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Vertical Handoff Model for Heterogeneous Wireless Network

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ABSTRACT

In heterogeneous wireless networks, handoff can be separated into two parts: horizontal handoff (HHO) and vertical handoff (VHO). One of the major design issues in heterogeneous wireless networks is the support of vertical handoff. Vertical handoff occurs when a mobile terminal switches from one network to another. The heterogeneous co-existence of access technologies with largely different characteristics creates a decision problem of determining the "best" available network at "best" time to reduce the unnecessary handoffs. In this paper, we propose a Vertical Handoff Model to decide the "best" network interface and "best" time moment to handoff. A score function is utilized in the model to make the vertical handoff decision based on the static factors (e.g. link capacity, power consumption, and link cost), and dynamic factors (e.g .Received Signal Strength (RSS),velocity). This model not only meets the individual user needs but also improve the whole system performance by reducing the unnecessary handoffs.

Keywords— Vertical handoff model, Seamless handoff, Heterogeneous wireless networks.

I. INTRODUCTION

The architecture for the Beyond 3rd Generation (B3G) or 4th Generation (4G) wireless networks aims to integrate various heterogeneous wireless access networks over an IP (Internet Protocol) backbone. As a result, an interesting problem surfaced on how to decide the "best" network interface to use any given moment. The decision to decide best network may be based on static factors such as the bandwidth of each network (capacity), usage charges of each network, power consumption of each network interface and battery level of mobile device. However, Dynamic factors must be considered in handoff decisions for effective network usage. For example, information on current network conditions such as received signal strength (RSS) can help in improving whole system performance; current user conditions, such as a mobile host's moving speed can eliminate certain networks that do not support mobility, from consideration.

In heterogeneous wireless networks, handoff can be separated into two parts: horizontal handoff (HHO) and vertical handoff (VHO). In the heterogeneous network [12], both the horizontal handoff and vertical Handoff take place as illustrated in Fig.1. Horizontal Handoff (HHO) is the process in which the mobile terminal hands-off between two Access Points (AP) or two Base Stations (BS) using the same access technology. On the other hand, Vertical Handoff (VHO), occurs when the MT roams between different access technologies. The main distinction between VHO and HHO is symmetry. While HHO is a symmetric process, VHO is an asymmetric process in which the MT moves between two different networks with different characteristics. This introduces the concept of a Preferred Network, which is the network that provides better performance at lower cost, even if several other networks are available and in good condition for the user.

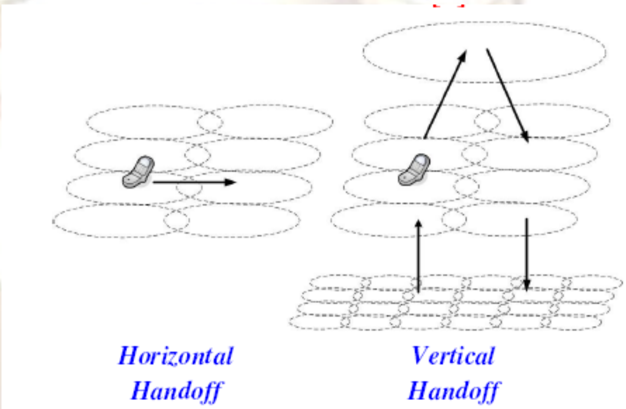

Fig.1 Horizontal and Vertical Handoff

The vertical handoff process involves three main phases [4], [5], namely system discovery, vertical handoff decision, and vertical handoff execution. During the system discovery phase, the mobile terminal determines which networks can be used. These networks may also advertise the supported data rates and Quality of Service (QoS) parameters. Since the users are mobile, this phase may be invoked periodically. In the vertical handoff decision phase,the mobile terminal determines whether the connections should continue using the existing selected network or be switched to another network. The decision may depend on various parameters including the type of the applications (e.g.,conversational, streaming),minimum bandwidth and delay required by the application, access cost, transmit power, and the user's preferences. During the vertical handoff execution phase, the connections in the mobile terminal are re-routed from the existing network to the new network in a seamless manner. This phase also includes the authentication, authorization, and transfer of a user's context information.

