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Interconnection Architectures of Wireless Access Networks. Requirements, Key Applications, and Challenges

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TITLE

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Abstract

In this paper we investigate the wireless networks that were created as an extension of the wired networks, to extend their capabilities and coverage, in places where a wired connection is not possible, but also the interconnection of devices that do not support a wired connection, except wireless. Wireless networks, since they were developed, have been directly connected to the architectures that structure and organize them.

Additional Keywords and Phrases: IBSS, BSS, ESS, Hot Spots, Wireless Sensor Networks, Mesh Networks, WLAN, WMAN, WWAN, WPAN

Introduction

In the last decade, human life has changed, for the better. The reason for this change is the development of telecommunications and the internet, which are directly related to the increased use of smart mobile devices. (mobile phones, tablets, computers, etc.). This development has led to the complete nullification of distances and the direct interaction of users in every part of the world.

The primary goal of networking various systems is to enable connectivity between different devices. The underlying network allows connecting computers, to other computers, sensors to computers, mobile phones to other phones, computers to phones and so on.

When we look at wireless networks today, we don't really care about point-to-point wireless connections. What makes wireless networks interesting is the fact that they offer portability and mobile access points to networks and applications. By portable, we mean the ability to carry the device anywhere. By mobile, we mean the ability to stay connected at any time even if the user is moving with the device at speeds of up to 100 km/h. Another type of wireless network of interest is that composed of low-energy devices (such as sensor networks or radio frequency identification (RFID) tags). Portability and mobility also help enable devices to run on battery power.

Wireless Networking Architectures

The architecture of wireless networks is divided into two categories, physical and logical. The logical architecture is based on the seven layers of the OSI standard and the layers' operating protocols, emphasizing Network and data. Data most relevant to wireless networking are: IP address, connection control, routing and media access. While physical architecture describes wireless networks, focusing on wireless network topologies and hardware devices.

Logical Architectures of Wireless Networks

The logical architecture of a network refers to the structure of standards and protocols that enable connections between physical devices and nodes, which control the routing and flow of data between devices and nodes. Since logical connections operate above the physical

layer, the logical and physical architectures rely on each other, but both also have a high degree of independence, such that the physical configuration of a network can change without changing its logical architecture. , and just as natural network can in many cases support different sets of standards and protocols. The logical architecture of the wireless network is described in this section, with reference to the OSI model.

Wireless Network Architectures

The following sections will detail the categories and architectures of wireless networks. Based on their architecture and topology, wireless networks are divided into the following major categories:
Wireless Local Area Networks (WLAN)
Wireless Metropolitan Area Networks (WMAN)
Wireless Personal Area Networks (WPAN)
Wireless Wide Area Networks (WWAN)

Regarding the construction of the networks there are two main ways of connecting:

Peer-to-Peer: No access point and no central management point. Networks of this type are suitable for small companies or for home use. The covered area (Basic Service Area or BSA) occupies a radius of approximately 100 meters.

Infrastructure wireless network: Includes access point. The majority of networks are set up with AP, as this ensures greater flexibility in installation and management. The area covered here depends on the range of each access point or on the existence of more than one access point in the operating area (Extended Service Area or ESA) [1].

Ad hoc Wireless networks– IBSS (Independent Basic Service Set)

The characteristics of an Ad hoc network are the following:

- They are based on the Ad hoc mode standard, which is characterized by free movement, without dependence on any central body. Each workstation acts as both a router and a host computer.
- Multiple devices can be connected provided all network cards are in Ad-Hoc mode and connected to the same SSID (wireless network name).
- Continually changing topology.

