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Survey and Analysis of Handoff Decision Strategies for Heterogeneous Mobile Wireless Networks

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Abstract— Mobility is the important feature of today's wireless network. Every user expects the best service network rather than best connected network. Due to the various heterogeneous wireless network availability, users get a choice of selecting the best service network, based on various preferences. Mobility is possible due to handoff process. The typical decision making before the handoff, to select the best connected network, plays a vital role, which decides service continuity. Entire service should be aware of the roaming events. In this paper we study various proposals of handoff decision strategies, based on various parameter listed below and the state of the art analytical analysis is presented with our notations.

Keywords— Mobility, Handoff, heterogeneous wireless networks.

I. INTRODUCTION

Seamless Mobility and roaming is essential features of today's wireless networking system. Mobility can be attained by handoff mechanism in wireless networks. Handoff or Handover is the process of maintaining user's active session when a mobile terminal changes its point of attachment [1]. Currently, mobile user have multiple interfaces and can access a wide range of applications provided by multiple wireless networks. So, the networks must be designed such that the related functions work independent of the network technology. The service provider's job is to deliver their network services in an efficient manner. Each application requires different QoS, so the network selection may vary accordingly. For achieving this goal and to select the best network, it is necessary to have a good decision making strategy for a specific application [2].

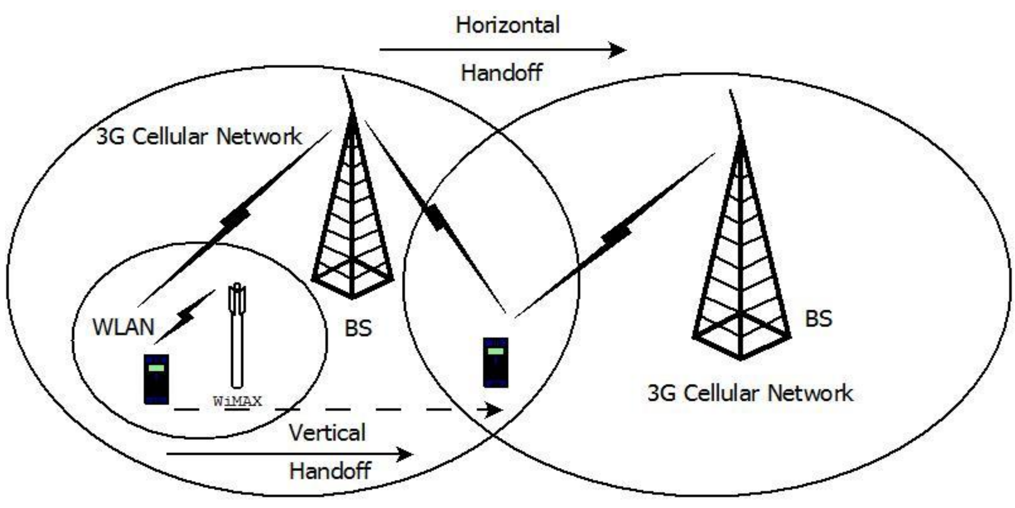

Fig. 1: Horizontal and Vertical Handoff

Depending on point of attachment the handoff can be either horizontal or vertical as expressed in Fig. 1. Horizontal handoff takes place between point of attachment supporting the same network technology e.g. between two neighbouring base stations [3],[4]. Vertical handoff takes place between points of attachment supporting different network technologies e.g. between an IEEE 802.11 access point and a cellular network base station [4].

The Vertical Handoff process involves three main phases [1],[2][3],[4] namely handoff initiation, handoff decision, and handoff execution as represented in Table I. Vertical handoff can be initiated for convenience rather than connectivity reasons. Here we focus on Handoff Decision Phase which decides whether to continue with current network or switch to another by calculating Network Selection Function.

TABLE I: Handoff Phases

Phases	Description
Handoff Initiation	Collects the information from different layers such as RSS, bandwidth, link speed, throughput, jitter, cost, power, and user preferences etc., based on this information handoff initiate in an appropriate time.
Handoff Decision	Decides whether the connection to be continue with current network or switch to another.
Handoff Execution	Includes the authentication and authorization, for transferring of user's context information.

The rest of the paper is organized as follows: Section II presents detailed survey of related work in this domain. Section III gives an insight brief idea about various strategies and handoff decision making parameters. Analytical and comparative analysis are presented in Section IV. Performance evaluation of Network Selection Function is presented in section V, followed by the conclusion in Section V.

II. RELATED WORK

In this section, we present a detailed study of various handoff decision strategies.

Sanjay Dhar Roy et al. [5] has proposed received signal strength (RSS) based strategy for vertical handoff (VHO) in heterogeneous networks. It computes RSS and bandwidth. Further this strategy has been modified considering averaging of RSS. For comparison purposes, the performance of the VHO algorithm also consider hysteresis and dwelltimer. Yutao Ling et al. [6] has analysed vertical handoff decision strategy which considers the performance of the overall system. This strategy uses parameters like network bandwidth, RSS and variation of RSS. The performance of this strategy has been analysed and it is observed that it greatly reduces the handoff call dropping probability than the current existing strategy.

Qing H. [7] have proposed Cost function based strategy with RSS, network bandwidth, monetary cost and user preference as the vertical handoff decision parameter. Network Selection Function with lower values is selected as target network. This evaluation carried out by considering network resources and decrease the probability of call blocking and call dropping.

K.Savitha et al. in [8] have explained the decision strategy for achieving the service continuity with minimum processing delay. Further, it is classified and compared in two schemes Centralized Vertical Handoff Decision (C-VHD) and Distributed Vertical Handoff Decision (D-VHD). In [9] and [10] authors objective is to provide seamless high data rate and multimedia services across different wireless networks. To achieve this they have proposed Simple Additive Weighting (SAW) based vertical handoff mechanism and reduce the processing delay used while calculating the network selection function.

