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Performance Investigation of Wireless LAN with Variable Channel Width

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Abstract- Today, mostly the wireless LAN is based on preset static channel widths. Considering unique benefits of adapting channel width, which is a fundamental yet under-explored facet in wireless communication, We carried out investigations on the performance of suggested scenario, which are based on IEEE 802.11 and composed of different number of nodes with different channel width (10MHz, 20 MHz and 40 MHz) associated to one AP. This research work makes a strong case for wireless systems that adapt channel width in WLAN. Adapting channel width offers rich possibilities for improving system performance. This thesis provides an outlook of the aforementioned issues associated with wireless communication for instance, fairness problem among users associated to same AP and hidden terminal problem. Some issues are investigated and analyzed with Matlab tool. We found that the variable channel width increases the range of communication, providing the users with the required spectrum, which offers a natural way to both improve flow fairness and balance the load across the APs. Also the increase in channel width increases the throughput of suggested scenario compare to the fixed channel width. In our future work, we also provide possible solutions to the new problems in WLAN with variable channel width.

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I. Introduction

a) Wireless Communication

Wireless communication is essentially any form of information exchange without use of wires. Therefore, the technology which can transmit or exchange information without the wires, in the form of electromagnetic spectrum is known as wireless technology. The electromagnetic spectrum is the range of all possible electromagnetic radiation frequencies, which are used to transmit the signal in wireless communication. Electromagnetic spectrum includes a range of frequencies including radio wave, microwave, infrared and visible light. Frequency is directly proportional to the band width i.e. if frequency is high, more information would be transmitted, and if frequency is low then it can transmit the information at longer distances but data transfer rate would be low. This trade off can be avoided by using another group of electromagnetic spectrum likes microwave or visible light. Radio waves have certain limits to carry and transmit data in wireless technology.

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The microwaves can carry and transmit the information with higher data transfer rate compared to radio waves. Visible light can also transmit signal at high data transfer rate as compared to microwaves. Different applications will require different bandwidth, and this is because deferent life style will require different technology. Like nowadays people want to get everything done from their mobile phones or to access everything from their work place. Even they may want to watch TV from their personal computer. Frequency spectrum has a certain limited range, and uses exponentially increasing frequencies in wireless technology device, the spectrum is congested and sharing is needed to use it effectively.

Beyond of that limitation the IEEE 802.11 was developed such that no licensing is required, and ensures the user the freedom to install and operate without any licensing or operating fees. This means that any manufacturer can create products and sell them at a local computer store or wherever. It also means that all our computers should be able to communicate wirelessly without configuring much. Because wireless communication standards are aimed to use unlicensed ISM band, and currently most of spectrums for wireless communication are saturated with heavy interference. On the contrary licensed users (primary users) like in TV broadcasting, the spectrum is busy in TV broadcasting hours, but no one can use the spectrum when broadcasting signs off. The FCC (Federal Communication Commission) presented the actual utilization of specific spectrum that has a value between 15% and 85%. It is waste of spectrum resource because of unused spectrums allocated for specific service; also it disturbs the efficient utilization of resource. To combat the problem of resource waste, the FCC announced the possibility of spectrum sharing. Executing a qualification of spectrum sharing, devices should not interfere to licensed incumbent users. New solution for scarcity of frequency spectrum is proposed and some results have been shown on the market but still researchers and engineers are challenging the FCC to come up with one word that is technology can solve the scarcity of frequency spectrum. [1]

Cognitive radio is the technology which uses software and hardware to sense their environment and adapt intelligently to meet any number of needs and requirement, the following are components of cognitive radio networks architecture in cognitive radio network, the components are classified into two groups as primary network and cognitive network. But cognitive network does not have a license to operate on desired band while primary network does' have right to operate on certain band. Primary user can operate and has license on a certain spectrum band and this access can be only controlled by access point or base station. And will not be affected by operations of any other authorized user. Primary base station or primary access point is the fixed infrastructure network which has a frequency spectrum license. Primary access point does not have cognitive radio capability for sharing with cognitive radio users. Cognitive radio user has no spectrum license, the spectrum access is allowed only in an opportunistic manner. The cognitive radio user has the following capabilities, spectrum sensing, spectrum decision, spectrum handoff and cognitive radio MAC/ routing /transport protocols [2]. And cognitive radio user is assumed that have capabilities to communicate both base station and cognitive radio users. Cognitive radio base station is a fixed infrastructure component with cognitive radio capabilities and it provides single hop connection to cognitive radio users without spectrum access license.

Cognitive radio (CR) which is the promising radio technology, aims to detect and utilize the temporally unused spectrum bands by sensing its radio environment in order to enhance the spectrum utilization therefore spectrum efficiency can be increased significantly by giving opportunistic access of the frequency bands to a group of cognitive users to whom the band has not been licensed.

A key challenge in technical designing of cognitive radios such that can utilize the dynamic allocation of white spaces in different radios when it operates in network Cognitive radios can dynamically adjust the center frequency and the bandwidth (channel – width) for each transmission[3]. But this is different from traditional wireless networks use channels of fixed Predetermined width. However cognitive radios pose a spectrum allocation problem of which node should use how a spectrum band at what center frequency and for how long.

Distributed spectrum allocation over white spaces (B-SMART) was proposed [5] to solve the spectrum allocation problem in real cognitive networks. B-SMART enables each node to dynamically decide on time-spectrum block based only on local information and uses MAC protocol called Cognitive MAC (CMAC) to support the reservation of a time in spectrum block. In [6] managing and coordinating spectrum access, Dynamic spectrum Access protocol (DSAP) is proposed For each available channel, TDMA frame is divided into N time slots, and each active cognitive user is assigned one transmission slot different from those of other active cognitive users in each frame. Here the author consider cognitive radio network as self organizing network. on this algorithm ,with the number of active CR users increasing, the system throughput decreases for given number of available channels because channels use fixed pre-determined width , figure 1.1 is an example of cognitive radio network, where the device operates as general WLAN device in ISM spectrum. When the ISM spectrum is insufficient, the device may search additional spectrum using cognitive radio engine.

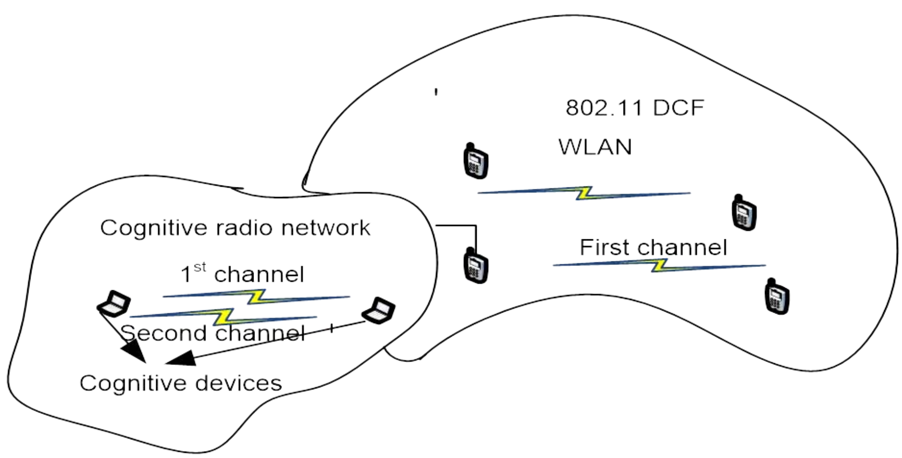

Figure 1.1: Example of cognitive radio Network

In the above figure cognitive device may have two links, one link is always available, and another is available occasionally. Therefore, the first channel used to exchange MAC frame and may transmit data through the second channel which is searched by cognitive engine.

