FACULTY OF COMPUTING AND INFORMATION MANAGEMENT

FRAMEWORK FOR BANDWIDTH SHARING AND REUSE IN IPTV DEPLOYMENT VIA WIRELESS SPECTRUM

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Declaration

I, Pius Cheruiyot, declare that this thesis titled, "*Framework for bandwidth sharing and reuse in IPTV deployment via wireless spectrum*" is my original work and has not been previously published or submitted elsewhere for award of a degree. I also declare that this document contains no material written or published by other people except where due reference is made and author duly acknowledged

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Abstract

The current evolution of technology in the recent past, television is geared to take a different turn from its traditional form of distribution which has been labeled ‘analogue’ to digital transmission via wireless connection.

The evolution of broadband networks has enabled the deployment to IPTV viable. For the IPTV to be successfully implemented there must be a high capacity and excellent performance without packet loss and delays.

Bandwidth is a key constraint in video distribution of IPTV (both live TV and video on demand) technologies; therefore an increase bandwidth utilization mechanism should be put in place.

This research paper addresses key aspects of bandwidth utilization via spectrum sharing and reuse among the key players in the industry. Sharing of spectrum entails several techniques which includes administrative, technical and market-based as noted by Philip V. D., Yvon G., Djamal, Z (2012)

Time, space and geography are ways in which sharing of spectrum can be done.

RF (radio frequency) spectrum is very important infrastructure for communication in wireless and its operation calls for issuance of licenses by a national monitoring whereby in most cases it’s the government.

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At last but most, this thesis is dedicated to my lovely family. Without your love and support, this research would have been impossible.

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Abbreviations and Acronyms

IPTV Internet protocol television

DTH direct to home

FWA federal wide assurance

CPE consumer premises equipment

QAM Quadrature amplitude modulation

RFID Radio Frequency Identification

TDD test driven development

FDD future driven development

LTE long term evolution

UWB Ultra wide band

NFC Near-Field communication

AMC Adaptive Modulation and Coding

XG Next Generation

EM Electromagnetic

E3 end to end efficiency

CPC Cognitive Pilot Channel

CBR Constant Bit Rate

RTP Real-time Transport Protocol

ITU International Telecommsunication Union

SDR Software Defined Radio

IP Integrated Project

QOS Quality of service

CRC cyclic Redundancy Check

UDP user datagram protocol

TxId Transmission identity

CMDA Code Division Multiple Access

CR cognitive radio

ASIC Application specific intergrated circuits

DTT digital terrestrial television

IP Internet protocol

DSLAM Digital subscriber line access multiplexers

FTTH Fibre-to-the home

BS base station

SAS Statistical Analysis Software

CMTS Cable Modem Termination system

HFC hybrid fiber coaxial

CHAPTER ONE

Introduction

IPTV is a system that is can of receive, decode and display compressed images distributed as internet protocol (IP) packet, *Simpson and Howard (2007)*

To transmit IPTV, good performance internet connectivity with less loss of data is required and decreases in variance connection delay or the service will dysfunction.

2Mbps/channel to 8Mbps /channel (for HDTV)is the typical bandwidth need for IPTV and requires a good quality of service support via broadband connections.

The best method to provide IPTV to clients comfortably is through use of fiber all the way to their premises which can be an expensive affair. Broadband upto 1Giga bytes per second can be supported and user with 30-75Mega bytes per second is allowed via fiber

IPTV playback needs a connection to a television via cable Tv or setbox. For streaming of videos , compression of pictures to Mpeg is done

1.1 Problem definition

The main issue in IPTV is delivery of packet timely and in correct format thus makes it sensitive to delays and packet loss. Good quality of service for IPTV depends on the bandwidth speed of the network connection thus facilitating the correct no. of frames per second to get moving pictures. This implies that, for a big IPTV clientele, the limited broadband speed and bandwidth available can lower the quality of service delivered. Good and reliable broadband infrastructure and mechanisms should be present so as to facilitate quality service.

As opposed to the analogy multiplexed delivery, IPTV channel list is transmitted one at a time to the use as a result of limitation to bandwidth.

High speed of bandwidth is required during distribution of multimedia. High speeds of bandwidth results to good quality or a lot of media being transmitted via the network. The quest for low bandwidth and good quality drives has made the media compression industry to tirelessly search for reliably and most convenient methods of sharing and utilizing the bandwidth use.

1.2 General objective

The specific objective for the research is establishing if spectrum on wireless network can be shared to fully utilize the bandwidth in implementing IPTV because of minimal usage of channel bands in the current allocation of frequencies

Second objective is to envision a broad range of sharing which can be achieved using two approaches Opportunistic sharing and Negotiated sharing

The third objective of the research is to test and validate the framework

1.3 specific objective

To understand the consequenses of emerging IPTV broadcasting technologies around the world, it is important to examine a global overview, from digital distribution of television on various platforms - the threats and opportunities of converging communications for conventional broadcasters, independent production companies and information technology businesses.

With the developments and rapid technological advances in broadcasting video and audio content being delivered over the Internet, it is important to look at the advantages and threats that impact IPTV. The threats are based around the struggle and control over cultural knowledge and representation within technological structures including the rapid distribution platforms that the world wide web provides.

In order to understand the implications of developing IPTV broadcasting technologies , it is important to examine a global overview, from digital distribution of television on various platforms - the threats and opportunities of converging communications for conventional broadcasters, independent production companies and information technology businesses.

CHAPTER TWO

LITERATURE REVIEW

A backhaul microwave networks are used for a a lot of applications, the paper seeks to focus mainly on the demand for backhaul facilities to support the accelerated growth of cellular networks and broadband access systems at frequencies up to 28 GHz. Use of microwave technologies for point-to-point access communications, and its associated demand for spectrum *Johnson(1999).*

Networks baded on fiber optic has been developed to service public telephones,data networks, Internet traffic transmission, inter-city carriage of television programming to cable TV head-ends and to DTH broadcasting satellite gateways, as well as to meet other d The role of heavy-route, livery needs on regional and national areas. long-haul microwave radio systems in certain bands below 10 GHz, such as the 4 and 6 GHz bands, has been replaced mostly by large fiber-optic systems. These systems are able to expand their transmission capacity with the adoption of new generation optical multiplexers and repeaters, and advanced signal processing techniques.

There have been similar initiatives undertaken by incumbent telecom carriers, local cable operators and new telecom entrants to build a wide range of fibre-optic systems in urban areas and surrounding communities to complement traditional copper and coaxial distribution facilities for residential and business customers.

As for microwave facilities, there has been considerable activity of rolling out point-to-point links in the 23 Giga Hertz and 38 Giga Hertz bands to serve large business customers as highlighted *O'Driscoll (2000)*

Point-to-multipoint spectrum below 6 GHz has been gradually assigned for FWA broadband access. FWA to households has not been economically viable in the 24 GHz to 38 GHz range due to the historic lack of cost-effective Consumer Premise Equipment (CPEs) for residential use. However, some of the spectrum is being used effectively for short-haul backhaul links.

Therefore, while the incumbent telecom and cable operators have extensive wireline-based facilities (copper/fibre and coaxial/fibre), microwave backhaul and FWA provide them another transmission alternative. For new entrants in cellular and broadband, the use of FWA and microwave backhaul are, often, their only options.

Given the number of national and regional cellular networks with thousands of cell sites concentration, and the rapid growth of mobile traffic, the use of backhaul microwave facilities has significantly increased to link clusters of cell sites to collector points and public switching networks. Due to the relatively short distances between cell sites in urban areas, the use of microwave spectrum in the Ku- (11/14 GHz) and Ka- (18/21 GHz) bands has exceedingly been in demand for backhaul. There has also been an increased use of these bands for microwave backhaul to support broadband Internet access using FWA bands below 6 GHz. *(Stallings 2004)*

The demand for microwave backhaul facilities and spectrum will be studied within the context of other backhaul transmission facilities, mainly fibre-optical systems and copper-based digital operators providing extensive routing of traffic of cellular and broadband Internet distribution services.