Huiling Jia et al. [11] suggested technique, designed to estimate the handoff metrics in IEEE 802.11. It improves the existing adaptive strategy for stability period and overcomes the drawback of the previous strategy in terms of sensitivity of stability period and avoid unnecessary handoff.

Jun Peng et al. in [12] have proposed judge whether handoff should take place or not. A new technique comprehensive utility evaluation function used to evaluate networks quality and the weights of decision factors are calculated by analytic hierarchy process (AHP). Analysis is carried out in the form of simulation results and it shows that the proposed handoff decision strategy greatly avoid unnecessary handoff.

In [13], [14] authors proposed a handoff decision strategy according to the users communicating types. The results of simulations show that the strategy reduces the frequency of vertical handoff and enhances the performance of the whole network by considering non-real-time and real-time services. NRS-VDA is an intelligent vertical handoff decision algorithm that ensures the avoidance of unnecessary handoff and provides high throughput and low blocking probability.

Handoff decision making phase in heterogeneous wireless networks is the heart of the handoff process. Our main focus in this study is provide seamless handoff for uninterrupted service continuity. A vertical handoff decision may be influenced by numerous issues, these issues we precisely discuss and have logically divided into several strategies that encompasses different categories to design a handoff decision based on the performance criteria given in Table II.

III. VERTICAL HANDOFF DECISION BASIS

Here we discuss in detail about the handoff decision strategies, handoff parameters and performance evaluation parameters which are used while making decision and tabulated in Table III.

TABLE II: Handoff Related Issue

Issues	Evaluating Parameter
Handoff Strategies	RSS Based, Cost function Based, QoS Based, Processing Delay Based, Policy Based, Context-Aware Based
Performance Criteria	Latency, Monitory cost, Unnecessary handoff, Ping-Pong Effect, Throughput, Delay, Packet loss, No. of handoff etc.
Handoff Parameter	RSS, Cost, Bandwidth, Delay, User preference, speed etc.

A. Handoff decision Strategies

1) *RSS Based VHO Decision Strategy:* Vertical handoff is an inter technological switching method. This strategy computes the network selection function for new calls and for ongoing calls. Several parameter, such as bandwidth, received signal strength (RSS) and the variation of (RSS) are considered [5]. The network having largest value of function will be selected as the target network as given in Fig. 2.

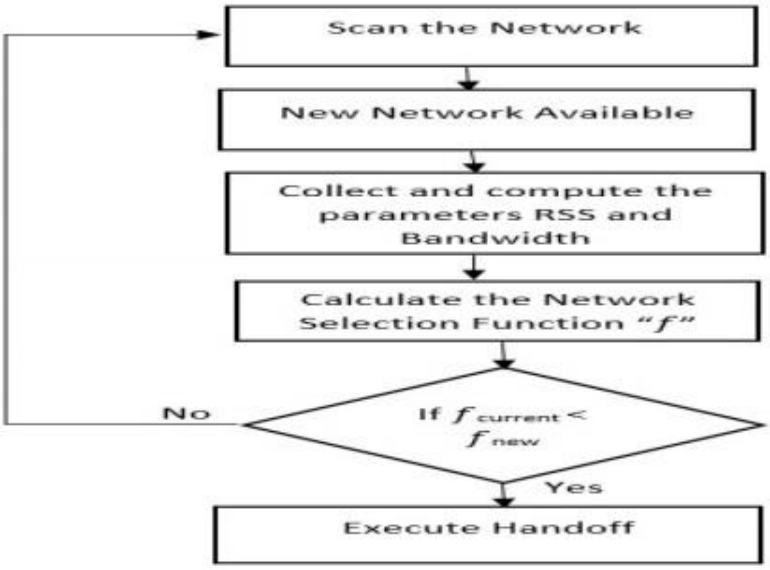

Fig. 2: Mechanism for Network Selection Function for RSS Based VHO

2) *Cost Function Based VHO Decision Strategy*: In this vertical handoff decision strategy not only considers the best network for the mobile nodes (MNs) to offer best performance, but also balances the resources for the attachment points. The Network Selection Function is used to determine which network to handoff as shown in Fig. 3. For that it further classifies the handoff decision criteria into positive metrics and negative metrics. Parameters considered are received signal strength, user preference, available network bandwidth, monetary cost [7].

