Wireless Local Area Networks-Transmission Technology and Application Methods

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Abstract: Wireless LANs are designed for local high speed (generally ≥1 Mb/s) wireless transmission between computer terminals. They are used in the applications where wiring is hard or practically impossible and where up to a degree of mobility is required. A typical wireless LAN supports a limited number of users in a completely determined local area and the existence of a standard for improving the products is not so important. There are products which have been used unlicensely in ISM(industrial, scientific and medical) bands. The demand on the higher capacities under a fixed bandwidth leads the researches for the spectral efficiency techniques in wireless LANs. There is still a strong trend to pass the wireless local communication systems to higher and less using frequency bands. Most of the researches in this area are focused on providing maximum bandwidth efficiency. High data rates are usually obtained in the resulting systems but a proportional increase in the system complexity and fixed channel requirement is occured.

1. Introduction

Wireless concept was firstly introduced at the beginning of 1980's. During the following ten years industrial, scientific and medical (ISM) bands were occured and several approaches for the applications were developed. Development of commercial wireless LAN products attracted a more serious interest after the announcement of the ISM bands. By 1990 wireless LAN products using direct sequence spread spectrum (DSSS) in the ISM bands, licensed radio at 18-19 GHz and IR technology appeared in the market. These products were the focal point of the standards activities and they were the first that could be called wireless LANs because they were operating at high speeds and could communicate with at least one standard LAN software product. In that year IEEE 802.11 committee was formed as an independent standards group. In 1992 the radio law enforcement rule was partly changed, following the recommendations of the Electrical Communication Technology Council of the Ministry of Posts and Telecommunications, and usage of the 2.4 GHz band (medium-speed wireless LAN) and 19 GHz band (high-speed wireless LAN) became available, resulting in the development of wireless LANs with high speed data transmission capability. [1],[3]

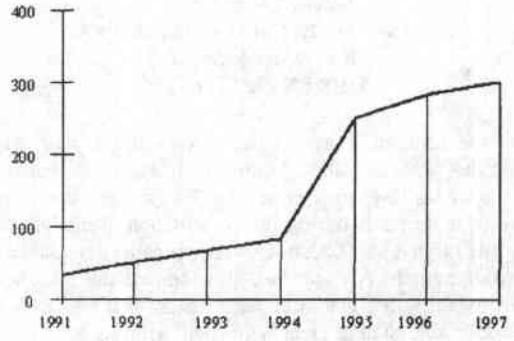
When the first wireless LANs were in the development stage it was thought that the additional cost brought by the wireless hardware will be negligible besides the savings in installation and transportation of wired LANs. In fact old buildings were already wired and some of the organizations installed the cables in all the possible process locations at the beginning in order to permit the reinstallation problems. Also most of the companies have wired LANs and a wide wired structure that will meet their future requirements. Furthermore the cost of installing wires in new buildings is too low so that this can be done easily during the construction of the building. Meanwhile twisted pair LAN technology became dominant over the coaxiel cabled LAN and this also reduced the installation cost significantly. It's not an enough reason to throw away the wired nodes and change them with their wireless counterparts because of their being the newest and biggest property and your requirement for a few wireless connections. As a result the first wireless LANs couldn't meet the expected market requirements. These problems occured at the beginning are also caused by wrong comments. The aim in wireless LANs is not how to save the money, it's how to do the work better.

2. Basic Application Techniques in Wireless LANs

The first generation wireless LANs are mostly used to complete a wired LAN. This is a widely used process and usually occurs when a wired LAN needs a few wireless connections. Wireless LANs are used as a LAN extension when the coverage of a wired LAN includes the areas having wiring hardness. The buildings having wiring problems are the ones having wide open areas or the ones built with hard and robust materials in its walls and floors in order to carry heavy working machines. Wireless LANs are also used to create an inter working link between two wired LAN segments or it can be used as a point-to-point connection between two nodes or two segments in a single wired LAN. If the true conditions are provided the wireless nodes can greatly perform their stand-alone wireless LANs without any connections to a wired LAN. Wireless LANs provide unique advantages such as fast and easy installation, a high degree of user mobility and the ability to recover the investment each time a move occurs. But as an enabling technology they may not replace with wired LANs. However, advantages such as these have led industry experts to project significant growth in the wireless LAN market. Wireless LANs will capture 17 percent of total LAN shipments by 1997 according to a 1993 BIS Strategic Decisions study. As Figure 1 shows it was predicted that the market will approach $300 million. But a major shift from current trends has occured. Wireless LANs only accounted for less than ½ percent of the total existing LAN connection base in the beginning of 1993. [2]

