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THE ROLE OF COGNITIVE RADIO TECHNOLOGY IN 4G COMMUNICATIONS

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Abstract

In present day communication, wireless communication has become the most popular communication. 4G will be intelligent technologies that will reduce the number of different technologies to a single global standard. We get the Software Defined Radio (SDR) by development of radio system. In the new era of wireless communication, a word cognitive radio is very renowned. With the use of CR, 4G wireless networks will support global roaming across multiple wireless and mobile networks. IEEE 802.22 wireless regional area network (WRAN) is an emerging cognitive radio-based system. It is the newest wireless standard being developed for remote and rural areas.WiMAX (IEEE 802.16e) provides extensions to support unlicensed coexistence. In this paper, the role of cognitive radio in 4G Communications is reviewed. We also observe the comparison and inquiry between Wireless regional area network (WRAN) and WiMAX. We have also investigated how Cognitive Radio Technology can be developed for better coverage range in rural areas to support broadband access. It is concluded that cognitive radio is very useful, because it provides efficient, cheaper and high capacity network. WRAN coverage range is significantly larger than WiMAX for rural and remote accessing. In rural areas a large number of subscribers can not be connected to broadband access in WiMAX. So, WRAN is the only single candidate to solve this problem by using cognitive radio technology.

Keywords: *Cognitive radio, SDR, WRAN, WiMAX and 4G.*

1. Introduction:

Short of spectrum, no wireless telecommunication or wireless internet services would be possible. Cognitive Radio is not only a radio technology; it also includes a radical change in how the spectrum is regulated. Cognitive Radio and 4G are two complementary improvements that will reframe the world of wireless communications. 4G networks giving cognitive radios are a solution that revolutionizes the telecommunication industry, significantly changing the way we design our wireless systems and services.[5]

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Cognitive radio is an intelligent software radio which changes its parameters according to available TV channels. The main functions of Cognitive Radio include Spectrum sensing, dynamic spectrum management and Adaptive communications. The development of the IEEE 802.22 WRAN standard is aimed at using cognitive radio (CR) techniques to allow sharing of geographically unused spectrum allocated to the television broadcast service, on a noninterfering basis, to bring broadband and access to hard-to-reach, low population density area, typical of rural environments, and is therefore timely and has the potential for a wide applicability worldwide. Cognitive radio is broadly projected to be the next Big Bang in wireless communications.

Ideal CR is still a challenge i.e. making a machine with the ability to intelligently make decisions based on its ownsituational awareness. Researchers expect intelligent reconfigurable CR prototypes to emerge within next five years. Some devices available already have some elements of CR for example WLAN, Military follower Jammers.[5]

In spite of the increased complexity, future networks should be easily maintainable and there capabilities should be continuously improved and upgraded by relying as little as possible on human intervention. In order to meet this demand, the networking research community proposed a new paradigm of networking: the cognitive network. [1][2]

Fourth Generation (4G) Technology will offer many advances to the wireless market, including downlink data rates over 100 megabits per second (Mbps), low latency, very efficient spectrum use and low cost implementations. With flexible network connections, efficient use of spectrum and impressive user applications, 4G will offer what consumers want [3]as shown in Figure 1. Figure 1 shows evolution of 4G communication by different generation.

