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Hand-off techniques for a cellular network Hard Handoff simulation in Horizontally WiMAX HHO

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Abstract: *Wireless networking is an attractive networking solution due to its flexibility, mobility and ease of installation. Now a day's mobile wireless with higher data rates, Quality of Service (QoS) and adaptability within the same network or among networks of different technologies and service providers is needed in mobility during communication. Continuation of an active call is one of the most important quality measurements in the cellular systems. Handoff is an essential element of cellular communications. Handoff process enables a cellular system to provide such a facility by transferring an active call from one cell to another. In this paper we present an overview about the issues related to handoff initiation and decision and discuss the different types of handoff techniques available in the literature. Then we illustrate an example of Hard Handoff using the Horizontally WiMAX - HHO which carried out in (OPNET) Modeler (simulation software Optimized Network Engineering Tools). We Provide the Performance evaluation of QoS metrics like good throughput and minimum access delay.*

I. Introduction

Wireless communication is exhibiting its fastest growth period in history; due to enabling technologies which permit a wide spread deployment. Now a day's cellular systems are the most popular system used in the telecommunication industries. Cellular systems have a large number of users over a large geographical area, which divided into small services area within a limited frequency spectrum. They are called cells. Cellular radio systems provide a high quality service. Cellular system provides a wireless connection to the Public Switched Telephone Network (PSTN) for any user location within the radio range of the system. Cellular network reducing factors such as the call drop rate and the congestion rate. [12]

The GSM cellular system is one of the most popular second generation digital cellular telecommunications systems, which is widely used throughout the world. These systems have many advantages such as high security, superior quality of voice transmission over the long distances, low average transmitted power, increased capacity with more efficient utilization of the radio spectrum.

Handoff is the most attractive features of any cellular system. The term handoff mean a different base station handles the radio communication task. It is the process where the call transfers a mobile station from one cell boundary to another cell boundary. When a mobile user or mobile terminal crosses the cell boundary or passes out of the range, the signal gets unacceptable. The transition and the process to make the transition are called handoff. So, handoff is the process of continuation of an active call when the mobile is moving from one cell to another without call termination. [5]

II. Handoff In Cellular Networks

Mobility is the most important feature of a cellular and mobile communication system. The mobile phone users are able to communicate with each other when moving inside or outside the cells. In a cellular network, the entire geographical area is divided into small cells in order to achieve high system capacity due to limited spectrum. The frequency band is divided into smaller bands and these are reused in non interfering cells. Smaller cells cause the Mobile Station (MS) to cross several cells during ongoing active call conversations.

Handoff is a mechanism of transferring an ongoing active call from one cell to another as a user moves through the coverage area of a cellular system. The transfer of current communication channel could be in terms of a time slot, frequency band, codeword, or combination of these for time-division multiple access (TDMA),

frequency-division multiple access (FDMA), code-division multiple access (CDMA), or a hybrid scheme, respectively. Each handoff requires network resources to reroute the call to the new base station and continuous service can be achieved. [3]

III. Handoff Categorization

Handoff divided from wireless access network perspective into vertical handoff (inter -system) and horizontal handoff (intra- system). Horizontal handoff means handoff occurring within the same wireless access network technologies while vertical handoff (inter-system) means handoff occurring among heterogeneous wireless access network technologies, while from administrative domain perspective macro mobility (its known as an inter domain mobility which means movement of a user in a number of subnet works of enterprise networks) and micro mobility (it is the mobility of a node inside an administrative domain which means moving from one subnet to another) are two different Schemes. There are four sub classes of handoff and roaming scenarios. [4]

- Vertical Macro mobility: Mobility among different administrative domains using different wireless technologies.
- Horizontal Macro mobility: Mobility among different administrative domains using same wireless access network technologies.
- Vertical micro mobility: Mobility with in the same administrative domain using different wireless technologies.
- Horizontal Micro mobility: Mobility with in the same administrative domain using the same wireless technology.

IV. Types of Handoff

Handoffs are broadly classified into two types.

a) Hard handoffs are also called "Horizontal handoffs" or "intra-system handoff "is a handoff that occurs between the Access points (APs) or Base stations (BSs) of the same network technology. In other words, a horizontal handoff occurs between the homogeneous cells of a wireless access system.

b) Soft handoffs define the ability to select instantaneous received signals from a variety of base stations.

