio frequencies to transmit both voice and data. This technology wirelessly and transparently synchronizes data across devices and creates access to networks and the Internet within a range of ten meters. The short-range networks Bluetooth enables are called Personal Area Networks (PANs) or piconets. Bluetooth is more able to move from frequency to frequency, making it better able to handle interference than competing protocols. Bluetooth technology is the result of the joint achievements of nine leading companies: 3com, lucent technologies, IBM, Intel, Microsoft, Motorola, Nokia, Toshiba, Ericsson altogether known as the Blue Tooth Special Interest Group (SIG), which has widespread participation by many companies. Originally initiated by L M Ericsson, it was designed as a short-range communications medium for wireless headsets to communicate with cellular phones.

Bluetooth technology Features:

a) It separates the frequency band into hops. This spread spectrum is used to hop from one channel to another, which adds a strong layer of security.

b) Signals can be transmitted through walls and briefcases, thus eliminating the need for line-of-sight. Devices do not need to be pointed at each other, as signals are omni-directional.

c) Both synchronous and asynchronous applications are supported, making it easy to implement on a variety of devices and for a variety of services, such as voice and Internet.

d) Governments worldwide regulate it, so it is possible to utilize the same standard wherever one travels.

The Aim of "Bluetooth" has been set quite high. It is to arrive at a specification for a technology that optimizes the usage model of all mobile computing and communications devices, and providing:

I. Global usage ,Voice and data handling.
II. The ability to establish ad-hoc connections.
III. The ability to withstand interference from other sources in open band
IV. Very small size, in order to accommodate integration into variety of devices with negligible power consumption in comparison to other devices for similar use.

An open interface standard and competitively low cost of all units, as compared to their non-Bluetooth correspondents.

BLUETOOTH is used in Phones and pagers and Headsets, Modems and LAN access devices , Notebook computers , Desktop and handheld computers, Printers and Fax machines, Keyboards and Joysticks.

Bluetooth Specification:

Bluetooth is a global specification for a small form-factor, low-cost radio solution providing links between mobile computers, mobile phones, and other portable handheld devices, as well as connectivity to the Internet. The Institute of Electrical and Electronics Engineers (IEEE) has given the IEEE 802.15 standard. A Time-Division Duplex (TDD) scheme is used for full-duplex transmission. Its main strength is its ability to simultaneously handle both data and voice transmissions. A mobile computer equipped with Bluetooth technology, for example, could link to a similarly equipped mobile phone to connect to the Internet. Multiple Bluetooth units form a Wireless Personal Area Network, called and up to seven client devices. A Bluetooth WPAN is capable of supporting an asynchronous data link with each client and synchronous voice links with up to three client devices. It provides a range of up to 10m
at a transmit power of 1 mwatt. The range can be extended to 100m if the transmit power is increased to 100 mwatt. Bluetooth has a data rate of 1 Mbps. Bluetooth is a standard for a small (9mm x 9mm) , cheap radio chip to be plugged into computers, printers, mobile phones, etc. A Bluetooth chip takes the information normally carried by the cable, and transmits it at a special frequency to a receiver. Bluetooth chip, which will then give the information received to the computer, phone whatever. Bluetooth offers the most economical solution for low-to-medium-speed device connectivity. It aims at low power consumption and provides security for both stationary and mobile devices. The basic function is to provide a standard wireless technology to replace the multitude of propriety cables currently linking computing devices.

Technical standards and performance levels

1. Bluetooth is based upon small, high performance integrated radio transceivers, each of which is allocated a unique 48-bit address derived from the IEEE 802 standards.
2. It operates in the unrestricted 2.45 GHz ISM "free band", which is available globally, although slight variation of location and width of band apply.
3. The range is set at 10 meters to optimize for target market of mobile and business user. The range can, however, be increased.
4. Gross data rate is 1Mbit/s, with second generation plans to increase to 2 Mbit/s. One-to-one connections allow maximum data transfer rate of 721 kbits/s (corresponding to 3 voice channels).
5. Bluetooth uses a packet switching protocol, based on a frequency hop scheme with 1600 hops/sek. to enable high performance in noisy radio environments. The entire available frequency spectrum is used with 79 hops of 1 Mhz bandwidth, analogous to the IEEE 802.11 standard.
6. It has low power consumption, drawing only 0.3 mA in standby mode. This enables maximum performance longevity for battery powered devices. During data transfer the maximum current drain is 30 mA. However, during pauses or at lower data rates the drain would be lower.

