

UDC 681. 3.07

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METHOD OF MODELING THE COGNITIVE RADIO USING OPNET MODELER

This article is a review of the first wireless standard based on cognitive radio networks. The necessity of wireless networks based on the technology of cognitive radio. An example of the use of standard IEEE 802.22 in Wimax network through which was implemented in the simulation software environment Opnet Modeler. Schedules to check the performance of HTTP and FTP protocols CR network. Simulation results justify the use of standard IEEE 802.22 in wireless networks.

Keywords: Wimax, CR, IEEE 802.22, OpnetModeler, SNR, HTTP, FTP, WRAN, TV broadcast bands, PHY and MAC layer design, spectrum utilization, spectrum sensing, topology, coexistence.

Problem statement. The wireless regional area network (WRAN) technology is initially targeted at wireless broadband access for geographically dispersed, hard-to-reach, low population density areas, or other unserved/underserved areas where wired infrastructure cannot be economically deployed, typical of rural environments. The transmission range can be up to 100 km, non line of sight due to use of TV broadcast bands as license-exempt spectrum [6].

The WRAN system will provide packet-based transport capabilities that can support a wide range of services (e.g. internet access, data transport, voice and streaming video) to residential, Small and Medium Enterprises (SME) and Small Office/Home Office (SOHO) locations [4].

The WRAN system must be capable of supporting a mix of data, voice and audio/video applications. The critical parameters for serving these markets using wireless access technology is the combination of coverage/capacity factors that affects access cost per user, the deploy ability, maintainability and product costs associated with the customer premise installation, and spectrum efficiency/reuse for economically serving the required number of customer locations with a minimum number of base station locations and backhaul routes [2].

Not all the TV channels are used as it is necessary to allow guard bands between active high power transmitters to prevent mutual interference. Also not all stations are active all of the time. Therefore by organizing other services around these constraints it is possible to gain greater spectrum utilization without causing interference to other users. One particular technology that is key to the deployment of new services that may bring better spectrum utilization is that of cognitive radios (CR) technology. By using this the radios can sense their environment and adapt accordingly [7].

The cognitive radio enables the usage of temporarily unused spectrum, which

is referred to as spectrum hole or white space. If this band is further utilized by a licensed user (primary system), the cognitive radio (secondary system) moves to another spectrum hole or stays in the same band, altering its transmission power level or modulation scheme to avoid interference. It is the key technology that will enable flexible, efficient and reliable spectrum use by adapting the radio's operating characteristics to the real-time conditions of the environment. CRs have the potential to utilize the large amount of unused spectrum in an intelligent way while not interfering with other incumbent devices in frequency bands already licensed for specific uses. CRs challenge the current notion of spectrum scarcity, and frame the problem as that of spectrum access and sharing [6].

The use of cognitive radio technology is therefore key to the new IEEE 802.22 WRAN standard (Figure 1). In October of 2004, the IEEE802 Committee had set up the IEEE802.22 Working Group. It's developing functional requirements for a Point-to-multipoint (P-MP) interoperable air interface of PHY and MAC. The standard applies to the current spectrum of TV broadcast services to implement CR-based Wireless Regional Area Network (WRAN) [8].

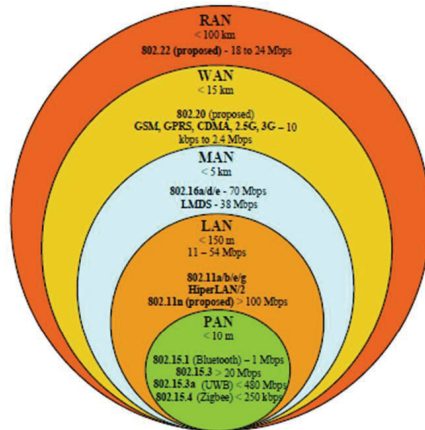


Figure 1 – Positioning of WRAN amongst IEEE 802 wireless networks

Analysis of the literature. Since 1999 when J. Mitola III specified the main concepts of cognitive radio technology[12], various researches to realize it are made [10]. A new IEEE 802 Working Group formed in 2004 has success in development and standardization of cognitive radio especially [2]. Working Group 802.22 solved a problem of spectrum sharing with licensed TV broadcast bands required for wireless regional area networks using cognitive radio. Nowadays many publications demonstrated necessity and currency of further researches for realization and optimization of this standard [1, 5, 9, 11].

