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Performance Enhancement of Heterogeneous Cellular Networks Using Vertical Handover

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***Abstract*—** In seamless and fast mobility, smooth handover is one of the major challenges in small cell heterogeneous cellular networks. This paper focuses on the phenomenon of vertical handover for wireless heterogeneous networks. This class of networks can be grounded on the parameter values such as bandwidth availability, received signal strength, call request/served per unit time (mean), power dissipation, consumption of power, duration of mobile station presence, network security, cost of the network and velocity of the mobile station. The proposed system, in this paper, is characterized on the basis of four network parameters which are scrutinized as per a pre-defined criterion. Thereafter, vertical handover occurs at the most suitable among the available four networks. In order to achieve the objective, various parameters are applied for the vertical handover decision and implementation. Furthermore, the final decision is taken on the basis of individual network's call blocking probability considering the aforesaid parameters.

***Keywords*—** Handover, Cellular Networks, HetNets, 3G, 4G, GSM, WLAN, QoS, RSS.

I. Introduction

Today's technological world is going towards swift development and express of evolution in wireless networks. In these advancements, trial and errors have been a common practice, resultantly; researchers have pinpointed various challenges in assembling different networks. For instance, the fourth generation (4G) of cellular networks integrate a huge amount of heterogeneous cellular networks (HetNets) [1]. This serves as a step towards universal seamless access; however, this does not mean that the issues encountered in the field of seamless mobility have all been met [2].

A quick scrutiny of the literature available in the domain of seamless mobility reveals that among many other areas to refine, one significant sub-domain is that of efficient handovers. Talking more specifically, one can tell that there is a need of efficient schemes to enable vertical handover among different types of radio technologies such as cellular, wireless area network (WAN), wide local area network (WLAN) [2],[3]. This handover bears emphasis because it acts as the decision-point for a mobile node in such HetNets. In the traditional cellular network like global system for mobile communication (GSM) authors compared different parameters in specific order using pre-defined threshold for handover decisions [3].

Furthermore, it encompasses multiple interfaces in order to select the best available link in all possible alternatives for mobile nodes connecting the network in real time. A survey with a scheme for the IEEE 802.11 protocol which modifies the distributed coordination function (DCF) admittance technique in the variance phase carry numerous levels of priorities in such a way that the user mobility is encouraged in WLANs [4],[5]. Different types of algorithms that are purely based on network technique (classical) and many other concentrates on the idea of Markov process outcome [6].

When it comes to maintaining quality of service (QoS) based connections between networks, there is a variety of parameters that need to be considered; for example, pre-defined QoS standards and minimum call dropping ratios. It is customary to mention here that the call dropping ratios are usually calculated after the undesired handover during which the call-in process may be affected and the chances of dropping increases abruptly. This undesired handover directly affects the scenario of ongoing connection of the transmission. One of the most important terms to be considered in handover is the enhancement of QoS. For instance, applications such as unicast and multicast video streaming and web browsing come with strict QoS requirements. In order to ensure quality, vertical handover concentrates on minimizing the ping-pong effect. This minimization helps in reduction of interruption in processing calls and provides an increase in throughput during the handover [7],[8].

In the light of the above-mentioned facts, one can state that the main challenge in upcoming networks would be quick handover in IP-based networks. Researchers have also anticipated this quick handover as a high transmission, packet loss small handover [9]. In the initial discovery stage, the connections of mobile nodes made up with various interfaces have to go through a decision-making. This decision-making takes into account the network's suitability for usage and the presence of services in network. In the second stage namely the system discovery, the mobile node seeks the network to which it may connect. This pursuit followed by the network selection depends upon many factors like jitter, access cost, available bandwidth, transmit power, delay, the user's preferences and current updated status of the mobile device. In the third stage, the need for re-routing from the network in use to the new one occurs. This requires the node to deal with authorization as well as authentication; it transfers the user information accordingly. A study of the recent literature shows that different types of vertical handover decisions scheme have been worked out. The networks in 4G HetNets are managed by distinct operators or in other words the service providers. The distribution of sustained services for mobile nodes is a principal complication for the fixed grid wavelet network (FGWN). This ensures the necessity to accord seamless handover while working in environment like this [10] - [13].