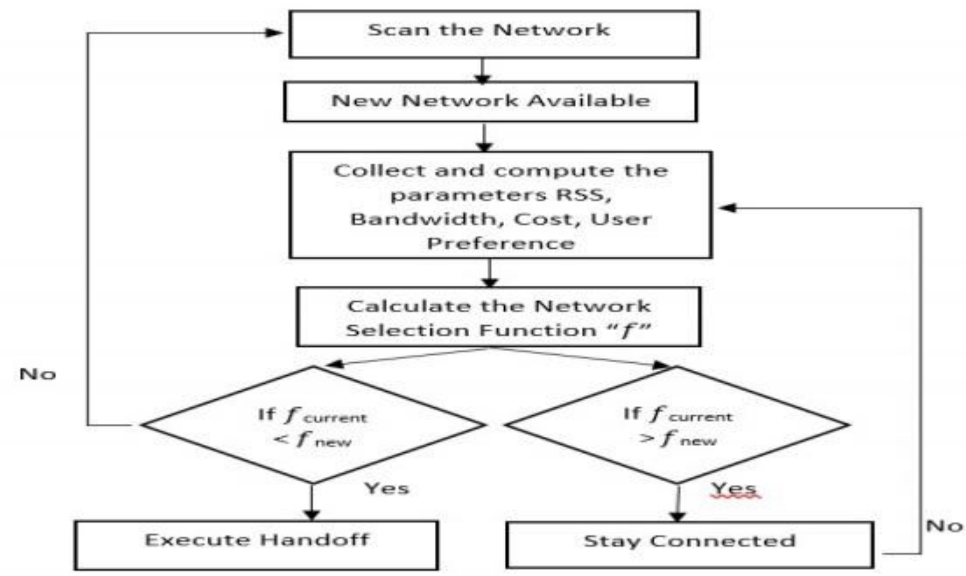

Fig. 3: Mechanism of Network Selection for Cost Function Based VHO

3) *Processing Delay Based VHO Decision Strategy:* This strategy compares two vertical handoff decision schemes C-VHD and D-VHD [8],[9] and [10], which uses Simple Additive Weighting (SAW) method and the Multiple Attribute Decision making (MADM) method, for normalizing the parameters. Parameters considered are packet dropping rate, bandwidth, delay and energy of the node. The best network is selected using a network selection function (NSF) and goes through phases Handoff Initiation, Handoff decision, Handoff execution as represented in flow chart Fig. 4.

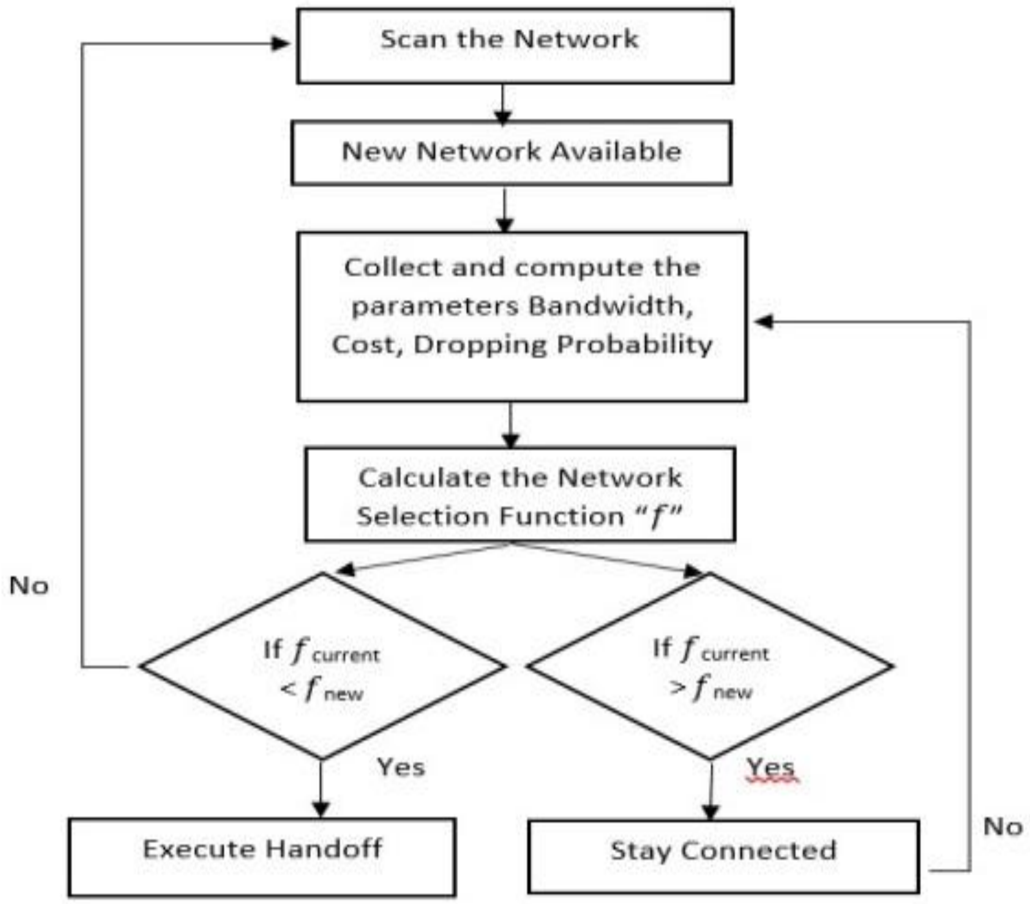

Fig. 4: Mechanism of Network Selection for Processing Delay Based VHO

- Centralized Vertical Handoff Decision (C-VHD) Mobile Node (MN) exchange the flow of information with MN and the neighbour networks. When it is done with the exchange, major effects has processed at MN which increases the processing delay [8]. Increase in processing delay results in increase in overall handoff delay and power consumption.
- Distributed Vertical Handoff Decision (D-VHD) The D-VHD scheme is used to decrease the processing delay than the C-VHD scheme. D-VHD happens when MN is exchanging the message to neighbour network. D-VHD also takes into account parameters like jitter, packet loss and cost for calculating the Network Selection Function. Normalization is carried out with MADM method on these parameters.

4) *Policy Enabled VHO Decision Strategy:* Stability period is observed before performing handoff in policy enabled strategy. Stability period is defined as the interval between the time of finding the target network and the time of starting to perform handoff into it [11]. For achieving seamless vertical handoff in heterogeneous wireless networks, the network parameter should always be obtainable. However, this is challenging task because there does not exist comparable signal strength to be utilized as physical layer handoff metric. It should always be noted that different wireless access technologies offer different QoS parameters, such as available bandwidth, access delay, and packet error rate, which are difficult to obtain compared to the physical layer parameters. Here MAC layer sensing technique is introduced to estimate the handoff parameter.
5) *QoS Based VHO Decision Strategy*: Future mobile network is aiming to provide different real-time and non-real-time multimedia services such as multimedia, video conference and mobile web access etc. meeting the demands of both enterprise and public environments anywhere and anytime. It enhances the performance of the networks and keeps the connection stable.
   - Real-Time-Service
     The request of QoS in the real-time services are higher than the non-real-time services. In order to ensure the real-time service to provide higher bandwidth, we give a loading threshold to WLAN system.
   - Non-Real-Time-Service
     The proposed algorithm takes several parameters into account such as velocity of mobile terminal, bandwidth, and Received Signal Strength (RSS) of the network. To avoid the ping pong effect and unnecessary handoff, the velocity of the mobile terminal and network bandwidth is taken as the most crucial factor in this scheme.

