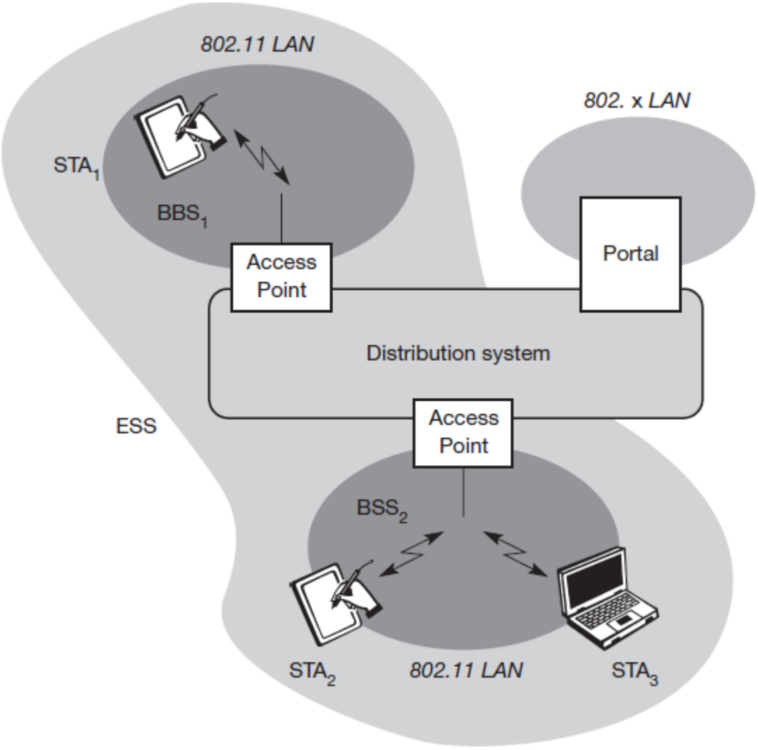
Q 1 Discuss the architecture of IEEE 802.11 wireless LAN wrt infrastructure mode and ad-hoc mode ?

Answer :-

Wireless networks can exhibit two different basic system architectures as shown in section 7.2: infrastructure-based or ad-hoc. Figure 7.3 shows the components of an infrastructure and a wireless part as specified for IEEE 802.11. Several nodes, called **stations (STAi)**, are connected to **access points (AP)**. Stations are terminals with access mechanisms to the wireless medium and radio contact to the AP. The stations and the AP which are within the same radio coverage form a **basic service set (BSSi)**. The example shows two BSSs – BSS1 and BSS2 – which are connected via a **distribution system**. A distribution system connects several BSSs via the AP to form a single network and thereby extends the wireless coverage area.

Figure 7.3
Architecture of an infrastructure-based IEEE 802.11



This network is now called an **extended service set (ESS)** and has its own identifier, the ESSID. The ESSID is the ‘name’ of a network and is used to separate different networks. Without knowing the ESSID (and assuming no hacking) it should not be possible to participate in the WLAN. The distribution system connects the wireless networks via the APs with a **portal**, which forms the interworking unit to other LANs.

The architecture of the distribution system is not specified further in IEEE 802.11. It could consist of bridged IEEE LANs, wireless links, or any other networks.

However, **distribution system services** are defined in the standard (although, many products today cannot interoperate and needs the additional standard IEEE 802.11f to specify an inter access point protocol, see section 7.3.8).

Stations can select an AP and associate with it. The APs support roaming (i.e., changing access points), the distribution system handles data transfer between the different APs. APs provide synchronization within a BSS, support power management, and can control medium access to support time-bounded service.

These and further functions are explained in the following sections.
In addition to infrastructure-based networks, IEEE 802.11 allows the building of ad-hoc networks between stations, thus forming one or more independent BSSs (IBSS) as shown in Figure 7.4. In this case, an IBSS comprises a group of stations using the same radio frequency. Stations STA1, STA2, and STA3 are in IBSS1, STA4 and STA5 in IBSS2. This means for example that STA3 can communicate directly with STA2 but not with STA5.

