# Design of Handover Scheme for IEEE 802.22 WRAN


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## ABSTRACT

In this paper, we propose a handover mechanism for supporting of IEEE 802.22 WRAN system. Generally, every CPE (Consumer Premise Equipment) in IEEE 802.22 WRAN (Wireless Regional Area Network) is considered as a fixed user device. 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 network service in IEEE 802.22 WRAN system, an efficient handover mechanism is essential. In this paper we propose an efficient handover mechanism using characteristics of IEEE 802.22 WRAN system. We discuss the how handover procedure can be achieved with IEEE 802.22 control frames and then we evaluate L2 handover IEEE 802.22 WRAN system. We define a handover process with a decision making algorithm to reduce the packet loss during handover operation. The handover decision is made at the BS(Base Station) based on collected information by CPEs which are located on the boundary region located near the edge of BS coverage. Also the performance results show that our proposed mechanism not only achieves low handover latency but also does so with low packet loss rate.



## Categories and Subject Descriptors

C.2.1 [**COMPUTER-COMMUNICATION NETWORKS**]: Network Architecture and Design - Wireless Communication

## General Terms

Algorithms, Management, Performance

## Keywords

Base Station MAP, White space, CPE, Base Station, Handover, Coexistence Beacon Protocol


## 1. INTRODUCTION

In November 2008, FCC (Federal Communications Commission) approved new rules that the frequency spectrum allocated to TV channels can be used for unlicensed access. This new rules enable devices to operate in TV frequency spectrum. The table 1 shows that frequency allocation of TV channels Networks using TV frequency spectrum can provide Wireless broadband services, because TV frequency spectrum can travel long distance. So, many kinds of TV white space technologies have been conducted to use TV white space. TV White space means unused TV broadcast channels.



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**Table 1. Frequency Allocation of TV Channels**

| Channel# | Frequency Band | |
|---|---|---|
| 2 – 4 | 54 – 72 MHz | **VHF** |
| 5 – 6 | 76 – 88 MHz | |
| 7 – 13 | 174 – 216 MHz | |
| 14 – 20 | 470 – 512 MHz | **UHF** |
| 21 - 51 | 512 – 692 MHz | |

As examples, IEEE 802.11af[1] standard is formed in January 2010 to adapt 802.11 to TV band operation and IEEE 802.16h[2][3] standard is defined to adapt 802.16 for operating on TV bands. Especially, IEEE 802.22 is one of the standards for WRAN using white spaces in the TV frequency spectrum. IEEE 802.22 WRAN system is intended to operate in the VHF (Very High Frequency) and UHF (Ultra High Frequency) bands. TV broadcast bands from 54MHz to 862MHz and can support maximum rate of 22 Mbps up to 100 km distance based on Cognitive Radio Technology. IEEE 802.22 WRAN using Cognitive Radio Technology can utilize geographically unused white spaces in the TV frequency and provide 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. Because Mobile devices equipped with wireless interface can perform many functions such as video streaming, voice calling and internet access through the network, the demand for wireless bandwidth is rapidly growing and we are facing shortage of spectrum. As a result, ISPs (Internet Service Provider) require more capacity than today's wireless networks for improving wireless network performance. 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 services (QoS) of the mobile CPE which is in transition from current BS to another BS. In order to prevent degradation of quality of services, a mechanism for low latency handover to reduce packet loss during mobility or transition is necessary. In this paper, we investigate various types of mobility scenarios and propose a novel handover mechanism reflecting features of existing IEEE 802.22 WRAN system to support a CPE's mobility. To design a handover mechanism, we define a control message and handover procedure which operates on MAC Layer. This paper is organized as follows: In section 2, we introduce the network initialization and Coexistence Beacon Protocol (CBP) in IEEE 802.22 WRAN system. In section 3, we explain our proposed handover mechanism for supporting mobility. In section 4, we present performance evaluation with OMNeT++. The conclusion and future works are discussed in last section.

## 2. RELATED WORKS

In this chapter, we explain about the problem of conventional mechanism in IEEE 802.22 WRAN and introduce Coexistence Beacon Protocol which has been proposed within the IEEE 802.22 for mobility support.

### 2.1 Initialization

IEEE 802.22 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:

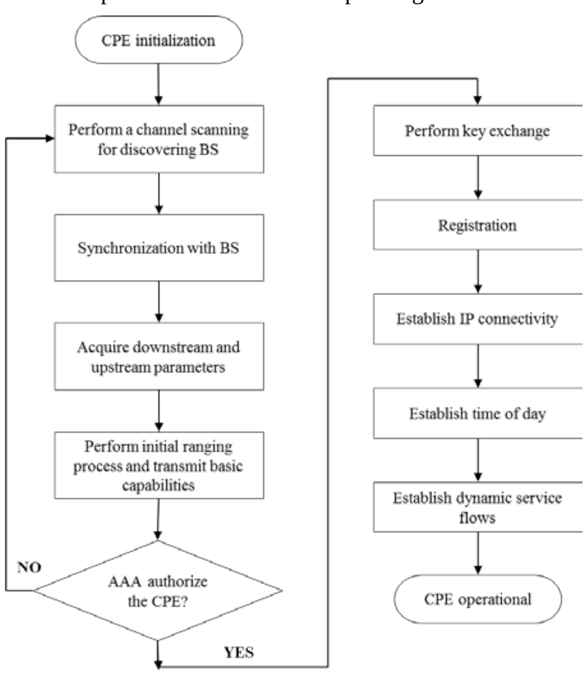


**Figure 1 The procedure of CPE initialization**

Initialization procedure of CPE at link layer 2 is comprised of channel scan, authentication, 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 82.22 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. So in this paper, we consider two parameters for our proposed handover mechanism: i) mobility characteristics of CPE and ii) received signal strength (RSSI) of beacon messages from other BSs.