A seamless handoff is defined as a handoff scheme that maintains the connectivity of all applications on the mobile device when the handoff occurs. Seamless handoffs aim to provide continuous end-to-end data service in the face of any link outages or handoff events. Achieving low latency and minimal packet loss during a handoff are the two critical design goals of our handoff architecture.To achieve low latency path switching should be completed almost instantaneously and service interruptions should be minimized. In case of an actual connection failure, the architecture should attempt to re-connect as soon as the service becomes available; packet losses during the switching should also be minimized.

A Universal Seamless Handoff Architecture (USHA) was proposed in [2] to deal with both horizontal and vertical handoff scenarios with minimal changes in infrastructure (i.e., USHA only requires deployment of handoff servers on the Internet.) USHA is an upper layer solution; however, instead of introducing a new session layer or a new transport protocol, it achieves seamless handoff by following the middleware design philosophy [6], integrating the middleware with existing Internet Services and applications. USHA is based on the fundamental assumption that handoff, either vertical or horizontal, only occurs on overlaid networks with multiple Internet access methods (i.e. soft handoff), which translates to zero waiting time in bringing up the target network interface when the handoff event occurs. If coverage from different access methods fails to overlap (i.e. hard handoff), it is possible for USHA to lose connectivity to the upper layer applications.

In this study, we propose a Vertical Handoff Model to decide the "best" network interface and "best" time moment to handoff. A score function is utilized in the model to make the vertical handoff decision based on the static factors (e.g. link capacity, power consumption, and link cost), and dynamic factors (e.g .Received Signal Strength,velocity). A Vertical handoff Model implementation is employed on the top of the Universal Seamless Handoff Architecture (USHA), which is a simple and practical seamless handoff solution [2]. The results show that the proposed Vertical handoff model can adequately perform vertical handoff to the "best" interface at the "best" moment.

This paper is organized as follows. The vertical handoff model is described in Section II. Simulation results are presented in Section III. Conclusions are given in Section IV.

II. VERTICAL HANDOFF MODEL

This section presents the proposed Vertical handoff decision model which support flexible configuration in executing vertical handoffs. Fig. 2 depicts the proposed Vertical handoff decision model. A Handoff Control Center (HCC), monitors the various inputs collected from the network interfaces and their base stations (BS), analyze this information and took handoff decisions. It also provides the connection between the network interface and the upper layer applications. HCC is composed of five components: Network Analysis (NA), Network Discovery (ND), Vertical handoff decision (VHD), system monitor(SM) and Vertical Handoff executor (VHE). NA is responsible for monitoring the status of each network interface (i.e. offered bandwidth, user charges, power consumption of network interface) and analyzing based on the calculated score function. SM monitors and reports system information(i.e.current remaining battery and user preferences) to NA module. ND module discovers all the available networks at fixed time intervals. It monitors the velocity of mobile station (MS) and the Received signal strength (RSS) of the base station (BS), select the candidate networks and assigns them priorities.Finally, the VHD module takes the decision, for selecting "Best" network to handoff, based on the inputs from NA and ND modules. Finally, the Decision Phase is used to select the "Best" network and executing the handoff to the selected network.

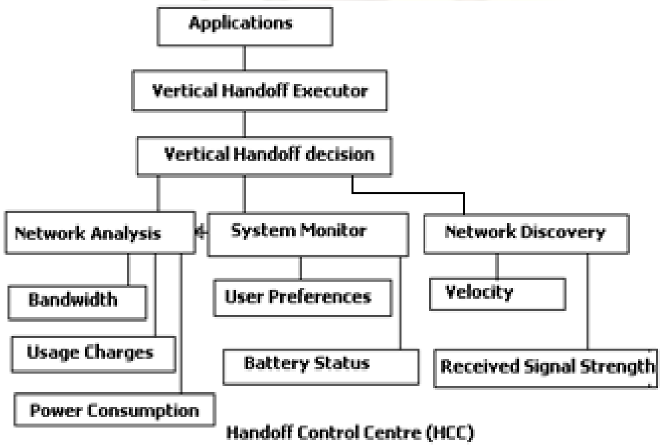

Fig. 2 Vertical handoff Model

The algorithm for Vertical handoff decision:
Priority Phase: (Network Discovery)

1. Add all the available network into list.
2. Scan all the networks and record their Received Signal Strength (RSS).
3. Record the velocity of the mobile station (MS).
4. Remove the networks which do not satisfy the required RSS and velocity criteria.
5. Calculate and assign the priorities to all the candidate network based on the difference between RSS and its threshold value RSST.
6. Continue with normal phase.

