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REVIEW ARTICLE

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COGNITIVE RADIO BASED WIRELESS REGIONAL AREA NETWORK (IEEE STANDARD 802.22): A REVIEW

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ABSTRACT

IEEE 802.22 wireless regional area network (WRAN) is a standard under development by the IEEE 802 LAN/MAN Standard Committee. This will be the first worldwide application of cognitive radio (CR) networks in unlicensed T.V. broadcast bands. CR is designed to help unlicensed users utilize the maximum available licensed bandwidth [1]. This allows improved commercial data services, new emergency and military communications services. This technique was taken into consideration by the U.S. FCC for communications services in unlicensed VHF and UHF TV bands. This paper provides a detailed overview of the 802.22 air-interface architecture, topology, and operation.

Keywords: Cognitive Radio (CR); Consumer Premise Equipments (CPEs); Base station (BS); Spectrum Manager (SM); IEEE 802.22; wireless regional area network (WRAN).

I. INTRODUCTION

Radio spectrum has become the most valuable resource of the modern era. From spectrum measurements, it was found that there is heavy spectrum utilization in unlicensed bands (e.g., ISM band) while Low and medium spectrum utilization in licensed bands e.g. in TV bands and cellular bands respectively. Cognitive radio (CR) technology offers a great promise for an efficient utilization of the available spectrum. It allows sharing of geographically unused spectrum allocated to the television broadcast service as shown in Fig.1. U.S. FCC in December, 2002 explored the possibility to allow access to the TV broadcast bands for unlicensed devices, provided no harmful interference is caused to incumbent services i.e. digital TV and analog TV broadcasting and low-power licensed devices such as wireless microphones so to bring broadband access to low population-density rural or sub-urban areas [2]. Thus it has potential for worldwide applicability. IEEE formed Working Group called IEEE 802.22 WG for wireless regional area networks (WRANs) in November 2004 whose task was to develop an air interface (i.e., PHY and MAC) based on CRs for unlicensed operation in the TV broadcast bands.

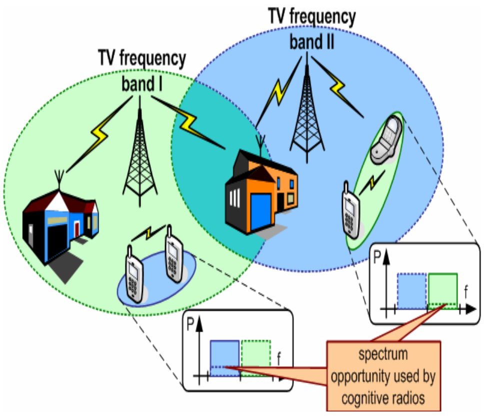

Fig. 1 Cognitive radios operating in TV and radio broadcast frequency bands. CR identifies different unused frequencies and regard them as spectrum opportunities.

II. IEEE 802.22 SYSTEM

The goal of IEEE 802.22 is to utilize the unused frequencies in VHF and UHF broadcast channels between 54 and 862 MHz while debate is going to extend the operational range to 41-910 MHz as to meet additional international regulatory requirements. Also, the standard is aimed to accommodate the various international TV channel bandwidths of 6, 7, and 8 MHz. [3]

Topology and Entities

The standard specifies a fixed point-to-multipoint (P-MP) wireless air interface. A base station (BS) manages its own cell and serving up to 255 fixed units of Consumer Premise Equipments (CPEs) associated with it as shown in Figure 2. The BS controls the access of medium in its cell and transmits in the downstream direction to the various CPEs. These equipments in return, respond back to the BS in the upstream direction. CPE has outdoor directional antennas located approx. 10 m above ground level, similar to a typical VHF/UHF TV receiving installation. WRAN will provide last-mile service in low populated areas with CR base station that covers an area of 33 km (typical) to 100 Km. The network is supposed to provide the minimum throughput of 1.5 Mbps for the downstream and 384 kbps for the upstream, allowing for video conferencing service. Four different lengths of cyclic prefix are defined as 1/4, 1/8, 1/16, and 1/32 of symbol duration to allow for different channel delay spreads while utilizing the spectrum efficiently. Due to the physical size of antenna structures at these lower frequencies, WRAN will not support multiple-antenna techniques such as (MIMO) or beam forming [3].

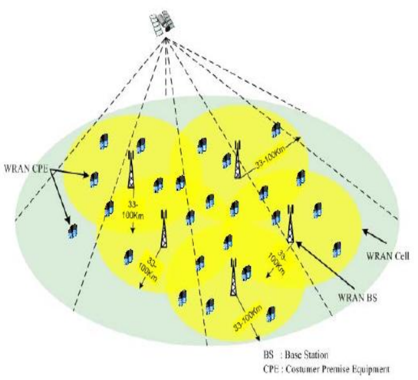

Fig.2 802.22 deployment configuration

III. ARCHITECTURE

The proposed protocol reference model (PRM) of IEEE 802.22 system shown in fig.3 addresses the PHY and MAC layers.