Several IBSSs can either be formed via the distance between the IBSSs (see Figure 7.4) or by using different carrier frequencies (then the IBSSs could overlap physically). IEEE 802.11 does not specify any special nodes that support routing, forwarding of data or exchange of topology information as, e.g., HIPERLAN 1 (see section 7.4) or Bluetooth (see section 7.5).

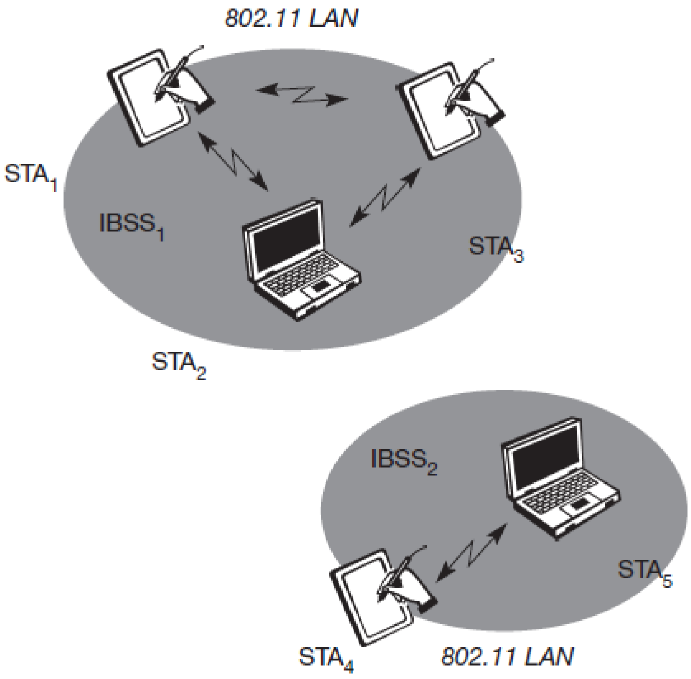
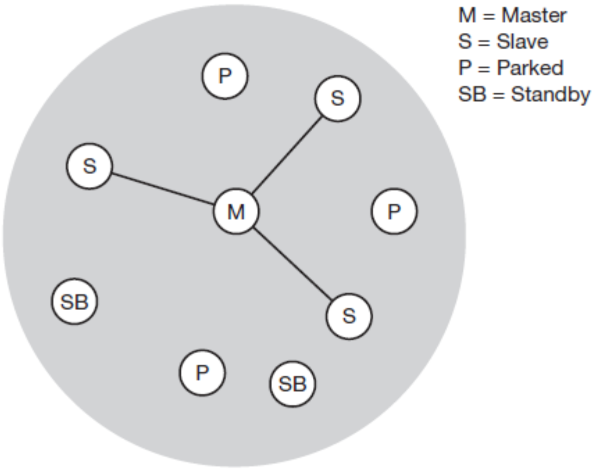


Figure 7.4
Architecture of
IEEE 802.11 ad-hoc
wireless LANs

Q 2 . Write a note on Bluetooth piconet ?

A very important term in the context of Bluetooth is a **piconet**. A piconet is a collection of Bluetooth devices which are synchronized to the same hopping sequence. Figure 7.41 shows a collection of devices with different roles. One device in the piconet can act as **master** (M), all other devices connected to the

Figure 7.41
Simple Bluetooth
piconet



master must act as **slaves** (S). The master determines the hopping pattern in the piconet and the slaves have to synchronize to this pattern. Each piconet has a unique hopping pattern. If a device wants to participate it has to synchronize to this.

Two additional types of devices are shown: parked devices (P) can not actively participate in the piconet (i.e., they do not have a connection), but are known and can be reactivated within some milliseconds (see section 7.5.5).

