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Master's Degree Thesis

IEEE 802.21 Assisted Handover using SINR and Occupied Bandwidth over Heterogeneous Network

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CERTIFICATE OF APPROVAL

MASTER'S THESIS

This is to certify that the master's thesis of

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has been approved by examining committee for the thesis requirement for the Master's degree in engineering.

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Acronyms

WLAN	Wireless Local Area Network
Wi-Fi	Wireless Fidelity
UMTS	Universal Mobile Telecommunications System
HHO	Horizontal Handover
VHO	Vertical Handover
VHD	Vertical Handover Decision
VHDA	Vertical Handover Decision Algorithm
SINR	Signal to Interference plus Noise Ratio
OB	Occupied Bandwidth
MIH	Media Independent Handover
4G	Forth Generations
IEEE	Institute of Electrical and Electronics Engineers
MIHF	Media Independent Handover Function
SAPs	Service Access Points
MIES	Media Independent Event Services
MICS	Media Independent Command Services
MIIS	Media Independent Information Services
DCD	Downlink Channel Descriptor
PoS	Point of Service
PoA	Point of Attachment
MN	Mobile Node
PDU	Protocol Data Unit
IP	Internet Protocol
IEs	Information Elements
3GPP	3rd Generation Partnership Project

AP	Access Point
BS	Base Station
MCHO	Mobile-Controlled Handover
NCHO	Network-Controlled Handover
MAHO	Mobile-Assisted Handover
MAC	Medium Access Control
RSS	Receive Signal Strength
QoS	Quality of Services
BER	Bit Error Rate
MIPv6	Mobility support for Internet Protocol v.6
IWU	Inter-Working Unit
SAHD	SINR Aware Handover Decision
E-SAHD	Enhanced SINR Aware Handover Decision
NQ	Network Quality
NS-2	Network Simulator-2
DSDV	Destination-Sequenced Distance Vector
CBR	Constant Bit Rate

ABSTRACT

IEEE 802.21 Assisted Handover using SINR and Occupied Bandwidth over Heterogeneous Network

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Nowadays, networks are large heterogeneous systems in which efficient and effective support for multi-access technologies is imperative. Handover algorithms in heterogeneous networks have a greater challenge to provide best network selection in terms of quality of service. Seamless handover within different overlapping network is another serious requirement for wireless access providers. This thesis contributes to the research and development in handover algorithm in a heterogeneous network. The main contributions are listed below.

Firstly, the enhanced handover decision algorithm is presented, which allows identifying the quality of network by evaluating a metric, signal to interference plus noise ratio (SINR). SINR can be taken as an effective decision metric, since it is more convincing and reflecting the current status of the network. To present the more competent performance, a new network parameter, occupied bandwidth is merged to make the decision for the selection of the appropriate network.

Secondly, to provide seamless connectivity during handover, IEEE 802.21 is adapted to the framework in this work. The research analysis presented in this

thesis provides the enhanced solution in handover decision algorithms. Moreover, this thesis focuses on increasing the overall performance of the system in terms of network quality, throughput, and handover latency under different handover scenarios of overlapped networks.

Finally, simulation based experimental results demonstrated the enhanced performance and efficiency of the proposed method.

한 글 요 약

이종망환경에서 **SINR**과사용대역폭을이용하는 **IEEE 802.21** 지원기반핸드오버

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오늘날, 효과적인 다중접속 기술을 지원하는 대규모 이종망 시스템이 요구되고 있다. 이종 네트워크 내에서의 핸드오버 알고리즘은 서비스 품질 측면에서 최상의 네트워크 선택을 제공해야 하는 도전 과제를 안고 있다. 서로 다른 중첩된 네트워크상에서 매끄러운 핸드오버는 무선 접속 제공자에게는 또 다른 중요한 요구사항이다. 본 논문에서는 이종 네트워크 내에서의 향상된 핸드오버 알고리즘을 소개한다. 주요 사항들은 아래와 같다.

첫 번째로, 본 논문에서는 신호 대 간섭•잡음비(SINR) 매개 변수 평가에 의한 네트워크 품질 식별을 할 수 있는 향상된 핸드오버 결정 알고리즘을 제시한다. SINR은 보다 확실하고 네트워크의 정보를 정밀하게 반영하는 효율적인 결정 매개변수로 사용될 수 있다. 보다 경쟁력 있는 성능을 보이기 위해, 결정에 있어 새로운 네트워크 변수인 사용 대역폭이 함께 사용되어, 적절한 네트워크의 선택이 가능하도록 한다.

두 번째로, 핸드오버 동안에 매끄러운 서비스 연결성 제공을 위해 IEEE802.21이 시스템에 적용되었다. 따라서, 핸드오버 결정이 매우 정밀해 질 수 있으며, 네트워크 품질, 처리량과 핸드오버 지연이라는 측면에서 전반적인 시스템의 성능 향상을 기대할 수 있다.

마지막으로, 실험 결과를 통해 본 논문에서 제안하는 방식이 향상된 핸드오버 성능과 효율을 보임을 알 수 있었다.

I. Introduction

Current wireless and mobile communication systems are comprised of heterogeneous networks using different technologies at the end nodes like mobile, Pam PCs, Laptops etc., which are equipped with multiple interfaces [1]. A wireless network which provides a service through a wireless LAN and is able to maintain the service when switching to a cellular network can be considered as an example of heterogeneous network [2]. Emphasizing on the demand of emerging technologies in the future, infrastructures have to be designed such that the evolution of communication technologies can be merged together to provide an optimum solution for inter-network environment.

As an example in a multi-network scenario, a host can move from one network (Wi-Fi) to another network (UMTS) requiring a handover. This handover is referred as vertical handover (VHO) [3]. The node changes the type of connectivity according to the kind of host network. In other words, VHOs refer to the automatic fall over from one technology to another in order to maintain communication. Careful design of VHO is required to achieve maximum efficiency in the system.

The next generation network also demands for seamless switching of the available networks to access the best one [4]. Moreover, there is always a requirement to find the best network to run the application without any interruptions [5] [6]. When a mobile user changes its location in order to find best network, initial connection is broken. To overcome this problem, a framework that enables seamless handover between heterogeneous technologies has to be studied along with the efficient performance of the system.

As an important step towards achieving this objective, media independent handover (IEEE 802.21) creates a framework to support protocols for enabling seamless vertical handovers. IEEE 802.21 provides only the overall framework, leaving the implementation of the actual algorithms to the engineers designing the system. Therefore, it is essential to develop efficient vertical handover decision (VHD) algorithms to ensure the success of this new framework.

The primary focus of this thesis is to develop a handover decision algorithm which guarantees a more accurate and efficient handover decision in a real network scenario with high user satisfaction compared to a conventional handover algorithm.

A. Problem statement

Heterogeneous networks still deserves lot of research attention to fulfill the user's requirement. Furthermore when different technologies are integrated together, handover from one technology to other plays a vital role. It is even necessary to investigate whether the handover carried out is seamless or not. This thesis basically focuses on finding the solution of improved handover decision. Problems in handover decision can be divided into two categories.

Firstly, finding out the quality of network before switching the network is an important approach. Analyzing network characteristics are a complex job. Thus, proper process along with appropriate metric has to be selected to achieve the real characteristics of the network. Hence, new vertical handover was introduced that finds a better target network by evaluating a metric, signal to interference plus noise ratio (SINR) and occupied bandwidth (OB), of each network and provides both high throughput and low handover latency.

Secondly, utilizing the information to make a suitable selection of network which provides better performance to the users. Finally, the scheme developed must provide seamless mobility and better quality of service.

B. Thesis objective and scope

As discussed in the problem statement, the main objective of this thesis is to design the handover decision algorithm based on the most suitable network parameter. The line of work includes identification of the problem and preparing the framework and evaluating the results.

There are varieties of handover algorithms being proposed to resolve the problem. But, the proposed studies lack consideration of accurate network parameter and implementation detail. Handover triggering to unwanted network due to the insufficient analysis of networks are observed. Furthermore, user leaving the existing network earlier than expected time led to unwanted wastes of network resource.

In this work, improved handover decision algorithm is presented, which is dedicated for optimum usage of resource available in the network with the help of the correct network parameter and displays closer characteristics of the network.

Hence, performance analysis will be presented based on network quality, throughput, unnecessary handovers, and the latency which ensures the quality of the proposed algorithm.

C. Thesis contribution

This thesis contributes to the given research area to overcome the greater challenge to provide a precise network selection during the handover procedure. Also the procedure to extract the information on the available networks is demonstrated. This is done by evaluating a metric signal to interference plus noise ratio (SINR) and occupied bandwidth. Handover decision algorithm being an important part in the handover procedure, allows the comparison of information provided and make the right decision. Seamless handover within different overlapping network is another greater task for wireless access providers. To overcome this problem IEEE 802.21 has been used along with the described metric. The brief overview of the contribution will be addressed in chapter 4 where observations, analysis, and solutions are discussed thoroughly.

D. Thesis outline

The structure of this thesis is as follows. This chapter showed short description about the importance of this research. In chapter 2, detailed description of IEEE 802.21 will be presented. Vertical handover decision algorithms will be continued in chapter 3. The proposed framework of the optimized handover scheme will be defined in chapter4. Chapter 5 comprises of performance evaluation and results. Finally, concluding remarks of this thesis will be presented.

II. Media Independent Handover

The popularity of wireless networking demands more facilities with ubiquitous services. Moreover, networks are large heterogeneous systems where support of multi-access technologies is imperative. Within this inter-technology environment, users will expect to be globally reachable anytime anywhere and remain always best connected. In order to meet these requirements, mobile device and access networks has to work together to select the best network. Fig. 2.1 shows the general media independent handover (MIH) concept.

