Chapter

An Overview of Wireless Mesh Networks

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Abstract

Wireless mesh networks (WMNs) are communication networks which comprise radio nodes in which nodes are arranged in a mesh topology. Mesh topology is an interconnection of all nodes connected with all other nodes in the network. The network includes devices like nodes, clients, routers, gateways, etc. As the nodes are fully connected, mesh networks are usually less mobile as rerouting is less difficult in predicting the reroute results in delay in data transmission. Mesh clients can be of any wireless devices like cell phones, laptops, etc. The gateways which act as forwarding nodes may not be connected with the Internet. As different devices come under a single network, it is also referred as mesh cloud. WMN is self-healable. It works better with various different networks which include cellular networks and IEEE 802.11, 802.15, and 802.16 as well. WMN is flexible to work with more than one protocol. This chapter gives architecture, layer functionalities, and applications.

Keywords: WMN architecture, layer functionalities, WMN standards, applications

1. Introduction

Wireless mesh network is a network which comprises various wireless nodes with access points. Each node in the network acts as a forwarding node to transfer the data. Since the network is decentralized, forwarding of data is possible only to the neighboring node. This results in the network structure simple and easy. WMN makes the people connected with the Internet who work at remote areas and operating business. This chapter throws light on WMN architecture, layer functionalities, various other networking standards, and applications.

2. Wireless mesh network

2.1 Architecture

Wireless mesh network is the architecture which provides less mobility with low cost within a radio range. WMN is an infrastructure which is a network of routers minus cabling between the nodes. It consists of radio nodes which need not to be cabled to a wired port like the conventional wireless access points. Shortest hops are predicted to transmit the data toward large distance [1]. Nodes between the source and destination act as a forwarding node which works cooperatively in making decisions in route prediction based on the topology and forwarding the data.

Wireless mesh network provides stability when compared to the rest of the network topologies rather than the node addition or deletion in the network. In infrastructure mesh network, the data forwarding and receiving are via gateway, whereas in the rest of the network, it is through pair of nodes [2].

The frequency of link breakage is higher in the case of wireless mesh networks when there is a high mobility which results in low performance in communication of information [3, 4].

Wireless mesh networks are categorized into three types based on the functionality of the nodes in the network:

- Infrastructure mesh architecture
- Mesh architecture based on clients
- Hybrid mesh architecture

2.1.1 Infrastructure mesh architecture

Mesh routers together act as a wireless back bone for infrastructure mesh architecture. Client node is passive in mesh infrastructure via Ethernet links; conventional clients with Ethernet interfaces can be connected to mesh routers.

If the traditional network and the mesh router are operating under the same radio range, then it is easy for the mesh network to communicate with the mesh router. Alternatively, if the radio ranges differ, the nodes will communicate to the base station so that with the help of Ethernet, it can be further communicated to the mesh routers. **Figure 1** shows the mesh architecture for infrastructure-based network.

2.1.2 Mesh architecture based on clients

Mesh architecture based on client is the one in which the client nodes are connected from peer to peer. Each node can act as a routing node to transfer the data. Here, the client performs the role of mesh routing by acting in the forwarding of the data packets.