A. Hard Handoff

When the received signal strength (RSS) is low, the switch over mobile station from the first base station to next base station makes the call connection quite difficult. So, call may be terminated. In hard handoff process the channel in the source cell is release before connecting to the target cell. It is also known as (brake-before make) the connection is break before connecting to other channel. This means, it connects with the new base station or the new network only after having broken its connection with the serving base station but it is one channel at a time is the advantage; the hardware has no need to be compatible of receiving two or more channels. [2] In hard handoffs, the data do not have to be duplicated and therefore, the data overhead is minimized. However, excessive service interruptions could result in an increased call dropped rate

Horizontal handoffs are mandatory since the mobile terminal (MT) cannot continue its communication without performing it. Hard handoffs are classified into intra - cell and inter - cell handoffs. The intercell handoff will occur when Mobile terminal moves into the adjacent cell of the any base station. For this reason all mobile terminals connection should be transferred to the new base station [1].

Hard handoff is primarily used in Time Division Multiple Access (TDMA) based systems such as Global System for Mobile Communications (GSM) and General Packet Radio Service (GPRS). In this, different frequency ranges are used in adjacent channels in order to minimize channel interference. So, when the MN moves from one BS to another BS, it becomes impossible for it to communicate with both BSs (since different frequencies are used).

The horizontal handoff procedure may be distinguished in the following four phases:-

i) Measurement: During this phase link measurements (Received Signal Strength (RSS), Signal to Interference Ratio (SIR), distance measure, Bit Error Rate (BER) are carried out at both parts: the Base station and the Mobile Terminal.

ii) Initiation: is the decide whether a handoff is needed. The handoff process should be accomplished, whenever the received signal quality deteriorates inside a cell, or between two adjacent cells, or when the MT is moving along the common boundary of two cells.

iii) Decision: is the selection of the new channel, taking into account the actual resource availability and the network load. The decision-making process of handoff may be centralized or decentralized the handoff decision may be made at the Mobile Terminal, or at the network). [6]

1) Handoff Initiation Techniques

Handoff initiation is the process of deciding when to request a handoff. Handoff decision is based on the received signal strengths (RSS) from the current BS and neighboring BSs. The RSS gets weaker as the MS

moves away from BS1 and gets stronger as it gets closer to BS2 as a result of signal propagation characteristics. The received signal is averaged over time using an averaging window to remove momentary fading due to geographical and environmental factors. [2]- [7]

The handoff initiation techniques are:

a) Relative Signal Strength (RSS): it chooses the strongest base station at all times.

b) Relative Signal Strength with Threshold (RSS+T) : Handoff is initiated if BS1‟s RSS is lower than the threshold value and BS2‟s RSS is stronger than BS1‟s. This handoff initiation algorithm allows a user to handoff only if the current signal is sufficiently weak (less than a threshold T2) and the other is the stronger of the two. The effect of the threshold depends on its value compared to the signal strengths of the two BSs at the point at which they are equal.

c) Relative Signal Strength with Hysteresis (RSS+H): This scheme allows a user to do handoff only if the RSS from new BS is sufficiently stronger by a hysteresis margin, H than the current one

d) Relative Signal Strength with Hysteresis and Threshold (RSS+T+H): The last technique combines both the threshold and hysteresis value concepts to come up with a technique with minimum number of handoffs. This scheme hands a MS over to a new BS only if the current signal level drops below a threshold and the target BS is stronger than the current one by a given hysteresis margin

2) Handoff Decision Protocols

In cognitive radio networks, the spectrum mobility function aims to help the secondary users select the best channel(s) to send and receive their data in the case of spectrum handoff.[8]

The decision - making process of handoff may be centralized or decentralized. There are three different kinds of handoff decisions protocols:[9]

a) Network Controlled Handoff (NCHO): is a centralized handoff protocol. In NCHO protocol, the network makes a handoff decision based on measurements of the RSSs of the mobile state. In cognitive radio networks, the spectrum mobility function aims to help the secondary users select the best channel(s) to send and receive their data in the case of spectrum handoff (MS) at a number of BSs.