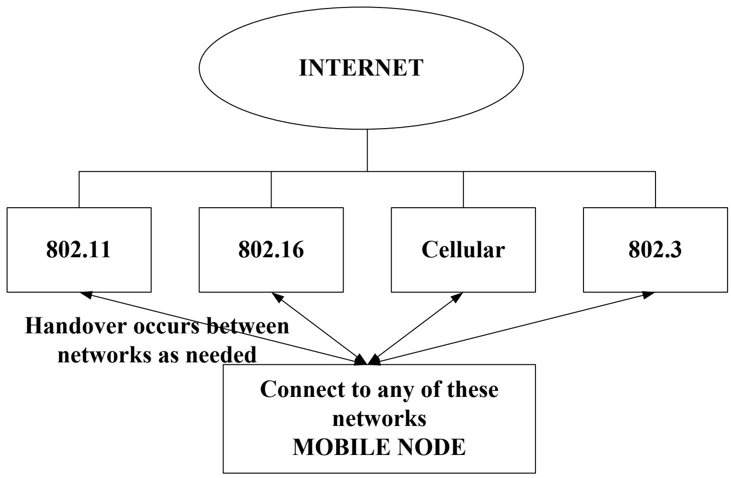

Figure 2.1: MIH concept

IEEE 802.21 standard for MIH has been developed in 2009. The primary focus of this standard is defining the mechanisms to enable and optimize the handover between heterogeneous IEEE 802 networks, cellular networks along with 4G networks without service interruption. Also it defines new entities and services that is implemented into the mobile and network devices [7]. For session continuity, it also provides a framework that allows interaction with higher layers to lower layers without dealing with the specifics of the technology. In other word, IEEE 802.21 for future networks would be like a "glue" to link up between inter-access technologies [8].

A. Objective of IEEE 802.21

IEEE 802.21 provides a seamless handover between heterogeneous technologies. This framework is based on the protocol stack implementation in all the devices involved in the handover [9]. The main principle of implementing the protocol stack is to provide necessary interactions among all the devices for the optimizing the handover decision.

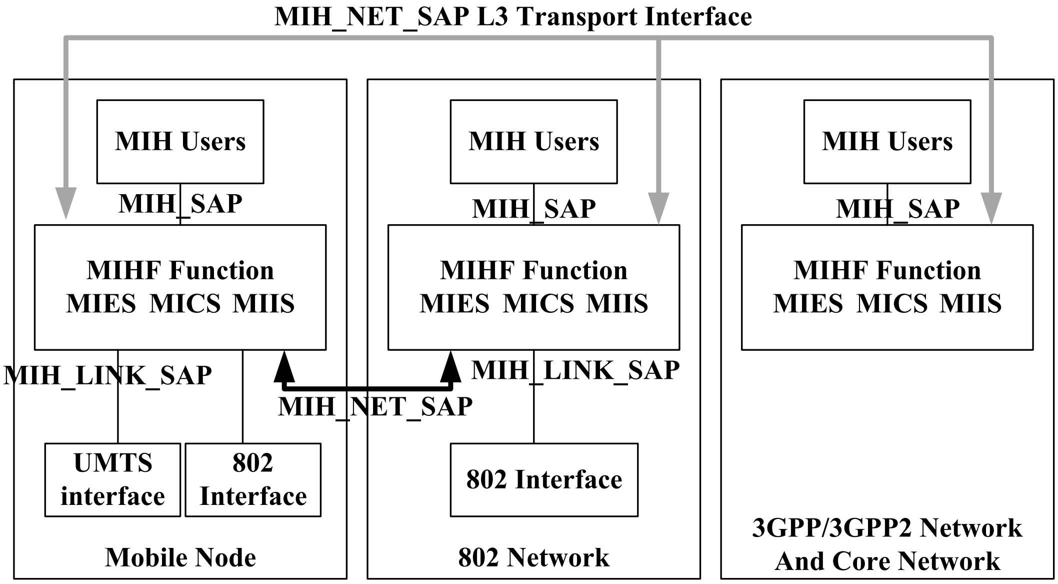

Figure 2.2: General architecture of MIH

As observed in the figure, IEEE 802.21 nodes have a common structure surrounding a central entity called media independent handover function (MIHF).

MIHF acts as an intermediate layer between link layer and the network layer. It coordinates information service and command service during the handover decision and executes the handover. From the MIHF prospective, each node has a set of MIHF users that uses the MIHF functionality to control and gain the handover related information. The communications between the MIHF and the other functional entities such as the MIHF users and the lower layers are based on a number of defined service primitives that are grouped in service access points (SAPs). Currently, the following SAPs are included in the 802.21 standard draft can be seen in Fig. 2.2.

MIH SAP: This interface allows communication between the MIHF layer and the higher layer MIHF users.
MIH LINK SAP: This is the interface between the MIHF layer and the lower layers of the protocol stack.
MIH NET SAP: This interface supports the exchange of information between remote MIHF entities.
MIH-enabled MN communicates with an MIH-enabled network. In Fig. 2.2, the gray arrows show the MIH signaling over the network, whereas the black arrow show local interactions between the MIHF and lower and higher layers in the same network or node block.

B. MIHF services

MIHF generally provides 3 services: (1) Media independent event services (MIES), (2) Media independent command services (MICS), and (3) media independent information services (MIIS) that facilitate handover across heterogeneous networks [11]. Prior to providing the MIH services from one MIHF to another, MIH entities need to be configured properly. This is carried out through following service management functions.

- MIH capability discovery
- MIH registration
- MIH event subscription

MIH capability discovery

MIH user uses this procedure to discover the MIHF's capabilities in terms of MIH services i.e. event, command and information services. MIH capacity is either performed with MIH protocol or media specific mechanisms (i.e., IEEE 802.11 beacon frames, IEEE 802.16 downlink channel descriptor (DCD), IEEE 802.11 management frames, or IEEE 802.16 management messages.

MIH registration

MIH registration is defined as a means of requesting access to specific MIH services. For example, in a network controlled inter-technology handover framework, MIH registration can be used by a mobile node (MN) to declare its presence to a selected MIH point of services (PoS).

MIH event subscription

The MIH event subscription mechanism allows an MIH user to subscribe to a particular set of events that originates from a local or remote MIHF.

1. Media independent event services

Generally handovers are commenced by the MN or by the network. Events relevant to handover originate from MAC, PHY or MIHF at the MN, at network point of attachment (PoA) or at the point of service (PoS).Multiple higher level entities are interested in these events at the same time and these events might have multiple destinations. MIHF is used to dispatch these events to multiple destinations.

The Event service can be divided into two different types of events, link events and MIH events [12]. Both the events are triggered from the lower layer to higher layers. Moreover link events are generated by lower layers and terminate at MIHF entities and MIH events are generated at MIH entities that are propagated to MIH users. The association can be clearly seen in the Fig. 2.3.

The Media Independent Event Service can support several event types:

a. MAC and PHY state change events

These events notify about a definite change in the MAC or PHY state. Link Up or Link Down events can be considered as an example.

b. Link parameter events

These events are created due to a change in the link layer parameters. They can be generated either by a synchronous method (report on a regular basis) or by an asynchronous method like reporting when a specific parameter reaches a threshold.

c. Link synchronous events

These events report deterministic information about link layer activities that are relevant to higher layers. The information supplied does not need to be a change in the link parameters; it can be suggestions about link layer activities such as the native link layer handover methods which are performed autonomously by the link layer, independently from the global mobility protocol.

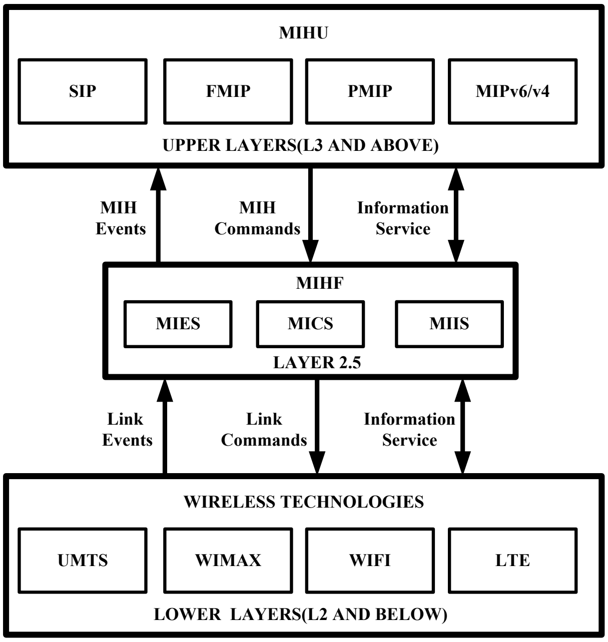

Figure 2.3: MIHF services

d. Link transmission events

These events update the information on the transmission status of higher layer protocol data units (PDUs) by the link layer. Through these events, the link layer may inform the higher layer of the losses in the ongoing handover. This information can be used to dimension the buffers needed for seamless handover or to adopt different retransmission policies at higher layers.

2. Media independent command services

These services refer to the command sent from higher layer to the lower layer in order to determine the status of link and control the terminals to obtain the optimal performance. Command service also facilitates the MIH user by optimal handover policies [12]. The link status varies with time and MN mobility. MICS provides the information which is a dynamic information composed of link parameters such as signal strength and link speed. However the information provided by MIIS is less dynamic or static in nature and is poised of parameters such as network operators and higher layer service information. MICS and MIIS could be commonly utilized by the MN/network to enable handover.