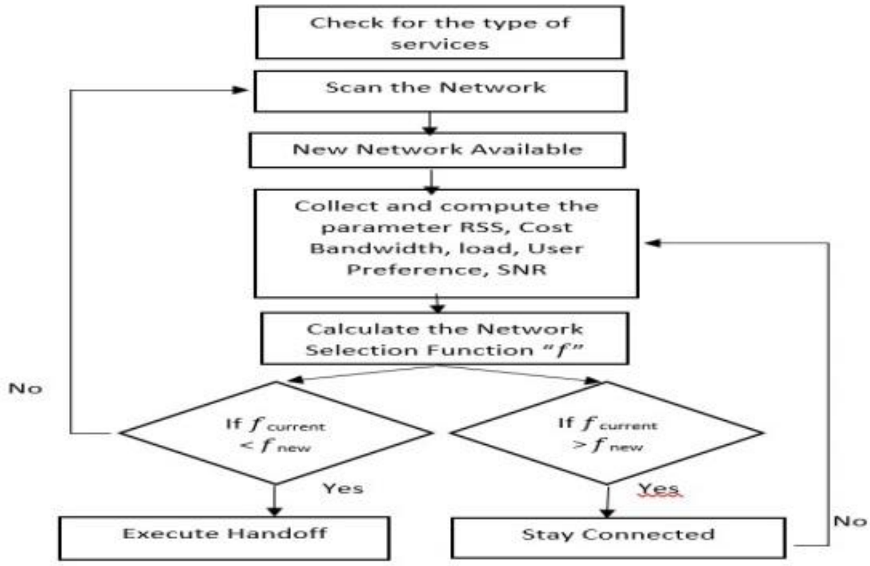

Fig. 5: Mechanism of Network Selection for QoS Based VHO

6) *Context-Aware VHO Decision Strategy*: In Context-aware based Vertical Handoff Decision Strategy energy consumption is used for deciding whether handoff should take place or not [12]. A comprehensive utility evaluation function, in which the weights of decision factors are calculated by the hierarchical analytical process. Then, it is formulated to evaluate the performance of candidate networks. Based on this the target network is selected. Parameters are considered here includes error rate, packet loss rate, packet retransmission rate, burst error, available bandwidth, response time, jitter, delay, cost and the distance. Mobile services can be divided into four classes, i.e. session services, interactive services, streaming services and background services. Different characteristics of services like reliability, throughput, real time, location factor, monetary cost are evaluated to select best network

B.VHO Decision Making Parameters

In NGWS, where networking standards are changing with each type of wireless network only Received Signal Strength (RSS) is not sufficient to take handoff decision. As heterogeneity of wireless networks are concerned recent study shows that there are various parameter by which handoff decision can be possible [1], [2], [3], [4].

- *Received Signal Strength* This is the most important factor that gives information about the power level received from the base station antenna. It decreases as user moves away from the current access point (AP).
- *Bandwidth* Higher offered bandwidth ensures lower call dropping and call blocking probability, hence archives higher throughput.
- *Velocity* it is also an important parameter which has to be considered during handoff decision. In heterogeneous networks for handling small cell area, if mobile host is travelling at high speeds switching occurs in very short time span.
- *Network Load* Background services (e.g., FTP and email) or streaming services (e.g., real-time video) perform better if higher bandwidth is provided by the network.
- *User Preferences* Based on the requirement for different applications like (real time, non-real time), service types (Voice, data, video), Quality of service etc. the user may prefer different network according to the network performance.
- *Delay* It is the distance when mobile moves from the point of attachment to the new point of attachment where handoff should occur.
- *Power Consumption* Mobile wireless devices which operate on limited battery power can degrade system performance. Therefore, it has to be taken into consideration.
- *Monetary Service Cost* The various billing plan provided by network service provider can influence the customer choice of network thus, the network with lower cost is usually preferred.

C. Performance evaluation parameters for VHO decision making

- *Handoff Latency* should be less for better seamless handoff, which occur when MN enters a new network without disconnecting the old network. Further, it results in detection and address configuration latency.
- *Network Throughput* Network throughput refers to the average data rate of successful data or message delivery over a specific communication link. Handoff to the network with higher throughput is desirable.
- *Number of unnecessary* handoff It is the probability of handoff simulation by particular handoff strategy when current strategy causing extra consumption of network resources. It must be less. This kind of switching also known as Ping-Pong effect.

- *Handoff failure probability* it occurs when a handoff is initialized by the network but the target network does not accommodate the handoff request due to deficiency of resources.

