International Journal of Engineering Innovation & Research
Volume 1, Issue 2, ISSN : 2277 – 5668

Study of Wireless Mesh Networks and WMN Architecture

Pawan C. Bangar
Dhole Patil College of Engineering, Wagholi, Pune (Pune University)
pa1.bangar@gmail.com

Jameer A. Mulani
Dhole Patil College of Engineering, Wagholi, Pune (Pune University)

Ashish B. Ekad Dhole Patil College of Engineering, Wagholi, Pune (Pune University)

Pramod D. Ganjewar
Dhole Patil College of Engineering, Wagholi, Pune (Pune University)

***Abstract* — The Wireless Mesh Network is a promising technology in providing the last mile broad band access. A Wireless Mesh Network (WMN) is a communications network made up of radio nodes organized in a mesh topology. In a WMN, a mesh client can access the Internet through formed wireless mesh routers which are interconnected in a multi-hop fashion. Wireless mesh Networks often consist of mesh clients, mesh routers and gateways. This paper is on technical overview and covers: WMN overview (i.e., fundamental concept, technology, standards, etc.) and WMN architecture (i.e., network and node architectures, components, applications, etc.) Finally, a list of issues requiring further research is deliberated. We have also discussed some challenges regarding use of Wireless Mesh Network for Different systems i.e. evolution of topology and enhancing the speed of mesh network topology. This paper may leads to a future scope for creation of a Network Topology System using existing topologies.**

***Key Words* — Wireless Mesh Networks, WMN Overview, WMN Architecture, WMN Challenges.**

I. Introduction

Wireless mesh network is an upcoming technology that has the potential to deliver Internet broadband access, wireless local area network coverage, and network connectivity for network operators and customers at low costs. It is a communication network that have increasingly attracted Internet Service Providers (ISPs) recently because of its rapid growing and developing of wireless technologies. WMN is a promising technology in providing high bandwidth network coverage. WMNs will greatly help the users to be always on-line anywhere anytime by connecting to wireless mesh routers [4]. Moreover, the mesh routers have the bridge functionality to connect WMNs with various existing wireless networks such as cellular, wireless sensor, wireless-fidelity (Wi-Fi), worldwide interoperability for microwave access (WiMAX), WiMedia networks. Thus, WMNs will deliver wireless services for a large variety of applications.

A. Classification of WMNs

Wireless networks can be classified based on the connectivity types of the various network elements [5], which are either Point to Point (PTP), Point to Multi-Point (PTM) or Multi-Point to Multi-Point (MPM) networks. The complete taxonomy of this classification is shown in Figure 1.PTP networks are reliable. However, they are not scalable and their level of adaptability is low. PTM networks are moderately scalable, but they have low adaptability and reliability.

In order to overcome these limitations, Multi-point to Multi-point (MTM) networks are offering features that provide high reliability, adaptability and scalability to accommodate a large number of users. As the number of nodes in the network [8] increases the transmission power needed for each node will be reduced. But, MTM wireless networks use multiple hops to increase coverage without the need for increasing the transmission power. MTM wireless networks are using today's standard like the IEEE 802.11 family. These types of networks are called mesh networks. In this paper we focus on a special class of MTM network called Wireless Mesh Networks.

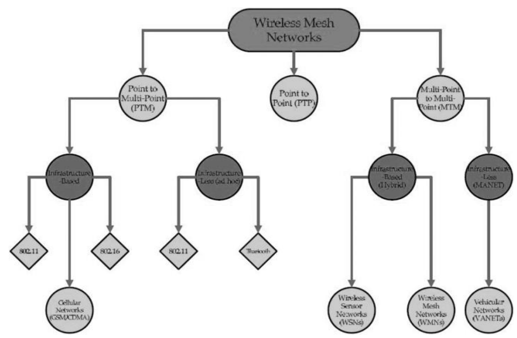

Fig. 1: Wireless Mesh Networks Classification

B. Academic Supporting and Industry Standards

Many universities have ongoing research projects on various aspects of WMN, including strategic planning, protocols, applications and services. Several communities already use WMN such as: Chaska, Minnesota and Rio Rancho, New Mexico; also many companies including: Bel Air Networks, Cisco Systems, Firetide, Mesh Dynamics, Motorola, Nortel Networks, Packet Hop, and Strix Systems, etc., have started to provide equipments and technologies for mesh networks [6].