Cognitive radios equipment are more difficult to design and costly, therefore WLAN was adopted as promising technology and now days is more used everywhere.

b) WLAN Overview

Wireless Local area Networks (WLANs) use Radio waves of different frequencies, to transmit signal. The antenna is used to transmit or receive radio wave from source to destination; this radio wave can be refracted, reflected, or absorbed by walls, water and metal surfaces. In office we can use printer or scanner without connected to the computer through the data cables and this makes flexibility and mobility to use network's resources from remote area. Characterization of transmission media of wireless LAN is key point for wireless LAN designing, the process of analysis of wireless LAN is investigation of RF aspects and the coverage of Access point and the purpose of analyzing is to optimize performance, enhance RF coverage and learn more about wireless LAN behavior, because analyzing is the process of learning. We can use hardware and software tools to analyze wireless LAN. Measuring, interpreting and reporting are operational mechanics of analyzing WLAN. As we know WLAN use fixed channel width and it has shown some limitations which will be discussed in this thesis. That motivated more researchers to move beyond the fixed channalization structure to see whether the network capacity, overall spectrum utilization and fairness of WLAN can be greatly increased

WLAN is one of the data communication systems with flexibility features implemented as an extension or as an alternative for wired LANs. Transmission and reception of data over the air in WLANs is facilitated by the use of Radio Frequency (RF) technology, thereby minimizing the need for wired connections. WLANs provide high-speed, reliable data communications in a building or campus environment as well as coverage in rural areas. These systems are simple to install. In WLANs, the connection between the client and the user is accomplished by the help of a wireless medium such as radio frequency or infrared communications instead of a cable as in wire line systems. This allows a remote user to stay connected to the network while mobile or not physically attached to the network. Each computer, mobile, portable or fixed, is referred to as a station in 802.11. Portable and mobile stations differ by the fact that the former moves from point to point but only used at a fixed point whereas the later accesses the LAN when in movement [7, 8]

Wireless has again provided a host of new services during the past twenty years. Firstly, using GPS, one can be trapped wherever situated within few meters on the globe by transmitting exact time over radio waves. The availability of the unlicensed wireless spectrum has been the biggest change in wireless over the past decade. Previously, the wireless technologies had evolved into a specific spectrum and specific protocols. Due to the problem of interference realized, transmission of electromagnetic energy was highly regulated. [9]

i. *Type of Wireless LAN*

802.11 defines two pieces of equipment, a wireless station, which is usually a PC equipped with a wireless network interface card (NIC), and an access point (AP), which acts as a bridge between the wireless and wired networks. An access point usually consists of a radio, a wired network interface, and bridging software conforming to the 802.11 bridging standard. The access point acts as the base station for the wireless network, aggregating access for multiple wireless stations onto the wired network. Wireless end stations can be 802.11 PC Card, PCI, or ISA NICs, or embedded solutions in non-PC clients (such as an 802.11-based telephone handset). The 802.11 standard defines two modes:

- Infrastructure mode
- Ad hoc mode (infrastructure less).

Infrastructure mode

In an infrastructure based, the wireless network consists of at least one Access Point connected to the wired network infrastructure and a set of wireless end stations.

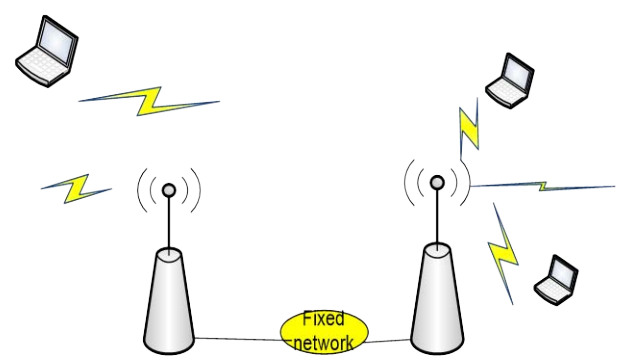

Figure 1.2: Infrastructure based

The above arrangement (figure 1.2) is called a Basic Service Set (BSS). When two or more stations come together to communicate with each other, they form a Basic Service Set (BSS). The minimum BSS consists of two stations. A BSS that stands alone and is not connected to a base is called an Independent Basic Service Set (IBSS) or is referred to as an Ad-Hoc Network. When BSS's are interconnected the network becomes one with infrastructure. 802.11, it has several elements, the media to interconnect two BSS is called Distribution System or DS. This concept of DS increases network coverage. Each BSS becomes a component of an extended, larger network. Entry to the DS is accomplished with the use of Access Points (AP). An access point is a station, in consequence addressable. So, data moves between the BSS and the DS with the help of these AP. Creating large and complex networks using BSS's and DS's leads us to the next level of hierarchy, the Extended Service Set or ESS.

Ad hoc mode

An ad-hoc network is a network where stations communicate only peer to peer. There is no base and no one gives permission to talk. Mostly these networks are spontaneous and can be set up rapidly. Ad-Hoc or IBSS networks are characteristically limited both temporally and spatially. Ad-hoc networks are formed in situations where mobile computing devices require networking applications while a fixed network infrastructure is not available or not preferred to be used. In these cases mobile devices could set up a possibly short-lived network for the communication needs of the moment, in other words, an ad-hoc network. Ad-hoc networks are decentralized, self organizing networks and are capable of forming a communication network without relying on any fixed infrastructure [10].

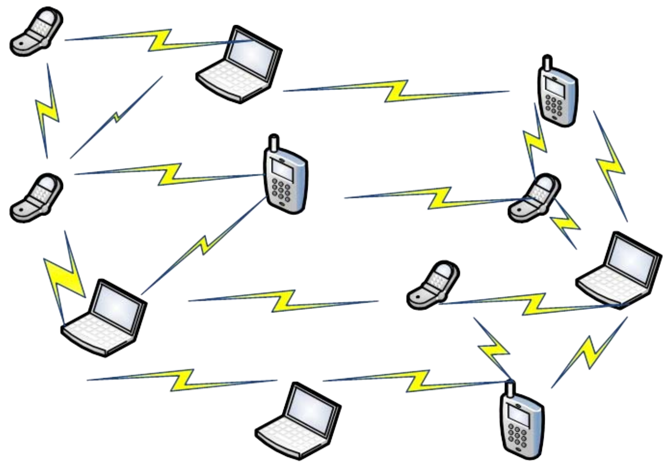

Figure 1.3: Ad hoc networks

As seen in the figure 1.3, wireless multi-hop ad-hoc networks are formed by a group of mobile users or mobile devices spread over a certain geographical area. We call the users or devices forming the network nodes. The service area of the ad-hoc network is the whole geographical area where nodes are distributed. Each node is equipped with a radio transmitter and receiver which allow it to communicate with the other nodes. As mobile ad hoc networks are self-organized networks, communication in ad-hoc networks does not require a central base station. Each node of an ad-hoc network can generate data for any other node in the network. All nodes can function, if needed, as relay stations for data packets to be routed to their final destination. A mobile ad-hoc network may be connected through dedicated gateways, or nodes functioning as gateways, to other fixed networks or the Internet. In this case, the mobile ad-hoc network expands the access to fixed network services.

c) *Objectives, scope and outline of the work*

As discussed above in WLAN different clients have different traffic requirements, some APs some times become saturated by handling high traffic load , as shown in the below (figure 1.4)

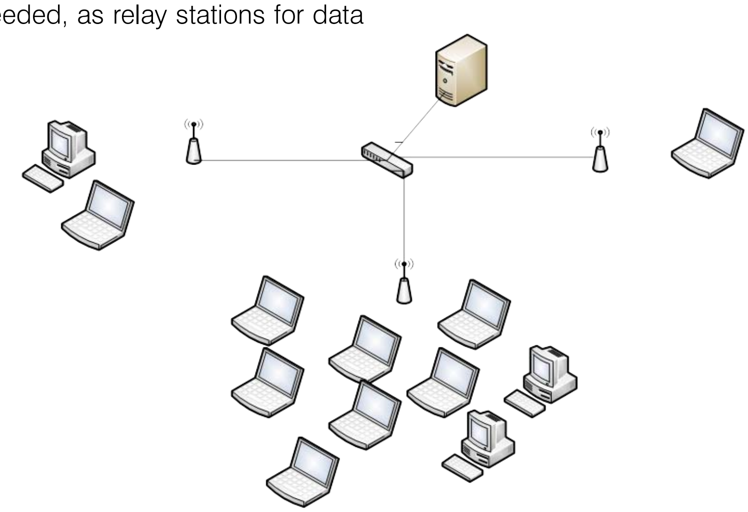

Figure 1.4: Example of WLAN

With fixed channel width, it is difficult to overcome that challenge of traffic distribution, which leads reduction of network capacity, also the fact that some APs are heavily loaded while others are not loaded too much, Creates unfairness among users. When traffic is uniformly distributed across the network, fixed width scheme increase the capacity and reduces interference, imagine in case of dynamic conditions, using fixed fewer than the number of available channels, the spectrum is not fully utilized since each AP uses only one channel. On the other hand, if the number of APs is large, two or more neighboring APs are inevitably assigned the same channel, which can create a varying degree of interference. Therefore, adaptive channel widthcan help overcome those challenges, by simply assigns the spectrum according to the specific needs. And impact of channel width to the distance and throughput will be investigated to improve performance of WLAN.

d) MAC Protocol of IEEE 802.11

IEEE 802.11 was the first, original standardized WLAN at 1 and 2Mbps. It runs in the 2.4GHz radio frequency and was ratified in 1997.One of the core design principles of IEEE 802.11basednetworks is the use of a simple, fixed channelization structure. The entire available spectrum is divided into smaller channels of equal channel-width (bandwidth), and each IEEE 802.11network is specified to operate on a specific set of channels [12,13].FCC released 14 different channel each 22MHz wide in 2.4 GHz range as shown in figure 2.1.