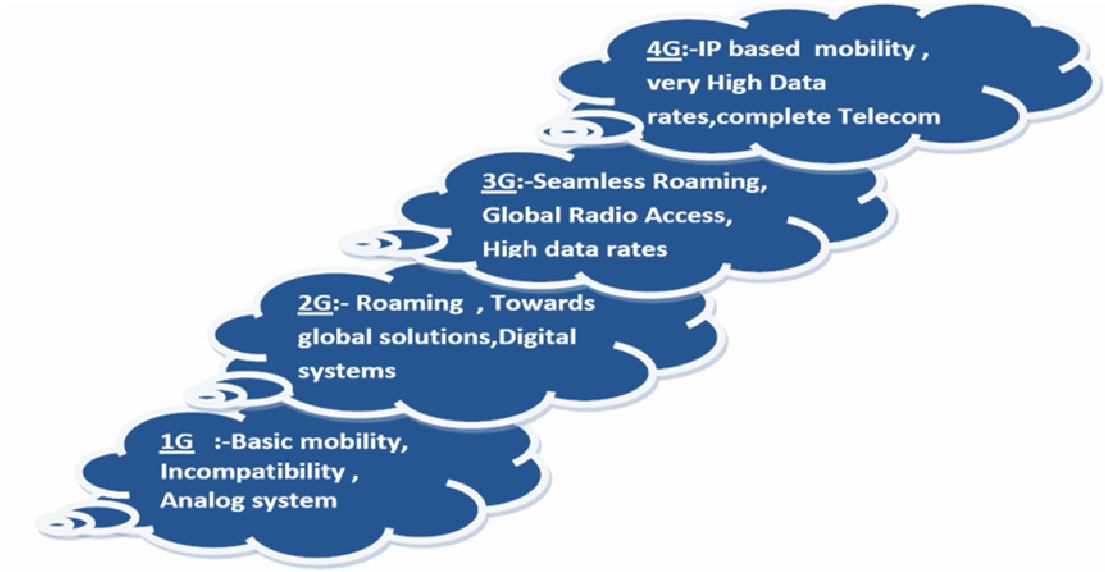

Figure 1. Evolution of 4G [4]

In developing countries like China, India & Bangladesh, about 70 percent of the total populations live in rural areas, which are spread far and wide over large geographic areas. For these communities, it is believed that providing communications services are an important step to facilitate development and social equity. However, providing communications to rural area is always challenging due to higher costs and lower demand. Most rural areas have low demand for services if compared to urban areas. To create a viable business, operators must aim for low-cost solutions. There are various standards developed and are used for the wireless communication. Wireless systems based on IEEE 802 standards such as IEEE 802.11 (WLAN) so-called Wi-Fi and IEEE 802.16 (WMAN) so-called WiMAX are examples of Broad Wireless Access (BWA) systems deployed for local and metropolitan area networks, respectively. These technologies have advantages and some drawbacks. Wireless Regional Area Network is an IEEE 802.22 standard which uses white spaces of the TV frequency spectrum. It uses Cognitive Radio to detect unused TV stations.[11]

WRAN is fixed point to multi-point (PMP) system and its connectivity between the base station (BS) and the Consumer premise Equipment (CPEs) is possible in both line-of-sight (LOS) and non line-of-sight (NLOS) situations.The standard typical support range is 30 km. meeting the demands of rural areas, but based on propagation conditions it may cover up to 100 km. The minimum data rate of the system is 1.5 Mb/s in the downstream (DS) direction, i.e. from BS to CPE and 384 kb/s in the upstream (US) direction, i.e. from CPE to BS. It is expected that a BS supports up to 255 CPEs. OFDMA is also a candidate access method for the IEEE 802.22 wireless regional area network.[11]

In this paper, we reviewed a cognitive radio technology as well as role of 4G communication. The cognitive radio system is defined in Section 2. Subsequently, in Section 3, defined Software defined radio and relation with cognitive radio. WiMAX and Wireless regional area network (WRAN) standards states and coverage range are defined in section 4. Finally, Comparison between WiMAX and wireless regional area network are represented in section 5.

2.Cognitive Radio Technology:

Cognitive radio was first proposed by the Swedish researcher Joseph Mitola in a seminar in The Royal Institute of Technology in Stockholm in 1998. There are many definitions of the term Cognitive Radio that have been introduced by other researchers as well afterwards.

Here we cite some of them and first we begin with that of J. Mitola:

"*Cognitive radio is a goal-driven framework in which the radio autonomously observes the radio environment, infers context, assesses alternatives, generates plans, supervises multimedia services, and learns from its mistakes. This observe-think-act cycle is radically different from today's handsets that either blast out on the frequency set by the user, or blindly take instructions from the network. Cognitive radio technology thus empowers radios to observe more flexible radio etiquettes than was possible in the past"* [20] [6].The concept of cognitive radio is shown in figure 2.

