Bluetooth versus WLAN IEEE 802.11x

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ABSTRACT

Comparison of the he two principal standards for the wireless home LAN market in the near future.

Keywords

Wireless LAN, Bluetooth, IEEE 802.11, IEEE 802.11b, IEEE 802.15, HiperLAN2

1. INTRODUCTION

Wireless LANs have been available for a decade [11]. The first technologies were using proprietary solutions but standard IEEE 802.11 products have already been for sale for 2 years [15]. The three principal standards for the wireless home LAN market are HomeRF, Bluetooth, and IEEE 802.11 wireless Ethernet [11].

2. Bluetooth

Bluetooth is a de facto standard for very low powered and short-range radio connections that would link your personal access devices (PDA), mobile phones and laptops, and give them Internet access via hot spots [1].

Bluetooth 1.0 specifications were completed 1999, but the first products are expected being shipping in the second half of year 2000 [15].

In the long term Bluetooth will be built in a chip e.g. on the morher board of a laptop or a cellular phone – in the shorter term it will be added using PC cards or USB adaptors [22], while in the IEEE 802.11x branch they are having similar progress. The IEEE 802.11x is shipped as PC cards, and soon the wireless connection will be build in notebook computers by PC makers [24].

Bluetooth's native ad hoc network property makes it very useful replacing cables at home, giving printing support at hotel or acting as an ID card at a shopping center. IEEE 802.11 WLAN does support ad hoc networking, and can be used likewise, but the main stream of the IEEE 802.11 developers isn't focused on that subject. [15]

3. WLAN IEEE 802.11x

Basically WLAN is an ordinary LAN protocol which is modulated on carrier waves. WLAN IEEE 802.11 is a natural extension to LAN Ethernet, and the modulated protocol is IEEE 802.3 Ethernet [3]. Actually, there are three IEEE 802.11 standards that cover FHSS (Frequency Hopping Spread Spectrum), DSSS (Direct Sequence Spread Spectrum), and infrared technologies [10]. No products have implemented the IR standard yet [15] or at least the spec is rarely used [11]. IEEE 802.11b is only using DSSS technology and CCK (Complementary Code Keying) modulation to achieve it's high data rates [11,15].

Common WLAN products, which are using IEEE standards, are based on the IEEE 802.11 and IEEE 802.11b specifications. 802.11b is a high rate extension to the original 802.11, and specifies 5.5 to 11 Mbps data rates [11].

The next generation of the standard, IEEE 802.11a, also known as HiperLAN2 [13], will operate in a new band of frequencies at 5 GHz, and achieves as high data rates as 54 Mbps [12]. It uses OFDM (Orthogonal Frequency Division Multiplexing) [12] as opposed to spread spectrum used in Bluetooth, IEEE 802.11 and IEEE 802.11b. The first 802.11a products are estimated to be on market in the year 2002 [15].

4. Bit rates

IEEE 802.11x WLAN is clearly faster than Bluetooth.

Bluetooth hop frequency (1600 hops/second) is very high when compared to the radio frequency usage of WLAN IEEE 802.11 (2.5 hops per second). The high hop frequency limits the maximum length of the datablocks. [3]'s opinion is that for this reason Bluetooth channel cannot handle as high data throughput as IEEE 802.11 WLAN does. His conclusion is not straightforward, but the overhead of switching between the frequencies could cause some delays, and affect the throughput in that way.

A Bluetooth node can send data at 1 Mbs flow [15,16] that is shared with the devices at the same piconet. The master device of the network can open asymmetric or symmetric data connections to the devices that are connected to the net. An asymmetric data rate 721Kbps (while permitting 57 kbps return direction) and symmetric rate of 432.6 kbps is possible according to Bluetooth specifications [9,18,19,20]. So, it's often suggested that Bluetooth's data throughput is around 721 Kbps, but [10] and [17] figure Bluetooth's actual data rate to be around 30 to 400 kbps in practice.

The original IEEE 802.11 network cards can transfer data at rates from 1 to 2 Mbps [15].