One main drawback of NCHO is that the measurements of neighboring channels cannot be made very often. Therefore, the accuracy is reduced.

b) Mobile Assisted Handoff (MAHO): is a decentralized handoff protocol. Both the mobile and the base station supervise the quality of the link (i.e., RSS, and BER (bit error rate). RSS measurements of neighboring base stations are done by the mobile. The mobile station MS transmits the measurement results up to the BS twice a second. The decision as to when and where to execute the handover is still made in the network (i.e., the base station and MSC). Both inter and intracellular handoffs are possible.

c) Mobile Controlled Handoff (MCHO): In this case, the mobile is the only entity which measures the handoff criteria and makes a decision based on them. The MSC is not involved in the handoff process resulting in reduced burden on the MSC. The mobile has to choose the optimum base station (BS) based on the measurements. Since the handoff process is implemented in the mobile itself, the delay is usually smaller with a typical value of 0.1 seconds and is suitable for micro-cellular systems.

3) Hard Handoff Algorithms in Cellular Systems

Handoff algorithms mainly depend on handoff initiation which is defined as monitoring the radio link, decision for commencing handoff process and the selection of new station. The parameters measured to determine handoff are usually the received signal strength, the signal to noise ratio and the bit error rate. Among all, RSS is the most commonly used criteria for handoff analysis.[10]

Horizontal Handoff algorithms used in GSM are:

a) RSS based handoff algorithm: According to this algorithm, the received signal strengths of two base stations are compared and when the received signal strength of base station 1 is less than the received signal strength of BS2 then the call is handover to BS2 otherwise the mobile station is in connection with the BS1.

(RSS (BS2) > RSS (BS1))

b) RSS based handoff algorithm with Threshold: if RSS of BS1 is less than the threshold value and RSS of BS1 is less than the BS2 the handoff is made to BS2 otherwise there is no handoff and MS still in connection with the BS1

(RSS (BS1) < T) & (RSS (BS2) > RSS (BS1))

c) RSS based handoff algorithm with hysteresis: when the RSS of BS2 exceeds the BS1 with hysteresis then call handoff to the BS2 otherwise it is connected to BS1. It minimizes the unnecessary handoffs. This method hysteresis is fixed that means the hysteresis value is either small or large.

(RSS (BS2) > RSS (BS1) + Hysteresis)

d) A new RSS based handoff algorithm with Adaptive hysteresis: when the RSS of BS2 is higher than RSS of BS1 with adaptive hysteresis value h, the call is handover to BS2 otherwise it maintains the current connection

with BS1. This adaptive handoff algorithm is developed by dynamically determining the hysteresis value as a function of the distance between the MS and the serving BS.

(RSS (BS2) > RSS (BS1) + Adaptive h)

$$Adaptive\_h = \max\left\{20\left(1-\left(\frac{d}{R}\right)^4\right),0\right\} \quad ,$$

$$R = \frac{Dc}{\sqrt{3}}$$

Where: d is the distance between the MS and serving BS, and

R: is the cell radius. For a hexagonal cell,

Dc: is the distance between two base stations.

B. Soft Handoff

Soft handoff defines the ability to select instantaneous received signals from a variety of base stations. Furthermore it allows continues calls without termination or any interference. In Soft Handoff the channel in the target cell is connected before releasing the source channel. The user is connected with both channels for a while. It is known as (make before break). The time for which both channels are used in parallel is short. The advantage of soft handoff is the chance of call termination is very low.

In soft handoff, the mobile terminal (MT) connection may be created at the target point of attachment before the old point of attachment connection is released (MT can communicate with more than one point of attachment during handoff).

Soft handoff can be used to extend the time needed to take a handoff decision without any loss of QoS. However, since the data are transmitted to all links, frequent soft handoffs may result to an increased data overhead. [1]

The cellular Code Division Multiple Access (CDMA) systems use soft handoff techniques, due to the fact that in these systems a mobile node may communicate with more than one coded channels, which enables to communicate with more than one base station. In CDMA cellular system usage of soft handoff, RAKE receiver technology and direct spread spectrum technology allows the mobile stations to communicate with two or more base stations at the same time. The mobile station does not interrupt the communication with old base station until a new connection is obtained with the new base station.

The purpose of handoff mechanism in CDMA networks, a soft handoff may be induced to reduce interference to a smaller neighboring cell. This is mainly attributed because of "near-far" effect even when the phone still has an excellent connection to its current cell.

