DAYNAMIC CHANNEL SELECTION FOR MESHED WIRELESS PERSONAL AREA NETWORK

AHMED ABDUL LATEEF

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Faculty of Electrical and Electronic Engineering

University Tun Hussein Onn Malaysia

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Abstract

Wireless Personal Area Network refers to the interconnection among devices within a limited range of meters. The need to extend the coverage area of the WPAN without increasing the transmission power and response to the suddenly user increase in the network is one of the primary motivations that lead researchers to investigate the required changes for topology and study performance parameters to support the meshed WPAN. Therefore, many prototypes have emerged as a draft candidate, but many problems have arisen. One of these problems is the restricted capacity of the meshed WPAN since they use TDMA scheme. This thesis focused on the meshed WPAN to investigate and determine the possibility of exploiting the available increasing in wireless nodes to enhance the performance and increase the capacity for meshed WPAN. A Dynamic Channel Selection Algorithm has been suggested. This algorithm uses the available channels, which are five channels in the WPAN, to enable simultaneous transmission of two or more channels to achieve a high packet delivery ratio and better performance of the network especially when it uses applications that needs high traffic. Furthermore, it gives the network the flexibility to increase the capacity when new devices want to join the network by allocating their location in the working topology. The new prototype of 46 wireless nodes was created by expanding an old prototype of 9 wireless nodes. The NS2 software tools function is used to implement the nodes in the network in order to examine the performance of the two prototypes network by making comparison.

Abstrak

Rangkaian Kawasan Peribadi Wayarles (WPAN) merujuk kepada sambungan antara peranti dalam julat yang meter terhad. Keperluan untuk memperluaskan kawasan liputan bagi WPAN tanpa meningkatkan kuasa penghantaran dan tindak balas kepada peningkatan mendadak pengguna dalam rangkaian adalah salah satu motivasi utama yang memimpin penyelidik untuk menyiasat perubahan yang diperlukan untuk topologi dan mengkaji parameter prestasi bagi menyokong jejaring WPAN. Oleh itu, banyak prototaip telah muncul sebagai calon draf, tetapi banyak masalah telah timbul. Salah satu daripada masalah ini adalah kapasiti terhad daripada jejaring WPAN kerana mereka menggunakan skema TDMA. Tesis ini memberi tumpuan kepada jejaring WPAN untuk menyiasat dan menentukan kemungkinan meningkat di nod wayarles bagi meningkatkan prestasi dan keupayaan jejaring WPAN. Algoritma Pemilihan Dinamik Saluran telah dicadangkan. Algoritma ini menggunakan saluran yang ada, iaitu lima saluran dalam WPAN, bagi membolehkan penghantaran serentak dua atau lebih banyak saluran untuk mencapai nisbah penghantaran paket yang tinggi dan prestasi yang lebih baik daripada rangkaian terutama apabila ia menggunakan aplikasi yang diperlukan pada trafik yang tinggi. Tambahan pula, ia memberikan rangkaian fleksibiliti untuk meningkatkan keupayaan apabila peranti baru ingin menyertai rangkaian dengan memperuntukkan lokasi mereka dalam topologi kerja. Prototaip baru 46 nod wayarles diwujudkan dengan mengembangkan sebuah prototaip lama 9 nod wayarles. Perisian NS2 digunakan untuk melaksanakan nod dalam rangkaian bagi mengkaji prestasi rangkaian dua prototaip dengan membuat perbandingan keputusan.

Special dedications to

My beloved mother, father and siblings who encouraged and inspired me throughout my journey of education.

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LIST OF ABBREVIATION

PDA	Personal Devices Assistance
NIC	Network Interface Card
Wi-MAX	Worldwide Interoperability for Microwave Accessr
IEEE	Institute of Electrical and Electronics Engineers
MAC	Media Access Control
WEP	Wired Equipment privacy
LAN	Local Area Network
ACK	Acknowledgment
WMN	Wireless Mesh Network
DSL	Digital Subscriber Line
PAN	Personal Area Network
WLAN	Wireless Local Area Network
WPAN	Wireless Personal Area Network
WMAN	Wireless metropolitan area network
MPAN	Mesh Personal Area Network
PHY	Physical Layer
DCS	Dynamic Channel Selection
MDEVs	Mesh Devices
APs	Access Points
PNC	Piconet Coordinator
CCTV	Closed-circuit television
WMPAN	Wireless Mesh Personal Area Network

CHAPTER 1

INTRODUCTION

1.1 Introduction

Wireless mesh network is the key technology for the present generation in wireless networking for providing fast and hassle free services to users. Nodes in wireless mesh networks comprise mesh routers and mesh clients. Each node operates not only as a host but also as a router, forwarding packets on behalf of other nodes that may not be in within direct wireless transmission range. Connectivity between nodes in wireless mesh networks is automatically established and maintained among the participating nodes.