IEEE 802.11b is advertised having 5.5 to 11 Mbps performance. However the real throughput is close to 4 - 5 Mbits [10,11], which match the situation where you and some other access point user are using a common hub instead of using switches in a wired Ethernet. There's no wireless equivalent to an Ethernet switch [15].

John Schafer suggests on [15] that 10 users using the 11 Mbps capacity would lead to performance 11 Mbps/10 = 1.1 Mbps. That cannot be the case, since, while there is a clear correlation, the function of the effective speed is not linear.

There are proposals to double the 11 Mbps performance in the future [12].

As I already mentioned above, IEEE 802.11a will support data rates from 24 to 54 Mbps [13,15]. The system is still comparable to the common Ethernet without any switch devices. In use, the actual speed of the solution can be estimated to be around 40% of the mentioned above, which is about 10 to 22 Mbps.

5. Range

Bluetooth is designed to use very low transmission power. Maximum transmission range will be around 10 m. Later versions may allow longer ranges. High-powered Bluetooth would extend the range to 100m [8,17,18].

IEEE 802.11 is planned to be used in office buildings and in a campus. The transmission range is around 15-150 m indoors and 300 m outdoors [8,10,17]

6. Multiplexed Connections

Bluetooth RFCOMM protocol emulates the common known serial standard RS232. There can be 59 simultaneous connections. TCP/IP protocol stack can be added to the serial data link via PPP [1].

Bluetooth L2CAP provides protocol multiplexing for software based third party upper-level protocols as TCP/IP [5]. This is depicted in the protocol stack introduced in [4], which shows IP and the TCP/UDP layers of TCP/IP implemented over the L2CAP link layer.

802.11 has full TCP/IP support [1]. The solution is a natural extension of using TCP/IP over the Ethernet LAN.

7. RF Output Power

Bluetooth uses very low transmission power, about 1 mw [6], which allows operation over distances up to 10 m. However, Bluetooth specification permits increasing the transmission power to 100 mw in the future [6], and then the Bluetooth devices could operate over distance of maximum 100 m.

WLAN IEEE 802.11: 1W into antennae US; 100mW Europe [7,26].

8. Security

Since the upper layers of OSI model are or can be made equal for both of the technologies, I compare here in this article mainly Data-Link Layer and Physical Layer of both of them.

Bluetooth devices use PIN (Personal Identification Number) codes and Bluetooth addresses to identify other Bluetooth devices [18].

The high hopping frequency used in Bluetooth transmissions is said to add protection against eavesdropping the connection [9,18], but, since the hardware address defines the used hopping frequencies [27], catching only one packet of a transmission is needed for a malicious listener to synchronize their devices.

Bluetooth uses 4 LFSR (Linear Feedback Shift Registers) to encrypt link level data and thus further enhance the security. The effective key length of the algorithm is selectable between 8 or 128 bit. This allows Bluetooth to be used in countries with regulations limiting encryption strength. [9,18]

The security setup for a Bluetooth connection is done in the software layer. An inexperienced or careless user can make the level of security down to almost zero [24].

IEEE 802.11 networks are based on absence of privacy, since the access point in the system is acting as a hub in a wired network. The basic nature of a hub is that it repeats all packets it receives from any device to each device in the network [23].

IEEE 802.11 standard includes an optional encryption capability WEP (Wired Equivalent Policy), which can be implemented by embedding RSA's RC4 security algorithm in the media access controller (MAC). The passwords are stored in the access points and on each mobile computer. It encrypts the transmissions between the access point and the mobile devices. All the devices are using the same password in a network. Obviously the encryption doesn't give much security in a public network, since they would have to publish the password. [8,12,23]

WEP uses 64-bit (while [8] claims the security of IEEE 802.11 being based on 40-bit RC4) encryption key [8,13].