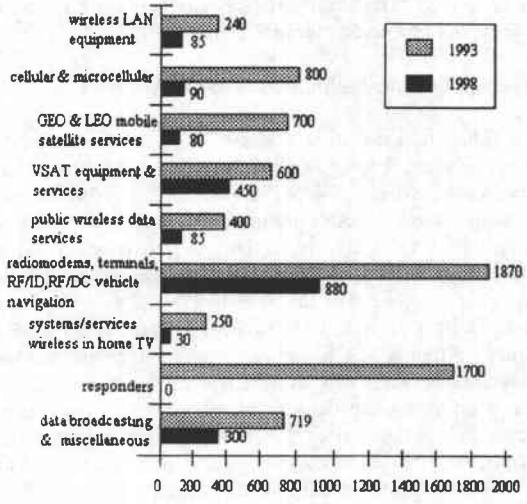
The wireless office is currently a small market but will grow in this decade. Future growth will result from improving prices compared to wired LANs, standard establishment and the emergence of a critical mass of mobile computing devices. In Windata Inc.'s "Providing the Industry's First Wireless LAN to Fully Deliver the Features and Benefits of Wired LANs " they

predict that the market will surpass the $500 million mark by the mid 1990's. Figure 2 shows the growth predicted by Windata. [2]



(BIS Strategic Decisions)

Figure 1. Wireless LAN revenues



(IRD)

Figure 2. U.S Wireless growth

The first generation wireless LANs had a power consumption about 20 watt and were not suitable for portable computers working with batteries. The later wireless LANs are developed around lap top, palm top and pen pad computers working with small batteries on a PCMCIA card. Wireless connection commonly became a natural transmission media. The researchers in this area started to think about new ideas like ad hoc networking, nomadic access and mobile computers. These concepts lead the integration of computer and communication. The market for wireless LANs is growing in the following categories: [1],[4]

- widening the existing LAN
- nomadic access
- ad hoc networking
- inter-working LAN bridges
- integration of computer and communication

The first three applications are the most common ones. There are two reasons permitting to remove wired LANs and change them with wireless LANs: performance and cost. The cables will always have an advantage when considered under performance. Furthermore if the cable is a fiber optic it will provide better performance than a direct transmitted light. Therefore it will be a mistake to expect the exchange of wireless LANs with their wired counterparts depending on only speed. Since the technology used is more complex and requires more components wireless LANs will always be more expensive than wired LANs.

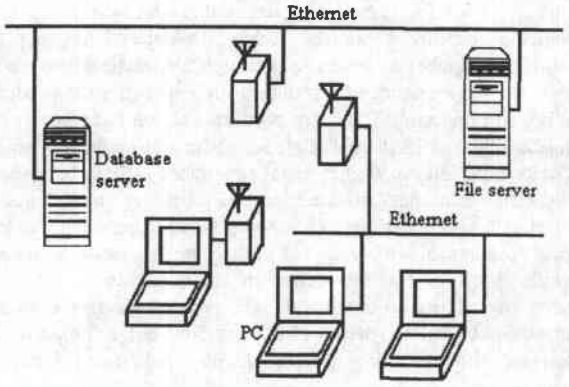


Figure 3. A wireless LAN system (expanded LAN)

Figure 3 shows an expanded LAN. The wired LAN is widened with a wireless LAN here. This configuration is one of the most usual forms of wireless LAN systems. As a connection interface, an IEEE 802.3 (Ethernet) is used. Ethernet is very popular in data link layer and physical layer. [3]

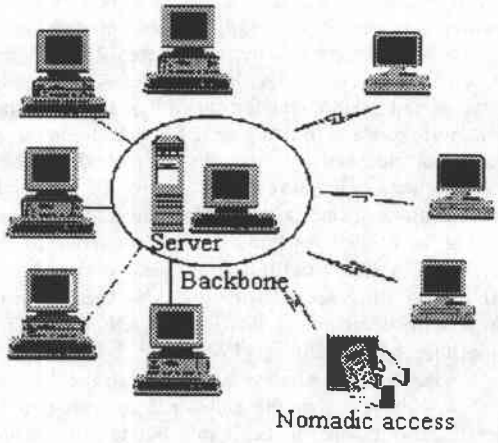


Figure 4. Applications of wireless LANs

Figure 4 shows the utilization of wireless LAN for nomadic access and a wired LAN connected to a wireless LAN.