In this regard, the handover serves as the main practice for maintaining ongoing call connections. It also aids in providing the best QoS packages and fulfilling the requirement for more stable services. However, the traditional handover of GSM based networks lacks when it comes to keeping trade-off between smooth handover and mobility. Fortunately, this glitch has been dealt with in 4G by introducing the idea of vertical handover based on received signal strength (RSS) values and services like class mapping [14]. A comparison between vertical and horizontal handovers reveals that vertical handover is likely to happen between radio access technologies (RATs) also called inter-system handover while horizontal handover is an intra-system means it occurs within the same network technology.

Apart from improved handover, the other notable advancements in 4G networks are that of data rate services (high) and global roaming (nonpareil) [15]. Nevertheless, in the current scenario, vertical handover decision is dependent upon the available bandwidth, access network, the available internet service provider (ISP) imposed to the specific network connection, power usage needs, and the battery status of concerned mobile device. The mechanism for vertical handover seems to be recommended for the users of mobile devices gaining a low-level control overhead. It would also be able to control connections acting as sources of packet loss and minimize transfers in times of delay as well. Vertical handover can be illustrated by categorizing it into three discrete steps; 1) handoff decision, 2) system discovery and 3) handoff execution [16].

The rest of the paper is organized as follows. Section II describes our system model. This is followed by Section III that highlights the background knowledge related to the topic. Furthermore, Section IV presents the proposed algorithm for our work. Section 5 shows the discussion of our experimental results. Finally, Section VI concludes the paper.

II. SYSTEM MODEL

In this work, we have taken four networks into consideration. One of them is the global system for mobile communication (GSM); while others are worldwide interoperability for microwave access (WiMAX), wireless local area network (WLAN) and code division multiple access as implemented in 3G (WCDMA/3G). All of these networks are different from one another and we look at various parameters of all these networks. After examining different parameters of these networks, a case study is presented that focuses on a scenario where disturbance is caused due to low level of signal or no network availability. Because of this, the proposed system goes through the aforementioned three steps of vertical handover to the desired network according to the proposed model.

A. Global System for Mobile Communication

GSM, abbreviated as global system for mobile communication is a communication system that works on the phenomenon of circuit switching shown in Figure 1. at the operating frequency of 900 MHz or 1800 MHz GSM, although obsolete now, is a standard that is elaborated by ETSI (european telecommunications standards institute) and is used to mark out second generation 2G protocols that are held by mobile phones. It is used for transferring of voice data in communication systems that is based on wireless technology.

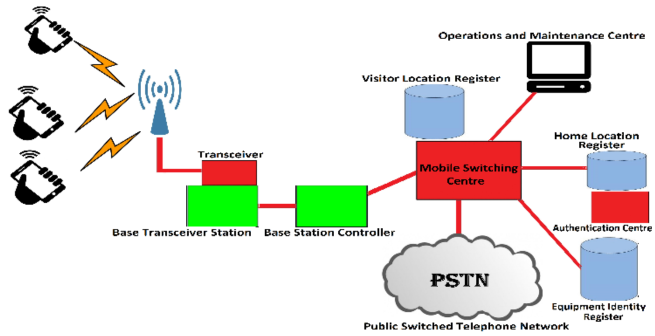

Figure 1. Architecture of GSM Based Cellular Network

The structure of this network is designed in terms of different sections named as base station subsystem (explains the idea of base stations and the controllers used in it), network and switching subsystem (the part identical to fixed network – also known as core network), general packet radio service GPRS core network (the non-obligatory part that allows packet based internet connections) and operational support system (for network preservation).

B. Worldwide Interoperability for Microwave Access

Worldwide interoperability for microwave access (WiMAX) is used for long-range wireless networks. WiMAX is linked with wireless metropolitan access network and is adapted at 802.16 standard of institute of electrical and electronics engineering (IEEE). The specialty of WiMAX is its high speed – long-range data network as compared to Wi-Fi (wireless fidelity). It has the ability to hold up both the broadband (mobile) and node (fixed) access. While focusing on mobile broadband, different sections combine to make WiMAX. These are mobile station (user's device), connectivity service network (used for connection of IP to user's device) and access service network (contains base stations, gateways and works for radio access).