The purpose of the article is to make complete in-depth overview of promising standard IEEE 802.22.

The IEEE 802.22 System. The current 802.22 project identifies the North American frequency range of operation from 54-862 MHz, while there is an ongoing debate to extend the operational range to 41-910 MHz as to meet additional international regulatory requirements. Also, since there is no worldwide uniformity in channelization for TV services, the standard shall accommodate the various international TV channel bandwidths of 6, 7, and 8 MHz [6].

The *topology* of 802.22 system specifies point-to-multipoint(P-MP) wireless air interface whereby a fixed base station (BS) manages its own cell and all associated fixed and portable Consumer Premise Equipments (CPEs), as depicted in Figure 2.

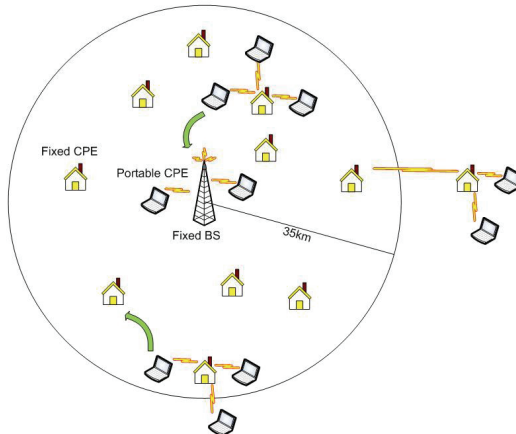


Figure 2 – Exemplary 802.22 deployment configuration

The specified *range* for a CPE is 33 km and in some instances BS coverage may extend to 100 km. To achieve the 33 km range, the power level of the CPE is 4 Watts EIRP. The system has been defined to enable users to achieve a level of performance similar to that of DSL services available. This equates to a downlink or download speed of around 1.5 Mbps at the cell periphery and an uplink or upstream speed of 384 kbps. These figures assume 12 simultaneous users. So the overall *system capacity* must be 18 Mbps in the downlink direction [8].

The *PHY layer* maintains a high degree of flexibility and adaptability. An OFDM scheme has been adopted. To provide access for multiple users, OFDMA is used for both upstream and downstream data links. Recent studies reveal that in order to obtain a flat fading channel the number of sub carriers per TV channel would have to exceed two thousand, which may increase cost and complexity for a standard. On the other hand, performance can be considerably enhanced. IEEE 802.22 allows a variety of modulation schemes to be used within the OFDMA signal: QPSK, 16-QAM and 64-QAM can all be selected with convolutional coding rates of 1/2, 3/4, and 2/3 [3].

Further, since 802.22 operation is unlicensed and a BS serves a large area, co-existence amongst collocated 802.22 cells (henceforth referred to as self-coexistence) is of paramount importance. In order to minimize interference not only to incumbent services but also self interference, effective power control is important. To meet this requirement, 802.22 specifies the Transmission Power Control (TPC) dynamic range to be at least 30 dB with 1 dB steps. Frequency agility is the other ingredient to the coexistence mechanisms of the 802.22 PHY that shall be able to adjust its frequency of operation not only within a short period of time, but also as often as necessary while conserving energy [9].

In order to be able to obtain the required level of performance, it has been necessary to the IEEE 802.22 to adopt a system of what is termed "Channel Bonding". This is a scheme where the IEEE 802.22 system is able to utilize more than one channel at a time to provide the required throughput. In practice the maximum number of channels that are bonded is likely to be limited to three as a result of the front-end bandwidth limitations [7].