Normal Phase: (Network Analysis)

7. Collect current system status from SM component and determined the weigh factors.
8. Collect information on every wireless interface in the candidate list.
9. Calculate static score "S" using a Cost function for every network.
10. Continue with decision Phase.

Decision Phase: (Network Selection and Execution)

11. Calculate a dynamic score "DScore" by multiplying the priority of each candidate with it's static score "S'.
12. Select the network with the highest value of "DScore".
13. Handoff all the current information to the "Selected Network" if different from current network.

The Priority Phase is used to remove all the unwanted and ineligible networks from the prospective candidate networks. The Normal Phase is used to accommodate user-specific preferences regarding the usage of network interfaces. The user preferences are expressed in terms of weight factors. Finally , the Decision Phase is used to select the "Best" network and executing the handoff to the selected network.

A. System Monitor

This module monitor the current battery level of the mobile station and record the user preferences for various networks based on the current battery level, offered bandwidth, usage charges and power consumption by their interface card. These preferences, expressed in terms of weight factors, are passed on to the Network Analysis module to calculate the score function.

B. Network Analysis (NA)

The network is analyses based on a static score S. The S can be defined as a function of the following parameters: the offered bandwidth (B_n), power consumption of using the network access device (P_n) and the usage charge of the network (C_n)-

$$S_n = f(B_n, P_n, C_n) \qquad (1)$$

Here, S_n is the static score for network n.

We can imagine that such a score function is the sum of some normalized form of each parameter. Normalization is needed to ensure that the sum of the values in different units is meaningful. In general, suppose that there are k factors to consider in calculating the score, the final score of the interface i will be a sum of k weighted functions.

$$S_i = \sum_{j=1}^{k} w_j f_{i,j} \quad 0<S_i<1, \qquad \sum_{j=1}^{k} w_j = 1 \qquad (2)$$

In the equation, w_j stands for the weight of factor j and $f_{i,j}$ represents the normalized score of interface i for factor j.

For our model –

$$S_i = w_b f_{b,i} + w_p f_{p,i} + w_c f_{c,i} \qquad (3)$$

Where

w_b is weight factor for Offered Bandwidth, w_p is weight factor for Power Consumption by network interface and w_c is weight factor for Usage Cost of network. $f_{b,i}$, $f_{p,i}$ and $f_{c,i}$ represents the normalized score of interface i for Offered Bandwidth, Power Consumption and Usage Cost respectively which are defined as :

$$f_{b,i} = e^{\alpha_i} / e^{M} \quad , \alpha_i \geq 0 \ \& \ M \geq \alpha_i \qquad (4)$$
$$f_{p,i} = 1/e^{\beta_i} \quad , \beta_i \geq 0 \qquad (5)$$
$$f_{c,i} = 1/e^{\gamma_i} \quad , \gamma_i \geq 0 \qquad (6)$$

The coefficients α_i, β_i, γ_i can be obtained via a lookup table or

well-tuned functions as below:

$$\alpha_i = Min(x_i, M)/M \quad ; M = 2Mbps \qquad (7)$$
$$\beta_i = 2/y_i \quad ; y_i: \text{hours} \qquad (8)$$
$$\gamma_i = z_i/20 \quad ; z_i : \text{Rs./min} \qquad (9)$$

Eq. 5 & 6, used the inversed exponential equation for $f_{p,i}$ and $f_{c,i}$ to bound the result to between zero and one (i.e. these functions are normalized) and properly model users preferences. For $f_{b,i}$ a new term M is introduced as the denominator to normalize the function, where M is defined as the maximum link capacity among all available interfaces. Note that, the properties of bandwidth and usage cost/power consumption are opposite (i.e. the more bandwidth the better,

Where as lower cost/power consumption is preferred).

C. Network Discovery (ND)

The object of this module is to identify all the Candidate

Networks from all the available networks and assign them Priority.

Candidate Network Selection:

A candidate network is the network whose received signal strength is higher than its threshold value and its velocity threshold is greater than the velocity of mobile station.

Let N= $\{n_1, n_2, n_3 \ldots\ldots\ldots n_k\}$ is the set of available network interfaces.

VT=$\{vt_1, vt_2, vt_3, \ldots\ldots\ldots vt_k\}$ is the set of threshold values of velocities for a mobile station for the respective networks.

RSST=$\{rsst_1, rsst_2, rsst_3, \ldots\ldots\ldots\ldots rsst_k\}$ is the set of threshold values of received signal strengths of respective networks.