Nomadic access provides a wireless connection between the personal computer and the hub. This access is useful for especially a person who turns to the office after a travel and has to transfer large data files between his or her personal computer and the backbone information network.

One another situation related to the same users is ad hoc networks. Ad hoc networks are multihop wireless networks in which nodes can be mobile. These types of networks are usually used in emergency situations, like disaster relief or battlesite networks or in situations where a temporary network connectivity is needed such as in a class or in a meeting. In this case there exist a group of mobile users and they are trying to set up a network between themselves in an unpredictable condition. The interest in wireless ad hoc networks came out from some of their well-known advantages for certain types of applications. Since there is no fixed infrastructure, a wireless ad hoc network can be deployed very quickly. Therefore, such networks can be used because of their cost and safety reasons where there is no secure network structure or in places where there is no other wireless communication infrastructure. However the problem of managing the network reduces the attentions. Managing ad hoc networks is actually harder than managing wired networks. First of all an ad hoc network topology might be quite dynamic. Secondly the network is maintained by the struggle of each of the mobile hosts operating with limited battery power, changeable link quality and limited capacity. As a third reason ad hoc networks are employed for a wide set of applications. Thus, the management protocol might be able to adapt easily to the characteristics of the situation. Figure 5 shows an ad hoc networking between several lap tops. [6]

Figure 5. Ad hoc networking

Point-to-point internal LAN bridges occured as a successful market for wireless LANs. A wireless LAN operating as a bridge between two wired LANs is shown in Figure 6. The first generation wireless LAN manufactures raised the transmission power to maximum and most of them have added directional antennes to sell their own products as point to point internal LAN bridges. Wireless inter-working bridges are used between buildings and in most applications they operate in line of sight connections. The last application area is passing through rapid evolution stages.

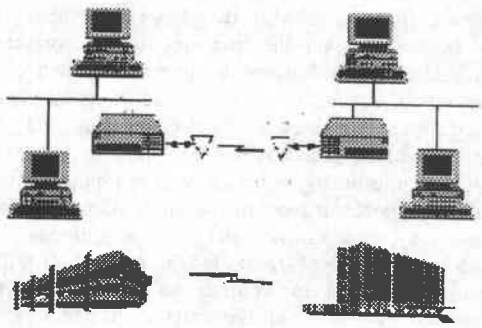


Figure 6. Using the wireless LAN as a bridge

3. The Role of the Frequency in Wireless LANs

A significant technical attack in the development of wireless LANs is the transmission of a high speed signal over indoor radio channels. While the technology evolutes and high microwave frequencies are invented the data rates will be inevitably increased. Furthermore because of the spectrum limitations causing an increase in the cost and a decrease in the performance new frequency bands must be considered. [5]

The most significant activities related to wireless LANs are IEEE 802.11, HIPERLAN and WINFORUM. Standards are being developed for wireless LANs under IEEE 802.11 in the United States and ETSI/RES10 in Europe (known as HIPERLAN, for High Performance Radio LAN). Originally formed in 1990, the P802.11 Working Group took on the task of developing standards for all kinds of wireless communications. For the time being IEEE 802.11 is developing standards for DSSS, FHSS and DFIR technologies and uses the ISM bands as the radio channel. The HIPERLEN standard is concerned with the use of space in 5.7 and 18 GHz shorter microwave bands and operate at speeds up to 20 Mb/s. HIPERLAN is focusing on higher data rates than IEEE 802.11. Furthermore, the HIPERLEN standard is planned to include provisions for a flexible forwarding mechanism for ad hoc networks. The aim of WINFORUM is to obtain parts of the PCS band for unlicensed data and voice applications and develop a spectrum etiquette for them. This means to provide fair access to an unlicensed band to widely different applications and devices. [1]