One of the main advantages of CDMA systems is the capability of using signals that arrive in the receivers with different time delays. This phenomenon is called multipath. [6]

1) Soft Handoff Mechanism in Cellular Systems

Handoff is the process of transferring the ongoing call from one cell to another. In Soft handoff is done in which the Mobile station (MS) makes the connection with the target BS and then breaks the previous connection. [10]

The objectives of handoff include:

i) Guaranteeing the continuity of wireless services when the mobile user moves across the cellular boundaries.

ii) Maintaining required QoS.

iii) Minimizing interference level of the whole system by keeping the mobile linked to the strongest BS or BSs.

iv) Roaming between different networks.

v) Distributing load from hot spot areas (load balancing).

2) Soft Handoff Process in Cellular System

With soft handoff, the wireless call is actually carried by two or more cells simultaneously. This is achieved because all of the cell sites are transmitting the same frequency.[10] In soft handoff, mobile communicates with the new base station without disconnecting with the old base station. After a mobile call is initiated, the mobile station continues to scan the neighboring cells to determine if the signal from another cell becomes stronger than that of the original cell. So, the mobile station knows that the call has entered a new cell‟s coverage area such that a handoff can be initiated. Then it will transmit a control message to the Mobile station (MS), which states that the mobile is receiving a stronger signal from the new cell site and the mobile identifies that new cell site. The MS initiates the handoff by establishing a link through the new cell while maintaining the link to the old cell that was managing the call. Although the mobile station is located in the transition region between the two cell sites, the call is supported by communication through both cells. This eliminates the effect of repeated requests to handle the call back and forth between two cell sites. The original cell site will discontinue handling the call only when the mobile station is firmly established in the new cell. [11]

V. Example in Hard handoff- WiMAX in HORIZONTAL HANDOFF

1) WiMAX

WiMAX, has been a competitive alternative broadband wireless access technology for metropolitan broadband with its high data rates, wide service coverage, huge "user traffic" tolerance, and high QoS supported by this technology.

When WiMAX was introduced, it was only for fixed and nomadic access. In the fixed access there is no support of mobility and the user supposed to be only in a single geographical area, whereas wandering access provides the ability of changing cells while moving but with no support of handover; that means the user should establish new connection while moving from one cell to another. The enhanced version of WiMAX is based on the IEEE 802.16e standard. [13] This version introduced mobility and handover technique.

2) Handoff Procedure in WiMAX

During normal operation of WiMAX, the Mobile Node (MN) is always scanning the RSS from the current serving Base Station (BS). RSS from the neighboring Base Stations (BSs) can be received through neighbor advertisement messages. This helps in selecting the new target BS in case RSS from the serving BS drops below the predefined threshold value. After gathering information about the neighboring BSs, MN sends a scanning interval request message to the serving BS if the conditions defined for triggering handoff is satisfied. [16] The HHO (Horizontal Handoff) process can be network-controlled or mobile-controlled. The very first step of handoff is the handover preparation stage. It is executed by transmitting a handoff request message; a MN_MNHO-REQ. MN will send this message if the handover is mobile-controlled and BS would send MN_BSHO-REQ in case of network-controlled handoff. MN_MNHO-REQ is transmitted to all neighboring target BSs by service access network of serving BS. This message includes flow management information required for re-establishment of the connections after the execution of handoff. After receipt of HO_Req, the target service network generates response message to serving BS. On receipt of response message, serving BS sends MN_BSHO-RSP to the MN and an acknowledgment message to all other neighboring BSs to complete the handoff preparation. The purpose of the MN_BSHO-RSP is to inform the MN on BSs it may connect itself during the actual handoff. Finally, handover indication message is sent by the MN to the serving BS before executing actual handoff. So, MN disconnects old connections and ranges itself with the target BS [14].

Further, a data path registration processes are executed between the target service access network and the anchor service network for bearer plane procedures. When the data path registration process is done, a HO_Complete message is sent from the target service network to the serving network to inform about completion of the handoff.

3) PERFORMANCE METRICS in Wimax

The Performance metrics or evaluation is the QoS metrics like good throughput and minimum Network delay and MOS in VoIP.

a) Throughput: Throughput or network throughput is the average rate of successful message delivery over a communication channel. Its means, more messages delivered over Channel will make network more reliable and fast. [3]

b) Network delay: Specifies how long it takes for a bit of data to travel across the network from one node or endpoint to another. It is typically measured in multiples or fractions of seconds. Delay may differ slightly, depending on the location of the specific pair of communicating nodes. There is a certain minimum level of delay that will be experienced due to the time it takes to transmit a packet, so this adds up more variable level of delay due to network congestion.