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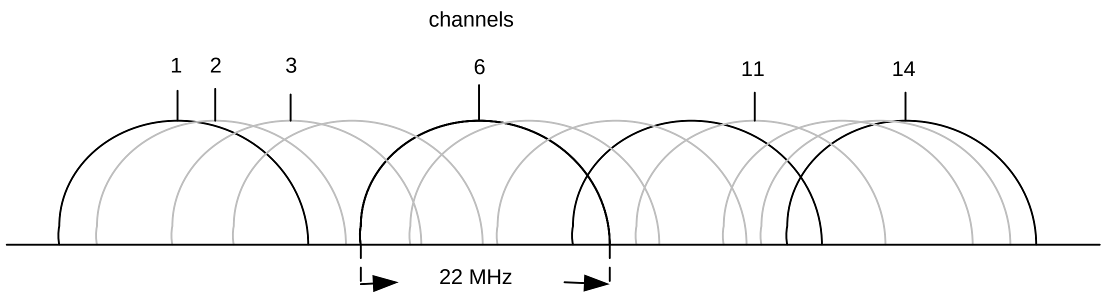

Figure 2.1: 14 different channels each 22MHz wide in 2.4 GHz

Hence in the U.S.A, only 11 channels are configurable; with channels 1, 6, and 11 being non-overlapping. This allows you to have three access points in the same area without experiencing interference. The largest driver for 802.11 products is “traditional” networking at home and in the office. In these networks, the traffic is primarily TCP/IP and looks much like the traffic over wired LANs. In offices, wireless LANs have generally been installed as overlay networks, on top of wired networks, to provide connectivity in conference rooms and cafeterias, as well as to allow Internet access. Early generations of 802.11 technologies have not had sufficient throughput and overall system capacity to allow offices to go completely wirelessly. The emergence of 5-gigahertz 802.11a, however, permits moderate-sized offices to “unwire.” Since the mid-80s, more and more spectrum has been allocated for free and unlicensed use.

The most important unlicensed allocations are at 2.4 GHz and 5 GHz. Spectrum from 2.400 to 2.4835 GHz has been available in most countries for many years. In 1997 the U.S. government allocated 5.15 to 5.35 and 5.725 to 5.825 GHz. Europe and Japan made similar allocations. Therefore a number of WLAN standards have developed over the years.802.11 is actually a family of standards that is constantly being extended. The following is a brief summary of some extensions that are completed [14]:

- 802.11 is an original standard , adopted 1997
- 802.11a is an enhancement to provide 54 Mbps in the 5GHz band, adopted 1999
- 802.11b the most popular of all standards often called Wi-Fi, operates in the 2.4 GHz frequency. With 802.11b WLANs, mobile users can get Ethernet levels of performance, throughput, and availability. The basic architecture features, and services of 802.11b are defined by the original 802.11 standard. The modulation scheme used is Direct Sequence Spread Spectrum. The chipping rate is 11 MHz, the same as in 802.11, providing the same occupied bandwidth.
- 802.11d Changes for international regulatory compliance, adopted 2001
- 802.11e is an enhancements to the MAC layer to provide Quality of Service (QoS) [15,16]
- 802.11g operates in the 2.4 GHz frequency and can achieve ranges up to 300 feet, but like 802.11a, it reaches speeds up to 54 Mbps. 802.11g uses a hybrid complementary code keying OFDM modulation. Though 5GHz has many advantages, it also has problems. The most important of these is compatibility. The different frequencies mean that 802.11a products aren't interoperable with the 802.11b base. To get around this, the IEEE developed 802.11g, which should extend the speed and range of 802.11b so that it's fully compatible

with the older systems. The standard operates entirely in the 2.4GHz frequency, the obvious advantage of 802.11g is that it maintains compatibility with 802.11b (and 802.11b's worldwide acceptance) and also offers faster data rates comparable with 802.11a. The number of channels available, however, is not increased, since channels are a function of bandwidth, not radio signal modulation and on that score, 802.11a wins with its eight channels, compared to the three channels available with either 802.11b or 802.11g. Another disadvantage of 802.11g is more affected by interference.

Those standards use MAC protocols to regulate communication among users[17] It corresponds to the data link layer (layer 2) of the OSI reference model (figure 2.2) .Many MAC protocols have been developed for communication in wired networks as well as wireless networks. For example IEEE 802.3 based on CSMA/CD for wired Ethernet and IEEE 802.11 for WLANs, Sharing a medium by many users unavoidably restricts system performance for users in average. A well-designed MAC protocol is essential to maximize the performance and the efficiency of the network. In wireless networks, MAC protocols are needed as well to ensure successful operation of the network. With the increased international attention to wireless networks many MAC protocols have been suggested for these networks in the past few years. Each of these MAC protocols may have different priorities for problems to solve, depending on the applications to be supported on higher OSI layers .802.11 standards focus on the bottom two levels of the ISO model, the physical layer and data link layer

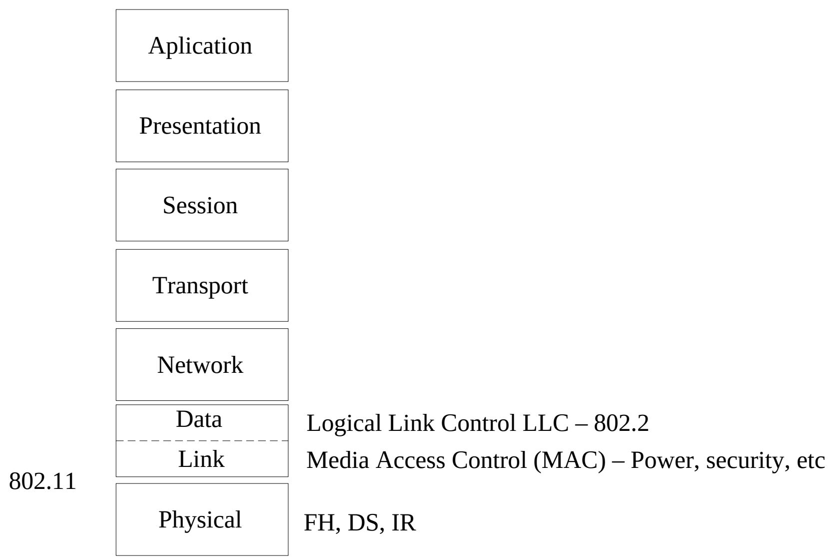

Figure 2.2: OSI Model

Physical layer

The three physical layers originally defined in 802.11 included two spread-spectrum radio techniques and a diffuse infrared specification. The radio-based standards operate within the 2.4 GHz ISM band. These frequency bands are recognized by international regulatory agencies radio operations. As such, 802.11-based products do not require user licensing or special training. Spread-spectrum techniques, in addition to satisfying regulatory requirements, increase reliability, boost throughput, and allow many unrelated products to share the spectrum without explicit cooperation and with minimal interference.

Data Link Layer

The data link layer within 802.11 consists of two sublayers: Logical Link Control (LLC) and Media Access Control (MAC). 802.11 uses the same 802.2 LLC and 48-bit addressing as other 802 LANs, allowing for very simple bridging from wireless to IEEE wired networks, but the MAC is unique to WLANs. The 802.11 MAC is very similar in concept to 802.3, in that it is designed to support multiple users on a shared medium by having the sender sense the medium before accessing it. In this thesis, effects of the MAC protocols on the interference, delay and throughput are relevant[18]. These parameters are affected directly by the way that the MAC protocol deals with the hidden terminal and the exposed terminal problems. Most of the protocol used in the wireless Local Area Network, due to its benefit is DCF.

