Handover Mechanism in IEEE 802.22 WRAN

Dr. ManinderJeet Kaur
Assistant Professor/Department of ECE
AmityUniversity, Dubai, UAE

***Abstract*—IEEE 802.22 is the first worldwide standard for wireless regional area network (WRAN) based on cognitive radio technique. It provides access to use unused TV band without causing any harmful interference to the primary users/incumbents. This paper studies the role of spectrum manager and the handover mechanism in the IEEE 802.22 system. Generally, every CPE (Consumer Premise Equipment) is considered as a fixed user service. For this reason, IEEE 802.22 WRAN system is not suitable for adapting to portable and mobile user devices. Mobility is one of the most important factors for mobile devices. In order to support mobility of CPEs and continue to provide broad band networks in IEEE 802.22 WRAN system, an efficient handover mechanism is essential. In this paper, we study the handover mechanism. The handover decision is made at the Base Station based on the collected information by CPEs which are located on the boundary region located near the edge of Base Station coverage**.

Index terms – WRAN, Cognitive Radio, CPE (Consumer Premise Equipment), Access Point.

I. INTRODUCTION

A. Mobile Ad-hoc Networks

An IEEE 802.22 WRAN use cognitive radio technology utilizes geographically unused white spaces in the TV frequency and provides Rural Broadband Wireless Access. IEEE 802.22 WRAN is a point to multipoint wireless networks comprised of one BS and multiple CPEs. Today, the number of mobile devices and mobile device usage has been growing quickly and it is expected to increase in the future [1] [2]. Mobile devise equipped with wireless interface can perform many functions such as video streaming, voice calling and Internet access through the network. As a result, the demand for wireless bandwidth is rapidly growing and we are facing shortage of spectrum. Therefore, ISPs (Internet Service Provider) require more capacity than todays' wireless networks for improving wireless network performance.

The basic purpose of this development was to provide broadband access in remote and rural areas by exploiting the unused TV band [3-5]. 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 can be extended up to 100 Km subject to weather condition which is larger than IEEE 802.11 based WiFi and IEEE 802.16 based WiMAX.

The WRAN cell consists of one Base Station (BS) and a number of fixed or portable Customer Premise equipment (CPE) having different quality of service (QoS) requirements. The cell follows fixed point to multipoint 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 any proper authorization from 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 Multiplexing (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.

However, each and every CPE in WRAN system is considered as a fixed user device. So IEEE 802.22 WRAN system is not suitable for adapting to portable user devices such as laptops, mobile smart phones, tablet devices etc. It means that if a CPE which is connected to a serving BS moves to another BS, connection between the CPEs and the current BS is disconnected. As a result, packet loss occurs as the CPE moves between the different BSs. Packet loss degrades quality of Service (QoS) of the mobile CPE which is in transition from current BS to another BS. In order to prevent degradation of quality of service, a mechanism for low latency handover to reduce packet loss during mobility or transition is necessary.

II. EXISTING HANDOVER MECHANISM

In this section, we discuss about the conventional mechanism in IEEE 802.22 WRAN. We also studied Coexistence Beacon Protocol (CBP) which has been proposed within IEEE 802.22 for mobility support.

We can see from the protocol architecture of cognitive radio network as shown in the Figure 1 showing the spectrum sensing and sharing transmit on the Media Access Protocol (MAC) layer and Physical layer (PHY) [9].

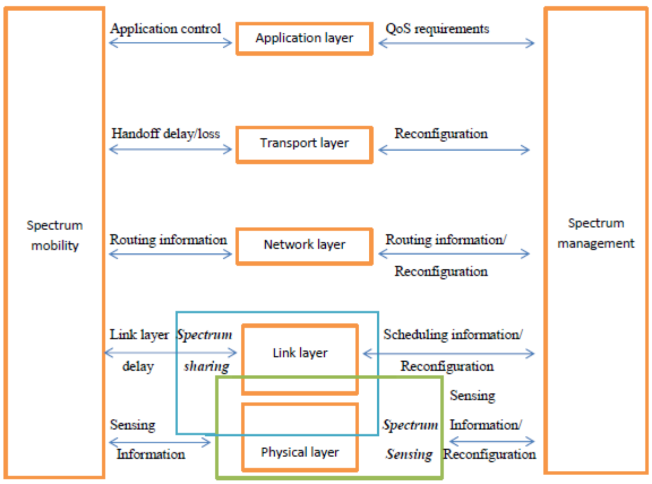


Figure 1 The protocol architecture of CR Network [9]

In the physical layer, the spectrum can detect the non-used spectrum in terms of the place and time and making secondary user able to use the empty channel without any probable interfering with the primary user.

The measurement function and the channel management in MAC layer can implement spectrum management and quality of service (QoS).