Figure 2. The Concept of Cognitive Radio
Source: www2.ece.ohio-state.edu

The Federal Communications Commission FCC has its own definition for cognitive radio as:

"*A radio that can change its transmitter parameters based on interaction with the environment in which it operates."* [10]

Based on this definition there are 2 main features that can be obtained [14] [15]

a) Cognitive capability: It is the capability of the system to detect the existence of the information from the surrounding environment of the radio. This capability has advanced techniques of sensing and the ability to capture the different variations of that environment, without the intrusion with other users except checking the power of the frequency band. In cognitive capability, the suitable spectrum and operating parameters are being selected according to the previous identification of the unused parts of the spectrum at a certain period of time and place.[14]

b) Re-configurability: For this property, the system has the ability to be programmed according to the radio environment rather than the spectrum attentiveness in the cognitive capability property. This programming can allow the radio to receive and transmit a wide range of frequencies using different transmissions techniques.[16]

The cognitive radio can sense a spectrum of wide range of frequencies and make some communication links by using the information opportunistically. Generally, there are 2 users in Cognitive radio networks, the primary user (PU) and the secondary user (SU). The PU uses the channel of the transmission and the SU tries to be in the channel in an opportunistic way when it's not used by the PU. So the SU tries to find an empty space in the transmission channel and to evacuate the channel when the PU starts to use the channel again. [17]

The SU access for the channel is considered as unstable, but this access should not be interfered by the PU when it needs to use the channel. When the SU starts to transmit in the channel of the primary user, then some delay is noticed in the arrival of the information.[19]

3. Software Defined radio: The software defined radio (SDR) forum has defined the cognitive radio as:

"*Radio in which communication systems are aware of their environment and internal state and can make decisions about their radio operating behavior based on that information and predefined objectives. The environmental information may or may not include location information related to communication systems."* [10]

Figure 3 shows that The Evolution of SDR & other wireless networks.

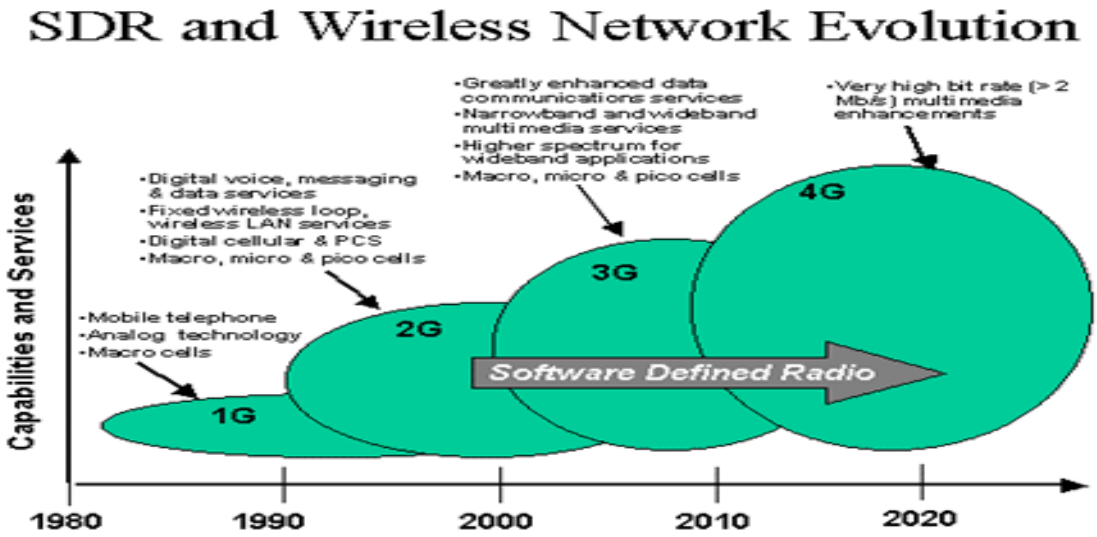

Figure 3. The Evolution of SDR & other wireless networks.[12]

Wireless technology basically depends on the signals, physical hardware and their attributes. In the past communication technology had straightforward signaling, analog hardware and very limited functionality. The Software Defined Radio (SDR) was introduced for handling more than one communication technology (e.g. GSM and CDMA) [8] such that the terminals can change their operation with respect to the software. In recent times different signaling methods have been proposed and used in various communication technologies all over the world. Software defined radio enhances the wireless devices with cognition abilities like awareness, learning, sensing and reasoning. Also, it has the capability to resolve the emerging interoperability issue by providing a global seamless connection. Before the invention of cognitive radio, SDR was focused on multi-mode and multi-standard devices. SDR plays a vital role, to realize the features of cognitive radio [8].In Figure 4. ShowsCompares cognitive radio with traditional and software radio.

