Wireless Communication - Project Report 3 Project 12 – Wireless Mesh Network

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***Abstract*—Wireless mesh networks(WMN) has become a key technology for next generation wireless networking. Wireless mesh networks are undergoing rapid progress and inspiring numerous applications because of their advantages over networks like DSL .However, many technical issues still exist in this field.**

***Index Terms*—WMN.**

I. INTRODUCTION

WIRELESS mesh networks is an emerging technology and may bring the dream of a seamlessly connected world into reality. Mesh networks can easily and effectively connect a significantly large area e.g. a city. In a wireless mesh network, the network connection is spread out among dozens or even hundreds of wireless mesh nodes that "talk" to each other to share the network connection across a large area. Mesh nodes are small radio transmitters that function in the same way as a wireless router. They use Wi-Fi standards known as 802.11a, b and g in order to communicate with users and with each other. They are programmed to tell them how to interact with each other. Only a fraction of nodes have direct access to the internet. That wired node shares the internet connection wirelessly with the nearest cluster of nodes, which then shares it with the nearest cluster of nodes and so on. In this case, the nodes don? need to be wired to anything but a power supply.

WMNs are has two types of nodes: mesh routers and mesh clients. Other than the routing capability for gateway/bridge functions as in a conventional wireless router, a mesh router contains additional routing functions to support mesh networking. Through multi-hop communications, the same coverage can be achieved by a mesh router with much lower transmission power. To further improve the flexibility of mesh networking, a mesh router is usually equipped with multiple wireless interfaces built on either the same or different wireless access technologies Mesh routers have minimal mobility and form the mesh backbone for mesh clients. Thus, although mesh clients can also work as a router for mesh networking, the hardware platform and software for them can be much simpler than those for mesh routers .To date, several companies have already realized the potential of this technology and offer wireless mesh networking products.

Wireless mesh networks are preferable to existing cable based networks or wireless LANs , due to the following potential advantages: (a) it is more cost effective, as service providers do not have to install a wired connection to each subscriber; (b) it is more reliable, as each node has redundant paths to reach the Internet; (c) the throughput got by a user can be increased through routing via multiple, bandwidth-abundant paths and (d) the wireless network can readily extend their coverage by installing additional ad-hoc hops.

Wireless mesh networks technology is flexible and has low budget which is now growing in the market due to its advantages or benefits both in developed and developing countries. According to a report by MuniWireless.com in March 2007, 81 U.S. cities have already installed citywide or region-wide municipal wireless networks and 164 more are actively building such networks. The report also says that 38 U.S. cities already have municipal wireless networks for the exclusive use of public safety and city employees.In this project, I will discuss what wireless mesh network is, how it functions, its advantages, the network architecture, applications, problems the new technology is facing and possible ways of solving them while using a better protocal.

II. NETWORK ARCHITECTURE

Mesh itself is a type of architecture. Originally, Ethernet was a shared bus topology in which every node tapped into a common cable that carried all transmissions from all nodes. In bus networks, any node on the network hears all transmissions from every other node in the network. Most local area networks (LANs) today use a star topology in which every network node is connected to a switch (switches can be interconnected to form larger networks).

Mesh networks are different full physical layer connectivity is not required. As long as a node is connected to at least one other node in a mesh network, it will have full connectivity to the entire network because each mesh node forwards packets to other nodes in the network as required. Mesh protocols automatically determine the best route through the network and can dynamically reconfigure the network if a link becomes unusable.

There are many different types of mesh networks. Mesh networks can be wired or Wireless. For wireless networks there are ad-hoc mobile mesh networks and permanent infrastructure mesh networks. There are single radio mesh networks, dual-radio mesh networks and multi-radio mesh networks. All of these approaches have their strengths and weaknesses. They can be targeted at different applications and used to address different stages in the evolution and growth of the network.

Wireless mesh networks has of two types of nodes: mesh clients and mesh routers. Compared with a conventional wireless router, a wireless mesh router can achieve the same coverage with much lower transmission power through multi-hop communications. Optionally, the medium access control (MAC) protocol in a mesh router is enhanced with better scalability in a multi-hop mesh environment.

