Chapter One(Introduction)

1.1 Introduction

Over the last decade, the telecommunication industry has undergone dramatic changes. Among these, the most significant are modifications. In terms of technology, usage demands and market structure. Spectrum sharing occurs when ever multiple wireless systems operate in the same frequency band. There are two dimensions to spectrum sharing, one can distinguish between vertical sharing systems with different levels of regulator status, e.g. primary and secondary users, and horizontal sharing system with equal regulatory status, various unlicensed network. Among sharing occurs when ever multiple wireless systems operate in the same frequency band one of this wireless 802.11 and 80.22. Among sharing occurs when ever multiple wireless systems operate in the same frequency band one of this wireless 802.11 and 80.22[1]. The analogue broadcast TV services operate in licensed channels over the Very High Frequency VHF and UHF bands, e.g. in 54 - 88MHz (channels A2 to A6), 174 -216 MHz (channels A7 to A13) and 470 - 698MHz (channels 14 to 51) portions of the spectrum in USA [2]. These channels offer attractive features like high building penetration and wide range coverage. Moreover, the wavelength of the signals in UHF band is short enough resulting in antennas with sufficient small footprint that are acceptable to be used in many portable devices[3].

Radio frequency is used inefficiently due to the nature of applications in those bands and hesitancy to improve the transmission technology to ensure backward compatibility. One of those bands was the spectrum allocated for terrestrial TV stations in VHF and UHF bands.

During the period of analog to digital conversion for TVs some of the spectrum is auctioned for other communication systems but more importantly, regulators are started to allow the use of spectrum by secondary unlicensed users if it is not used by a licensed broadcasting system in a given location in a given time. This spectrum is called Television White Spaces (TVWS).

First regulations related to TVWS came from the USA, FCC allowed TVWS operation of both fixed and personal/portable devices [4], [5].Three working groups of IEEE 802 LMSC are active in PHY/MAC layer standardization. Each has different applications in mind. For long distance communication IEEE 802.22 working group will known by Wireless Regional Area Network (WRAN) developed a standard and also started a new activity for enhanced broadband service and wireless monitoring [6].

The IEEE 802.11 working group will known by 802.11 Wireless Local Area Network (WLAN) standards [7]. 802.22 is the first standard for devices to operate on TVWS, providing a cell radius of up to 100 km. A new version has been released in July 2011 .802.11af is also referred to as White-Fi or super Wi-Fi and is targeted at providing local area coverage. These two standards are both envisioned to have wide applications in the future [8].But these standard heterogeneities in operating powers and sensitivities and protocol stack [9].

1.2 Problem Statement:

The two standards 802.22 and 802.11af are different at almost all levels in the protocol stack, due to the heterogeneities of the 802.22 and 802.11af systems, it is challenging to enable their coexistence. The two networks are heterogeneous in operating powers and sensitivities. The transmission power of 802.22 can be as high as 4 W (36 dBm) and the reception sensitivity can be as low as -97 dBm. On the other hand, 802.11af tends to use much lower transmission power of 100 mW(20dBm) and its sensing threshold is usually -64 dBm .802.22 standard adopts the point to multi-point architecture and has a TDMA-like MAC while the 802.11af is expected to use CSMA at MAC[3].since the reception threshold of 802.11af is much higher than that of the 802.22 receiver, it is possible that the 802.11af transmitter cannot detect the existence of a faraway 802.22 transmitter and thus becomes a hidden terminal to the 802.22 receive.Figure 1.1 show that.

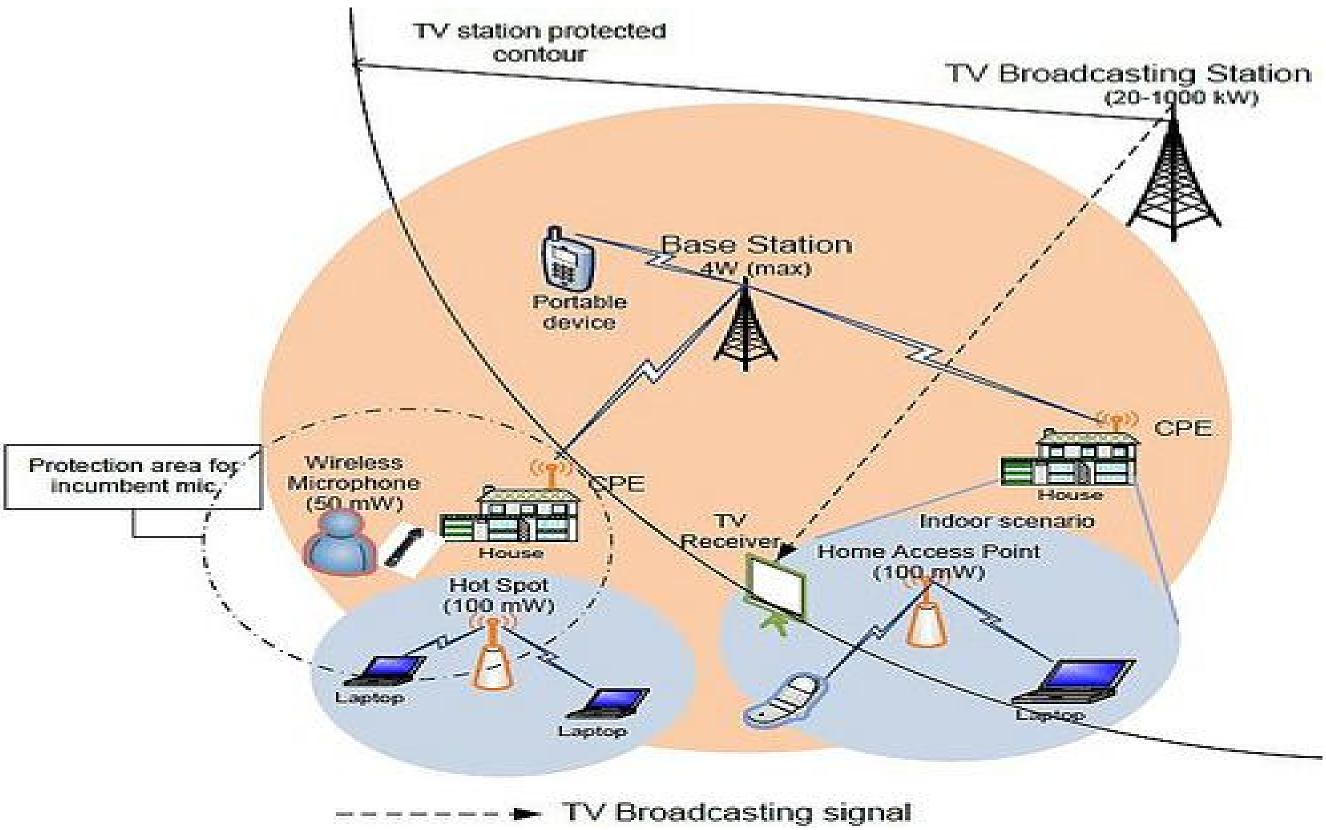


Figure 1.1 show the coexistence between 802.22 and 802.11 in TVWS

1.3 Literature review

To enable coexistence of heterogeneous system on TVWS, the 802.19.1 protocol [10] requires all the networks operating on TV white spaces to have a common interface to access the coexistence database and the channel allocation will be scheduled by a centralized entity called coexistence manager. Recently In

[11], two standard independent mechanisms are proposed to provide an information exchange platform for heterogeneous TVWS standards. Both the proposed mechanisms required either a coexistence database or the use of multiracial cluster head equipment.

On the other hand [12] solved two problems of coexistence(Hidden Terminal to 802.22 and Exposed Terminal to 802.11af) by propose busy tone frame work ,but this tone decrease the throughput of 802.11. In [13], we propose a new paradigm, called Cooperative Busy Tone (CBT), that enhances the mutual observe ability between ZigBee and Wi-Fi. However, in TVWS it is not practical for the low device to transmit a higher power due to the regulation.

The IEEE 802.15.2[14] proposed an adaptive frequency hopping (AFH). However, AFH is ineffective at Wi-Fi hotspots where the entire 2.4GHz spectrum is congested by multiple WLAN cells configured to orthogonal channels.[15] proposed parameters to coexisting networks to minimize mutual interference .It is only applicable to static. Another approach, called SWIFT [16] (a Split Wideband Interferer Friendly Technology) Prior work avoids narrowband devices by operating below the noise level and limiting itself to a single contiguous unused band. But this requires learning the reactions of the other systems.We note this solutions do not make assumptions for the throughput and delay time this is important parameters in coexistence also, another work operate at the application layer. However, in this work we tend to tackle the coexistence problem between the 802.22 and the 802.11af networks in an integrated way by proposed algorithm depend of frame times and operate at the MAC layer.

1.4 Aim and Objectives

- To analyze the coexistence problem between 802.11 and 802.22.
- To enhance algorithm for coexistence between 802.11af and 802.22.

- To enhance the 802.11af TVWS throughput and delay time with presence of 802.22.

1.5 Methodology

The main contributions of this work, we have worked to resolve problem of coexistence between 802.22 and 802.11 by proposing algorithm work by a frame time scheme, the basic idea of this algorithm give 802.22 opportunity to send at a specific frame time after frame time finish the 802.11 send at a specific frame time (two networks send by equal opportunity) , also we apply the proposed algorithm in three cases when 802.22 send high traffic and 802.11 low traffic, also 802.22 send medium traffic as well as 802.11 and when 802.22 low traffic and 802.11 high traffic to know the waiting time(Delay) for each of two networks in the three cases to enable coexistence without deteriorate in throughput of 802.11 and 802.22.