The interface to a station management entity (SME) through PHY and MAC layer management entities (MLMEs), as well as to higher layers such as IP, asynchronous transfer mode (ATM), through an IEEE 802.1d compliant convergence sublayer is shown. The PHY interfaces with the MAC through the PHY service access point (SAP), as well as to the MLME and the SME through the PHY layer management entity (PLME) and its SAPs.

A functional entity known as the spectrum manager (SM) exists in the MLME at the BS and a “lightweight” version of the SM, known as a spectrum automaton (SA), exists in the MLME at the CPE. The SM at the BS controls use of and access to spectral resources for the entire cell and all associated CPEs served by the BS. The SA at each CPE provides the autonomous behaviors necessary to ensure proper no interfering operation of CPE during startup/initialization, channel changes, and in case of temporary loss of communications with the BS. [2, 3]

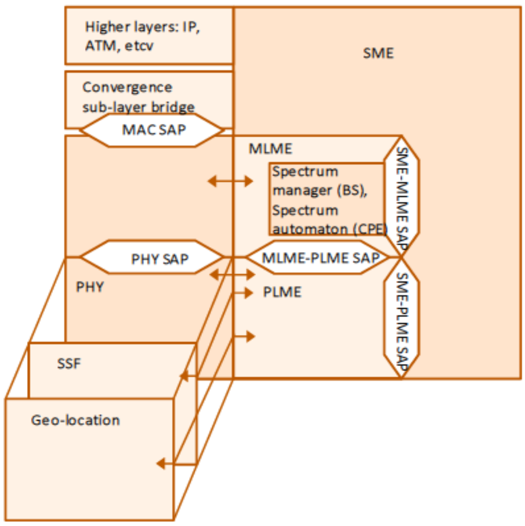

Fig.3 802.22 Protocol reference architecture for 802.22 BS or CPE

IEEE 802.22: Physical layer

PHY layer supports a system that uses vacant TV channels to provide wireless communication access over distances of up to 100 km. The specification of PHY layer is based on orthogonal frequency division multiple accesses

(OFDMA) for both Upstream (US) and Downstream (DS) access. At the PHY layer there are three primary functions: the main data communications, the spectrum sensing function (SSF), and the geo-location function, with the latter two providing functionality to support the cognitive abilities of the system.

IEEE 802.22: MAC layer

The MAC layer coordinates access to the media. It uses a synchronous timing structure, in which frames are grouped into a superframe structure. Each superframe consists of 16 frames with a fixed duration of 10 ms each. Superframe structure makes incumbent protection and self-coexistence far better.

Each frame consists of Superframe preamble for time synchronization, Frame preamble for channel estimation and Superframe Control Header (SCH) that carries BS MAC address along with the schedule of quiet periods for sensing.

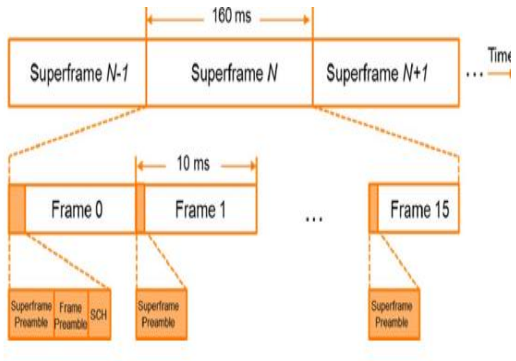

Fig.4 MAC Super frame structure

IV. INCUMBENT DETECTION

Both BS and CPE have the capability to detect the presence of an incumbent user on any channel, but the final decisions are made only by the BS. Different techniques used for detection are:-

1) Geo-location: - The IEEE 802.22 standard requires all devices in the network to be installed in a fixed location and the BS is required to know its location and the location of all of its associated CPE. The geo-location module in the protocol reference model does this function and reports the current location to the SM.
2) Incumbent database: -This is the database maintained by regulatory bodies, of licensed transmitters that can be used to determine which channels are locally available for reuse by the cognitive radio network.
3) Spectrum sensing: BS and CPEs need to perform channel sensing periodically to get the knowledge of the presence of licensed incumbents and their used channels. The 802.22 network quickly modifies its operating frequency so as to only operate on channels unused by licensed transmissions. Thus, the network must both quickly identify which channels are allowed for use and should vacate and move to unused channel within channel move time (2 seconds), if the current operating channel becomes occupied by a licensed transmission [4].