DCF MAC protocol

In IEEE 802.11 MAC the distributed coordination function (DCF) is the basis MAC protocol in all IEEE 802.11 wireless local area networks. The DCF protocol has two access mechanisms, namely, basic and request-to-send/clear-to-send (RTS/CTS) access mechanisms. A DCF station sends packets to destination through a backoff process. If a collision occurs, the station increases the contention-window (CW) size to retransmit the packet However, once the data packet is transmitted successfully or discarded after reaching maximum retry attempts; the size of the CW is reset to the minimum value for the next packet transmission. DCF is the fundamental mechanism to access the shared medium randomly based on the carrier sense multiple accesses with collision avoidance (CSMA/CA) with a binary slotted exponential backoff mechanism. Therefore A station transmits a packet when its backoff counter reaches zero.

The basic operation of IEEE 802.11 DCF protocol is illustrated in Figure 2.3. If a station has a packet to transmit, it first checks the medium status by carrier sensing. If the medium is found to be busy, the station defers (and continues listening to the channel) until the medium becomes idle for at least a DCF inter-frame space (DIFS). Then the station begins its backoff time to avoid future collisions. After a successful backoff time the station transmits a packet, here channel access is controlled by the use of Interframe space (IFS) time between the frame transmission. As seen in the figure after the packet has been transmitted ,source wait acknowledgement (ACK) before sending another frame for SIFS (short Interframe space) which is the smallest interval that has been specified by 802.11 standards.

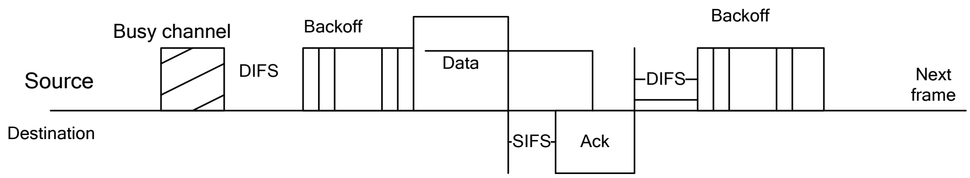

Figure 2.3: Basic Principal of DCF protocol

One of the limitations of IEEE 802.11 DCF protocol is the low bandwidth utilization in the medium-to-high traffic load conditions, and consequently, it achieves low throughput and high mean packet delay. The IEEE 802.11 DCF protocol also suffers from the spatial fairness problem where different nodes achieve different throughput due to their topological distributions. Some users get very poor service compared to other users. Unfairness in wireless networks can be caused by unequal channel qualities [19]

Causes of spatial unfairness

- Due to their different local topologies, different nodes have different opportunities to contend for the channel. Some nodes are blocked from accessing the channel more often than others;
- Some nodes may have to compete for the channel with more competitors than other nodes. This causes more collisions for these nodes;
- The above factors force the BEB (Binary exponential backoff) processes of some nodes to back off more than the other nodes. This rewards nodes which already have higher throughput and punish those nodes which have lower throughput. It becomes an undesirable positive feedback and it aggravates the fairness problem; the fairness problem becomes worse when the data packet size increases.

Related work in adapting channel width

Currently wireless communication technology occupies the use of channels with preset widths. Means that the width of the spectrum over which the radio transmits and receives its signals is already fixed. It has been specified in MHz. Fundamentally a wireless channel is a block of frequency spectrum over which nodes can transmit its data. As an example, the spectrum block of IEEE 802.11 b and g has been divided into 11 overlapping channels that are 20 MHz each and are separated by 5 MHz. The nodes (for this IEEE 802.11 b and g), communicate over one of these channels. Similarly in IEEE 802.16 WiMax, division of the frequency spectrum block based on different widths of channels but these channel widths assigned as fixed width. So the main problem is the limitation for wireless users.

With time the entire scenario for wireless users is changing and this change demands some new features i.e. reduce power consumption, increase range to improve flow throughput, fairness improvement, enhanced network capacity, good performance, less interference etc. Therefore a new system is required that improves the system and provides equal opportunity among all users. Moreover it is required that the implementation should be easy and less costly. To accomplish requirements related to new features, it has been proposed that wireless nodes must adapt dynamically the width of communication channel[20, 21]. This type of adapting channel width behavior has its impacts on IEEE 802.11 network i.e. simultaneously reduction in consumption of power and increased range at the same time, improve flow throughput as different range requires different channel bandwidth, improve fairness in terms of allocation of more bandwidth to more loaded applications and less bandwidth to less loaded applications, improve network capacity that solve the rate anomaly problem. Adapting to dynamic allocation of channel width is difficult because the radio spectrum is expensive resource and also it has directly effect the Transmitter and Receiver sampling rate. But the Wireless card's channel width determined by frequency synthesizer in the Radio Frequency (RF) front end circuitry. Related to wireless systems, the frequency synthesizer is implemented using a Phase Locked Loop (PLL). A frequency divider on the PLL feedback path determines the centre frequency of the card, and the reference clock frequency used by the PLL determines the channel width.

The effect of adapting channel width
Increases network throughput

As expected, Throughput performance may be achieved by changing channel width or SNR which depends on the modulation rate used by a radio to transmit the data. That can be proved by theoretically using Shannon's equation

$$Capacity = Bandwidth * log\ (1+SNR) \qquad (2.1)$$

According to Shannon's capacity formula the theoretical capacity of a communication channel is proportional to the channel width Therefore the throughput increases with channel width increases. More details are provided on simulation part.

Reducing channel width increases transmission range

Narrow channel widths have same signal energy but lesser noise better SNR. This is advantage compare to fixed channel width, fixed channel width Systems can only increase range by increasing transmission power or using lower modulation. Narrower channels in Adaptive channel width have both lower power consumption and longer range. Reducing channel width may come at the cost of reduced throughput; however, the width should be reduced when the additional throughput of the wider channel is not desired. Reducing width increases guard interval more resilience to delay spread (More range) at long communication distances, wireless receivers get multiple copies of a signal due to multipath reflections. Delay spread is the time difference between the arrival of the first and last copies of the multipath components. It is a well-known and theoretically well studied subject that communication signals through a fading channel are heavily attenuated, and that the information might be lost in deep fade. It would greatly improve the reception if we are able to present the receiver with two or more replicas of the same information signal subject. These replicas would have to be transmitted through independent fading channels so that the probability of all fading at the same time is very small. For example, if the probability that any one signal will fade is 2%, then the probability that three copies, for example, propagated through independent paths fading simultaneously, is reduced to 0.0008%.

We may provide the signal replicas using various techniques. For instance, we can transmit the information signal on L carriers where the separation between adjacent carriers equals or exceeds the coherent bandwidth of the channel. This method is called frequency diversity. We can, if we prefer, transmit the information on L time slots where the separation between successive time slots equals or exceeds the coherent time of the channel. This method is called time diversity. We may also use one transmit antenna but receive the information signal using multiple receiving antennas. This method is called space diversity. Clearly all of these diversity techniques require extensive planning and the skills of specially trained engineers. However, from its very nature, multiple path propagation of wireless signal creates a number of replicas arriving at the receiver at different times. The time it takes a wireless signal to travel from A to B is given by the distance between A and B divided by speed of light c ($=3\times108$ m/s). The delay spread of the replicas is the time it takes the wireless signal, traveling at speed of light, the longest path minus the shortest path.

Lower channel widths consume less power

Lower bandwidths run at lower Processor clock speeds, lower battery power consumption. In[20] proved that narrower channel widths consume less battery power when sending and receiving packets, as well as in the idle states. A 5 MHz channel width consumes 40% less power when idle, and 20% less power when sending packets than 40 MHz channel width.

How to achieve different channel width

Transmission with a high-bandwidth utilization is fundamentally power in-efficient in the sense that it will require un-proportionally high signal-to-noise and signal-to-interference ratios for a given data rate. Providing very high data rates within a limited bandwidth, for example by means of higher-order modulation, is thus only possible in situations where relatively high signal-to-noise and signal-to-interference ratios can be made available, for example in small-cell environments with low traffic load or for mobile terminals close to the cell site.

However, there are several critical issues related to the use of wider transmission bandwidths in Wireless networks. Spectrum is often a scarce and expensive resource, and it may be difficult to find spectrum allocations of sufficient size to allow for every wideband transmission, especially at lower-frequency bands. The use of wider transmission and reception bandwidths has an impact on the complexity of the radio equipment, both at the base station and at the mobile terminal. As an example, a wider transmission bandwidth has a direct impact on the transmitter and the receiver sampling rates, and thus on the complexity and power consumption of digital-to-analog and analog-to-digital converters as well as front-end digital signal processing. RF components are also, in general, more complicated to design and more expensive to produce, the wider the bandwidth they are to handle.

