Business and Technology Issues in Wireless Networking

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INTRODUCTION

A major development in the enabling technologies for mobile computing and commerce is the evolution of wireless communications standards from the IEEE 802 series on local and metropolitan area networks. The rapid market growth and successful applications of 802.11, WiFi, is likely to be followed by similar commercial profitability of the emerging standards, 802.16e, WiMAX, and 802.20, WiMobile, both for network operators and users. This article describes the capabilities of these three standards and provides a comparative evaluation of features that impact their applicability to mobile computing and commerce. In particular, comparisons include the range, data rate in Mbps and ground speed in Km/h plus the availability of quality of service for voice and multimedia applications.

802.11 WiFi

WiFi (IEEE, 1999a, 1999b, 1999c, 2003) was originally designed as a wireless equivalent of the wired local area network standard IEEE802.3, Ethernet. In fact there are many differences between the two technologies, but the packet formats are sufficiently similar that WiFi packets can easily be converted to and from Ethernet packets. Access points can therefore be connected using Ethernet and can communicate with end stations using WiFi.

WiFi can transport both real-time communications such as voice and video plus non-real time communications such as Web browsing, by providing quality of service, QoS, using 802.11e (IEEE, 2005). There are 2 QoS options. One provides four priority levels allowing real-time traffic to be transmitted ahead of non-real-time traffic, but with no guarantee as to the exact delay experienced by the real-time traffic. The other allows the user to request a specific amount of delay, for example, 10 msecs., which may then be guaranteed by the access point. This is suited to delay sensitive applications such as telephony and audio/video streaming.

WiFi has a limited range of up to 100 metres, depending on the number of walls and other obstacles that could absorb or reflect the signal. It therefore requires only low powered transmitters, and hence meets the requirements of operating in unlicensed radio spectrum at 2.4 and 5 GHz in North America and other unlicensed bands as available in other countries.

WiFi is deployed in residences, enterprises and public areas such as airports and restaurants, which contain many obstacles such as furniture and walls, so that a direct line of sight between end-station and access point is not always possible, and certainly cannot be guaranteed when end stations are mobile. For this reason the technology is designed so that the receiver can accept multipath signals that have been reflected and/or diffracted between transmitter and receiver as shown in Figure 1(a). WiFi uses two technologies that operate well in this multipath environment: DSSS, Direct Sequence Spread Spectrum, which is used in 802.11b, and OFDM, Orthogonal Frequency Division Multiplexing, which is used in 802.11a and g (Gast, 2002). A key distinguishing factor between these alternatives, which is important to users, is spectral efficiency, that is, the data rate that can be achieved given the limited amount of wireless spectrum available in the unlicensed bands. DSSS as implemented in 802.11b uses 22 MHz wireless channels and achieves 11 Mbps, that is, a spectral efficiency of 11/22 = 0.5. OFDM achieves a higher spectral efficiency and is therefore making more effective use of the available wireless spectrum. 802.11g has 22 MHz channels and delivers 54 Mbps, for a spectral efficiency of 54/22 = 2.5 and 802.11a delivers 54 Mbps in 20 MHz channels, with a spectral efficiency of 54/20 = 2.7. A recent development in WiFi is 802.11n (IEEE, 2006a), which uses OFDM in combination with MultiInput, MultiOutput, MIMO, antennas as shown in Figure 1(b). MIMO allows the spectral efficiency to be increased further by exploiting the multipath environment to send several streams of data between the multiple antennas at the transmitter and receiver. At the time of writing the details of 802.11n are not finalized, but a 4x4 MIMO system (with 4 transmit and 4 receive antennas) will probably generate about 500 Mbps in a 40 MHz channel, that is, a spectral efficiency of 500/40 = 12.5. 802.11n is suited to streaming high definition video and can also support a large number of users per access point.