IEEE 802.11s Wi-Fi Mesh: Currently the IEEE 802.11 family is the most acceptable standard. Extended Service Set (ESS) and Wireless Distribution System are defined in IEEE 802.11s for applying multi-hop mesh techniques and providing a protocol for auto-configuring paths between WMRs [1]. 802.11s has three main components [10]:

1. Mesh Portal (MP): acts as a gateway to other networks.

2. Mesh STA (station): acts as a router to relay frames hop-by-hop.
3. Mesh AP (Access Point): provides relaying functions as well as the connectivity services for clients. Further more, IEEE 802.11s defines an extensible path selection technique which is Hybrid Wireless Mesh Protocol (HWMP) for its routing protocol [9].

IEEE 802.15.1 Blue tooth: Blue tooth is the commercial name of this standard and it is specializes on Wireless Personal Area Networks (PANs). Task group 5 from 15th working group of IEEE 802 is organized to determine the necessary mechanisms that must be provided in the physical and MAC layers of Wireless PANs (WPANs) to enable mesh networking. There are two possible mesh topologies in WPAN mesh networks: full mesh topology or partial mesh topology [2]. A full mesh topology employs direct connection arrangement. It means that, each wireless node is connected directly to all other nodes. On the other hand, inthe partial mesh topology, some wireless nodes are connected to all others while some are connected only tothe wireless nodes which relay the data [9].

IEEE 802.15.4 Zigbee: Zigbee was initially proposed by Motorola. In Wireless Personal Area Network (WPAN) standard there are two connection arrangements, single-hop and multi-hop connection. Zigbee can support mesh topology by defining a coordinator. Coordinator is responsible to configure the network topology in multi-hop fashion. It is very suitable for Wireless Sensor Mesh Networks (WSMNs).

IEEE 802.16 WiMAX: The IEEE 802.16j is a wireless communication standard for Metropolitan Area Networks (MANs) which aims to provide Mobile Multi-hop Relay (MMR) functionality. This will allow deploying multi-hop mesh topology in WiMAX using some WiMAX base stations to work as relay stations. Setting up a multi-hop mesh topology provides a cost efficient way to extend the network coverage while saving the cost on the fixed line connection installation. The IEEE 802.16j standard was approved on May 2009 as an amendment to the IEEE 802.16-2009 standard [3].

II. WMN Architecture

Wireless mesh architecture design is a first step towards providing high-bandwidth Internet access over a specific coverage area. WMNs consist of Mesh Clients (MCs) and Wireless Mesh Routers (WMRs), which relaying each other's packets in a multi-hop fashion, where mesh routers have minimal mobility and form the Backbone of WMNs (BWMNs) [12]. To illustrate more, it is made up of wireless communication nodes, each of which can communicate with other nodes [11]. Mesh architecture breaks the long distance into a series of shorter hops to boost the signal by intermediate nodes. Intermediate nodes not only sustain signal strength, but also forward packages on behalf of other nodes based on their knowledge of the network. Such architecture allows continuous connections and reconfiguration around broken or blocked paths by making forwarding decisions from node to node until the destination is reached. Besides, it provides high-bandwidth Internet access and offers a low costing and also a much flexible deployment [11].

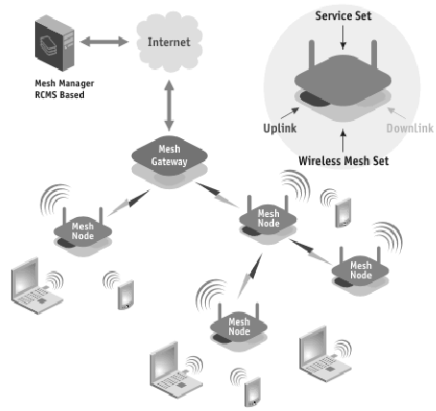

Fig. 2: Wireless Mesh Network Architecture

The infrastructure that supports a WMN is a wireless mesh router network, or Backbone Wireless Mesh Network (BWMN) [7]. BWMN provides Internet connectivity to MCs in a multi-hop fashion. MCs can access the Internet via BWMN formed by Wireless Mesh Routers (WMRs). BWMN consists of some special WMRs, called as Internet Gateways (IGWs). IGWs act as communication bridges between the Internet and BWMN, and provide Internet accessibility. A typical WMN is illustrated in Figure 2.

Components of WMNs

There are three types of node in a WMN: WMN client, WMN router, and WMN gateway.

WMN clients are the end-user devices such as: laptops, PDAs, smart phones, etc. that can access the network for using applications like email, VoIP, game, location detection, etc. These devices are assumed to be mobile; they have limited power, they may have routing capability, and may or may not be always connected to the network.