Spectrum Handoff in IEEE 802.22

Spectrum handoff mechanism is initiated through the spectrum manager 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 on 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 cognitive radio/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 spectrum manager after every 2 seconds and therefore, these periodic interruptions degrade the system throughput and can considerably decrease the QoS of the 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 channels and the previous channel is vacated. As a result, no interruption is needed for sensing any more [10] [11] [12]. 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.

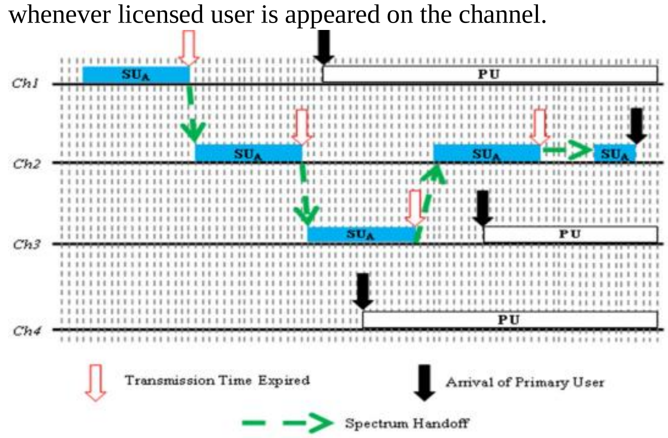


Figure 2 Appearance of Primary User after transmission time expired

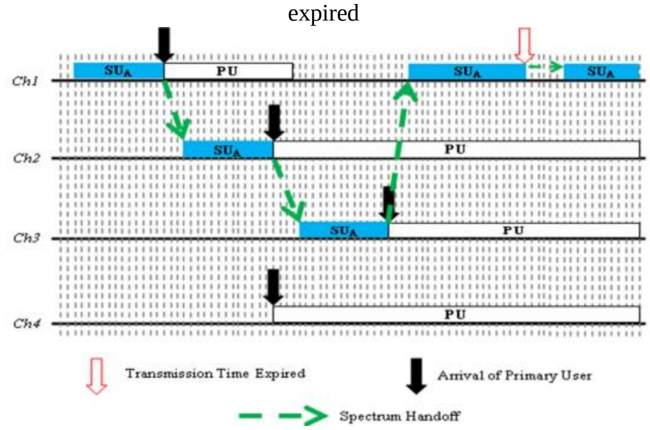


Figure 3 Appearance of Primary User before transmission time expired

Figure 2 and Figure 3 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 that there are two possible cases.

Case 1: Appearance of Primary User After TTE: 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 2. In this situation, the handoff delay *H1* is equal to the channel switching time.

At the 2nd interruption, the SU_Achanges 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.

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.

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 behavior. 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 information.

Finally, SU_A completes its transmission on *Ch2*.

Case 1: Appearance of Primary User Before TTE: 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 Spectrum Manager as shown in Figure 3. Therefore, handoff delay *H1* is equal to the switching time.

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.

At the 3rd interruption, the SUA 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.

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.

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. $i = j$, he 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.

III. Initialization

IEEE 802.22 WRAN is a standard for fixed broadband access network comprised of a fixed BS and fixed CPEs operating in the TV white space. So if a CPE in IEEE 802.22 WRAN system moves to another BS from serving BS where CPE currently is located in, the link between BS and CPE is disconnected. Since the CPE doesn’t have a handover mechanism for supporting mobility, the CPE detects a link disconnection and it has to perform initialization procedure again to detect the new BS. The CPE initialization procedure with the corresponding BS is as follows:

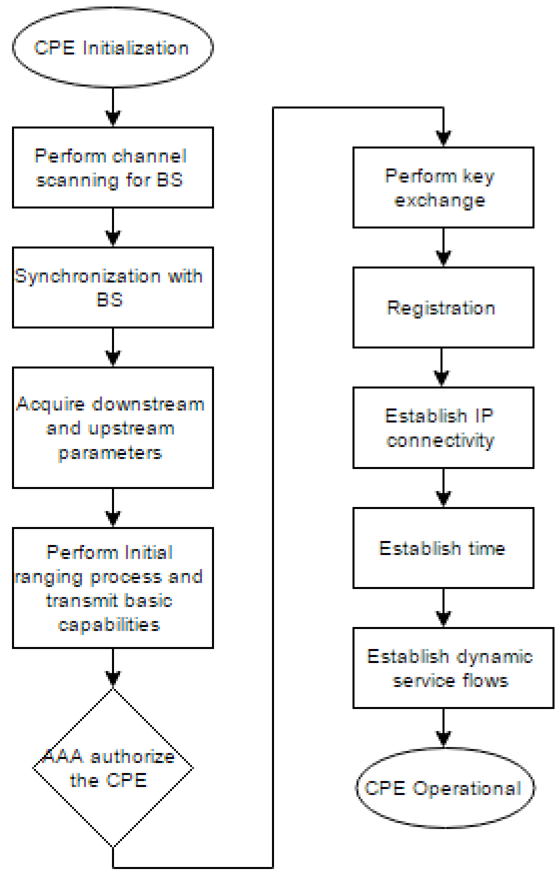


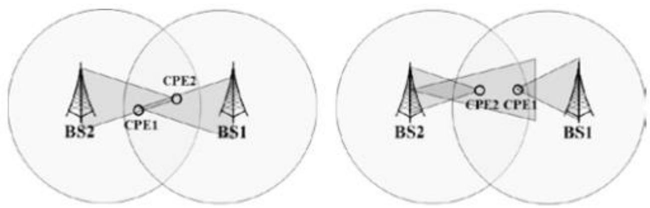
Figure 4: The Procedure for CPE Initilization

Initialization procedure of CPE at link layer 2 is comprised of channel scan, authentication, and registration and so on. So it takes a considerable amount of time to establish a connection with new BS. As a result, during the initialization procedure, a number of packets are dropped reflecting on degradation of QoS. Hence, it is evident that existing IEEE 802.22 WRAN system is difficult to provide seamless service. In order to reduce the packet loss, when CPE moves to another BS, handover mechanism for supporting mobility is necessary. At present, the re-initialization phase of IEEE 802.22 WRAN employs only received signal strength (RSSI) is used as a parameter to discover another BS. Since RSSI is only an approximate value, it is difficult to select the best target BS.

We are considering two parameters for handover mechanism: (i) mobility characteristics (ii) received signal strength (RSSI) of beacon messages from other BSs.

IV. CBP (COEXISTENCE BEACON PROTOCOL)

This section describes about self-coexistence among WRAN systems and how to use Coexistence Beacon Protocol (CBP) in IEEE 802.22 WRAN system. As presented in Figure 5, multiple BSs and CPEs operate in the same vicinity. Because many WRAN systems operate on the same channel, the interference between them will occur. So, in order to avoid interference between WRAN systems and maintain a WRAN system, Coexistence Beacon Protocol (CBP) mechanism is proposed in the IEEE 802.22 WRAN system.



(a) The face to face CPEs case (b) The back to back CPEs case

Figure 5: Coexistence Problem in IEEE 802.22

The Figure 5 shows Inter-WRAN communication scenarios. In case of the face to face CPEs which is presented in figure 5(a), CBP packet can be transmitted and received by the face to face CPEs associated with neighboring BSs. On the other hand, in case of the back to back CPEs which is presented in figure 5(b), CBPs transmitted by the BSs can be received by CPEs which belongs to the neighboring cells. The Figure 6 depicts the general frame structure of IEEE 802.22 WRAN system. One frame consists of a downstream sub frame and an upstream sub frame.

CBP packets can be transmitted during the SCWs (Self Coexistence Windows) at the end of upstream sub frames by the BS or designated CPEs. This self-coexistence window can be scheduled by the base station when transmission of coexistence beacon is necessary. CBP packet from BS or CPE is received by the serving BS and other CPEs from both the same and different BSs either on the same channel or different channels. These CBPs contain information about the other neighboring BS for self-coexistence of IEEE 802.22 WRAN systems on the same operating channel and synchronization of quiet periods between the BSs. Here, we make the assumption that BSs are not in the transmission range of each other but there are overlapping coverage areas.

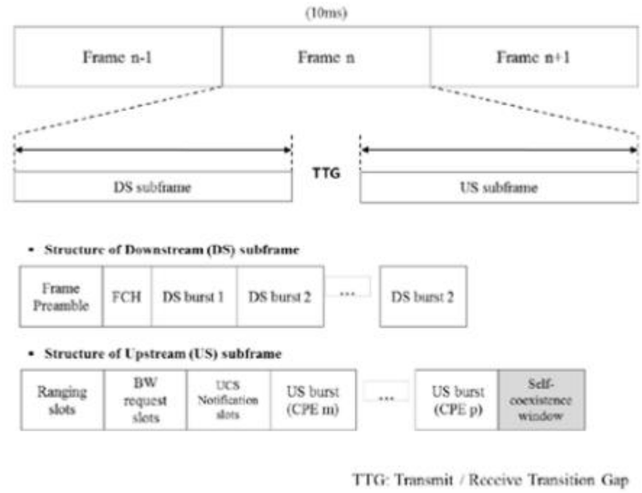


Figure 6: The Structure of the Frame

V. CONCLUSION

In this paper we discussed the operational procedure for IEEE 802.22 WRAN. The spectrum manager is an 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 the incumbent detection based on incumbent database, geolocation and spectrum sensing results. The main functionality of the spectrum manager is to impose IEEE 802.22 policies within the cell to ensure incumbent protection and maintain QoS in WRAN system.