MOS in VoIP: It works as follows; first, a voice signal is sampled, digitized, and encoded. The encoded data (called frames) is/are packetized and transmitted using RTP/UDP/IP. At the receiver's side, data is de-packetized and forwarded to a playout buffer, which smoothes out the delay incurred in the network. Finally, the data is decoded and voice signal is subjective and therefore is measured by mean opinion score (MOS). MOS is a subjective quality score that ranges from 1 (worst) to 5 (best) [17].

4) Simulation Scenario

Here we determine the concept of Hard Handoff through simulation using OPNET program.

a) OPNET Program

OPNET version 14.5 modeler is a very flexible tool which provides drags and drop facilities for the communication devices like (routers, user equipments, and servers), interconnecting models(ATM link, fiber optics, both wired and wireless LAN and PPP links) and multiple protocols.

The simulation analyzes the Handoff management procedures within a WiMAX access networks and evaluate its impact on different QoS metrics like throughput and End-to-End Delay.

Simulation scenario includes Four MN and Four BSs of WiMAX network. The Trajectory shows the movement of MN over the BSs.

Figure (1) shows the transfer of the voice packets from the Four MNs over the BSs.

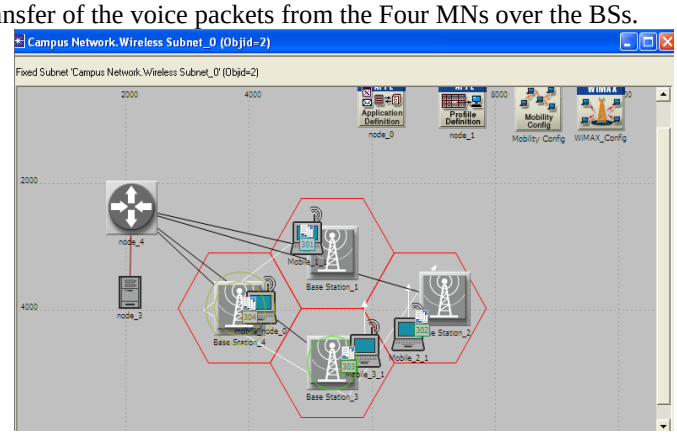

Fig.1 shows the WIMAX network with four MN and four BSs.

Figure (2) shows the Hard Handoff process when the channel in the source cell is release before connecting to the target cell (illustrated in fig. by the red crosses).

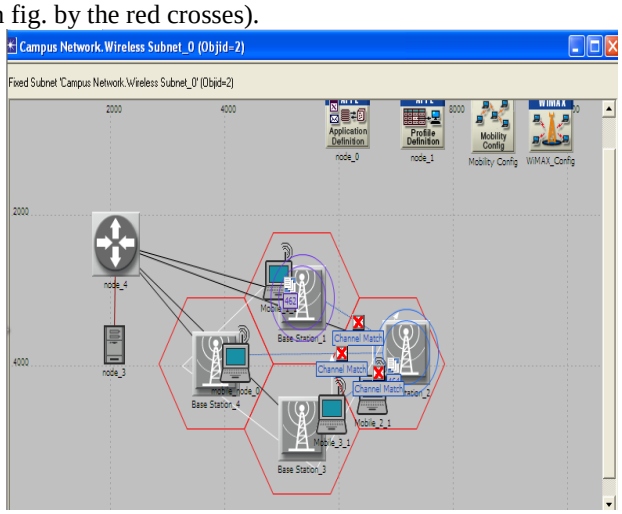

Fig. 2 shows the Hard Handoff

Use either SI (MKS) or CGS as primary units. (SI units are encouraged.) English units may be used as secondary

b) Performance Analysis

When the transfer is started initially the packets will be transferred from MN to CN via BS1.