Commands can be conveyed locally or remotely. Local MIH commands are sent by MIH users to the MIHF in the local protocol stack. Similarly remote MIH commands are sent by MIH users to the MIHF in a peer protocol stack. This remote MIH commands delivered to the peer are executed by the lower layer. The network may force a terminal to handover, allowing the use of Network initiated handovers and network assisted handovers through remote commands. Commands are defined in the description to authorize the user to regulate the lower layers configuration and behavior. The communication flow mechanism is shown in fig. 2.3. Commands are classified into two main categories.

a. MIH commands

MIH commands are generally sent by the higher layer to the MIHF .The sent command is addressed to remote MIHF and then to local MIHF. Finally local MIHF will deliver it to the appropriate destination through MIHF transport protocol. All commands are designed to help with the handover procedure but the routing of the user packets is left to the mobility management protocols located at higher layers, like Mobile internet protocol (IP).

b. Link commands

These commands are originated in the MIHF and helps in controlling lower layers on behalf of MIH users. Link commands are local only and should be implemented by technology dependent link primitives to interact with the specific access technology. New link commands shall be defined as amendments to the current technological standard.

3. Media independent information services

Media independent information service (MIIS) delivers a framework by which an MIHF, located in in the MN or in the network, discovers and acquire network information within a geographical area to assist network selection and handovers [12]. The objective is to acquire a global view of all the heterogeneous networks pertinent to the MN in the area to facilitate seamless roaming across these networks.

MIIS is based on information elements (IEs) and these elements delivers information essential to the network selection algorithm to make a successful handover across heterogeneous networks and technologies. Information provided by IE can be related to the lower layers like coverage zone and other link parameters. Also information related to higher layer services such as lack of connectivity or availability of certain services etc. MIIS is designed to provide information mainly about 802, 3GPP and 3GPP2 networks, although this list may be extended in the future.

The main target of MIIS is to provide the essential information that may affect the selection of the appropriate networks. The information elements can be generally divided into the following groups:

a. General information

These IEs gives the general overview about the networks covering a precise area such as network type, operator identifier or service provider identifier.

b. Access network specific information

These IEs provide particular information for each technology and operator. The information is associated with security characteristics, QoS information, revisions of the current technology standard in use, cost, roaming partners etc.

c. Point of attachment (PoA) specific information

These IEs delivers information for each PoA (for each technology and operator). The information covers the features like MAC address of the PoA, geographical location, data rate, channel range etc.

d. Higher layer services/information per PoA

The information provided is related to the available services on this PoA and network. The information provided may be the number of subnets these PoS support, the IP configuration methods available, or even a list of all supported services of the PoA.

III. Vertical Handover Decision Algorithm

Vertical handover decision algorithm (VHDA) aims to provide the solution to ensure the automated quick and right handover decisions for the network solution [13]. The demand of efficient handover to provide the required QoSfor a wide range of applications along with seamless roaming ensures the importance of the right technique to be adopted for handover decision. This chapter demonstrates the brief overview and mechanisms of the previously designed vertical handover decision algorithms (VHDA). Furthermore evaluation and complication of the presented algorithms will be discussed.

The rest of the chapter is organized as follows. The first section provides information about the overview of handover. A vertical Handover mechanism will be followed in the second section. Finally the demands and requirements to design VHDA are discussed.

A. Handover and its classification

Handover refers to the action of transferring an ongoing data session from an area or channel covered by one cell or networks to another area or channel of cell or networks. Classification of handovers can be presented as follows:

1. Horizontal and vertical handover

As illustrated in the Fig.3.1, a handover can be classified as horizontal or vertical. Handover between the PoA (point of attachment) within the same technology can be referred as horizontal handover (HHO) or intra-system handover. Basically HHO is mainly based on received signal strength (RSS) levels. Similarly vertical handover (VHO) or inter-system handover occurs between PoA's supporting different technologies [14]. Handover between the two cells in UMTS and handover between an AP of WLAN and BS of UMTS are the examples of HHO and VHO [15].

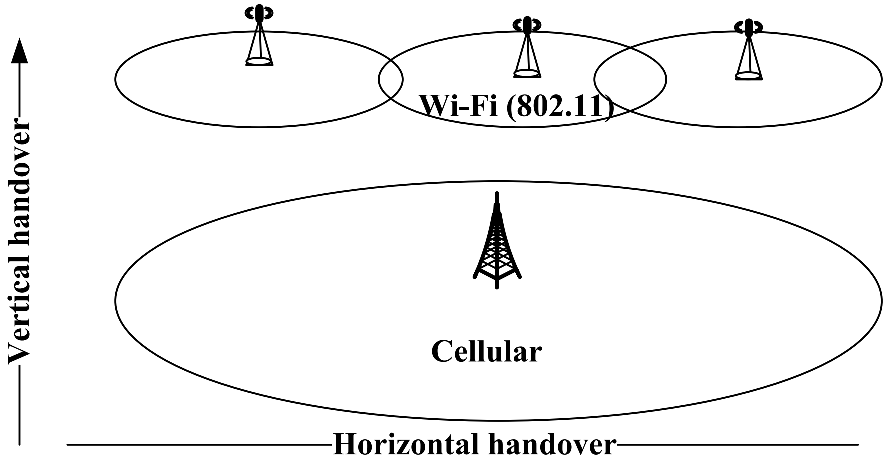

Figure 3.1: Handovers

2. Mobile-controlled, network-controlled and mobile-assisted handover

a. Mobile-controlled handover (MCHO)

MCHO refers as mobile node taking the handover decision on its own. The mobile terminal is completely in control of the handover process [16].

b. Network-controlled handover (NCHO)

NCHO refers to the network measuring the transmission quality via stations and decides when handover should be executed [16][17]. In this case the mobile terminal makes no measurements. The decision is carried out by intense signaling between the base station and the nodes.

c. Mobile-assisted handover (MAHO)

MAHO refers to continuously measure the transmission quality from the serving and neighboring base stations and sends the recorded values to the serving base station. On the basis of these values, the network decides when handover should take place. Unlike NCHO, the terminal's situations are taken into account, as terminal does in by itself [16].

3. Hard and soft handover

Based on the number of connections involved, handover can be classified as hard and soft handovers. Fig. 3.2 demonstrates the clear overview of hard and soft handovers.

Hard handover or Break-before-make handover refers to the association with only one access point at a time and connection to the old network is released before making the new connection [18].

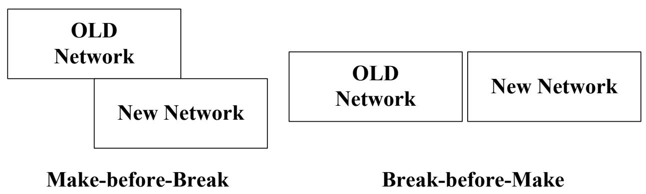

Figure 3.2: Hard and soft handover

Soft handover or Make-before-break handovers refers to the communication with more than one access point during handover. In this type of handover new connection is established before the old connection is released. After the successful handover, the old connection is released.

B. Handover management procedure

VHO process should include service continuity, network discovery, network selection security, device power management and QoS issues for the efficient performance. The vertical handover process is presented in fig. 3.3. This process can be generally divided into three parts: (1) Network discovery, (2) Handover decision, and (3) Handover execution [19].

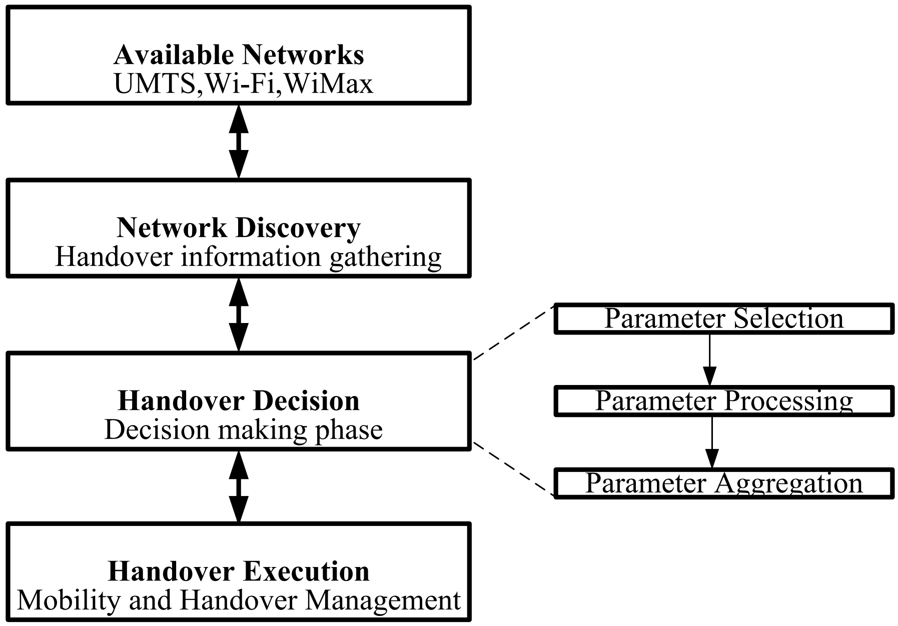

Figure 3.3: Handover procedure

1. Network discovery Phase

Network discovery or handover information gathering phase involves in collecting the information of networks [19] [20]. Additionally it even collects the information about the rest of the components of the system such as network properties, mobile devices, access points and user preference.

