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Design and Performance Evaluation of Cost Function Based Vertical Handoff

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ABSTRACT
The main objectives of a handoff procedure are, first, to minimize the number of link transfers and second, to minimize the handoff processing delay by correct choice of target BS/AP with speedy execution. This minimizes the probability of connection interruptions and reduces the switching load. If the handoff is not fast enough, the quality of the service experiences degradations. A handoff should be evaluated as to its impact on the mobile to network connection.

I.INTRODUCTION
In cellular networks such as GSM, [2] a call is seamlessly handed over from one cell to another using hard handoff without the loss of voice data. This is managed by networks based handoff control mechanisms that detect when a user is in a handoff zone between cells and redirect the voice data at the appropriate moment to the mobile node via the cell that the mobile node has just entered. In 4G networks a handoff between different networks is required. A handoff between different networks is referred to as a Vertical handoff (VHO).
Handoff management process
Many literatures describe the handoff process in three phases.

1. Handoff Information Gathering:
2. Handoff Decision:
3. Handoff Execution:

II. CLASSIFICATION OF VERTICAL HANDOFF
For VHO, there are two additional and useful classifications to understand why VHO mechanisms are different from traditional horizontal handoff (HHO) mechanisms such as signal strength-based.

The first classification is: upward and downward. An upward VHO occurs from a network with small coverage and high data rate to a network with wider coverage and lower date rate. On the other hand, a downward VHO occurs in the opposite direction. As an example for this classification let's consider the case of two of the most important current wireless technologies: 3G cellular networks and WLANs. The WLAN system can be considered as the small coverage network with high data rate while the 3G cellular system is the one with wider coverage and lower data rate. The trend in the literature has been to perform downward VHOs whenever possible.[8]

The second classification is: imperative and alternative. An imperative VHO occurs due to low signal from the BS or AP. In other words, it can be considered as an HHO. The execution of an imperative VHO has to be fast in order to keep on-going connections. On the other hand, a VHO initiated to provide the user with better performance (e.g., more bandwidth or lower access cost) is considered to be an alternative VHO. This VHO can occur when a user connected to a 3G cellular network goes inside the coverage of a WLAN, even if the signal of the connection to the 3G cellular networks does not lose any signal strength, the user may consider the connection to the WLAN a better option.

III. COST FUNCTION-BASED STRATEGIES (CFBS)
Vertical handoff decision cost function is a measurement of the benefit obtained by handing over to a particular network. It is evaluated for each network n that covers the service area of a user. It is a sum of weighted functions of specific parameters. The general form of the cost function f_n of wireless network n is

$$f_n=\Sigma_s\Sigma_i w_{s,i}.p^n_{s,i}$$

$P^n_{s,i}$ is the cost in the i^{th} parameter to carry out service s on network n; $w_{s,\,i}$: the weight (importance) assigned to using the i^{th} parameter to perform services (with $\Sigma_i w_i=1$). The parameters used are bandwidth B_n that network n can offer, power consumption P_n of using the network device for n and monetary cost C_n of n. The cost of using a network n at a certain time, with N (i) as the normalization function of parameter i is defined as:

$$f_n= w_b .N(1/B_n)+w_p .N(P_n)+w_c .N(C_n)$$

The network that is consistently calculated to have the lowest cost is chosen as the target network. Therefore, this cost function-based policy model estimates dynamic network conditions and includes a stability period (a waiting period before handoffs) to ensure that a handoff is worthwhile for each mobile.

The proposed policy-enabled handoff system allows users to express policies on what is the best network and when to handoff. To achieve flexibility, the system separates the decision making scheme from the handoff mechanism (routing table manipulation and sending location updates). To achieve seamlessness, the system considers user involvement (for policy specification) with minimal user interaction (for automation). To improve system stability in the handoff mechanism, load balancing solution is proposed avoiding the handoff synchronization problem (simultaneous decision by many mobiles). For that, we have implemented a performance agent that collects the information on the current bandwidth usage at base stations, and periodically announces this information to its coverage.