Devices in stand-by (SB) do not participate in the piconet. Each piconet has exactly one master and up to seven simultaneous slaves. More than 200 devices can be parked. The reason for the upper limit of eight active devices, is the 3-bit address used in Bluetooth. If a parked device wants to communicate and there are already seven active slaves, one slave has to switch to park mode to allow the parked device to switch to active mode. Figure 7.42 gives an overview of the formation of a piconet. As all active devices have to use the same hopping sequence they must be synchronized.

The first step involves a master sending its clock and device ID. All Bluetooth devices have the same networking capabilities, i.e., they can be master or slave.

There is no distinction between terminals and base stations, any two or more devices can form a piconet. The unit establishing the piconet automatically becomes the master, all other devices will be slaves.

The hopping pattern is determined by the device ID, a 48-bit worldwide unique identifier. The phase in the hopping pattern is determined
by the master’s clock. After adjusting the internal clock according to the master a device may participate in the piconet. All active devices are assigned a 3-bit **active member address** (AMA).

All parked devices use an 8-bit **parked member address** (PMA). Devices in stand-by do not need an address.

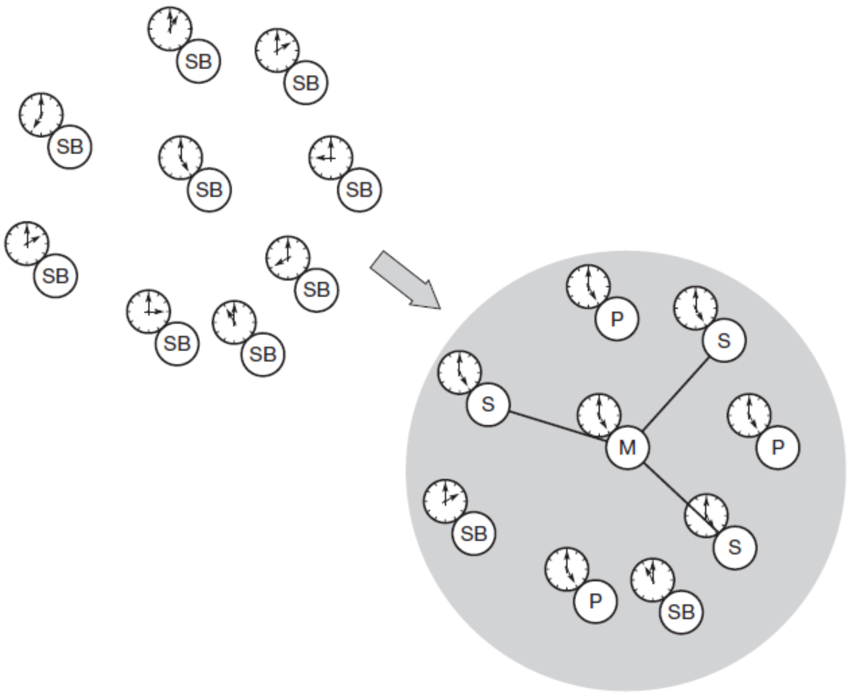


Figure 7.42
Forming a Bluetooth piconet

Q 3 Describe the syncronisation and power management as function of MAC management in wireless LAN ?

Answer :-

- **Synchronization :-**

  Each node of an 802.11 network maintains an internal clock. To synchronize the clocks of all nodes, IEEE 802.11 specifies a **timing synchronization function (TSF)**. As we will see in the following section, synchronized clocks are needed for power management, but also for coordination of the PCF and for synchronization of the hopping sequence in an FHSS system.

  Using PCF, the local timer of a node can predict the start of a super frame, i.e., the contention free and contention period. FHSS physical layers need the same hopping sequences so that all nodes can communicate within a BSS.

Within a BSS, timing is conveyed by the (quasi)periodic transmissions of a beacon frame. A **beacon** contains a timestamp and other management information used for power management and roaming (e.g., identification of the BSS).