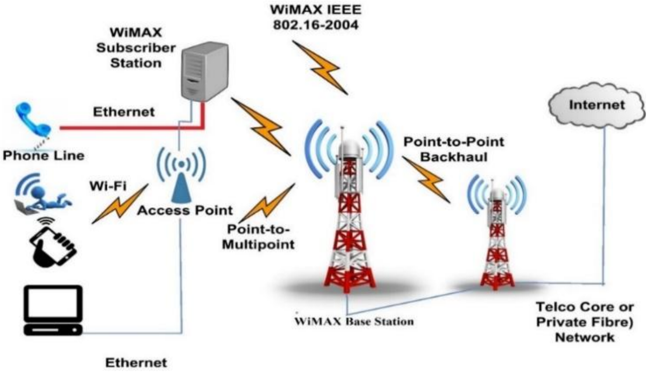

Figure 2. Illustration of WiMAX Connecting Both Fixed and Mobile Nodes

C. Wireless Local Area Network

Commonly known as wireless fidelity (Wi-Fi) is a type of wireless network that usually works for short ranges as depicted in Fig.3. IEEE has given it a standard of 802.11 and its basic idea is to provide connection to a number of daily use devices like laptops, mobiles, printers etc. The standard 802.11 establishes connection in two modes of operation. Ad hoc mode (support of access point is not required and communication of devices is direct) and Infrastructure mode (access point is required for communication of Wi-Fi nodes).

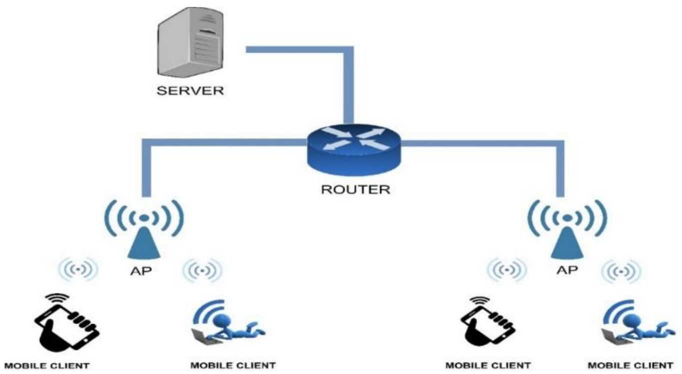

Figure 3. A Small Infrastructure Mode WLAN

D. Wide Band Code Division Multiple Access

Wide band code division multiple access – 3G network standard is a third-generation network (WCDMA/3G) as shown in Figure 4. and serves as an updated version to the typical 2G/CDMA network. It comes with two versions called as UMTS (universal mobile telecommunications systems) and HSPA (high speed packet access) and both use WCDMA as the prime multiple access technique. WCDMA is responsible to manage the traditional voice and text services as well as high speed multimedia messaging service (MMS) /data services. 3G uses different air interfaces; however, its standards are similar as 2G/ GSM and enhanced data for GSM evolution (EDGE). It has the ability to switch between GSM and EDGE. The transition of network from GSM to 3G does not require large investments due to the introduction of general packet radio services (GPRS) and EDGE.

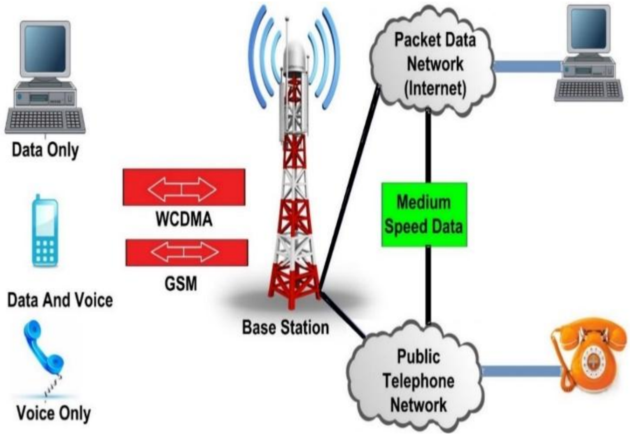

Figure 4. Illustration of the Entities Inside a 3G Network

III. HANDOVER MANAGEMENT STRATEGY

To maintain uninterrupted connection for active mobile node, the connection has to smoothly move from one access network to another. Referring to handover management strategy shown in Figure 5. the work at hand considers a systematic handover process that consists of a variety of steps:

A. Stage 1:

Initiative: is setting up the threshold values, which helps to select the best available network in the process of handover.