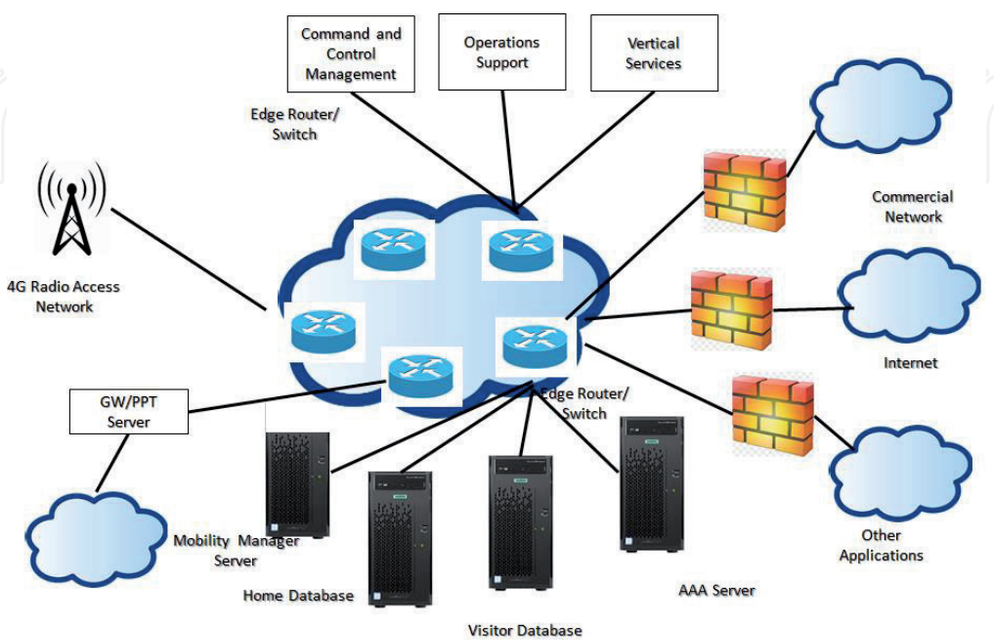

Figure 1.
Mesh architecture for infrastructure-based network.

Figure 2 shows the architecture of mesh based on clients. In this we can see that the network with no router is connected to it, and rather all clients are interconnected to perform data transfer.

2.1.3 Hybrid mesh architecture

In hybrid mesh architecture, usually the mesh nodes/router acts as a back bone of the entire network operation. With the help of network mesh router, it performs routing and forwarding of data packets toward its destination [5] which is shown in **Figure 3**.

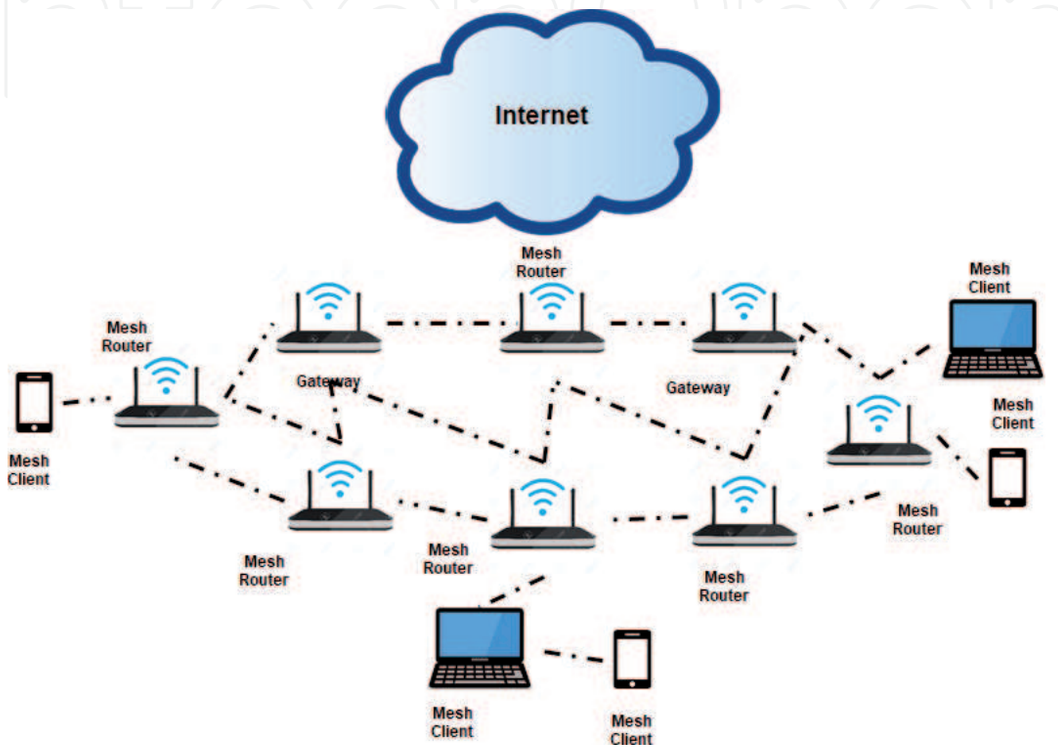

Figure 2.
Mesh architecture based on clients.