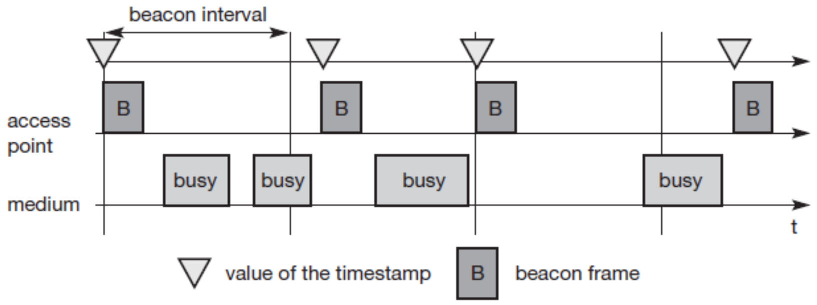
The timestamp is used by a node to adjust its local clock. The node is not required to hear every beacon to stay synchronized; however, from time to time internal clocks should be adjusted. The transmission of a beacon frame is not always periodic because the beacon frame is also deferred if the medium is busy.

Within **infrastructure-based** networks, the access point performs synchronization by transmitting the (quasi)periodic beacon signal, whereas all other wireless nodes adjust their local timer to the time stamp. This represents the simple case shown in Figure 7.18. The access point is not always able to send its beacon B periodically if the medium is busy.

However, the access point always tries to schedule transmissions according to the expected beacon interval (**target beacon transmission time**), i.e., beacon intervals are not shifted if one beacon is delayed.

The timestamp of a beacon always reflects the real transmit time, not the scheduled time.

Figure 7.18
Beacon transmission in a busy 802.11 infrastructure network



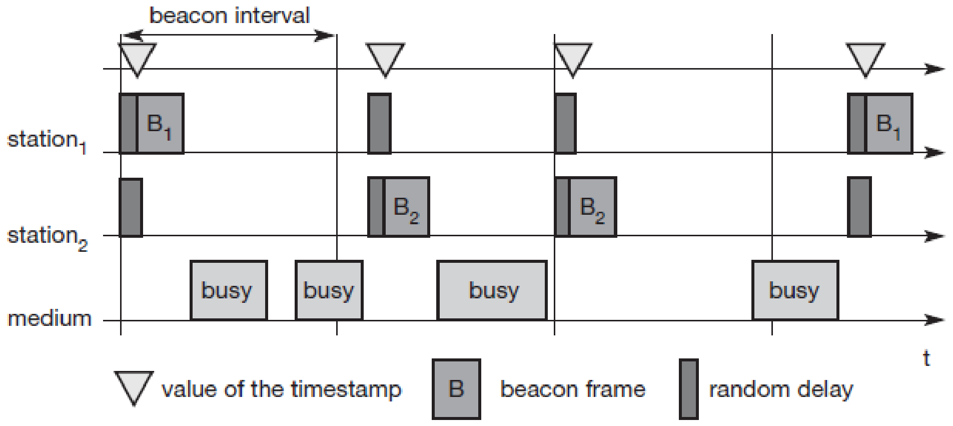


Figure 7.19
Beacon transmissi
in a busy 802.11
ad-hoc network

For ad-hoc networks, the situation is slightly more complicated as they do not have an access point for beacon transmission. In this case, each node maintains its own synchronization timer and starts the transmission of a beacon frame after the beacon interval. Figure 7.19 shows an example where multiple stations try to send their beacon. However, the standard random backoff algorithm is also applied to the beacon frames so only one beacon wins. All other stations now adjust their internal clocks according to the received beacon and suppress their beacons for this cycle. If collision occurs, the beacon is lost. In this scenario, the beacon intervals can be shifted slightly because all clocks may vary as may the start of a beacon interval from a node's point of view. However, after successful synchronization all nodes again have the same consistent view.

➢ Power management :-

Wireless devices are battery powered (unless a solar panel is used). Therefore, power-saving mechanisms are crucial for the commercial success of such devices. Standard LAN protocols assume that stations are always ready to receive data, although receivers are idle most of the time in lightly loaded networks.

However, this permanent readiness of the receiving module is critical for battery life as the receiver current may be up to 100 mA (Woesner, 1998).