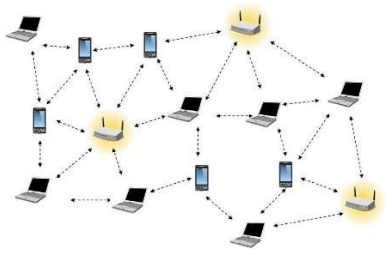

Figure 1: Ad-Hoc Architecture (via research-gate.com)

Advantages of Ad-Hoc networks: Due to their decentralized nature, they are used in applications that do not rely on central nodes and predefined wireless networks. They can be used in emergency situations where the core network and infrastructure have been

destroyed, due to their quick installation and minimal configuration. They allow the network to be quickly restored in the event of a failure, since they can choose another route. One station may not be communicating with another, but that doesn't mean it isn't communicating with the others.

Disadvantages: Requires a lot of resources from the devices to be able to maintain the connection as they move. They have a shorter range than those with a fixed access point. Finally, its most important disadvantage is that possible situations that will arise cannot be predicted, due to their dynamic nature.

Wireless LANs BSS Networks (Basic Service Set)

Communication in BSS networks is done with the help of a wireless hub called an Access Point. The operation of the central access point is similar to that of switches and hubs in wired Ethernet networks. The wireless access point may be wired or wirelessly connected to a backbone network to thereby promote the movement of wireless stations.

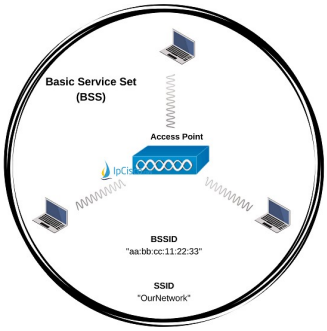

Figure 2: BSS Architecture (via IPcisco.com)

The coverage area of the access point in the BSS topology constitutes the network cell. Workstations have a unique identification number called SSID (Service Set Identifier), which they use to communicate with each other and which is set by the network administrator at the Access Point. Many times, the wireless access point is directly connected to the internet (usually with xDSL connections), so it also acts as a router for the stations connected to it. Wireless APs and Wireless Routers are no different in appearance, with the only difference being that a wireless access point cannot route and forward traffic from wireless stations [2].

Advantages: Used as a permanent network when coverage areas are known in advance. It has a greater coverage range due to the access points, resulting in greater mobility of devices within the network cell.

Disadvantages: They have a more complicated design and many parameters must be considered for the correct placement of the access point. This is because the wireless access point is the only available network resource in that area and must cover as much as possible, without physical obstacles that weaken the signal.

Extended Service Set (ESS) Networks

When a wired backbone network is connected to several BSS networks, wanting to create a wider and larger network, the topology is called ESS. In this case, the coverage radius of the network expands according to the number of wireless connection points. The connection between wireless and wired networks can be done by wireless bridges.

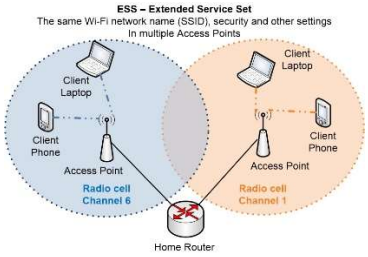

Figure 3: ESS Architecture (via homenet.com)

Hot Spots

Hot Spots topology refers to wireless local area networks that also provide Internet connectivity. We usually find them in recreational areas (cafes, restaurants), in public areas of cities and airports. Each network with the Hot Spots topology can be a BSS network with a wireless access point a router or an ESS topology, to cover a longer distance but which also has an Internet connection. [3]

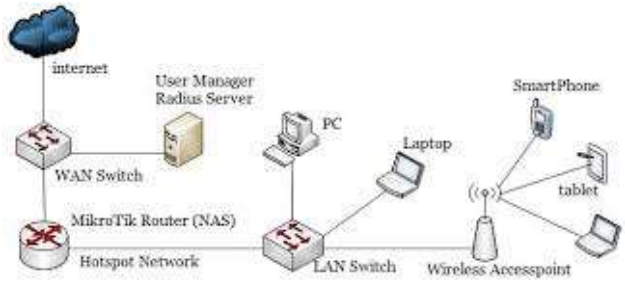

Figure 4: Hot Spots Topology (via systemzone.net)