RssDiff $=\{RssDiff_1, RssDiff_2, \ldots\ldots RssDiff_k\}$ is the set of values of difference between the received signal strength and its threshold value.
CN = { } is the set of all eligible candidate networks into which the handoff can take place.
$P=\{0,1/k,2/k,..j/k,\ldots,1\}$ is the set of priority values for jth network, where j=1..k
The network base station (BS) and mobile station(MS) is observed for the RSS and Velocity respectively at the specified time intervals and the decisions are taken as below to select the candidate networks :
Let the MS is currently in network ni Then If $RSS_i < rsst_i$ then
For all n_j where $j \neq i$
If ($RSS_j > rsst_j$ and $v_i < vt_j$) then
$\{CN\} = \{CN\} \cup \{n_j\}$
$RssDiff_j=RSS_j-rsst_j$
Priority Assignment:

The priority is based on RssDiff where higher the RssDiff means higher the priority. It is so because higher RssDiff indicate that the MS is more nearer to the BS of that network and hence the MS can stay for more time in the cell of the respective network before asking for another handoff. Thus it makes possible to reduce the unnecessary handoffs and improve the overall performance of the system. The priory p is assigned to all the networks as below-
Let there are n candidate networks out of k available networks then
For j=1 to k Do
If j is not a candidate network Then
$P_j=0$
Else if j is the only candidate network Then
$P_j=1$
Else if network is at ith position in an ascending order sorted set of RssDiff Then
$p_j=i/k;$
Using above rule based the Network Discovery module select the eligible networks from the all available networks and assign the priority.

D. Dynamic Decision (DD)

This module is responsible to take final decision of selecting a particular candidate networks from a set of candidate networks decided earlier by network discovery (ND) module. A dynamic score "DScore" is calculated for each network i as below-

$$\textbf{DScorei= Si * pi} \qquad (10)$$

Where Si is the score calculated by the NA module and pi is the priority decided by the ND module for the ith network. A candidate networks which has highest corresponding value of "DScore" is selected as the "best" network to handoff.

III. SIMULATION

In order to evaluate and analyse the proposed Vertical handoff model, an application is written in VC++ to simulate a heterogeneous network system where two cellular systems GSM & CDMA and a WLAN form an overlay structure, as shown in Fig. 3. A mobile terminal (MT) with triple network interfaces can move in the cell boundaries of any network during simulation.

The mobile terminal MT can be in any one of the regions from A, B, C and D at a moment of time and is able to access the networks as per below:
If the MT is in-
Region A – can access only CDMA network.
Region B – can access CDMA & GSM both.
Region C – can access only WLAN.
Region D – can access only GSM network.

The simulation is carried out for all four possible scenarios where the MT can be in WLAN or in CDMA or in GSM or in CDMA and GSM network at the start of simulation based on the assumed parameters as mentioned in Table I.While in roaming, the mobile terminal MT monitors the networks as well as system continuously for various parameters but the handoff decision function is executed at a specified time intervals, the value of which is provided by the user at the start of simulation.

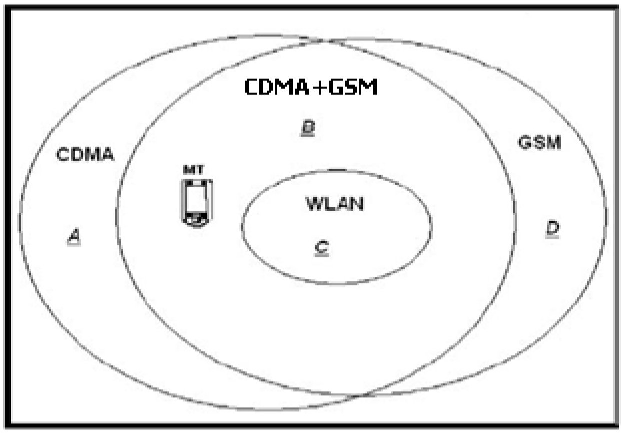

Fig.3 The Proposed Model for Simulation

The simulations are performed for both SDM (i.e. standard decision model, which does not use received signal strength and velocity in decision making) and proposed VHDM (Vertical Handoff Decision Model) and The results are carried out for the randomness in RSS(Received Signal Strength) signal with respect to time and the static score S with respect to Band Width.