This makes wireless mesh network a dynamic, self-organized, and self-configured wireless network. This feature brings many advantages such as low installation cost, low cost of maintenance, robust and reliable service coverage. The most commonly used technology in day to day life, such as desktops, laptops, PDA’s, Pocket PC’s, Phones etc. is based on conventional nodes equipped with Wireless Network Interface Cards (NIC’s) which in turn can connect to wireless mesh routers [1,2].

Nodes without a wireless NIC can still access wireless mesh networks by connecting to wireless mesh routers through other technologies such as Ethernet. In addition, gateway or bridge functionalities in mesh networks enable integration of wireless mesh networks with various existing wireless networks such as Cellular networks, wireless sensors, wireless-fidelity (Wi-Fi) and worldwide inter-operability for microwave access (Wi-MAX). Wireless mesh networks can also be used in other applications such as broadband, networking, community and neighborhood networks, enterprise networking building automation [3].

Wireless mesh networks can be deployed one node at a time and they also have a capability of self-organization and self-configuring. Reliability and connectivity for the users of such networks increases significantly as more nodes are installed. As all the required components are already available in the form of Ad-hoc network routing protocols, IEEE 802.11 MAC protocol, wired equipment privacy (WEP) etc., deploying a wireless network is not difficult, so this feature also brings up several companies offering wireless mesh networking products [4].

However, considerable research efforts are still going in the case of MAC and routing protocols applied to wireless mesh networks which do not have enough scalability. The throughput drops significantly as the number of hops or nodes in a wireless mesh network increases. Consequently, all existing protocols in the protocol stack need to be adapted or modified in order to handle these conditions. Many research groups focus on protocol design of existing wireless networks such as IEEE 802.11 network, ad-hoc networks and wireless sensor networks [5].

Industrial standards groups are also actively working on new specifications for the wireless mesh networking. Despite significant advances in physical layer technologies, today's wireless LAN still cannot offer the same level of sustained bandwidth as their wired brethren. The advertised 54 Mbps bandwidth for IEEE 802.11a/g wireless LAN interface is the peak link-layer data rate. When all the overheads-MAC contention, 802.11 headers, 802.11 ACK, packet errors Are accounted for, the actual good put available to applications is almost halved. In addition, the maximum link layer data rate falls quickly with increasing distance between the transmitter and the receiver. The bandwidth problem is further aggravated for multi-hop ad hoc networks due to interference from adjacent hops on the same path as well as from neighboring paths [1, 2]. Fortunately, the IEEE 802.11b/g standards and IEEE

802.11a standard provide 3 and 12 non-overlapped frequency channels, respectively, which could be used simultaneously within a neighborhood.

Ability to utilize multiple channels substantially increases the effective bandwidth available to wireless network nodes. Such bandwidth aggregation is routinely used in 802.11-based wireless LANs that operate in infrastructure mode, where traffic to and from wireless nodes is distributed among multiple interfaces of an access point or among multiple access points. However, bandwidth aggregation is rarely applied to 802.11-based LANs that operate in the ad hoc mode. As a result, most ad hoc network implementations use only a single frequency channel, wasting the rest of the spectrum [6].

1.2 Problem Statement

The main problem with wireless networks is repeating the enlargement process for many times. Understanding this area is also considered as it improves the performance of the whole network. Familiarity with the behavior and the performance of the meshed wireless network and interacts with the cases of expansion and the influence of many factors while adding new users or subscriber join the network. Comparing the performance of 9-node network with 46-node network and understanding the behavior of these networks. Last, but not least, a discussion about possible future works as well as specifying a system that will help to improve the performance.

1.3 Objectives

The main aim of this project is to get better performance, scalability on a wireless mesh network. This is comparatively a new area in the networking field and therefore the aim has been decided to find new methods that could help using this technology more effectively. This was done by providing a study of what is suitable and providing some measures for what needs to be done by making a comparison with a chosen related work.

The objectives of this project are as follows:

I. To exploit multiple NIC cards in wireless nodes, most of them were based on hardware and software installed.
II. To work and manipulate directly with the unknown and unexpected expansion of the network, which requires only systems topology modification.