1.6 Thesis outline

The rest of this work is organized as follows. In chapter one, we discuss in brief the basic address of this work. We identify the second access and coexistence problem also related works are further reviewed in detail in chapter two. In Chapter three we propose the frame times coexistence frame work .chapter four presents and discussion the numerical results. We conclude the work in chapter five

Chapter Two(Literature Review)

2.1 Introduction

In recent years, the wireless industry has experienced momentous growth. The wireless communication has enabled the development of numerous innovative and user-friendly mobile platforms and mobile services, which is becoming an integrated part of our daily life. Therefore, it is not surprising to read the recent forecast of 20-30 folds increase in wireless traffic [17] by 2015, and over 1000 folds increase by 2020, the underlining assumption is that the mobile operator is able to provide enough capacity to meet the growing demand. However, it is a challenging task to achieve with a solution that is both affordable and flexible. Generally speaking, there have been three main drivers for the increasing capacity and higher data rate in wireless network: the evolution of wireless technology, the densification of base stations and the acquisition of more radio spectrum.

Traditionally, the development of wireless technology with higher spectral efficiency has contributed considerably to the improving network capacity. However, the current wireless access technology is already approaching the theoretical bound of the spectrum efficiency performance. Any further improvement would come at great cost of complexity and energy consumption.

The deployment of denser network has also been playing a key role in enhancing the system capacity. Nevertheless, the cost for building new transmitter site is increasing rapidly. It would require excessive investment to deploy a network dense enough to accommodate the predicated traffic volume by 2020. Thus, even with better technologies and denser networks, we still need a lot more spectrum than that is available today [18]. However, current static spectrum allocation policy prevents the easy access to wider spectrum due to its lengthy allocation process and high auction price, resulting in a so-called "spectrum scarcity" phenomenon. It would discourage new entrant to the wireless market and hinders the adaptation to changes in demand, market and technology. On the contrary, recent measurements have revealed that many of the allocated frequency bands are actually underutilized either spatially or temporarily.

Motivated by these facts, a novel concept for spectrum re-use, the secondary access, is developed to facilitate flexible spectrum usage by secondary service .It allows the secondary system to access the geographically or temporarily unused spectrum bands licensed to the primary service, on a non-interfering basis. To access the spectrum and protect the primary user, the secondary user must rely on cognitive techniques such as spectrum sensing or the use of geo-location database to detect the secondary access opportunity and assess its interference inflicted on the primary user.

2.2 TVWS Overview

The TV broadcasting spectrum is seen as one of the first opportunities to adopt and implement innovative and more efficient dynamic spectrum access (DSA) models supported by cognitive radio technology [6]. With the transition to digital TV (*e.g*. June 2009 in the USA), considerable amount of vacant spectrum have been generated in the TV spectrum. This group of non-contiguous vacant channels is collectively known as **TV White Spaces** (TVWS) [12]. Regulatory efforts are currently ongoing in many countries to enable secondary access to TVWS, provided that harmful interference to incumbent services is avoided.

The TVWS availability is time and location dependent and it may include the following portions of the radio spectrum: 54-72 MHz, 76-88 MHz, 174-216 MHz, and 470-806 MHz In order to improve utilization of TV spectrum, regulatory bodies around the world have been developing rules to allow operation by secondary users in these bands provided that interference to incumbent broadcasters is avoided. Thus new services may opportunistically use temporarily un-occupied TV channels. This has motivated several standardization efforts such as IEEE 802.22, 802.11af, 802.19 TG1, and ECMA 392 for furthering cognitive networking. Specifically, multiple co-located secondary networks are expected to use TVWS, each with distinct requirements (bandwidth, transmission power, and different system architecture and device types) that must all comply with regulatory requirements to protect incumbents. Heterogeneous coexistence in the TVWS is thus expected to be an important research challenge. The IEEE 802.19 Working Group (WG) has taken actions to work on the issue and the latest result is formation of a new task group (TG), 802.19 TG1. This TG has been chartered with the specific task of developing a standard for TVWS coexistence methods.There are number of wireless technologies that are likely to be deployed in the TVWS, The IEEE 802.22 WG has been developing a standard for wireless regional area networks (WRAN) in the TVWS [4] .Recently the IEEE 802.11 WG has initiated development of an amendment (802.11.af) to the 802.11 wireless local area network (WLAN) standard [5] to operate in the TVWS. Good coexistence between these different wireless network technologies means that the networks do not cause unacceptable interference to one another. Since the devices in these networks are unlicensed, like the 2.4 GHz ISM band, one of the network operators own the spectrum and they cannot prohibit use by any network owned or operated by other operators [1]. This diverse set of wireless technologies could lead to interference issues in geographic locations with a limited number of TVWS channels. The number of white space channels varies from location to location due to the number of TV stations operating in any given area. In addition, professional wireless microphones used by members of the broadcast industry may be used in a variety of venues, and since channels occupied by these wireless microphones are not to be used by WSDs (white space devices), the number of channels can be reduced even further. Also, since the usage patterns of the wireless microphones can change from day-to-day or even hour-to-hour the number of available white space channels can vary with time. If different wireless technologies, like an 802.22 WRAN and an 802.11 WLAN, are deployed in a common region there is a potential for interference. They operate on the same white space channel it is possible for either of the networks to cause interference to the other network [1], [2].

2.3 Heterogeneity and Coexistence

Heterogeneity and coexistence are a characteristic of any unlicensed band and is not unique to TVWS. However, the dynamic nature of TVWS coupled with incumbent protection requirements poses new and subtle challenges that should be considered in achieving the end goals of improved spectrum utilization. The challenges can be broadly classified into three categories: spectrum availability detection, interference mitigation and spectrum sharing [6].

2.3.1 Spectrum Availability Detection

2.3.1.1 Incumbent Detection

The CWNs must apply reliable methods to detect available TVWS. For instance, requires secondary systems to determine an available TV channel using two methods:

-White Space Database (WSD) Access: AWSD is a central repository managed by a secure and reliable authority. It stores information about primary user operations [11]. Secondary systems will query the WSD to determine availability of a TV channel while providing their own geographic locations. On receiving a query, the WSD sends information about the channels available at the specified location and allowed power levels for transmission [12] on such channels.

-Spectrum Sensing: Process of scanning the RF(radio frequency) spectrum in order to detect the presence of incumbent signals, usually above a certain sensing threshold, which defines the minimal signal level at which the incumbent signal must be detected. Spectrum sensing and WSD access will be key technologies to efficiently utilize the TVWS in most regulatory domains [12].

2.3.1.2 Incumbent Detection Challenges

Geo location and WSD access, certain secondary devices are required to self-geo locate in order to access the WSD. In fixed CWNs, the BS and CPEs will likely be equipped with satellite-based geo location [11], although an alternative over-the-air mechanism is proposed in the 802.22 standard [8]. An over-the-air option could be used as backup in areas where satellite coverage is not available. In the case of Wi-Fi-like CWNs, access points (APs) will need to implement self-geo location, in order to operate as master for lower power slave devices. In many indoor use cases, availability of satellite signals could be an issue; hence over-the-air localization techniques and cooperation with other networks are feasible options, especially given the relatively low-resolution required by the geo location mechanism [7].

-Reliable Spectrum Sensing: Proposed techniques to date can be classified in five broad categories (i) energy detection, (ii) waveform-based sensing, (iii) matched filtering, (iv) radio identification based sensing, and (v) cyclostationarity-based sensing.

Energy detection does not require any prior information about the incumbent signal, but they do not perform well in cases where the detection threshold is very low, which is the case according to the TVWS requirements. Therefore, other techniques that use (varying) side information about the incumbent signals are more appropriate for TVWS, although performance and complexity varies **[7].**

2.3.1.3 Considerations for TVWS Standards

In order to increase sensing reliability, new standards for TVWS should introduce techniques to address the sensing coordination in heterogeneous scenarios. In 802.22, the BS schedules quiet periods for sensing during which no transmission takes place. Similar methods are used in ECMA 392 and may be introduced in 802.11af. Hence, coordination and synchronization of quiet times across CWNs is one possible option. Another approach could be to use sensing techniques that take into account the transmission characteristics of other CWNs in the sensing process. Furthermore, it is important to define not only standard sensing thresholds, but also minimal sensing requirements in terms of overhead needed to meet the regulations.The heterogeneous scenarios could also enable opportunities to share capabilities amongst networks. For instance, a Wi-Fi AP may be connected to the home CPE and share the satellite interface to obtain its own location and access the WSD through the 802.22 BS [7].

2.3.2 Secondary User Detection

Future CWNs will also need to detect coexisting secondary systems operating in same or different TV channels. This will require detection of potentially different air interfaces. For instance, it will be critical for 802.11af and ECMA 392 networks to detect presence of nearby 802.22 networks since they will impose serious interference and avoid situations in which network capacity drops due to interference, while spectrum is not fully utilized. Now, we focus on detection challenges of similar and heterogeneous secondary networks [7].

2.3.2.1 Detection of Similar Networks

Coexistence of similar networks, also called self-coexistence, is considered in the scope of current standards, such as 802.22 [8]. The first step in any self-coexistence mechanism is the ability to detect neighboring networks. Otherwise, this may lead to following problems:

- Performance loss due to interference within the overlapping regions.
- Undetected asynchronous quiet periods among similar networks may result in transmission during sensing time.
- In complete discovery of neighboring networks (*i.e.*, hidden node problem) may cause data loss and impact the effectiveness of over-the-air (in-band) communication amongst networks [8]

The above problems highlight the importance of detecting similar networks, and some of the

challenges include:

- **Network discovery overhead**: Most standards include some form of beacon transmission to facilitate network discovery. The 802.22 BS transmits regular Super-frame Control Header (SCH) [8], which carry information about the cell and are transmitted using the most robust modulation/code option [12]. In the case of ECMA 392, all devices also transmit regular beacons. Similarly, 802.11af AP will also transmit regular beacons as the current 802.11 APs do. One fundamental difference in TVWS is the fact that the list of channels to be scanned may change dynamically and the frequency of scanning those channels may have to be increased due to the potential impact on incumbent.
- **Coordination and overhead of in-band signaling:** The use of common control channels to enable network discovery has been proposed before for CWNs [11]**.** However the current and standards for TVWS are not expected to support a

dedicated (out-of-band) over-the-air control channel option. Instead, an in-band signaling approach has been adopted in 802.22 and ECMA 392 based networks.