### 2.2 CBP (Coexistence Beacon Protocol)

This chapter 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 4, 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.

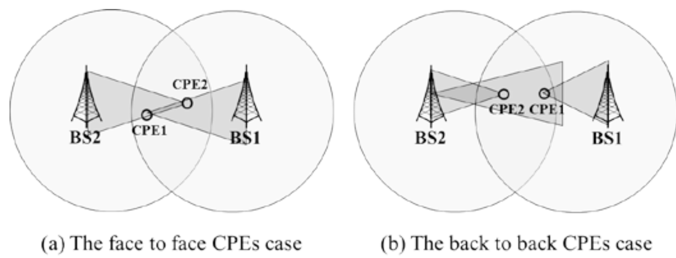


**Figure 2 Coexistence Problem in IEEE 802.22 WRAN**

The figure 2 shows Inter-WRAN communication scenarios. In case of the face to face CPEs which is presented in figure 2(a), CBP packet can be transmitted and received by the face to face CPEs associated with different neighboring BSs. On the other hand, in case of the back to back CPEs which is presented in figure 2(b), CBPs transmitted by the BSs can be received by CPEs which belongs to the neighboring cells. The figure 3 depicts the general frame structure of IEEE 802.22 WRAN system. One frame consists of a downstream subframe and an upstream subframe.

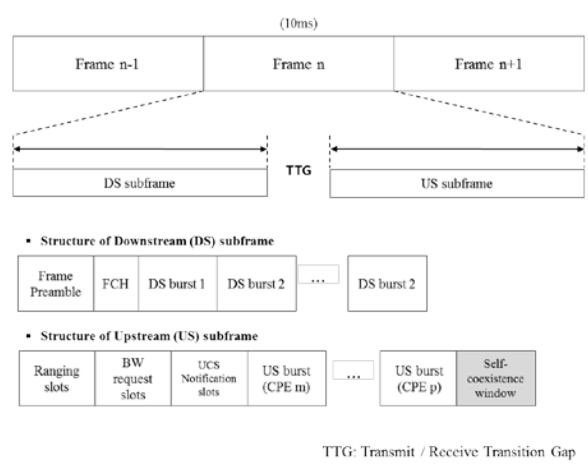


**Figure 3 the structure of frame**

CBP packets can be transmitted during the SCWs (Self-Coexistence Windows) at the end of upstream subframes 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.

# 3. PROPOSED HANDOVER SCHEME FOR IEEE 802.22

In this part, we describe a handover scheme for IEEE 802.22 WRAN in detail. Subchapter includes BS-MAP for mobility support and proposed handover process consists of four steps: neighboring BS detection, handover preparation, handover execution, and handover completion

## 3.1 BS-MAP for Mobility Support

In this chapter, we describe a Base Station MAP which is an efficient data structure to improve the latency in handover mechanism.

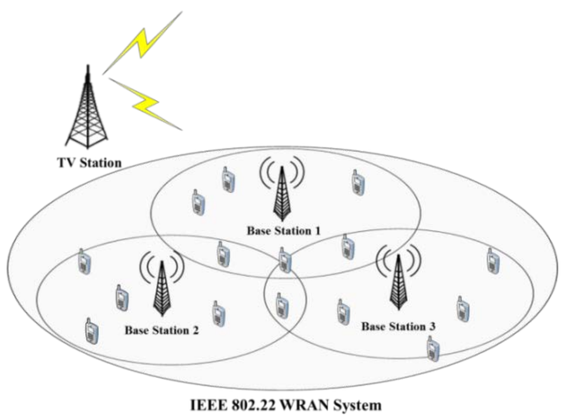


**Figure 4 Deployment of IEEE 802.22 WRAN System**

Each BS has its own Base Station MAP (BS-MAP) and it stores the set of neighboring BSs. As in the case of traditional IEEE 802.22 WRAN system, BS is in charge of periodically monitoring the neighboring networks and updating BS-MAP which contains status and information of neighboring networks. In order to design a handover mechanism for IEEE 802.22 WRAN system, we use the features that each CPE has a GPS module and CBP can be transmitted by the CPE at the end of upstream subframe which is used for avoiding self-coexisting problem [4]. From the features, we can create a BS-MAP which is to select the most suitable BS for handover procedure. BS MAP consists of some information which is very useful in handover decision. In order to create a BS-MAP, all of distributed CPEs collect information such as location, available channel list, and throughput and then report the gathered information to their serving BS. Especially to collect information which will benefit in handover decision, we use the Coexistence Beacon Protocol[5],[6]. CPEs located in an overlapping area of at least two WRANs which operate in coexistence mode can receive a CBP packet from other WRAN BSs then report it to its serving BS periodically. BS can control the operation mode of all CPEs which the BS is currently serving. The CBP packet includes at least one information element in their payload. If a CBP packet is received by the CPE in the overlapping region, that CPE shall report the information to its serving BS. Table 2 shows that CBP information elements.