Modify frequency of clock that drives PLL

Implemented on Atheros cards – programmable clock can generate 5, 10, 20, 40 MHz widths because the reference clock frequency used by the PLL determines the channel width. A phase-locked loop or phase lock loop (PLL) is a control system that generates a signal that has a fixed relation to the phase of a "reference" signal. A phase-locked loop circuit responds to both the frequency and the phase of the input signals, automatically raising or lowering the frequency of a controlled oscillator until it is matched to the reference in both frequency and phase. A phase-locked loop is an example of a control system using negative feedback

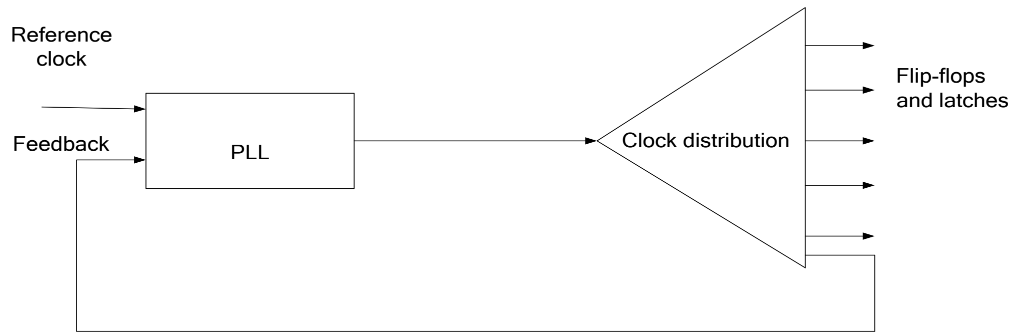

Figure 2.3: Clock distribution

Typically, the reference clock enters the chip and drives a phase locked loop (PLL), which then drives the system's clock distribution (figure2.3). The clock distribution is usually balanced so that the clock arrives at every end point simultaneously. One of those end points is the PLL's feedback input. The function of the PLL is to compare the distributed clock to the incoming reference clock, and vary the phase and frequency of its output until the reference and feedback clocks are phase and frequency matched

Turn off certain subcarriers of OFDMA

Transmission by means of OFDM can be seen as a kind of multi-carrier transmission. The basic characteristics of OFDM transmission, which distinguish it from a straight forward multi-carrier extension of a more narrowband transmission scheme as are, the use of a relatively large number of narrowband sub carriers, OFDM transmission may imply that several hundred sub carriers are transmitted over the same radio link to the same receiver[22,23,24,]

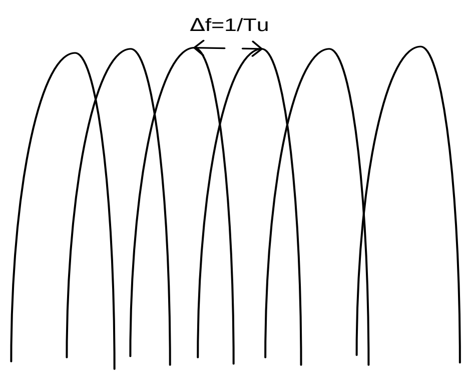

Figure 2.4: OFDM subcarrier spacing

Tight frequency-domain packing of the subcarriers with a subcarrier spacing f =1/Tu, (figure 2.4), where Tu is the per-subcarrier modulation-symbol time. The subcarrier spacing is thus equal to the per-subcarrier modulation rate 1/Tu. The number of OFDM subcarriers can range from less than one hundred to several thousand, with the subcarrier spacing ranging from several hundred kHz down to a few kHz. That subcarrier spacing to use depends on what types of environments. The system is to operate in, including such aspects as the maximum expected radio channel frequency selectivity (maximum expected time dispersion) and the maximum expected rate of channel variations (maximum expected Doppler spread).Once the subcarrier spacing has been selected, the number of subcarriers can be decided based on the assumed overall transmission bandwidth, taking into account acceptable out-of-band emission, etc..

The number of subcarriers depends on transmission bandwidth, with in the order of 600 subcarriers in case of operation in a 10MHz spectrum allocation and correspondingly fewer/more subcarriers in case of smaller/larger overall transmission bandwidths.

II. The Possible Problems

The transmitting frequency of the nodes in wireless LAN communications at the moment is 20 MHz. The width of a wireless communication channel is one of the most important parameters in wireless communication. It's been surprising that fixed channel widths are taken for granted in virtually all wireless networking research. Thereby each AP is assigned a fixed width of 20 MHz channel and the neighboring APs are placed on orthogonal frequencies. For the network whose traffic is uniformly distributed, there is an increase in capacity as well as a reduction in interference [25]. Therefore the following are main problems in wireless LAN communication which we need to investigate if we allow adapting channel with.

a) Fairness problem among users

Fixed channel width has many problems as the number of APs is few compared to the number of available channels. This causes the available spectrum not fully utilized since each AP is entitled to only one channel. On the other hand, if the number of APs is large, two or more neighboring APs are inevitably assigned the same channel, which can create interference. Also, as the traffic requirement is different from users associated in one AP, it is a big problem to satisfy each and everyone with fixed channel bandwidth; therefore they will be unfairness among users to access the channel [26].

Imagine in case where you have for example 3 access points. First access point is associated to 10 users, second one associated to 4 users and last one associated to only 2 users, as we can see well that users associated to the first AP will suffer compared to others because of limited channel width. Therefore, there will be unfairness among users. To solve fairness problem,[33] proposed an intelligent association control to reduce load imbalance and unfair bandwidth allocation among users, associated with different APs. As shown in the figure 3.1

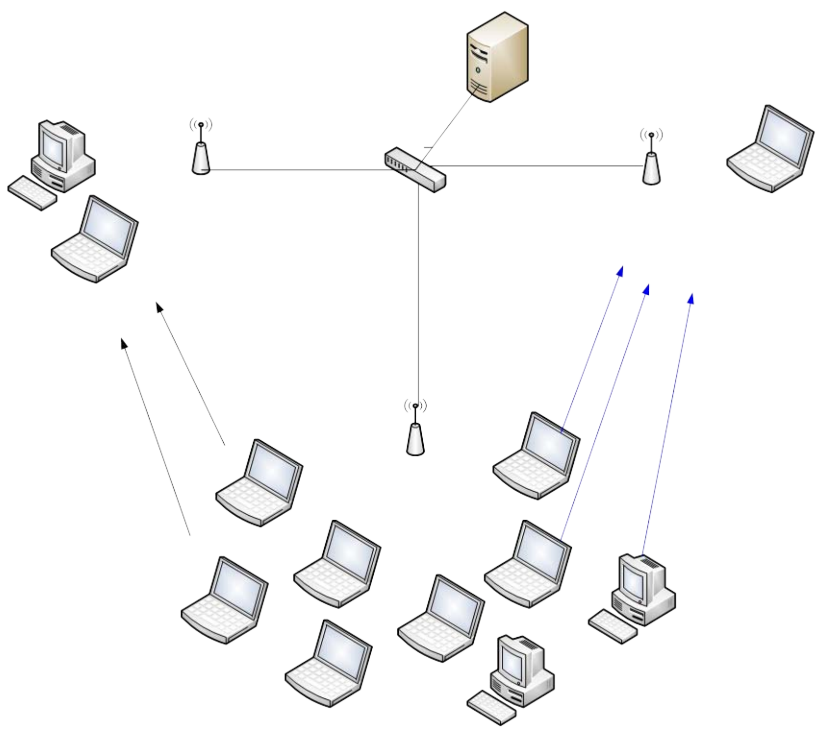

Figure 3.1: WLAN scenario discussion in [reference 33]

But their mechanism has shown some drawback for some clients connected to far APs. Those users suffer low SNR which leads to their lower data rate and low throughput. In Cell Breathing a load balancing mechanism was proposed to handle client congestion in WLAN. Also power management algorithms for controlling the coverage of APs were developed to handle dynamic changes in client workloads, just as solution to overcome the drawbacks mentioned above. But their algorithms don't always achieve good solution. Because transmission power control is practically difficult to implement therefore problem of clients connected to far APs still persists. [27]

[28] Proposed a technique to improve the usage of wireless spectrum by using new channel assignment methods which are Dynamic channel re-use and weighted channel assignment where channel assignment problem is modeled as graph coloring problem. As shown in the figure 3.2