TABLE I
SIMULATION PARAMETERS

	WLAN	GSM	CDMA	CDMA& GSM
Offered Bandwidth(x)	2 Mbps	100 kbps	150 kbps	120 kbps
Power Consumption (y)	3hrs	2.5hrs	2hrs	3.5hrs
Usage Cost (z)	10 Rs./min	5 Rs./min	2.5 Rs./min	7 Rs./min
Received Signal Strength Threshold (rsst)	100dB	150dB	125dB	170dB
Velocity Threshold (VT)	11 m/sec	13 m/sec	12 m/sec	15 m/sec

Fig. 4 to Fig.7 shows the randomness in RSS(Received Signal Strength) signal with respect to time for WLAN, GSM,CDMA and CDMA & GSM. Fig.8 to fig.11 shows the static score S with respect to Band Width for WLAN, GSM, CDMA and CDMA & GSM.

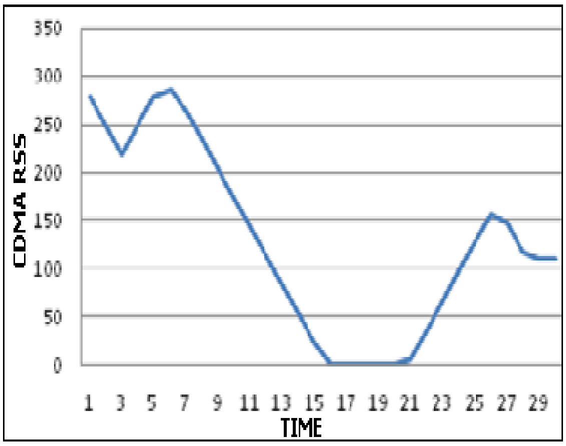

Fig.4 RSS signal with respect to time for CDMA

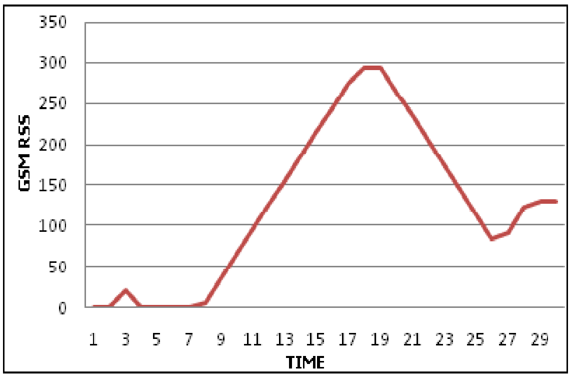

Fig.5 RSS signal with respect to time for GSM.

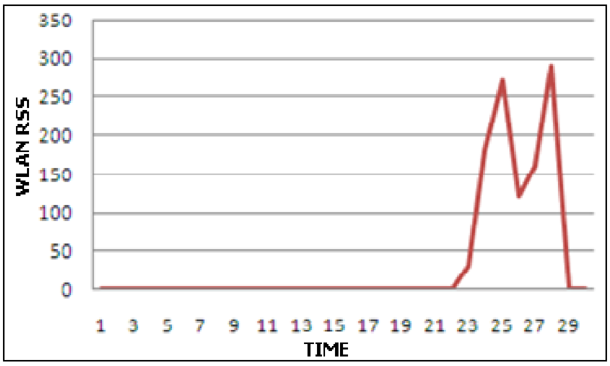

Fig.6 RSS signal with respect to time for WLAN.

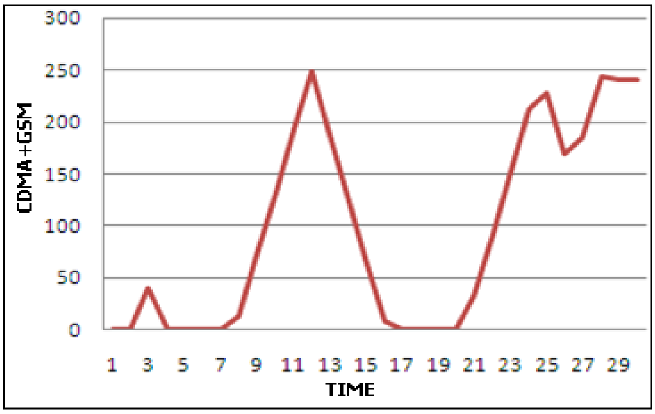

Fig.7 RSS signal with respect to time for CDMA+GSM.