CBP Information Elements (IEs) such as, Backup and Candidate Channel List IE (0x00) and CBP_Identification IE (0x05), among other IEs can be used for creating BS-MAP. The Backup and Candidate Channel List IE includes a list of the current backup channels and candidate channels which are defined by the neighboring BSs. The BS schedules idle CPEs to sense other channels periodically in quiet periods. So the CPE located in overlapping region of two WRANs can receive CBP message from other BS and report them back to its current BS. The CBP message can also include: Identification IE consisting device ID, latitude, longitude, etc. The Table 3 shows that information elements of Base Station MAP

**Table 2. CBP Information Elements**

| Element ID | Name |
|---|---|
| 0x00 | Backup and Candidate Channel List IE |
| 0x01 | FC_REQ IE |
| 0x02 | FC_RSP IE |
| 0x03 | FC_ACKE IE |
| 0x04 | FC_REL IE |
| 0x05 | CBP_Identification IE |
| 0x06 | Signature IE |
| 0x07 | CERT-REQ IE |
| 0x08 | CERT-RSP IE |

**Table 3 Structure of BS-MAP**

| Field | Description |
|---|---|
| CPE ID | The device ID of CPE |
| CPE position | The position of CPE |
| Neighboring BS ID | The device ID of neighboring BS |
| Neighboring BS position | The position of neighboring BS |
| Available Channel List | Channel lists of neighboring BS |
| RSSI | Signal strength of beacon message |
| Distance | The distance between BS and CPE |

The Base Station MAP can be generated by the report message of IEEE 802.22 WRAN system. The figure 4 shows the deployment scenario of an IEEE 802.22 WRAN system which is comprised of CPEs and a BS with two neighboring WRAN systems. In this scenario, the serving BS can control each CPE, which is located near the edge of serving BS’s coverage, to be operating in coexistence mode. The CPEs which are operating in coexistence mode are in charge of gathering information about neighboring BS such as available channels, neighboring BS ID, signal strength of current position, etc. CPEs can be distributed in different locations of the serving BS which means at least a number of CPEs located in the overlapping region of coverage between two different BSs. After generating a Base Station MAP (BS-MAP), the BSs exchange their (BS-MAP to support more efficient handover. As a result, BS can know their neighboring BS list. Let's consider following scenario:

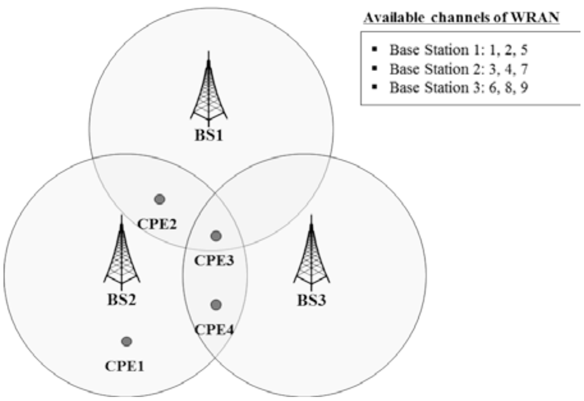


**Figure 5 Deployment Scenario**

In the figure 5, the network consists of three neighboring BSs. Four CPEs are deployed in area of BS2. So BS2 is responsible for CPE1, CPE2, CPE3 and CPE4, and currently serving them. Channel group {1, 2, 5} is used to serve BS1, channel group {3, 4, 7} is used to serve BS2, and channel group {6, 8, 9} is used to serve BS3. Channel group is defined as the set of operating channel, backup channel and candidate channels. In this scenario, BS2 can periodically learn the position of served CPEs by result of CPE report either periodically or by sending a special request. From the position of CPEs, BS2 can select a specific CPE which is operating in coexistence mode. Usually, if CPE is located near edge of coverage of BS, the CPE is selected to operate in coexistence mode. Because CPE 2 is located in an overlapped area between BS1 and BS2, the CPE can tunes to operating channels of either BS1 or BS2 periodically. As a result, CPE2 can detect a beacon message[9] from BS2 as well as BS1. Also The CPE measures RSSI from each beacon message from the BSs. The measured value of RSSI is stored to generate a Base Station MAP. From this mechanism, CPE3 and CPE4 can also detect neighboring BS lists together with other IEs necessary to build the BS-MAP. Figure 6 shows that result of Base Station MAP of BS2.

