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The Role of Spectrum Manager in IEEE 802.22 Standard

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ABSTRACT

The IEEE 802.22 is the first worldwide standard for wireless regional area network (WRAN) based on cognitive radio techniques. It provides access to use unused TV band without causing any harmful interference to the incumbents. This paper aims to elaborate the significance of the Spectrum Manager (SM) in WRAN Base Station (BS). It is responsible to maintain spectrum availability information of the cell. Using incumbent database, geolocation and spectrum sensing results, the SM defines the status of the channels with respect to incumbent detection. On the basis of channel status, the SM classifies the channel into different categories. A pseudocode has been proposed for the SM to perform channel decision process in two steps. Spectrum etiquette procedure is activated due to incumbent detection, neighboring WRAN cell detection/update, operating channel switching request and contention request obtained from neighboring WRAN cells. An example is given to demonstrate this procedure in a WRAN cells. Spectrum handoff mechanisms is initiated through the SM either when primary user is detected on the licensed channel or when the specified transmission time is terminated as discussed in the IEEE 802.22 standard. Other responsibilities of the SM are to impose IEEE 802.22 policies within the cell to ensure incumbent protection and maintain QoS in WRAN system. The policies are concerned with events and their corresponding actions. The SM also controls the sensing behavior of the Spectrum Sensing Automation (SSA), where SSA is an entity that must be present in all IEEE 802.22 devices which performs spectrum sensing through spectrum sensing function (SSF) after receiving request from SM.

KEYWORDS: IEEE 802.22, WRAN, Spectrum Manager, Spectrum Sensing Automation, Spectrum Sensing Function, Spectrum etiquette.

INTRODUCTION

IEEE 802.22 is the first international wireless standard based on cognitive radio techniques for the opportunistic use of spectrum on non interfering basis [1], [2]. The basic purpose of this development was to provide broadband access in remote and rural areas by exploiting the unused TV band [3], [4], [5]. The WRAN systems can operate on vacant TV channels in VHF/UHF band ranging from 54 MHz to 862 MHz frequency subject to non-interfering to the broadcast incumbents which may be digital TV, analog TV or wireless microphone. The main reason for TV band selection is two folds [6], [7]. The TV band is not always used in the geographical area, it is remained underutilized. The second reason is of having lower frequencies compared to other licensed band, therefore, results in lower propagation path loss. Due to this feature, spectral power density of the radio signal reduces slowly which results in high coverage area. The average coverage area of WRAN cell is 33 Km but it can be extended up to 100 km subject to weather condition which is larger than IEEE 802.11 based Wi-Fi and IEEE 802.16 based WiMAX. The WRAN cell consists of one Base Station (BS) and a number of fixed or portable Customer Premise Equipments (CPEs) having different quality of service (QoS) requirements. The cell follows fixed point to multi point topology with master/slave architecture and can facilitate up to 512 CPEs after fulfilling the requirements necessary for the protection of incumbent. No CPE is allowed to transmit without receiving any proper authorization from the BS. The BS manages all the activities regarding modulation, coding etc. of its all associated CPEs by controlling medium access. The downstream transmission where the BS transmits and the CPE receives is based on Time Division Multiplex (TDM) and the upstream transmissions are shared by the CPEs on demand basis according to Orthogonal Frequency Division Multiplex (OFDMA) scheme. The desired throughput between the CPE and the BS in the upstream is 384 kb/s and 1.5 Mb/s in the downstream [8].

When CPE is powered on, it first scans the TV band to determine which channels are occupied by the incumbent and which channels are free. On the basis of this observation, it establishes the spectrum usage report. The same mechanism of spectrum sensing is also performed on the BS and it periodically broadcasts using some operating channel. The broadcast from the BS is distinguished from other TV broadcasts by the preamble transmitted at the beginning of each frame. The CPE after receiving the particular frame tunes to that frequency and sends its unique identifier in the uplink direction. The BS comes to know its presence in its regional area. Then authentication and connection registration process is performed. After the connection has been established, the CPE sends its spectrum usage report to the BS in the form of feedback. When more than one CPE attempts to create an initial connection then contention based procedure similar to IEEE 802.11 takes place.

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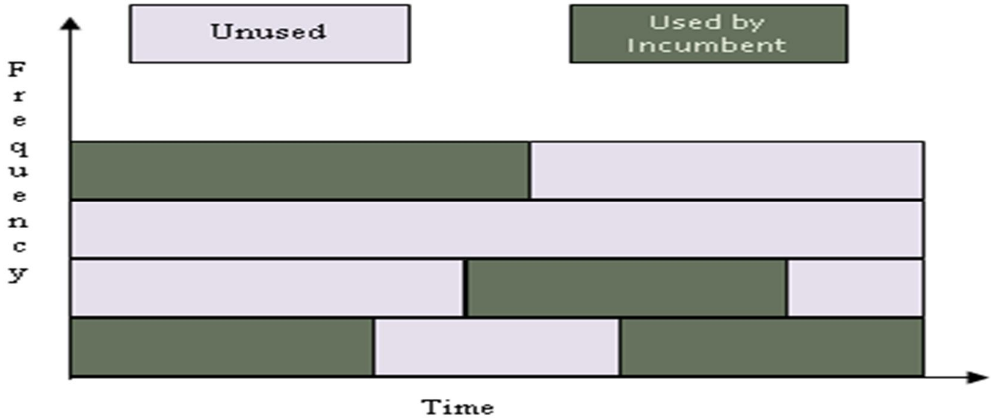

Figure 1: TV band occupancy over Time and Frequency.