The Bluetooth Network Topology:

There are 3 types of connections in Bluetooth, as shown below:

Either: Single-slave or Multi-slave (up to 7 ”slaves” on one master) or Scatternet. Multiple Bluetooth units form a Wireless Personal Area Network, called a piconet. A piconet consists of one hub device and up to seven client devices. It is possible to support more devices in a piconet by placing one or more of the clients into what is referred to as park mode. In order to exchange information with the parked client, the hub must take it out of parked mode and return it to active mode. Only seven clients can be in active mode at any given time. When two piconets are in close proximity, they have overlapping coverage areas - a scenario referred to as a scatternet Clients in one piconet can participate in another piconet as either a hub or client. This is accomplished through time division on multiplexing. In a scatternet, the two (or more) piconets are not synchronized in either time or frequency. Each of the piconets operates in its own frequency-hopping channel, while any devices in multiple piconets participate at the appropriate time via time division multiplexing. A piconet can be created in one of 4 ways: A page (used by Master to connect to Slave) or A page scan (a unit listens for its´ device access code) or A Master – Slave switch is made or An ”Unpark” of a unit is made (provided there are no active slaves).

Personal Networking Hardware And the Protocol Stack Layers:Bluetooth radio modules use Gaussian Frequency Shift Keying (GFSK) for modulation. The data is transmitted at a data rate of 1 Mb/second. The Bluetooth Baseband Layer: The baseband layer performs functions like Bluetooth packet assembly, forward error correction (FEC), automatic repeat request (ARQ), data whitening, Bluetooth clock synchronization, and frequency hopping control.

The Bluetooth Link Manager Layer: The Link Manager forms the piconet by inquiring what other Bluetooth radios are in the area, establishing connection and maintaining the piconet. The Link Manager also handles security issues like authentication and encryption.
Radio: The Radio layer defines the requirements for a Bluetooth transceiver operating in the 2.4 GHz ISM band.
Base band: This layer describes the specification of the Bluetooth Link Controller (LC) which carriesout the baseband protocols and other low-level link routines.The Link Manager Protocol (LMP) is used by the Link Managers (on either side) for link set-up and control.The Host Controller Interface (HCI) provides a command interface to the Baseband Link Controller and Link Manager, and access to hardware status and control registers.

.Logical Link Control and Adaptation Protocol (L2CAP) supports higher level protocol multiplexing, packet segmentation and reassembly, and the conveying of quality of service information. L2CAP, which adapts upper layer protocols over the Baseband, provides data services to the high layer protocols with group abstractions. The RFCOMM protocol provides emulation of serial ports over the L2CAP protocol. The protocol is based on the ETSI standard TS 07.10. The Service Discovery Protocol (SDP) provides a means for applications to discover which services are provided by or available through a Bluetooth device. Device information, services and the characteristics of the services can be queried using the SDP.

The Power Modes:
Bluetooth provides for three low power modes to conserve battery life: sniff mode, hold mode, and park mode. While in the sniff mode, a device listens to the piconet at a reduced rate. The sniff interval is programmable, providing flexibility for different applications. In hold mode, only an internal timer is running, and data transfer restarts when units transition out of the hold mode. Park mode is used to handle more than seven clients - since only seven clients can be "active" at any time, one client can be "parked" and another one activated.

The advantage of "frequency-hopping"
Bluetooth has been designed to operate in noisy radio frequency environments, and uses a fast acknowledgement and frequency-hopping scheme to make the link robust, communication-wise. Bluetooth radio modules avoid interference from other signals by hopping to a new frequency after transmitting or receiving a packet.
Compared with other systems operating in the same frequency band, the Bluetooth radio typically hops faster and uses shorter packets. This is because short packages and fast hopping limit the impact of microwave ovens and other sources of disturbances. Use of Forward Error Correction (FEC) limits the impact of random noise on long-distance links. Bluetooth can support an asynchronous data channel, or up to 3 simultaneous synchronous voice channels, or a channel which simultaneously supports asynchronous data and synchronous voice.

Safer transmission of data: "Security":
Bluetooth has built in sufficient encryption and authentication and is thus very secure in any environment. In addition to this, a frequency-hopping scheme with 1600 hops/sec. is employed. This is far quicker than any other competing system. This, together with an automatic output power adaption to reduce the range exactly to requirement, makes the system extremely difficult to eavesdrop. The transmitting power is far too weak to be noticeable for humans.
Moreover, the radiation is not concentrated in a beam, but dispersed more or less in all directions. Hence not dangerous!!
Bluetooth units often have to contend with electro-magnetically noisy environments. Thus, the need for some kind of error-detection and -correction. When errors are detected, there are 3 error-correction schemes defined for Bluetooth: 1/3 rate FEC (Forward Error Correction) , 2/3 rate FEC , ARQ unnumbered scheme (Automatic Repeat Request).
In Bluetooth, it has these components: Random Number Generation, Encryption, Encryption Key Management and Authentication.