TABLE III
Vertical Handoff Decision Basis

Handoff Decision Strategy	**Description of the strategy**	**Handoff Parameter**	**Performance criteria**	
			Advantages	**Limitations**
RSS Based Strategy	Reduce handoff call dropping probability Dwell Timer and hysteresis based handoff can be employed for high mobility scenario	RSS, Bandwidth And variation of Rss	-Monitory Cost is low -Signalling Cost is low -Throughputnis high -Reduce Handover Failure probability	-Handover Latency is high -Packet Loss is high -Unnecessary Handover is high -Ping-Pong Effect is high -Reliability is low
Cost Function Based	Make selection quickly, balances the network resources decreases the probability of call dropping and call blocking.	RSS, Bandwidth, Monitory cost, User preference.	-Reduce call dropping and blocking probability -Unnecessary handoff is low -System throughput is high	-Handoff latency is high. -Packet loss is high -Reliability is low
Processing Delay Based	Reduces the processing overhead by delegating the calculation of handoff metric.	Bandwidth, Dropping Probability and Cost.	-Handoff latency is low -Monitory Cost is low -Throughput is high -Packet loss is low -Reduce processing delay	-Unnecessary Handoff is high
Policy Enabled	MAC layer Sensing technique is used.	Bandwidth and mobile host moving speed	-Reduce Handoff latency -Packet loss is less Monitory cost is low	-Unnecessary Handoff is high -Increase Complexity
Context-aware based Strategy	A mobile service is divided into four classes Session service, Interactive services, Streaming services and Background service.	Error rate, Packet loss rate, Packet retransmission rate, Burst error rate, Available bandwidth, Response time, Jitter, Delay, Cost, Distance.	-Handover Latency is low -Packet Loss is low -Unnecessary Handover is low -Ping-Pong Effect is low -Throughput is high -Handover Failure is low -Reliability is high	-Monitory Cost is high -Signalling Cost is high
QOS Based Strategy	Make decision according to users communication type and the performance of the network	RSS, Bandwidth, Loading Security, SNR Ratio , Power, Velocity, Preference	-Handover Latency is High -Monitory Cost is low -Signaling Cost is low -Throughput is high	-Packet Loss is high -Unnecessary Handover is high -Ping-Pong Effect is high -Handover Failure is high -Reliability is low

IV. ANALYSIS

Notations of various parameters, weighted function and normalized values for the analysis of Network Selection Function are given in Table IV.

TABLE VI : Table of Notation

Symbol	Description
rss	Received Signal Strength
rss'	Received Signal Strength for handoff call
b	Bandwidth
c	Monetary Cost
pf	User Preference
dp	Dropping Probability
l	Network Load
s	Moving Speed
e	Error Rate
L	Packet Loss Rate
t	Packet Retransmission Rate
g	Burst Error
f	Response Time
j	Jitter
d	Delay
sd	Distance
$W_{(rss)}$	Weight function for RSS
$W_{(b)}$	Weight Bandwidth
$W_{(c)}$	Weight Monetary Cost
$W_{(pf)}$	Weight User Preference
$W_{(v)}$	Weight Velocity
$W_{(dp)}$	Weight Dropping Probability
$N_{(rss)}$	Normalize RSS
$N_{(b)}$	Normalize Bandwidth
$N_{(c)}$	Normalize Monetary cost
$N_{(pf)}$	Normalize User preference
$N_{(v)}$	Normalize Velocity
$N_{(dp)}$	Normalize Dropping Probability

A. RSS Based VHO Decision Strategy

- The general network selection function can be shown as,

$$f = \sum_i \mathbb{W}i\, \mathbb{N}(Qn,i) \quad (1)$$

- The network having largest value of network selection function will be selected by the system for the mobile users. When a new call comes, we prefer the call to be accepted by the network with freer bandwidth and stronger RSS. Which is helpful to balance the traffic load among different networks [5], [6]

$$f(new\ call) = (\mathbb{W}bw.\mathbb{N}(bw) + \mathbb{W}rss.\mathbb{N}(rss)) \quad (2)$$

- A handoff call will select the network with smaller RSS because a large RSS indicates poor quality of received signal. Therefore, the cost of network n for a handoff call is defined as

$$f(on\ going\ call\ ) = (\mathbb{W}bw.\mathbb{N}(bw) + \mathbb{W}rss.\mathbb{N}(rss) + \mathbb{W}rss'.\mathbb{N}(1\backslash(rss')) \quad (3)$$

- Where $\mathbb{N}(rss')$ is defined as

$$\mathbb{N}(rss') = \frac{rss - rss\prime k}{rss\prime max} \quad (4)$$

- The constraint of the weights is given by

$$\mathbb{W}\ bandwidth + \mathbb{W}rss + \mathbb{W}rss' = 1 \quad (5)$$

A. Cost Function Based VHO Decision Strategy

TD-SCDMA covers the entire service area providing lower data rate and WLAN only covers some portions of the service area providing higher data rate. The vertical handoff decision is triggered [7] when any of the following events occurs:

- The MN detects a new wireless link.
- There is severe signal degradation of the current wireless link.

- A new service request is made.
- Resources of some network are insufficient and resource balancing is required.

The normalized functions of rss, b, c and pf are given in Table V.

Table IV: Normalized Values

Variation of rss'	$\mathbb{N}(rss') = \frac{rss - rss'k}{rss'max}$
Bandwidth	$\mathbb{N}(b) = \frac{b - bmin}{bmax - bmin}$
Monitory cost	$\mathbb{N}(c) = \frac{c - cmin}{cmax - cmin}$
User preference	$\mathbb{N}(pf) = \frac{pf}{10}$

Further, classifying the handoff decision criteria into positive metrics and negative metrics. Suppose that m positive metrics and negative metrics are considered in the cost function based VHD. The cost function is given by,

$$f = \sum_{m+1}^{m} \mathbb{W}i.\mathbb{N}(xi) - \sum_{i=m+1}^{m+n} \mathbb{W}i.\mathbb{N}(xi) \quad (6)$$

Where, $$f = \sum_{i=1}^{m+n} \mathbb{W}i. = 1 \quad (7)$$

- If the current access network is WLAN, the cost of network selection function is expressed as
$$f(WLAN) = (\mathbb{W}rss.\mathbb{N}(RSS) + \mathbb{W}bw.\mathbb{N}(BW) - \mathbb{W}c.(\mathbb{N}(C)) + \mathbb{W}pf.(\mathbb{N}(PF)) \quad (8)$$
- If the current access network is TD-SCDMA, the cost of network selection function is expressed as
$$f(TD - SCDMA) = (\mathbb{W}rss.\mathbb{N}(RSS) + \mathbb{W}bw.\mathbb{N}(BW) - \mathbb{W}c.(\mathbb{N}(C)) - \mathbb{W}pf.(\mathbb{N}(PF)) \quad (9)$$

B. Processing Delay Based VHO Decision Strategy

Here we compare the Centralized Vertical Handoff Decision (C-VHD), Distributed Vertical Handoff Decision (DVHD) classes which are used to reduce the processing delay. Processing delay was caused by exchanging the information between mobile node and neighbor networks [8],[9],[10].