The cognitive plane particularly consists of Spectrum Manager, Geolocation, Spectrum Sensing Automaton and Spectrum Sensing Function as shown in the Figure 2.

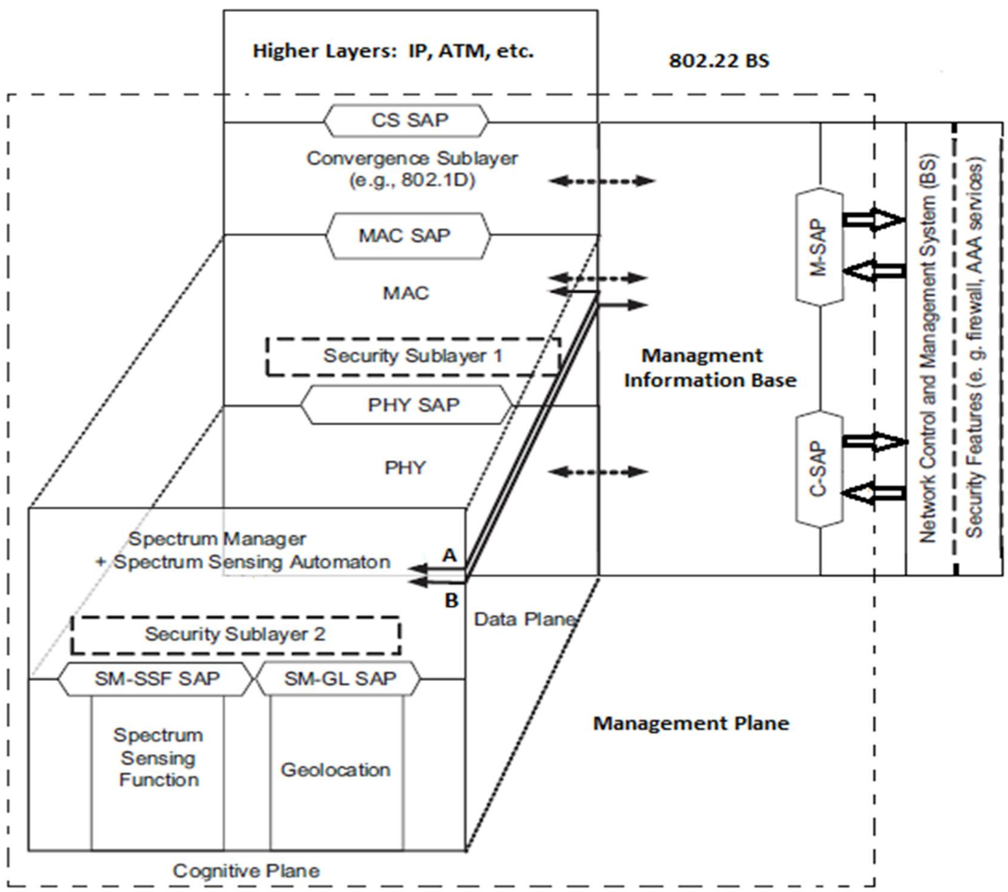

Figure 2. The IEEE 802.22 protocol reference model of a BS.

SPECTRUM MANAGER

Spectrum Manager (SM) is the integral part of the BS which should be responsible for performing the following main functionalities:

- Maintain spectrum availability Information
- Channel classification and selection
- Association control

- Accessing the database service
- Scheduling quiet periods for spectrum sensing
- Enforcing IEEE 802.22 and regulatory domain policies
- Making channel move decisions for one or more CPEs or the entire cell
- Self-coexistence with other WRANs [9], [10], [11], etc.

MAINTAINING SPECTRUM AVAILABILITY INFORMATION

The SM keeps the record of spectrum availability in its WRAN cell operation while following the rules and policies defined for that domain. It attains the information about the status of the channels with respect to incumbent occurrence and other WRAN cells in the region. This achieved information will further be used as the input in decision making for channel selection, channel state management and self coexistence issues. To make channel status operational, SM can access information from the following three sources:

Incumbent Database

The database service provides a list of available channels and their respective allowable Effective Isotropic Radiated Power (EIRP) which the CPE can transmit without providing any harmful interference to incumbent in any given geographical area and is officially incorporated by the local regulatory authority. The SM attains this incumbent database through higher layers and updates it at least once in 24 hours. Moreover, the database service may send any update relevant to the BS.