The main advantages provided by a wireless LAN are:

- Broadband: Allows devices to be accessed regardless of the user's location. It can provide high speeds resulting in the coexistence of many types of data, such as streaming, voice over ip and simple network data which coexist on different radio frequencies.
- Ease of implementation: They can be connected more easily because there is no need to use cables. You can access different floors without using cables.
- Lower cost of expansion: Wireless networks allow the quick, easy and low-cost expansion of networks in areas where either cabling is too difficult to implement, or the existing one is too difficult to expand. The initial cost of equipping a wireless local area network may be comparatively more expensive than that of a wired one, but in cases of dynamic workplaces that require frequent changes, as the cost of reconfiguring the pre-existing wireless network will be negligible.
- Quick installation/deployment: A wireless network can be used as a quick installation tool for a branch office of a company or remote area. A wireless device can provide a network interface to several users without the time and expense of cabling to provide the same to each user. With wireless technology, network access to a remote area can be implemented in hours instead of days [4].

The main disadvantages of WLANs are:

- Security: In wireless networks, the security provided lags behind compared to wired networks, as attackers can attack in different ways.
- Interference: Because the bands used by wireless LANs are usually low they are vulnerable to interference. Wireless LANs transfer data through the air, which often

leads to signal distortion because the same transmission medium (air) is used by all neighboring devices.

- Allocation of frequencies: The operation of a WLAN assumes that all its users can have the same frequency.
- Range: The range of wireless systems is quite limited in many cases and the functionality expected by users either cannot be achieved, or can be achieved to a limited extent.

Wireless metropolitan networks (WMAN)

Wireless metropolitan networks allow connection between two or more points located in the same metropolitan area. They can connect buildings that are several kilometers apart and are usually used for the interconnection between buildings in a university, offices of a company in the same city or municipal buildings, etc. The main difference with local wireless networks is the hardware used in the interface as typically the interface is point-to-point and the distance is longer [5].

A type of WMAN is also the so-called hotzones. A hotzone consists of a large number of nearby Wi-Fi hotspots. These are usually implemented in the central areas of large cities to attract people to these areas. Compared to wired metropolitan networks, they do not require cables to be installed or rented, but usually use radio waves or infrared radiation to transmit data between two points, thereby reducing costs.

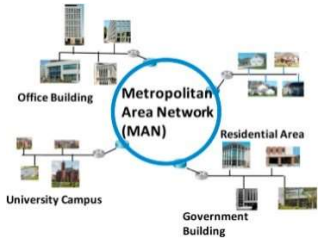

Figure 5: WMAN Architecture (via sciencedirect.com)

Metropolitan wireless networks broadcast over a greater distance than local wireless networks, meeting the needs of a larger population. Also using WiMax technology it can be extended to rural towns and inaccessible areas. The term WiMAX refers to the 802.16x standards that have been developed in recent years to provide high speeds and mobility services in metropolitan wireless connections. These connections can be either point-to-point or cellular as in mobile networks. The coding of the signal is OFDM which allows high speeds and the purpose of the technology is to provide an alternative way of accessing xDSL technologies in places where these technologies cannot for some reason be implemented [6].

This type of network is mainly characterized by the sum of many interconnected local area networks. What is also known by many as wireless local loop. Its main features are:

- WMAN coverage distance up to 50km max
- Infrared transmission frequencies from 300GHz - 384Thz
- It offers portable and mobile broadband connections

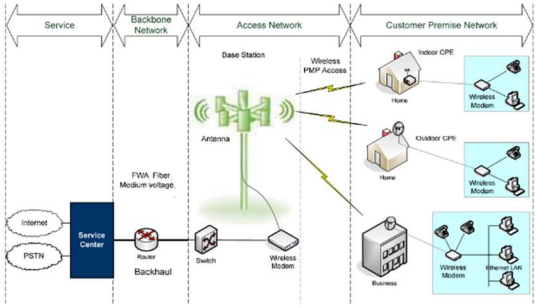

Figure 6: WiMAX Architecture (via sciencedirect.com)