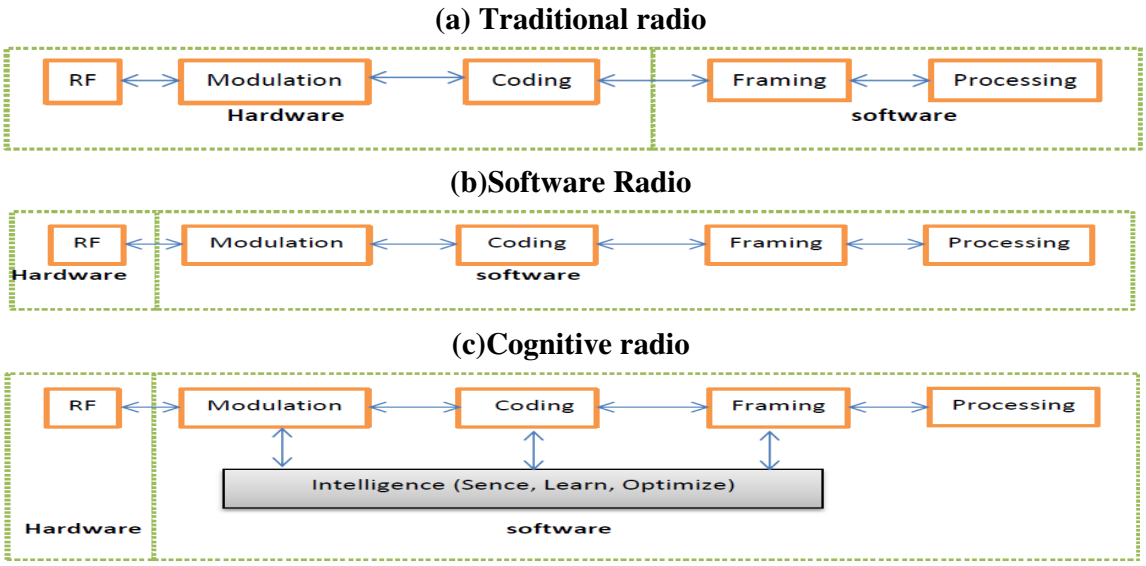

Figure 4. Logical diagram contrasting traditional radio (a), softwareradio (b) and cognitive radio (c).[14]

3.1 SDR and its relationship with Cognitive Radio:

The relation between the SDR and the cognitive radio can be demonstrated in Figure 5. It is clear from the below diagram that the cognitive radio encompasses the SDR. The SDR is developed in software based on Digital Signal Processing with the modifiable Radio Frequency components .Hence, the SDR is a generic radio platform which has the capability to operate in different bandwidths over a large number of frequencies as well as using different modulation schemes and waveform formats. As a result, the SDR can support multiple standards such as GSM, WCDMA, WiMAX as well as 4G networks and multiple access schemes such as TDMA, OFDM and SDMA etc. [7]