2.1 Utilization of spectrum

The spectrum of interest for backhaul facilities in this Study is the frequency bands above 10 GHz for two-way point-to-point microwave links *Wiley (2006).*

These links are in increasing demand, as a result of growth in traffic of mobile cellular networks and broadband distribution systems. Specifically, the 11 GHz, 14 GHz, 18 GHz and 23 GHz bands are of interest. These bands are experiencing the greatest demand to provide short transmission links in urban and rural areas.

Benefits of microwave

Advantages of microwave backhaul networks are as follows,*Sousa(1992)*

Microwave offers a pocket friendly ways to increasingly utilize the networks, and move traffic from cell locations to point of aggregation. It’s more important for newbies with limited fibre-optic and wireline infrastructure, the backhaul facilitates broadband distribution of networks.

Currently, High Speed Packet Access sites utilize microwave backhaul channels with 150 Mbps capacity. These channels supports upto 220 Mbps load. When Long Term Evolution sites are initiated, the channel load expands to support 530 Mbps I.F.Akyildiz (2011)

Future concerns by service providers of are indicated as:

The establishment of 4G technology, for services of broadband, there will be dramatic demand on backhaul networks in 5 years to come.

An incumbent local exchange carrier (ILEC) expects exponential growth in backhaul capacity needs in the coming years

Research on industry done by Beile (2005) indicates that they are moving to fiber optic to save costs: Meanwhile, it was also noted that, over time, multiple microwave channels will be needed per link, which are more expensive than fibre facilities. Therefore, it is expected that there will be an increase in the use of fibre-optic-based systems to backhaul.

A public power utility indicated that they have replaced microwave with fibre optic connections already, as a result of the long-term cost benefits for them.

Another major carrier indicated that most of their heavy-transmission routes have moved from microwave to fibre. It also indicated that the majority of its light-transmission routes, that have more than two hops, will be replaced by fibre within five years. However, for the foreseeable future, it sees using microwave backhaul for switching office transport and to access remote sites, where fibre costs are prohibitive S. Haykin (2005)

It was noted that bands used for the types of hops are as follows:

Long hops: 6, 7, 8 GHz

Medium hops: 11, 15 GHz

Short hops: 18, 23 GHz

Some observed that, in some cases, the 24 and 28 GHz, even the 38 GHz, FWA bands for point-to-multipoint applications have been treated more like backhaul bands and as broadband pipes to enterprises.

New entrants are using several bands for backhaul, including 11 GHz, 14 GHz, 18 GHz and 23 GHz bands, plus the 24 GHz and 38 GHz bands in large urban centres. Transmission capacity ranges from 30 Mbps up to 227 Mbps with channel bandwidth of 4 MHz to 10 MHz. In many cases, those without existing wireline facilities see an annual growth of 50% in the use of microwave assignments.

A large broadband service provider indicated using the four prime bands above 10 GHz with bandwidth ranging from 30 MHz to 50 MHz, to support up to 300 Mbps capacity, depending on the number of relay hops. The first link from a point of presence (POP), or where the link connects to the fibre backhaul facility, has the highest transmission capacity. In the near future, with 4G broadband, the minimum microwave backhaul capacity is expected to rise to 150 Mbps. Hence, the last microwave link connected to the fibre system for three to four broadband sites will require 500 Mbps capacity.

According to a research done in Canada, microwave backhaul has reached more than 70% utilization on some hops and will require solutions in the short term to sustain the incrementing traffic load

2.2 Spectral Access

With the usage of channel band increasingly high and channels being overloaded, more so in urban centers where its densely settled. Different methods frequency sharing are being followed by spectrum managers like use of administrative techniques as noted by *Fazel and Kaiser (2007)*.

Sharing of spectrum basically involves various applications and techniques been shared on the same spectrum by more than one user. Overlay method of sharing spectrum occurs when existing licensed frequency being used by internet service provider is used among other operators. For instance when a channel band used for delivery of television in one locality being used for programs like WLAN access in different location with no fear of interception, despite another allocation on a national basis as highlighted by *Geirofer (2006)*

Spectrum should be allocated in the 13 GHz band, which provides similar propagation characteristics as 11 GHz, and the 80 GHz band, as well, which is instrumental in supplying multiple gigabit access in dense urban areas as highlighted by S.Geirofer (2006)

50 MHz channels are especially preferred because they maximize the potential of the hardware. Currently, all new microwave hardware deployed is capable of supporting 50 MHz channels but is typically used only with 30 MHz channels. 40% of the radio's potential is going untapped.

Utilize Cross-polarization whenever possible to maximize capacity on a single channel. Make use of adaptive modulation (up to 256 QAM) in order to provide the highest-possible best-effort data rates.

Systems in the 11 GHz band utilize high-modulation schemes up to 256 QAM, with good propagation and small channel bandwidths of 30 MHz–40 MHz; the spectral efficiency allows capacity up to 200 Mbps. In addition, the spectral efficiency is doubled by employing two independent microwave links, by using a single assigned pair on both polarities along the same path. This supports aggregated traffic upwards of 400 Mbps. With authorization to use 50 MHz of channel bandwidth, radio systems can achieve the same 400 Mbps at 256 QAM on a single radio and 800 Mbps at 256 QAM, when employing dual radio systems.

2.3 **Research Analysis**

As a review of trends in other markets, the U.S. market was reviewed.

A research done on Mobile Wireless Competition by FCC summarizes the situation with backhaul facilities supporting cellular networks. It notes that, with growing mobile voice and data traffic, the existing backhaul facilities need to accommodate greater transmission capacity and, often, these facilities need major rebuilds.

The rapid expansion of smartphones gargets incorporating compressed media and data browsing has brought in alot network usage than previously expected.

As smartphone usage increases, data services have become a major utilisation of the overall traffic.

The rollout of HSPA and HSPA+, with greater transmission speed, the availability of high-end smartphones and tablets, aircards for netbooks and laptops with an ever-increasing number of applications, will greatly increase the backhaul capacity requirements. Further, pressure will be exerted on backhaul facilities in the next years or so with the rollout of 4G mobile networks with a much higher access speed.

The Inventory Report summarizes the number of frequency assignments for two-way microwave bands between 2 GHz to 38 GHz. A number of these bands have been identified as the prime spectrum for backhaul facilities for the expanding number of cellular networks and for wireless broadband access systems. The microwave bands above 10 GHz are well suited for short hops (typically less than 16 km) to link cellular sites and broadband access hubs directly to networks or through other transmission backhaul facilities. Microwave bands below 10 GHz provide for much longer hops (20-50 km) and are most suitable for medium-to-long haul inter-city microwave transmission systems.

2.**4 Unlicensed spectrum**

433/434 Mega Hertz, 902/928 Mega Hertz, 1880/1900 Mega Hertz, 2483/2500 Mega Hertz, 5150/5350 Mega Hertz, and 5725-5775 Mega Hertz are the specific channel bands that asked not to be licensed as stated *Federal Communications Commission (2002)*

The main purpose for having controlled distribution of unlicensed channels is frequency interruptions concerns to licensed users which are greatly diminished. Interference-free spectral usage is achieved by several ISPs operating on short-range, minimal-power nature techniques servicing on this channel list, and having technologies which enable sharing of spectral.

2.5 WIFI

Wi-Fi has sought to be the major telecommunications application for non-licensed channel. It entails WLAN technologies and is included on the specifications of IEEE 802.11. A Wireless-Fidelity capable gadget can have a broadband connection in range to Access Point (AP). Wi-Fi applications include but not limited to broadband connection and Voice over internet protocol access and games. Most WI-FI techniques use 2.4 GHz and the 5 GHz bands which are unlicensed spectrum *Thool (2013)*

More efficient utilization of spectrum has been made possible by emerging of advanced technologies

2.6 Spectrum Sharing

In wireless communication radio spectrum is the primary resource. Hence its regulation is an important task, from which the spectrum licensing concept was evolved in the last century. However, it becomes apparent that tight licensing might no longer be required for all wireless services with the mature technologies and continuous improvements in different aspects in the world *Thomas, (2011)*

That is the reason which originates the concept of using the unlicensed bands for wireless communication. The concept of open spectrum has been a tremendous success in such a coexistence of technologies in unlicensed bands. In an open spectrum, dynamic spectrum sharing among collocated wireless systems is one of the requirements as noted by *K'onsgen (2008)*

2.7 Spectrum Bands

Electromagnetic (EM) radiation is classified by wavelength into EM waves, which are then classified into different regions of the electromagnetic spectrum.