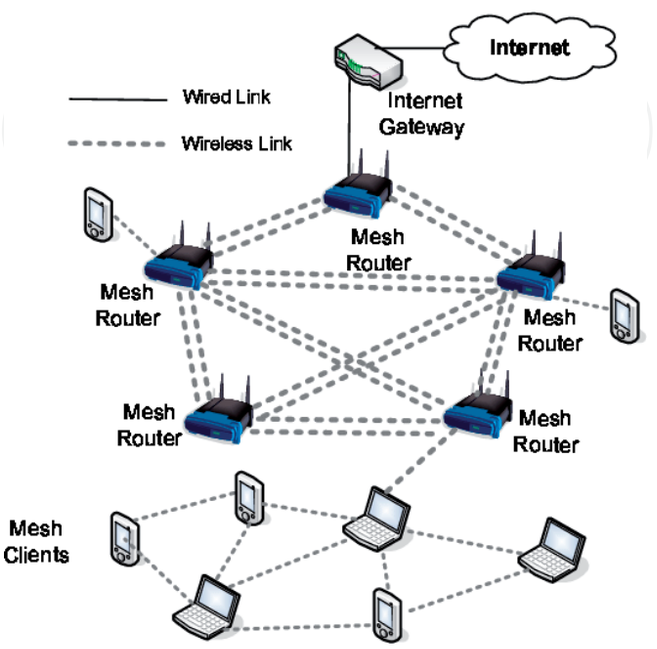

Figure 3.
Hybrid mesh architecture.

2.1.4 Characteristics of wireless mesh networks

- Dynamic self-configuration and self-organization
- Adaptation
- Fault tolerance and robustness
- Low-cost
- Integration and interoperability

2.2 Management

The infrastructure-based wireless mesh network is a decentralized network without a centralized management or with no centralized server which is more expensive. These methods are more reliable and efficient as each node has to transmit to the next node. Here, nodes act as router to transmit the data to its peers which are located far even it is a single hop. Wireless mesh network should be stable, i.e., there should not be high mobility. If node failure occurs due to any hardware problem or any other, the neighbor node will perform rerouting with the help of routing protocols.

2.2.1 Applications

Mesh network may comprise of mobile devices or stationary devices. Some of the applications of mesh networks which deserve communication are:

- Battlefield surveillance
- Tunnels
- Mobile video applications
- Emergency situations
- Tunnels
- Real time car racing, etc.

Voice over Internet Protocol (VoIP) is the main application of wireless mesh networks. In order to provide quality of service (QoS), wireless mesh network is used in telecommunication for voice communication. In current scenario, some of the applications where wireless mesh has been used include:

- Military forces in the USA are using wireless mesh networks to connect their devices for field operations.
- In residences, electric smart meters have been implemented to transfer the reading from one point to another (say as, from home to centralized office) to eliminate the man power.
- Wireless mesh network is used in one laptop per child program, in which it makes the students to share their files even when they are not connected with the Internet or with any physical connections.

- From 2010 onward, Wi-Fi-enabled mesh routers are available in the market which is installable even in homes or at small workplace. Google Home, Google on Hub, and Google Wi-Fi are various Wi-Fi wireless mesh networks.

- Iridium constellation with 66 satellites works under mesh network. This topology connects various wireless links with other satellite. Voice calls can be communicated via mesh networks between one satellite and another across constellations without transferring the signal to the ground station. Latency is highly reduced by avoiding the signal transfer to the nearby mesh instead of transferring to ground station.

2.2.2 Operation

The working principle of wireless mesh network is the same as that of the packets that travel around the wired internet data transfer between one node and another toward the destination [6]. This is implemented with the help of dynamic routing algorithm. It is possible by making each node communicate its routing information to other nodes within the network. With the received information, each node will decide whether to forward or to keep the data for itself. It is based on the functionality of the routing protocol. It is necessary for any routing algorithm to ensure that routing is done by predicting the shortest path between the source and destination. **Figure 4** shows the architecture of wireless mesh network.

Wireless mesh network can be connected with the existing network to provide effective communication. In traditional network comprises of various wired nodes, hotspots to communicate with the users, whereas in wireless mesh networks, the network is established with the help of various numbers of wireless nodes to communicate with each other.

The wireless nodes used in wireless mesh networks play same role as wireless routers. Various Wi-Fi communication IEEE standards like IEEE 802.11a, 802.11b, and 802.11 g are used for wireless mesh communication. Nodes in the network are