Even though there are the above differences, mesh and conventional wireless routers are more often built on a similar

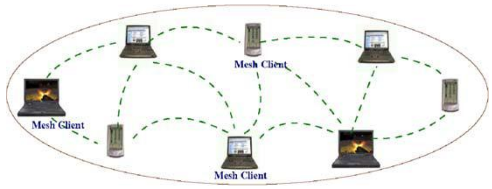

Fig. 1. mesh client

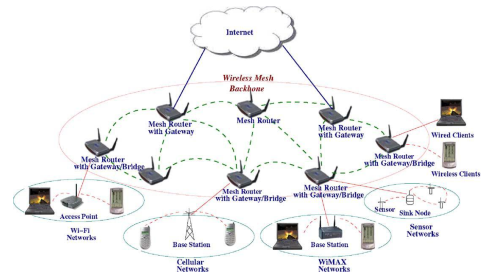

Fig. 2. Infrastructure of WMN

hardware platform. Mesh routers can be built based on dedicated computer systems and look compact. They can also be made based on general-purpose computer systems for example laptops and desktops .Mesh clients also have necessary functions for mesh networking, which make it function as a router. They usually have only one wireless interface. Due to that fact, the hardware platform and the software for mesh clients can be much simpler than those for mesh routers. Mesh clients have a higher variety of devices compared to mesh routers. The architecture of WMNs can be categorized into three main groups :

A. The client Wireless Mesh Networks

It provides peer-to peer networks among devices. Client nodes constitute the actual network to perform routing and configuration functionalities as well as providing enduser applications to customers. Therefore , a mesh router is not required for these types of networks. In this type of mesh network, a packet destined to a node in the network hops through multiple nodes in order to reach the destination. The networks are usually formed using one type of radios on devices. The architecture is shown in figure 1.

B. Infrastructure of WMN

These types of networks are the most commonly used which include mesh routers forming an infrastructure for clients that connect to them. The WMN infrastructure can be built using various types of radio technologies, in addition to the mostly used IEEE 802.11 technologies. The mesh routers form a mesh of self-configuring, self-healing links among themselves. With gateway functionality, mesh routers can be connected to the Internet.

This method can also be referred to as infrastructure meshing. It provides backbone for conventional clients and enables integration of WMNs with existing wireless networks, through gateway/bridge functionalities in mesh routers. Conventional clients with Ethernet interface can be connected to mesh routers via Ethernet links. For conventional clients with the same radio technologies as mesh routers, they can directly communicate with mesh routers. If different radio technologies are used, clients must communicate with the base stations

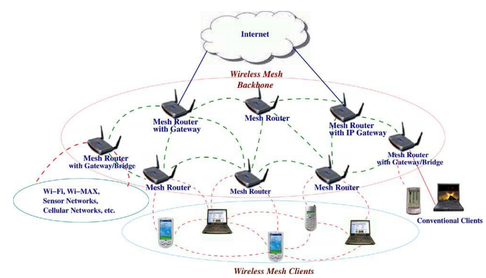

Fig. 3. Hybrid of WMN

that have Ethernet connections to mesh routers. For example, community and neighborhood networks can be built using infrastructure meshing. The mesh routers are placed on the roof of houses in a neighborhood, which serve as access points for users inside the homes and along the roads. The mesh backbone communication can be established using long-range communication techniques including directional antennas. See figure 2.

C. The Hybrid of WMN

The hybrid wireless mesh networks architecture is basically the merging of client meshing and infrastructure. Mesh clients can access the network through mesh routers as well as directly meshing with other mesh clients. While the infrastructure provides connectivity to other networks such as the Internet, Wi-Fi, WiMAX, cellular, and sensor networks; the routing capabilities of clients provide improved connectivity and coverage inside the WMN. See figure 3.

III. THE CAPACITY OF WMN

Mobile ad hoc networks were the first wireless mesh networks whereby wireless stations were moving around and participating in a peer to peer network. Mobile peer to peer networks benefit from the sparse connectivity requirements of the mesh architecture; and the combination of wireless and

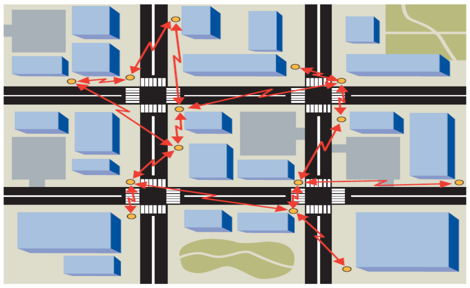

Fig. 4. Mesh around corners

mesh can provide a reliable network with a great deal of flexibility.