The *MAC layer* design. As there is no fixed channel for the system, and no pilot channel can be broadcast, any CPE when turning on and initializing needs to be able to find the signals. Accordingly, when initializing, any CPE first scans the available spectrum to look at channel occupancy. It will detect those channels free of television transmissions. In the remaining empty channels it will then scan for base station pilot signals and acquire any network information. Once it has acquired the correct network it can then proceed to connect to the network.

It is also necessary to have a defined format for the data. To enable the data to be suitably structured, the transmission is formatted into frames and super frames. The super frame is built up from the smaller frames. The super frame is used to provide overall synchronization for the system, and in particular provides the initial network access/entry initialization. Frames are split into two elements: the upstream sub frame and the downstream sub frame. The boundary between these two sub frames is variable and can be adapted to accommodate changes on the levels of upstream and downstream capacity required [1].

An 802.22 cell can operate without causing harmful interference to incumbents, the BS shall instruct its associated CPEs to perform periodic measurement activities, which may be either in-band or out-of-band. In-band measurement relates to the channel used by the BS to communicate with the CPEs (and also those affected by this communication such as adjacent channels), while out-of-band correspond to all other not affected channels [2].

The 802.22 MAC also incorporates a vast set of functions that allow it to efficiently manage the spectrum. Operations such as switch channels, suspend/resume channel operation, and add/remove channels are among the many actions the MAC may have to take in order to guarantee incumbent protection and effective coexistence.

Coexistence is critical to the 802.22 air interface. To this end, CR techniques are incorporated into 802.22 by means of distributed spectrum sensing, measure-

ments, detection algorithms, and spectrum management.

The 802.22 doesn't only provide its intended service, but also guarantees that existing incumbent services can continue to be provided. With these two goals, it is believed in 802.22 the need for each CPE radio to possess two separate antennas (under the control of a single MAC and PHY): one directional and one omni-directional (with gain of 0 dBi or higher). The directional antenna would be the operational antenna generally used by a CPE to communicate with the BS. The omni-directional antenna, on the other hand, would be used primarily for sensing and performing measurements.

The BS vacates a channel if licensed signals are detected above the following thresholds (referenced to the receiver input):

- Digital TV (DTV): -116 dBm over a 6 MHz channel;
- Analog TV: -94 dBm measured at peak of sync of the NTSC picture carrier;
- Wireless microphones: -107 dBm measured in a 200 KHz bandwidth [11].

The response time is the time during which TV broadcast and wireless microphone operation can withstand interference before the 802.22 system vacates the channel. The minimum rate of sensing for TV broadcast could be 1 hour and the vacate time could be no more than 30 minutes, allowing for the distributed sensing mechanism to confirm presence of DTV operation. However, in the case where TV stations are not operating in a continuous mode (e.g., turned off during the night), much faster sensing is needed to vacate the channel when the TV station comes on. Here, the minimum rate of sensing could be 5 minutes and the vacate time no more than 1 minute.

Another functionality required by 802.22 is the maintenance of a table that classifies channels as per availability, such as occupied (e.g., by an incumbent), available (for use by 802.22), and prohibited (cannot be used at all by 802.22). This table is to be updated either by the system operator (e.g., setting certain channels as prohibited) or by the 802.22 sensing mechanism itself.

To avoid the interference that an 802.22 BS/CPE may create to a TV receiver, some of the assumptions made are:

- CPE antenna mounted outdoors at 10 m above ground;
- A minimum separation distance of 10 m between the BS/CPE and DTV receiving antennas;
- The antenna polarization discrimination is assumed to be equal to the DTV antenna back lobe rejection;
- No signal depolarization is assumed between the two antennas.