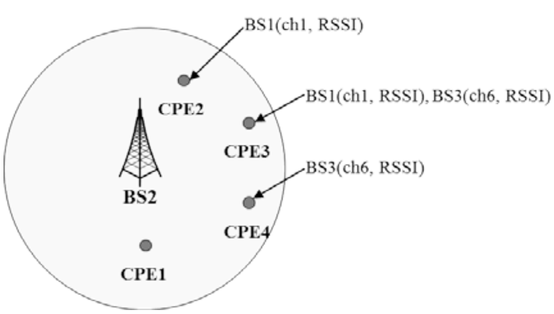


**Figure 6 Base Station MAP of BS2**

According to Base Station MAP, BS can know neighboring BS lists, so CPE can reduce latency during the handover procedure. Generally, in order to gain access to a new BS, a mobile node has to scan all channels from first channel to the last channel, because the mobile node does not know the deployment of the new BS. However in case of our proposed system, the CPE does not need to scan all channels, because Base Station MAP has complete information about channels of neighboring BSs as well as network topology.

## 3.2 Neighboring BS Detection

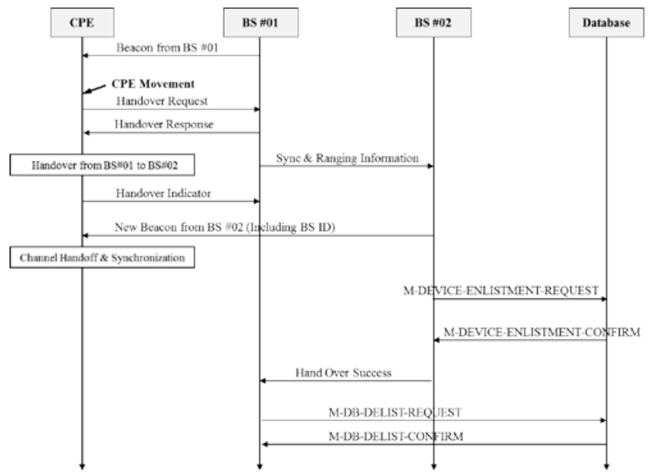


**Figure 7 Handover Procedure of IEEE 802.22 WRAN**

In this section, we describe the detection mechanism of IEEE 802.22 WRAN system of neighboring BSs. Before operating the handover procedure, CPEs have to detect a neighboring BS and its operating channel. The selection of the target BS allows for the configuration of required parameters at the CPE to reduce handover latency. Generally, when a mobile node moves into a neighbor BS from the serving BS, it starts the channel scanning procedure to discover operating channel of the new BS. So, channel scanning time occupies the longest time period of the handover latency. In this paper, we aim to reduce channel scanning time and then decrease the handover latency by using a Base Station MAP. Basically, in the IEEE 802.22 WRAN standard assumes that all of CPEs and BS have a Global Positioning System (GPS) module in their system. So each CPE can locate its position in the network and distinguish whether it is moving or not by its GPS. According to the CPE's mobility, reselection procedure for the neighboring BS is required to support handover mechanism at the CPE. In order to initiate reselection procedure for a neighboring BS, the CPE has to find a neighboring BS. The CPE uses BS-MAP form current BS which is proposed in this paper to find a neighboring BS from its current position and movement. Basically, to find and initiate reselection procedure for a neighboring BS is based on measurement of downlink signal strength. When the CPE begins to move, it records the start time and the position at initial location and instantaneously monitors the strength of down link signal. If the signal level from the current serving BS drops below a certain threshold then the CPE sends out a HANDOVER-REQUEST message including CPE's current time and position together with initial time and position. Upon receiving a HANDOVER-REQUEST message from a CPE, the serving BS shall find a neighboring BS based on current position and movement of the CPE.

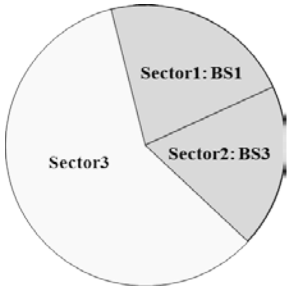


**Figure 8 Base Station MAP of BS2**

From the collected information by CPEs, which are operating coexistence mode, Base Station MAP is divided into three sectors. In the figure 8, if the moving CPE is in sector1, the serving BS indicates the BS1 as its neighboring BS then the moving CPE scans only channel 1 to detect BS1. The operation is also similar in case of sector2 with BS3. Otherwise, if the moving CPE is in sector3, because the serving BS can't find a neighboring BS, the CPE have to scan all channels to detect a neighboring BS. The current serving BS can easily know neighboring BSs and available channel lists by looking-up the stored BS-MAP using neighboring BS ID.