Informative: is the collection of information data in order to initiate handover. This term can also be defined as system discovery and can be related to initiative stage.

B. Stage 2:

Conclusion: is the stage where the decision and execution of handover process takes place. Moreover, the requirements and needs for performing the handover are indicated and the choice of best available network is taken into account.

Evaluation via Dynamic Call Blocking Probability: is the stage where the blocking probabilities of the available networks are observed, because performing handover would be based on the call blocking probability of the networks under consideration.

C. Stage 3:

Handover Operation: is the stage where the process of handover actually takes place according to the requirements of the system and selects the best available network that is based on the handover algorithm.

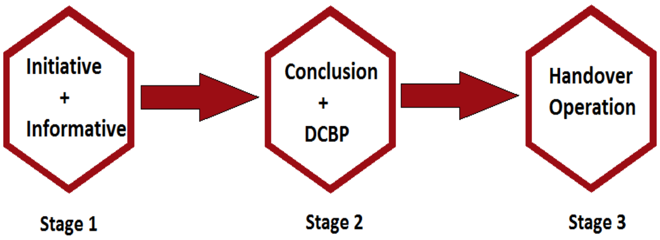

Figure 5. Handover Management Strategy

IV. Mathematical Model

Commencing with Stage 1 – handover informative, we collected the basic information given below, required to handle vertical handover. Furthermore, we pre-defined the number of total evaluation networks (NEN) presently available to be 4.

The available bandwidth of currently connected network ID 1 is Bx = 900 MHz. Furthermore, received signal strength (RSS) of currently connected network is set as RSS = -55dB.

RSS value can be obtained by values of effective isotropic radiated power (EIRP) and path loss (ήo) [16] as follows:

RSS = EIRP– ήo, (1)

where EIRP can be mathematically represented as:

EIRP = Ptrans+Ga, (2)

where Ptrans shows antenna power and Ga is antenna gain. Similarly, in order to model the path-loss [17] we used the following mathematical expression

ήo =34.4 (dB)+20log [f(MHz) + log [d (km)], (3)

where 34.4 is proportionality constant, f is frequency of mobile node and d is distance between mobile node and base station (BS).

The estimated time for which a mobile node stay in the network coverage is 10ms. Battery power of mobile node currently connects with network 50 Wh. The mean number of request arrivals per unit time is, λ=10. where λ is the number of call per unit time.

Furthermore, average number of calls serving in certain time frame are shows as =3.

Using values of the above-mentioned parameters, we calculate weightages for each of the networks considered in our proposed system. For this, power dissipation in network is assumed as 20 Wh.

The process was repeated for the second, third and fourth networks with respective network IDs 2, 3 and 4. This can be seen in Table I given below. In the Stage II respectively i.e. handover decision, we compared these parameters values with the pre-defined threshold values. It is customary to mention here that the threshold values were those that defined the handover decision and also the best network for handover. If any network had values greater than these pre-defined thresholds, the mobile node would jump to that network and continue communication with good quality.

The value of bandwidth threshold, Bxi, is 1800 MHz. Similarly, the pre-defined threshold for RSS is set as - 65 dBm.

It is noteworthy here that the RSS mentioned here is the signal strength measured at receiver side and its values is always negative on the logarithmic scale. Table II gives the values we considered during the work.

TABLE I. NETWORK PARAMETER VALUES

S No:	Parameter	GSM Network ID 1	WLAN Network ID 2	WiMAX Network ID 3	3G Network ID 4
1	Available Bandwidth (Bx)	900 Mhz	2400 Mhz	5000 Mhz	2100 Mhz
2	Received signal level (RSS)	-55 dBm	-70 dBm	-60 dBm	-65 dBm
3	Estimated Time for MS (TE)	10 ms	15 ms	10 ms	10 ms
4	Power Dissipation in Network (Pj)	20 Wh	30 Wh	40 Wh	40 Wh
5	Lambda (λ)	10	5	10	10
6	Call served per unit time (mu)	3	2	4	4
7	Battery Power of MS (P)	50 Wh	50 Wh	50 Wh	50 Wh
8	Velocity of MS (V)	2 m/s	2 m/s	5 m/s	3 m/s