In the EM spectrum, the range from 3 kHz to 300GHz is very often called radio wave spectrum.

2.8 Research projects

Dynamic spectral access and sharing of channels is currently a huge concern for researchers from the field of communication technology. Two research projects in this respect are discussed below X Jing (2005)

*2.8.1 D***efence Advanced Research projects Agency (DARPA) neXt Generation**

The DARPA-next generation communication project presents an intelligent spectrum access technology to the public.1 XG denotes the opportunistic spectrum access technology and develops the opportunistic use of wasted spectrum both in space and time in such a way that interference to the primary (incumbent) user will be reduced. For example, this can be an adaptive radio technique to use an unoccupied TV-band. XG program published Requests for Comments (RFCs) describing the vision, system architecture and policy architecture.

The DARPA documents include the terms ’policy’ and ’protocol’ which are of major importance throughout all considerations. Policy means behavioral rules how a system should react to varying conditions inside the frequency spectrum which it is using. A policy can be, for example, a rule such as ’if a TV signal is sensed on the current frequency, then the transmission range must not be higher than 20meters’. It is then up to the station how it actually implements this policy by using a protocol.

Another option might be to switch to another frequency channel for which the policy given above does not apply. It can be seen that the policy is an abstraction of the actual protocol: the policy describes a goal, but not how to achieve it, which is performed by the protocol.

Another important term, ’spectrum’ is highlighted in the XG context, which means any resource which is used or can be modified when performing a wireless communication; thus, it means not only frequency but also transmitter power, modulation scheme, channel bandwidth, channel allocation in the time domain, etc.

In traditional radio systems operating policies are hard or soft coded with protocols and any change in policies would require re-design, reimplementation and re-accreditation. However, according to XG, a radio could be made policy agile by decoupling the policies from behaviors, behaviors from protocols and protocols from their implementations and these policies could be changed dynamically Nate Anderson (2006)

To change the policies, the radio part should have the capability to read and interpret the spectrum policies (published by a spectrum authority) which are encoded in a machine interpretable form and can be loaded into the XG radio using smart media or over the Internet.

2.8.2 End-to-End Efficiency

The E3 project is a high Scale Integrated Project (IP) of the seventh Framework Programme of the EC (European Commission). The key objective of the program is to provide an efficient start of the concept of cognitive wireless network in the Beyond 3G (B3G) wireless systems , where different WLAN infrastructures are considered. Some of the results of the project are: the market assessment and the business models, the overall E3 Functional System Architecture, cognitive dynamic

The market assessment and the business models, the overall E3 Functional System Architecture, cognitive dynamic are some of the results for the project.

2.9 Spectrum sharing Techniques

Spectrum management, Cognitive Pilot Channel (CPC) concept, spectrum sensing methods and E3 provides contributions to the standardization work like ETSI, IEEE and influences the regulations area, like providing contributions to ECPTA (European Conference of Postal and Telecommunications Administrations) and ITU(International Telecommunication Union).

• Spectrum Sensing and Measurement Method: Spectrum Sensing and Measurement Methods are considered as the enabler techniques for spectrum sharing, because by these methods, the knowledge about the wireless environment can be obtained. Further processing and management of this gained knowledge is needed to detect the presence of other wireless systems and to perform estimation of relevant parameters *Simpson (2007)*

In the framework of this thesis, sensing methods are developed including the detection of signals from other systems followed by system identification techniques and estimation of traffic demand.

• Software Defined Radio: it’s a radio system in where parameters like frequency delivery, type of varying wavelength of signal, and high radiation power is reconfigured with no changes to the hardware, which was previously not possible in traditional radio or adjusted manually. Enhancements in SDR technologies have the potential to facilitate dynamic spectrum sharing.

Adaptive Method: An adaptive method is defined as a method where operating parameters are updated or reconfigured during the operating time of the system, where the method is invoked. Facilitating the method with continuously updating the parameters based on a specific strategy would increase the performance.

• Cooperative Communication Method: During the spectrum sharing, cooperation between the systems is expected to raise the throughput results. The benefits of cooperative communication in wireless networks are provided in:

The generic method developed in this thesis is originated by keeping the idea of cooperation between the systems. The hypothesis considered in the generic method is:

In the time domain, regular spectral occupation by one system, can do detection and effectively estimate spectral possibilities as well utilize idle periods efficiently, resulting in fair sharing as well as a better accumulated performance; and

Policy based Adaptation Method: Like in the DARPA XG concept, the usage of policy regulated methods to reconfigure the system parameters is considered as an enabling technique. The application of policy in multi-layer and in multi-scale, would help the service providers and operators (intra and inter level) to update the spectrum sharing policy whenever required in a flexible way.

2.10 Quality of service parameters for IPTV

QOS is the capacity of a network to offer better services for a selected part of the traffic as noted by *Howard (2007)*

Better quality than just classic television must be the key for IPTV service operators for assuring success. The variation of the one-way-delay parameter can cause distortion of the received IPTV signal. The following are the quality of service parameters

• **Throughput:** The performance metric throughput used in this thesis is defined as the number of useful databits received successfully (excluding the retransmissions) divided by the time taken to transmit it via a medium. The individual as well as aggregated throughput for the systems are evaluated, where aggregated throughput is calculated by summing the individual. Generally, the throughput with respect to the MAC layer is considered unless stated otherwise. The achieved throughput, normalized by the physical bit rate of the channel, is often considered as the channel utilization.

• **Packet Delay:** Delay is also known as Latency. Delay is technically the period used by a data frame to be distributed from the origin to the designated place. The delay definition is layer dependent, in the sense that from which layer the packet transmission starting time is considered.

The definition of the delay considered in this thesis is as follows. The time taken to send a data frame from the period is passed to MAC layer until it is received successfully at the destination. The queues and channel access delays are highlighted during the performance evaluation and in the rest of the thesis; retransmission delay will be calculated inside access delay, unless stated otherwise.

• **Delay-jitter:** Delay-jitter is technically the measure of the variability of the delay on time. In the framework of this thesis, the standard deviation of the delay is defined as delay-jitter.

• **Packet loss ratio**: From the technical point of view, it is the rationale between the no. of data frames lost to the sum of no. of data frames generated. Data loss considered in this thesis, in broader sense, is due to two reasons: packet drop in the buffers and packet loss during the transmission via the channel. Generally there are several buffers located in several layers in the transmitter and the receiver where a packet could be dropped if the consequent process is not ready to accept the packet and eventually the buffer becomes full. During the transmission, packet loss is caused by several factors, like channel congestion, lower signal-to-noise ratio, collisions due to random channel access, etc. In this thesis, packet loss ratio thus is evaluated in two sub-ratios: buffer loss ratio and Cyclic Redundancy Check (CRC) loss ratio.

2.11 IPTV protocol architecture

Most audio and video application use Real-time Transport Protocol for packet delivery and real-time applications. Real-time transport protocol lies above transport protocol. User Datagram Protocol offers real-time application with high end delivery of services such as payload type application as described by *IEEE Std. (2004)*

Real Time Protocol messages contains sequence number that provides capacity for application to monitor frame disappearance, double delivery and packet disordering.

2.12 sharing based on market-based techniques

Beneficently efficient usage of spectral channels implies high result values generated from existing frequencies, which involves monitoring of general feedback. Channel bands should be distributed ways that the value to the overall industry are equal from various uses of channel for an equally amount of spectral provided from an economic efficient point of view

In case where channel band is a limited resource, decisions on efficiently distribution is based on cost. Good planned and well managed bids are attractive since they make sure that channel bands go to the companies which offer the most, and that in some conditions, be the highly performing company as noted by G Hiertz (2008)

2.13 sharing on technically enabled

Efficiently usage of spectral channel, at its primary definition, implicates the maximum utilization for all free channels. Evaluation of technically performance ways are channel occupation and rate of data transfer. Data-rate is the number of packets or frames transported for a specific size of channel band. Technologies used in sharing of Spectrum are described below as noted G Hiertz (2008)

2.14 Over-lay Techniques and Dynamic Spectral Access

These technologies have started to develop and be tested. Such techniques include:

2.16.1 Dynamic Spectrum Access

It includes utilizing spectral channels in form of period slots or location. It enables consumers to view a specific channel at a given time and in a given location and can’t exceed without re applying for the resource.

