Reduction of Wrong Decisions for Vertical Handoff in Heterogeneous Wireless Networks

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ABSTRACT
Handover decision algorithms are essential components for the successful implementation of mobility which is the basic concept of mobile communication. These algorithms need to be designed to provide the required Quality of Service (QoS) to a wide range of applications while allowing seamless roaming among a multitude of access network technologies. Wrong decision probability is a performance metric which is used to measure the efficiency of handover algorithms in providing such seamless service. In this work, handover algorithms for the three network models are designed and compared with the two network models. The wrong decision probability model is used to predict the probabilities of missing handovers and unnecessary handovers. The traffic load of each network is varied based on the maximum bandwidth, number of neighboring networks and the advantage of having a dynamic decision time for handover has been studied. Analytical and simulation results are presented to validate the vertical handover for three network model.

Keywords- Wrong Decision Probability (WDP), Missing handovers, Unnecessary handovers, Vertical handover (VHO).

1. INTRODUCTION
After more than two decades of development, modern mobile cellular networks have now almost approached to the commercial level of fourth generation communication networks. For each of the mobile solutions, there are special attributes but also similarities compared to the other competitive solutions though relationship between the old and the new generation solutions still exists. During communication, the handover procedure is a very important concept that may affect the connection quality and continuity.
So, efficient and reliable vertical handover schemes and algorithms are required for seamless mobility between heterogeneous wireless access networks.
The co-existence of mobile cellular networks enables achieving higher data rates over a wider coverage area. Under such situations, several Media Independent Handover (MIH) proposals can handle the vertical handover scenario such as between wireless local area network (WLAN), Global Systems for Mobile communication (GSM) or Universal Mobile Telecommunications System (UMTS) through different solutions [1]. For a satisfactory user experience, mobile terminals must be able to seamlessly transfer to the ‘‘best” access link among all available candidates with no perceivable interruption to an ongoing conversation. Wireless Networks are complementary to each other, their integration will allow mobile users to be connected using the best available access network that fits their needs Hand over may be required, because a mobile device may experience degradation in the radio signal, or an access point may experiences heavy traffic [2]. It is important that QoS is maintained, not just before and after a handover, but also during the handover.Such ability to hand over between heterogeneous networks is referred to as seamless vertical handovers.

The handover algorithms can be based on different metrics like Bandwidth, Received Signal Strength, power level, user preference, network conditions, Network connection time, Bit Error Rate (BER), Signal to Interference Ratio (SIR), distance, traffic, velocity, application types, cost etc. There is no single technology that offers low cost, high-speed, nearly universal coverage, and a high QoS, all at the same time that suits different needs of the user [3]. Thus, these algorithms can be broadly classified based on RSS, BW, cost and also on a combination of some of the metrics considered for performing handover. The usage scenarios like handover delays, number of handovers, number of failed handovers due to incorrect decisions and the overall throughput of the call maintained over a typical mobility pattern can also be considered for the analysis of these handover algorithms [2].
WDP is a performance metric used to measure the accuracy of a handover algorithm which can be applied equally well for a homogeneous or a heterogeneous network [4] [5]. The probability of the algorithm making a wrong decision has to be evaluated in order to determine the efficiency of any algorithm. In this work, WDP has been used to measure the performance of a BW based vertical handover algorithm and the algorithm is evaluated for different decision times and different number of networks. A conclusion has been drawn that having a variable decision time and having ‘n’ number of neighboring networks reduces the probability of making a wrong decision. VHO analytical methods based on Wrong Decision Probability (WDP) are described in [6] and [7].
In [6] efficient vertical handover decision algorithm is developed involving cost differentiation in the network as a gain function and selecting the best network to handover based on overall gain function. In [7] the VHO decision is performed in order to limit unnecessary vertical handover leading to ping pong occurrences affecting the mobile terminal performance and a static decision time has been considered.
But since the unnecessary handoff leads to ping-pong effect and brings in low network throughput, longer handoff delay and high dropping probability [8], in our work it has been shown that the ping pong effect can further be minimized by considering a dynamic decision time and increasing the choice of available networks.
The paper is organized as follows. The analytical model for Two and Three network has described in section II. A Bandwidth based decision algorithm for Two network and Three network models has been proposed in section III along with the performance comparison of these two networks. Section IV concludes the paper.