As depicted in Figure 2, multiple 802.22 BSs and CPEs may operate in the same vicinity and provided appropriate measures are taken at the air interface level, self-interference may render the system useless. This is further aggravated by the fact that 802.22 coverage range can go up to 100 Km, and hence its interference range is larger than in any existing unlicensed technology. Please note that contrary to other bands such as cellular where operators have a dedicated portion

of the spectrum licensed for their specific use, 802.22 BSs and CPEs operate in an opportunistic way in an unlicensed spectrum and hence coordination amongst networks of different service providers cannot be assumed and will most likely not exist [6].

Conclusion. As the time of ON and OFF iterations is highly frequent in the CR, the choice between transmission protocols is essential to NOT increase the traffic over the network. The goal is to guarantee that data is transmitted smoothly between the data providers and the end-users. The Wimax 802.16 is used to simulate the high load FTP and high browsing HTTP applications using the Opnet simulator. The Wimax 802.16 node was run over different channels individually to create the environment of CR. This assumption is based on perfect sensing and cancellation of any possibility of interference created by the primary user. The simulated scenario was arranged to test a network of CR's as shown in fig. 3.

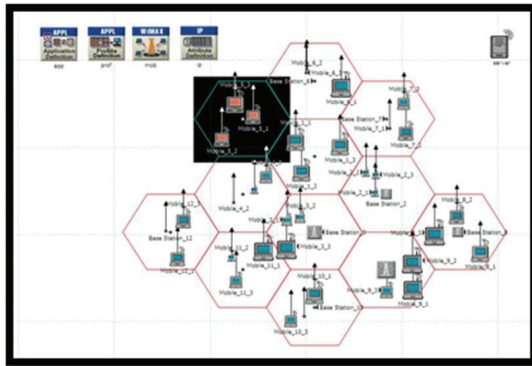


Figure 3 – Creation of cognitive radio network using Wimax

The wireless server acts as the main data provider for different base stations. Routes and transmission trajectories are formed all over the network as each base station should consider neighbouring cells in transmission requests. The Routing Information Protocol next generation (RIPng) was set as the routing protocol for the network. This protocol is used in the IPv6 for the next generation networks. The operation mode is set to Serial (Ordered) where applications are started after each other in a sequential form. The cyclic order for transmissions was chosen to be uniformly arranged. The simulation was run for 90 minutes and results were taken for cell 5 as labelled on fig. 3. The reason for this is to redirect most of the packets to pass through cell 5. Analysis of performance for the base station shows that Signal-to-Noise Ratio (SNR) in dB is considerably higher for the HTTP than FTP in Uplink average as shown in fig. 6. Whereas, the SNR associated with FTP is slightly higher, on average, than that of HTTP as shown in fig. 5. FTP is also dominant in average uplink/downlink packet dropping over HTTP as shown in figs. 6-7.