Accessibility of neighboring network links by offering information such as throughput, cost, packet loss ratio, handoff rate, received signal strength (RSS),carrier to interference ratio (CIR), signal to interference ratio (SIR), bit error ratio (BER), distance, location, and QoS parameters. The information mentioned earlier is gathered as per the requirement and provided to the decision phase to achieve correct and efficient handover. The collected information's reliability is significant since the decision making procedure relies on this data. The considered information can be further classified into three categories:

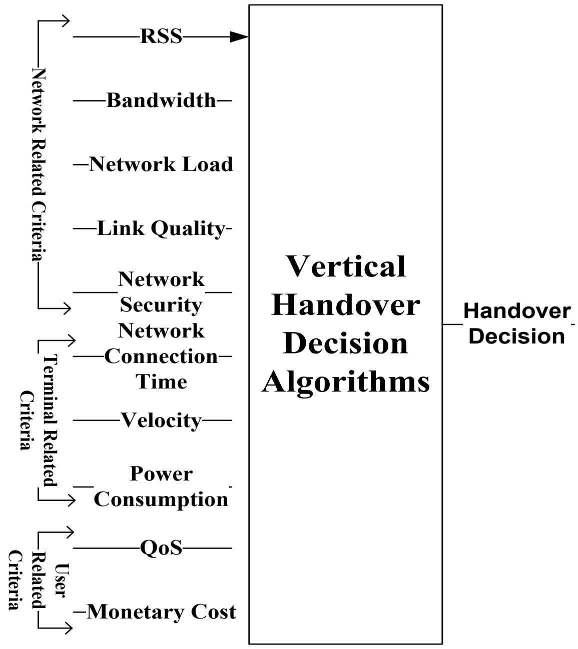

Figure 3.4: Handover decision criteria

a. Network related criteria

These criteria provide network conditions and system performances [13] [24].

i. Received signal strength (RSS)

This is the most common and crucial criteria which are being used. This is easy to measure and is appropriate for the service quality. RSS can be considered as main decision criteria for horizontal handover. Also it is an important criterion for VHD algorithms. Lots of RSS based algorithms for VHD can be found which used RSS as a main handover decision criterion [21].

ii. Bandwidth

Available and offered bandwidths are the measure data available and offered. These parameters are taken as important parameters due to their direct effects on QoS. In the case of coexistence of different networks, available bandwidth behaves as an important criterion [22].

iii. Network load

Network load provides information about the congestion of the network. Thus having information about the load reflects the network scenario. In fact, it is another important criterion for VHD.

iv. Link quality

Link quality is a measure of signal quality and can be considered as another important criterion for VHD. SINR, BER, FER, SIR etc. are generally examined in making decisions about link establishment. The knowledge of such information provides efficient VHD especially with applications requiring high quality and as well as reliability.

b. Terminal-related criteria

A terminal-related criterion refers to the decision parameter information taken from terminal side.

i. Network connection time and velocity

Network connection time refers to the extent that terminal remains connected to the specific network. This is related to terminals location as well as the velocity of the mobile device. Unnecessary handover can also be reduced discouraging the network with short connection time. Velocity is another important factor. Fast moving terminal do not prefer the network with short connection time which results in quick successive handover and high signaling overhead.

ii. Power consumption

Power consumption is another important criterion for VHD. Network and terminal criterion is utilized to make the optimum use of power.

c. User-related criteria

A user's particular interest towards an access network may perhaps lead to the selection of one of the network type among many networks.

i. QoS

This actually depends upon the ongoing applications and its demands.

ii. Monetary cost

Charging policies in different network might be different. Hence, it is important to include the cost of network for making decisions. However there is always a tradeoff between cost and QoS.

A VHD algorithms attempt to use multiple parameters to take the decision. This type of combined algorithms will satisfy system requirements, the service provider's goal, user satisfactions and many more. However, considering a larger set of parameter results in a higher degree of complexity in the algorithm.

2. Handover decision phase

Handover decision phase is in charge of estimating and determining the most appropriate network choice in order to fulfill the both network as well as user requirement. Therefore handover decision phase is considered as a core phase of

VHO.A decision for vertical handover may depend on several issues relating to the network. Vertical handover algorithms (VHA) are defined based on the information available to make the accurate decisions. VHA design consists of a wide range of varieties. Some of them do in the straight forward process, handover decision is carried out considering only the lower layers given by media independent information services (MIIS) and most of the proposals are interested in building cross layer handover algorithm along with combining the metric [23].

Decision making phase can be further divided into three steps: Firstly (1) parameter selection, which accounts to evaluate and weight the candidate with the information provided in the previous phase. Secondly, (2) parameter processing, allows for the normalization of all the parameter. Finally (3) parameter aggregation, makes decision by selecting the best networks with the support of normalized parameters.

3. Handover execution phase

This phase generally focuses on execution. There are two main processes participating in this phase.

a. Handover management

Handover can be either network controlled or mobile controlled. Therefore there must be an entity in-charge of controlling the VHO process. There are VHO with network assisted as well as mobile assisted. Generally, VHO can be network assisted where VHO initiated by mobile device and assisted by network with the help of information services. When the terminal reaches the new point, the execution of some procedures like registration, association, re-association has to be performed [19].

b. Mobility management

Mobility management is the key concept for seamless connectivity in VHO. In IP-based networks, standard protocol intended for mobility becomes an imperative solution to maintain system stability aiming seamless handover. These protocols typically work on the intermediate layers of the TCP/IP protocol stack. The most common protocols used for mobility in VHO are the mobility support for internet protocol v.4 (MIPv4), mobility support for internet protocol v.6 (MIPv6), session initiated protocol (SIP), network mobility basic support protocol (NEMO) and host identity protocol (HIP).

C. VHD Algorithms: Problems and Requirements

Handover decision process decides when and where to perform handover in a heterogeneous environment. The Handover decision is taken by the mobile node (MN) depending upon the different metrics like received signal strength (RSS), quality of services (QoS), network load and user preferences, signal to interference and noise ratio (SINR) [24] - [28]. Although RSS is a popular metric for handover decision but it cannot adopt the different network conditions such as noise level and network load. RSS based schemes do unnecessary handovers under interference and noisy conditions even though the signal strength of the current network is still higher than the defined threshold [29]. SINR is a parameter which can reflect the actual properties of the networks and with this decision parameter, selection of appropriate networks can be done resulting into high performance of the entire system. By using SINR, handover can be carried out only when it is necessary and unnecessary handovers under interference and noisy environment can be eliminated. This section presents some of the VHD algorithms already published and their drawbacks.

Here, existing works for vertical handover decision are briefly discussed. [30] shows that the vertical handover is generally based on RSS, MN velocity, monetary cost, link capacity, and power consumption. However, this work uses lots of metrics increasing signaling overhead and doesn't deal with seamless handover. Similarly, [31] describes a novel measurement-based network selection technique mainly dealing with the cost function approach that provides a practical way to acquire QoS information and reduces unnecessary handovers. Furthermore, the minimization of unnecessary handover is also discussed by the prediction of the travelling distance, based on the RSS measurements [26]. But, seamless handover and higher throughput are not adequately addressed in this study.

In [32], three different approaches for vertical handover decision are presented which are RSS, data rate, and their combined function. Simulation result shows that the combined handover decision approach is better than the other two approaches. However, the better approach might be feasible for the environment where the cells of different network have slight signal overlapping region. This is because they use RSS to trigger the network discovery.

[33] and [34] presented RSS based handover decision algorithms without the consideration of any QoS parameters. As a decisive parameter, RSS can't be able to reflect the actual state of the network and doesn't give higher performance in term of data throughput on the switched network. Results observed are sometimes premature in handovers although the user achievable data rate is still higher.

SINR based handover decision is shown in [35] dealing with the QoS requirement. This work requires inter-working unit (IWU) and SINR conversion between networks, which might increase the signaling overhead in a network. Moreover, this handover decision doesn't deal with seamless handover.

[13] Shows that most of the handover schemes still rely on traditional RSS-based approach. Seamless handover schemes are the necessity for the future networks.

Also, providing the required QoS is still the major issue due to the increase in mobility and overlapping network environment.

RSS and bandwidth based VHD algorithms are usually simple and are not sufficient to reflect the exact properties of the network. Also considering one or two handover criteria as the inputs and other important parameters such as latency, congestion, monetary cost or power consumption level of the networks are ignored.

Furthermore, they are usually targeted to only two specific types of network technologies. Cost function based and combination algorithms are more complex, and they take into account a wider range of network parameters as compared to others. However, they are mostly on the theoretical analysis stage or are too complicated for implementation yet.

IV. Proposed Framework of Optimized Handover Scheme

This chapter presents proposed algorithm for the optimized handover decision scheme. It includes the explanation of signal to interference and noise ratio, occupied bandwidth and heterogeneous network model used for vertical handover. This is followed by SINR aware handover decision, its enhanced version and eventually their observations.

A. Signal to interference and noise ratio (SINR)

Wireless communications take various environmental parameters like background noise, interfering state of simultaneous transmission etc. which are related to SINR. Thus, SINR is commonly used to measure the quality of the wireless connections. SINR can be represented as:

$$SINR = \frac{S}{N + I}, \qquad (4.1)$$

where S represents the received power and N and I are the noise power and interference of all other simultaneous transmissions, respectively.

In Ns-2, signal strength of one frame is calculated by corresponding propagation model and the distance between transmitter and receiver. Signal strength is calculated with the help of corresponding propagation model and distance between transmitter and receiver. Noise power includes noise from the receiver and the environment. Since different environments have different noise distribution, environmental noise is not simulated in this work. Noise received from the receiver can be further categorized as thermal and platform noise. Different products may have different receiver sensitivity. Receiver sensitivity is the received signal power where the bit error rate (BER) is less than a certain threshold.