2.3.2.2 Detection of Heterogeneous CWNs

Some of the main considerations include:

- Channel bandwidth definitions by each of the coexisting networks: Channelization bandwidths vary according to different networks [7].
- Transmission signal power variations among operating standards: Some networks have users with low power requirements while others have high power users [7].
- Signal characteristics among heterogeneous PHY modes: Broadcast DTV standard specifies known pilots and/or preambles, an inherent characteristic that is exploited for effective spectrum sensing. For secondary system signals, the available characteristics will differ from one standard to another and therefore need to be known in order to apply sensing based on signal characteristics [7]. Otherwise, detection using signal characteristics is not a viable option.

2.3.4 Considerations for TVWS Standards

Some of the possible solutions that could be adopted in standard to support efficient and reliable detection of CWNs in TVWS are:

-Intelligent management of out-of-band sensing: New standards should enable intelligent management of out-of-band sensing during stations idle time together with cooperative sensing techniques. Furthermore, new standards will have to support reporting mechanisms which stations use to send spectrum utilization updates with respect to neighboring networks to a central spectrum manager or share with other peer stations in a distributed system [7].

-Preamble detection: Usually, a data packet consists of three sections namely, preamble, header, and data payload. Definition of a distinct preamble in a data packet for a CWN can help in the detection process. Correlation of received data packet preamble with known preamble sequences can be a potential solution to detection of heterogeneous networks. Lower values of correlation imply packets from undesirable networks and detection of the same [7].

-Secondary network database: A database approach for storing information about secondary systems may also help detection of fixed networks such as 802.22, but it would be less effective for low power personal/portable and peer-to-peer networks due to high mobility and need for connection to the infrastructure in order to update the database [7].

2.3.5 Interference Mitigation

Interference in the TVWS will be a challenging issue especially in areas of limited channel availability and where network coverage overlaps. Currently, heterogeneous networks share the unlicensed 2.4 GHz band, and interference among them has been subject of extensive research [19]. Similar interference problems will exist as these technologies migrate into the TVWS. However, new interference situations will evolve in the TVWS, such as that between low power personal/portable devices (e.g. 802.11af and ECMA 392) and higher power fixed systems (e.g. 802.22). Furthermore, the good propagation characteristic of TVWS may also contribute to increased interference as transmission and interference ranges increase. For instance, Wi-Fi home networks typically operating co-channel without serious performance degradation in the 2.4 GHz due to spatial reuse, could potentially experience more interference while operating in the same TV channel due to larger transmission and interference ranges. Last, interference from incumbents, mainly high power TV stations is another specific problem to the TVWS.

2.3.5.1 Interference Related Considerations for TVWS Standards

To combat the interference challenges that may evolve over time due to coexistence in the TVWS, we provide some considerations for TVWS standards Cooperative approaches can be utilized in terms of synchronization of quiet periods, sharing of sensing information as well as usage patterns between networks. Spatial diversity, in terms of multiple-input-multiple-output (MIMO) options can also be exploited with smart antenna technology to avoid interference from the direction of the interferer Receiver sensitivity threshold: This threshold needs to be considered carefully in order not to trigger the receiver on unintended signal transmissions. This implies the idea of differentiating between users in the same network and the presence of interference from different networks. The thresholds can be set based on interference patterns of coexisting WRAN, WLAN, or WMAN networks.

2.3.6 Spectrum Sharing

Avoiding operating channel overlap between CWNs is always desirable. However, given the dynamism of TVWS, it is possible that overlapping CWNs share available TVWS channels. Typical spectrum sharing solutions can be broadly classified as cooperative or non-cooperative mechanisms [20]. Cooperative schemes require coordination amongst coexisting networks. In the case of similar networks, implementation of both cooperative and non-cooperative approaches is facilitated by the fact that the networks operate according to the same PHY/MAC protocols. Inter network communication capabilities necessary for cooperative mechanisms are supported in 802.22. In heterogeneous CWNs, the spectrum sharing becomes even more challenging, when given the intrinsic differences in the protocol stacks [20].

2.3.6.1 Spectrum Sharing Challenges in Heterogeneous CWNS

Distinct MAC strategies: CWNs may operate according to different MAC techniques like time division multiple access (TDMA), frequency division multiple access (FDMA), code division multiple access (CDMA) or contention-based protocols. For instance, the 802.22 MAC is TDMA-based with PHY resources allocated on demand using OFDMA, while 802.11af will use its CSMA-based protocol and ECMA 392 uses a combination of reservation and contention based access. While 802.11af users could back-off when the medium is occupied by 802.22 transmissions, the other way around may not be true, since 802.22 devices do not need to listen before transmitting. The differences in MAC strategies may limit the effectiveness of non-cooperative list-before talk mechanism in achieving fairness in TVWS coexistence situations [7].

Inter-network communication: Currently, most MAC/PHY standards do not support over-the-air communication across heterogeneous networks, limiting the applicability of cooperative sharing strategies. One possible way is to multiplex transmissions of multiple overlapping networks in the time domain, as is done across 802.22 networks [8]. Where certain time slots are reserved for use by the 802.22 system, and others are reserved for contention-based a access(Wi-Fi clients). Although this concept seems simple, its implementation in the TVWS is not straight forward. First, it would require communication and negotiation between many competing networks. The 802.22 BS would cover a large number of 802.11 WLANs, ECMA 392 networks or other low power systems involved in the negotiation process. Second, the overhead in adapting the sharing schedule could be large depending on the number of coexisting systems and could also result in instability or convergence issues [7].

Synchronization*:* Assuming there are mechanisms that support the negotiation between heterogeneous CWNs, the implementation of such cooperative strategy would only be possible with tight time synchronization across all devices from different networks, which is a challenging problem. Although it is possible to keep tight synchronization within an 802.22 WRAN, or even across different WRANs, extending the synchronization to a potentially large number of personal/portable networks may not be possible, unless all systems and protocols are based on a universal reference clock [7].

Independent channel selection: channel selection is an implementation dependent procedure in most wireless standards. In TVWS, however, channel selection may be needed in more instances than just at network initialization [7].

2.3.6.2 Spectrum Sharing Considerations in TVWS Standards

The first step towards efficient utilization of TVWS is to avoid co-channel operation, if enough channels are available. This can only be done with reliable network discovery mechanisms for heterogeneous scenarios. Further more, being able to detect specific characteristics or operational parameter, such as priority list of backup channels, of heterogeneous CWNs would also be useful to non-cooperative channel selection strategies that avoid co-channel operation. This is achieve by exchanging information about backup channel lists, which would off course require some form of inter-network communications across heterogeneous CWNs. Another non-cooperative strategies for low power personal/portable devices is to give priority to the first adjacent channels of an active TV channel, since higher power fixed devices are not allowed on adjacent channels according to the FCC rules. In this case, the personal/portable devices would still have to reduce the maximum power (40 mW), but this could be a good trade-off to avoid potential interference from high power secondary users in the area.

In case co-channel operation cannot be avoided, non-cooperative mechanisms to avoid interference could also be applied, but the effectiveness will depend on the characteristics of specific scenario including relative location of the devices, traffic load, transmit power, *etc*. The cooperative strategies that require inter-network communication and time synchronization are the most challenging as they would require a broad standardization effort across all secondary systems. There have been some proposals for utilizing a simple common control channel across networks in the context of the 802.19 coexistence standard, but it adds extra-cost and it is unclear whether other standards will reach a consensus on the "universal" PHY mode as the coexistence control channel 70.

2.4 Wireless Standards in TVWS

This section provides a summary of five projects specifying MAC/PHY standards for TVWS.

The first TVWS standard published is from ECMA International. Standard ECMA-392, MAC and PHY for Operation in TV White Space, was published in December 2009 [21]. ECMA-392 was mainly designed for communication between personal/portable devices; specifically, in-home multimedia distribution. It supports both mesh and centralized networks. The standard defines an orthogonal frequency-division multiplexing (OFDM) PHY with modulation schemes of quadrature phase shift keying (QPSK), 16-quadrature amplitude modulation (QAM), and 64-QAM. For forward error correction (FEC), concatenation of a Reed-Solomon (RS) outer code and a convolution inner code with puncturing provides five different coding rates. Channel widths of 6, 7, and 8 MHz are supported for TV channels in any regulatory domain. The maximum data rate of ECMA-392 is 31.64 Mb/s. To protect incumbents, dynamic frequency selection and transmit power control are included in the specifications.

In 2004 the IEEE started the 802.22 projector develop a MAC and PHY to use TVWS for rural broadband services. In July 2011, the IEEE 802.22-2011standard was published [22]. Although mobility is supported, the main focus of this system is long-range communication between fixed devices. Typical range of an 802.22 fixed device can vary between 10 km to 30 km assuming outdoor directional antennas. Maximum supported range of the MAC layer is 100 km. The IEEE 802.22 standard uses a centralized topology in which a base station (BS) serves up to 512 customer premises equipments (CPE). Radio downlink is based on time-division multiplexing, whereas uplink is based on orthogonal frequency-division multiple access to support simultaneous transmission from multiple CPE units. Details of the PHY layer design are as follows. OFDM is used with a fast Fourier transform (FFT) size of 2048 to cope with delay spread for long-range links. Similar to ECMA- 392, QPSK, 16-QAM, and 64-QAM modulations are utilized and 6, 7 and 8 MHz channel widths are supported. FEC options include binary convolution code, convolution turbo code, shortened block turbo code, and low-density parity Check (LDPC). The 802.22 standard incorporates many cognitive functions, both to protect incumbents and also for coexistence among 802.22 networks. These cognitive functions include channel classification and channel set management, quiet period scheduling for spectrum amendment to the 802.15.4 wireless personal area network (WPAN) standard for TVWS operations [23].