1.3 Project Scopes

This project describes and evaluates a novel multi-channel WPAN architecture that is built on 802.11-based on wireless WMN hardware and is specifically tailored to multi-hop wireless access network applications. Although the multi-NIC approach has been mentioned in the past, Believed that this work represents a more comprehensive study of this approach in the context of a wireless access network. In particular, this project makes the following research contributions:

I. A fully distributed channel assignment algorithm that can adapt to traffic loads dynamically.
II. A load-balancing routing algorithm that can adapt to traffic load changes as well as network failures automatically.
III. A comprehensive performance study that shows significant packets delivery ratio improvements over multi-NIC WPANs, which are validated through empirical measurements on a fully working prototype.
IV. Implementation metric types and choose the best.
V. NS2 software simulation environment.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

Wireless mesh networks have been adopted to be the key technology for the next generation wireless networking. They have provided great advantages in different fields and applications in recent years; that make wireless mesh networks issues first priorities for researchers in many networking categories such as WLAN, WMAN, and WPAN which has led to a rapid development in mesh networking technologies. However, in terms of wireless Meshed Personal Area Networks (MPAN) standards, IEEE 802.15 Task Group 5 and many researchers are still working to determine and provide the necessary mechanisms that should be supported in PHY and MAC layers for both high data rate and low data rate WPAN to enable mesh networking capabilities [7].

Dynamic channel selection (DCS) is one of the mechanisms that could be used to increase the network capacity or reduce the interference resulting from the increment of the number of mesh devices (MDEVs) in the same network or the interference from other networks operate on the same channel [8]. In 2000 a Dynamic Channel Selection (DCS) scheme was proposed for IEEE 802.11 [9], which takes into account the interference by the other neighbouring access points (APs) or devices (DEVs).

The access point of the BSS will determine the best channel for all the stations within its BSS and initiate channel switching for all its stations to the new channel. This mechanism has succeeded in being implemented-independent as it does not require any change of the PHY layer specification of IEEE 802.11. Another Dynamic channel selection mechanism is given in [10], in which the necessity of DCS is demonstrated as well as the lack of the present mechanism in IEEE 802.15.X, that the PNC listening range is limited for one hop only. Therefore, it cannot detect the interference outside its pickets and its transmission range. Furthermore PNC cannot know when and which node is the one that should inquire the channel status. With the new proposed mechanism the nodes decide to do interference detection by themselves periodically. In this way the detection result is reported to PCN which will make an analysis and determine whether to change the operating channel: this gives faster channel change.

Another approach has been adopted in [10]; scheduling algorithm is presented to allow simultaneous utilization of the available multiple channels, thereby enabling the sharing of the channels among the nodes. Therefore, each device is made to be able to transmit and receive on any channel. This mechanism uses distributed dynamic channel allocation algorithm so that each piconet will determine the set of channels depending on the local information. This algorithm shows an increase in the throughput of the piconet and reduces the average packet delay, but the scheduling efficiency drops when the number of channels used by the piconet increase.

The suggested dynamic switching of the channels in such a way that neighbors meet periodically common channel for communicating [11]. This approach is proposed to be compatible with IEEE 802.11 and it can be done in software. Therefore, one of the main advantages is that it does not need any change in the MAC protocol specifications. Furthermore, it achieves significant improvement in the capacity of ad hoc wireless networks. The proposed a MAC protocol, so that the nodes dynamically negotiate who sends in specific times and on which channel. It uses the idea of dividing time into fixed time intervals using beacons and each interval have small a window used to determine the traffic and channels during that interval. This protocol successfully exploits multiple channels and shows significant enhancement for throughput over the total network.

The problem of the previous two approaches is they assume that all nodes are synchronized [12].

Another proposal by Po-Jen C. [1] Has been proposed in 2010 uses the idea of Dynamic Channel Selection to balance traffic in mesh networks. It records the information on the history of channel utilization in each node by adding a counter to each end of a channel to record the frequency of packet routing. Based on these records the node will determine the channels to work on and divert the traffic from the current load distribution through the less trafficked channels. This gives balance traffic load of the network. The backdraw of this approach is it assumes a specific scenario and each node has four channels to communicate with neighbors.