## 3.3 Handover Preparation

In this section, we describe how the serving BS prepare for the handover procedure to the target BS. In our proposed system, handover procedure is fully controlled by the serving BS. In our proposal, the serving BS judges a handover suitability to neighboring BS. From the BS-MAP, the serving BS selects a target BS to handover and evaluates handover suitability based on Base Station MAP. The target BS is assumed to be the nearest neighboring BS and provide high quality of service than any other BS at the time when the handover will occur. The serving BS can get the position of CPE from which it receives a HANDOVER-REQUEST message and neighboring BSs list from Base Station MAP. The neighboring BS group is represented as neighboring BSs = $\{bs_1, bs_2, bs_3 \ldots, bs_n\}$. From the CPE's position, the serving BS can calculate the distance between CPE and the neighboring BS and the distance between two points is calculated by the GPS module. The distance between the CPE and the neighboring BS $bs_i$ is defined as $\mathrm{D} = \{d_1, d_2, d_3, \ldots, d_n\}$. From this algorithm, the BSs whose distances from CPE are less than the threshold are selected as candidate BSs. After selecting the candidate BSs, the serving BS compares the candidates to select the best as the target BS. In the IEEE 802.22 WRAN system assumes that all BSs and CPEs have a GPS module. From this feature, our proposed system can perform mobility prediction based on position, speed and direction dynamically. From the CPE's start time and initial position and movement, the serving base station defines a probability $P_{ij}$ that the CPE will move to another BS from the serving BS. Probability to move to another BS depends on the CPE distance to the target BS, speed and the direction of movement. The CPEs located at the border of cell or CPE with high speed has more chance to move to other BSs. Otherwise, as the CPE gets nearer to BS or the CPE moves with low speed, it has lower probability to move to another BS.

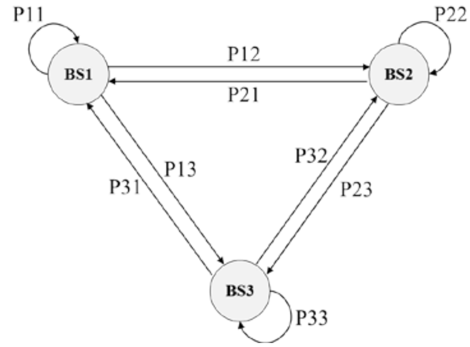


**Figure 9. State Diagram**

The states of the CPE is illustrated in Figure 9. Each state means that the CPE located in coverage area of each BS. For example, state which is defined as BS3 means that CPE is located in coverage area of BS3. Probability, $P_{ij}$, is termed as the probability of transition from state-i to state-j. If i equals j, the CPE stays at same the BS. Otherwise, if i and j are different, it means that the CPE moves from $BS_i$ to $BS_j$. The following figure 10 shows that algorithm for selecting target BS in handover mechanism.

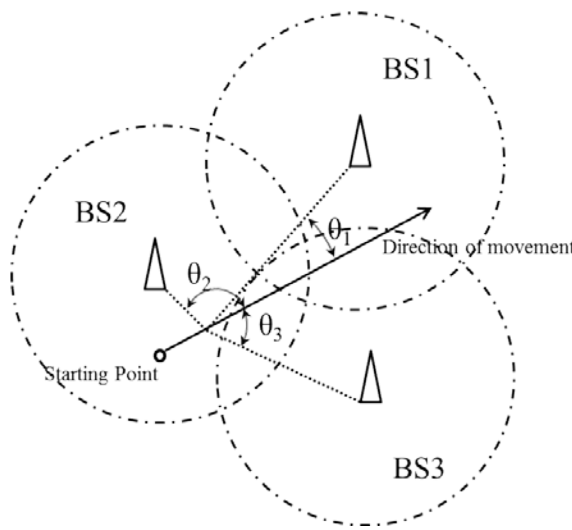


**Figure 10 Algorithm for selecting Target BS**

The transition probabilities Pij can be calculated as:

$$\mathrm{P_{ij}(t) = P\{Direction\} \times P\{Speed\} \times P\{Distance\}} \quad (1)$$

where P{Direction}, P{Speed} and P{Distance} are the probabilities of CPE moving from BSi to BSj based on direction, speed of the movement of CPE and distances from BSi and BSj. These probabilities are independent and defined as follows:

$$\mathrm{P\{Direction\}} = \left|\cos \theta_j(t)\right| \quad (2)$$

$$\mathrm{P\{Speed\}} = \frac{v(t)}{v_{max}} \quad (3)$$

$$\mathrm{P\{Distance\}} = \frac{d_i(t)}{d_j(t)} \qquad \text{where } d_i(t) \leq d_j(t) \quad (4)$$

From above equations, we can populate the transition probability matrix P:

$$P = \begin{bmatrix} P_{11} & P_{12} & P_{13} \\ P_{21} & P_{22} & P_{23} \\ P_{31} & P_{32} & P_{33} \end{bmatrix} \quad (5)$$

Now we can calculate the limiting probabilities of the system. Let $\Pi = [\pi 1\ \pi 2\ \pi 3]$ be the limiting probability matrix. Then we can solve for the values $\pi i$ by the following equations for Discrete Time Markov Chains,

$$\Pi = \Pi \cdot P$$

$$\Pi \cdot 1 = 1$$

where 1 is the all ones vector. These values of $\pi i$ will determine which BS the CPE will most likely to move to. For the case i = j, it means that CPE will stay in the current BS. Now we can predict and estimate which BS the CPE. The serving BS has a responsibility to select the best target BS which can provide good connection to the mobile CPE. From these states and transition probabilities, the serving BS decides which neighboring BS is the target BS for handover procedure and which base station has a better signal from the current position of the CPE. After comparing and evaluating neighboring BSs, if the target BS is not the same as the serving BS where CPE is currently located in, the serving BS sends a HANDOVER-RESPONSE message including success to indicate the handover procedure is accomplished. The target BS ID and the operating channel are included in the HANDOVER-RESPONSE message. Otherwise, if the target BS is the same as serving BS where the CPE is currently located in, the CPE is not necessary to perform handover, so the serving BS sends back a HANDOVER-RESPONSE message including fail. If the CPE receives a HANDOVER-RESPONSE message including success, the CPE performs the next step of handover procedure. If the CPE receives a HANDOVER-RESPONSE message including fail, the CPE terminates the handover procedure.