The popularity of Wi-Fi has generated a lot of interest in developing wireless networks that support Wi-Fi access across very large areas. Large coverage access points (AP) are available for these scenarios, but the cost of deploying these wide area Wi-Fi systems is dominated by the cost of the network required to interconnect the APs and connect them to the Internet the backhaul network.

Even with fewer APs, it is very expensive to provide T1, DSL or Ethernet backhaul for each access point. For these deployments, wireless backhaul is an attractive alternative and a good application for mesh networking. Wireless connections can be used between most of the APs and just a few wired connections back to the Internet are required to support the entire network. See figure 4.

Wireless links work better when there is clear line of sight between the communicating stations. Permanent wireless infrastructure mesh systems deployed over large areas can use the forwarding capabilities of the mesh architecture to go around physical obstacles such as buildings. Rather than blasting through a building with high power, a wireless mesh system will forward packets through intermediate nodes that are within line of sight and go around the obstruction with robust wireless links operating at much lower power. This approach works very well in dense urban areas with many obstructions.

The capacity of WMNs is affected by many factors such as network architecture, network topology, traffic pattern, network node density, number of channels used for each node, transmission power level, and node mobility. A clear understanding of the relationship between network capacity and the above factors provides a guideline for protocol development, architecture design, deployment and operation of the network.

A. *Analysis of the capacity*

The past few years, research has been done to study the capacity of ad hoc networks which can be adopted to investigate the capacity of Wireless mesh networks. For a stationary multi-hop network, it has been shown that the optimum transmission power level of a node is reached when the node has six neighboring nodes [12]. With this value, an optimum tradeoff is achieved between the number of hops from source to destination and the channel spatial-reuse efficiency. This result is useful for infrastructure WMNs with minimal mobility. When the mobility is a concern as in hybrid WMNs, no theoretical results are reported so far. Some experimental studies have been performed in [11], where the simulation results of a stationary network validate the theoretical results of [12]

An important implication is derived in [18] as a guideline to improve the capacity of ad hoc networks: A node should only communicate with nearby nodes. To implement this idea, two major schemes are suggested in [18]: Throughput capacity can be increased by deploying relaying nodes. Nodes need to be grouped into clusters. Thus, communications of a node with another node that is not nearby must be conducted through relaying nodes or clusters. However, these schemes have limitations. In the first scheme, a very large number of relaying nodes are needed in order to increase the throughput by a significant percent. This will definitely increase the overall cost of a network. In the second scheme, clustering nodes in ad hoc networks or WMNs is not a preferred approach, because it is difficult to manage clusters in a distributed system.

Nevertheless, this implication has motivated other research work such as [13], [15], where a hybrid network architecture is considered to improve the capacity of ad hoc networks. In the hybrid architecture, nodes only communicate with nearby nodes. If they need to communicate with nodes with many hops away, base stations or access points are used to relay packets via wired networks. The hybrid architecture can improve capacity of ad hoc networks, however, it may still not be favored by many applications because wired connections between base stations do not exist in many ad hoc networks. The implication given in [18] can also be reflected in [14]. The scheme proposed in [16] increases the network capacity of ad hoc networks by utilizing the node mobility. When a node needs to send packets to another node, it will not send until the destination node is close to the source node. Thus, via the node mobility, a node only communicates with its nearby nodes. This method has disadvantages: The transmission delay might become large and the required buffer for a node might be infinite.

The approach in [18] has driven the progress in capacity research of ad hoc networks but has limitations. The networking protocols have not been fully captured by the analysis. For example, power control mechanisms, commonly used to improve the network capacity, is not considered in the analysis.

The application of [18] the theoretical results on network architectures is unclear. A close match between the theoretical results in and IEEE 802.11 based ad hoc networks is reported in [17]. Therefore, this study relies on the assumption that the traffic pattern in a large ad hoc network tends to be local and thus, nodes usually communicate with nearby nodes. The above assumption is not always valid in a network unless it is intentionally designed so.