Some past works have been done to dynamically select channels some of them use load-aware dynamic channel assignment algorithm. The proposed mechanism needs the traffic loads to be known before channel selection take place. The other algorithm is based on the knowledge of interference in the mesh networks, but all these proposals use multiple radios whereby the node has two or more channels to use simultaneously [1].

In IEEE 802.15.3 standard, dynamic channel selection is defined in such a manner that the PNC initiates the dynamic channel selection if it determines that the current channels are poor and that one or more of the other channels operate with better conditions, but the algorithm needed to utilize the channel status information when deciding whether to change channels is not defined [13]. Furthermore, IEEE 802.15.5 is still a draft candidate and to the best of our knowledge not much work has been done for dynamic channel selection in meshed WPAN.

In this project a new algorithm has been proposed to dynamically select channels and we have focused on this algorithm's ability to increase the capacity of the mesh network. This algorithm is implementation-independent, as it does not need changes in the current standard and can be implemented using software. With the increase of needs for mobility and the expansion of the coverage area, wireless networking became the dominant communication technology to serve all over the world.

Wireless networks provide great advantage of mobility and offer cheap solutions, thereby increasingly replace the wired communications. But like any technology, wireless networks are not free of challenges such as data transfer speed, reliability and security, which leads the mesh networks to be the key technology among the other wireless networks evolving into the next generation because it contributes to solve most of those problems.

It is believed to be a highly promising to offer enhancements to the performance of the existing standards in terms of cost, providing reliable service coverage, robustness, easy configuration, and extend the coverage area. Unlike the centralized wireless systems such as the cellular networks and wireless local area networks, it gives the divergence of features for all those networks which it is involved in. Furthermore, WMNs are different from the other networks that even if more than one node are failed, the network will remain working and keeping the ability to relay data between nodes, in this way they will not affect their performance.

2.2 Mesh Networking

When somebody speaks about the mesh network, it means the network has many-to-many connections that capable of dynamically optimizing and updating these connections, because the dynamic self-organization, self-configuration and self-healing represent the most important features of wireless mesh network. This may be a mobile network in which some or all the nodes of the network are mobile units that change position over time.

A mesh networks employ to be one of two types, full mesh topology or partial mesh topology. In the full mesh topology, each node is connected directly to every other node in the network. This connecting is very expensive to be built, but it gives the most reliable performance so in case when one of those nodes fails, the others can direct traffic to each other so that it is usually used for backbone networks figure 2.1 [13].

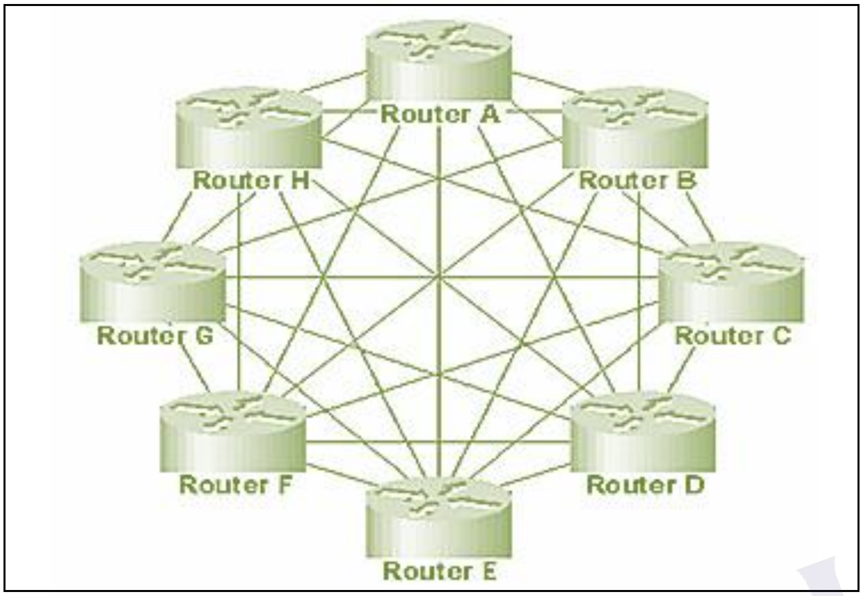

Figure 2.1: Full mesh networking [14].

In the partial mesh topology, some nodes are connected to all the others, but some of the nodes are connected only to those other nodes with which they exchange the most data [14].