Wireless LAN manufactures are the people who have to be thoughtful for the frequencies which they can operate on. The main difference between a wired link and a radio service is the requirement of frequency administration for radio communications. While making a market research for a new idea or concept using radio technology firstly the ratify of the frequency administration organization must be taken. Wireless LANs need a great bandwidth for a high speed transmission and the markets need much more time to achieve a significant growth. On the other hand it is expected that wireless LAN technology is a new technology which will bring revolutionary applications to the markets. Thus to excuse the allocation of sufficient bandwidths to these applications while the traditional voice-based systems use the same bands to perform a wider market leaves the frequency management committees in a difficult position. Two levels were taken to bring a solution to

this situation: first one is using the higher frequencies where large bandwidths exist and the other one is not to prevent the use of unlicensed bands. Raising the process frequency reduces the dimensions and power consumption and limits the coverage of the signal in indoor areas. The dimensions and power consumption will be reduced with the time as long as the electronic design technologies improved. The limitations on the coverage is negligible in most of the applications and can be solved easily by reducing the cell size. An unlicensed band provides a convenient background for the research of different wireless technologies having contrast with markets in a multi vendor environment. Today all the activities related to wireless LANs are focused on unlicensed operations.

4. Technical Components Creating the Network

Mostly the protocols depending on the physical components will be different in a network for wireless LANs. The network topologies and access methods used are nearly the same from one system to the other. The technical components related to the subject can be categorize under five main headlines:

- •data rate
- •coverage
- •power consumption
- •protocols
- •security

Data rate, coverage and power consumption are arousing the transmission technology. The protocols and security take place while creating the network. Data rate is the most important factor in wireless industry and can be determined as a function of transmission technology. The communication media is the air in wireless industry. However the transmission technology and the constructivities and limitations in the current bands affect the data rates as much as the process frequency. These factors also affect the power and size requirements changing from one application to the other. Since the wireless LANs require a certain market approach the manufactures must evaluate the transmission techniques in the available bands very carefully. Simply they can extend the current protocols for wireless LANs. The protocols must be changeable in order to dominate the mobility for a mobile user who wants to have service maintenance while changing the wireless access point. Since the wireless information is transmitted over the air naturally the users couldn't feel as secure as it was in the wired systems.

Figure 7 shows the coverage area and data rate to several wireless local services. Here the expanded LANs as mentioned above as existing LANs widened with wireless LANs cover distances of less than 50 m. These services are the most general form of what it was referred to as a wireless LAN. This group includes fixed first generation high speed wireless LANs like PCMCIA cards designed for mobile lap tops. For the services with fixed terminals data rate and coverage is the most important components. The range of inter-working bridges is on the order of a kilometer. Mobile networks usually develop in campus environments. The objective of these services is to ensure a wireless LAN service that covers an area at a campus size. [4]

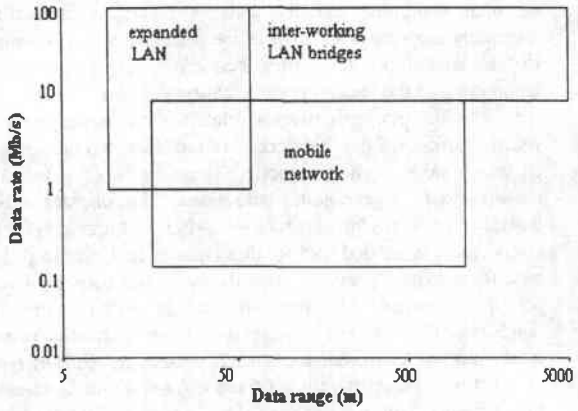


Figure 7. Data rates and appropriate distances for several wireless LAN services

5. The Transmission Techniques Used in Wireless LANs

Wireless LANs are generally designed for a few number of users working in indoor areas with small coverage. The technologies used in current wireless products are divided into five categories:

- •Diffused IR(DFIR)
- •Direct beam IR(DBIR)
- •Standard radio(RF)
- •Direct sequence spread spectrum(DSSS)
- •Frequency hopping spread spectrum(FHSS)

There are products having different features in the markets. These technologies are developing around the convenience of the transmission technique and validity of the channel to ensure high data rates in wireless media. The IR products are designed to operate in ISM bands in the frequencies which didn't determined by FCC(federal frequency comission) and in spread spectrum LANs. These products are implemented in 18-19 GHz licensed bands or in ISM bands using low power. If the power is too low the ISM bands allow the utilization of non-spread spectrum devices.