The new 802.15.4m task group is just beginning its work and will address device command and control applications including the smart grid in the TVWS band. Targeted data rates are in the 40 kb/s–2 Mb/s range. Another design target is to achieve high power efficiency [23].

Finally, there is the IEEE DYSPAN Standards Committee (DYSPAN-SC), which addresses cognitive radio and dynamic spectrum access. DYSPAN-SC formed a new 1900.7 task group to create yet another MAC/PHY standard for

TVWS [24]. According to its project authorization request, the new MAC/PHY will enable fixed and mobile operation in white space frequency bands, while avoiding harmful interference to incumbent users. Sensing fusion of information from sensing and database. BSs follow spectrum etiquette to coexist with other networks in the area. Another related standard published by this same group is IEEE 802.22.1; this related standard enhances the protection of licensed users from interference by 802.22 systems [25].

In 2009, the popular IEEE 802.11 WLAN working group launched a TVWS project. The 802.11af task group is drafting an amendment to the IEEE 802.11 standard, including MAC/PHY modifications and enhancements to meet legal requirements for channel access and coexistence in the TVWS [26]. The completed IEEE 802.11af standard will likely utilize the OFDM PHY proposed by project P80211ac. The 802.11af task group plans to enable the use of multiple contiguous and non-contiguous channels in TVWS. In 2011 the IEEE 802.15 working group formed a new task group to develop an amendment.

2.5 Analysis of The Coexistence Problem in TVWS

In this section we examine six aspects of the coexistence problem in TVWS.

The first problematic aspect results from the use of TVWS as a public unlicensed resource. Any free public resource which is available to anyone tends to be in discriminately used until it is depleted. In the case of wireless communication this tendency manifests itself as spectrum congestion in unlicensed bands.

In that spectrum, the coexistence problem is a well recognized challenge, one that is getting ever increasing attention as new services begin to be deployed. However, the propagation characteristic of the TV spectrum (which is located below 1 GHz) is likely to significantly exacerbate this problem. Quite simply, signals in the 2.4 GHz band and especially in the 5 GHz band lose power much faster with distance than do signals below 1 GHz. The ISM signals are attenuated by the environmental obstacles (e.g., walls) significantly more than TVWS signals below 1 GHz. It is precisely these excellent propagation characteristics that make TV spectrum so attractive for many of the use cases addressed in [27]. However, these propagation characteristics also severely exacerbate the coexistence problem by greatly increasing the size and coverage area of every TVWS network cell. The much larger cell sizes tend to cover larger areas and serve many more users than smaller cells, thus increasing congestion. What was considered extraordinary congestion in the 2.4 GHz band may become a common condition in TVWS.

The second aspect of the coexistence problem is due to the multiple incompatible wireless networks that will be deployed in the TVWS. We listed a number of different MAC/PHY standards in the previous section. It is likely that Wi-Fi will take advantage of the spectrum using 802.11af. IEEE 802.15.4m-based devices may be used to enable many of the use-cases which involved machine-to-machine communication. Fixed wideband access will be provided by using 802.22-based or ECMA 392 based systems. Since these wireless networks are conformant to incompatible standards, the networks are not interoperable and hence cannot communicate over the air with each other. The benefit of increased radio propagation range also increases the area in which a TVWS transmitter may cause interference to other incompatible TVWS networks. One network's communication is perceived as interference to the other neighboring networks.

A third aspect of the TVWS coexistence problem is due to the way TVWS networks will be deployed. Individuals and competing network service providers may all deploy networks in the same area. These different operating entities deploy their networks independently and with no coordination or even knowledge about the other operators in the area. The 802.22 wireless regional area networks will be operator deployed with fixed high-power base stations serving fixed CPE and portable devices. On the other hand, 802.11 WLAN networks are commonly deployed by a consumer in the home or in small offices. It is very unlikely that the network operator will be aware of what consumer networks are deployed in any given area. Similarly, it is also unlikely that a consumer will be aware of any operator which has deployed networks in his area. If an operator deployed WRAN and a consumer deployed WLAN operate on the same TVWS channel, it is very likely that the networks will interfere with one another.

A fourth aspect of the coexistence problem is due to the spectral performance of low-cost commercial WSDs. If two networks are very close to one another and operating on adjacent channels, the interference may also cause network degradation. This can happen due to out of-
band leakage from one network spreading into the adjacent channel being used by the other network.

A fifth aspect of the coexistence problem is caused by network cells with widely varying coverage areas. Some wireless networks may be high-power networks deployed for long-range communication by network service providers, while other networks may be low-power consumer networks deployed in a less controlled manner by individual consumers. High-power long-range networks tend to use high-sensitivity receivers, while short-range networks tend to use low-sensitivity receivers. A given interference level may be harmless to short-range networks but highly disruptive to long-range networks.

The last aspect of the coexistence problem deals with the scarcity of TVWS in populated areas. TVWS operation is only permitted on TV channels not locally used by primary systems (TV broadcasts and licensed wireless microphone). In urban areas with high population density there are numerous local TV stations, resulting in a very limited number of available TVWS channels [28].

2.6 Coexistence Mechanisms

This section provides a detailed overview of the existing coexistence mechanisms, which can generally be divided into two distinct groups based on the level of cooperation among the coexisting networks.

Non-collaborative mechanisms may be used autonomously by any network or device to facilitate coexistence with other networks and devices. These non-collaborative mechanisms may be used unilaterally and do not require any action by any other system in order to be effective. Most of these non-collaborative mechanisms may be used by any radio MAC/PHY, while others, like carrier sense multiple access (CSMA), are particular to one or several MAC/PHY designs. It is important to note that for this discussion of coexistence mechanisms.

Collaboration refers to communication and cooperation between interfering spectrum users and networks. This collaboration is not related to the cooperative use of protocols to improve operation within network. In addition, use of transmit power control (TPC) as a protocol within a network may increase battery life and reduce emitted transmit power levels [29]. Effective use of TPC requires cooperation inside the network. If the network using TPC operates on the same frequency as another nearby network, the TPC will also decrease interference and thus improve coexistence. Since the use of TPC within the network does not require communication or collaboration with another network, it is considered a non-collaborative coexistence mechanism.

Two popular non-collaborative coexistence mechanisms are dynamic frequency selection (DFS) and dynamic channel selection (DCS).DFS allows spectrum sharing systems to share spectrum with existing regulatory protected systems such as radar systems, satellite systems, TV broadcasting systems, etc. The DFS concept is to detect protected devices on the operating channel and, if detected, to switch frequency to another channel.DCS enables spectrum sharing systems to select the best channel based on channel measurements [30]. A channel is regarded as an unusable channel if it has surpassed the acceptable threshold or degraded the bit error rate (BER) sufficiently. In this case there are two options; to move to a new channel or to use a more robust modulation and coding scheme.

DCS is used to minimize or avoid interference with other networks. DFS detects and switches frequency, while DCS selects the best frequency for those available. In this way, DCS is quite different from DFS. DFS and DCS are typically used together in unlicensed systems like 802.11. Listen before talk (LBT) is an effective mechanism for sharing spectrum among multiple 802.11 systems using different modulations [30]. The concept of LBT is that before transmitting over a shared channel, a transmitter decides if the channel is in use by using a clear channel assessment (CCA) check. During CCA observation time the energy in the channel is measured and compared to an energy detection threshold (EDT). If the energy level in the channel exceeds the predefined threshold, a transmitter must defer its transmission by an arbitrary time. In addition, LBT limits the maximum contiguous transmission time so that a transmitter provides reasonable opportunities for other transmitters to operate. Modifying EDT is also an autonomous coexistence mechanism that affects the performance of CSMA and LBT. For transmit purposes, decreasing a network's EDT may serve to desensitize the network's receivers by desensitizing the CCA function. As the EDT is raised, additional "clear" channel time becomes available since low-energy packets on the channel are not detected. Clearer channel time provides more channel time for network transmissions. Similarly, increasing the EDT may decrease the radio range of the network receivers, since low energy packets from network nodes are not detected or received. This has the effect of decreasing the network coverage area, decreasing the number of served network nodes and thus decreasing the network traffic load. Increasing EDT has the indirect negative effect of increasing interference to the neighboring networks by permitting network transmission during periods when the neighbor network is transmitting packets which are received at energy levels below the EDT threshold. Finally, certain networks are equipped with directional antennas. Using multiple or steerable directional antennas for transmission decreases interference when compared to the use of an Omni-directional antenna. A transmitting Omni-directional antenna radiates energy in all directions, not only in the direction of the intended recipient. When transmitting with a directional antenna, energy is radiated only in the direction of the intended recipient, thus decreasing the interference in all other directions. This space division mechanism may be applied autonomously to decrease interference between networks.

Non-collaborative mechanisms are generally sufficient to promote coexistence in systems with adequate spectrum resources so that separate operating frequencies may be used by each network. The real coexistence challenge materializes when the available TVWS spectrum is insufficient to provide a separate operating frequency for each network or MAC/PHY design [29]. In the TVWS bands, this is a likely scenario due to the proliferation of unlicensed device designs and high consumer adoption, particularly in dense metropolitan areas where many TV channels are occupied by licensed broadcasters. With the exception of CSMA, non-collaborative coexistence mechanisms do not enable channel sharing. Yet channel sharing is required for coexistence where spectrum is limited.

In the TVWS bands, the spectrum is expected to be quite limited in densely populated areas served by many TV broadcasters. The collaborative mechanisms channel sharing to further enhance coexistence. The sharing of spectrum by networks requires that the networks agree on the operating parameters to enable spectrum sharing.

The partitioning of the available spectrum bandwidth or time between two networks is complex and should equitably consider the individual network traffic demand, priority, and user scenarios [31].