The basic idea of IEEE 802.11 power management is to switch off the transceiver whenever it is not needed. For the sending device this is simple to achieve as the transfer is triggered by the device itself. However, since the power management of a receiver cannot know in advance when the transceiver has to be active for a specific packet, it has to ‘wake up’ the transceiver periodically.

Switching off the transceiver should be transparent to existing protocols and should be flexible enough to support different applications. However, throughput can be traded-off for battery life. Longer off-periods save battery life but reduce average throughput and vice versa.

The basic idea of power saving includes two states for a station: **sleep** and **awake**, and buffering of data in senders. If a sender intends to communicate with a power-saving station it has to buffer data if the station is asleep. The sleeping station on the other hand has to wake up periodically and stay awake for a certain time.

During this time, all senders can announce the destinations of their buffered data frames. If a station detects that it is a destination of a buffered packet it has to stay awake until the transmission takes place. Waking up at the right moment requires the **timing synchronization function (TSF)** introduced in section 7.3.5.1. All stations have to wake up or be awake at the same time.

Power management in **infrastructure**-based networks is much simpler compared to ad-hoc networks. The access point buffers all frames destined for stations operating in power-save mode. With every beacon sent by the access point, a **traffic indication map (TIM)** is transmitted. The TIM contains a list of stations for which unicast data frames are buffered in the access point.

The TSF assures that the sleeping stations will wake up periodically and listen to the beacon and TIM. If the TIM indicates a unicast frame buffered for the station, the station stays awake for transmission. For multi-cast/broadcast transmission, stations will always stay awake. Another reason for waking up is a frame which has to be transmitted from the station to the access point. A sleeping station still has the TSF timer running. Figure 7.20 shows an example with an access point and one station.

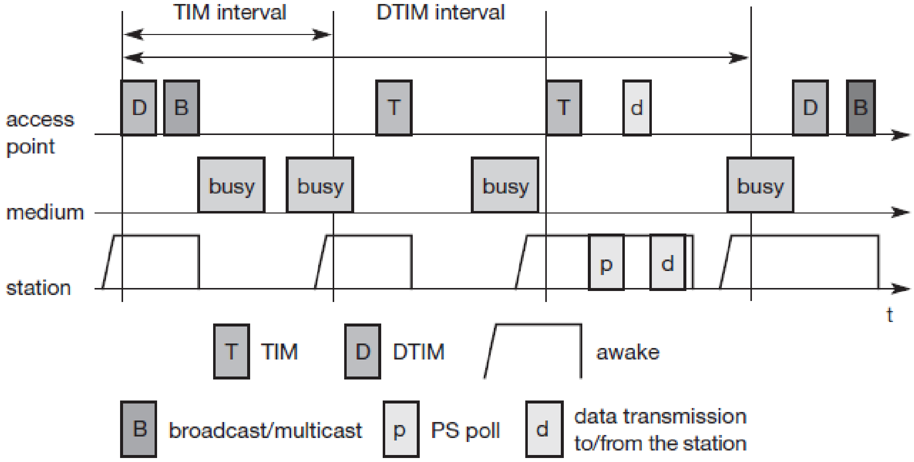
The state of the medium is indicated. Again, the access point transmits a beacon frame each beacon interval. This interval is now the same as the TIM interval.

Additionally, the access point maintains a **delivery traffic indication map (DTIM)** interval for sending broadcast/multicast frames. The DTIM interval is always a multiple of the TIM interval.

All stations (in the example, only one is shown) wake up prior to an expected TIM or DTIM. In the first case, the access point has to transmit a broadcast frame and the station stays awake to receive it. After receiving the broadcast frame, the station returns to sleeping mode. The station wakes up again just before the next TIM transmission. This time the TIM is delayed due to a busy medium so, the station stays awake.

The access point has nothing to send and the station goes back to sleep. At the next TIM interval, the access point indicates that the station is the destination for a buffered frame. The station answers with a **PS** (power saving) **poll** and stays awake to receive data. The access point then transmits the data for the station, the station acknowledges the receipt and may also send some data (as shown in the example). This is acknowledged by the access point (acknowledgments are not shown in the figure). Afterwards, the station switches to sleep mode again.