9. Interference and robustness

2.4 GHZ ISM radio frequency band is a broad, free and unlicensed spectrum space. That is an advantage that attracts the designers of portable data devices. But all of their inventions have potential of interfering with each other's [2]. Bluetooth uses much lower transmission power than its competing technologies (e.g. IEEE 802.11b). So, more powerful devices may overwhelm its signal [2].

IEEE 802.15 (Coexistence Task Group 2) is established to improve the coexistence of the two standards. The standards committee and vendors are trying to make changes to prevent the collisions of the data transfers. The goal is to decrease the probability of Bluetooth and IEEE 802.11x devices transmitting at the same time [15, 20,21].

Jim Geier writes, "Preliminary analysis conducted by the IEEE 802.15 group indicates that the 802.11 direct sequence high rate devices are very reliable in the presence of transmitting Bluetooth products. Another recommendation is to avoid having Bluetooth products transmit within 50 feet of 802.11 radios and access points. The relatively low power signals of the Bluetooth devices diminish rapidly over longer distances. If these tactics aren't feasible or don't provide adequate results, also consider decreasing the distances between 802.11 radios and access points. This strengthens the 802.11 signals, which reduces the affects of Bluetooth interference. " [21]

Bluetooth may be able to handle this interference by using its narrowband fast-frequency-hopping scheme that uses pseudo random-hop pattern and short data packets. Its high hopping rate at 1600 hops/second can help Bluetooth evade interference and stand noise that could swamp IEEE 802.11 [19, 20]. Further, the use of forward error correction (FEC) decreases the number of needed retransmissions by adding redundant data to the data stream [19].

On the other hand, Peter L. Fuhr had 802.11 wireless Ethernet operating right next to a Bluetooth transceiver module, but he didn't detect any degration in the 802.11

link as the result of the operation of the Bluetooth device [19]. It may imply the systems aren't as error prone as people are afraid of.

As well, IBM reported very little degradation of signal while the two technologies are operating near each other [25].

To an unintended receiver, a device using some other standard (i.g. IEEE 802.11x) at a the same frequency band, the frequency hopping scheme (FHSS) of Bluetooth appears as a low powered and short-duration impulse noise [18]. The data transmission looks like it is the normal background noise, and they are designed to handle it.

Still, the interference can cause problems for a mobile laptop user using devices that follow both the IEEE 802.11b and Bluetooth standards. At circuit level at a device you cannot possibly transfer data using both of the specifications at the same time, since they are utilizing the same radio frequencies, and shielding them from each others disturbance may not be possible. That may set limit for the coexistence of the standards.

9. Future

As both standards go more sophisticated the difference between them will be narrowed. In the next few years the transmission power of Bluetooth is expected to allow the devices to operate in a range which is ten times wider than for the first prototypes. Further, the bandwidth is anticipated to be greater [18] allowing higher data rates. The 2.0 version of the spec will likely elevate the data rate to 2 Mbps [14].

If Bluetooth SIG keeps its promise of relatively very cheap radio chips, they will heavily compete with the WLAN cards that are already in the market [22]. However, the costs of IEEE 802.11x WLAN are getting down. A version of Lucent PC card can be got from Apple for only $99 [13], and Rang-Hong Yan of Lucent Technologies' Bell Labs is aggressively suggesting the cost of wireless LAN cards will drop below $50 and as low as $5 in the next few years [14]. At the same time Ericsson Bluetooth marketing manager says he never promised the Bluetooth chips to cost only $5. The cost of the module is around $27 and might drop to about $10 in 2003 [14].

Still another issue, Bluetooth transmitters have reportedly cut down portable battery life more than expected [24]. If that defect won't be alleviated that will affect the mobility of Bluetooth appliances and indirectly have effect on its success in the market.

10. CONCLUSIONS

IEEE 802.11 standard is better suited for wireless local area networks. It is faster and gives wider range of use. On the other hand, Bluetooth's natural ad hoc connectivity makes it need fewer configurations, and gives it good usability in many new applications. Bluetooth does stand better noisy data channels.

It is not easy to say, if security of either of them is better. It varies a lot, depending on the user selections. And, in many aspects, they are very similar.

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