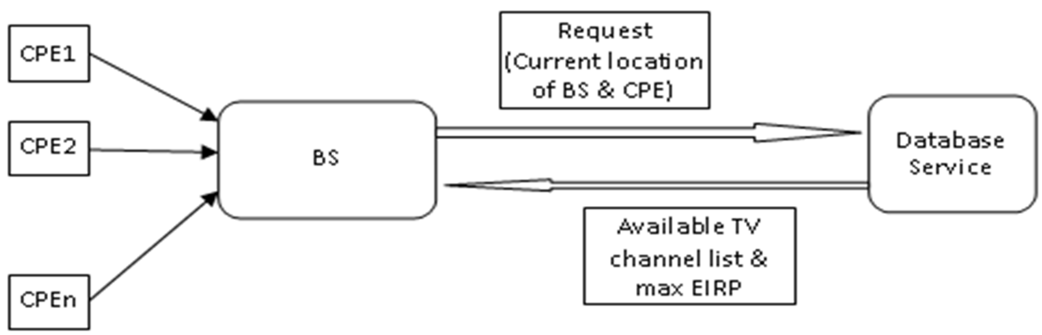

Figure 3: Structure of the IEEE 802.22 WRAN access to the database service.

Geolocation

The SM obtains the geolocation information at the BS to identify its own location and also determines the locations of all associated CPEs with the BS. There are two modes of geolocation i.e. satellite based geolocation and Terrestrial-based geolocation. The satellite based geolocation is compulsory for all IEEE 802.22 devices to find out longitude and latitude of its antenna within a radius of 50 meter. Each CPE propagates its coordinates to BS during registration phase.

The terrestrial-based geolocation is used to determine how far CPE is located from the BS. The geolocation technology assists in detecting if any device moves a distance greater than the specified distance, then in such situation WRAN system will follow the local regulations to acquire the new list of available channels for the new location of the device.

Spectrum Sensing

Simply, the process of observing TV band to determine the occupancy of TV channel is called spectrum sensing. All IEEE 802.22 devices (CPEs & BS) has Spectrum Sensing Automation (SSA) entity which is incorporated by the SM using PHY/MAC layer functionalities and management frames to control spectrum sensing with in WRAN cell. The SM sends the requests for SSAs to perform spectrum sensing and combines the received spectrum sensing reports from CPEs with local sensing report. There is no particular spectrum sensing technique recommended by IEEE 802.22 standard, any technique can be incorporated subject to fulfill the specification requirements. The sensing requirement can be expressed in term of sensing receiver sensitivity, channel detection time, probability of detection and probability of false alarm [12]. All devices in IEEE 802.22 network will sense incumbent transmission using omni-directional antenna which should be at least 10 meter high from the ground as well as 10 meter away from TV antenna. For 0 dbi antenna gain, the sensing receiver sensitivity for digital TV, analog TV and wireless microphone are –116 dBm, –94 dBm, –107 dBm respectively. The channel detection time is 2 second and the probability of detection is 0.9, whereas the probability of false alarm is 0.1 for all signal types.

After gathering information from incumbent database, geolocation and spectrum sensing results, the SM defines the status of the channels with respect to incumbent occurrence. In a situation where database service is not required like regulatory domain, all channel are assumed to be available, the SM declares the channels status on the basis of spectrum sensing. This channel availability information is defined during network initialization and is periodically updated during network operation.

CHANNEL CLASSIFICATION AND SELECTION

Another important task of the SM is to perform channel management process. Its key objective is to protect incumbent from interference of WRAN device. Here the main functionality is the classification and selection of TV channels which is primarily based on channel status. Broadly speaking, the SM categorizes channels into two main groups: available/unavailable for WRAN operation at a given geographical area. The available channels are further classified into 6 mutually exclusive groups [8].

Disallowed: Due to regulatory/operational constraint, these channels are not employed for WRAN operation. For example, channel 37 is reserved in USA for medical telemetry equipment.

Operating: The current channel utilized for communication between the BS and the CPEs in WRAN cell is termed as operating channel. This channel should be sensed after every 2 seconds for incumbent detection and wireless beacons depending upon the regulatory domain.

Backup: These channels have been declared free from incumbent occupancy and may be used as an operating channel if WRAN needs to move to another channel. The backup channels should be sensed for incumbent protection at least once every 6 seconds and are maintained by the BS at any given time and location. This channel remains in backup channel state as long as no incumbent occurs.