TABLE II. SHEET FOR RANGE RSS

RSS Value in dBm	**Scale**
Up to -65 dBm	Excellent
-75 to -95	Normal
-65 to -75	Good
<-95	Worst

Thresholds for estimated time mobile node stays in the network coverage and transmit power are given by the following set of values:

TEi=5ms

10 Wh

TABLE III. THRESHOLD PARAMETER VALUES

S No.	Parameter	Threshold
01.	Current Available Bandwidth (Bxi)	1800 MHz
02.	Received Signal level (RSSi)	-65 dBm
03.	Estimated Time MS will be in present network (TEi)	5ms
04.	Power Dissipation in Network(Pji)	50 Wh
05.	Battery Power Of MS (Pi)	10 Wh
06.	Velocity Of Mobile Station (Vi)	3 m/s

Once the thresholds were defined, we evaluate the initial step that is basically decision algorithm to look for the worthy enough network in the other present networks with values more than threshold. For this, we considered the following relation:

$$\alpha=\tau-\mu, \quad (4)$$

where *'τ'* is available network value and *'μ'* is the threshold value. Threshold velocity (V) of the mobile station is 3.

$$\Phi=[Bx\text{-}Bxi\ (\alpha)]\ [RSS\text{-}RSSi\ (\alpha)]\ [TE\text{-}TEi\ (\alpha)]\ [V\text{-}Vi\ (\alpha)]\ [P\text{-}Pi\ (\alpha)]\ [Pj\text{-}Pji\ (\alpha)], \quad (5)$$

The threshold of Phi Φ is network value - threshold value

If is equal 1 it means we have the network to be consider for operation of vertical handover either value comes 0 it means no other network having the value greater than the predefine threshold and should not be consider for operation. Thus, the mobile node will remain connect in the same network.

For Φ =0 is assumed that no network was available for handover at the moment. Greater will be the value of Φ, the greater was the probability of finding a good QoS network using dynamic call blocking probability (DCBP) based vertical handover and is given as

$$i = \frac{\lambda}{\odot} \quad (6)$$

$$DCBP=\frac{i^B}{B!} \quad (7)$$

V. SIMULATION RESULTS

In Fig. 6, vertical handover decision function graph is shown, as we can see from the Figure 6., the point is on Network with ID 3 means vertical handover was successfully completed and newly selected network is 4G. This has been implemented based on parameters values according to DCBP which clearly identify the network with good parameters. From Figure 6., we can see EVHDF (extended vertical handoff function) which conclude the systematic algorithm for all the selected pool of network, this decision will be based on DCBP function.

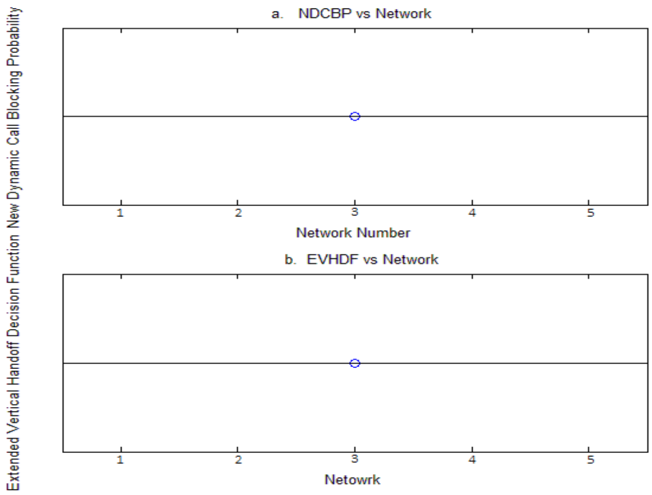

Figure 6. Handover decision

CONCUSLION

In this paper, we presented a comparative analysis of vertical handover that explain the notion of vertical handover and its implementation. The process of vertical handover mainly depends on available networks in surrounding environment in HetNets. In this paper, we considered four different networks that were available to the mobile nodes. These networks available to mobile node are used for the benefit of users through handover management. This was further enhanced by selecting pre-defined threshold as compared with standards for switching mobile nodes from connected network to the best available network. In the results, we observed parameters of four different networks and compared them with pre-defined threshold for an accurate analysis of the vertical handover process. The proposed model identifies the available network with best parameter values in a well-scrutinized manner.

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