# WIRELESS LOCAL AREA NETWORKS: A COMPREHENSIVE GUIDE

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## Abstract

*Nowadays the demand on exchange of information is higher and higher. During recent years rapid development of radio communication, both mobile and non-mobile has been experienced. Because of need of wider frequency range and expansive number of services using "the air" as the medium, higher frequencies have to be applied. This paper deals mainly with wireless LAN using license-free band such as 2.4GHz (ISM) or 5.2GHz.*

## Keywords

Wireless network, WLAN, IEEE 802.11

## 1. Introduction

A couple years ago the importance of computer networks has made significant step. Because of big and continuously expanding area of network services (Internet, shared databases, voice services etc.) the standalone computer was slowly becoming rare and useless. Thus the development in the networking (both hardware and software) could go on the full steam ahead. The results we can see all around us, even without noticing about that.

The goal of the first epoch of the networking was reached quite long time ago in the sense that it was really common and easy to connect the computer (in general any device) to a network. The only limitation was the length of the LAN cable or the availability of the telephone socket. People get used to comfortable access to the local or global network and with increasing speed of the connection started to explore new services and utilities.

Nevertheless, although the demands of the end users were fulfilled, there was still something to improve. How can we get rid off the cables, which are coming with us all the time that we want to be on-line? This is the moment when people have invented (probably not the in the literal sense of the word) connection to the infrastructure without any wires: wireless network.

The idea of the wireless networking is simple, making radio connection (in an ideal case bi-directional) to any client, which desires to receive or transmit packets. The design of such a system is not easy anymore.

This article tries to summarize today's development in wireless network area. It deals with most of the current standards with special accent on networks based on TCP/IP protocol, as this is probably the most common usage of radio networks.

## 2. How Does It Work?

Let's describe the basic components of a wireless network: radio modems on both ends of the link and free path (physical layer) for the signal between those modems.

The modem modulates or demodulates the signal and transmits or receives it. The main characteristics of the modem are working frequency band, data transmit rate, type of modulation and output power.

There is a statutory body, which is responsible for managing the frequency bands and should ensure the same conditions and rights for any user of the spectrum. Those are FCC (Federal Communications Commission) in America and ETSI (European Telecommunications Standard Institute) in Europe. But there are several bands, which are licence free, thus intended for use with no need of permission or fee. The only rule is defined by list of devices, which can be used in the particular area of spectrum.

This is also the way, how many devices, providing the gateway to the wireless network, work. Nowadays, the 2.4 GHz frequency band (Industry, Scientific and Medical - ISM) is extensively used.

To ensure the compatibility of wireless cards from various manufactures, the biggest producers have concluded to define an industry standard, with the list of properties and features of wireless devices. In 1997 the standard IEEE 802.11 was formed as the fundament for further development in this area [1].

The standard defines three protocols for the physical layer: Frequency Hopping Spread Spectrum (FHSS), Direct Sequence Spread Spectrum (DSSS) and communication using infrared rays. The speed of the links was up to 2 Mb/s. We can also find here definition of some ciphering standard Wired Equivalent Privacy -WEP.

In 1999 IEEE extended the standard to 802.11b (also known as 802.11 HR) for high-speed connection with the transmit data rate up to 11 Mb/s and 802.11a for communication on 5.2 GHz.

Recently there are some more standards, which are not necessary competing with the most spread 802.11a (WLAN). This is because they are more suitable for another type of deployment. The short overview could be found in Tab. 1.

Bluetooth is one of quite popular technology used for connecting devices over short distance (up to 10 meters, for Personal Area Networks - PAN). Bluetooth extension did not win the users as fast as the manufactures would expect and desire. It took quite a long time (longer then WLAN products) to have “reasonable” offer of independent interoperating devices based on this standard. But today we can already say that bluetooth is not dead as many predicted couple years ago (probably thanks to rapid development of personal digital assistants and smart phones).

# 3. Devices

Devices of the most common standard IEEE 802.11b could be divided into two categories according the modulation they are using: FHSS or DSSS based systems.