Candidate: The channel that can attain the status of backup channel is termed as a candidate channel. To search the candidate channel among the available channels, the BS may send request to the CPEs to sense and evaluate its possibility. Before declaring it a backup channel, it is mandatory to sense it in at least every 6 seconds but not more than 30 seconds, so that no incumbent may appear. This is the additional work a CPE has to perform to constitute the list of candidate channels. It is important to note that each candidate channel can become a backup channel and each backup channel can become an operating channel based on channel state.

Protected: These channels are occupied by the incumbent or WRAN device. The channel occupancy information is received from database service or through sensing results. These protected channels can acquire the status of candidate channels in the case when the incumbent or WRAN systems have left the channel. It is also possible that a protected channel may turn into a backup channel when no incumbent is found through sensing which should be carried out in at least every 6 seconds but not more than 30 seconds.

Unclassified: These channels could not be sensed due to some delay in channel sensing schedule. Once the unclassified channels have been sensed, they can get the status of protected channel or candidate channel subject to the sensing results.

These channel sets are maintained by the WRAN BS and each CPE is responsible for maintaining only operating, backup and candidate channel sets. These channel sets are updated individually. For example, from CPE side, operating set is updated after receiving super frame control header (SCH) where as backup and candidate channel sets are confirmed by getting downstream channel descriptor (DCD) message. From the above classification, it can also be observed that the sensing time fluctuates with channel status, i.e. sensing time for operating channel is 2 seconds but for backup channel, it is 6 seconds. Table-1 depicts the sensing time for different channel types. The SM normally makes the channel decision process in two steps which has been demonstrated in the PSEUDOCODE-1. First, the SM contacts the database service if it exists, gets information about the availability of TV channels. As discussed earlier, if database service does not exist, then the all TV channels are assumed to be available. On the basis of sensing results, the SM is in a position to pronounce the channel status.

PSEUDOCODE-1 FOR CHANNEL DECISION

```
MAIN PROCEDURE Channel_Decision
BEGIN
    IF database service exists   THEN
        PERFORM database authentication process
            IF Channels are available THEN
                CALL PROCEDURE Channel_Classification
            ELSE
                DISPLAY   Channels are unavailable
            ENDIF
    ELSE
        CALL PROCEDURE Channel_Classification
    ENDIF
END
PROCEDURE Channel_Clasification
BEGIN
    IF Channels are sensed THEN
        DISPLAY     Disallowed Channel List
        DISPLAY     Operating Channel
        DISPLAY     Backup Channel List
        DISPLAY     Candidate Channel List
        DISPLAY     Protected Channel List
    ELSE
        DISPLAY     Unclassified Channel List
    ENDIF
END
```

Table-1: Sensing time for different channel types.

Channel Type	Sensing Time
Operating Channel	2 seconds
Backup Channel	6 seconds
Candidate	$\geq$ 6 seconds but $<$ 30 seconds

SPECTRUM ETIQUETTE

A channel cannot have more than one state at a time but it may be possible in a situation where operating channel for one WRAN cell can also be the same operating channel for neighboring WRAN cell. This situation is called self-coexistence. To avoid this phenomenon, there are certain rules called spectrum etiquettes used for channel selection so that the neighboring WRAN cells may not experience interference. In this regard, cooperation plays an important role in minimizing the channel collision probability when more than one WRAN cells switch their operational channels having the same backup channel set. Without cooperation, the channel selection of one cell may cause the shortage of channels for the other cells. For example we have three cells *C1, C2, C3*. Suppose the backup channel sets for *C1*, *C2* and *C3* are denoted by β1, β2 and β3 respectively such that β1= {4, 5. 6}, β2= {4, 5, 6} and β3= {4, 6}. Now, suppose the cell *C1* decides to utilize channel 4 as an operating channel and the cell *C2* wants to operate on channel 6, so in this case the cell *C3* will have no channel to operate on. Therefore cooperation is an important factor for smooth running of WRAN cells.

Spectrum etiquette is activated due to incumbent detection, neighboring WRAN cell detection/update, operating channel switching request because of interference and contention request obtained from neighboring WRAN cells. In addition of operating, backup and candidate channel sets, the following channel sets are also employed in spectrum etiquette operation.

WRAN occupied Channel Set = Operating channels of the detected neighboring WRAN cells = Ω_1

Neighbor WRAN Backup Channel Set = Backup channels of the detected neighboring WRAN cells = Ω_2

Local Priority Set1 = $\{x |\ x \in Backup\ channel\ set\ or\ x \in Candidate\ channel\ set\ and,\ x \notin \Omega_1 \text{ or } x \in \Omega_2\} = \Omega_3$

Local Priority Set2 = $\{x |\ x \in Backup\ channel\ set\ or\ x \in Candidate\ channel\ set\ and,\ x \in \Omega_1\} = \Omega_4$

Local Priority Set3 = $\{x |\ x \in \Omega_1\} = \Omega_5$

The local priority sets are not shared with neighboring WRAN cells. Spectrum etiquette procedure is illustrated in Pseudocode-2.