Collaborative mechanisms improve throughput for all networks in the shared spectrum. Also a collaborative time-division multiple access (TDMA) coexistence mechanism is the Contention Beacon Protocol (CBP) of the 802.22 standards. The CBP enables the sharing of a channel with other 802.22 systems (or possibly with other TDMA MAC/PHYs using scheduled operation). The CBP is best-effort protocol based on coexistence beacon transmissions, and can be exchanged between 802.22 systems over the air interface or through the backhaul. The CBP consists of two different modes: Spectrum Etiquette (SE) and on-demand frame contention (ODFC) [32].

In the SE mode, each 802.22 system tries to choose a channel which will minimize interference to neighboring systems. If there are not enough channels for each 802.22 system individually, the ODFC mode is initiated so that several 802.22 systems can share the same channel on a frame-by-frame basis. In the ODFC mode, the contention numbers are randomly generated by each neighboring 802.22 system and the winner with the smallest contention number has a right to access the frame.

Collaborative mechanisms depend on the ability to exchange information between heterogeneous networks, for example network characteristics and traffic load information, and to use this information to negotiate the partitioning of the shared channel. When the operating parameters (time assignment, frequency partitioning, power partitioning, and space partitioning or code assignment) are agreed, the channel may be cooperatively shared [33]. The exchange of information for coexistence requires a means for two heterogeneous networks to communicate with each other, either directly or indirectly mechanisms.

2.7 Related Work:

To enable coexistence of heterogeneous system on TVWS, 802.19.1 Coexistence system considers 5 types of logical entities both internal and external and interfaces between them, among entities internal to the coexistence system Coexistence Manager (CM) is responsible for making coexistence related decisions. This includes generating and providing corresponding coexistence requests /commands and control information. Another responsibility of the CM is discovery of and communication with other CMs, also Coexistence Enabler (CE) is responsible for the communication between the CM and TVWS network. It obtains information required for coexistence from the TVWS or TVWS network and it translates reconfiguration requests/commands and control information received from the CM into network-specific reconfiguration requests/ commands, in addition to Coexistence Database and Information Server (CDIS) collects and aggregates information related to TVWS coexistence and provides this information to the CMs. First external entity considered in the system architecture is TVWS network for which the system is designed. Second external entity is the TVWS database, which is mandated by regulators, contains the location, operating area and schedule for all protected licensed networks, and provides lists of available TVWS channels to networks. But this system requires all the networks operating on TV white spaces to have a common interface to access the coexistence database and the channel allocation will be scheduled by a centralized entity (coexistence manager)[34].

Recently in [35], we present independent framework to enable exchange of information relevant for coexistence based on two mechanisms: centralized and distributed. Both mechanisms introduce the use of multi radio cluster head equipment (CHE) as a physical entity that acquires relevant information, identifies coexistence opportunities, and implements autonomous coexistence decisions. The major conceptual difference between them lies in the fact that the centralized mechanism utilizes coexistence database(s) as a repository for coexistence related information, where CHEs need to access before making coexistence decisions. On the other hand, the distributed mechanism utilizes a broadcast channel to distribute beacons and directly convey coexistence information between CHEs. Furthermore, we give a concise overview of the current activities in international standardization bodies toward the realization of communications in TVWS along with measures taken to provide coexistence between secondary cognitive networks. But the proposed framework required either a coexistence database or the use of multi radio cluster head equipment.

There are related works focused on the scenario of 2.4 GHz ISM band addressing the coexistence problem between Wi-Fi and Zigbee networks. In [13], we propose a new paradigm, called Cooperative Busy Tone (CBT) that enhances the mutual observability between ZigBee and Wi-Fi, thereby improving their coexistence. CBT builds atop the legacy ZigBee MAC, but allows the clients to cooperatively strengthen their visibility to Wi-Fi, CBT designates a separate node (either a ZigBee client closer to the Wi-Fi transmitter, or a dedicated high-power ZigBee transceiver) as a signaler that emits the busy tone. The busy tone harbingers the actual data transmission, and continues throughout the DATA-ACK transmission, so as to prevent Wi-Fi preemption. In this work it requires the Zigbee node to send a busy-tone with a much higher power than the Zigbee transmission. However, in TVWS it is not practical for the low device to transmit a higher power due to the regulations.

The IEEE 802.15.2[14] proposed an adaptive frequency hopping (AFH) mechanism to smooth the coexistence among incompatible MAC/PHY protocols, such as Bluetooth/ZigBee and Wi-Fi. However, AFH is ineffective at Wi-Fi hotspots where the entire 2.4GHz spectrum is congested by multiple WLAN cells configured to orthogonal channels. AFH also incurs substantial overhead to a ZigBee WPAN, as the network coordinator needs to scan the entire 16 channels and re-establish connections with clients. This problem becomes more pronounced in a dynamic network with mobile Wi-Fi nodes and burst interference. Alternatively, coexistence can be arbitrated in space by adjusting the transmit power and carrier sensing threshold. Gummadi et al. [15] proposed a policy framework that as signs such parameters to coexisting networks, so as to minimize mutual interference. This framework requires an arbitrator that can communicate with different network devices. It is only applicable to static networks, as any node movement would require the arbitrator to re-initiate a spectrum survey and re-allocate the parameters. Another approach, called SWIFT [16] (a Split Wideband Interferer Friendly Technology) the first system where high-throughput wideband nodes are shown in a working deployment to coexist with unknown narrowband devices, while forming a network of their own. Prior work avoids narrowband devices by operating below the noise level and limiting itself to a single contiguous unused band. While this achieves coexistence, it sacrifices the throughput and operating distance of the wideband device. In contrast, SWIFT creates high throughput wireless links by weaving together non-contiguous unused frequency bands that change as narrowband devices enter or leave the environment. This design principle of cognitive aggregation allows SWIFT to achieve coexistence, while operating at normal power, and there by obtaining higher throughput and greater operating range. But this requires to learning the reactions of the other systems to make a coexistence decision, which incurs high implementation complexity.

We note this solutions do not make assumptions for the throughput and delay time this is important parameters in coexistence also, this solution operate at the application layer .however, In this work we tend to tackle the coexistence problem between the 802.22 and the 802.11af networks in an integrated way by proposed algorithm depend of frame times and operate at the MAC layer.

2.8 Chapter Summary

In this chapter we talked in general about TVWS this is anew frequency with the transition from analog to digital TV amount of vacant spectrum have been generated in the TV spectrum[1]. This group of non-contiguous vacant channels is known as **TV White Spaces and works in** the following portions of the radio spectrum: 54-72 MHz, 76-88 MHz, 174-216 MHz, and 470-806 MHz [2]. In this frequency There are number of wireless technologies that are likely to be deployed like ECMA-392 standard , MAC and PHY for Operation in TV White Space, was published in December 2009 [21] , in 2004 the IEEE started the 802.22 projector develop a MAC and PHY to use TVWS for rural broadband services[22]. The new 802.15.4m task group is just beginning its work and will address device command and control applications including the smart grid in the TVWS band [23], IEEE DYSPAN Standards Committee (DYSPAN-SC) which addresses cognitive radio and dynamic spectrum access [24], in 2009, the popular IEEE 802.11 WLAN working group launched a TVWS project. The 802.11af task group is drafting an amendment to the IEEE 802.11 standard, including MAC/PHY modifications and enhancements to meet legal requirements for channel access and coexistence in the TVWS [26]

some problem can occur while coexistence between this different networks like the use of TVWS as a public unlicensed resource, the coexistence problem is due to the multiple incompatible wireless networks that will be deployed in the TVWS, coexistence problem is due to the way TVWS networks will be deployed, individuals and competing network service providers may all deploy networks in the same area, the spectral performance of low-cost commercial WSDs network cells with widely varying coverage areas and the scarcity of TVWS in populated areas[27][28].

But there are some solution proposed to coexistence like non-collaborative mechanisms and collaborative mechanisms. Collaborative mechanisms improve throughput for all networks in the shared spectrum like collaborative time-division multiple access (TDMA) also some related work tried to solve this problem by different way such as the 802.19.1 protocol

Chapter Three(Methodology)

3.1 Introduction

In this chapter, we will present scenario of coexistence between the two networks (802.11afand 802.22) also we defined number of components in scenario and values used in simulation to get to result in addition show the two algorithms and implementation in three different cases to send data and see the results consist of six different scenarios to compare between two algorithms to show the best algorithm in aspect of delay and throughput.