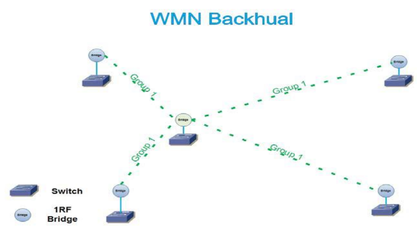

Fig. 5. WMN Backhaul

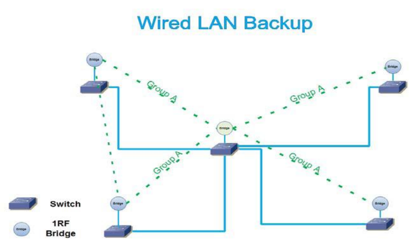

Fig. 6. Wired LAN backup

IV. APPLICATIONS

A. Wireless Backhaul

It forms a wireless backhaul fast while implementing the MESH network in the areas that are not convenient to wire. A good example is a temporary and short-termed working area, which can avoid the waiting time of applying for the least - line. When moving to the next working area, no sooner had the set-up location been chosen than the network backhaul can be constructed quickly, meanwhile, the number of nodes can be adjusted to fit the demands for the real environment. See figure 5.

B. Backup Network

In order to satisfy a non-interrupted operation environment, we utilize MESH network to build up a backup network. When a breakpoint happens to the physical line, the wireless network can take the place of the original lines at once and maintain the necessary operation until the physical line is repaired. See figure 6.

C. Developing countries

Wireless mesh networks can be used in countries that do not have a large area of wired infrastructure, like telephone services or even electricity in general. Solar-powered nodes can be connected to one cellular or satellite Internet connection, which could keep a whole village online.

Fig. 7. Improved Mesh Network

D. Isolated locations

Both developed and developing countries have places which have rugged locations too far off the grid for normal high-speed Internet service providers. Wireless mesh networks are being considered for these areas.

E. Warehouses

There is simply no effective way to keep track of stock and shipping logistics without the types of Ethernet-enabled handheld scanners used in modern warehouses. Wireless mesh networks can ensure connectivity throughout a huge warehouse structure with little effort.

F. Education

Recently, Many education institutions are converting their entire campuses to wireless mesh networks. This discards the need to bury cables in old buildings and across campuses.

In general, there are many unmentioned applications of wireless mesh networks which in turn extrapolate the importance and advantages that this new technology has to offer to the ever changing world.

V. IMPROVEMENT OF THE MESH NETWORKS, CHALLENGES AND POSSIBLE SOLUTIONS

We all know that the most effective way of improving the efficiency of a mesh network is to increase the amount of nodes in an area, but, recently Engineers around the globe have been disputing that Idea because of factors that I will outline and discuss. However, I still think that we can increase the amount of mesh clients and still evade the challenges.

Figure 7 shows my idea of increasing the mesh clients such that anyone who walks in the street or anywhere in general, will be a walking node and walking network. Just imagine for a second how easy it will be to communicate, download data while sitting in a train or even while walking on your way to work. Faster internet means better communication, and better communication is what we need now for globalization in this ever changing world in order to make the world a better place.

VI. Challenges faced and possible ways of improving them.

From what I have discovered, all the challenges for the network are subject to change. I will outline the challenges and discus how to solve them.

A. Management

1) Challenge: It is said that increase of nodes might make it almost impossible to manage the network. There might security risks too involved.

2) Solution: In this world of ever changing technology, time has proven that anything is possible. Just a few centuries ago, we never thought we would fly, but now we not only can go around the world with Aeroplanes in hours but we can also go to the moon using a space shuttle. Time has proven to be an asset, hence, management of such a network needs just time for someone to come up with a new routing protocol.

B. Costs

1) Challenge: The cost of managing the network would be expensive.

2) Solution: Time yet again plays a major role as a solution whereby, technology improves yearly and engineers find easier and cheaper ways of doing things for example a computers few years ago cellular phones were expensive but in this 21st century, cell phones are readily available to almost everyone.

C. Health risk(radiation)

1) Challenge: High amount of radiation exposure is not good for the health.

2) Solution: It has been claimed that mesh clients and mesh routers produce a certain amount of radiation. The speculation about this fact hasnt been proven yet and is all based of probability and assumptions. There are two types of radiation:

- ionizing radiation- dangerous
- non-ionizing radiation- not dangerous

The kind of radiation produced from the nodes fall under non-ionizing radiation which is not dangerous. Furthermore, the fact that we have been having radiation caused by natural causes (like sun, underground gases, and soil) for millions of years and we havent been affected by it in the past, it means that non-ionizing radiation is not necessarily a threat as long as we control it.

VII. Conclusion

Wireless mesh networks is the key technology for the next generation wireless networking. It still growing but the fruits of it have proved to be promising and thus improvement of this network will have a huge impact in the next generation globalization.

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