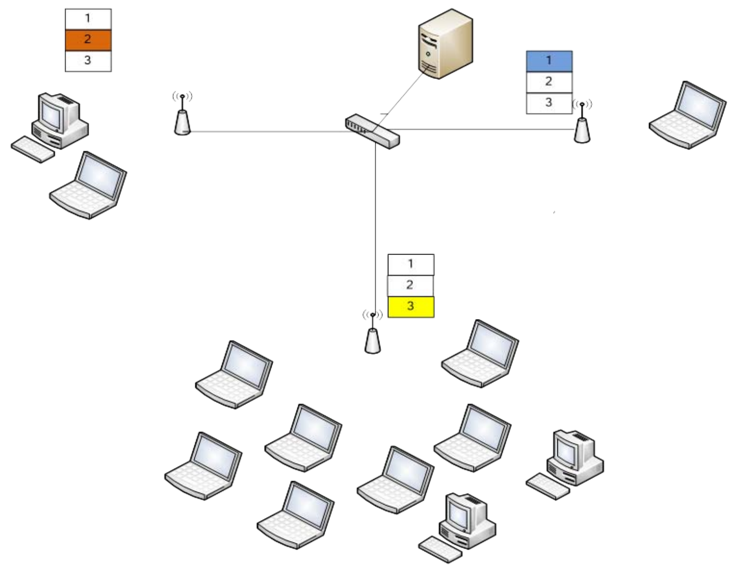

Figure 3.2: Dynamic channel reuse discussion in [reference 28]

This is indeed a nice idea but it has limited potential because an AP is still assigned to one channel only. After all proposed mechanism, in the fixed channel width there is no other choice as the channel is fixed to 20 MHz.

In fact the best mechanisms should assign more spectrums, where spectrum is needed. Therefore, in [20] adapting channel width is extensively studied, and proposed to be sufficient solution to provide fairness among users. By allocating more bandwidth to more loaded applications and less bandwidth to less loaded applications. That can be achieved by using OFDM transmission. The bandwidth of *OFDM (BW)* $= N_c.\Delta f$, where, *Nc* is number of subcarriers and Δf is carrier spacing. In our investigations $\Delta f = 15$ KHz. And the number of subcarriers to generate different channel width is given bellow.

Table 3.1: Number of OFDM subcarriers for different channel width

Number of subcarriers	600	1200	2400
Channel width (MHz)	10	20	40

Summary on the fairness problem, in the fixed channel structure presence of multiple users in WLAN creates a competition for access to the wireless channel. To be fair, node should have equal opportunity to win the contention, and gain an equal share of the wireless channel. However, the two goals in the design of a MAC protocol, namely maximizing wireless channel utilization and fair allocation of wireless channel bandwidth, are not always compatible with each other. Base station buffer size, wireless link interference, link asymmetry or hidden terminals etc. further exacerbate the fairness issue, sometimes even shutting off all flows through a node or excessive collisions, making the default allocation of the medium by 802.11, below optimal.

Considering the different channel width will result in different performance even thought the user can be guaranteed the spectrum according to its need, by using current MAC protocol which offer equal channel access opportunity, that can creates fairness problem among nodes, due to different performance discussed above. But here if the MAC protocol is designed to assure fairness in terms of channel capacity, adapting channel width will be a solution to guarantee the fairness among users, because any user can get more resources according to its need. Therefore fairness may be achieved by controlling the contention window size for each station properly or assigning different priorities to different nodes.

b) New hidden terminal problem

By adapting channel width, different nodes hold different channel widths, which lead in showing them in different transmission ranges and interference range, consequently hiding some nodes from each others. To avoid hidden terminal problem for any node which it wants to transmit to AP, it will use RTS/CTS handshake before transmitting any frame.

i. *Concept of hidden terminal*

In WLAN, the Station cannot transmit and sense the channel at the same time, therefore it may happen that two stations transmit to the AP at the same time or another station may transmit to the AP, resulting in a collision, because two stations are hidden from each other and have a different view of the channel state (busy or idle) [29].

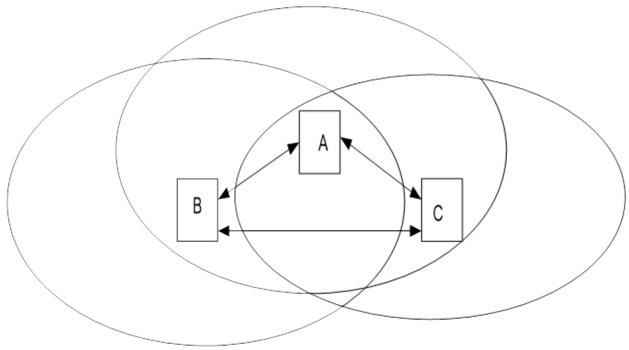

Figure 3.3: Example of hidden nodes

As shown in figure 3.3, node A can communicate with both B and C but B and C are hidden from each other. The collision can occur when those nodes want to communicate at the same time and same destination. Hidden terminal problem may be caused by signal fading and attenuation caused by static obstruction. It can also be caused by transmission range. One of the best methods to overcome hidden terminal problem, is the use of the request to send and clear to send (RTS/CTS) incorporated into IEEE 802.11. [30, 31]

ii. *RTS/CTS to overcome hidden terminal problem*

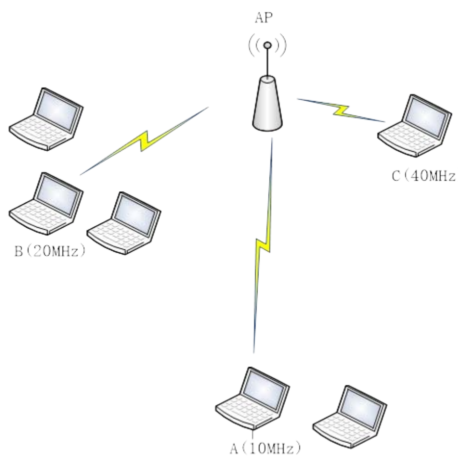

Figure 3.4: Nodes with different channel width

Consider Figure3.4 where the nodes transmit with different channel width. Those nodes are within a range of an Access Point. Due to their different channel width requirements, they intend to access the AP in different manner [32]. For example node B may be communicating with AP, because node A is not in the same range of B, it listens and hears no traffic in that case it may think that the medium is free of transmission. Then starting to inquire the channel, since B is already transmitting collision may occur, Because B is hidden from A. this problem known as Hidden terminal problem. To avoid such situation we need to enable RTS/CTS on a particular station. So that while a node is initiating the RTS, others are hold off from accessing the medium RTS/CTS scheme is shown with a figure 3.7

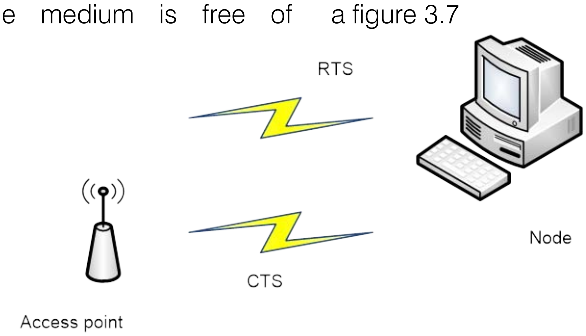

Figure 3.5: RTS/CTS scheme

Because overhead of RTS/CTS packets increases WLAN delay, the Threshold RT frame should be provided to determine when RTS/CTS handshaking mechanism takes place. Before communication .DCF MAC is designed to solve the hidden terminal problem here we set RTS threshold and compare it with the frame length, if the length of a data frame is greater than a preset RTS threshold. After a backoff procedure the station sends an RTS, reserving the channel for the following data frame, figure 3.6

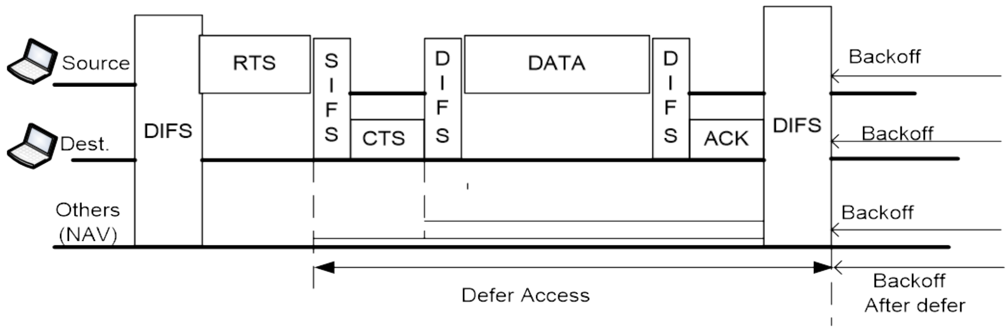

Figure 3.6: 4 way handshaking schemes

When RTS frame is detected by a receiver, after SIFS time period, the receiver responds with a CTS frame. All stations in the network hearing the sender or receiver set their Network Allocation vector (NAVs) to that value. After DIFS time period, sender transmits its data to the receiver node. If data received correctly after DIFS time period, receiver sends an Acknowledgement to the sender by data received confirmation.