2.16.2 Passive overlay

The other method is the passive overlay like the Amateur radio program that has shared spectral with several government users using passive overlay technologies that require the user to look for a Citizen Band radio channel that is free.

2.15 Emerging Technology Enablers

In adittion to the techniques of sharing spectrum mentioned above there are developing technologies which are significant in enabling these technologies, as well as mastering potential new methods of sharing spectrum. They are:

2.17.1 Software-defined Radio (SDR) and Cognitive Radio (CR)

SDR are radio systems whose implementation is done on general purpose hardware system where specific operational characteristics are implemented in software – different radio systems and standards are essentially loaded as software programs (e.g. a GSM program or a Wi-Fi program).

Software defined radios allow a high flexible spectral distribution since these radio systems have potential to utilize channel much more and have high tolerance to interference.

A CR is a radio that in some capacity is aware of the surrounding by monitoring distribution across a big connection, noting locations of unutilized channel and is capable of modifying its distribution using the right modulation and coding methods *Balakrishnan (2011)*

2.17.2 Smart Antennas and Other Technologies

Smart Antenna programs and technologies have being emerging in the past decade and are have the ability to highly increase the efficiency of different WLAN networks, such as 2.5 generation (GSM-EDGE), third generation (IMT 2000) mobile cellular networks and BWA.

Smart Antenna technology explores several antennas in transmit and receive mode with associated coding, modulation and signal processing to enhance the performance of wireless systems in terms of capacity, coverage and throughput

2.17.3 Digital Terrestrial Television

Broadcast mobile Television is a highly efficient multicast service that enables clients with a smartphone to watch more than one television channels in ways similar to Digital Terrestrial Television.

The 470/862 Mega Hertz channel is liked by mobile ISPs to use in broadcasting mobile television and internet services. While other channels can be used to distribute mobile television such as the VHF TV channel as noted by *Sadler(2006)*

2.16 The Standards

Successful studies and innovations in the field of dynamic spectrum access, sharing, cognitive radio, and software defined radio have triggered the standardization initiatives *IEEE std. (2008).* Some of them are listed below

2.16.1 IEEE Standards Coordinating Committee 41

It is giving its potential to develop standards related to Dynamic Spectrum Access (DSA) and Cognitive Radio (CR), focusing on the capacity enhancement and improved utilization of spectrum. In 2005, the IEEE1900 Standards Committee was established with the objective of developing standards for dealing with emerging technologies and techniques being developed for next generation radio and advanced spectral management.

In 2007, the IEEE 1900 Committee ceased and the work of the IEEE 1900.x Working Groups (WGs) continued under SCC41.

2.16.2 ITU-R Working Party 1B

ITU-R is responsible for spectral management principles and techniques, general techniques of sharing spectral, spectral monitoring, long-term strategies for spectral usage, market approaches to national spectral management. Working Party 1B (WP 1B) is created under SG 1 to develop the definitions of software defined

2.17 Enabling Techniques towards Cognitive Dynamic Spectrum Sharing51

Radio and cognitive radio systems, to identify potential regulatory issues associated with SDR and CR Systems, and to innovate related concepts such as the Cognition supporting Pilot Channel. Working Party 1C (WP 1C) is responsible for issues on spectrum monitoring.

ETSI - Reconfigurable Radio Systems

The ETSI Board decided to create a Technicality Committee for Reconfigurable Radio Systems (RRS) in January 2008 with the aim of studying the viability of standards activities related to RRS, a generic concept based on technologies such as SDR and CR.

There is high interest in CR methods in Europe similar to the rest of the world. Based on the outcomes of feasibility, the ETSI Board will then decide on a possible continuation into actual standardization activities *Anderson(2006)*

CHAPTER THREE

RESEARCH METHODOLOGY

3.0 Introduction

Research methodology refer to methods and technique employed during research to in the area of data collection, analysis and presentation of the finding *Creswell (2002)*

The major role of research methodology as used in this research is to assist in achieving the set objectives of the spectrum sharing and reuse for IPTV. The aim is to specify certain research problems objectives, scope, domain and barriers to achieve the limits of the research problem statement.

3.1 Data collection

The research was conducted mainly using information provided in other spectrum and bandwidth utilization for IPTV and HDTV techniques. Several research papers from various conference and journals were chosen for this research. A survey was done for all the research paper on iptv. Upon analyzing each paper, different questions, topics, relevance information, prediction, and details were studied and investigated.

The researcher also spent time observing different media behavioral changes with different bandwidth usage in order to gather firsthand information.

I took into account different aspects of spectrum sharing and reuse for iptv as I discussed the need for proposed framework.

First I analyzed the spectrum sharing design process.

Secondly, I looked at the cross section of many sharing techniques in existence in order to determine which features were commonly implemented, or which their creators indicate would be useful.

Thirdly, I looked at the existing platforms for creating spectrum sharing and reuse and analyzed needs for future improvements.

3.2 validity and reliability

The validity and reliability of the methods applied was achieved through information triangulation. This involved incorporating multi-disciplinary teams with different skills, experience and viewpoints that will validity different parts of the research. Also incorporating different tools and research techniques for data collection and analysis; and gathering different sources of information on the same research problem. In this way, biasness and reliability of the finding is accessed and addressed if necessary.

3.3 Design and implementation

In development and implementation phase, the aim is to accomplish the physical and logical design of the solution according the requirements. To successfully implement spectrum sharing, both vision and commitment from current national regulatory allocation and assignment should practice a sound understanding of technology and systems operating.

Efficient spectral distribution can be done by SDR since there is more intensively potential use of spectrum by the radios systems and are more tolerant of interference.

3.4 Testing and evaluation

After the design I needed to know whether the system meets the set objectives. The criteria employed include:

As a system for analyzing, I consider how spectrum can be shared and reused to optimize and maximize the bandwidth use.

As a system, it aims at assisting efficiency and effectiveness of the system by permitting communications to work by: unused frequencies detection monitoring; Agree on which similar devices and frequencies utilized; frequency evaluation different parties; and frequency changing lists and output adjustments as required.

CHAPTER FOUR

CONCEPTUAL MODEL

4.1 Introduction:

The purpose of a conceptual model mainly is to describe different terms and methods utilized by experts to define a problem, and also establish the right relationship among various methods. What the conceptualization process does is try to distinguish definitions of different and ambiguous terms, and make sure that several misconceptions of the problem statement and can't repeat.

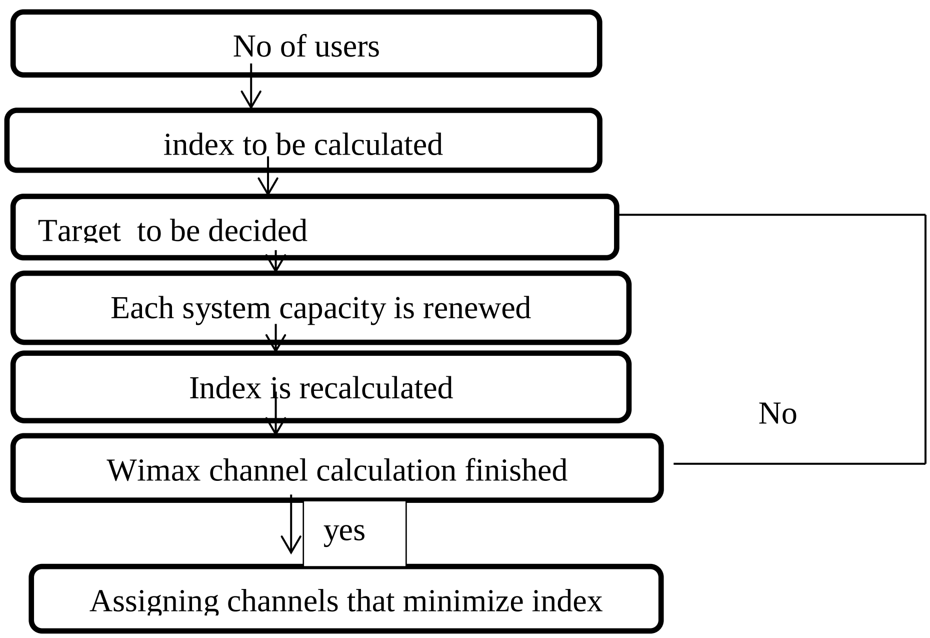

Figure 4.1: Conceptual model for IPTV via wireless

The number of users is entered into the system then the index is calculated and the target is decided. Each system capacity is renewed and index recalculated then WiMAX channel is calculated, if the not finished the target is decided, system capacity is renewed and index is recalculated. If finished it proceeds to assigning channels to user.