Since, all data traffic goes through base station they have the most accurate information on current bandwidth usage and the available bandwidth in the network. They solve the problem through a randomized stability period. We use the utility function (higher utility = target network), to evaluate the reachable wireless networks discovered (bandwidth and movement speed as factors) and to quantify the QoS (Quality of Service) provided by the wireless network on the mobile terminal. We introduce two adaptive handoff decision methods adjusting the stability period, according to the network resources and the running applications on the mobile terminal. In the proposed handoff scheme, the handoff decision method is preceded by a system discovery method (Algo-1). [10] The latter is based on an adaptive interface activating method that adjusts the interface activating interval relying on the distance between the mobile terminal and the base station. For that, an ideal coverage concept (i.e., the real coverage in a wireless overlay network) is introduced in which mobile terminal's position information and a Location Service Server can assist mobile terminal in deciding when to activate its interfaces (Algo-2). Thus, the system discovery method can balance the power consumption and system discovery time.

The proposed vertical handoff decision is based on a policy- based networking architecture (i.e., IETF framework). All the described decision strategies were evaluated on two types of networks: WLAN and WWAN such as GSM or GPRS.

In the simulations, the evaluated heterogeneous wireless networks consist of a single GSM network, 100 WLANs where WLANs are randomly deployed [11] . The topology covers an area 3000 m in length and 3000 m in width with 10 base stations. The number of mobile nodes ranges from 10 to 70 in the area of 100×100 m, and the mobility of random way point is adopted for each mobile node with random direction and random velocity from 1 to 25 m/s. The transmission range of GSM covers the whole area, where that of each WLAN is 100 m^2. The bandwidths of GSM, WLAN, are 384 kb/s, and 54 Mb/s respectively.

The simulation considers two classes of traffic, i.e., constant bit rate (CBR) and variable bit rate (VBR). The CBR traffic is assumed to arrive at the heterogeneous network to a Poisson distribution with arrival rate λ. The average holding time of the CBR traffic is exponentially distributed (μ), and its mean is normalized to unity. On the other hand, the VBR traffic is assumed to arrive based on a self similar model.

The RSS received by a mobile node is different when it uses different wireless networks.Several useful parameters for the simulations are summarized in Table I.

Table1: Simulation parameters for Vertical Handoff Evaluation

Simulation Parameter	Values
Area of Coverage for Simulation	3000(m)×3000(m)
Number of WLAN Access Points	100
Number of Base Stations	10
Transmission Range of WLAN	100 m
Transmission Range of GSM	1000 m
Path Loss Exponent (WLAN)	4.5
Path Loss Exponent (GSM)	2.8
Arrival Rate CBR	variable
Arrival Rate Self Similar Traffic	variable
Data Rate : WLAN	1.6 Mbps
Data Rate: GSM	384 Kbps
Mobility model (Random way Point)	Velocity (1-25 m/sec)

IV. RESULTS FOR CBSF VERTICAL ALGORITHMS

In case of CBSF we have evaluated the performance in terms of number of handoffs, handoff delay and dropping probability. The blocking probability is not evaluated since this is a heterogeneous network, because it is assumed that two different networks have already accepted the call/request from the mobile terminal. The RSS based algorithms are derivatives of the conventional handoff algorithms in homogeneous networks. In case of heterogeneous network we applied the same logic only difference is the propagation characteristics and the threshold is different for two networks.

Figure 2 shows the performance of vertical handoffs in discussion in terms of number of handoff requests generated. From the graphs we observe that for handoff algorithm based on RSS threshold performs similar to the handoff algorithm in homogeneous network. In this case also we observe the 'ping-pong' effect.[6] To improve the performance we have tested the network for handoff algorithm based on RSS with hysteresis, the results of simulation indicate that number of handoff requests have reduced by a factor of 10 for traffic of 100 packets per second. For algorithm-1 the numbers of requests are 2 times less as compared to RSS with Threshold based algorithm. The simulation results indicate that the algorithm-2 improves the performance by a factor of 1.6 as compared to algorithm-1.