3.2 Simulation Scenario

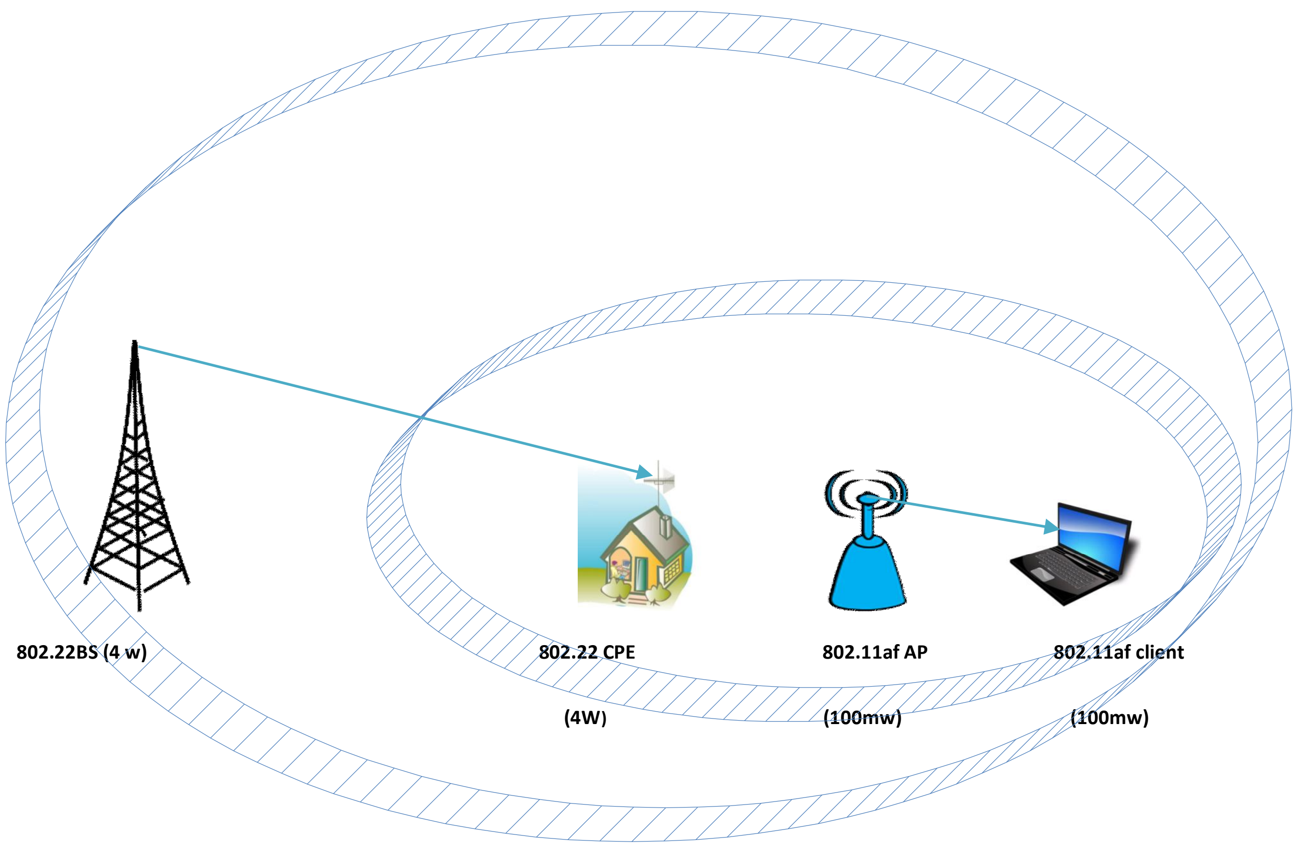


Figure 3.1coexistence Scenario

- **A: 802.22 Base Station (BS)** **C: 802.11af access point**
- **B: 802.22 CPE** **D: 802.11af client device**

3.2.1 System Model

We assume there is an 802.22 network deployed in the same geographical areas as multiple 802.11af networks, each 802.22 device (Base Station/Customer Premises Equipment) is equipped with two antennas. The TX/RX antenna is Omni-direction antenna at the BS and direction antenna at the CPE. The sensing antenna is Omni-direction antenna at both the BS and the CPE. All the 802.22 devices are operating with maximum power of 4 W and operating on the same 6 MHz TV channel with TDMA at the MAC layer. All the 802.11af devices are operating with a maximum power of 100 mW. Although by combining adjacent TV channels, the 802.11af can use a bandwidth of up to 40 MHz and operating in the MAC layer with CSMA mode.

3.2.2 Simulation Setup:

We assume the 802.22 CPEs are uniformly distributed around the 802.22 BS, so we need to consider only one 802.22 BS and one CPE in the simulation. The network topology is shown in Fig. 2. We randomly generate one 802.11af AP and one 802.11af client.

In the MAC layer, we implement a simplified version of the MAC protocols. For the 802.22 network, nodes transmit without carrier sense the channel (TDMA). For the 802.11af network, nodes transmit after carrier sense (CSMA). In the physical layer, we consider the power of 802.22 is 36 dBm, the power of 802.11af is 20 dBm.

In the simulation we vary the traffic load of both networks from zero to 1.0, and we will apply two algorithms one of this algorithm use the technique of busy tone another algorithm use the technique of frame time and we use data rate and frame size to calculate the delay of both networks, we apply the two algorithm in three case:

1) When CPE transmitting data with high traffic load .9 at the same time 802.11 low traffic load .1.

2) When CPE transmitting data with medium traffic load.5 at the same time 802.11 medium traffic load .5.

3) When CPE transmitting data with low traffic load .1 at the same time 802.11 high traffic load .9.

We apply the two algorithms in this three case to find the best algorithm to improve the performance of each of the networks to coexist in TVWS, and we compare the delay of two algorithms for each network under six scenarios:

1) 802.11 throughput when coexistence with 802.22 if we use algorithm one.

2) 802.11delay when coexistence with 802.22 if we use algorithm one.

3) 802.22 delay when coexistence with 802.11 if we use algorithm one.

4)802.11 delay when coexistence with 802.22 if we use algorithm two.

5)80.22 delay when coexistence with 802.11 if we use algorithm two.

We will describe the algorithms is now more widely.

3.3 Simulation assumption

	802.11 af (WLAN)	**802.22(WRAN)**
Data rate	12 Mbps	22.69 Mbps
Frame size	18432 Bits	22690 Bits
Frame duration	1536 µs	10 ms

Traffic load	0.1 , 0.5 , 0.9	0.1 , 0.5 , 0.9
Probability with busy tone	0 to 1	0 to 1
Probability without busy tone	0 to 1	0 to 1

3.4 Algorithm one (is based on a busy-tone scheme implemented on the 802.22 CPEs)

The basic idea of this algorithm is to use Busy Tone scheme to solve the problem of coexistence between the two networks. The busy tone scheme is apply in the 802.22 CPE. When the 802.22 receiver can receive packet with its receiving antenna while transmitting the busy tone with its sensing antenna at the same time, the power of the busy-tone to be 100 mW, which is the same as the power of the 802.11af devices to be sensible by the 802.11af devices. In this case 802.11af transmitter can be a hidden terminal that interferes with 802.22reception, algorithm one solve this case based on busy tone scheme as follows:

When the 802.22 transmit to CPE the CPE at the same time sends power by 100mw (busy tone) in this case the 802.11 can not be send as a result of presence of busy tone so every time try to send prevent from transmission (denial of service) , 802.11 can not send without CPE send all data or all frames.

To find out the effect of this algorithm in general on 802.11 we calculate the throughput in three cases:

Case one: when 802.11 only occupying the entire channel

$$T(only) = Ge^{-G} \quad \text{...} \quad (3.4.1)$$

Case two: when 802.11and 802.22 coexistence with busy tone

$$T\left(\frac{W}{BT}\right) = p\left(\frac{W}{BT}\right).T(only) \qquad \text{..} (3.4.2)$$

Case three: when 802.11coexistence with 802.22 without busy tone

$$T\left(\frac{W0}{BT}\right) = p\left(\frac{W0}{BT}\right).T(only) \qquad \text{..} (3.4.3)$$

T = Throughput

G = Traffic load

$T\left(\frac{W}{BT}\right)$ = Throughput with busy tone

$T\left(\frac{W0}{BT}\right)$ = Throughput without busy tone

$p\left(\frac{W}{BT}\right)$= probability with busy tone

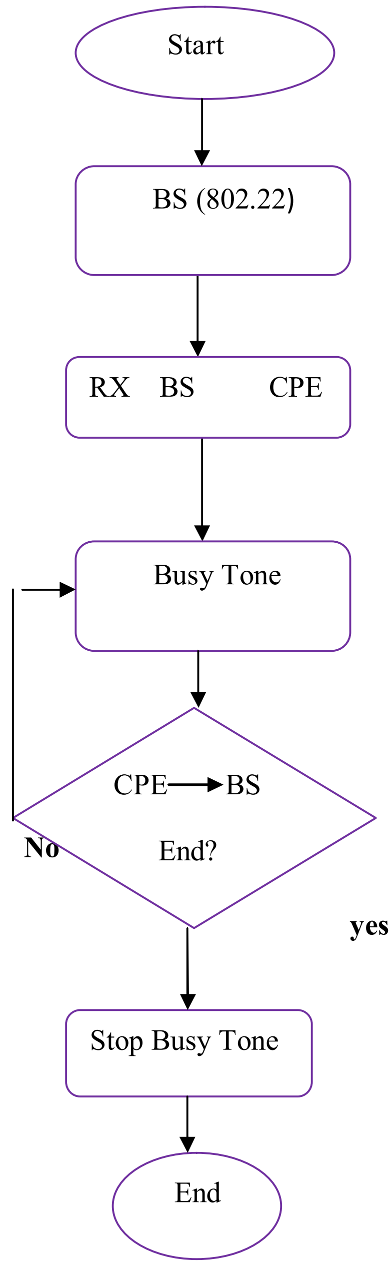
$p\left(\frac{W0}{BT}\right)$ = probability without busy tone

Also we calculate the delay of 802.11to knows the waiting time; even CPE send all their data by the equation:

Delay of 802.11(with busy tone) = Throughput of 802.22 (with busy tone)/data rate 802.22 …(3.4.4)

When we calculate delay of CPE we find that equal zero because CPE do not wait; at any time receive data from 802.22 send busy tone. We find that, the 802.11 waiting too much even CPE send all frames there for, this algorithm reduces the throughput of 802.11.

Algorithm One Coexistence With Busy Tone Scheme (existing solution)



3.5 Algorithm Two (based on a frame time scheme implemented in 802.22 CPE)

In this work we propose algorithm depend of frame size for each of the CPE and 802.11 in this case there is a specific frame time for each network, so the 802.11 do not wait until CPE send all the data or frames but wait for a specific frame time and then transmission chance move to the 802.11, we note in this algorithm the sending technique be a variable between two networks. Also, we find that 802.11 waiting a specific number of frame duration of CPE and also CPE waiting specific number of frame duration of 802.11.

By the clear manner, we find that this algorithm reduced the waiting time of 802.11 this lead to reduced delay.