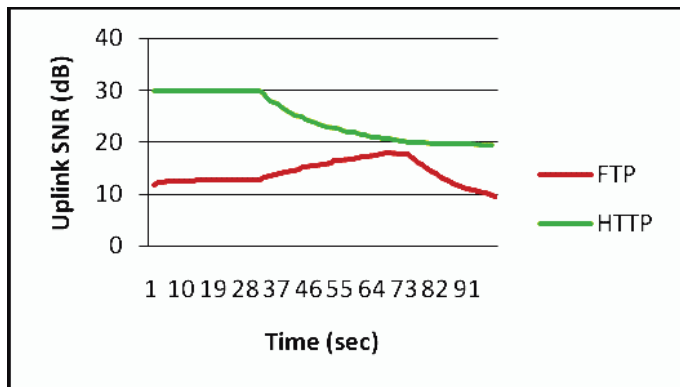


Figure 4 – Average Wimax uplink SNR

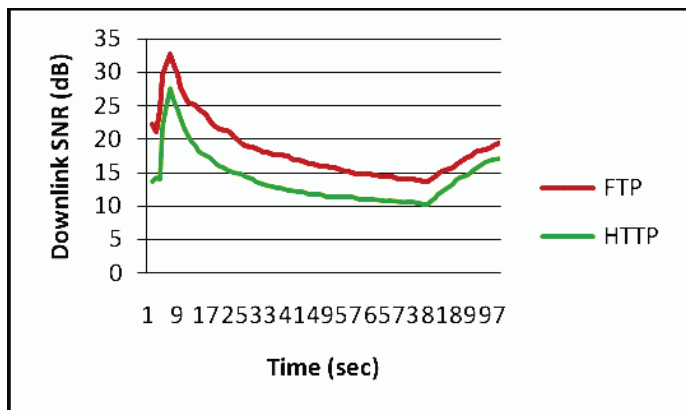


Figure 5 – Average Wimax downlink SNR

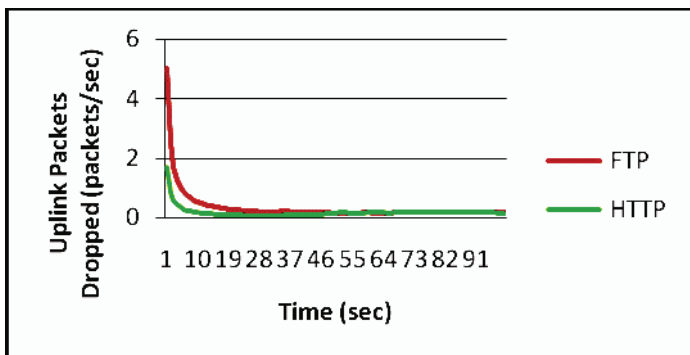


Figure 6 – Average Wimax uplink packets dropped

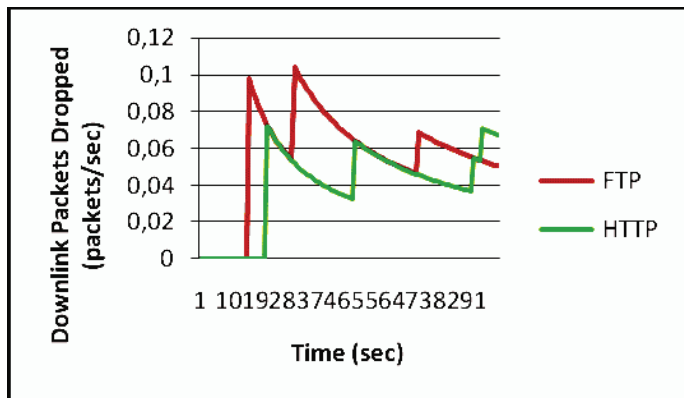


Figure 7 – Average Wimax downlink packets dropped

Summary. The CRN simulation scenario was designed using the Opnet Wimax nodes. Simulations were conducted to test the performance of HTTP and FTP protocols over CRN's. Results show that FTP transmission outperforms the HTTP transmission in terms of SNR. Files transfer may show better performance when dealing with reconfigurable systems. The doubt about the m-learning success using the CRN needs to be further analysed especially in image transfer environment.

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Has gone to editorial board 15.10.2012

Method of modeling the cognitive radio using Opnet Modeler / I. V. Yakovenko, V. M. Poshtarenko, R. V. Kostenko // Вісник НТУ «ХПІ». Серія: Техніка та електрофізика високих напруг. – Х.: НТУ «ХПІ», 2012. – № 99 (999). – С. 209-217. – Бібліогр.: 12 назв.

Ця стаття являє собою огляд першого бездротового стандарту, заснованого на мережах когнітивного радіо. У роботі були розглянуті основні елементи стандарту IEEE 802.22, такі як структура фізичного і каналного рівнів, топологія системи, сміст системи і задане покриття системи. Також були визначені головні переваги та проблеми стандарту 802.22. Використовуючи пакет Opnet Modeler, було промодульовано сегмент CR мережі через Wimax, використовуючи RIPng протокол.

Ключові слова: Wimax, CR, IEEE 802.22, Opnet Modeler, SNR, HTTP, FTP, WRAN, полоси телевізійного мовлення, структура фізичного та каналного рівнів, використання спектру, виявлення спектру, топологія, співіснування,

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