4.2 Proposed solutions

To solve the issue of bandwidth, we propose a new multicast mechanism for IPTV application over WiMAX multihop relay network, which would make it possible to reduce bandwidth consumption while satisfying QoS requirements.

The main idea of this solution is to use only one main server for all Internet protocol television services. Furthermore, I propose a different multicast tree construction method by introducing MT-CID (Multicast Tunnel CID) and Transmission Identity (TxId). The TxId is attributed for each IPTV services and to transmit video contents towards the users with the desired performance.

4.3 IPTV architecture

The functional blocks of the IPTV architecture includes :

Super head-end: location mostly used by Internet protocol television frequencies to enter the infrastructure from national broadcasters

Core network: an internet protocol/Multiprotocol label switching network transmitting traffic to the access network

Access network: transmits the IPTV streams to the Digital Subscriber Line Access Multiplexers

Regional head- end: it's a place where local content is added to the network

Customer premises: where IPTV stream is terminated and viewed

There is often a hierarchy of facilities constructed to deliver video signals across a large expanse of territory for a large IPTV delivery service. Video channels that are common to all subscribers across the serving area can serve million customers and processed by one Super Head-end. A Video Serving local programming and channels specific to a single city or geographic area are located in an office is located at that region.

Customers in a local area can use the Remote Terminal that serve as a Regional Head-end and contains the equipment needed to actually deliver the programming as noted by *Simpson (2007)*

Distribution of MPEG-2 multi-program transport stream (MPTS) to the video service node is mainly done from the antenna or a settlite dish at the super head-end. The distribution of the actual SDTV or HDTV channel content is performed using various devices on the access network, such as digital subscriber line access multiplexers (DSLAM) and other technologies like fibre-to-the-home (FTTH) can be used to interface with the user's STB. A multicast IP address is used to distribute each channel in IPTV.

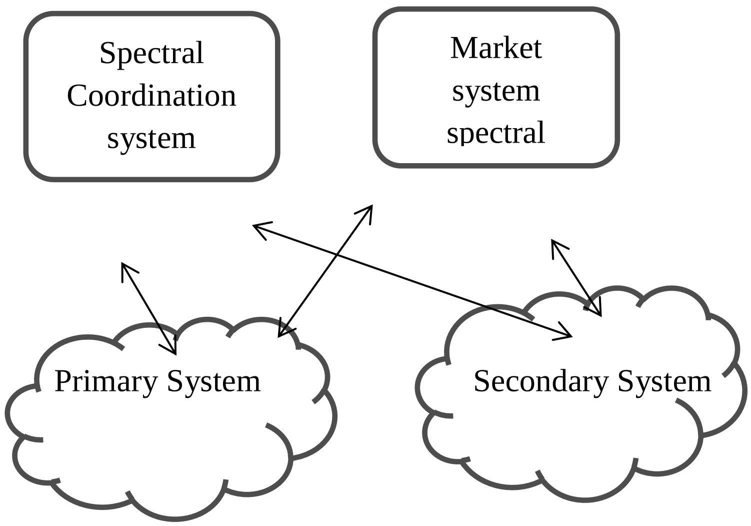

Figure 4.2: Shared Spectral Architecture

Both spectral organization network and economical system have to be planned and created

4.3 cognitive radio

Current wireless network environment employs differentiation in aspects such as spectral policy and telecommunication techniques. To design and develop telecommunication protocols a clear defination of cognitive radio is crucial.

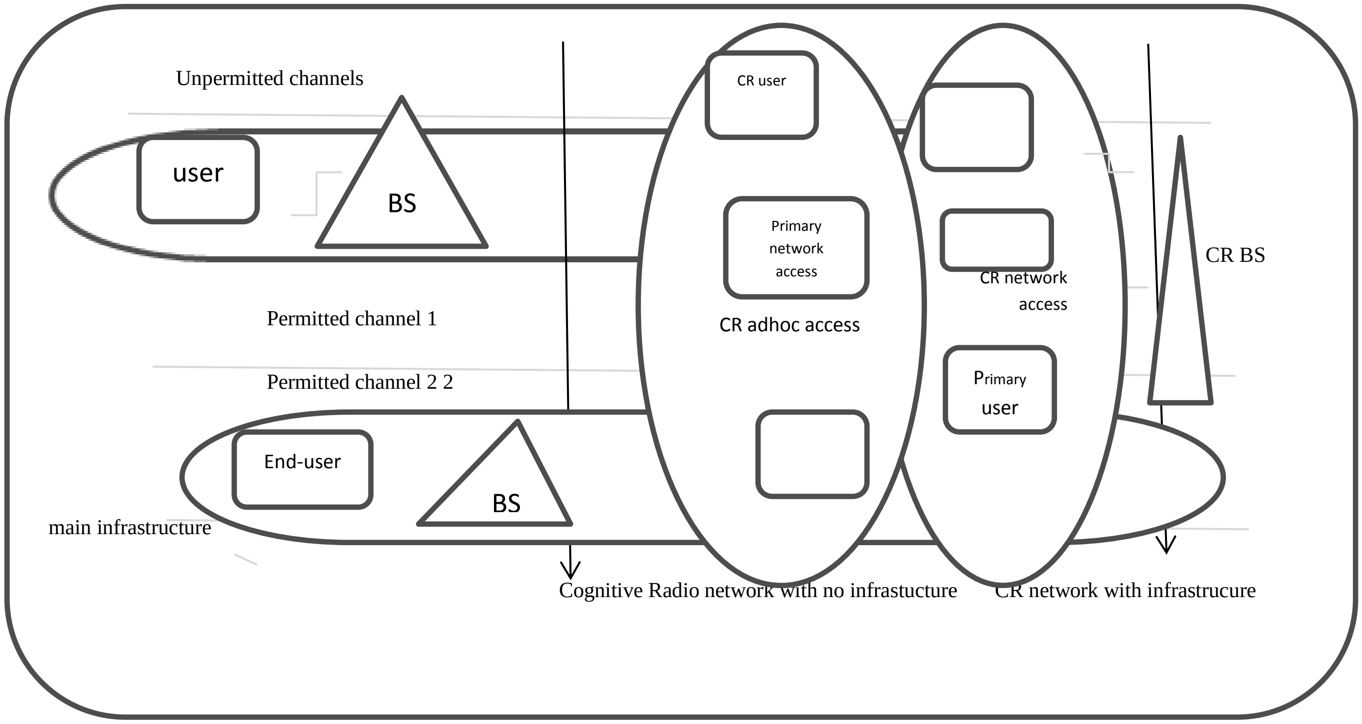

Figure 4.3: components of Cognitive Radio

As shown above, elements of the CR system is categorized in to primary network and the cognitive network.

The common components of the primary and non-licensed network are described below:

Primary User: is authorized to use in a specific frequency channel. The operation of primary user is only monitored by BS and cannot be interfered by usage of any other non-permitted user.

Primary Base-Station: It's a fixed architectural system element with a spectral permit. The main BS doesn't have CR capabilities of sharing frequencies with CR users.

Cognitive Radio User: CR user has no frequency permit. Therefore, the channel permission is accessible only in an advantages manner. The CR user is presumed to be having the opportunities to telecommunicate with both the BS and other CR users.

Cognitive Radio BS CRBS: CRBS is an established network element with CR opportunities. Cognitive radio base-station provides single hop connection to cognitive radio users without spectral permit *Janka (2005)*

4.4 Spectral Management Framework for Cognitive Radio Networks

CR networks have several limitations due to the co-existence with primary networks and diverse Quality of Service requirements. The following are some of the limitations experienced:

Interference Avoidance: Cognitive radio systems should avoid interrupting with primary networks.