So the accounts have been as follows:

When the frames number of 802.11 is less than or equal frames number of CPE:

Delay802.11=frame number of 802.11*(1536*10^-6)……………………….. (3.5.1)

When the frames number of 802.11 is more than frames number of CPE:

Delay802.11=frame number of CPE*10^-3…………………………… (3.5.2)

When the frames number of CPE is less than or equal frames number of 802.11:

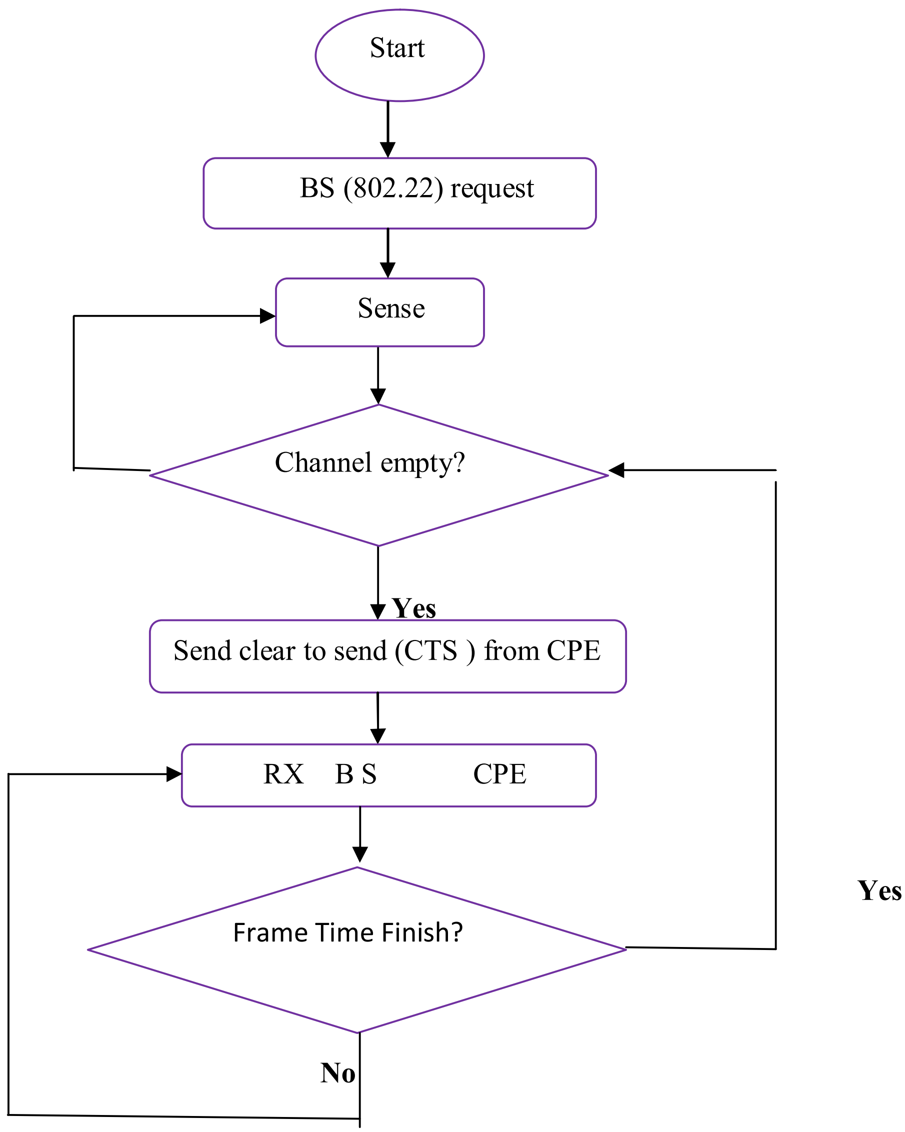
Delay CPE=frame number of CPE*10^-3…………………………….. (3.5.2)

When the frames number of CPE is more than frames number of 802.11:

Delay CPE=frame number of 802.11*(1536*10^-6) ………………... (3.5.3)

From this equation we can conclude the waiting time (Delay) for each of the two networks and the throughput. We will see the impact of this algorithm on each of the two networks by using the frame time in the three cases (high traffic, medium traffic, low traffic) to see how the algorithm is improved in the performance of 802.11 and reduced waiting time of 802.11, at the same time do not reduced CPE performance, also we note the performance of the two networks performance of the two networks nearest to be equally.

Algorithm Two Coexistence With Frame Time Scheme (our solution)



3.6 Chapter summary

To enable coexistence between two different networks in TVWS we assumption scenario for coexistence consist of one base station(802.11af), customer premises equipment(802.11af), access point and personal computer(802.22) also we apply two algorithm ,one algorithm work by busy tone scheme another algorithm work by frame time scheme. In scenario assuming three cases when 802.11 send low traffic while 802.22 high traffic, 802.11 send high traffic while 802.22 low traffic and 802.22 send equal data of 802.11, we can show result of each algorithm in aspect of delay and throughput.

Chapter Four(Simulation and Result)

4.1 Introduction

This chapter show the results and discussions, we can see results of algorithm one when we apply in two networks in aspect of throughput and delay for 802.11 and delay for 802.22 also we apply algorithm two in each of 802.11 and 802.22 to show the 802.11 throughput enhancement and reduce the waiting time for 802.11.

4.2 Numerical Results

The general idea of this work , we apply the two algorithm to given the results which contain all of them on the relations between the throughput and delay by using the traffic load and find the traffic load in three cases:

Medium traffic=solid line

High traffic=dotted dash line

Low traffic=dotted line

Also we assume the probability from zero to one

4.3 Results of Algorithm One (busy tone scheme)

In general we will show the impact of the first algorithm when applying the busy tone scheme in the 802.11.

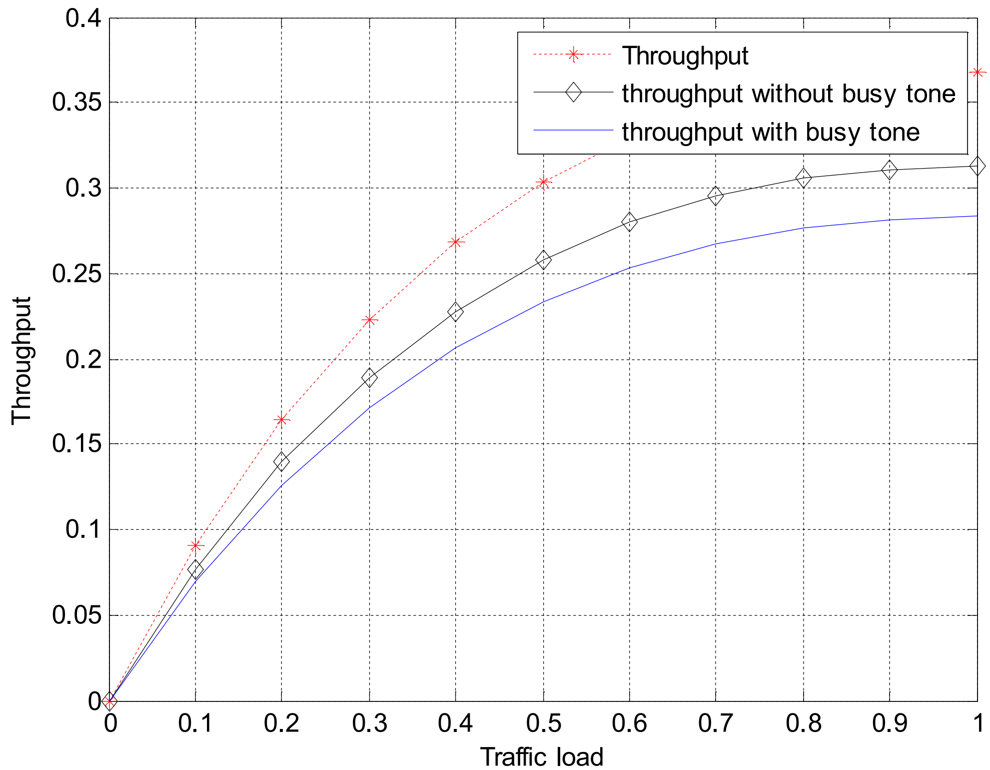


Figure 4.1 show the effect of busy tone scheme in 802.11 only also coexistence

with and without802.22and only

In Figure 4.1, we fix the traffic load of 802.11 network within zero to one and we assume probability without busy tone equal 0.85 and probability with busy tone equal 0.15 , we can see that when using the busy tone scheme and 802.11 is only occupying the entire channel the throughput equal 0.37 and the throughput of 802.11 when coexistence with 802.22 is equal 0.28 also in case 802.11 and 802.22 coexistence without busy tone the throughput is equal 0.32 , so we can note when use busy tone the throughput of 802.11 is deteriorate by a notable way.

Now we can see the impact of this algorithm on each of 802.11 and 802.22 based on delay in three cases:

1) When 802.22 transmitting data with high traffic load0 .9 at the same time 802.11 low traffic load 0.1.

2) When 80.22 transmitting data with medium traffic load0.5 at the same time 802.11 medium traffic load 0.5.

3) When 802.22 transmitting data with low traffic load 0.1 at the same time 802.11high traffic load0.9.