The spectrum-sensing function (SSF) and geo-location function that interface with the RF stage of the device provide information to the SM (at BS) on the presence of incumbent signals, as well as its current location via its associated SSA. [5]

The SM uses these inputs to determine TV channel for WRAN base station and the EIRP threshold for particular WRAN terminals. [6] Thus almost all of the intelligence and the decision-making capability will reside at the SM of the base station.

V. 802.22 PARAMETERS

Table1: System Parameters

S.No.	Parameter	Specification
1	Frequency range	54-862 MHz
2	Bandwidth	6 MHz, 7 MHz, 8 MHz
3	Payload modulation	QPASK, 16-QAM, 64-QAM
4	Transmit effective isotropic radiated power	Default 4 W for CPEs
5	Multiple access OFDMA Cyclic prefix modes	1/4, 1/8, 1/16, 1/32
6	Duplexing	TDD

VI. SELF-COEXISTENCE

Self-coexistence is a problem among IEEE 802.22 networks. In areas with large incumbents (licensed services), proper allocation of open channels among IEEE 802.22 BSs will be important so that the interference among the users under these BSs can be minimized .Self-coexistence refers to coexistence among 802.22 systems which ensures efficient and fair spectrum utilization. This coexistence can be achieved if 802.22 networks that are within radio range of each other must be able to synchronize their superframes with each other.

802.22 coverage range can go up to 100 Km, and hence its interference range is larger than in any existing unlicensed technology. Mutual interference among collocated WRAN systems due to co-channel operation could degrade the system performance significantly but the self-coexistence problem is approached in 802.22 with the following key elements:

1. *Neighboring network discovery and coordination*: - The WRAN operating spectrum environment is dynamic. This requires sensing not only for incumbent detection, but also for other neighboring 802.22 systems. Network discovery is part of the initialization procedures for both BSs and CPEs. WRANs can be discovered through the SCH transmitted by the BSs or by Coexistence beacon protocol (CBP) packets, which are transmitted during the self-coexistence window (SCW) window by CPEs or BSs. CPEs that discover other neighboring WRANs send this information back to their BS in the format of measurement report messages. [7]

2. *Coexistence beacon protocol:* The CBP is a communication protocol based on beacon transmissions among the coexisting WRAN cells. Synchronization of superframes is achieved by BSs and/or CPEs transmitting beacons called coexistence beacons, so that CPEs from a neighboring network may overhear them. CPEs within a network, when not communicating with their BS, look for coexistence beacons from a neighboring network. When a BS receives a neighbor's coexistence beacon, directly or from one of its CPEs, it adjusts the start time of its superframe according to certain rules.

An SCH can include various CBP which provides Backup channel information, Frame Contention information, Geo-location information etc. Thus WRAN BS can intelligently manage the operation of its associated CPEs and neighboring WRAN cells under co-existence situation. CBP packet delivered in a dedicated SCW to convey all necessary information across TV channels and facilitates network discovery, coordination, and spectrum sharing.

3. *Resource sharing mechanism*: Suppose BS A and CPE A1 operate on a given channel N. When a new BS B and CPE B1 start operation, they first scan the available channels and CPE B1 eventually detects BS A's SCH or CBP packet transmitted by A1. At this point, BS B must execute the first coexistence mechanism, called spectrum etiquette. [7]

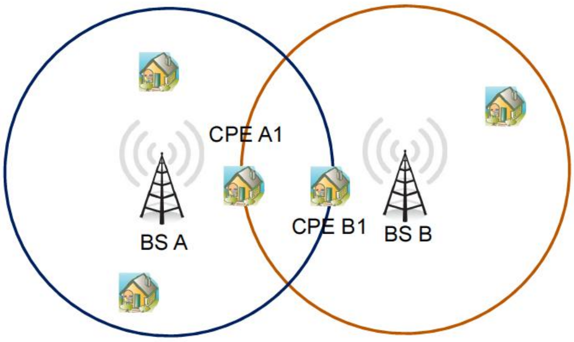

Fig.5 Resource sharing mechanism.

VI. CONCLUSION

The IEEE 802.22 is the first worldwide air interface standard based on CR techniques. This standard will operate in the white spaces of TV bands and makes use of techniques such as spectrum sensing, incumbent detection and spectrum management to achieve effective coexistence and radio resource sharing with existing licensed services. This article has reviewed the status of the work being conducted at 802.22. It can be concluded that the future of CR based wireless communication holds great promise. Thus 802.22 with CR abilities will serve as the basis for new and innovative research in this promising area.

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