Application Examples:

1. A Bluetooth-mouse or a Bluetooth-keyboard could be used at a further distance from a monitor, and while moving about in the room.
2. Use e-mail while your portable PC is still in the briefcase! When your portable PC receives an e-mail, you'll get an alert on your mobile phone.
3. A travelling businessman could ask his laptop computer to locate a suitable printer as soon as he enters a hotel lobby, and send a printout to that printer when it has been found, and replied in a positive manner.
4. Cable-less connection to printers and faxes, to digital cameras and video projectors. Cordless connection from cell phone to handsfree headset.
5. Bluetooth interface to office PBX and Dial-up networking and automatic e-mail and use cell phone as office cordless phone. Use of PC or PDA as handsfree phone.
6. Automatic exchange of files, electronic business cards, calendars etc.

III. Challenges In Bluetooth Design

The Bluetooth specifications have left several design issues open to implementation, when it comes to its use as a networking technology. The objective is to allow designers flexibility so as to cater to the individual network requirements. However for adapting the technology towards large scale deployment in adhoc networks it is imperative that there be a systematic procedure sharing the communication channel associated with each master.

Similarly, the number of bridge nodes that should exist between different piconets is also unclear. Many bridges can facilitate load distribution and improve connectivity, but this comes at the cost of increasing the complexity of synchronizing communication schedules an added overhead when switching from piconet a bi-partite graph. This is because neither masters nor slaves can communicate directly, and therefore the set of nodes associated
with masters only has edges to the set of nodes corresponding to slaves. Similarly, the constraint that a piconet cannot contain more than 7 slaves implies that all nodes associated with masters must have a degree less than or equal to 7. This also implies that if at any time the total number of masters is less than one eighth of the total number of nodes, then certain nodes will not belong to any piconet and thus the topology remains disconnected. These are constraints that any topology formation algorithm must take into account. In addition, it is not only the choice of role, i.e., master, slave, or bridge, that is important in determining connectivity, but the order in which nodes are assigned their role is also a key factor. In particular, because connectivity between piconets is ensured through bridge nodes and not all (slave) nodes are capable of playing such a role (the node must be able to "hear" the master
of each piconet), connectivity between two piconets may be precluded if the corresponding node attempts to join one of the piconets after the piconet has become full, i.e., already has 7 slaves. This can possibly be fixed by having some slaves relinquish their membership in the piconet, but identifying when this is needed, e.g., connectivity might still exist between the piconets through a multi-hop path, and which node should leave the piconet, is a complex problem. Achieving connectivity is, therefore, a complex and possibly unachievable task, but it provides a benchmark against which heuristics can be evaluated.

Our second design objective, namely a distributed operation and low overhead, is a must for any practical solution. As pointed out earlier, node state changes should be triggered in response to changes in the physical topology. Our third design objective of maximizing throughput, while obviously desirable, unfortunately adds complexity of its own to an already complex problem to piconet (recall that a node can be active in only one piconet at the time).

Assuming that some initial answers can be given to the problems we have just outlined, it is unlikely that static solutions will be sufficient in the context of adhoc networks. As a result, yet another level of complexity gets added when trying to determine when and how node states should change over time. Some of the factors that need to be taken account include the activity status of nodes themselves, e.g., a node may suspend its activities for some time and enter a "sleep" state in order to save power. Another aspect that needs to be considered is the
dynamic nature of adhoc networks, where the number and position of nodes involved is likely to continuously vary. Obviously, node configuration and network topology need to evolve in response to such changes. For example, if a master moves out of the transmission range of its slaves, then the piconet must identify a new master, presumably from the existing members of the piconet, and this calls for a change of state from slave to master in one of the nodes. The difficulty in making such decisions, even in the simple example just outlined, is in their distributed nature. Deciding when and which node state to change requires a significant amount of information exchange and processing, which besides its intrinsic cost can also translate into substantial latency. As a result, any feasible solution calls for some trade-off between "optimality" and its cost and responsiveness to changes.

For Bluetooth to succeed as a technology on which adhoc networks can be built, it is not only essential to find light-weight solutions to the above problems, but those solutions must be fully distributed. In other words, they should not assume the existence of a central entity with access to the entire system/network state, and nodes decisions should only be based on information about their own state and that of their "neighbors." However, the definition of what a node's neighborhood consists of is itself not clear. Does it consist only of nodes belonging to the same piconet(s), or does it also include other nodes within communication reach? More generally, a neighborhood could be defined as all nodes that are k or less "hops" away (hop count corresponds to the number of masters/piconets that need to be
traversed). Clearly there is a trade-off between the accuracy (or optimality) of the decisions that can be made under different scenarios. In general, the more information is available, the better the decisions. However, this comes at the cost of a higher latency, a higher processing cost, and a higher control overhead.

IV. Conclusion:

Despite some of the problems, Bluetooth remains a very promising technology, with plenty of medium and long term applications. But the real test will be whether it survives the hype. Promoters are laying on it, with their unrealistic claims. This technology is probably the only one which has a good chance to become widely available among PDAs and mobile devices. Bluetooth-equipped gadgets can connect to the LAN through the Access Protocols at once.50 kilobytes per second is about all you can expect from Bluetooth. So there we are: Bluetooth is simply the best !!

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