Quality of Service Awareness: To choose a suitable frequency channels, CR networks should allow Quality of Service-aware telecommunication, taking into account dynamic and heterogeneous spectral surrounding.

Continuous Communication: Cognitive Radio systems must offer continuous communication despite of the looks of the primary users *Withers (1991)*

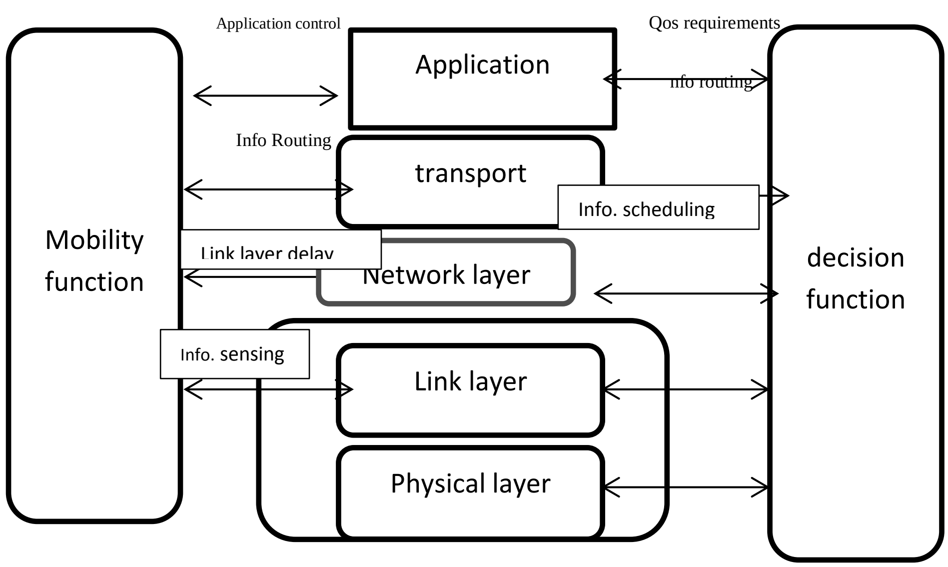

Figure 1.4: Spectrum Management Framework

The spectral management includes:

Spectral Sensing: A Cognitive Radio user can only distribute unutilized piece of the channel. Therefore, the CR user should manage the free spectral channels, gather their profile and then identify any channel loopholes.

Spectral Decision: on regards to channel suitability, Cognitive radio user can distribute frequencies. This distribution is dependent on free spectra, but it is also decided on basis of surrounding policies.

Spectral Sharing: if there are many Cognitive radio users indenting to establish a connection to the channel, Cognitive radio system permission should implement in order to deny multiple users colliding in overlapping portions of the spectrum.

Spectrum Mobility: If the exact piece of the channel in use is required by the main user, the telecommunication requirements to be continued in different vacant piece of the channel.

4.5 Spectral Sensing on Cognitive Radio Networks

Monitoring of the free channel lists, capturing their profile, and then accessing the channel limitations should be carried out by CR. Henceforth; spectral sensing is a major technique in cognitive radio systems.

The following design issues should be addressed in sensing

Avoiding interruptions: Interference is brought about by sensing efficiency depending on oversee period but also the Cognitive Radio distribution time and traffic statistics in the periodic sensing.

Spectral Efficiency: efficient use of spectrum resources is the main objective of cognitive radio. However, spectrum efficiency is degraded in evitably since users can’t transmit during sensing

4.6 Spectrum Decision Framework for Cognitive Radio Networks

Unlicensed and licensed bands are spread over wide frequency range of unused spectrum in a cognitive radio (CR) networks.

These unused spectrum bands detected through spectrum sensing show different characteristics according to the radio environment. Since CR networks can have multiple available spectrum bands having different channel characteristics, they should be capable of selecting the proper spectrum bands according to the application requirements, called *spectrum decision* as defined by *Sandelowski and Barroso (2003)*

In this project, I propose an application-adaptive spectrum decision method over heterogeneous spectrum bands

4.7 Sharing of spectrum using inter-cell in CR nodes

Cognitive radio (CR) networking achieves high utilization of the scarce spectrum resources without causing any performance degradation to the licensed users. Since the spectrum availability varies over time and space, the infrastructure-based CR networks are required to have a dynamic inter-cell spectrum sharing capability. This allows fair resource allocation as well as capacity maximization and avoids the starvation problems seen in the classical spectrum sharing approaches.

In this paper, a joint spectrum and power allocation framework is proposed that addresses these concerns by:

(i) Opportunistically negotiating additional spectrum based on the licensed user activity (exclusive allocation), and

(ii) Having a share of reserved spectrum for each cell (common use sharing). Our algorithm accounts for the maximum cell capacity, minimizes the interference caused to neighboring cells, and protects the licensed users through a sophisticated power allocation method.

Event Monitoring: The event monitoring has two different functionalities. One is to detect the PU activities, called spectrum sensing. CR users sense the radio environment continuously and send monitoring results to their base-station. Here we assume the periodic sensing which has separate time slots for sensing and transmission. In addition, CR users monitor the quality-of-service (QoS) of their transmission. According to the detected event type, the base-station determines the spectrum sharing strategies and allocates the spectrums to each user adaptively to the radio environments.

Cell Spectrum Sharing: The intra-cell spectrum sharing enables the base-station to avoid the interference to the primary networks as well as to maintain the QoS of its CR users by allocating spectrum resource adaptively to the event detected inside its coverage. If a new CR user appears in this cell, the base-station determines its acceptance and selects the best available spectrum band if it is admitted. Furthermore, when some of its CR users cannot maintain the guaranteed QoS or lose their connections due to the PU activities, the base-station should re-allocate the spectrum resource to them immediately. Also a CR MAC protocol is required to allow multiple CR users to access to the same spectrum band. The intra-cell spectrum sharing has been widely investigated in many literatures and is out of the scope in this project.

Inter-Cell Spectrum Sharing: In CR networks, the available spectrum bands vary over time and space which makes it difficult to provide reliable spectrum allocation. Especially in the infrastructure-based networks, the inter-cell interference also needs to be considered in spectrum sharing so as to maximize the network capacity. In the proposed framework, the inter-cell spectrum sharing is comprised of two subfunctionalities: spectrum allocation and power allocation.

In the spectrum allocation, the base-station determines its spectrum bands by considering the geographical information of primary networks and current radio activities. The power allocation enables the base-station to determine the transmission power of its assigned spectrum bands so as to maximize the cell capacity without interference to the primary network. When the service quality of the cell becomes worse or is below the guaranteed level, the base-station initiates the inter-cell spectrum sharing and adjusts its spectrum allocation.

Based on the spectrum allocation, the base-station determines its transmission power over the allocated spectrum bands as refered by *Akyildiz, Lee, Vuran, Mohanty (2006)*

CHAPTER FIVE

IMPLEMENTATION AND TESTING

5.1 introduction

In order for a system operator to deliver IPTV, it would require to encode, broadcast, and do the appropriate management before the end user can connect their set-top-box.

Success in implementing spectrum sharing requires both vision and commitment for moving from current regulatory allocation and assignment practices based on a sound understanding of technology and systems operating under predictable circumstances.

Incentives for innovation, flexibility promotion, spectrum users' rights establishment and determination of reliable form for complying with evaluation, managing of interference and resolution of disputes are some of the issues the spectrum policies should address.

5.2 Channeling Plans

In order to critically ease the problems of congestion and potential interference its important to create channeling plans which compact the assignments of spectrums and increase occupant numbers via techniques such as reuse.

5.3 Acquisition of Spectrum Occupation

It means, a station acquires information about the spectrum occupation by measuring dynamically and changing RSS values due to transmissions of the other system.

In this case, the received RF power is treated as 'noise' by the station. Generally, spectrum occupancy of the spectrum can be measured along time, frequency, and space dimensions.

5.4.1 Spectrum Occupation Measurement

During measurement and processing, the received RF power is considered as a parameter, nevertheless, care should be given on how it is defined, modeled and implemented. In this project it is defined as the Received Signal Strength (RSS) of a received frame measured at the receiver's front end antenna. In the case of this thesis, RSS measurements per frame are considered in the simulation, where the RSS consists of signals from other stations and interference.