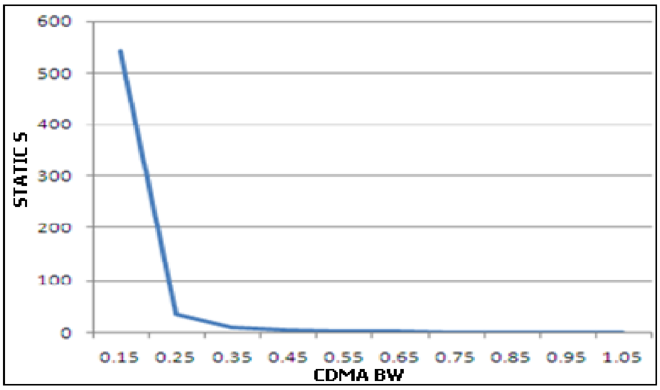

Fig.8 Static score S with respect to Band Width for CDMA.

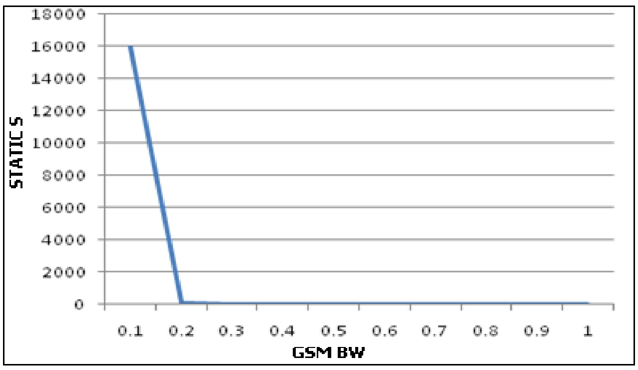

Fig.9 Static score S with respect to Band Width for GSM.

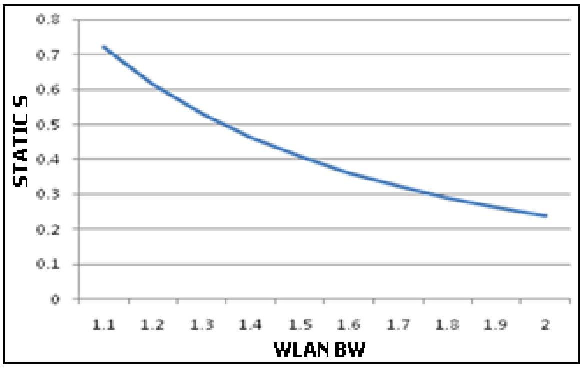

Fig.10 Static score S with respect to Band Width for WLAN.

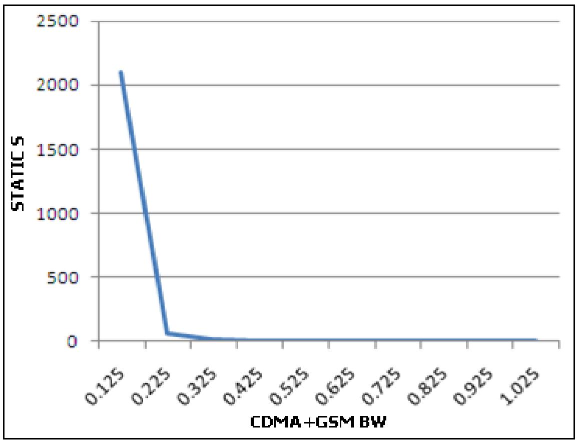

Fig.11 Static score S with respect to Band Width for CDMA and GSM.

The results show that the proposed Vertical handoff model can adequately perform vertical handoff to the “best” interface at the “best” moment.

IV. CONCLUSIONS

In this paper, we present a Vertical Handoff Model to “smartly” perform vertical handoff to the “best” network interface at the “best” time moment. The proposed model is able to make the “vertical handoff” decision based on the static factors (e.g. link capacity, power consumption, and link cost), and dynamic factors (e.g .Received Signal Strength (RSS),velocity). This model not only meets the individual user needs but also improve the whole system performance by reducing the unnecessary handoffs. The results show that the proposed Vertical handoff model can adequately perform vertical handoff to the “best” interface at the “best” moment. This Vertical handoff Model is simple and applicable with any handoff Implementation techniques. However, this model is more suitable to perform “Soft Vertical Handoffs” using application layer approaches like USHA.

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