2. ANALYTICAL MODEL
Consider two networks n_1 and n_2 with the maximum available bandwidth for these two networks as B_1 and B_2 respectively. In figure1 $P_{nj/ni}$ denotes the probability of mobile moving from network n_i to n_j; and $P_{ni/ni}$ denotes the probability of mobile continuing to stay in n_i after a time interval D. The Two network model can be treated as a two state Markov model and the probabilities that a mobile stays at n_1 and n_2 can be expressed as

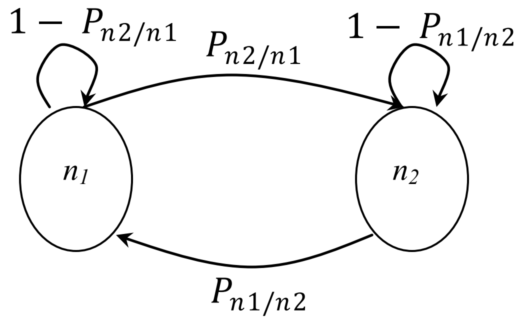

Figure 1: Two state Markov Model

$$P_{n1} = \frac{Pn\,1/n\,2}{Pn\,1/n\,2 + Pn\,2/n\,1} \quad \text{(a)}$$

and

$$P_{n2} = \frac{Pn\,2/n\,1}{Pn\,1/n\,2 + Pn\,2/n\,1} \quad \text{(b)}$$

respectively.

Fig. 2 shows the layout of a Three network model having three networksn1n1 n_1, n_2 and n_3; and the maximum available bandwidth for the Three networks are, B_1,B_2 and B_3 respectively. Pn_j/Pn_i denotes the probability of mobile moving from network n_i to n_j; and Pn_i/n_i denotes the probability of mobile continue to stay in n_i after a time interval *D*. The Three network model can be treated as a three state Markov model and the probabilities that a mobile stays at, n_1, n_2 and n_3 can be expressed as

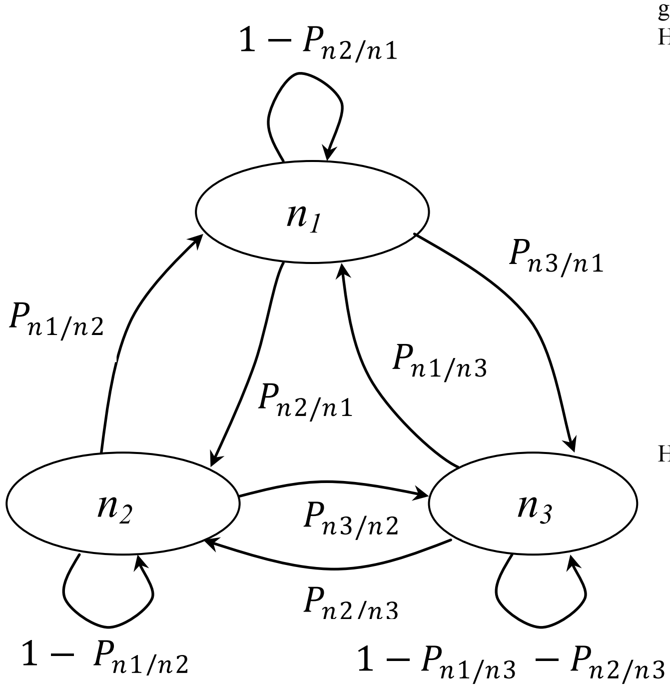

Figure 2: Three state Markov Model

$$P_{n1} \qquad Pn1/n2 + P_{n1/n3} \quad (1)$$

and

$$P_{n2} \qquad Pn2/n1 + P_{n2/n3} \quad (2)$$

and

$$P_{n3} \qquad Pn3/n1 + P_{n3/n2} \quad (3)$$

respectively.

3. GENERAL ALGORITHM

In this algorithm, a mobile decides to move to another network when its available bandwidth in the new network is greater than by a threshold over the available bandwidth of current network. However, the value of the threshold value can be zero or a positive integer. Following list of steps describe the algorithm designed in this work:

1. Assume that mobile in the network n_1 and wants to move to another network assuming the networks n_2 and n_3 can provide the service where the user wants to move to.
2. Define the threshold value as *L*.
3. If the mobile is at n_1, then decision is made to switch over n_2 when $b2 - b1 \geq L$,
4. Else verify $b3 - b1 \geq L$ and switch over to n_3 if $b3 - b1 \geq L$ is true.
5. Else maintain the status quo.

Practically the available bandwidth of any network changes dynamically, and some times rapidly. For simulations purposes, the bandwidths of the networks are assumed to be static. All the analytical expressions listed in the previous section are based on the general algorithm defined above.
Hence,

$$\left.\begin{aligned} P_{n2/n1} &= P_r\,(b_2 - b_1 \geq L), \quad (4) \\ P_{n1/n2} &= P_r\,(b_1 - b_2 \geq L), \\ P_{n3/n2} &= P_r\,(b_3 - b_2 \geq L), \\ P_{n2/n3} &= P_r\,(b_2 - b_3 \geq L), \\ P_{n3/n1} &= P_r\,(b_3 - b_1 \geq L), \\ &\text{and} \\ P_{n1/n3} &= P_r\,(b_1 - b_3 \geq L) \end{aligned}\right\}$$