Frequency	Band
<30 kHz	Very low frequency (VLF)
30-300 kHz	Low frequency (LF)
300 kHz - 3 MHz	Medium frequency (MF)
3-30 MHz	High frequency (HF)
30-300 MHz	Very high frequency (VHF)
300 MHz - 3 GHz	Ultra high frequency (UHF)
3-30 GHz	Super high frequency (SHF)
>30 GHz	Extremely high frequency (EHF)

Table 1. Radio frequencies and bandwidths

In spread spectrum you can produce and send radio waves across a wide range of frequencies between 10 kHz and 50 GHz as shown in Table 1.The radio waves produced for spread spectrum are typically 902-928 MHz. These specialities make spread spectrum ideal for transmission. The transmitter

diffuses the data through a wide radio frequency band in spread spectrum. Furthermore the transmitter adds extra bits to the signal to perform its radiation pattern. The receiver using these extra bits as a key decodes the radiation pattern and gets the original signal. Spread spectrum system creates an acceptable data transmit rate, generally 2 Mb/s, by means of radiation of data through radio frequencies. Furthermore the interference on one side of the frequency band doesn't affect the other side. [2]

The major problem in wideband radio while evaluating the performance of spread spectrum is that the collection of a large set of wideband measurements in a site is very expensive and time consuming so that the procedure will need to be repeated in a new area. As a result, the most popular mathematical model to calculate the probability of error or the probability of outage of a transmission technique for describing channel characteristics given below is used to support the accuracy of statistical or building specific channel models that can be extended to other areas more economically. [4]

$$h(t) = \sum_{l=0}^{L-1} \beta_l \cdot \delta(t - \tau_l) \cdot e^{j\varphi_l}$$

This model, developed by Turin to describe propagation in the urban radio channel and was later applied to radio channels in closed areas describes the channel as a linear time invariant filter whose impulse response is the sum of L paths. Here the lth path has three parameters, amplitude β_l, phase φ_l, delay τ_l and δ is the dirac delta function.

The spread spectrum wireless LANs are more successful than the others in the markets and most of the companies interested in wireless LANs use this technology. DSSS technology was first proposed in 1980 for wireless LANs. Today DSSS wireless LANs sell more than any other wireless LAN technology and lots of companies are improving the products of spread spectrum systems DSSS and FHSS on PCMCIA cards. FHSS involves dividing a range of the radio spectrum into individual channels on specific frequencies. A transmitter can use any subset of these channels. The transmitter will hop from channel to channel during its transmission, following a specific pattern. The receiver most follow the transmitter as it hops between frequencies using a mechanism as the Code Division Multiple Access(CDMA). But this is not the CDMA technology as used in the cellular telephone industry. Wireless LAN users need the full capacity of the channel for quick transmission and CDMA is not convenient for this purpose. As a result CDMA is not considered by IEEE 802.11 and it wasn't used in any of the major market products. But some of the wireless LAN manufacturers allocate several codes to individual users to increase the data rate while still operating under the constraints of ISM band and refer to this technique as CDMA based wireless LAN. In another method of spectrum spreading that is to say DSSS transmissions occur not on one channel at a time, but over a continuous band of frequencies. A unique spreading code is applied to the input signal before it is applied to the carrier wave. The receiver uses the same code to recover the information.

The spread spectrum wireless LANs are developed in ISM bands, the first unlicensed bands, in which a high speed wireless LAN is implemented. These bands can be used for several applications but wireless LANs are the ones having priority during the rule generation. The most practical reason of using spread spectrum in ISM bands for wireless LAN applications is the validity of high speed unlicensed data link within these bands. Data rate is the most significant factor for communication networks in offering the products to the markets and selling them. Higher the data rate greater the effect of the product in markets. Mobility of the terminal is one another speciality affecting the markets. Mobile terminal is a function of power consumption and product dimension. This is unvalid for DBIR only. Since the terminal must be kept stationary in DBIR in order to maintain the radiation pattern of the device effective. If the technology is verified with small batteries and light width then it's convenient for mobile applications and can be used in portable computers. However when it's planned to insert wireless LANs in actual systems the communication range and operation performances of the devices must be considered too.

6. Conclusion

Wireless LANs generated an alternative against wired systems in closed areas. They offer advantages like removing the cables around the building, providing several types of services to a number of users, hardware flexibility and upkeeping facilities. However, most of the wireless LANs will have several types of connections to wired LANs and here by a wireless LAN user will have access to common sources like file servers, printers and electronic mail entrances which are available for wired LANs only. Since the bandwidth is inadequate to meet the requirement of wireless systems for a multi access capacity the spectral efficiency needs to be increased. The actual power of technology is not hidden in how the old processes can be done better, it's hidden in how the start can be given to the organizations for new concepts. Wireless LANs terminated the necessity of physically connecting the network devices to each other. Finally people can communicate directly with the main system from where they are.

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