PSEUDOCODE-2

```
PROCEDURE Channel_etiquette
BEGIN
    IF      exclusive operating channel available THEN
            Move to the selected channel
    ELSE
            CALL PROCEDURE contention_based_coexistence
    ENDIF
END
```

This spectrum etiquette procedure is explained in the following steps.

1. The SM constructs or renews all above mentioned channel sets using information received from incumbent database, geolocation and WRAN spectrum sensing. These channel sets are built or updated periodically.
2. Update backup channel set using one or more elements of Local Priority Set1 (LP1). If there is no element in LP1 then Local Priority Set2 (LP2) can be utilized for this purpose. Moreover, if LP2 also has no element then Local Priority Set3 can be incorporated for updating the backup channel set.
3. In case of channel switching due to incumbent detection on the operating channel, elevate the first back up channel to operating channel and then perform the step 2.
4. In the scenario when the new operating channel of a cell is also the operating channel of neighbouring WRAN cell then in this situation, execute self coexistence contention process.
5. Update the neighbouring WRAN operating/backup channel Sets.

ILLUSTRATIVE EXAMPLE OF SPECTRUM ETIQUETTE

Suppose, the central WRAN cell exists with 6 neighboring cells. Let the backup channels and candidate channels be represented in bold and italic characters respectively. The central cell is assumed to have one operating channel ch_4, one backup channel $\mathbf{ch_5}$ and one candidate channel ch_8 as shown in the Figure 4. Suppose, two incumbents are detected on ch_4 and $\mathbf{ch_5}$. On account of this, the central cell will have to update its channel sets; therefore the spectrum etiquette procedure will be executed. Under this procedure, the candidate channel ch_8 will be promoted to operating channel and channel ch_3 being the operating channel of one of the neighboring cell will be promoted to the backup channel as shown in the Figure 5. Due to this transition on central cell, all the neighboring cells will perform spectrum etiquette procedure.

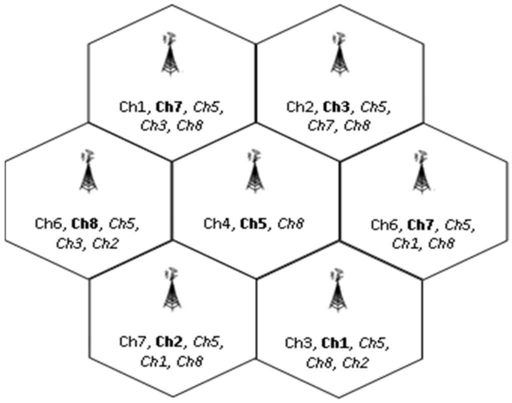

Figure 4: Before spectrum etiquette.

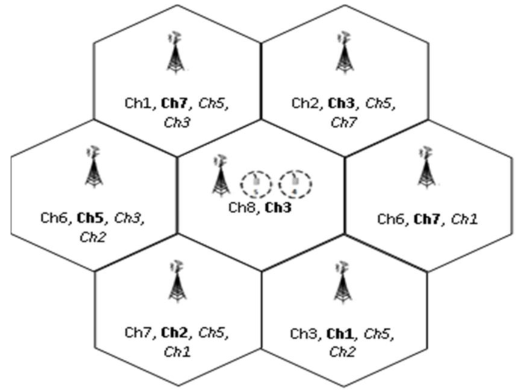

Figure 5: After spectrum etiquette.

Table 2: Spectrum Etiquette Procedure.

Central Cell Status	Before Spectrum Etiquette	Over Incumbent Detection	After Spectrum Etiquette
Operating channel set	$\{ch_4\}$	{~~ch_4~~}	$\{ch_8\}$
Backup channel set	$\{\mathbf{ch_5}\}$	{~~$\mathbf{ch_5}$~~}	$\{\mathbf{ch_3}\}$
Candidate channel set	$\{ch_8\}$	$\{ch_1, ch_2, ch_3, ch_6, ch_7, ch_8\}$	{ }
$\mathbf{\Omega_1}$	$\{ch_1, ch_2, ch_3, ch_6, ch_7\}$	$\{ch_1, ch_2, ch_3, ch_6, ch_7\}$	$\{ch_1, ch_2, ch_3, ch_6, ch_7\}$
$\mathbf{\Omega_2}$	$\{ch_1, ch_2, ch_3, ch_7, ch_8\}$	$\{ch_1, ch_2, ch_3, ch_6, ch_7, ch_8\}$	$\{ch_1, ch_2, ch_3, ch_7, ch_8\}$
$\mathbf{\Omega_3}$	$\{ch_5\}$	{~~ch_5~~}	{ }
$\mathbf{\Omega_4}$	$\{ch_5, ch_8\}$	{~~ch_5~~, ch_8}	{ }
$\mathbf{\Omega_5}$	$\{ch_1, ch_2, ch_3, ch_6, ch_7\}$	{$ch_1, ch_2, ch_3,$ ~~ch_5~~, ch_6, ch_7, ch_8}	$\{ch_1, ch_2, ch_3, ch_6, ch_7\}$

Now further if another incumbent occurs on an operating channel ch_8 of the central cell then its backup channel $\mathbf{ch_3}$ will be promoted to operating channel and contention based self coexistence process with its neighboring cell will be carried out. The above response can be envisaged in Table-2.