The data rates in WiFi are shared among all users of a channel, however some users can obtain higher data rates than others. Network operators may choose to police the data rate of individual users and possibly charge more for higher rates, or they may let users compete so that their data rates vary dynamically according to their needs and the priority levels

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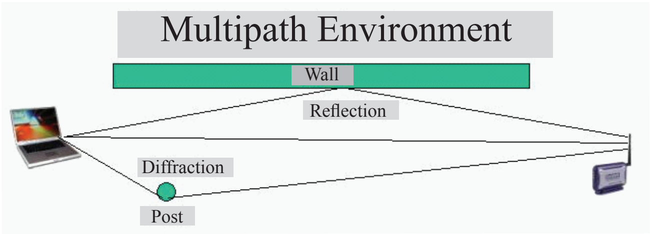
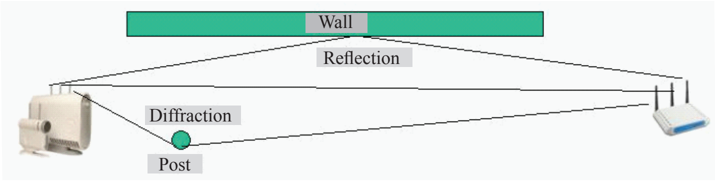
Figure 1. (a) Receiver recovers a single signal from multiple incoming signals; (b) MIMO receiver recovers multiple signals using multiple antennas



(a)



(b)

of their traffic. This provides considerable flexibility allowing many users to spend much of their time with low data rate applications such as VoIP, e-mail and Web browsing, with occasional high data rate bursts for audio/video downloads and data-intensive mesh computing applications.

Many deployments of WiFi use multiple access points to achieve greater coverage than the range of a single access point. When the coverage of multiple access points overlaps they should use different radio channels so as not to interfere with each other, as shown in Figure 2. For instance, in the North American 2.4 GHz band there is 79 MHz of spectrum available and the channels of 802.11b and g are 22 MHz wide. It is therefore possible to fit 3 non-overlapping channels into the available 79 MHz, which are known as channels 1, 6 and 11. Other intermediate channels are possible, but overlap with channels 1, 6 and 11. In Figure 2, the top three access points are shown connected by Ethernet implying that they are under the control of a single network operator, such as an airport. As an end-station moves among these access points the connection is handed off from one access point to another using 802.11r (IEEE, 2006b), while maintaining an existing TCP/IP session. Movement can be up to automobile speeds using 802.11p (IEEE, 2006c). Standard technology, 802.21 (IEEE, 2006d), is also available to handoff a TCP/IP session when a mobile end-station moves from an access point of one network operator to that of another, and this requires a business agreement between the two operators.

802.11 networks can therefore span extensive areas by interconnecting multiple access points, and city-wide WiFi networks are available in, for example, Philadelphia in the U.S., Adelaide in Australia, Fredericton in Canada and Pune in India. The broad coverage possible in this way greatly expands the usefulness of WiFi for mobile computing and electronic commerce. Enterprise users can set up secure virtual private networks from laptops to databases and maintain those connections while moving from desk to conference room to taxi to airport. A VoIP call over WiFi can start in a restaurant, continue in a taxi and after arriving at a residence.

The features of WiFi, IEEE 802.11, that are of particular importance for mobile computing and commerce are:

- Broad coverage achieved by handing off calls between access points, using 802.11r and 802.21, in cities where there are sufficient access points.
- Multimedia capability achieved by QoS, 802.11e.
- Flexibility in data rates achieved by allowing the total data rate of an access point to be shared in dynamically changing proportions among all users.
- Low cost achieved by using unlicensed spectrum, low power transmitters and mass produced equipment.

The downside to WiFi, IEEE 802.11, is limited coverage in cities that do not have extensive access point deployment.

802.16E WIMAX

802.16E (IEEE, 2006e) has a greater range than 802.11, typically 2-4 km and operates between base stations and subscriber stations. The initial IEEE standard 802.16 is for fixed applications, which compete with DSL and cable

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