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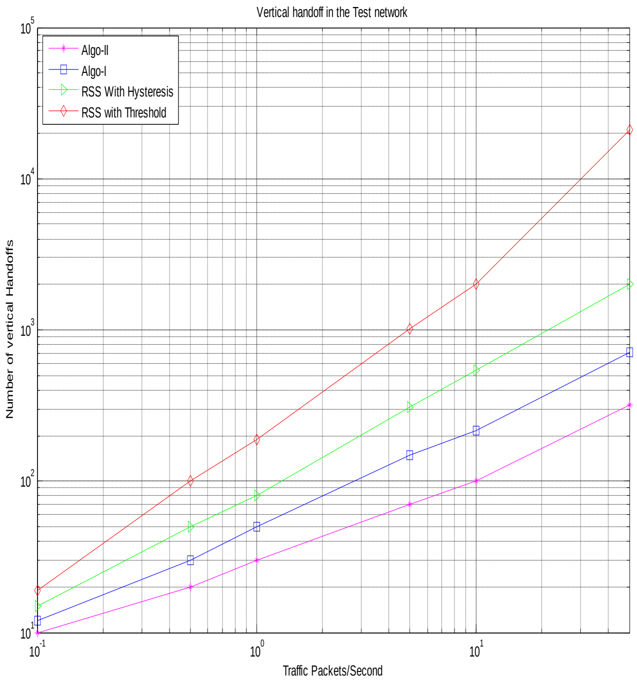

Figure1:Number of vertical handoffs requested for variable traffic (CBR)

In case of heterogeneous networks it important to evaluate the handoff process in terms of time taken by the mobile terminal to change of its link from one type of network to another. We call this as ‘handoff delay’. Figure .3 shows the performance of the network under test for variable traffic (CBR). It is observed that handoff algorithm-2 strategy results in maximum delay for handoff execution; this is due to time taken by both the networks to evaluate handoff requirement and passing on the information of requirement and availability of resources and confirming the handoff request. Further it is observed that the variability of the delay is very high with respect to the traffic variations ($\sigma = 452$ with mean delay of 64 ms). The delay of handoff algorithm-1 is less as compared to algorithm-1 ($\sigma = 244$ with mean delay of 45 ms).

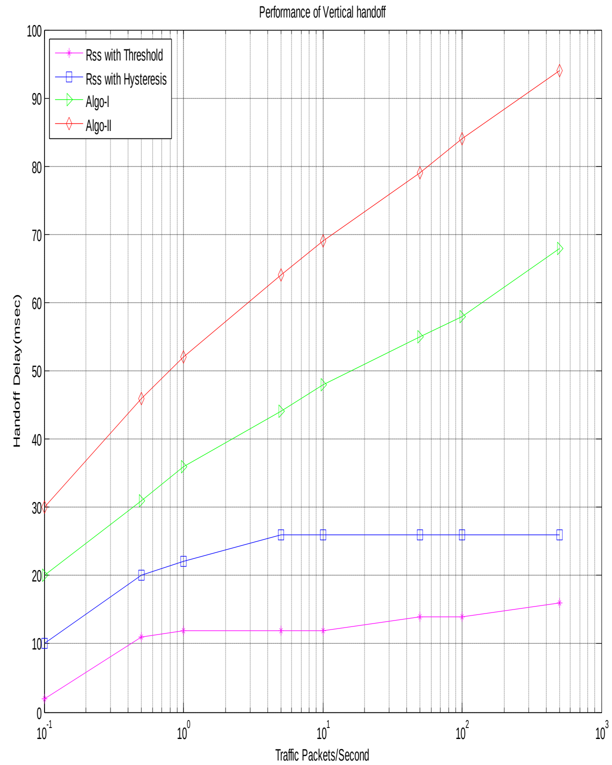

Figure:2 Handoff delay for vertical handoff execution for variable traffic (CBR).

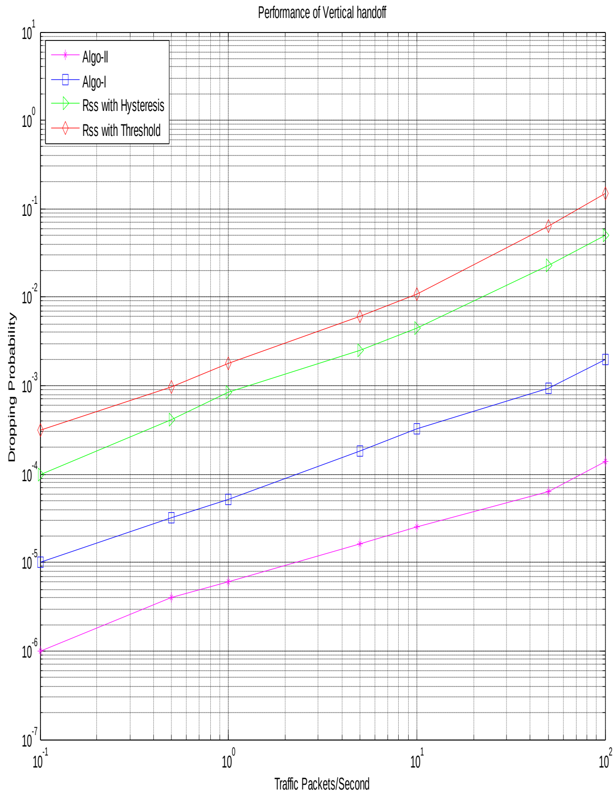

Figure 4: Dropping probability of vertical handoff for variable traffic (CBR)