WMN routers are in the network to route the network traffic. They cannot terminate nor originate the traffic. The routers have limitation in mobility and they have reliable characteristics. Transmission power consumption in mesh routers is low, for multi-hop communications strategy. Additionally, the Medium Access Control (MAC) protocol in a mesh router supports multiple-channels and multiple interfaces to enable scalability in a multi-hop mesh environment [13].

WMN gateways are routers with direct access to the wired infrastructure / Internet. Since the gateways in WMNs have multiple interfaces to connect to both wired and wireless networks, they are expensive. Therefore, there are a few number of WMN gateways in the network. Moreover, their placement has a significant impact on the performance of the network [15].

III. Advantages of WMNs

1) *Self-Organizing and Self Configuring*

Wireless Mesh Networks can self-form and self-heal. WMNs are flexible in network architecture and not depend onthe implementation and the protocols. Self-healing [15] and self-configuring are the WMNs features. This, reduces the set-up time and maintenance cost. Apart from this, it enhances network performance. Due to these features, the network service providers are able to change, expand, and adapt the network as needed to meet the demands of the end users.

2) *Low Deployment Cost*

Mesh routers are wireless and they have the ability to service in multi-hope environments. Thus, using wireless routers in large areas are cheaper compared to single hop routers/accesspoints that they have wired connections. Typically, due to wired connections those are more expensive to installand maintain, the WMNs deployment with easier plus faster installation and maintenance, leads to a lower operation cost.

3) *Increased Reliability*

In a WMN there are multiple paths from source to destination nodes. This provides alternate paths in case of failure. Alternate paths may chose, in order to minimize the bottle necks in congested area of the network too. This also allows the traffic loads to be balanced in the network. Load balancing and minimizing the bottleneck via alternate routing can significantly increase network reliability in WMNs.

4) *Scalability*

In traditional wireless networks, when number of nodes increases, the network performance will be affected downward. But, in WMNs, increasing the number of nodes will increase transmission capacity for better load balancing and alternate routes. Usually, the local packets (generated in clients of mesh router) run faster compared to packets (generated in two or more hops away) from the neighbors. This is mainly achievable using some WMNs configurations and protocols that manage the communication medium.

5) *Interoperability*

Wireless Mesh Networks can be implemented with various wireless technology including 802.11, 802.16, cellular technologies or combinations of more than one type.WMN has a hybrid multi-point to multi-point architecture which is compatible with existing standards such as: WiMAX, Cellular, Wi-Fi, Zigbee, Bluetooth, Sensor, MANET, Vehicular, etc. Thus, it is attractive for incremental deployment and reuse of existing infrastructures. All technologies mentioned above, are able or will be able soon to configured a WMN and communicate with each other’s. Most of necessary improvements needed in any type of networks to enable them communicate with others; can augment the current standards to maintain interoperability.

IV. Applications of WMNs

Wireless mesh networking is a promising technology for numerous applications which appeals especially to those applications that cannot be directly supported by other wireless technologies.

1) *Broadband Wireless Access:*

Currently, Broadband access has an important role in information economy. It provides services for real time applications such as: video telephony, online-gaming, video on demand, and telecommunications. Each new application has a significant impact on quality of life. For example, Telecommuting can reduce daily travelling of individuals. It leads to increased productivity for the time Saving. It also reduces traffic on the streets, thus it has a positive impact on the environment. In urban and sub-urban areas, wired access (Cable and DSL) is the first choice if the population density be reasonably high. Rural areas have limited coverage using wireless technologies like satellite and cellular networks. Satellite access has two drawbacks: expensive technology and high latency due to the distance between the end client and the satellite.

In the case of cellular networks the towers are expensive to install and operate. Lack of service providers and the higher cost of the service itself make lower usage of broad band access. In order to wider adoption of Internet access, WMNs offer an easy-to-deploy and cost effective alternative in areas where cable TV or DSL lines are not available. WMNs can be deployed quickly without expensive equipment and the service provider can see a quick return on investment. Besides, because of the low cost deployment and operations of WMNs, free broadband accesses to city residents are also become possible. Many such networks already exist, and more are on the way.

2) *Industrial Applications*

In a building, there are many devices need to be monitored and controlled like electrical devices including power, light, air conditioner, elevator, etc. Today, the wired networks are taking care of such environment. This is very expensive due to the complexity in deployment and maintenance of a wired network. Currently, Wi-Fi networks are another option to reduce the cost of such networks. But, this solution has not achieved satisfactory performance yet for expensive wiring of Ethernet which is needed for Wi-Fi Access Points (APs). Replacing APs by mesh routers will solve the problem. The deployment process will be much simpler and also the deployment cost will be significantly reduced.