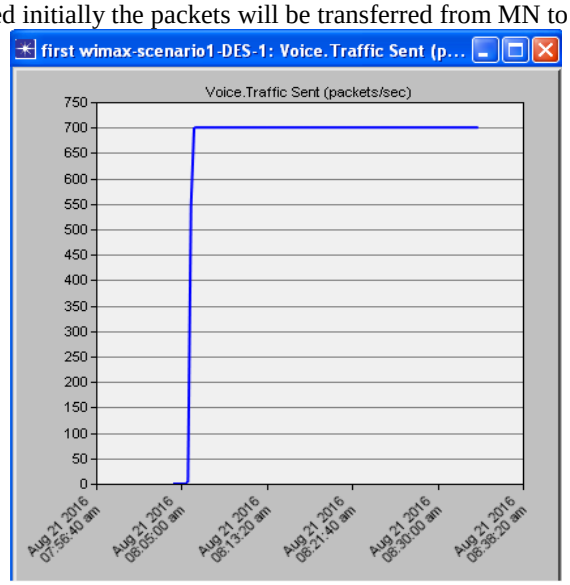

Fig.3 shows the voice traffic sent

As the simulation time increases, MN starts moving away from BS1 and at a point moves out of coverage area of BS1 (the crosses in red determine that). Further it senses the presence of better coverage by BS2 so handoff takes place and now the packets are sent from MN to CN via BS2. During this transfer CN is steady. Throughout and end-to-end delay are plotted using Opnet.

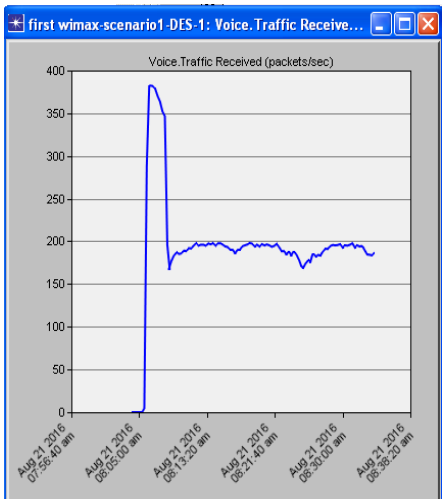

Fig.4 shows the voice traffic received

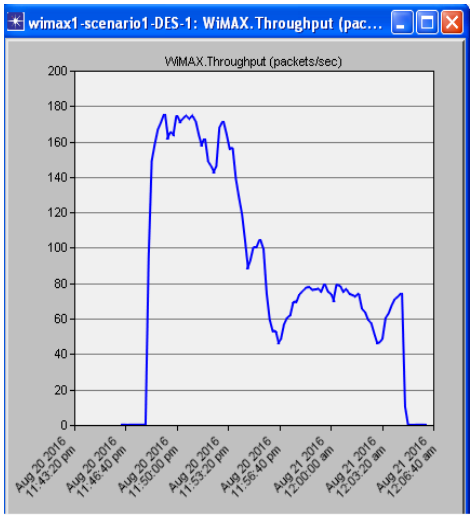

Fig.5 shows the throughput

It is seen that the throughput remains changes by the changing of the received signal. Throughput increases as the data rate increases

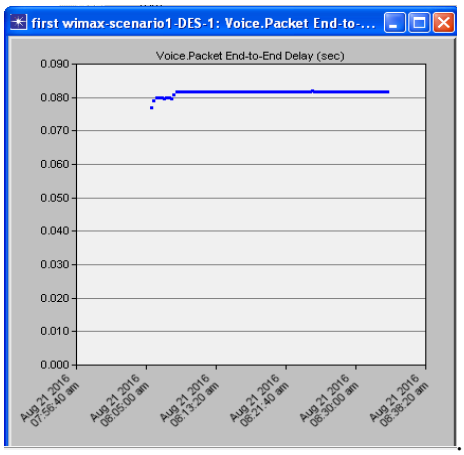

Fig.6 shows the End – to – End Delay

V. Conclusion

In this paper, we introduced an overview on the concept of handoff and its types (Hard & Soft handoff). Then we discussed the handoff initiation and its evaluation parameters and also the handoff decision protocols that are used. Finally, we illustrate the Performance evaluation of QoS metrics during the hard handoff by the Horizontally WiMAX HHO which carried out in OPNET.

The simulator has been designed to simulate WiMAX network in order to analyze the mobility of a node during HHOs. It is seen that when a mobile node moves away from coverage area of one network and finds better coverage in another network it undergoes handoff management procedures and starts communicating via newly detected PoA. The Throughput and End-to-End Delay results are obtained.

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