FHSS systems use set of channels, which are periodically changed (every 20-400 ms) according to the given hopping pattern. In the ISM band there are 79 channels defined with the width of 1 MHz. The goal of the frequency hopping is to minimise the noise level by never staying on the same channel. If the chosen channel has bad properties, the system changes to the next one with better quality.

In some cases FHSS is more resistant to the interference, but it depends of the type and power of the noise signal. On the other hand, changing frequency in short periods increases the demand on the complexity of MAC controller (part of radio modem), which has to be able to resolve signal with variable frequency. Also the header of packets has to be bigger, thus the effective transmit rate usually does not exceed 1 or 2 Mb/s.

| Standard | Frequency Range GHz | Number of Channels | Bandwidth MHz | Data Rate (PHY) (Mbps) | Modulation | Spreading | Media Access Control | Output Power (mW EIRP) | Range (m) |
|---|---|---|---|---|---|---|---|---|---|
| DECT | 1.88 –1.90 | 10 | 0.864 | 1.152 | GFSK | no | TDMA/FDM | 250 | <300 |
| IEEE 802.11 | 2.4-2.4835 | 79 | 1 | 1 | 2-level-GFSK | FHSS | CSMA/CA | 100 | 50-300 |
| | | | 1 | 2 | 4-level-GFSK | | | | |
| | | 13 | 11 | 1 | DBPSK | DSSS | | | |
| | | | 11 | 2 | DQPSK | | | | |
| IEEE 802.11b | 2.4-2.4835 | 13 | 11 | 1 | DBPSK | DSSS | CSMA/CA | 100 | 30-100 |
| | | | 11 | 2 | DQPSK | | | | |
| | | | 11 | 5.5 | DQPSK/CCK | DSSS with CCK | | | |
| | | | 11 | 11 | DQPSK/CCK | | | | |
| IEEE 802.11a | 5.15-5.25<br>5.25-5.35<br>5.725-5.825 | 40 | 20 | 9 | BPSK | no | CSMA/CA | 160<br>800<br>3200 | 30-100 |
| | | | | 18 | QPSK | | | | |
| | | | | OFDM, 52 sub-carrier | | | | | |
| | | | | 36 | 16-QAM | | | | |
| | | | | 54 | 64-QAM | | | | |
| Hiperlan/1 | 5.15-5.25 | 3 | | 1.47/23.5294 | FSK/GMSK | no | EY-NPMA | 200 | 30-100 |
| | 5.25-5.35 | | | | | | | | |
| Hiperlan/2 | 5.15-5.25 | 3 | 22 | 9 | BPSK | no | TDMA/TDD | 200 | 30-100 |
| | | | | 18 | QPSK | | | | |
| | | | | OFDM, 52 sub-carrier | | | | | |
| | 5.25-5.35 | ** | | 36 | 16-QAM | | | 200 | |
| | 5.47-5.725 | ** | | 54 | 64-QAM | | | 1000 | |
| Bluetooth | 2.4-2.4835 | 79 | 1 | 1 | GFSK | FHSS | TDD/FH | 1/2.5/100 | 10/20/150 |
| Home RF | 2.4-2.4835 | 75 | 1 | 0.8/1.6 | 4FSK | FHSS | TDMA | 100 | <50 |
| | | 15 | 5 | 5/10 | QPSK | | | | |
| HiSwan | 5.15-5.35 | in development | | | | | | | |

BPSK Binary Phase Shift Keying
CSMA/CA Carrier Sense Multiple Access - Collision Avoidance
CSMA/CD Carrier Sense Multiple Access - Collision Detection
DBPSK Differential Binary Phase Shift Keying
DBPSK Differential Binary Phase Shift Keying
DQPSK Differential Quadrature Phase Shift Keying
EIRP Equivalent Isotropic Radiated Power
** - varies due to national restrictions
EY-NPMA Elimination Yield-Non-preemtive Prio. Multiple Access
FSK Frequency shift keying (4FSK = 4 level FSK)
GFSK Gaussian Frequency Shift Keying
OFDM Orthogonal Frequency Division Multiplexing
PSK Phase Shift Keying
QAM Quadrature Amplitude Modulation
TDMA Time Division Multiple Access