## 3.4 Handover Execution

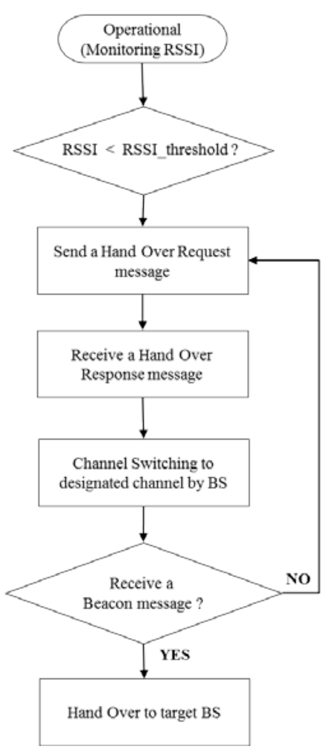


**Figure 11. Execution for Handover**

The serving BS controls the channel switching procedure for the handover through HANDOVER-REQUEST/RESPONSE messages. After the exchange of HANDOVER- REQUEST /RESPONSE messages between the CPE and the serving BS, the CPE conducts a handover procedure for connecting to the target BS. Firstly, to disconnect a connection between the CPE and the serving BS, the CPE sends a HANDOVER-INDICATOR message including the CPE's device ID to the serving BS. At the serving BS, upon receiving a HANDOVER-INDICATOR message, the CPE can't communicate with the serving BS anymore, so the CPE has to establish a new connection with the target BS as soon as possible. Re-entry procedure to the target BS is as follows. The CPE scans only the selected channel by the previous serving BS without scanning all the channels. Therefore, the delay occurred during the channel scanning can be reduced drastically. For example, in the deployment scenario of figure 5, if the target BS for handover is selected as BS3, the CPE scans only channel 3 which is the operating channel of BS3. When the CPE starts a channel scanning, CPE starts a timer. During the time T, if the CPE cannot detect a beacon message from operating channel of the target BS, the CPE gets information from beacon message then moves to another channel which in this case is the backup channel listed in the channel group of the target BS. Otherwise, if the CPE doesn't receive the beacon message from any of the selected channels of the target BS, the CPE sends a HANDOVER-REQUEST message to the previous serving BS again.

When the CPE completes the re-entry procedure to the target BS, the CPE conducts a registration procedure to the database service. Because in the IEEE 802.22 WRAN standard, in order to protect an incumbent user, the BS and CPE have to register with their information such as geographic location and device identification to a database service. So, after the handover procedure, the CPE sends an M-DEVICE-ENLISTMENT-REQUEST message to the database which includes a device ID and the CPE's location information. Upon receiving an M-DEVICE-ENLISTMENT-REQUEST message, the database service updates the information tables and sends M-DEVICE-ENLIST-CONFIRM message back to the target BS which indicates the successful registration.

## 3.5 Handover Completion

When the CPE completes a handover procedure with the target BS, the CPE in target the BS shall send HANDOVER-SUCCESS message to its previous serving BS to alert a successful completion of handover procedure through backbone network. If the CPE's previous serving BS receive a HANDOVER-SUCCESS message, the previous serving BS sends an M-DB-DELIST-REQUEST message to the database service in order to delete an entry in the table. After deletion of the entry in table, the database service responds with an M-DEVICE-ENLIST-CONFIRM message to the previous serving BS.

# 4. SIMULATION MODEL DESCRIPTION

In this chapter, we explain about our simulation model. We design and implemented in OMNeT++. In order to perform a simulation, we define a typical inter-BS mobility scenario under the IEEE 802.22 WRAN system.

## 4.1 SIMULATION SETUP

The architecture of proposed system is depicted in following figure 11

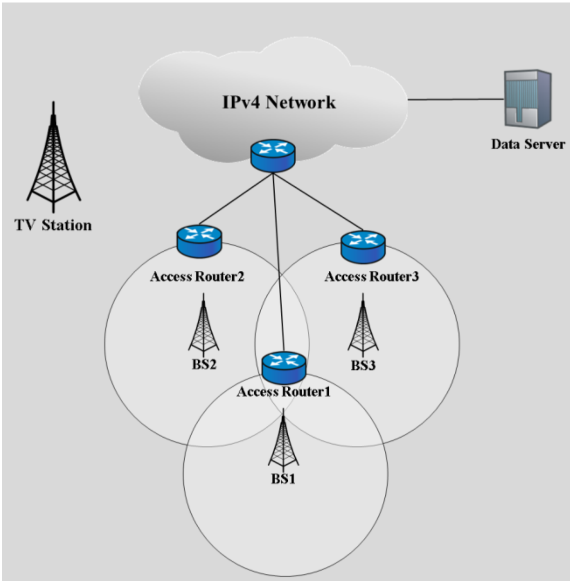


**Figure 12 Simulation model of IEEE 802.22 WRAN system**

The architecture of our simulation model consisting of BSs, Data server and corresponding CPE.The simulation model consists of 3BSs and The number of CPEs are randomly distributed over the three WRAN cells. Each BS is operating at the equal transmitting power as defined in following Table 4. these parameters correspond to standard of the IEEE 802.22[10]