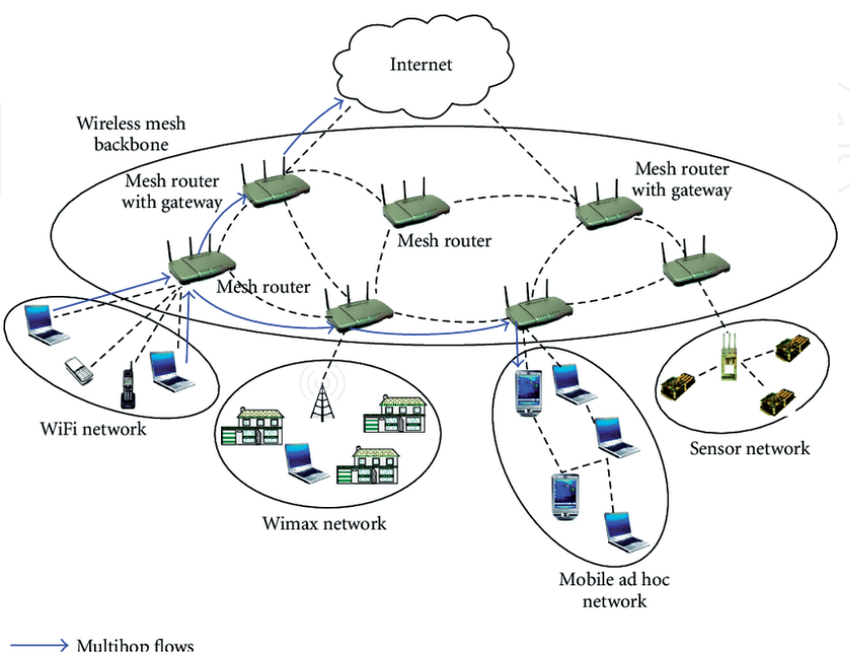

Figure 4.
Architecture of wireless mesh network.

capable of predicting the shortest path from the available path between source and destination. Addition and deletion of nodes and the routes will be updated then and there whenever there is a change in the network infrastructure. Dynamic routing is the capability of the node to predict the shortest available path between source and destination [6].

2.2.3 Advantages

- The cost of designing the network is lesser for fewer numbers of nodes even for large network coverage.
- Wireless mesh network shows better performance even for large number of nodes in the network.
- Wireless mesh networks relay on various Wi-Fi standards.
- It is useful for Non-line-of-sight (NLoS) network.
- It is self-configuring and self-healing.
- Easy to install and uninstall which makes network more adaptable with less or more number of nodes.

2.2.4 Backhaul nodes

In wireless LAN, there may be a chance that the information may be returned to the wired access point. Getting back the information to access is called backhaul. Small networks can be handled without any special configuration, whereas in larger network, backhaul nodes are required to retrieve the information from wired access node.

3. Protocol layer and functionalities

Factors that influence the performance of wireless mesh networks include:

- Architecture
- Topology
- Data pattern and traffic
- Density of the nodes
- Number of channels used by the nodes in the network
- Transmission power
- Mobility of the nodes

In order to develop the protocols, we need to clearly understand the relationship between the above factors and the capacity of WMNs and is given in **Figure 5**.

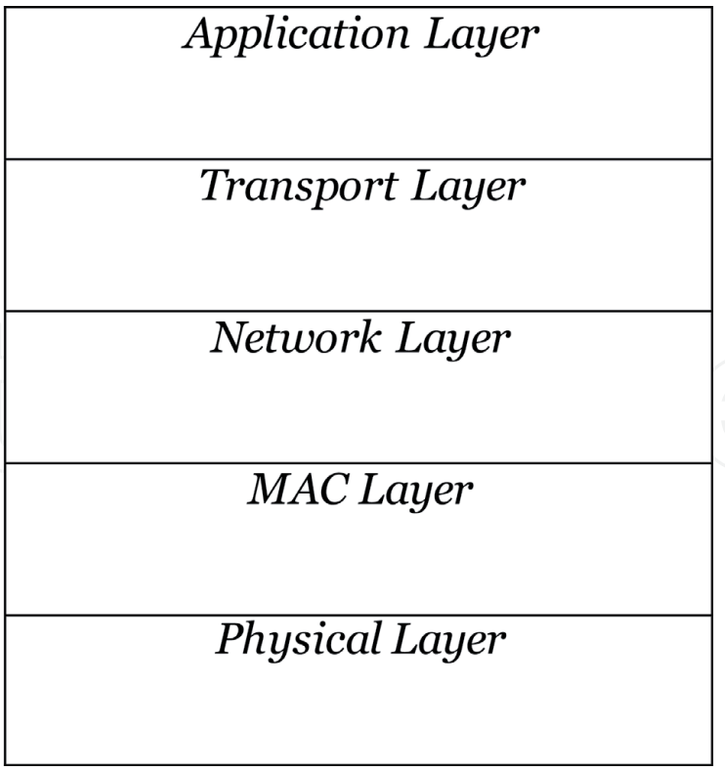

Figure 5.
Layer structure of WMN.

3.1 Physical layer

Wireless mesh networks are capable of multiple data rates simultaneously. It is achieved with the help of various modulation techniques and coding rates. Link adaption provides adaptive error resilience. High-speed data transmission is achieved with orthogonal frequency-division multiple access (OFDMA) and ultra-wideband (UWB) techniques.