As it is well known the delay characteristics of RSS based handoff algorithms is less and variance is low[1] . We observe the same effect in our experiment. The RSS with hysteresis executes handoff with mean delay of 22 ms and with variance of 31. For RSS with Threshold, the mean handoff delay is 11 ms and variance of 17.

In this research we are targeting the performance of the network to support uninterrupted service to the user hence we selected dropping probability as the prime performance metrics.

In our simulation experiment we computed the dropping probability for four vertical handoffs in discussion. Figure 4 shows the simulation results CBR traffic. Since we have considered a high performance network, the resource capabilities are assumed to be sufficient to get best possible performance.

That is the underlay network (WLAN) has 100 access points in single overlay network with 10 base stations (GSM). The results indicated in figure4 for RSS based algorithms show the dropping probability as low as 10^{-4} for RSS with hysteresis and 3×10^{-3} for RSS with Threshold for traffic of 10^{-1} packets per second.

From figure 4 we observe that alogorithm-1 and algorithm-2 outperform the RSS based handoff algorithms. Algorithm-2 gives 100 times better performance than RSS based handoff algorithms and 10 time better performance than algorithm-1. [3]

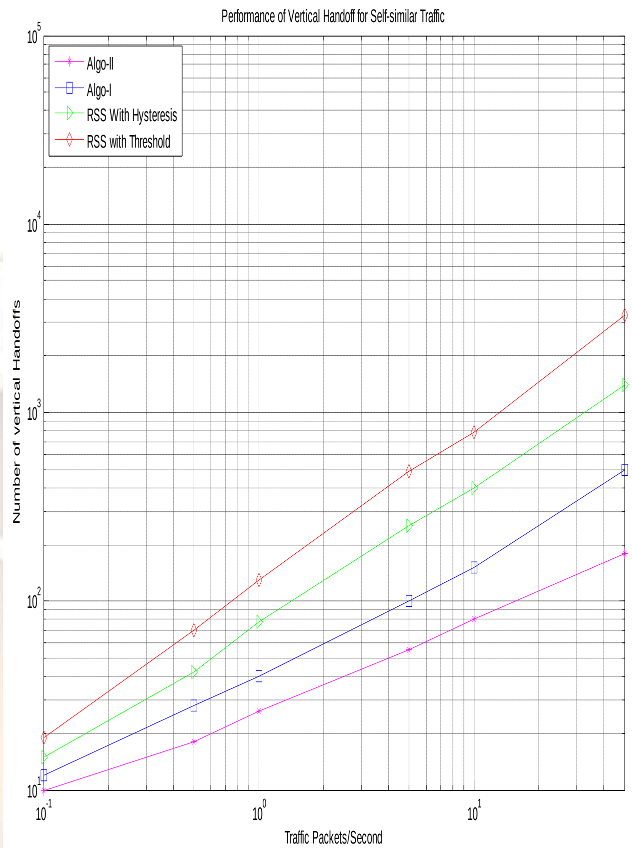

Figure 5: Number of Handoffs versus variable traffic (Self-similar Traffic)

Present day networks have been demonstrating a shift in the traffic pattern, called 'self-similar' traffic. Figure .5 shoes the simulation results of the network under consideration for number of handoff requests generated if the traffic is self-similar one.

From Figure .5 we observe that the vertical handoffs under consideration results into less number of handoff requests generated as compared to CBR traffic.Figure .6 shows the delay

Table2: Comparison of Delay Characteristics

	CBR Traffic		Self-similar Traffic	
	Mean	Variance	Mean	Variance
RSS with Threshold	11.625	17.6964	11	29.42
RSS with Hysteresis	22.75	31.92	22.37	54.83
Algo-I	45	244.28	41.12	185.83
Algo-II	64	452.78	57.37	303.12

Performance of the network under test for four vertical handoff algorithms under self-similar traffic condition can be observed. It is observed that the delay characteristics are similar in nature as were observed in CBR traffic condition. The only difference is in the mean delay and variance values.