**Table 4 Simulation Environments**

| | |
|---|---|
| **Network Area** | 150km x 150km |
| **Number of BSs** | 3 |
| **Number of CPEs** | 100 |
| **Number of Mobile CPE** | 5 |
| **Frequency Range** | 54~862 MHz |
| **Transmit Power** | Default 4W EIRP |
| **Range of BS** | 33kms |
| **Network topology** | Point to Multipoint Network |

The simulation procedure consists of the following steps.

Firstly, we turn on the BS1, BS2 and BS3. Each BS has the responsibility to coordinate each CPE's operational mode. The CPEs which are located near the edge of coverage (in overlapped area of 2 BSs) of the BS operate in coexistence mode and receive CBP packets from the neighboring BSs. The CPEs gather the information from neighboring BSs and relay them to the serving BS. From this procedure of WRAN system, each CPE is able to perform a neighboring WRAN discovery and generates the Base Station MAP for supporting the handover mechanism.

Secondly, after the Base Station MAP is generated, only one CPE is chosen randomly to move to another BS from the serving BS where the CPE is located in. The chosen CPE moves within a network area (150km x 150km) according to random way point mobility model which is well known for general mobility model. The CPE stays in one location for a certain period of time then select a random destination in the simulation area and a speed that is uniformly distributed between minimum speed and maximum speed. The CPE then travels toward the newly chosen destination at the selected speed. The following table 5 describe a simulation parameters for mobility

**Table 5 Parameters for mobility**

| | |
|---|---|
| **Mobility Type** | Random way point Model |
| **Mobility Speed** | 2 m/s ~ 10 m/s |
| **Wait Time** | 3sec ~ 8 sec |
| **Update Interval** | 100 ms |

Handover procedure is triggered according to our proposed handover mechanism which is presented in section 2, when the CPE moves out from the serving BS.

## 4.2 NETWORK MODEL

In this chapter, we describe a traffic generation model of packet flows in the simulation. The simulation model of IEEE 802.22 WRAN is point to multipoint wireless regional area networks comprised of a BS with multiple CPEs and data server. Data server generates the data packet then sends it to BS through a wired network. We assume that packet arrival rate to a BS follows Poisson process with rate $\lambda$ (packets per unit time t). Then the arrived packets are relayed to moving the CPE. The size of the packets exchanged between the serving BS and the CPE is static. The traffic model is depicted in table 6. The inter packet arrival time follows an exponential distribution with $\frac{1}{\lambda}$ (unit time).

**Table 6 parameters for traffic generation**

| | |
|---|---|
| **Packet Size** | 512 byte |
| **Packet rate** | 20 packets per second |
| **Bandwidth** | 23 Mbit/s |
| **Protocol** | UDP |

# 5. PERFORMANCE EVALUATION

In this chapter, we present a performance evaluation of the proposed handover mechanism. To evaluate the performance, we implemented the simulation model for IEEE 802.22 WRAN in OMNeT++ (Objective Modular Network Test bed in C++) simulator. We compare the our proposed mechanism with traditional IEEE 802.22 WRAN system.

## 5.1 CHANNEL SCANNING TIME

Firstly, we observed the channel scanning time of our proposed mechanism. Channel scanning is an important element to provide seamless handover. In this chapter, we compare the channel scanning time with passive channel scanning and active channel scanning to figure out how much efficient to reduce handover latency

**Table 7 Channel Scanning Time**

| #Base Station | Mechanism | Scanning Delay(ms) |
|---|---|---|
| 3 | Proposed mechanism | 50 ms |
| 3 | Conventional Mechanism | 205 ms |

As shown in table 7, the scanning time of proposed mechanism is shorter than the general channel scanning time. Usually, general channel scanning mechanism scans all channels to detect a BS. In contrast, proposed mechanism scans only one channel designated by serving BS.

## 5.2 HANDOVER LATENCY

We evaluate the handover latency over IEEE 802.22 WRAN system using our proposed mechanism. Note that the handover latency we defined is the latency during the inter BS mobility. Handover latency of IEEE 802.22 WRAN system can be defined by figure 12.