SPECTRUM HANDOFF in IEEE 802.22

Another important functionality of the SM is to execute spectrum handoff requests. Spectrum handoff mechanisms is initiated through the SM either when primary user/incumbent is detected on the licensed channel or when the specified transmission time is terminated as discussed in IEEE 802.22 standard [8]. The operating channel should be sensed after every 2 seconds in order to provide incumbent protection. There are two modes promoted in this standard [8] i.e. hopping and non hopping mode. In non hopping mode, the CR/secondary user/CPE has to wait on the operating channel during sensing time and resumes its transmission for 2 seconds only if no incumbent is detected. In this mode, data transmission is interrupted by the SM after every 2 seconds and therefore, these periodic interruptions degrade the system throughput and can considerably decrease the QoS of secondary users. For example, an interruption of more than 20 ms is normally unaffordable for many delay-sensitive applications such as voice transmission etc. In hopping mode, spectrum sensing and data transmission take place simultaneously. After 2 seconds, the channel switching is performed. One of the backup channels becomes the new operating channel and the previous operating channel is vacated. As a result, no interruption is needed for sensing any more [13], [14], [15]. The only condition for efficient hopping mode operation is to perform channel switching process fast enough and this requirement is fulfilled by the power electronics.

A secondary user may face multiple interruption requests during its data transmission period. Spectrum handoff mechanism must be performed after every 2 seconds or whenever licensed user is appeared on the channel. The Figure 6 and Figure 7 elaborate the scenario where four spectrum handoff requests are initiated during transmission period of secondary user SU_A. In this particular example, the default operating channel is *Ch1*. Let the data transmitted by the secondary user in 2 seconds be expressed by the event called Transmission Time Expired (*TTE*) and the backup channel list be represented by *Ch2, Ch3, Ch4,….* Let the handoff delay in the *i*th interruption be denoted by *Hi*; where *Hi* is the time interval between the moment when transmission is interrupted and the moment when unfinished transmission is started again. Since primary user may appear either before *TTE* or after *TTE*, so there are two possible cases:

Case-1: Appearance of Primary User after TTE Event

1. When the CPE is powered on, it tries to register with the BS. Suppose connection is established at the operating channel *Ch1*. When *TTE* event occurs, spectrum handoff procedure is initiated. The SU_A is assumed to decide

Ch2 as the next operating channel as shown in the Figure 6. In this situation, the handoff delay *H1* is equal to the channel switching time.

2. At the 2nd interruption, the SU_A changes its operating channel from *Ch2* to *Ch3* because the next backup channel is *Ch3*. In this case the handoff delay *H2* is again equal to the channel switching time.
3. At the 3rd interruption, the SU_A changes its operating channel from *Ch3* to *Ch2* because *Ch4* is not listed in backup channel set because it is busy at the moment and the resulting handoff delay *H3* is equal to the switching time.