1) *Centralized Vertical handoff decision (C-VHD):* In network selection decision process there are several parameters used to calculate NSF. The highest NFS value of MN will be selected as Visited Network (VN) by the mobile node.
$$f(C - VHD) = (\mathbb{W}b.(bi)) + (\mathbb{W}dp.(dp) + \mathbb{W}c.(c)) \quad (10)$$
2) *Distributed Vertical handoff decision (D-VHD):* NSF is given by a set of evaluation parameters as network condition, bandwidth, power consumption, cost, latency and security. As stated, for our work we used only three parameters bandwidth, dropping probability and cost. The function measures the target handoff network value. Thus, the decision maker can select as the "best network", with the highest value.
The generic weighted function is defined as depicted by,
$$f = \sum_{i=1,j=1}^{m+n} \mathbb{W}j * Pij. + \sum_{i=1,k=1}^{m} \mathbb{W}k \frac{1}{P\prime ik}. \quad (11)$$

Therefore, the function used in our proposal as depicted by
$$f(D - VHD) = (\mathbb{W}b * (bi)) + (\mathbb{W}dp * \frac{1}{dp} + \mathbb{W}c * \frac{1}{c}) \quad (12)$$

D. Policy Enabled VHO Decision Strategy

Policy Enabled Vertical Handoff Decision Strategy is focused on the WWAN to WLAN roaming direction. Mobile Hosts moving speed and bandwidth are the parameter used for calculation of Network Selection Function. Also, the existence of a location service server (LSS), provides all the necessary handoff metrics of the target network. However, in this proposed strategy, the bandwidth in WLAN is obtained by the MLS technique [11].
Network Selection Function used in the proposed scheme can be shown as.

$$f = (\mathbb{W}bw.\mathbb{N}\left(\left(\frac{1}{bw}\right)\right) + \mathbb{W}s.\mathbb{N}(S)) \quad (13)$$

E. QoS Based VHO Decision Strategy

We utilize the Network Selection Function to judge the network performance [13] [14].

1) *Real-Time-Service:*

$$f(Real-Time) = (\mathbb{W}b.\mathbb{N}(b)) + \mathbb{W}l.\mathbb{N}(l) + \mathbb{W}rss.\mathbb{N}(rss)) +(\mathbb{W}pf.\mathbb{N}(pf)) + (\mathbb{W}snr.\mathbb{N}(snr) + \mathbb{W}v.\mathbb{N}(v)) \quad (14)$$

2) *Non-Real-Time-Service:*

$$f(Non-Real-Time) = (\mathbb{W}b.\mathbb{N}(b)) + \mathbb{W}rss.\mathbb{N}(rss) + \mathbb{W}v.\mathbb{N}(v)) \quad (15)$$

F. Context-aware Based VHD Strategy

For each of the parameter the normalized value can be given as

$$\mathbb{N}(Zk) = \frac{Ki-Kmin}{Kmax-Kmin} \quad (16)$$

- Where, $\mathbb{N}(Zk)$ indicates the normalized value of the available parameter for application *k* in candidate network K*i* is the actual available bandwidth in the candidate network *i*. Kmax is the ideal maximum available bandwidth for users' application *k* and Kmin is the minimum required corresponding parameter for application *k*.
- Comprehensive utility evaluation function for different services characteristics like Reliability, Throughput, Real Time, Location , Monetary cost.
- The relative importance weights of network parameters, $\mathbb{W}e$, $\mathbb{W}l$, $\mathbb{W}t$, $\mathbb{W}b$, $\mathbb{W}g$, $\mathbb{W}f$, $\mathbb{W}j$, $\mathbb{W}d$, $\mathbb{W}c$, $\mathbb{W}s$ as well as that of utility evaluation factor of different services characteristics are $\mathbb{W}A$, $\mathbb{W}B$, $\mathbb{W}C$, $\mathbb{W}D$, $\mathbb{W}E$ are calculated by AHP approach. Based on the correlation between parameters indicators, we use multiplication index method to construct utility evaluation functions with normalization for each characteristics and its corresponding application is as,
  $\mathbb{N}$(A, x), $\mathbb{N}$(B, x), $\mathbb{N}$(C, x), $\mathbb{N}$(D, x), $\mathbb{N}$(E, x)
- Multiplication index method is less sensitive to weight changes so, it can avoid evaluation distortion arising from weight bias.
  $\mathbb{N}(A, x)= \mathbb{N}(e, x)\mathbb{W}e * \mathbb{N}(l, x)\mathbb{W}l * \mathbb{N}(f, x)\mathbb{W}f * \mathbb{N}(g, x)\mathbb{W}g$
  $\mathbb{N}(B, x)= \mathbb{N}(b, x)\mathbb{W}b$
  $\mathbb{N}(C, x)= \mathbb{N}(f, x)\mathbb{W}f * \mathbb{N}(j, x)\mathbb{W}j * \mathbb{N}(d, x)\mathbb{W}d$
  $\mathbb{N}(D, x)= \mathbb{N}(s, x)\mathbb{W}s$
  $\mathbb{N}(E, x)= \mathbb{N}(c, x)\mathbb{W}c$
- After sorting the comprehensive utility evaluation value of candidate networks for application k, the Network Selection Function calculated for candidate network and the network with highest value is selected as target handoff network.
  $$f= \mathbb{N}(A, x)\,\mathbb{W}A + \mathbb{N}(B, x)\,\mathbb{W}B + \mathbb{N}(C, x)\,\mathbb{W}C + \mathbb{N}(D, x)\,\mathbb{W}D + \mathbb{N}(E, x)\,\mathbb{W}E \quad (17)$$