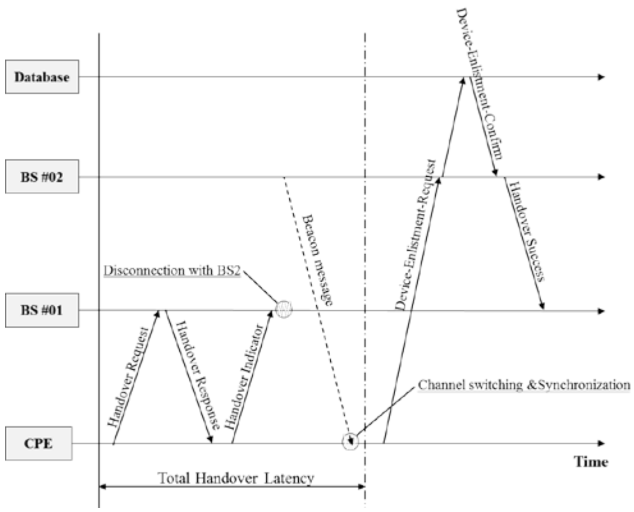


**Figure 13 Handover latency of proposed mechanism**

In order to show the reducing handover latency, We compare the layer 2 handover latency among the existing IEEE 802.22 WRAN system and the proposed mechanism. We measure the handover latency to establish the new connection with target BS after the disconnecting from the serving BS.

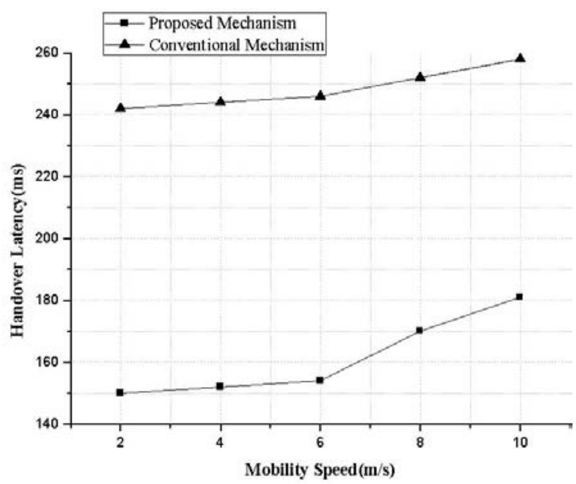


**Figure 14 Handover Latency**

In the case of this simulation results in figure 13, the handover latency of proposed mechanism is lower latency than that of existing IEEE 802.22 WRAN system., since the registration and authentication of CPE is skipped. Also during handover procedure, the CPE already knows the details of the target BS. For this reason, channel scanning time is reduced by our proposed mechanism.

## 5.3 PACKET LOSS

We also evaluate the packet loss during the handover. The simulation is performed with different moving speed of CPE from 2m/s up to 10m/s and beacon period time which is depicted in table 5. also when CPE is moving, packets generated at data server are transmitted in the downlink direction simultaneously. The packet arrive to the BS according to a Poisson process with rate λ (packets/sec). The BS is assumed to have enough buffer to receive packet from data server. So packet loss at BS is ignored. Suppose that the packets arriving at the CPE have a Poisson distribution. The probability that the packet arrival (A) after handover time t is defined as formula (6)

$$P(A > t) = P(N(t) = 0) = \frac{e^{-\alpha}\alpha^{0}}{0!} = e^{-\lambda t} \qquad (6)$$

Also the probability that the packet arrives in handover time [0,t] can be denoted by (6)

$$P(A \leq t) = 1 - e^{-\lambda t} \qquad (7)$$

Therefore the number of arrival packets at CPE during the handover procedure is defined as (8)

$$N = \frac{\lambda t}{1 - e^{-\lambda t}} \qquad (8)$$

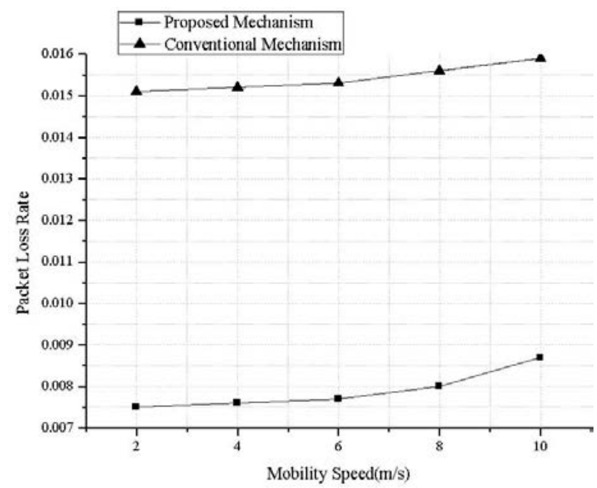


**Figure 15 Packet Loss Rate**

As illustrated in figure 14, the packet loss rate increase as the moving speed of CPE increases. The simulation results shows that when CPE moves faster, the packet loss is increased due to CPE having not enough time to perform handover procedure to target BS. As a result, CPE performs an initialization operation based on with the new BS. There is higher probability to occur packet loss.

## 6. CONCLUSION AND FUTURE WORKS

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 802.22 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 order to solve the above mentioned problems of IEEE

802.22 WRAN, in this paper, we propose a mobility support mechanism which can support inter-BS mobility for the CPE and evaluate a performance by OMNeT++. Simulation results show that our proposed mechanism can reduce the handover latency and packet loss during the inter-BS mobility by using proposed Base Station MAP (BS-MAP). However, our proposed mechanism adopts a hard handover process; some packets are dropped by handover latency. It means that our proposed mechanism is not suitable for supporting real time service such as VoIP and IPTV. So in the future works, we will research on optimized handover mechanism which can support real-time services.

## 7. ACKNOWLEDGMENTS

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