During the measurement period when the own system is silent, the RSS consists of the signal power of the other system/s (which are treated as noise).

5.4 Application area

So there are principally four domains which are explored to have an optimum spectrum sharing method.

5.4.1 Frequency domain:

Spectrum sharing in the frequency domain means the coexisting systems should not use, or at least try to avoid transmission in overlapping frequency bands. The spectrum sharing concept Dynamic Frequency Selection (DFS). A multi-carrier modulation approach like OFDM is a way to exploit several smaller idle frequency bands to combine and create a proper transmission opportunity for a system . A similar approach is done in two ways:

1) Adjusting the bandwidth by means of adjusting the number of OFDM subcarriers,

2) The total no. of OFDM subcarriers can be divided over different frequencybands (channels) with a synchronization symbol (pilot), based on identifying several smaller idle frequency bands (opportunity). A hybrid approach combining the above two can provide even better spectral efficiency.

5.4.2 Space domain

Channel reallocation in the space domain is trivial in some perspectives. When the systems are located in such distant places that there is no possibility of overlapping of transmission coverage areas, then the systems can share the same frequency bands. This kind of approach is generally followed in cellular networks for frequency planning and reusing the spectrum.

Mobile cellular networks are operating in the licensed spectrum bands, which are very expensive, for example, Universal Mobile Telecommunications System (UMTS) licenses. Non overlapping cells reuse the same spectrum bands.

5.4.3 Time domain

Spectral reallocation in time domain is unavoidable when density of networks is much more than the no. of available (orthogonal)spectrum in the same location.

In time domain spectrum sharing, the systems use the same frequency band in different time periods with CSMA concept being an example. Another possibility of using idle periods is TDMA fashion. However, direct or indirect coordination and synchronization among systems needs to be present.

5.4.4 Power domain

Spectrum in the power domain can be shared as follows. A system can transmit in a specific power level in any of the above domains (time, frequency, space, or any combination) in such a way that its transmission does not exceed the tolerable interference threshold of receivers from other systems. Transmission opportunities in this case are called ’grey spaces’.

5.5 Delay Analysis

In case of Time division multiple access like frequency access method like the RCA, the frequency check period for each station is based on cycle duration, which is RCA Interval (RI), and service duration (i.e., the number of time slots) assigned to that station. The values are required to be determined and used in the coexisting networks to get maximum traffic load.

5.6 Sharing spectrum challenges

The only possible way to move forward is to first clear spectrum for exclusive use whenever possible and then limit the number of variables involved in spectrum sharing.

Challenges span maturity, modeling, frequency management, disparate secondary users, unclear use of cognitive sensing, database development, cost of dynamic radios and front-end filters, and security.

5.6.1 Multiplicity of Government Systems

Determining the ability of a government system to share spectrum requires an analysis of multiple factors, including the susceptibility of the government system to interference and the propagation of its radio signals.

Of concern to industry is the number of different government systems to analyze.

5.6.2 SAS Definition and Complexities (3.5 GHz)

Architectures, concepts, and implementation details for performing the SAS management function need a great deal of definition and work to address:

- Algorithms and methods
- Methods of nesting hierarchical SAS entities (federal secure SAS versus commercial SASs)
- Coordination among multiple, competing commercial SAS managing entities
- interface definitions
- Communication protocol definitions
- Database and protocol security
- Policy enforcement
- Speed of channel allocation/reallocation
- Time intervals for spectrum allocation
- Effectively managing large numbers of Tier 3 GAA users
- Data ownership, fees, rules, fairness, and conflict resolutions, all of which have policy, regulatory, and business implications

5.6.3 Propagation Modeling Complexities

Radio propagation models play a crucial role by determining spectral reuse factors and interference maps. Industry and government are using multiple models and have not yet agreed on what type of model is appropriate for each sharing scenario.

For example, differences exist between Longley-Rice models that assume line-of-sight propagation and Hata models that better account for near-the- ground clutter. Appropriate models have not yet been developed for small cells that operate at lower power with low antenna heights.

5.6.4 Lack of Maturity

Currently, academia, government, and industry are still assessing the various forms of architecture that could be employed, including the best balance of sensing and databases, as well as unsupervised versus centrally supervised versus decentralized supervisory systems. One architecture may ultimately prevail, or multiple architectures might exist based on scenario requirements.

Until spectrum sharing matures, industry will be reluctant to invest heavily in unproven approaches that may change or be abandoned. The situation argues for incremental developments with well-defined constraints and objectives.

5.6.5 Frequency Management

This wideband approach also raises concerns about front-end overload, consequent damage, as well as small-signal-blocking effects (from adjacent and other channel interference), thus limiting performance. In sharing scenarios with disparate power levels and lack of synchronization, these concerns place the entire coordination burden on the SAS manager

5.6.6 Database Security

Database attacks include malicious corruption of the database, intrusion to obtain sensitive information about primary users, or even threats to the privacy of primary users by queries to the database that can reveal the types and locations of incumbent systems. Database vulnerabilities further include systems masquerading as others, impersonation of the database, and modification or jamming of either queries to the database or responses from the database.

5.6.7 Sharing Security

Potential threats to systems employing spectrum sharing are numerous and perhaps not sufficiently appreciated. Malicious attacks, or even broken systems, can threaten both spectrum-sensing mechanisms and databases.

5.7 IPTV performance measure

The efficiency and effectiveness of IPTV is measuesd in quality of service and quality of experience

Main measures are: End user quality; Ability to use the system easily;Application driven;Content impairments; Blockiness, and Jerkiness

Simulation parameters

Parameter	**Values**
Subscriber IPTV services request	Random
Maximum number of IPTV channels	60
Channels request	Random
Maximum allowable bandwidth for the IPTV services [Mbps]	256
IPTV services	Random [1, 4]
Requested bandwidth by a IPTV service [Mbps]	HD-TV 6 SD-TV 2.5 Web-TV 0.650 Mobile-TV 0.350

5.8 simulation results

The following screen shot was captured during a simulation experiment using MATLAB software. Matlab software is used in cognitive spectrum (CR) sharing via wireless networks

When network infrastructure of a ISP is congested, a requests is send to the nearby cognitive Radio nodes based on the channel availability. Free channel can be established by sending request to BS (Base station). When the it gets the request from the nearby nodes, it sends the channel list to Cognitive Radio node