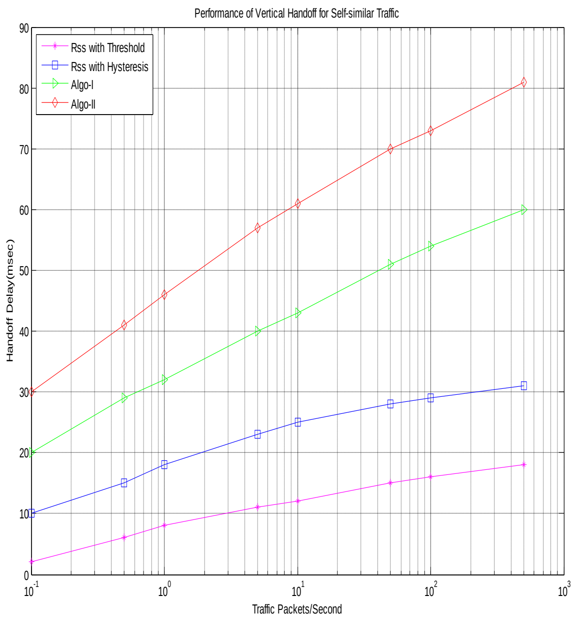

Figure 6: Handoff Delay of vertical handoff for variable traffic (Self-similar Traffic)

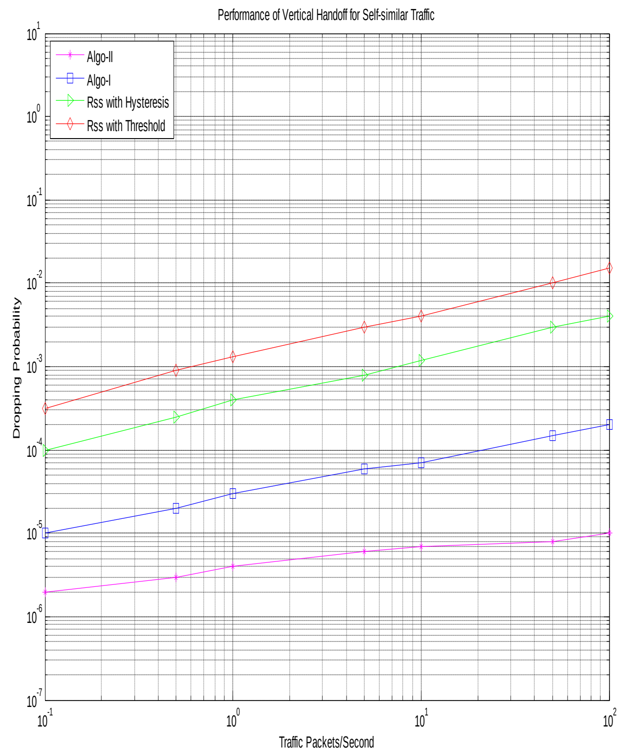

Figure 7: Dropping probability of vertical handoff for variable traffic (Self-similar Traffic)

Figure 7 shows the performance of the network for self-similar traffic in terms of dropping probability. It is observed that the dropping probability is less as compared to the values observed for CBR traffic. Table III shows the comparison of the two at traffic = 5 packets per second.

Table 3: Comparison of Dropping Probability (5 Packets per second)

	CBR Traffic	Self-similar Traffic
RSS with Threshold	0.0061	0.003
RSS with Hysteresis	0.0025	0.0008
Algo-I	0.00018	0.00006
Algo-II	0.000016	0.000006

V. CONCLUSION

To demonstrate the design of new context based handoff algorithm, the analysis and performance evaluation of CBSF vertical handoff, in which two variants have been designed and evaluated, has been presented first. Number of researchers dealt with the performance of vertical handoff for complexity, throughput, etc. In this research, the dropping probability and delay characteristics have been considered as the major performance metrics. To improve the performance of the network, a context aware handoff algorithm has been designed and shown that it out performs the adaptive vertical handoffs giving moderate rise in delay characteristics. Most importantly, the experimental work has been carried out to test the algorithms under considerations for CBR as well as self-similar traffic.

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