Figure 7.20
Power management in IEEE 802.11 infrastructure networks



Finally, the access point has more broadcast data to send at the next DTIM interval, which is again deferred by a busy medium. Depending on internal thresholds, a station may stay awake if the sleeping period would be too short. This mechanism clearly shows the trade-off between short delays in station access and saving battery power. The shorter the TIM interval, the shorter the delay, but the lower the power-saving effect.

In ad-hoc networks, power management is much more complicated than in infrastructure networks. In this case, there is no access point to buffer data in one location but each station needs the ability to buffer data if it wants to communicate with a power-saving station. All stations now announce a list of buffered frames during a period when they are all awake.

Destinations are announced using **ad-hoc traffic indication map (ATIMs)** – the announcement period is called the **ATIM window**.
Figure 7.21 shows a simple ad-hoc network with two stations. Again, the beacon interval is determined by a distributed function (different stations may send the beacon). However, due to this synchronization, all stations within the ad-hoc network wake up at the same time. All stations stay awake for the ATIM interval as shown in the first two steps and go to sleep again if no frame is buffered for them. In the third step, station1 has data buffered for station2.

This is indicated in an ATIM transmitted by station1. Station2 acknowledges this ATIM and stays awake for the transmission. After the ATIM window, station1 can transmit the data frame, and station2 acknowledges its receipt. In this case, the stations stay awake for the next beacon.

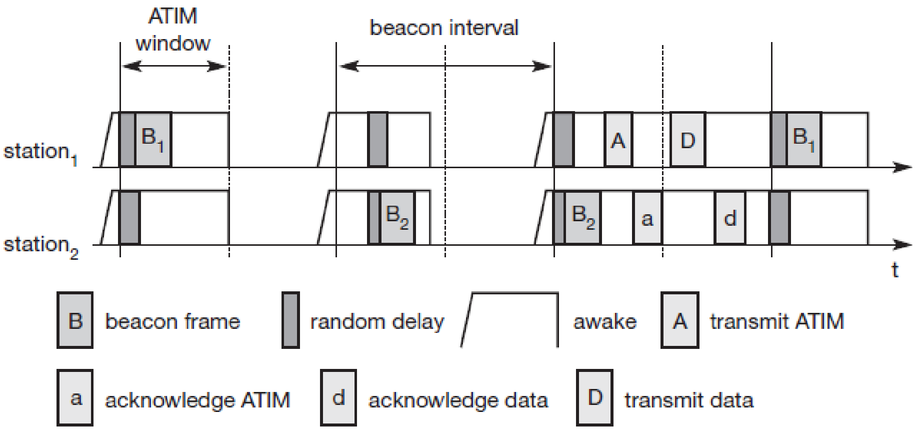


Figure 7.21
Power management in IEEE 802.11 ad-hoc networks

One problem with this approach is that of scale. If many stations within an ad-hoc network operate in power-save mode, they may also want to transmit their ATIM within the ATIM window. More ATIM transmissions take place, more collisions happen and more stations are deferred. The access delay of large networks is difficult to predict. QoS guarantees can not be given under heavy load.\

Q 4. Write a note on roaming ?

Answer :-

- Roaming:-

  Typically, wireless networks within buildings require more than just one access point to cover all rooms. Depending on the solidity and material of the walls, one access point has a transmission range of 10–20 m if transmission is to be of decent quality. Each storey of a building needs its own access point(s) as quite often walls are thinner than floors.

  If a user walks around with a wireless station, the station has to move from one access point to another to provide uninterrupted service. Moving between access points is called **roaming**.

  The term "handover" or "handoff" as used in the context of mobile or cellular phone systems would be more appropriate as it is simply a change of the active cell. However, for WLANs roaming is more common.
  The steps for roaming between access points are:

- A station decides that the current link quality to its access point AP1 is too poor. The station then starts **scanning** for another access point.