Wireless Personal Area Networks (WPANs)

Wireless personal networks are essentially short-range local networks aimed at wireless networking of heterogeneous mobile devices. The range distance is a few meters and allows the exchange of files, applications and communication between devices. Wireless personal network technologies are:

a) Bluetooth: It is a standard used in wireless personal networks with which we can connect different devices such as mobile phones, cameras, laptops, printers, smart devices through a radio frequency. Bluetooth supports low power consumption and devices very small in size and cost. The radio frequency of the Bluetooth standard is very low in power and is effective for distances of 1 – 10 meters. It offers relatively slow speeds and is considered a form of wireless USB connection. It is commonly used for communication between devices, for wireless communication between computers and peripherals, replacing infrared and connecting to the Internet for computers that have Bluetooth. The 2.0 standard allows speeds of up to 2.1Mbps [7].

Figure 7: Bluetooth Architecture (via ICTlounge.com)

b) Zigbee: The standard describes a family of protocols, responsible for the interconnection of devices of small size, low power and cost. It is suitable for wireless personal networks and wants to replace the Bluetooth as it requires the half the code to control a device as compared to Bluetooth.

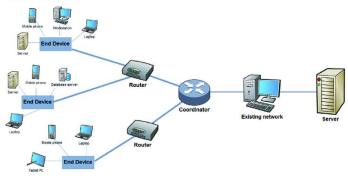

Figure 8: Zigbee Architecture (via sciencedirect.com)

Wireless Wide Area Networks (WWAN)

One of the most common forms of wireless wide area network is the cellular network. Fifth-generation 5G networks will consist of a system that will support a wide range of applications from mobile voice to multi-Gigabit-per-second mobile Internet. 3D-sMIMO will be embedded in BS to further improve data rate and capacity at macrocell level. The system performance in terms of coverage, capacity and EU will be further enhanced in hot spots with relay stations, state-of-the-art small cell installations or WiFi. D2D communications will be assisted by the macro-BS, providing the control layer. Additionally, mobile users will be able to create a virtual resource pool that will manage the network. Approaching applications through the cloud will be closer to the end user to reduce latency [8].

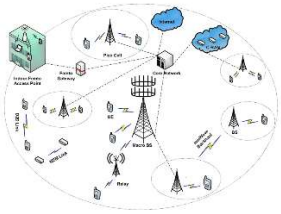

Figure 9: 5G Architecture (via sciencedirect.com)

Wireless Sensor Networks

By the term wireless sensor networks, we mean a set of autonomous sensors that are scattered and have the purpose of monitoring environmental and natural phenomena. Sensors may also be embedded in devices. Each device is energy autonomous and for the network it is a node. Nowadays, nodes are grouped and create so-called clusters or bundles. Each node of a cluster, after collecting its data, transmits it to the "head" node of the cluster, called the cluster head, and in turn, the cluster head alone transmits the collected data to the collector node of the wireless network, called the sink node. The collector node has the main responsibility of collecting and storing large amounts of data and transmitting them to a computer system [9].

The architecture of a sensor network consists of:

- Sensors that collect the data
- Gateway Base which collects the information and controls the sensors
- Computer sends the data to a server
- Router for sending the data to the server
- The server responsible for collecting, storing and processing data

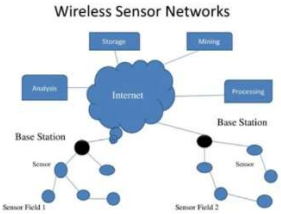

Figure 10: Wireless Sensors Network Architecture (via sciencedirect.com)

For the design of a wireless sensor network, a number of characteristics that define them are considered. These are the guide for the protocols to be used and for the algorithms of each wireless network. Such features are:

- Fault tolerance. That is, to be able to perform its function regardless of the problems that will occur in one or more nodes. Some of these problems can be failure and lack of power in a sensor. Fault tolerance is different depending on the network application.