In wireless communication, interference plays a vital role in the performance of the network system. If more than one frame arrives simultaneously at the receiver interference occurs. When a frame arrives at the receiver, the receiver detects the frame if it has strength greater than the carrier sensing threshold (*CsThreshold*). The frame is passed to the MAC layer which receives the frame if it is above receiving threshold (*RxThreshold*). A frame stronger than *Rxthreshold* as shown in equation (4.2) is received correctly else it is tagged as corrupted by the MAC layer and discarded. Ns-2 has one threshold known as a collision threshold (*Cpthreshold*) which calculates the ratio of strongest frame signal to the signal strength of the sum of all other simultaneously arrived frames. If the ratio is larger than the *CpThreshold* as shown in equation (4.3), the frame is received correctly and other frames are ignored.

Let us assume that packet received from link "*l*" is successful during the time of packet transmission and "*i*" denote the remaining simultaneous active links.

$$G_l P_l \geq \text{RxThresh}, \qquad (4.2)$$

$$\frac{G_l P_l}{G_i P_i} \geq \text{CpThresh}, \qquad (4.3)$$

where G denotes the channel gain and P denotes received power. If only one frame is received by the receiver

$$\text{SINR} = 10\log\left(\frac{\text{Rx\_Power}}{\text{Noise}}\right), \qquad (4.4)$$

If the other frame arrives to the receiver when it is receiving one frame, SINR of this receiving frame is,

$$\mathrm{SINR} = 10\log\left(\frac{\mathrm{Rx\_Power}}{\mathrm{Noise} + \sum_{i=1}^{i-1} \mathrm{Rx\_Power}_i}\right), \qquad (4.5)$$

where $\mathrm{Rx\_Power}_i$ is the signal strength of other frames at the receiver.

B. Occupied bandwidth(OB)

Bandwidth is the measurement of bit-rate of available or consumed data communication resources expressed in bits per second. The estimation of occupied bandwidth delivers the approximate usage of the total bandwidth provided. Hence to perform handover to the preferred network, occupied bandwidth can be considered as an important parameter.

The bandwidth of the network can determine its information carrying capacity. There are many factors that can reduce the capacity of the networks. This capacity depends upon the total number, status and position of MN. RF channel may also vary in capacity, depending on range, environmental conditions, mobility, shadowing, etc. In this work, we modify the IEEE 802.11 MAC layer in order to estimate the occupied bandwidth under noisy environment. Furthermore, occupied bandwidth along with SINR is used to make the handover decision.

C. Heterogeneous network model used for vertical handover

Here basic network model, definitions and assumptions are explained. Fig. 4.1 shows a heterogeneous network where a vertical handover decision is taken in the selection of appropriate network during movement of mobile nodes. As shown in the Fig. 4.1, the network is composed of two different wireless technologies: Wireless local area network (IEEE 802.11) and cellular universal mobile telecommunications system (UMTS). When a mobile node (MN) moves through these heterogeneous networks, the node uses IEEE 802.21 for seamless handover.

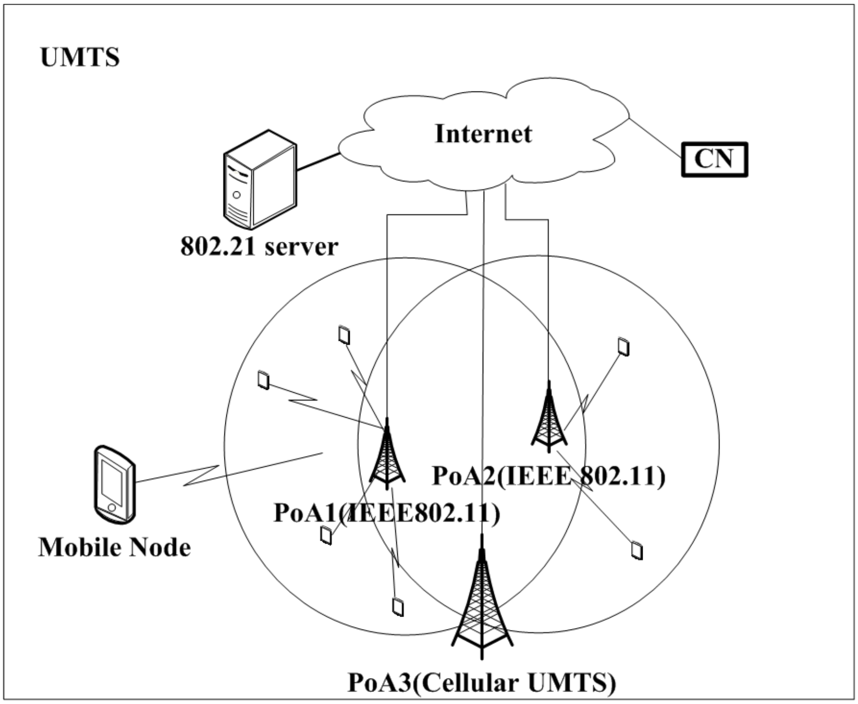

Figure 4.1: Network model for heterogeneous network

In the presented network model, UMTS is always available even when there are no other networks. UMTS provides a large range and consistent bandwidth to users although is not a cost effective solution.

On the other hand, Wi-Fi has shorter range with high bandwidth and is a cost effective solution for the user. Therefore, the selection of Wi-Fi has a greater advantage than UMTS when both of them are available. MN is equipped with multiple network interfaces. Function of IEEE 802.21 has been adapted to both

MN as well as access points and plays the vital role for the handoff procedure. Any stationary or moving node that communicates with MN is a corresponding node (CN). All domains presented in the Fig. 4.1are interconnected to each other through a common IP core network. Points of attachments (POA) are the access point that includes MN as the other endpoint. An effective and efficient handover decision is necessary for the MN to select the best network.

D. SINR aware handover decision

The proposed SINR aware handover decision (SAHD) comprises the acquisition of current SINR and its comparison with other networks. The SINR is obtained through MAC and physical layers and used to select a better network for a vertical handover. During handover, IEEE 802.21 is invoked for seamless handover of MN. Fig. 4.2 demonstrates the handover decision procedure of a SAHD. When a multi-interface enabled MN detects a new network, SINR reflecting noise and interference at MN is estimated. A network with greater SINR is preferred for handover among the available networks.

Fig. 4.3 shows media independent handover (MIH) message for SAHD using IEEE 802.21. The primary step involves querying the MIHF located on the MN itself. With this procedure, MN gets the required information about the quality of network for switching to the candidate network.

Successful reception of beacon causes a link-detected trigger on the MN. The information regarding the potential candidate is discovered at this moment. The serving network starts a query asking the available resource. Finally, the reply of the query is sent back to MN. Now, MN has sufficient link status information about the networks. Selection of best network is done based on SINR sent for the valuable vertical handover. In this proposed SAHD, SINR can be effective for handover even when RSS of a link is high but has traffic congestion or big interferences with other channels.

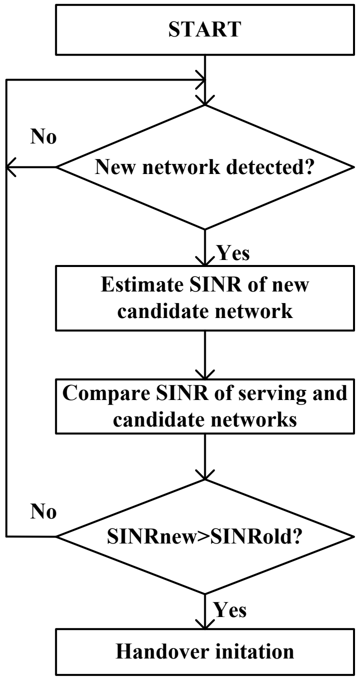

Figure 4.2: Handover decision procedure

Hence network quality (NQ) is evaluated for the target networks. NQis used to represent the quality of network with the help of parameters like SINR and occupied bandwidth. The network with the highest NQ is most desirable for MN. The normalized equation of NQ for SAHD is introduced as

$$NQ = SINR_{normalized}, \qquad (4.6)$$

Hence from this algorithm, we can resourcefully and commendably adapt the network conditions and can obtain improved results. The other positive aspect of the presented algorithm is it can perform handover when it's necessary under interference and noisy conditions even though signal strength in a current network is greater than the threshold.