**Tab. 1** Wireless Standards Overview

The principle of the spread spectrum technique is to use more bandwidth than the system really needs for transmission to reduce the impact of localized interference on the system. Direct Sequence spreads the signal over larger band by multiplexing it with a code. The system works on fixed channel. To spread the signal, each bit of the packet to transmit is modulated by a sequence. In the receiver, the original signal is recovered by receiving the whole spread channel and demodulating by the same code. For example, a 2 Mb/s signaling rate modulated by 11 chips code results in a signal spread over 22 MHz of bandwidth.

Any narrow band interference will not be so significant to the DS system, because it uses only small part of the total bandwidth used by the system.

If we would compare two above mentioned technologies, we would find out that DS systems tend to be faster, not so sensitive to strong narrow band interference but with FH devices we can built larger networks (longer reach) and networks with higher density (several network overlapping over each other).

The reality is that DSSS devices gain the majority on the market. Explanation could be that wide public pays more attention to the speed of the device (easy to measure and understand) than to the interference resistance.

With the variety of the products new problem has been raised – interoperability of different brands. The Wi-Fi Alliance was originally established as the Wireless Ethernet Compatibility Alliance (WECA) in August, 1999 by several of the leading wireless LAN manufacturers [2]. The goal was to test and certificate compatible devices. Nowadays the Wi-Fi label is acknowledged as a standard for 802.11b products.

**Fig. 1** Wi-Fi label ensuring the interoperability of products.

Since the demand for higher data rates will probably never stop, new standard has been defined. IEEE 802.11a and Hiperlan2 (extension of Hiperlan1, which was never implemented into any device) are both working on 5.2 GHz band. But as the first one is defined by FCC (United States) and the second by ETSI (Europe) they are not interoperable and equipment of different standard could not be used in another region (e.g. IEEE 802.11 radio card in Europe). Unification of them should be defined in IEEE 802.11h prepared for year 2003.

The transmission in 5 GHz band is based on OFDM (Orthogonal Frequency Division Multiplexing), which has some advantageous properties (e.g. interference resistance). As well, there are some extra features implemented in Hiperlan2, above all QoS (quality of service), stronger encryption algorithm DES (Data Encryption Standard), PPP tunneling (Point to Point Protocol) or ARQ-Schema (Automatic Repeat Request).

# 4. Topology

There are two basic configurations: point-to-point link (PtP) and point-to-multipoint connection (PtMP). Each configuration is suitable for different purposes. Example of network architecture could be seen in Fig. 2.

PtP connection is convenient for long distance directional link coupling two points together. In such a mode both ends has the same role in the communication, often called as peer-to-peer communication.

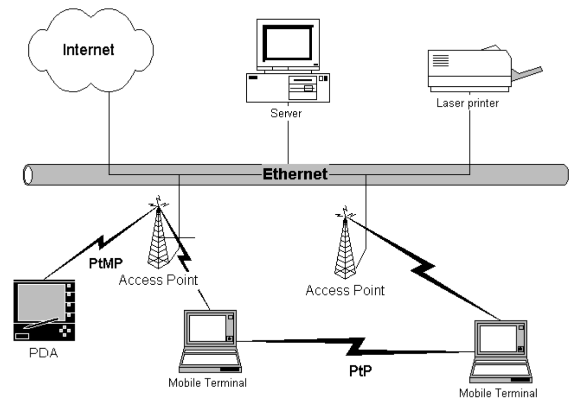


**Fig. 2** Configuration of wireless network with both Access Point and Peer-to-Peer mode.

Point-to-multipoint connection is usually used to connect end users within certain area to one gateway providing the connectivity for the user group. In this configuration is the communication of each client steered by the central point of the cell - access point. Access point co-ordinates the communication to the outside of the network, but also between the clients of the network.

There is one special type of PtMP connection. Surprisingly the largest coverage is not the goal, but signal is concentrated to a small area with high density of potential user – a hotspot. We could consider airport, train station, restaurant or swimming pool as a hotspot. On some big international airports people could already enjoy the advantage of wireless surfing, whilst waiting for the plane.