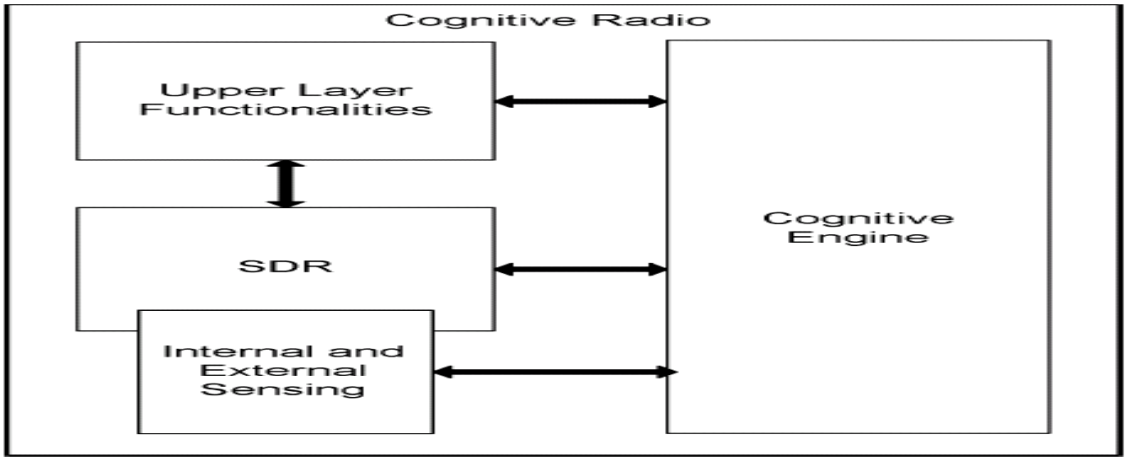

Figure 5. The relationship between the SDR and the cognitive radio.[7]

I. Why Cognitive Radio?

Cognitive radios are built on software-defined radio (SDR) technology [9]. Which involves authorities in digital communication, wireless networks, and so many other fields? While providing greater flexibility and access to the spectrum the SDR system also respect the rights of the obligatory license holders. For revolutionize the telecommunications industry, Dynamic Spectrum Access (DSA) networks employing cognitive radios is the key by the given request for more bandwidth and the quantity of underutilized spectrum. Apart of which we use spectrum resources, to design wireless systems and services.

(A).Benefit of Cognitive Radio

CR offers optimal variety in coding, frequency, modulation, power, time, space, polarization and so on which leads to

Efficiency of spectrum- This will allow upcoming demand for spectrum to be encountered and is the basic purpose behind implementation of CR.

High bandwidth service- Demand of wireless service is continuously increasing which will be fulfilled by the implementation of CR.

Graceful Degradation of Services - When conditions are not ideal, a graceful degradation of service is provided, as opposed to the less desirable complete and sudden loss of service.

This feature of CR is very important in providing services to the users especially when they are mobile and the base stations in contact are constantly changing.

Quality of Service improvement- availability and reliability of wireless services will improve from the user's point of view.

Benefits to the Service Provider- Because of increased information transfer rates more customers attract towards the services.

Future-proofed product-A CR is able to modify services, protocols, modulation, spectrum etc. without the need for a user or manufacturer to upgrading to device.

Common hardware platform- Manufacturers does not need to build several hardware variants, instead using a single common platform to run a wide range of software.

Emergency communication services- At the time of major incidents joint operations would greatly beneficial to police, fire, ambulance could be linked together in one radio.

Benefits to the Licensee- In this, licensee would be allowed to rent a portion of their spectrum rights to other parties and make money.

(B). Application of cognitive Radio

There are various new generation wireless applications and services in which we can add CR capabilities. Some of this application is as follows

Future (upcoming) internet services- upcoming internet services supporting wide band, high data rates, and seamless quality of service guarantee for various multimedia and other applications.

Multimedia downloads in mobile- To download music, video and other files in portable player, requires moderate data rates and good coverage.

Communication during emergency services- we require localized coverage and moderate data rates at the time of emergency for communication. (Military, surveillance etc.)

Wireless multimedia services-For audio, video distribution using wireless system requires higher data rates.

4. Description of WiMAX & WRAN standards:

The WiMAX(IEEE Standard 802.16e) technology is widely used now-a-days whereas WRAN (IEEE Standard 808.22) is a developing project of IEEE which was finally published in July 2011.

4.1 WiMAX (IEEE Standard 802.16e) outline:

WiMAX is a standards-based wireless technology that provides high-throughput broadband connections over long distances and mobile environment. The IEEE 802.16e is based on Orthogonal Frequency Division Multiple Access (OFDMA) whose main aim is to give better performance in non-line-of-sight (NLOS) environments [22]. IEEE 802.16e introduced scalable channel bandwidth up to 20 MHz, Multiple Input Multiple Output (MIMO) and MAC enabled 802.16e technology to support peak downlink (DL) data rates up to 63 Mbps in a 20 MHz channel through Scalable OFDMA (S-OFDMA) system.[23][22]

4.2 WRAN (IEEE Standard 802.22) Outline:

The idea behind 802.22 is that there are considerable unused frequencies between VHF and UHF broadcast channels between 54 and 862 MHz [24]. This is possible by using cognitive radio capabilities. These include dynamic spectrum access, incumbent database access, accurate geolocation techniques, spectrum sensing, spectrum etiquette, and coexistence for optimal use of the available spectrum. Essentially this means that it will be possible to send wireless broadband access without interfering with TV signals [13]. It is designed for last-mile service in low populated areas especially rural area. Infigure 6,shown a typical IEEE 802.22 (WRAN).