In this situation, nodes are assured of having no collision; therefore, hidden terminal problem is avoided. [34]

With variable channel width nodes will be having different capacity which makes them to be in different ranges (proved by numerical analysis) that will give more chance the nodes to be hidden from each other compare to the fixed channel width where the nodes range is not much different. Therefore in designing MAC protocol for evaluating performance of suggested scenario, care should be taken for the use of RTS /CTS, due to higher communication range of some nodes which require low throughput.

Analysis relationship among power, channel width and transmission distance

In a typical wireless communication environment, multiple propagation paths often exist from a transmitter to a receiver due to scattering by different objects. Signal copies following different paths can undergo different attenuation, distortions, delays and phase shifts. At the receiver side, these different signal copies may add constructively or destructively. This leads to the so-called multipath or small-scale fading. Fading manifests as significant fluctuation in signal-to-noise ratio (SNR), bit error rate (BER) increase, more frequency packet loss and link failure. The SNR is computed from the power of the received signal and the noise power [35, 36, 37, 38]

Pathloss describes the loss in power as the radio signal propagates in space. In any real channel, signals attenuate as they propagate. For a radio wave transmitted by a point source in free space, the loss in power, known as pathloss, is given by

$$L = \left(\frac{4\pi d}{\lambda}\right)^2 \qquad (3.1)$$

Where λ is the wavelength of the signal and d is the distance between the source and the receiver. The power of the signal decays as the square of the distance Hence the impact of pathloss exponent parameter was evaluated and found that the communication distance between sender and receiver to be different with different pathloss exponent Signal coverage is influenced by a variety of factors, like radio frequency of operation and terrain. The core of the signal coverage calculations for any environment is path-loss model which relates to loss of signal strength to distance between terminals. Using path loss modals, radio engineers calculate the coverage area of wireless base stations and access points as well as maximum distance between two terminals.

Let Pt, be transmitted power, after distance d in meters, the signal strength will be proportional to Pt $d^{-\alpha}$ where α is a path loss gradient, which is equal to two in free space ($\alpha = 2$)

Therefore relationship between the transmitted power P_t and received power *Pr* in free space is given by

$$\frac{Pr}{Pt} = GtGr\left(\frac{\lambda}{4\pi d}\right)^2 \qquad (3.2)$$

Where, G_t, G_r are transmitter and receiver Gain, d = distance between transmitter and receiver in our case can be considered as Distance between node and AP. λ = (c/f) is the wave length of the carrier. From (3.2)

$$Pt = \frac{Pr}{GrGt(\frac{\lambda}{4\pi d})^2} \quad (3.3)$$

Assume other parameters to be constant; we can say that $Pt/f^2 \equiv k\, d^2$

Also from equation (3.2)

$$(d)^n = \frac{Pt}{Pr} GtGr(\frac{\lambda}{4\pi})^\alpha \quad (3.4)$$

As we know $\lambda = \frac{c}{f}$, hence in the fixed power if the frequency varies d also vary.

For bandwidth greater than 10 KHz, for any two channel width B2 and B1, the required dynamic range ration in db is

$$10\log (B2/B1) \quad (3.5)$$

c) Numerical analysis Plan and purpose

We intend to investigate by numerical analysis using MatLab tool the performance of WLAN given on the figure3.7

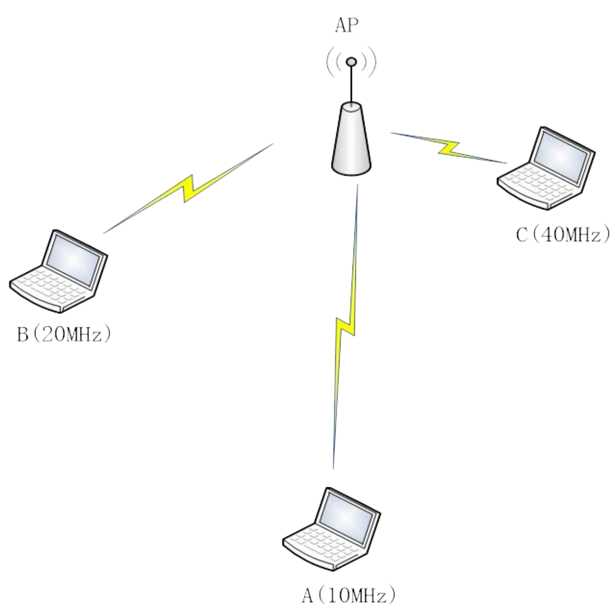

Figure 3.7: Nodes with different channel width

In this scenario topology we suggested to use 3 nodes of different channel width with fixed power. Let us assume that node A transmits at 10 MHz, Node B with 20 MHz and Node C with 40 MHz channel width. According to the study carried out in paper [20], we can increase transmission range by reducing channel width or in other words node A has higher transmission range compared to Node B, and node B has higher transmission range as compared to node C. Therefore, those different nodes hold different bandwidth which leads to fairness problem and hidden terminal problem due to interference and transmission range. Here different policies and different protocols should be adapted.

By investigating the performance of figure 3.7, with fixed power, we can see that all stations are in the communication range of access point (AP) and due to the different channel width all nodes may not be in the same carrier sense range. Therefore, the traffic only exists on 2 directions: from AP to stations and from stations to AP. According to the node's locations, AP always can sense the traffic from stations and the traffic from AP to stations will be sensed by all the stations. Hence all Analysis will focus on traffic from stations to the AP. Because all nodes are in the transmission range of AP therefore no problem of hidden terminal or interference to the traffic from AP to stations.

d) Impact of channel width on distance

We investigate and analyze the topology given in the figure3.7 which is infrastructure base service set for each node transmits with different channel width in the fixed power transmission, that is for example node "A", with 10MHz , node "B" with 20MHz, and node "C" with 40MHz, and the distance is measured from the each node to the access point. The investigation is intended to see that whether the distance is function of channel width, but the following consideration is taken in place to make sure that the collision is avoided.

Using path loss modals, we can calculate the coverage area of wireless base stations and access points as well as maximum distance between two terminals.

$$L = (\frac{4\pi d}{\lambda})^2 \quad (4.1)$$

$$(d)^n = \frac{Pt}{Pr} GtGr(\frac{\lambda}{4\pi})^\alpha \quad (4.2)$$

For any two channel width B2 and B1 the required dynamic range ration in dB is given as

$$10\log_{10}(\frac{B2}{B1}) \quad (4.3)$$

The dynamic range depends on the bandwidth and the centre frequency on our investigation all adapted channel width have the same centre frequency (2.412GHz)

Data Analysis

For this experiment power transmission is fixed to 1mW and $\alpha = 4$ and peak level in db attenuation for 20 MHz channel width is given to 80 db as required in practice.

$$A = 10\log_{10}\frac{Ps}{Pr} = 10\alpha\log_{10} d \quad (4.4)$$

Where:

- A is maximum range in db attenuation,
- Ps is power sent
- Pr is power received.
- α is path-loss exponent and d the distance from AP to node.
- d: is a distance in meter

In this case Ps is fixed to 1mW, therefore from the results given on table 5.2, signal strength Vs Distance is plotted as in the figure 4.2

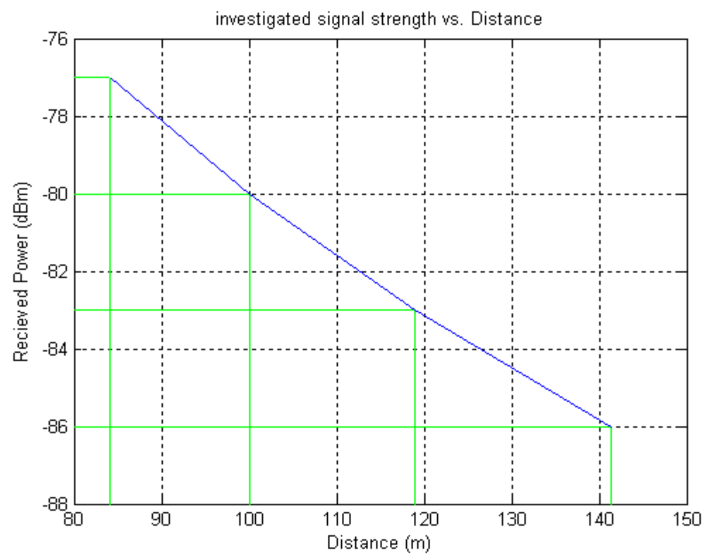

Figure 4.2: Signal strength Vs. Distance

On figure 4.2, more the node communicates to the higher distance, more received power reduced, therefore the node required to transmit with lower channel width without any interruption. 120m is found to be the maximum transmission distance achieved by a node which transmits with 10MHz channel width with minimum signal strength.