V. PERFORMANCE EVALUATION OF NETWORK SELECTION FUNCTION

Heterogeneous network model is shown in Fig. 6. We assume that mobile devices available with multiple interfaces, are capable of accessing the service area covered by Wi-Fi, WiMAX, UMTS/CDMA networks with constant speed. Consider that the mobile device is busy in downloading data for real time application like VOIP and the user is moving via the heterogeneous wireless network. The handoff policy differs based on the user services and network characteristics. For non-real-time services, the amount of data transmission is more important than the delay so it is more preferable to connect to WLAN/WiMAX as long as possible due to higher

TABLE VI: On the basis of Network Selection Function

Strategy	Network Selection Function
RSS Based Strategy	$f_{newcall} = W_b.N_{(b)} + W_{rss}.N_{(rss)}$
	$f_{ongoingcall} = W_b.N_{(b)} + W_{rss}.N_{(rss)} + W_{rss'}.\frac{1}{N_{(rss')}}$
Cost Function Based	$f_{WLAN} = W_{rss}.N_{(rss)} + W_b.N_{(b)} - W_c N_{(c)} + W_{pf} N_{(pf)}$
	$f_{TD-SCDMA} = W_{rss}.N_{(rss)} + W_b.N_{(b)} - W_c.N_{(c)} - W_{pf}.N_{(pf)}$
Processing Delay Based	$f_{C-VHD} = W_b.N_{(b)} + W_{dp}.N_{(dp)} + W_c.N_{(c)}$
	$f_{D-VHD} = W_b.N_{(b)} + W_{dp}.N\left(\frac{1}{b}\right) + W_c.N\left(\frac{1}{c}\right)$
Policy Enabled Vertical Handoff Decision	$f = W_b.N\left(\left(\frac{1}{b}\right)\right) + W_s N_{(s)}$
QoS Based VHO Decision Strategy	$f_{Non-Real-Time} = W_{rss}.N_{(rss)} + W_b.N_{(b)} + W_v.N_{(v)}$
	$W_{rss}.N_{(rss)} + W_b.N_{(b)} + W_v.N_{(v)}$
Context-aware Based Vertical Handoff Decision	$f = N_{(A,x)}W_A + N_{(B,x)}W_B + N_{(C,x)}W_C + N_{(D,x)}W_D + N_{(E,x)}W_E$

data rate provided. For real time applications (e.g. Voice over IP), handoff should be performed as fast as possible by considering network load, cost, user preference etc. Traditionally received signal strength (RSS) was only the main criteria to decide to handoff.

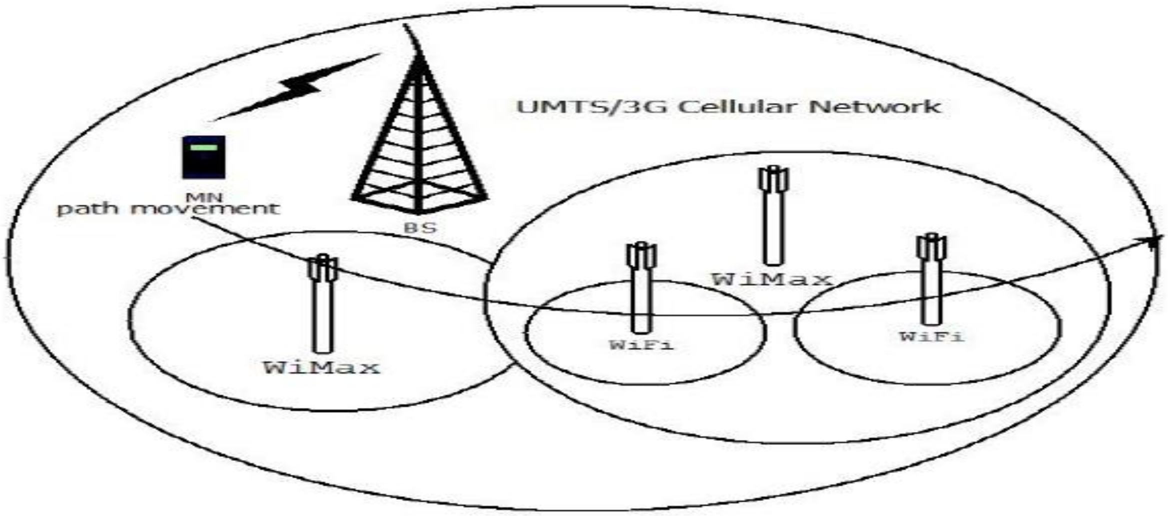

Fig. 6: Integration of Wi-Fi, WiMAX and UMTS/3G Cellular Network

With technology advancements and real time applications, consideration of RSS only, would not be a good choice. We have to consider other parameter like bandwidth, monetary cost etc. We have proposed Network Selection Function to select the best target handoff network from the available candidate networks by taking optimized parameter values from Table VII. It considers dynamic weights also. The analytical results are presented in Table VIII, we evaluate the influence of different handoff decision strategy on the available networks for real-time and non-real-time services with the support of empirical example.