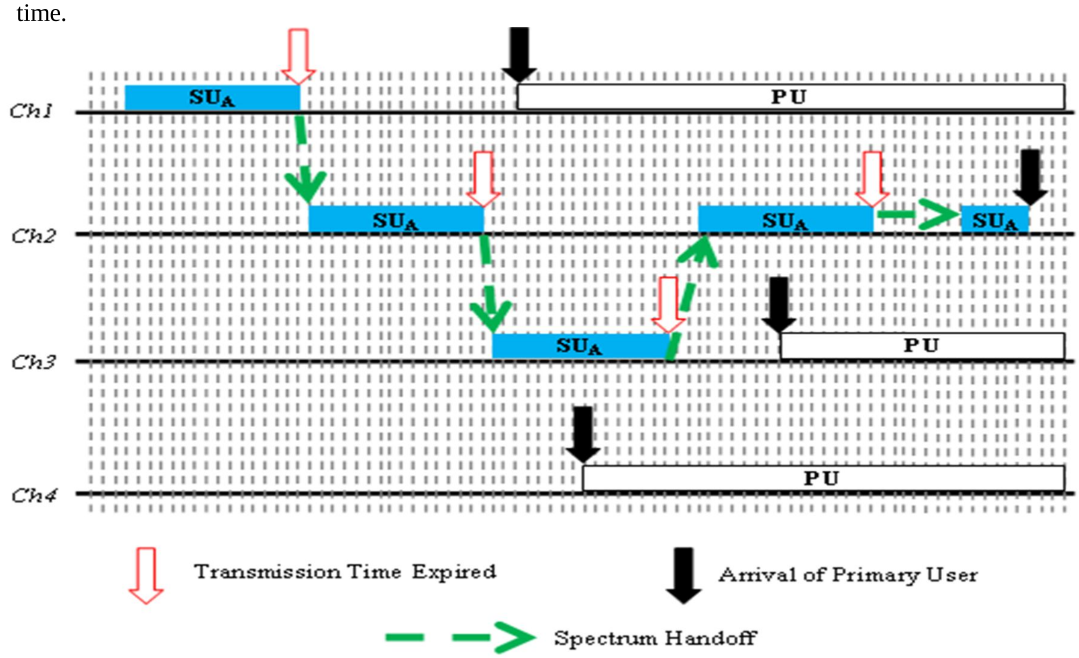

Figure 6: Appearance of Primary User after transmission time expired.

4. At the 4th interruption, no backup channel is available at the moment; therefore SU_A will wait at the current operating channel *Ch2* which shows non hopping mode behaviour. The SU_A will sense the channel and if primary user is detected, it will wait until the transmission of primary user. In this case, the handoff delay *H4* is equal to the addition of sensing time and waiting time due to primary user data transmission.
5. Finally, SU_A completes its transmission on *Ch2*.

Case-2: Appearance of Primary User before TTE Event

1. Suppose, the default operating channel is *Ch1*. At the appearance of primary user, the SU_A changes its operating channel from *Ch1* to *Ch2* by the SM as shown in the Figure 7. Therefore, handoff delay *H1* is equal to the switching time.
2. At the 2nd interruption, the SU_A selects *Ch3* as the next operating channel and resumes its transmission at this channel. In this situation, the handoff delay *H2* is again equal to the switching time. It is important to note that in the meantime the primary user has been appeared on *Ch4*. Therefore, *Ch4* will no longer be available in the backup channel list.
3. At the 3rd interruption, the SU_A changes its operating channel from *Ch3* to *Ch1* because *Ch1* is only the available channel in the backup channel list. The handoff delay *H3* in this case is equal to the switching time.
4. The 4th interruption is due to TTE event, the SU_A has to wait on the same channel and perform sensing because no backup channel is available at the moment. The overall system moves in non hopping mode and the resulting handoff delay is equal to the sensing time.
5. Finally, the SU_A completes its transmission on the *Ch1*.

In this scenario, when secondary user shifts from operating channel *Chi* to operating channel *Chj* where $i \neq j$, the expected handoff delay $E(H)$ is equal to the sum of all switching times. In the non hopping mode, i.e. $i = j$, the expected handoff delay is equal to the sum of all sensing times plus waiting time due to the appearance of primary user. Secondary user will wait until all the data of primary user is transmitted.

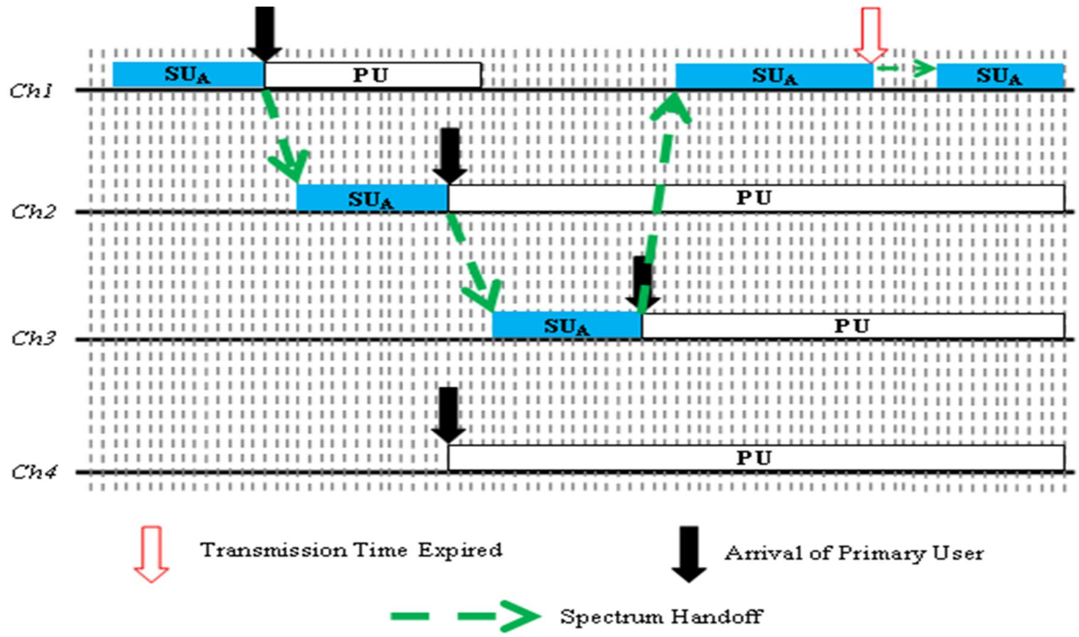

Figure 7: Appearance of Primary User before transmission time expired.