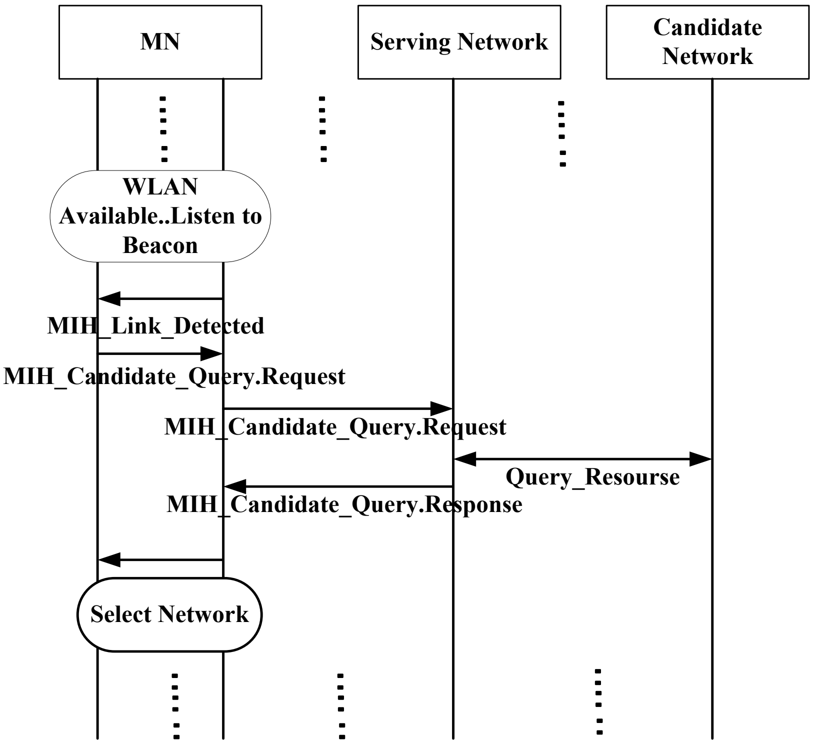

Figure 4.3: Message sequence diagram for handover decision

E. Enhanced SINR aware handover decision (E-SAHD)

The real network scenario has lots of networks overlapping with each other like Wi-Fi WiMAX LTE UMTS etc. From the previous section, SINR is considered as a good parameter for the link quality in handover decision procedure. Moreover,the primary objective was to take a handover decision in such a way that we will have best and effective results in all types of scenario.

In a network, if the data traffic is high, the network slows down or suffers packet loss. It vitiates quality of service (QoS) and lead to increase latency and packet loss. Although SINR is a good parameter and shows fine performance, it can still be improved adopting along with occupied bandwidth. With the use of these two parameters (i.e. SINR+ occupied bandwidth) named as an E-SAHD, more precise and accurate handover decision can be obtained resulting higher throughput, lower handover latency and number of handovers.

Hence NQ is evaluated for the target networks with the help of SINR and occupied bandwidth. The normalized equation of NQ for E-SAHD is

$$\mathrm{NQ} = \mathrm{SINR}_{\mathrm{normalized}} + (1 - \mathrm{occupied\_bandwidth}_{\mathrm{normalized}}), \qquad (4.7)$$

where $\mathrm{SINR}_{\mathrm{normalized}}$ denotes the value of SINR after the normalization between 0 to 1. Similarly $\mathrm{occupied\_bandwidth}_{\mathrm{normalized}}$ is the value obtained after the normalization. Normalization refers to the process of organizing the values or database to minimize redundancy and dependency.Normalization usually involves dividing large values into smaller (and less redundant) values and defining relationships between them.

In order to allow different circumstances, there is an apparent necessity to weight each factor for the vertical handover decision. Therefore different weight is introduced as follows:

$$\mathrm{NQ} = \alpha \times \mathrm{SINR}_{\mathrm{normalized}} + \beta \times (1 - \mathrm{occupied\_bandwidth}_{\mathrm{normalized}}), \quad (4.8)$$

where α and β are weights for each network parameter. The values of these weights range from

$$0 \geq \alpha, \beta \leq 1, \qquad (4.9)$$

And the total of the weight must be equal to 1

$$\alpha + \beta = 1, \qquad (4.10)$$

In order to evaluate the NQ, a value of the weighting factor is varied as follows:

Table 4.1: Weight value

α	β
0.25	0.75
0.5	0.5
0.75	0.25

With new parameter i.e. occupied bandwidth, quality of network can be measured precisely. Merging this parameter to SINR will increase the confidence level to select the best network. Observation shows that networks with low traffic are not selected with SINR alone due to the low SINR. Similarly, SINR of some network will be high although it is highly populated. Hence to obtain a precise handover decision to select the best network, ESAHD seems to be effective algorithm. Results are presented in the next chapter to verify the analysis presented.

F. Observations

In a network, with a few MN which are placed far apart from the access point, handover is not performed using SAHD because of low NQ. In this case the nodes are far apart; power is low and gives low SINR. However, handover should be performed in this type of network. Hence we require E-SAHD to get the accurate decision. NQ in this algorithm is calculated with the help of occupied bandwidth along with SINR which gives the higher value.

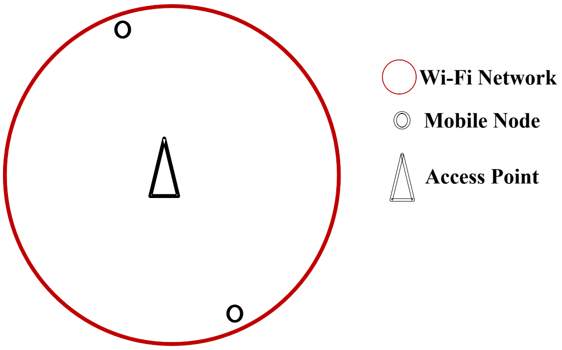

Figure 4.4: Observation 1

A network with a high density of MN is not selected during the handover procedure. SAHD and E-SAHD both provides low NQ because of interference.

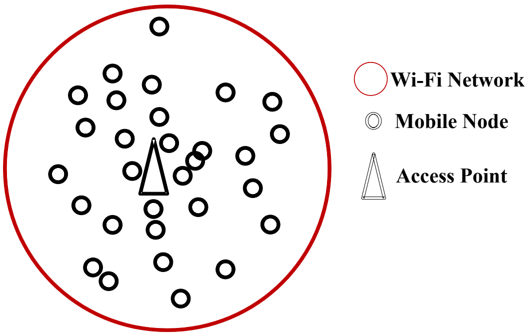

Figure 4.5: Observation 2

In a network with few MN which are placed close to the access point, handover is performed using SAHD because of high NQ. In this case the nodes are closer to the access point, power is high and gives higher SINR. However, SINR could be low in the network with closer nodes with high data rate. In this case, NQ value might be lower with SAHD. Hence E-SAHD always gives higher NQ value and provides the right decision.

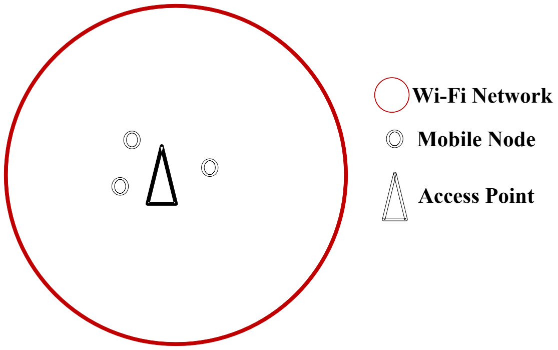

Figure 4.6: Observation 3

V. Performance Evaluation and Results

This section demonstrates the detail performance evaluation of handover decision based on E-SAHD, SAHD with IEEE 802.21. The proposed E-SAHD is compared with SAHD and simple IEEE 802.21 based vertical handover. The simulation initiates with the reception of IEEE 802.11 beacon. Link detected indication event is generated after the beacon reception. IEEE 802.11 defines primitives within the link layer that indicate the detection of a new link. In E-SAHD, SINR and occupied bandwidth are chosen as a handover decision parameter in order to select a suitable network. The performance in terms of throughput, number of handovers, network quality, and handover latency has been tested for the usefulness and versification in all methods.

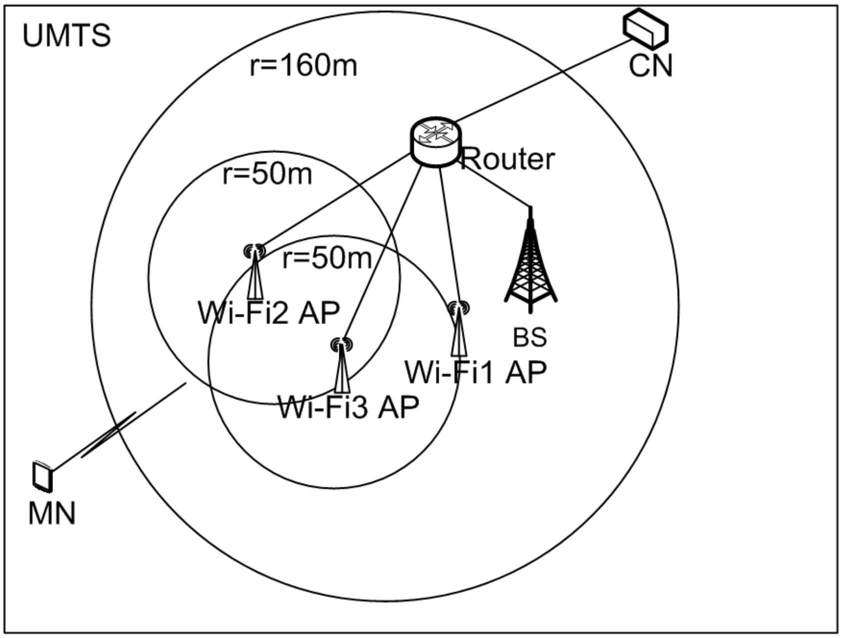

Figure 5.1: Simulation network topology

Table 5.1: Condition for network simulation

Parameters	Values
Simulation Area	1000m x 1000m
Traffic Source	CBR
Packet Size	500 bytes
Packet Interval	0.01s
Routing Protocol	DSDV
Simulation Time	1000s
Node Speed	5m/s,10m/s,15m/s, and 20m/s
Network Type	UMTS and 802.11
Network Coverage	160m and 50m

Fig. 5.1 shows the network topology in NS-2, which comprises 3 Wi-Fi networks with different ranges and UMTS as backend. The RF signal coverage of simulation area is set to 1000m x 1000m, where UMTS is available everywhere. CN generates and transmits constant bit rate (CBR) traffic to the MN. Furthermore, IEEE 802.21 is built on MN and base stations. A modification on MAC and PHY layer of IEEE 802.11 is done in NS-2 to enable SINR and occupied bandwidth. Also modifications on IEEE 802.21 are carried out in order to adopt the decision procedure. Node locations and moving direction are considered to be random in the simulation. The simulation conditions such as data rate, coverage, simulation time, and node speed are listed in Table 5.1. In the absence of Wi-Fi links, a new connection is directly handed to UMTS.