4.3. Coverage design of WiMAX & WRAN:

Network design, cell structure, and frequency usage policies are three important issues for coverage design. Distance between transmitter and receiver, signal to noise ratio, transmitter and receiver antenna height and modulation technique are also considered.We considered link budget calculations in a rural area such as parameter like path loss, mobile antenna height, carrier frequency, base station height, mobile station height and correction factor etc. Path losses are calculated by Cost-231 Hata Model.[25]

The goal of our paper is to review the coverage design of existing WiMAX technology and seek to improve the coverage range by using the IEEE Standard 802.22(WRAN).

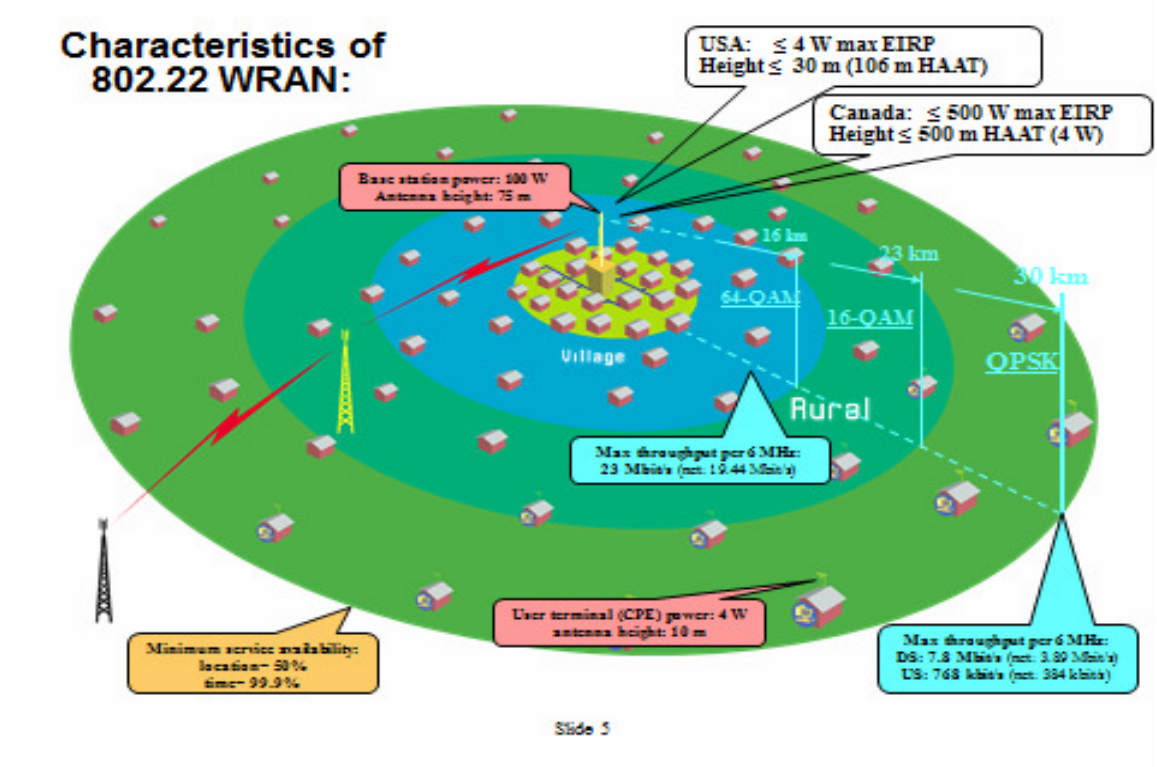

Figure 6.A Typical IEEE 802.22 (WRAN) networks.[21]

Our aim is to observe the change of cell range with respect to transmitter height, modulation schemes and compare the results to find out the better coverage design. 730MHz frequency band is used as a TVWS, transmitter and receiver heights are assumed as 32 m and 5.5 m. The parameters are considered for QPSK 1/2, QPSK 3/4, 16-QAM ½,16-QAM 3/4 and 64-QAM 3/4.The results are showed in Table-1.