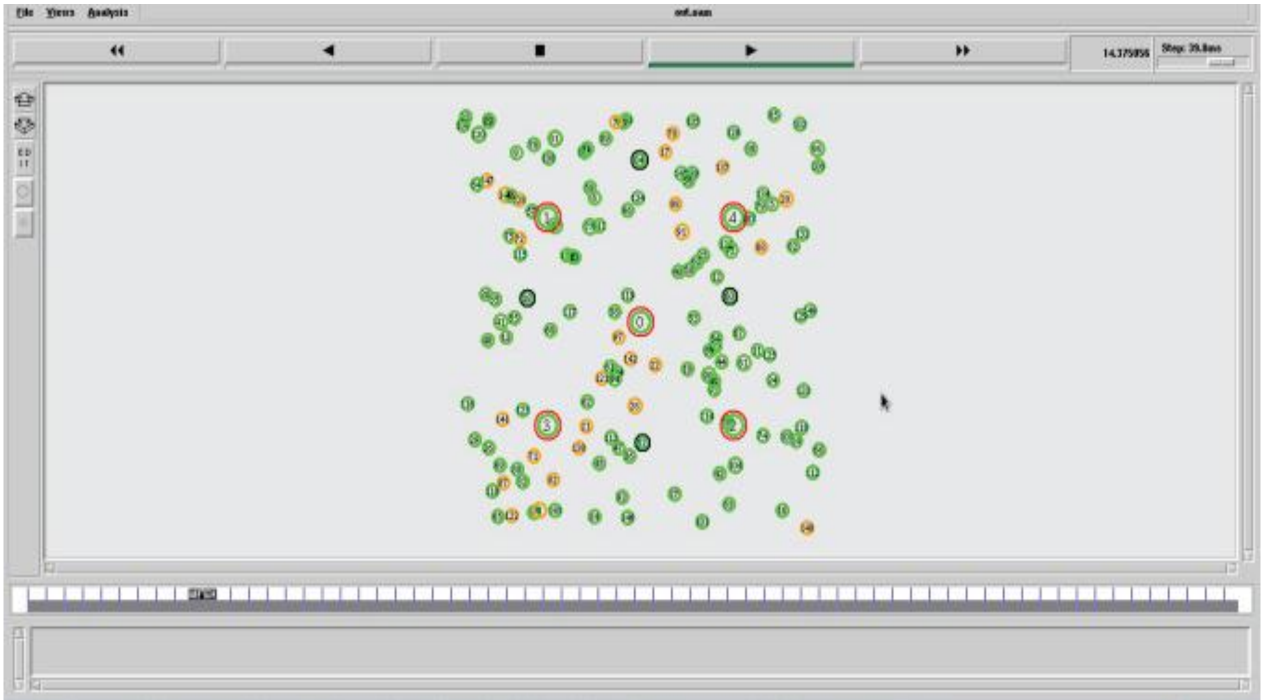

Figure 2.1 : Cognitive Radio node sending request

When the channel requested is received by the Cognitive Radio node , it sends a broadcast message to the nearby Cognitive Radio node. A neighbor Cognitive Radio node will receive the message and also updates the Base station on free channel list.

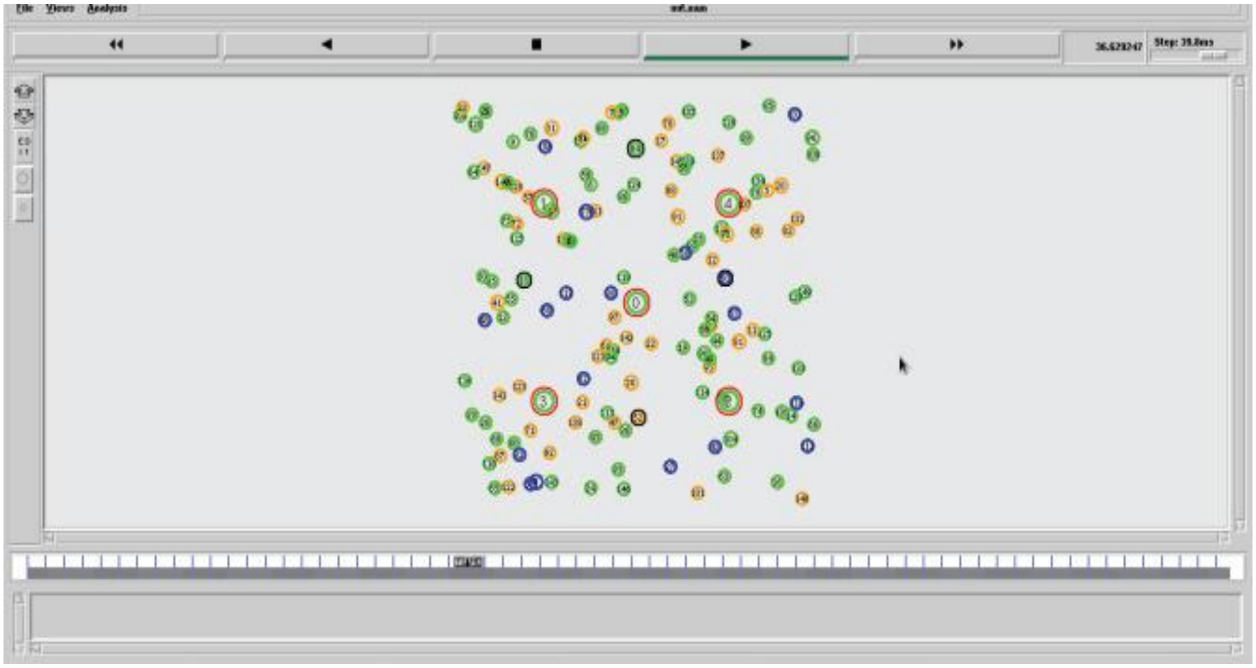

Figure 5.2: Transmitting and receiving feedback from Cognitive Radio nodes

If Base station gets the feedback from the Cognitive Radio node, the selection of the free channel is done, and allocation is done to the ISPs. The above screenshot show the maximum channel utilization which can support several services such as internet, calls, compressed media and much more.

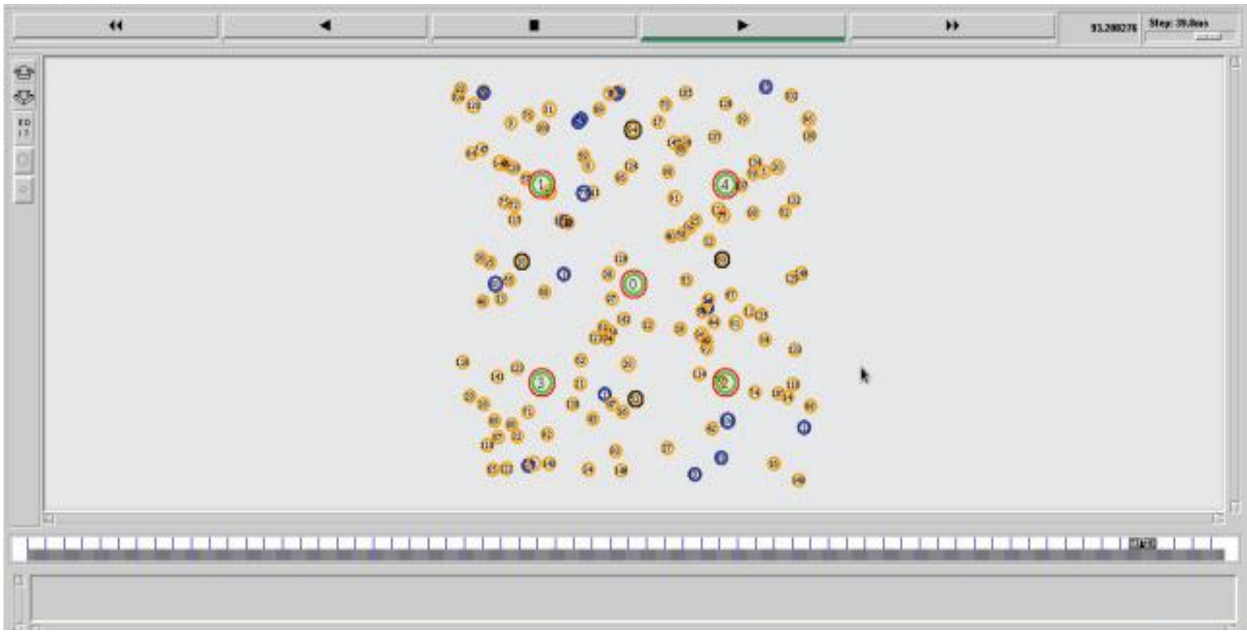

Figure 5.3: Response from CR

CHAPTER SIX

CONCLUSION AND RECOMMENDATIONS

6.1 Conclusion

Spectral distribution involve different process and methods that requires designing and developing a layout of what system and infrastructure to be reused and shared and also establishing the right market for sharing the resources, coming up with specifications and standards to facilitate distribution which includes spectral coordination architectures, defining primary and backup systems to be integrated with the new sharing architectures and models, and coming up with new structures and gadgets to use in implementation of spectral reuse.

In-depth research of existing and emerging technologies of spectral usage will be required in order to help establish which channels to be involved and how and when they should be renewed. A well Plan must engage dialogue with different stakeholders within the industry. At least a careful revision and well understanding of current policies in certain leading countries will be both helpful and necessary. The main concern is to ensure adequate frequencies are there to satisfy the demand and also for proper market functioning. As stated earlier to which depth the channel is given for economic purposes or exclusive usage by the government has an important impact on improved performance. Mechanisms to review and understand government needs and to shift frequency away from exclusive use require both time and negotiation.

6.2 Recommendations

I recommend that any future work projects should explores the wider issue of Collective Usage of Spectrum and also include a more in-depth assessment of the concept of Licensed Shared Access. To be specific, further work may engage a wider understanding as to how feasible the technique is and the accessibility might be, in real application.

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