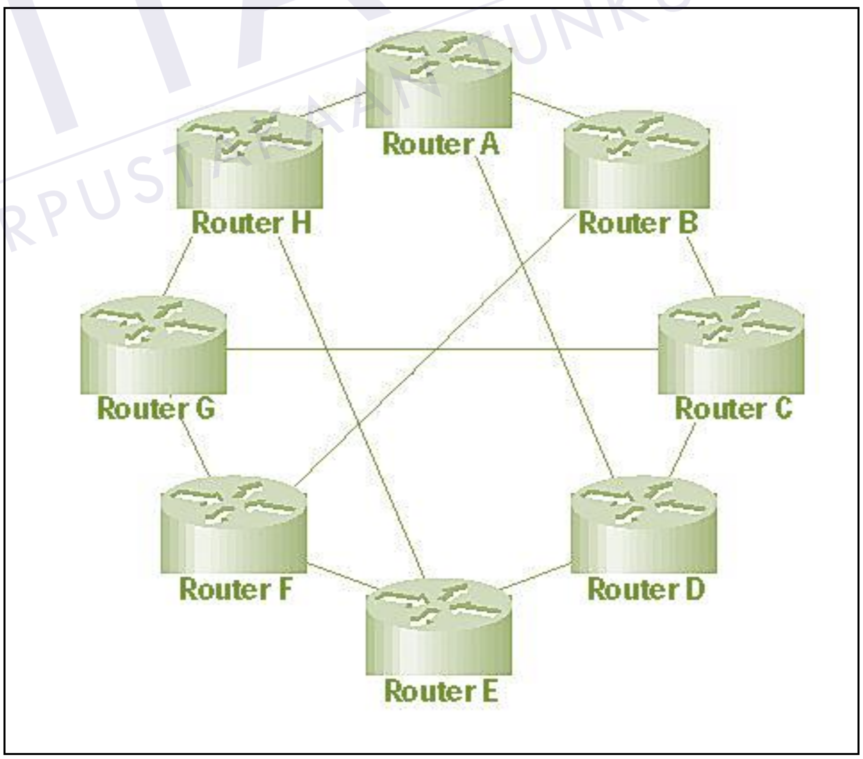

Figure 2.2: Partial Mesh Networking [14].

WMPANs consist of two types of nodes: mesh routers and mesh clients. In addition to the routing capability for gateway/bridge functions as in a traditional wireless router, additional routing functions are contained in the mesh router to support mesh networking. Through multi-hop communications, the same coverage can be achieved by a mesh router with much lower transmission power. A mesh router is usually equipped with multiple radios for further improvement to the flexibility of the mesh networking, and it is built on either the same or different wireless access technologies.

In spite of all these differences, mesh and conventional wireless routers are usually built based on a similar hardware platform. Mesh routers have minimal mobility therefore they 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. For example, communication protocols for mesh clients can be light-weight but the gateway or bridge functions do not exist in them, and only a single wireless interface is needed in a mesh client.

2.3 Wireless Mesh Network Architecture

Based on the functionality of the WMNs' node, they can be classified into three types. Those types are:

2.3.1 Client WMNs

In this type of architecture, peer-to-peer networks are provided by connecting client devices to form a mesh network. Clients act as hosts and routers to perform routing and configuration functionality as well as delivering end-user applications to customers. Here all the nodes are at the same level with each other so that it is the simplest case among the three WMN architectures. Clients WMN are usually provided by single radios on devices and the packets are forwarded by hoping through multiple nodes to reach its destination as shown in figure 2.3. It is similar to ad hoc networks in term of simplicity and this feature is the primary advantage for such architecture, but the scalability is one of the disadvantages as well as routing, addressing scheme, and service discovery schemes [15].

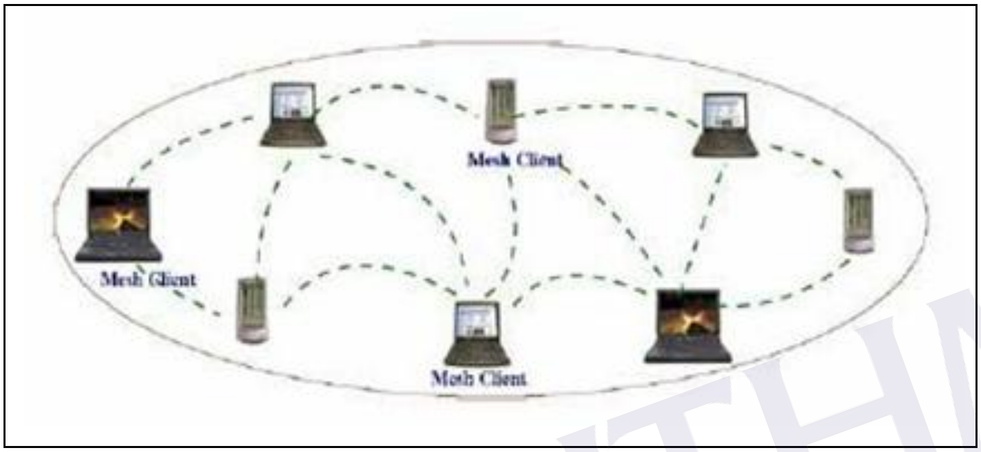

Figure 2.3: Client WMNs [16].