The topology is also given by the range possibilities of the radio device. The propagation of radio transmissions is influenced by many factors. Walls and floors tend to decrease and reflect signal and the background noise makes it more difficult to demodulate. Most vendors attempt to define a range for their products, which is the maximum distance between two nodes under usual operating conditions. But there is no standard or standard procedure of measuring a range (except in free space, but this is useless), so we can't really compare different products.

To extend the range of operation we can use an extra device. Most common are antennas (omnidirectional or directional), amplifiers, splitters etc. Nevertheless, we have to bear in mind the legal limits of the EIRP (Effective Isotropic Radiated Power), which might not be exceeded (could disable communication of other networks in the same location).

## 5. Real Usage Constraints

The exploitation of wireless networks based on IEEE 802.11b in urban area was tested. There were several links in the different environments over different distances and with various range extending devices.

In the urban area the link quality is changing during the day, especially when the radio path is going partially close to the street level. In that case, the quality is influenced by the traffic on the street. The explanation of that could be that the vehicles (especially busses or trams) are moving and thus producing time dependent interference. The signal is coming to the receiver from different location (reflection), with different time delay (delayed after propagating trough obstacles or just going via longer path). The receiver has to determine from which direction the strongest signal is coming and adapt to it. If it is changing too fast we can experience packets losses. Of course, the higher is the speed of the link the more sensitive it is to such a phenomena.

One of the most important aspects of the radio link is that it might not be too obtrusive (especially on the historical building). In other words, it is not possible to use as big aerial as it would be desirable on some locations. It was found that the directivity of the antenna is more important than its gain. If we are not able to make the signal noise ratio higher by power diversity (by increasing the radiated power) we have to apply spatial diversity (let the receiver listen only to the direction, which is the desired signal coming from). On some sites using of omnidirectional antennas was less effective than deployment of small patch antennas with lower gain but with desired directivity pattern.

In general it is really hard to get the line of sight (ability to see one node from the other one) in the cities. With this kind of devices it is not necessary in all cases anymore. Of course, it is a big advantage and a "must" for long distance links to see the other end of the connection. But for making small radio cells, connecting two buildings across the road you don't have to care about it too much. This opens new horizons for using wireless networks and contributes to the further development of this technology.

Speed of the link is very important parameter. One would expect that 11Mb/s device would be able to transfer data at that speed. Unfortunately it is the speed on the physical layer. Effectively we get much lower speed. Average throughput on WLAN device is 3-5 Mb/s for asymmetrical load and 2-3.5 Mb/s for symmetrical transfer.

## 6. Conclusion

It was proven that the development in the wireless data transmission field is now already in the mature state. The devices are reliable, easy to install and fast, which is all what we would demand from this kind of equipment.

WLAN is gaining more and more popularity not only thanks continuously dropping prices. It is now considered as successor of wired Ethernet. It is also playing important role on the ISP (Internet Service Provider) market. Although denoting WLAN as "UMTS killer" may be a bit exaggerated, but in some aspect it may offer better functionality.

In wide variety of technical applications wireless devices are currently exploited. It makes the equipment mobile and not dependent on some wiring or the permanent place of use. In the future we will probably meet this technology more often but also today's applications let us enjoy all benefits of a wireless connectivity.

## References

[1] IEEE Wireless Standard Zone, http://standards.ieee.org/wireless/

[2] Wi-Fi Alliance, https://www.wi-fi.com

[3] ETSI Telecom Standard, http://www.etsi.org

## About Author...

**Petr POMĚNKA** was born in 1973. He received his Ing (M. Sc.) degree in electrical engineering from the Brno University of Technology (BUT) in 1997. From 1997 to 2002 he was postgraduate student at the Department of Radio Electronics, Faculty of Electrical Engineering and Communication, Brno University of Technology. His research interests are analysis and design of microwave structures, wireless LAN technology and computer-aided education and exploitation of new technologies in educational process.