II.Coverage Range in Rural Area(Downlink)

Modulation Technique	WRAN (IEEE 802.22)	WiMAX (IEEE 802.16e)
QPSK 1/2	59km	7km
QPSK 3/4	46km	6km
16QAM 1/2	40km	5km
16QAM 3/4	29km	4km
64QAM 3/4	21km	3km

III.Coverage Range in Rural Area (Uplink)

Modulation Technique	WRAN (IEEE 802.22)	WiMAX (IEEE 802.16e)
QPSK 1/2	61km	9km
QPSK 3/4	49km	8km
16QAM 1/2	41km	7km
16QAM 3/4	31km	5km
64QAM 3/4	19km	3km

Table 1. Comparison coverage range between WRAN & WiMAX in Rural Areas (II and III).

5. Comparison betweenWRANand WiMAX:

For descriptive reasons technical parameters of the standard of IEEE 802.22(WRAN) the comparative table with WiMAX (IEEE 802.16e) is more low result:

Table 2.Comparison between WRAN(IEEE 802.22) &WiMAX (IEEE 802.16e).

Technical Parameter	WRAN(IEE802.22)	WiMAX(IEEE 802.16e)
Air interference	OFDMA	OFDMA, OFDM, single carrier
Multiple Antenna techniques	Not supported	Support Multiplexing, space time coding and Beam forming
Self coexistence	Dynamic spectrum assignment	Master frame assignment
Coexistence with incumbent	Spectrum sensing management, Geolocation management, incumbent database query and channel management	Not supported
Internetworking communication	Over the IP network	Over the IP network
OFDMA channel profile (MHz)	6,7,8 (according to Regulatory Domain)	28, 20, 17.5, 14, 10, 8.75, 7, 3.5, 1.25
Coverage Area	33-100 Km (Rural) 30-94Km(Urban)	1-6 Km(Rural) 1-17 Km(Urban)
Cost	Costly compare than WiMAX	Less Costly compare than WRAN
Projects	IEEE 802.22, IEEE 802.22.1, IEEE 802.22.1	IEEE 802.16, IEEE 802.e, IEEE 802.16h, IEEE 802.16m
Network Topology	Point-to-Multipoint (PMP)	Point-to-Multipoint (PMP)& Mesh Topology
Geo-location	GPS based geo-location is mandatory, but terrestrial geo-location (triangulation) is supported	Use Only GPS based geo-location.
Mode of BPF	2048	512
Layout of packets	The Linear	2D
Data flow rate (max)-for 6 MHz	22.7 Mbit\s	15.8 Mbit\s

In table 2, the specification of the standard of IEEE 802.22(WRAN) is simple and easy to understand. Developers try to make the optimal technology of a data interchange for rather big distances and comprehensible transit velocities.

(C) Application of WRAN

The main application for IEEE 802.22 standard (WRAN) is the access of the wireless broadband in distant areas. This access has the voice, data and the support of the quality of service (QoS). In areas like villages and suburbs, it is valuable to use bands of low frequencies because of the preferred transmission conditions that face these low frequencies in cognitive radio networks, which are licensed for wireless microphones and TV broadcasting. As an example there are many unoccupied TV channels in many different areas in United Stated of America, and through the satellite or by cable access the TV signal is delivered. So, economically and technically it is a worthy case to open those low frequency bands for WRAN. Additionally, the IEEE 802.22 WRAN can also be used for home offices and small businesses.

6. Conclusion:

In this paper the role of cognitive radio on 4G communication systems has been emphasized. 4G is a fourth generation network in which we access many applications anywhere and anytime. Cognitive radio is very useful, because it provide efficient, cheaper and high capacity network. We observe the comparison between WRAN and WiMAX in our work. WRAN coverage range is significantly larger than WiMAX for rural and remote accessing. In rural areas a large number of subscribers can not be connected to broadband access in WiMAX. So, WRAN is only single candidate to solve this problem by using cognitive radio technology. It's peak data rates also much higher than WiMAX.Thedevelopment in day-to-day communication is not just a 4G EVOLUTION; it's the REVOLUTIONISATION in the world of technology."

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