TABLE VII
Comparison of different network characteristics

Network Parameter	**WiFi(IEEE 802.11g)**	**WiMax(IEEE 802.16e)**	**3G cellular UMTS/WCDMA**
Coverage	100 - 300 m	1.5 - 4.5 km	4 - 10 km
RSS	-90 to -10 dBm	-90 to -30 dBm	-90 to -60 dBm
Bandwidth	6 - 54 Mbps	15 - 30 Mbps	1.8 - 14.4 Mbps
Monitory Cost	Low (0.08 - 3.0)	Medium (1.0 - 4.0)	High (1.5 - 4.0)
User Preference	5 - 10	5 - 10	0 - 5
Dropping Probability	0.235	0.537	0.678
Network Load	Low	Medium	High

For application like video streaming, if the handoff decision is based on RSS strategy, then the selected network would be WiMax, but considering other parameters like monetary cost, users speed, network load and dropping probability 3G cellular would be the best network. It is also proved in Table VIII. The future lies with context based handoff strategy which uses a wide range of context information about the network, users, user devices and user applications that provide adaptations to a variety of context changes.

TABLE VIII: Empirical values of Network Selection Function

Handoff Strategy	**RSS Based**	**Cost Based**	**Processing Delay**	**Policy Enabled**	**QoS Based**
WiFi	0.325	**0.1465**	0.147	**0.96**	0.243
WiMAX	**0.492**	0.2580	0.732	0.36	0.4192
3G Cellular	0.4692	0.3347	**0.8298**	0.36	**0.5488**

VI. CONCLUSION

It is important to consider the user requirements as well as network parameters to decide a proper handoff strategy which selects the best connecting network. By considering its feature and user requirements, we have studied various proposals and suggested categories based on that. Our proposed network selection function conforms the best handoff decision. The state of the art handoff decision strategies and its pros and cons are presented with the help of empirical example.

REFERENCES

[1] Arvind Kumar Singh, Pankaj Singh, Sandeep Singh, Akhilesh Kumar Singh "*Handover in Advanced Wireless communication A Survey*" IJCSET ,September 2011,Vol 1, Issue 8, 510-515.

[2] A. Bhuvaneswari,"*An Overview of Vertical Handoff Decision Making Algorithms*", I. J. Computer Network and Information Security, 9, 55-62 August 2012 in MECS (http://www.mecs-press.org/).

[3] Xiaohuan Yan, Y. Ahmet ekerciolu, Sathya Narayanan "*A survey of vertical Handover decision algorithms in Fourth Generation heterogeneous wireless networks computer Networks*", Volume 54, Issue 11, 2 August 2010, Pages 1848-1863.

[4] Ahmed, A.; Boulahia, L.; Gaiti, D., "*Enabling Vertical Handover Decisions in Heterogeneous Wireless Networks: A State-of the-Art and A Classification*", Communications Surveys & Tutorials, IEEE , vol.PP, no.99, pp.1,36, 2013.

[5] Yutao Ling; Benshun Yi; Qiuping Zhu, "*Vertical Handoff Decision Strategy in Wireless Overlay Networks*", Wireless Communications, Networking and Mobile Computing, 2009. WiCom 09. 5th International Conference on , vol., no., pp.1,3, 24-26 Sept. 2009.

[6] Roy, S.D.; Anup, S., "*Received signal strength based vertical handoff algorithm in 3G cellular network*", Signal Processing, Communication and Computing (ICSPCC), 2012 IEEE International Conference on,vol., no., pp.326,330, 12-15 Aug. 2012.

[7] Qing He, "*A novel vertical handoff decision algorithm in heterogeneous wireless networks*", Wireless Communications, Networking and Information Security (WCNIS), 2010 IEEE International Conference on , vol., no., pp.566,570, 25-27 June 2010.

[8] Savitha, K.; Chandrasekar, C., "*Comparison of vertical handoff decision scheme in heterogeneous wireless network*", Computational Intelligence and Computing Research (ICCIC), 2010 IEEE International Conference on , vol., no., pp.1,5, 28-29

[9] Tawil, R.; Pujolle, G.; Salazar, O., "*A Vertical Handoff Decision Scheme in Heterogeneous Wireless Systems*", Vehicular Technology Conference, 2008. VTC Spring 2008. IEEE , vol., no., pp.2626,2630, 11-14 May 2008.

[10] Tawil, R.; Demerjian, J.; Pujolle, G.; Salazar, O.,"*Processing-delay reduction during the vertical handoff decision in heterogeneous wireless Systems*", Computer Systems and Applications, 2008. AICCSA 2008. IEEE/ACS International Conference on , vol., no., pp.381,385, March 31 2008-April 4 2008.

[11] Huiling Jia; Peng Cheng; Zhaoyang Zhang; Shiju Li, "*An Improved Adaptive Decision Scheme for Vertical Handoff in Heterogeneous Wireless Networks*", Communications, Circuits and Systems Proceedings, 2006 International Conference on , vol.3, no., pp.1816,1820, 25-28 June 2006.

[12] Jun Peng; Huiyuan Xian; Xiaoyong Zhang; Zheqin Li,"*Context-Aware Vertical Handoff Decision Scheme in Heterogeneous Wireless Networks*", Trust, Security and Privacy in Computing and Communications (TrustCom), 2011 IEEE 10th International Conference on , vol., no., pp.1375,1380, 16-18 Nov. 2011.

[13] Ying-Hong Wang; Chih-Peng Hsu; Kuo-Feng Huang; Wei-Chia Huang, "*Handoff decision scheme with guaranteed QoS in heterogeneous network*," Ubi-Media Computing, 2008 First IEEE International Conference on , vol., no., pp.138,143, July 31 2008-Aug. 1 2008.

[14] Rizvi, S.; Aziz, A.; Saad, N.M., "*An overview of vertical handoff decision policies for next generation wireless networks*,"Circuits and Systems (APCCAS), 2010 IEEE Asia Pacific Conference on , vol., no., pp.88,91, 6-9 Dec. 2010