2.3.2 Infrastructure/Backbone WMNs

Two levels are there in this architecture, the first one is the routers that form the backbone of the WMN and the other one is the clients that are connecting to them. The mesh routers are responsible to self-organize and maintain the backbone network. That's why in most of the times the router nodes may not originate or terminate data like the client devices. This backbone can be provided with different types of radio technologies in addition to the most used IEEE 802.11 technologies. Sometimes mesh routers are connected to the internet using external interface with gateway/bridge functionality to provide connectivity with the existing wireless networks [16]. As shown in figure 2.4.

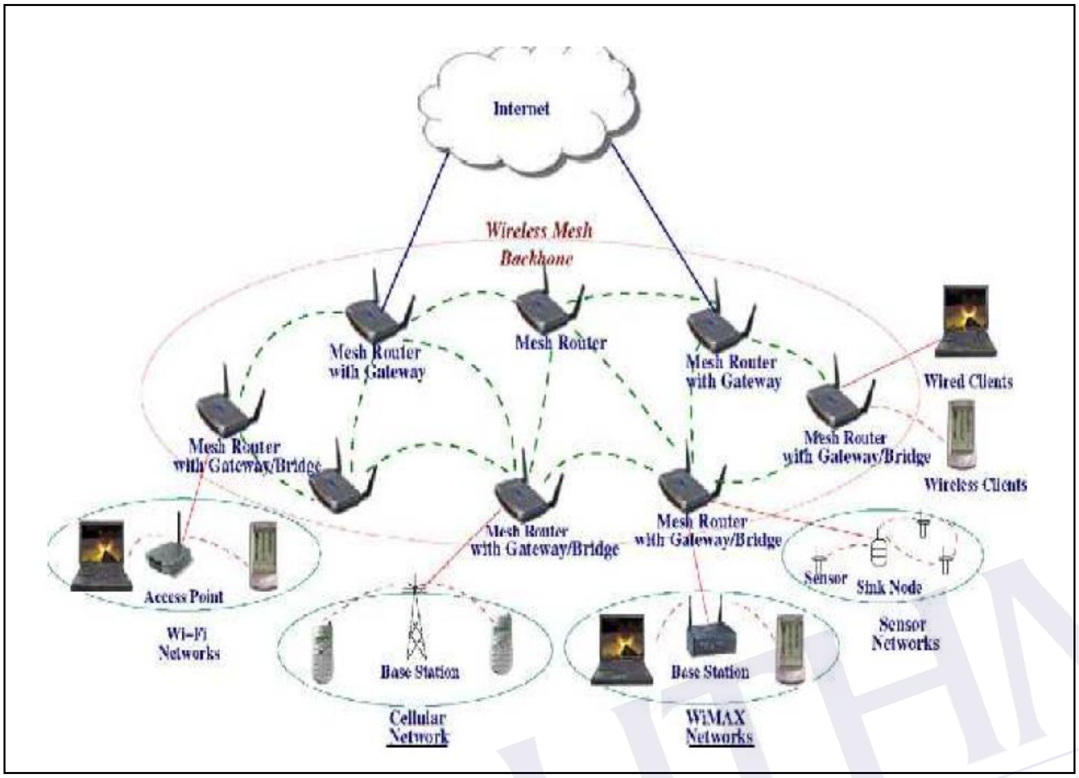

Figure 2.4: Infrastructure/Backbone WMNs [16]

2.3.3 Hybrid WMNs

In this architecture, both infrastructure and client meshing are forming this type of networks and through routers the clients can access the network as well as directly meshing with the other mesh clients. Furthermore, because of the routing clients' capabilities, high connectivity improvement and coverage inside the WMN can be provided while the network connecting to the other networks like internet, WiFi, WiMAX, cellular, and sensor networks [16]. Figure 2.5 shown.

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