Table 5.2: Different number of nodes allocated to Wi-Fi's for the network simulation

Network	Case 1	Case 2	Case 3
Network 1	15 nodes	20 nodes	5 nodes
Network 2	5 nodes	15 nodes	20 nodes
Network 3	20 nodes	5 nodes	15 nodes

Three simulations are conducted in different environments with varying speed and number of MNsas listed in Table 5.2. The main purpose of performing the simulation in a different environment is to test the proposed E-SAHD in different types of the network scenarios. This gives the detail and precise analysis of the SINR and occupied bandwidth operation in vertical handover.

A. Quality of network

The performance of E-SAHD depends on proper selection of networks. From the observation presented in the previous chapter, it is seen that SAHD might lack in determining the real condition of the network. However, with E-SAHD, we can get better NQ. This is because occupied bandwidth will mirror the available capacity of target network in term of network load than SINR alone in SAHD. Nodes are placed in three different locations: random, far, and close to verify the performance of E-SAHD. ”Random” refers to the placement of node in random order. “Far” depicts the placement of nodes distant from access points and “Close” refers to the placement of nodes close to the access point. Also, we analyze NQ with different weighting factor (α and β) for ESAHD and SAHD respectively. The weighting factor is given less, equal and more preference and tested as shown in table 4.1. From the experiment, it is clear that NQ of the network with low traffic is constantly high in E-SAHD compared to SAHD. Similarly NQ of the network with high traffic is comparatively low in ESAHD then in SAHD.The results are clearly shown in the Fig. : 5.2, 5.3, and 5.4.

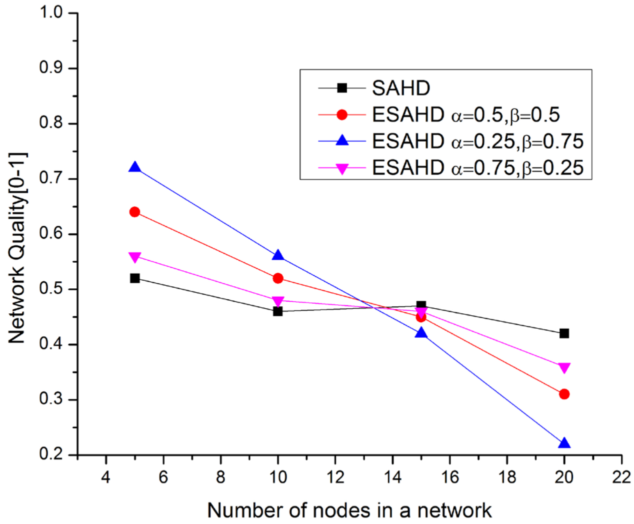

Figure 5.2: Network quality: Node position-Random

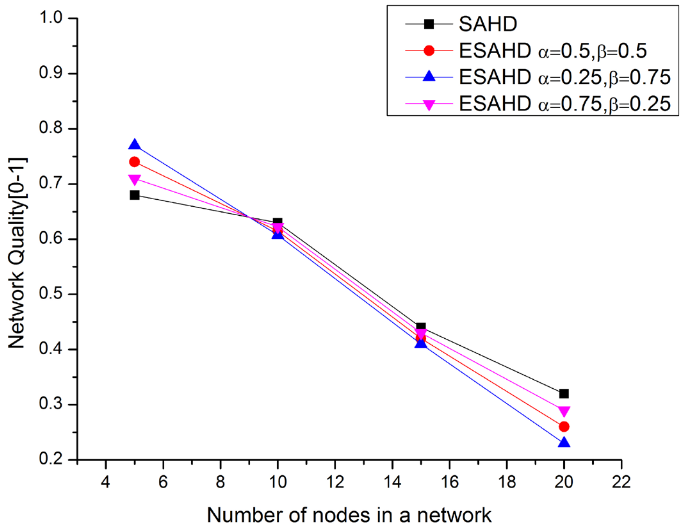

Figure 5.3: Network quality: Node position-Close

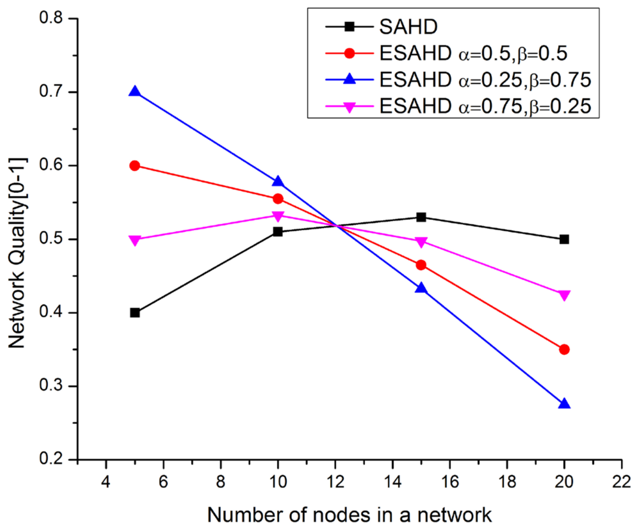

Figure 5.4: Network quality: Node position-Far

B. Throughput

This section demonstrates average throughput observed at the different environments and speeds. In all environments, the number of simulations carried out is 4. Simulations are done with 2 different MN speed, 5m/s and 10 m/s. The results show that E-SAHD and SAHD in all three cases outperforms the IEEE 802.21 with respect to throughput as shown in Fig. 5.5, 5.6, and 5.7. This is because the MN selects the best network and stays on the network for the longer time. Since the probability of selection of best network is high, E-SAHD has the better result than SAHD. Table 5.3 shows the percentage of increased throughput when E-SAHD and SAHD is compared to IEEE 802.21 alone.

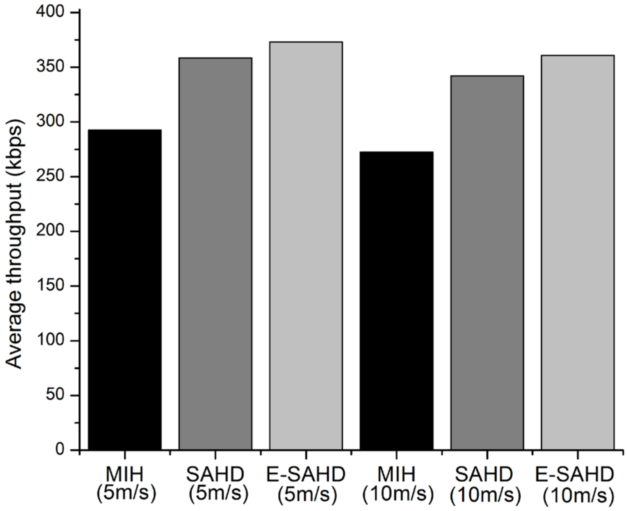

Figure 5.5: Average throughput observed: case 1

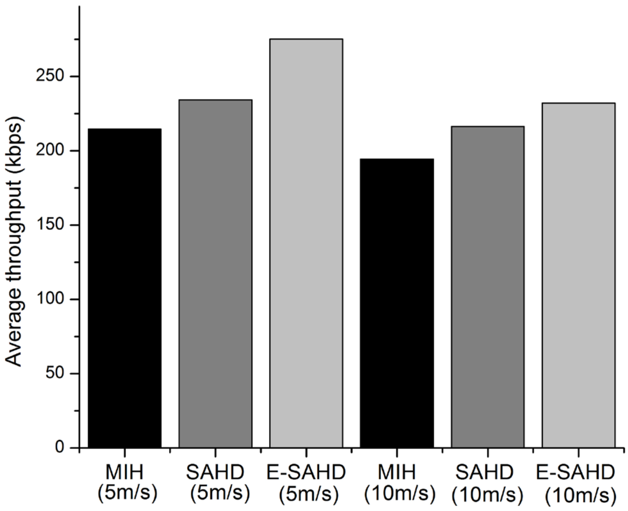

Figure 5.6: Average throughput observed: case 2

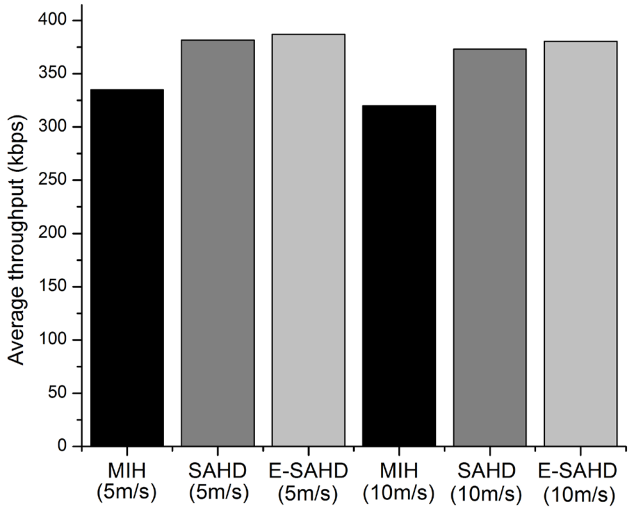

Figure 5.7: Average throughput observed: case 3

Table 5.3: Percentage of increased throughput

MN Speed	SAHD Case 1	E-SAHD Case 1	SAHD Case 2	E-SAHD Case 2	SAHD Case 3	E-SAHD Case 3
5m/s	17%	21%	5%	15%	15%	16%
10m/s	15%	22%	6%	10%	13%	16%

SINR is increased when the MN approaches to the access point. SAHD selects the network having higher SINR for the target during the handover decision. Reversely, when the position of MN is far apart from access point, low SINR was observed. However, E-SAHD has the highest probability to make the correct decision since new parameter; occupied bandwidth was used with SINR that increases the average throughput.