Wireless communication system is provided with smart antenna for the purpose of increasing the capacity and to overcome the co-channel interference, fading, multi-antenna systems, etc. But it is tedious for designing the same for wireless mesh networks though it is available with the existing system. Unoccupied spectrum can be utilized by proper frequency planning with the help of WMN. Frequency agile/cognitive radio is used in order to utilize the unused spectrum.

As most of the radio components, RF band, various channel modulations, and access modes are programmable in such a way that it can be implemented in a software for working under cognitive radio range. It will be easier if further updating is to be carried out.

With the available physical test beds, the software platform is not much appropriate to provide desired solution. But still it can able to make advance changes in physical layer techniques which suit better for wireless communications.

3.2 MAC layer

MAC layer in WMN plays a unique role when compared to various other wireless networks:

- In WMN, communication is focused on more than one hop rather than single hop with the help of MAC.

- Multipoint to multipoint communication is possible with the help of distributed MAC.
- Self-healing and self-organization of node are the prime requirements of WMN for better performance.
- Communication between the node and the node which are located far (multihop distances) from the source node should be proper for providing better stability.
- Even less mobility influences the system performance of MAC.
- MAC protocol is designed in such a fashion that WMN can work simultaneously with both single and with multiple channels.

3.3 Routing layer

Though various routing protocols are available for ad hoc networks, it cannot be directly used for wireless mesh networks. It is still a big research to perform modifications of the available protocol to be adopted for WMN. There are the same salient features that WMN should provide with which are:

- Various performance metrics
- Scalability
- Robustness
- Energy-efficient routing algorithm suits for mesh network

Various routing algorithms in ad hoc network are available with any one of the above features, but not with all which makes it difficult to adopt with the mesh network. Some of the routing concepts for mesh network are as follows.

3.3.1 Multi-radio link quality source routing (MR-LQSR)

In MR-LQSR, a metric called weighted cumulative expected transmission time (WCETT) is used for measuring the system performance. In WCETT, link quality and minimum number of hop counts are considered as a system metric which results in better throughput and less delay.

3.3.2 Multipath routing

The objective of multipath routing is to provide load balancing and fault tolerance. Between the source and destination, multiple paths are predicted. When the shortest path link breaks, it can be easily switched over to other available paths. This results in better system performance by reducing the waiting time for computing the path at the time of fault. It also improves throughput and reduces end-to-end delay and fault tolerance. Still complexity exists with the multipath routing as it has to keep record of multipath always even if there is no breakage or fault.

3.3.3 Hierarchical routing

Hierarchical routing protocols show better performance when there is dense number of nodes in the network. This is due to fast setup procedure, reduced overheads, and shortest routing path. Complexity is higher on maintaining the hierarchy and directly relates to the performance of the system.

3.3.4 Geographical routing

It is a unique routing scheme in which it forwards the packets with the knowledge on the position of the node which is being communicated instead of the topology-based method. Geographical routing algorithm (single-path greedy routings) finds difficulty in delivering the data, if the path is available between source and the destination as data forwarding with the help of current location information.

Data delivery is guaranteed by using planar-graph-based geographic routing algorithms but results in more overhead information.

3.4 Transport layer

A large number of transport protocols are available for ad hoc networks, and WMNs depend on those transport layer protocols. Till date, there is no transport protocol that has been proposed specifically for WMNs. We know that ad hoc network is also not mature. It also has various unresolved issues. This suggests further research in this area.

3.5 Application layer

WMN supports enormous applications which include:

- Internet access
- Distributed information storage and sharing
- Information exchange across multiple wireless networks

Various research works have been carried out under these domains but focusing on modifying the existing application layer protocol by adapting various features for the mesh application layer protocol [7].

3.6 Issue in network performance

WMNs have their merits and drawbacks too. There are some issues to be concentrated for improving the network performance which include connectivity, radio range, interoperability, compatibility, etc.

3.6.1 Security issues

The weak area of WMN is security. Strong research is demanded due to the absence of centralized authority or key management for assuring security to provide fully trusted system.

3.6.2 Other issues

The common issues in WMNs are channel capacity expansion, scalability, and quality of service [8].

4. Conclusion

The nodes in WMN are self-configurable and self-healable. Such self- configuring nodes are better which improves the system performance, whereas self-healing makes the network to reconfigure if there are any addition and deletion of nodes in the network. Due to the huge number of nodes and data, there will be a high fault tolerance and degradation in performance. Integration of existing network leads to more complexity. By eradicating these drawbacks, the performance of WMN can be enhanced.

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