The following figure shows the relationship between transmission distance and channel width.

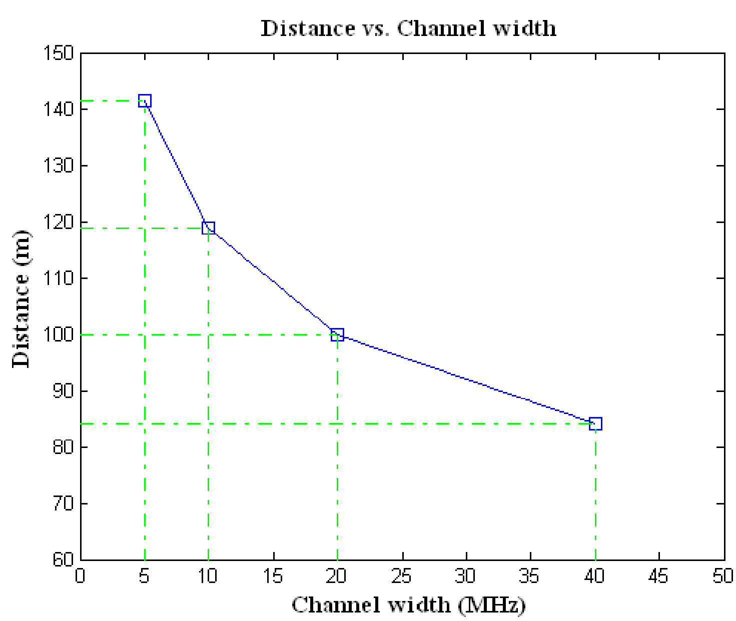

Figure 4.3: Distance vs. Channel width

Figure 4.3, transmission distance increases by reducing channel width. For example for 40 MHz channel width, the transmission distance is found to be 82 meters, whereas for 10 MHz is approximately 120 m.

Hence, the channel width has big impact to the distance, when channel width reduces the distance transmission increases.

Impact of Modulation on transmission distance

To provide higher data rates within a given transmission bandwidth, we use higher order modulation that allowing for more bits of information to communicate per modulation symbol. Therefore we are investigating different symbol interval of OFDM modulation [39].

Nominal bandwidth of transmitted signal (B) = M / N.fs (4.5)

Where:

M: Modulation symbols from some modulation alphabet like QPSK, QAM etc.

N: bits size. = 2^n and fs is a sampling frequency.

From (1) during transmission with OFDM modulation scheme, normal bandwidth of the transmitted signal is proportional to modulation symbols per second (M).

If M is Higher, the bandwidth increased hence the transmission distance reduced.

Above figures show that the modulation used by the radio while transmitting has also a big impact on distance

$$A = 10\log_{10}\frac{Ps}{\Pr} = 10\alpha\log_{10} d$$

We can investigate the impact of modulation with different cases of communication by applying different modulations. The data used to investigate the impact of modulation were taken on reference. [10]

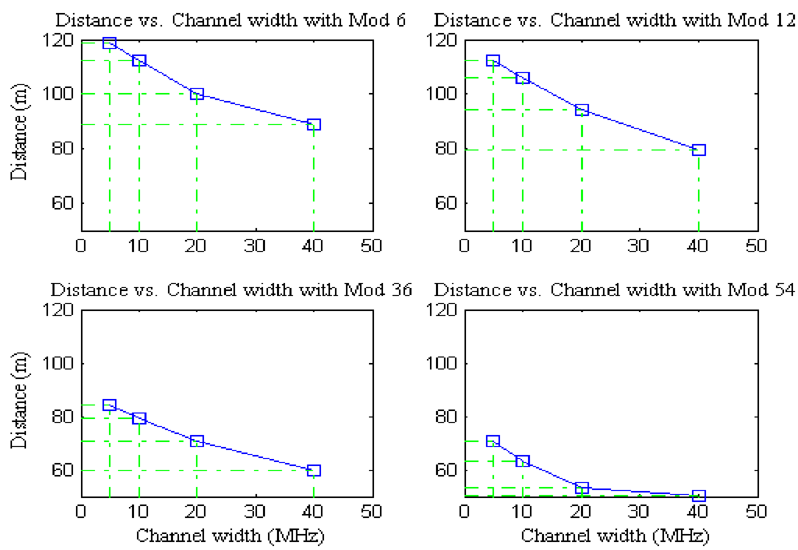

Figure 4.4: Distance Vs Channel width with different modulations

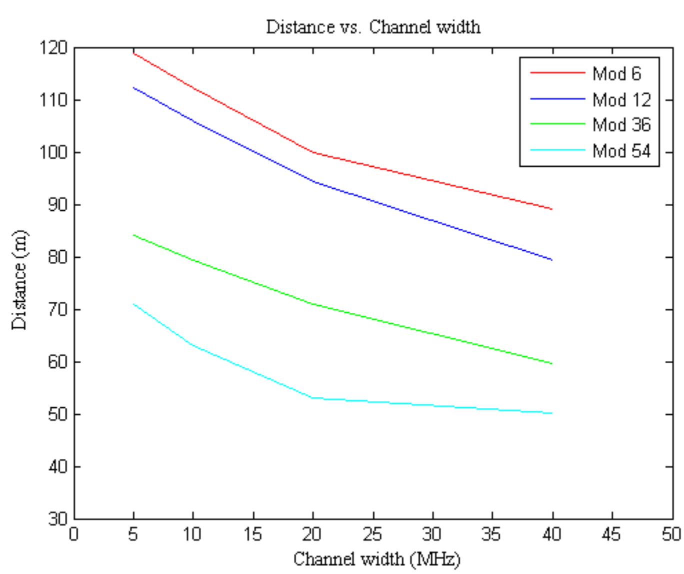

Figure 4.5: Comparison of distance with different modulations

On figure 4.5, we can see well that lower modulation provide more range compare to others. Therefore if you need to reach at higher distance by transmitting with low channel width (example 10 MHz for our proposed model) it is better to transmit with lower modulation (modulation 6). To maximize the performance of our topology OFDM modulation 6 is preferred.

III. Conclusion

This study focused on the performance of WLAN of different nodes from which transmit the information with different channel width. We assumed that AP can adaptively change its channel width according to the user requirements. We discussed two major problems which arise to reduce the performance of WLAN: which are fairness and new hidden terminal problem. The following Observations were made from the Analysis obtained by MatLab simulating tool:

Adapting channel width offers rich possibilities for improving system performance.

Because, it increases the range of communication, providing the users with the required spectrum, which offers a natural way to both improve flow fairness and balance the load across the nodes. in our investigation we found that by transmitting with channel width of 5 MHz, we can still access the channel and communicate with an AP with required signal strength, i.e. a kind of improvement in fairness among users, because every user can be allocated the spectrum according to his requirement, which is practically impossible with naturally fixed channel width of 20 MHz, because maximum distance it can offer is not more than 100m (figure 4.3) and access for the nodes at higher distances suffers.

Increase in channel width increases the throughput for investigated scenario

The whole throughput found is approximately 20 MHz, which is near to 25MHz found by others, which consequently improves the fairness. Because modulation used in the transmission has an impact on distance, it is found that low modulation can be used to maximize transmission distance in case of low throughput. For new hidden terminal problem we purposed to use RTS/ CTS incorporated in MAC protocol, which we put on future work to improve it according to the scenario proposed.

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