- Expandability. Since the number of sensors in any network can be from a few tens to thousands, the protocols and algorithms used in the design of the network should be suitable so that they can manage these numbers.
- Installation costs. Sensors should be chosen in such a way that there is the best relationship between cost and utility.
- Hardware limitations. Sensors must be small in size, consume as little energy as possible, work without someone's supervision and adapt to the environment in which they work.
- Environment. It plays an important role because the environment changes depending on the application (underwater, on farms, on land or in the air).

Wireless Mesh Networks

When the organization of the nodes is based on the mesh topology, the network is called a wireless mesh network (WMN). Your network coverage depends on the coverage of wireless nodes, which work as a single network called a "cloud". Mesh networks offer reliability and economy. Wireless mesh networks can be easily created because of the adaptive and dynamic protocols they use. When a node goes down, the remaining nodes continue to communicate either directly with each other or by using one or more intermediate nodes. Mesh wireless networks are similar to Ad-hoc wireless networks except that all nodes in the network remain fixed and do not test for mobility. The network is configured in advance to provide dynamic access to a specific geographic area [10].

Wireless mesh networks are categorized into three categories:

- Hierarchical structure: In the hierarchical structure the stations - nodes are divided into groups called clusters. There are three categories of nodes in each cluster: cluster head (ch), gateways (GW) and clients (cluster member). The beam leader performs the functions of a wireless access point (AP). All stations and nodes in a bundle can communicate with the bundle simulating the access point and can communicate with any other member of the bundle. The selection criteria of the head beam are many, such as the connectivity with the neighboring nodes and the power it transmits. Gateways are used to talk different bundles together, as well as bridges to extend the mesh network and connect it to other networks [11].

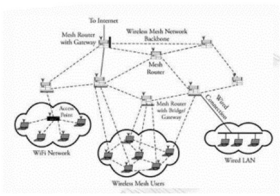

Figure 11: Hierarchical structure of MESH Architecture (via sciencedirect.com)

- Flat type of structure: In this architecture the nodes have the same responsibilities and are not grouped. The connection is achieved between nodes that are sufficiently close to each other, so as to create conditions suitable for the propagation of radio waves and the establishment of the connection. All nodes perform the function of routing, so a packet you send from one node passes through many to reach the final destination.

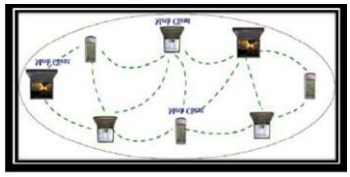

Figure 11: Flat type of structure of MESH Architecture (via sciencedirect.com)

- Hybrid type: In this case we have the combination of the above two types of structure, thus giving us the possibility of interconnection with other networks and stability in the routing of packets [12].

Figure 11: Hybrid type of structure of MESH Architecture (via sciencedirect.com)

Advantages of wireless mesh networks and applications

- Low to minimal power consumption due to dynamically managed routing
- Low cost
- Ease of installation
- Quality of communication
- The transmission signal is maintained at high levels until the final destination due to the rebroadcasting of the signal by nearby nodes
- Interoperability

Because wireless mesh networks can be applied to fixed and mobile devices, their number of applications is large. Applications of wireless mesh networks are:

- In military applications
- In satellite applications
- In VoIP
- In wireless electricity meters
- In places where there is no infrastructure and reliable communication is required
- In car networks

Conclusion

In this paper we presented a detailed thesis of the architectures and topologies for the wireless networks. In particular we presented the wireless networks that were created as an extension of the wired networks, to extend their capabilities and coverage, in places where a wired connection is not possible, but also the interconnection of devices that do not support a wired connection, except wireless. Wireless networks, since they were developed, were directly connected to the architectures that structure and organize them.

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