ASSOCIATION CONTROL

Association means the process in which the CPE performs its registration with the BS. During registration, the SM takes the location information and basic capabilities (sensing and geolocation) of CPE into account and then contacts to the database service for available channels together with their allowable EIRP. The purpose of having sensing and geolocation capabilities in CPEs is to protect incumbent from harmful interference. On the basis of the received information, the SM has to decide whether to grant or deny the association rights to the requesting CPEs on its current operating channel. If CPE‘s capabilities are in an appropriate limits, then SM permits it to join the network.

SM POLICIES AND OPERATIONS

It is the responsibility of the SM to impose IEEE 802.22 policies within the cell to ensure incumbent protection and maintains QoS in WRAN system. The policies are related with events and their corresponding actions. The events may be initiated from database service or occur in the form of incumbent detection and beacon signal detection. When events are triggered, one of the following actions may take place [8].

- Move the entire cell to the new operating channel.
- Direct the CPE (s) to another operating channel if possible.
- Terminate the operation of CPE (s) or entire cell in a given channel.

A number of policies are described in IEEE 802.22 standard to deal with different situations. For instance:

1. If the SM is informed about the unavailability of current operating channel for the BS by the database service, then the entire cell will be moved toward the new operating channel within 2 seconds. The new operating channel will be the highest priority backup channel.
2. If the SM is informed about the unavailability of current operating channel for some CPEs by the database service, then the entire cell will be either shifted towards the new operating channel within 2 seconds or the affected CPEs will be disassociated from the current operating channel within 2 seconds while the remaining CPEs will continue their normal operation.
3. If the database service directs the SM that the current operating channel is no more available, or in case of incumbent detection on either the operating channel or on any adjacent operating channel, and also the backup channels are not available then the entire WRAN cell operation will be terminated within 2 seconds.
4. If incumbent is detected by the CPE on the operating channel before the registration request with the BS then the corresponding CPE will not send its registration request on that channel.
5. If incumbent is detected by the CPE on the operating channel and CPE has already been registered with the BS then CPE will alert the BS about incumbent presence by sending UCS (Urgent Coexistence Situation) message.
6. If the BS comes to know that the current position of CPE has been changed by greater than 50 m radius (or some specified distance defined by local regulation), then BS will send the request to the CPE to verify its new location. If it is verified, the SM will contact to the database service to acquire update list of available channels based on the new location of the CPE. If the service is protected at the new location, then BS will deregister the CPE.

The SM operations can be classified into two states; network initialization state and network operation state. During network operation, the SM directs the BS to synchronize to other WRAN systems. The BS begins its transmission on the identified operating channel and waits for the CPEs to connect to the network. In this phase, the main activities of the SM include accessing to the database service, maintaining spectrum availability information, channel selection, channel management, scheduling quiet periods, imposing IEEE 802.22 policies, etc.

SPECTRUM SENSING AUTOMATION

Spectrum sensing automation (SSA) is an entity that must be present in all IEEE 802.22 devices. The SSA performs spectrum sensing through spectrums sensing function (SSF) after receiving request from the SM. The SM is responsible for controlling the sensing behavior of the SSA. However, the SSA locally manages its sensing behavior in the following situations [8]:

- At the initial turn on of the BS before transmitting any signal
- At the initial turn on of the CPE before creating association with the BS
- During quiet periods for in-band sensing
- During out-of-band sensing at the BS when it is not broadcasting
- During out-of-band sensing at the CPE during its idle time
- At the time when the CPE drops its contact with the corresponding BS

When the BS turns on, it is interested in finding the free channel to establish its service whereas, when the CPE initializes, it is interested in finding the operating channel through which it can associate with the BS. The quiet period is scheduled by the SM for in-band (N & N±1) sensing and is broadcasted by the BS through SCH. The CPE incorporates these quiet periods autonomously to perform in-band sensing and sends the spectrum sensing report to the SM. Out-of-band sensing does not need any scheduling. The CPEs can carry out out-of-band sensing during their idle time in normal IEEE 802.22 cell operation. In particular situation, the BS can also send the request to the CPEs in order to perform out-of-band sensing to maintain record of the potential backup channels.

CONCLUSION

In this paper, we discussed the importance of the Spectrum Manager in WRAN cell. The SM is the integral part of the BS which keeps track the spectrum availability information of the entire cell. It defines the status of the channels with respect to incumbent detection based on incumbent database, geolocation and spectrum sensing results. A pseudocode has been developed for the SM to perform channel decision process. Spectrum etiquette procedure and spectrum handoff mechanism has been demonstrated by example/cases. The main functionality of the SM is to impose IEEE 802.22 policies within the cell to ensure incumbent protection and maintain QoS in WRAN system.

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