The CPEs are considered as fixed equipment in IEEE 802.22 WRAN system, so if a CPE moves to another BS, the connection between the CPE and the serving BS is disconnected. After the realization of disconnection between the CPE and the BS, it takes a very long time to scan for the operating channel of the new BS to perform initialization with the discovered new BS. As a result, a lot of the serviced packets from the BS to the CPE are dropped during initialization procedure. For this reason, in the existing IEEE WRAN system, the CPEs can only operate in only one cell and IEEE 802.22 WRAN system cannot be adapted to mobile devices such as PDAs, laptops, tablets and smart mobile phones. In future works, we will research on optimized handover mechanism which can support real-time services.

REFERENCES

[1]. U.S Khan, T. Maqsood, “CRN survey and a simple sequential MAC protocol for CRN learning,” in Proc. 2nd International Conference on Advances in Cognitivce Radio (COCORA), 2012, pp. 22-27.

[2]. H. Afzal, U.S. Khan, I. Awan, M. R. Mufti, “A Simple Greedy Algorithm for Cognitive Radio Networks,” in Proc. 29th Annual UK Performance Engineering Workshop (UKPEW),

2013, pp. 3-7.
[3]. FCC, Notice of Proposed Rule Making, ET Docket No. 04-113, 2004.
[4]. WRAN website http://www.ieee802.org/22/
[5]. FCC, ET Docket 04-186, ET Docket 02-380, Third Memorandum Opinion and Order, in the matter of Unlicensed Operation in the TV Broadcast Bands Additional Spectrum for Unlicesed Devices Below 900 MHz and in the 3 GHz Band, 2012.
[6]. Y.C Liang, A.T. Hoang, H. H. Chen, "Cognitive radio on TV Bands – A new approach to provide wireless connectivity for rural areas," IEEE Wireless Communication, 15(3), pp. 16-22.
[7]. Z.K Gwang, A.A. Franklin, Y. Sung-Jin, P. Jin-Suk, S. Myung-Sun, K. Chang-Joo, "Channel management in IEEE 802.22 WRAN systems," IEEE Communications Magazine, 48(9), pp. 88-94, 2010.
[8]. 802.22, IEEE Standard for Information Technology – Telecommunications and information exchange between systems Wireless Regional Area Networks (WRAN) – Specific requirements Part 22: Cognitive Wireless RAN Medium Access Control (MAC) and Physical Layer (PHY) Specifications: Policies and Procedures for Operaion in the TV Bands, pp 1-680, 2011.
[9]. L. Wang, S. Hu, Y. Xiao, X.Zhou, G.On and K. Kim, "A new MAC scheme in cognitive network for different priority of secondary users," in Wireles, Mobile and Multimedia Networks(ICWMNN 2010),IET 3rd International Conference on, 2010, pp. 191-195.
[10]. W. Hu, D. Willcomm, M. Abusubaih, J.Gross, G. Vlantis, M. Gerla, W. Caldwell, "Cognitive Radios for Dynamic Spectrum Access – Dynamic Frequency Hopping Communities for Efficient IEEE 802.22 Operation," IEEE Transactions on Communications Magazine, 45(5), pp – 80-87, 2007.
[11]. J. Tong, H. Wu, C. Yin, Y. Ma, J. Li, "Dynamic Frequency Hopping Vs Non-hopping in IEEE 802.22 Systems," in Proceedings of the IEEE International Conference on Network Infrastructure and Digital Content, pp-95-99, 2009.
[12]. R. Al-Zubi, M. Z. Siam, M. Krunz, "Coexistence Problem in IEEE 802.22 Wireless Regional Area Networks," in Proceedings of the IEEE Global Telecommunications Conference, pp. 1-6, 2009.

Authors Profile

Dr. ManinderJeet Kaur is currently working as Assistant Professor, Amity University, Dubai. She has previously worked as a Visiting Research Assistant at Communications Research Group at University of York, United Kingdom under Commonwealth Scholarship by British Council. She has obtained her PhD from Dr. B R Ambedkar National Institute of Technology, India in the field of Wireless Communications (Cognitive Radio) after completing B. Tech (Electronics and Communication Engineering) andM.Tech (Computer Science Engineering). She has published and presented about 15 research papers in reputed International Journals and Conferences. She holds membership of many professional bodies like Institute of Electrical and Electronics Engineers (IEEE), International Association of Engineering (IAENG) and International Association of Engineering and Scientists (IAEST). She has presented and attended many technical sessions at various seminars, workshops and conferences on Wireless and Radio Communications. Her current research interests include Cognitive Radio, Software Defined Radio, Mobile Communications, Artificial Intelligence and more.