3) *Healthcare*

In a hospital or medical center, monitoring and updating patient information like medical history, test results, insurance information, etc., need to be processed and transmitted from room to room. The ability to connect to the network is crucial to ensure data access in every operating room, office, and lab. In many hospitals data transmission is usually broadband due to large amount of data, for instance: high resolution medical images and

Volume 1, Issue 2, ISSN : 2277 – 5668

periodical monitoring information. WMN provides unlimited network access to any fixed medical devices. It does not need to use existed Ethernet connections, so that, it will eliminate dead spots and it also cause low system cost and simplicity which cannot be find in traditional wired networks.

4) *Transportation Systems*

Internet access is limited to stations and stops using IEEE 802.11 and IEEE 802.16. To extend access into buses, plains, ferries, and trains, WMN technology can help. Thus, passengers on-board can access to the net while travelling from one place to another. Other services such as remote monitoring in-vehicle, driver communications and security cameras can be supported too.

5) *Hospitality*

In hotels and resorts, one of their services is high-speed Internet connectivity which is free. Wireless mesh networks are easy to set-up, lower in cost, and without having to change the existing structures or disrupt business for both indoor and outdoor.

6) *Warehouses*

One way to keep track of stock in warehouses is using handheld scanners. It needs connectivity throughout the area. Wireless mesh networks can ensure connectivity in modern warehouses and shipping logistics with little cost and effort.

7) *Temporary Venues*

Construction sites can enjoy the easy set-up and removal of wireless mesh networks. Architects and engineers can stay connected and using camera to communicate and talk to each other on spot. It provides them to see the real picture of the project progresses. Other temporary venues such as : political rallies, street fairs, and outdoor concerts can set-up and remove wireless mesh networks in minutes.

V. Problems and Challenges in WMNs

Many problems still remain to fully realize the WMN potential while significant advances have been made. Challenges are at different layers of a WMN which briefly discussed here.

1) *Physical Layer Issues*

The most common radio models in use today are single radio single channel, single radio multiple channels, multiple radio multiple channels, and directional antennas.

In single radio single channel environment, nodes are half duplex. It means, they cannot transmit and receive a signal simultaneously. Thus, the bandwidth utilization is significantly reduced. Furthermore, when one node transmits, all other nodes have to listen and cannot transmit without causing a collision. In single radio multiple channels, each node can tune its single radio into several non-overlapping channels to reduce contention and increase the capacity [17]. In multiple radio multiple channel model, a node can use multiple non overlapping channels at a time. Finally, in directional antennas, multiplexing is used to reduce interference.

2) *Medium Access Layer Issues*

In WMNs, improvements to the traditional contention based protocols are usually not sufficient to improve allocation efficiently and fairness. Traditional MAC protocols are limited. Thus advantages of newer underlying models are limited. Multiple radios and multiple channels bring new problems of channel assignment and medium access for instance. Multiple Input and Multiple Output (MIMO) radios been proposed to increase the capacity of WMNs to mitigate unfair access and underutilization. However, current MAC protocol cannot take advantage of this underlying technological improvement.

3) *Transport Layer Issues*

WMNs have some challenges at the transport layer. The transport protocols should efficiently utilize available network resources and allocate them fairly. However, fairness problem in wireless mesh networks is inherently due to the inter dependencies among neighboring wireless links.

4) *Network Layer Issues*

At the network layer, distinct characteristics and traffic flow direction, is highly skewed between the client and the gateway. In order to take the advantage of this, WMNs need the new and improved protocols.

5) *Topological and Deployment Issues*

The key purpose of a WMN is to equip the end users with high speed Internet access. To achieve this, the design of the network architecture should be addressed carefully. This is a fundamental issue, and providing Quality of Service (QoS) for end users and determining the network performance is critical for a WMN. Planning a WMN includes determining the number of gateways, optimal placement of gateways, utilizing bandwidth, and minimizing the deployment cost.

There are typically two types of deployment: structured deployment and organic deployment. In structured deployment, services will be provided in a new area, thus, it has the flexibility of choosing the topology. This flexibility may translate into improved network performance by capturing the regularity of the deployed mesh network. On the other hand, in organic deployment, the mesh network will be deployed organically over existing infrastructure. Thus, there are limited options of topology for the network architect to choose.