The obtained throughput at different level of node speed is presented in Fig. 5.8, 5.9, and 5.10. Also, the throughput is reduced for MN with higher speed within the networks. This is because associations to the network are frequently lost and reestablishment of path after every re-association is carried out as the MN moves fast. Even in this high MN speed, E-SAHD and SAHD shows higher throughput by selecting the network which is in the lower interference environment. However, SAHD might not be able to select the best network as E-SAHD. Thus, it is certain that E-SAHD provides consistently maximum available throughput in a seamless manner to the end user selecting the network with higher QoS.

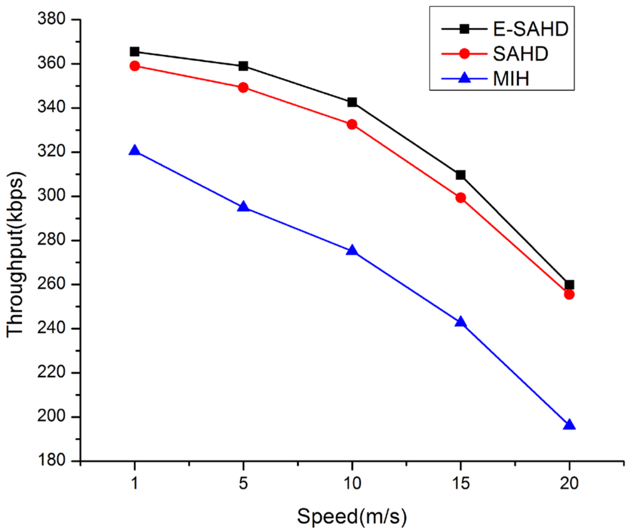

Figure 5.8: Throughput vs. Speed: Case 1

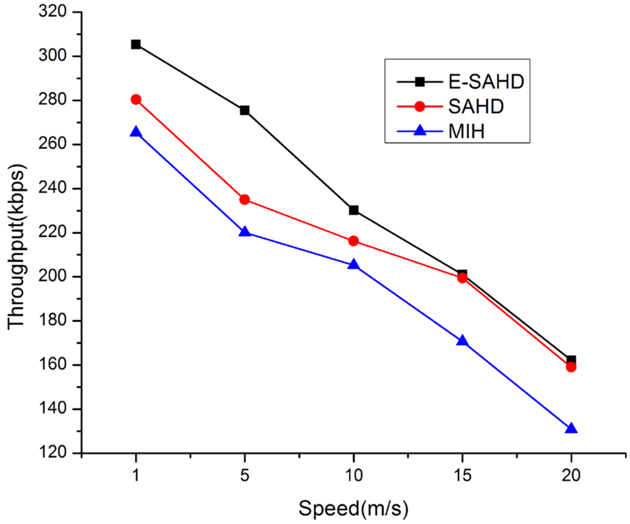

Figure 5.9: Throughput vs. Speed: Case 2

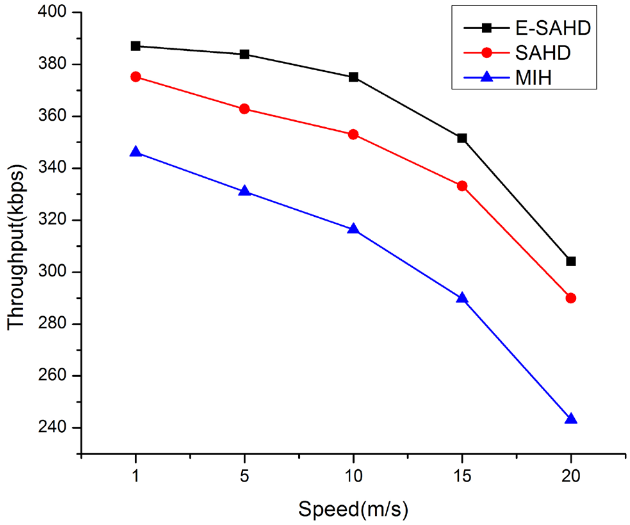

Figure 5.10: Throughput vs. Speed: Case 3

C. Number of handovers

Real network scenario contains many networks and reduction in the unnecessary handover will definitely improve the entire performance of the network. Fig 5.11 shows that unnecessary handovers are reduced in the proposed schemes i.e. E-SAHD and SAHD as compared to IEEE 802.21 alone. SAHD has 8%, 4% and 30% reduction in unnecessary handover observed in case 1, case 2, and case 3 respectively as shown in the Fig. 5.11. Similarly, E-SAHD has 30%, 12% and 60% reduction of unnecessary handovers respectively. Case 3 has higher performance because of the fact that a network with greater range 'Wi-Fi 1' has low traffic load and MN stays on the same network for longer time. Results show noteworthy improvements for both the case, E-SAHD and SAHD in the reduction of unnecessary handovers in all cases.

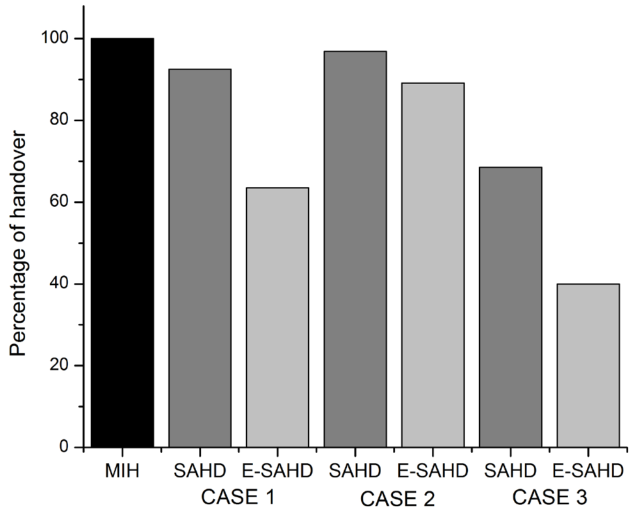

Figure 5.11: Number of handover

D. Latency

Handover latency is the fundamental service interrupted time on the wireless overlay networks. Handover latency is the measurement of total time spent during the period of handover in absence of packet transmission. During simulation, variation in handover latency is measured for different environment and the result is presented in Fig. 5.12. Total handover latency in E-SAHD and SAHD is significantly less than pure IEEE 802.21 because unnecessary association with different networks is reduced. From the simulation, reduction of latency approximately up to 32% in different cases is observed in SAHD while E-SAHD have reduced up to 50% as presented in Fig. 5.12. This verifies that E-SAHD and SAHD in all the cases performs better than IEEE 802.21 alone.

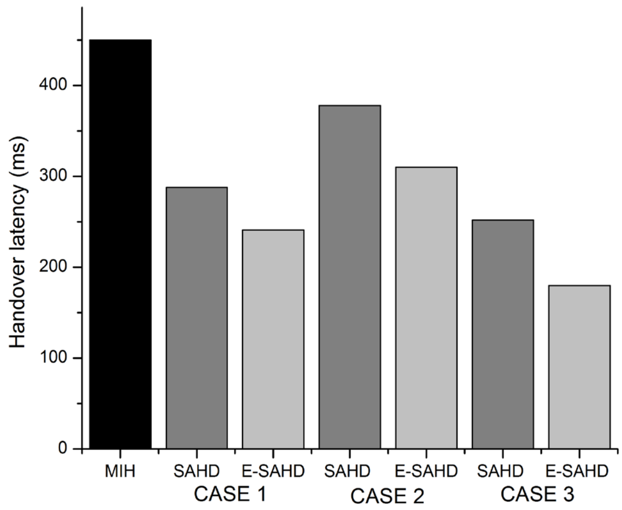

Figure 5.12: Handover latency

VI. Conclusion

Vertical handover is one of the important radio resource management functions in a heterogeneous network. The primary goal of a vertical handover is to allow users to access services, while they keep moving across networks. The enhanced performance and availability of various technologies like Wi-Fi, WiMAX, and UMTS have motivated network users towards increased utilization.Growing consumer demands seamless transition from one network to another with acceptable quality of service.

The focus of the research project presented in this thesis is to develop a vertical handover decision mechanism that finds a better target network by evaluating a metric,SINR of each network. The proposed scheme provides high throughput and low handover latency. It minimizes communication interruptions due to handovers whilst maximizing the utilization of network resources in a cost effective way. The simulated result showed that SAHD method alone is not able to present the precise information of the target network under noisy environment. Thus, a new parameter called occupied bandwidth is combined with SINR and is termed as E- SAHD. The efficiency and preciseness of E-SAHD algorithm tested under different environments are analyzed. To adopt seamless handover, IEEE 802.21 is used on both the mobile as well as base station during the simulation.

Simulation results have shown that E-SAHD successfully increases the throughput and decreases unwanted handovers and latency. The major reason behind the success of E-SAHD is the use of SINR and occupied bandwidth ashandover decision metrics that help in providing more accurate network condition and ensuring right decision during handover.

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