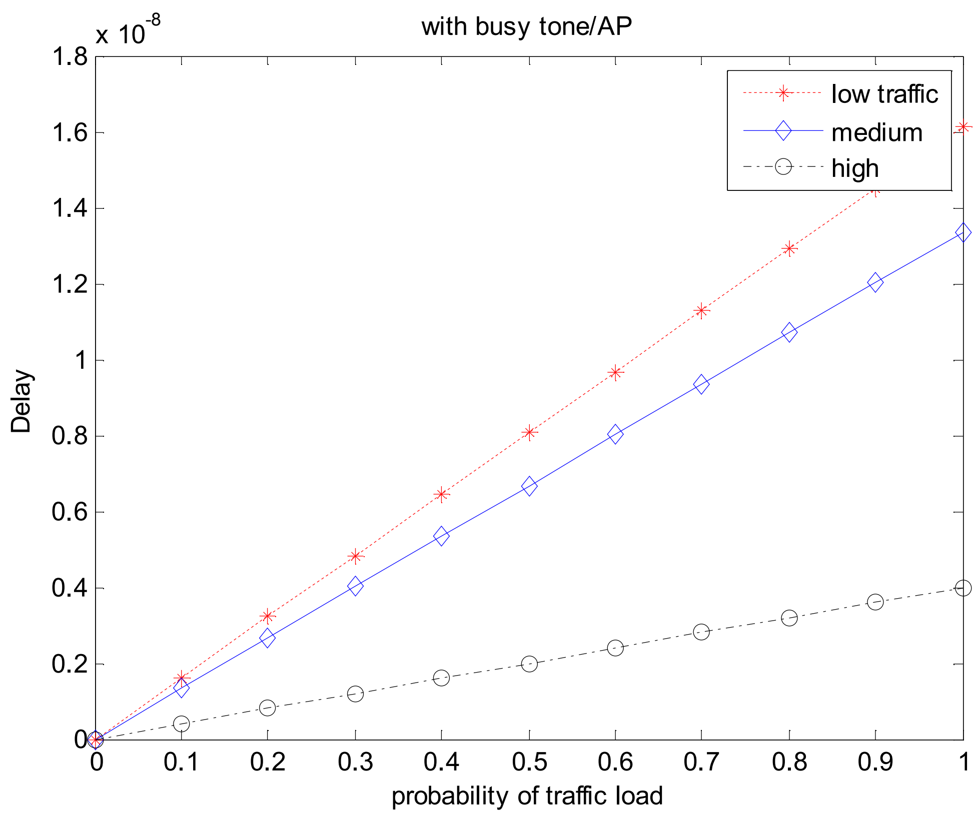


Figure 4.2 show the effect of busy tone scheme in 802.11when coexistence with 802.22 in three cases (high, medium and low traffic)

In the above Figure 4.2 , when 802.11 send 0.1 traffic load and 802.22 send 0.9 traffic load we find that the waiting time of 802.11will be along time(1.62*10^-8) even to 802.22 send all data or frames.

In the second case 802.11 send 0.5 traffic load as well as 802.22 so the waiting time will decrease from(1.62*10^-8 to 1.38*10^-8) because the traffic load of 802.22 decrease from 0.9 to 0.5 so we find the waiting time of 802.11 equal transmission time of 802.22 to transmit all data.

We will find this case is the best case for 802.11 when 802.11 send 0.9 traffic load and 802.22 send 0.1 traffic load this is because the 802.11 waiting few time (.4*10^-8) and 802.22 send low traffic .there for, send busy tone for a short period after that 802.11 can send their data.

In the aspect of 802.22 delay we find that the 802.22 do not waiting any time but at any moment receive data from any base station you can re transmit this data by send busy tone so this work do not contain fig of delay for 802.22.

4.4 Results of Algorithm Two (frame times scheme)

Now we will analyze the result of algorithm two which is depend of frame time to know how algorithm two improve the delay on 802.11 .

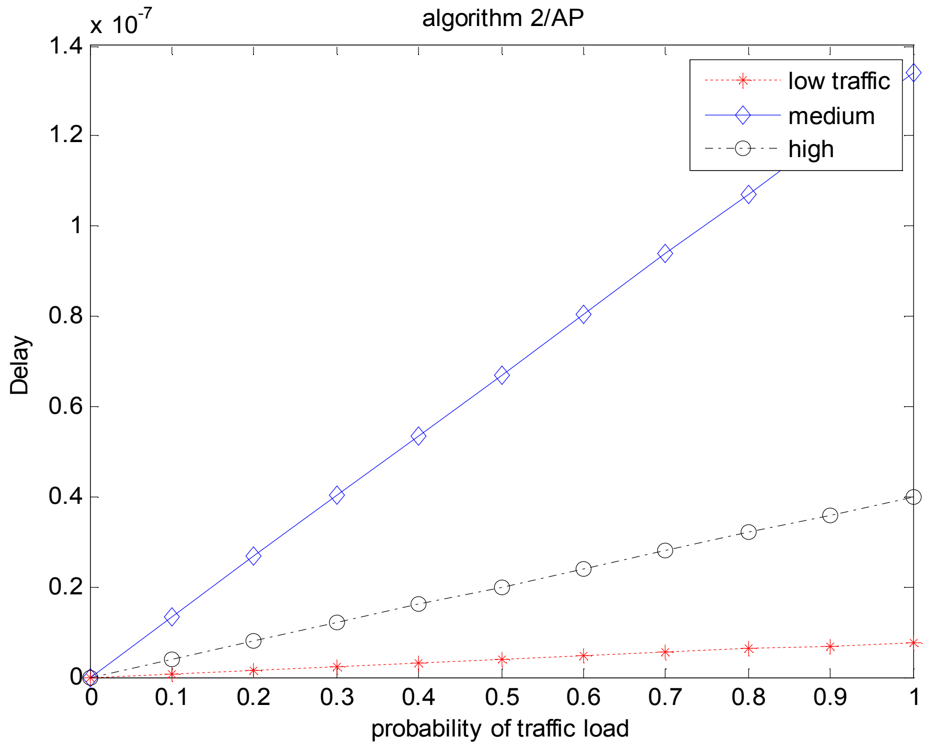


Figure 4.3 show the effect of frame time scheme in 802.11 when coexistence with

802.22 in three cases (high, medium and low traffic)

Figure 4.3 show different results for the delay when we send 0.9 traffic load from 802.11 and 0.1 traffic load from 802.22 we can see the value of traffic load is (0.4*10^-7) and if 802.11 send the same amount of data from 802.11 the value of delay equal 1.38 in the last case we note algorithm two improved in the delay time when 802.11 send 0.1 traffic load and 802.22 send 0.9 traffic load in this case we note the delay time is improved to (0.14*10^-7).

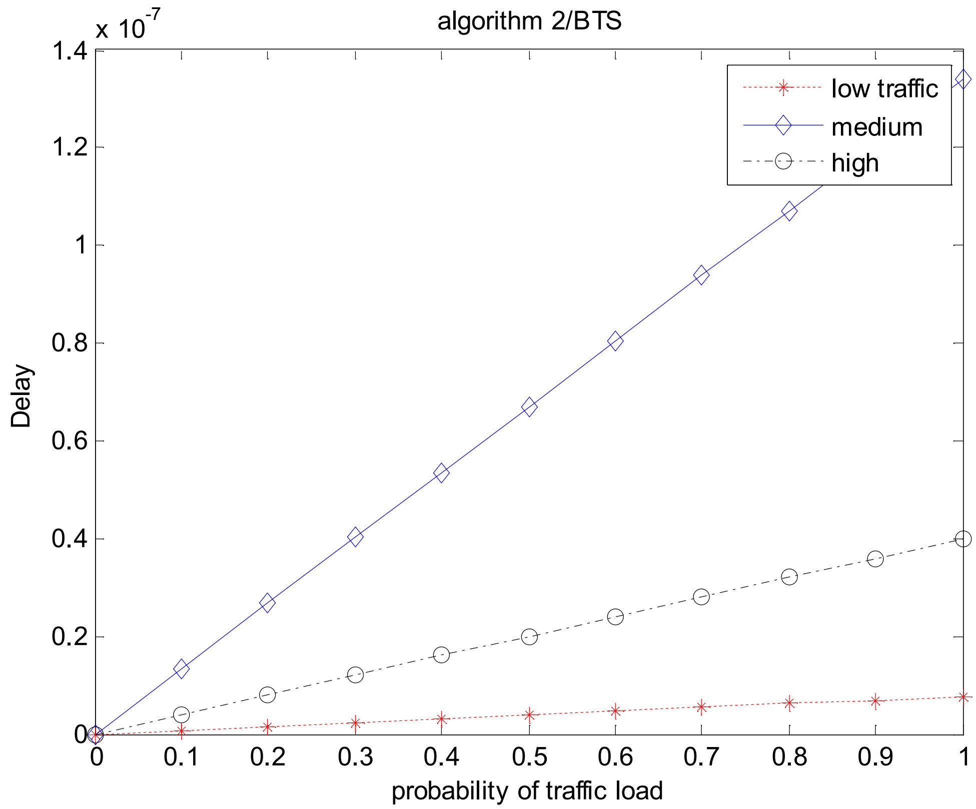


Figure 4.4 show the effect of frame time scheme in 802.2when coexistence with 802.11 in three cases (high, medium and low traffic)

The last figure show the result of delay in three cases, when 802.11 send data more than 802.22 (0.9 to 0.1) and when 802.11 send data equal to 802.22(0.5 to 0.5) finally if 802.11 send data less than 802.22 (0.1 to 0.9) in this cases the values of the delay is in order (0.4, 1.38 and 0.14) we can note this values is the same values which apply the algorithm two in case access point.

4.5 Chapter summary

After we apply two algorithm we can note, when we apply algorithm one the 802.22 after send all data the 802.11 can get chance to send so the delay time for 802.22 equal zero this increase delay time of 802.11 and decrease the throughput, and when we apply algorithm two the throughput of 802.11 enhancement because we assume a frame time for each networks so the two networks work by equal chance and equal delay time for each network, so we note the algorithm two enhance in the throughput of 802.11 by a clear manne

Chapter Five(**Conclusion and Recommendation**)

5.1 Introduction:

In this work we apply each of two algorithms on to CPE, one algorithm use busy tone scheme and other use frame times to know the effect of each algorithm on 802.11 based on the delay or the waiting time of 802.11 to send the data in three cases (low traffic, medium or high) so in this chapter we will know what are the best algorithm through conclusion and contain recommendation.

5.2 Conclusion:

We find when we apply the first algorithm the 802.11 throughput decrease because do not send data when 802.22 send all data , so we note this algorithm increased the waiting time of 802.11 but 802.22 waiting time equal zero, but when we apply algorithm the basic idea of this algorithm depend of frame time we find 802.11 waiting time decrease by a clear manner at the same time 802.22 waiting time do not increase by a notable way there for, the second algorithm improved the throughput and delay time of 802.11

5.3 Recommendation:

This algorithm until this time is the idea, also we need to work test for protocols, so we need more research in this work.

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