VI. Conclusion

WMN Technology is facing many issues while it has some great advantages which make it a technology of today. This paper provided the quick and technical overview of concept, technology, standard, and architecture for wireless mesh networks. Many of these aspects have been discussed in literature, we described the most recent and critical challenge on topological and deployment issues. As it mentioned above the main reason for existing WMN is to provide high bandwidth Internet access with high quality of service for end users anywhere any time. Internet through put and WMRs through put capacity are restricted by location of WMRs and IGWs. Different locations of WMRs and IGWs lead to different through put and capacity, while different through put and capacity lead to different network topologies and architectures. Thus, placements of WMRs and IGWs have to address carefully. The objective is to minimize the number of IGWs while designing a WMN. There are three main QoS constraint which has to be considered in design of WMNs, Delay constraint, Relay constraint, and Capacity constraint. The Delay is the maximum number of hop that can be served by an IGW. The relay is the maximum number of WMR that every WMR can relay packets to them. Finally, the Capacity is the maximum number of WMRs can be served by each IGW further research needed to locate the IGWs at the right place in WMNs, to minimize the number of deployed IGWs, and at the same time, maximize the network capacity.

REFERENCES

[1] IEEE 802.11 standard. http://www.ieee802.org/11/
[2] IEEE 802.15 standard. http://www.ieee802.org/15/
[3] IEEE 802.16 standard. http://www.ieee802.org/16/
[4] Ian F Akyildiz, Xudong Wang, and Weilin Wang. Wireless mesh networks: a survey. Computer Networks, (47), 2005.
[5] S. Bellovin, *ICMP Traceback Messages*, Internet draft, work in progress, Mar. 2000.
Yasir Drabu. Gateway Placement and Fault Tolerance InQoS Aware Wireless Mesh Networks. PhD thesis, Kent State University, College of Arts and Sciences, Department of Computer Science, 2010.
[6] Bing He. Architecture Design and Performance Optimization of Wireless Mesh Networks. Ph.D. thesis, Computer Science and Engineering, College of Engineering, UNIVERSITY OF CINCINNATI, OHIO, spring 2010.
[7] Maolin Tang. Gateways placement in backbone wireless mesh networks. Int'l J. of Communications, Network and System Sciences, 2:44–50, 2009.
[8] How Wireless Mesh Networks and multiradio mesh Workshttp://en.wikipedia.org/wiki/Wireless_mesh_network#Multi-radio_mesh
[9] Faccin, S.M., Wijting, C., Kenckt, J,Damle, A., Mesh WLAN networks: concept and system design, IEEE Wireless Communication, Vol 13, No. 2, 2006
[10] Lee, M.J.; Jianliang Zheng; Young-BaeKo; Shrestha, D.M., Emerging standards for wireless mesh technology, IEEE Wireless Communication, Vol. 13, No. 2, 2006
[11] S.M. Chen, P, Lin, D-W Huang, S-R Yang, "A study on distributed/centralized scheduling for wireless mesh network" in Proceedings of the 2006 International Conference on Wireless Communications and Mobile Computing, pp. 599 - 604. Vancouver, British Columbia, Canada. 2006
[12] Akyildiz, I.F., Wang, X. and Wang, W., Wireless Mesh Networks: A Survey, Computer Networks Journal (Elsevier), March 2005.
[13] Wireless Mesh Networks and sensors Working athttp://www.sensorsmag.com/listing/wireless-mesh-network
[14] Ian F. Akyildiz, Xudong Wang, Weilin Wang: "Wireless mesh networks: a survey", "Computer Networks and ISDN Systems", v.47 n.4,p.445-487, 15 March 2005
[15] Self-healing Wireless Mesh Networks and mesh routers Working www.techrepublic.com/safemeshwireless-mesh-network/1195299
[16] V. Kawadia, P.R. Kumar, "A Cautionary Perspective on Cross-Layer Design," in IEEE Wireless Communications, pp. 3-11, February 2005.
[17] J. Jun, M.L. Sichitiu, "The nominal capacity of wireless mesh networks", in IEEE Wireless Communications, Vol 10, 5 pp. 8-14. October 2003.

AUTHOR'S PROFILE

Pawan Bangar

Final year student of B.Eng. degree in Computer Science from Pune University, India. His current interests include Internet network security, Computer Networking.

Jameer Mulani

Final year student of B.Eng. degree in Computer Science from Pune University, India. His current interests include Computer Networking and Java.

Ashish Ekad

Final year student of B.Eng. degree in Computer Science from Pune University, India. His current interests include network security and Computer Networking.

Pramod Ganjewar

Completed his B.Eng. degree in Computer Science from Pune University, India. Asst. Professor of Computer Science department from Pune University, India. He is currently Head of Computer Department. His interests include security systems for Information security, Computer Networking.