- Scanning involves the active search for another BSS and can also be used for setting up a new BSS in case of ad-hoc networks. IEEE 802.11 specifies scanning on single or multiple channels (if available at the physical layer) and differentiates between passive scanning and active scanning.

Passive scanning
simply means listening into the medium to find other networks, i.e., receiving the beacon of another network issued by the synchronization function within an access point. **Active scanning** comprises sending a **probe** on each channel and waiting for a response. Beacon and probe responses contain the information necessary to join the new BSS.

- The station then selects the best access point for roaming based on, e.g., signal strength, and sends an **association request** to the selected access point AP2.

- The new access point AP2 answers with an **association response**. If the response is successful, the station has roamed to the new access point AP2. Otherwise, the station has to continue scanning for new access points.

- The access point accepting an association request indicates the new station in its BSS to the distribution system (DS). The DS then updates its database, which contains the current location of the wireless stations. This database is needed for forwarding frames between different BSSs, i.e. between the different access points controlling the BSSs, which combine to form an ESS (see Figure 7.3).

Additionally, the DS can inform the old access point AP1 that the station is no longer within its BSS. Unfortunately, many products implemented proprietary or incompatible versions of protocols that support roaming and inform the old access point about the change in the station's location.

The standard **IEEE 802.11f (Inter Access Point Protocol, IAPP)** should provide a compatible solution for all vendors. This also includes load-balancing between access points and key generation for security algorithms based on IEEE 802.1x (IEEE, 2001).

Q 5. Explian the design issue for IEEE 802.11 Wireless LAN ?

Answer :-

- **Global operation:** WLAN products should sell in all countries so, national and international frequency regulations have to be considered. In contrast to the infrastructure of wireless WANs, LAN equipment may be carried from one country into another – the operation should still be legal in this case.

- **Low power:** Devices communicating via a WLAN are typically also wireless devices running on battery power. The LAN design should take this into account and implement special power-saving modes and power management functions. Wireless communication with devices plugged into a power outlet is only useful in some cases (e.g., no additional cabling should be necessary for the network in historic buildings or at trade shows). However, the future clearly lies in small handheld devices without any restricting wire.

- **License-free operation:** LAN operators do not want to apply for a special license to be able to use the product. The equipment must operate in a license-free band, such as the 2.4 GHz ISM band.

- **Robust transmission technology:** Compared to their wired counterparts, WLANs operate under difficult conditions. If they use radio transmission, many other electrical devices can interfere with them (vacuum cleaners, hairdryers, train engines etc.). WLAN transceivers cannot be adjusted for perfect transmission in a standard office or production environment. Antennas are typically omnidirectional, not directed. Senders and receivers may move.

- **Simplified spontaneous cooperation:** To be useful in practice, WLANs should not require complicated setup routines but should operate spontaneously after power-up. These LANs would not be useful for supporting, e.g., ad-hoc meetings.
- **Easy to use:** In contrast to huge and complex wireless WANs, wireless LANs are made for simple use. They should not require complex management, but rather work on a plug-and-play basis.

- **Protection of investment:** A lot of money has already been invested into wired LANs. The new WLANs should protect this investment by being interoperable with the existing networks. This means that simple bridging between the different LANs should be enough to interoperate, i.e., the wireless LANs should support the same data types and services that standard LANs support.

- **Safety and security:** Wireless LANs should be safe to operate, especially regarding low radiation if used, e.g., in hospitals. Users cannot keep safety distances to antennas. The equipment has to be safe for pacemakers, too.

Users should not be able to read personal data during transmission, i.e., encryption mechanisms should be integrated. The networks should also take into account user privacy, i.e., it should not be possible to collect roaming profiles for tracking persons if they do not agree.

- **Transparency for applications:** Existing applications should continue to run over WLANs, the only difference being higher delay and lower bandwidth. The fact of wireless access and mobility should be hidden if it is not relevant, but the network should also support location aware applications, e.g., by providing location information.