Handover probabilities for such an arrangement is given by

$$\left.\begin{aligned} HP = \frac{1}{3}\,[&P_{n1}(P_{n2/n1} + P_{n3/n1}) + \\ &P_{n2}(P_{n1/n2} + P_{n3/n2}) + \\ &P_{n3}(P_{n1/n3} + P_{n2/n3})] \end{aligned}\right\}$$

3.1 Unnecessary Handover

Unnecessary handover is a major issue leading to two problems in the network- firstly it increases the network load since each handover requires network resources and secondly it causes shortage in

channel resources leading to call dropping. Hence an efficient handover algorithm which increases the efficiency of handover decision process is proposed in this paper.
The probability for the unnecessary handover is computed using MATLAB and the results are presented in the following plots. Simulation results are presented for the cases where number of the channel are 21 and decision times are 2 and 3 ms. Two different values of decision time are taken to show that having dynamic decision time is more advantageous than static decision time.

Unnecessary handover Probabilities for Two and Three network models are computed for conditions like the maximum bandwidth available, decision time and threshold value. Fig 3 shows the comparison of the probabilities for the both these network models for a case with decision time of 1 ms . It is clear from the plots that there is a good amount of reduction in the unnecessary handover for the three network model compared to the two network model.

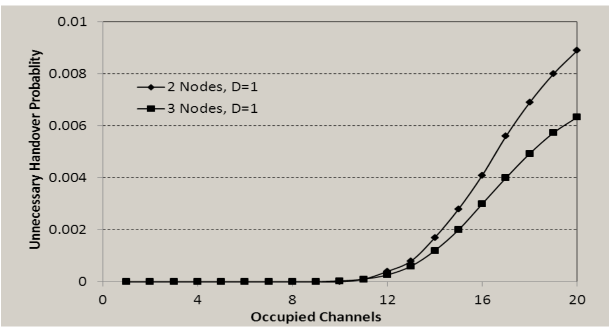

Figure 3: Unnecessary Handover Probability Vs Occupied number of channels for two and three network models for D = 1 ms

Fig. 4 shows the unnecessary handover for the Two and Three network model for same conditions but with increase in decision time to 3 ms. By comparing Figs. 2 and 3, it can be concluded that with increase in decision time, the probability of unnecessary handover decreases for both the networks with an increased D. It is obvious that with more delay in the decision making, the probability that the available bandwidth in the present network changing will be more.

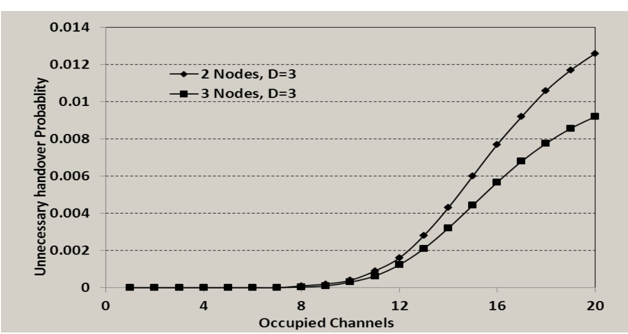

Figure 4: Unnecessary Handover Probability Vs occupied number of channels for two and three network models for D = 3 ms.

3.2. Missing Handover

The missing handover is the major issue, leading to two problems in the network- firstly it increases the network load since each handover requires network resources and secondly it causes shortage in channel resources leading to call dropping.

The problem arising due to Unnecessary Handover and Missing handover is the same since both are complementary process.
The same network conditions used for analyzing the probability of unnecessary handover has been used for analyzing missing handovers Fig. 5 shows the comparison of the probabilities for the both these network models for a case with decision time of 2 ms. Based on the probabilities computed, it is clear that there is a good amount of reduction in the missing handover.

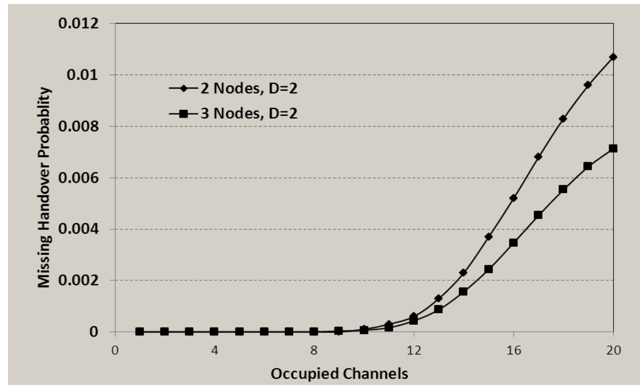

Figure 5: Missing Handover Probability Vs Occupied number of channels for Two and Three network models for D = 2 ms.

Fig. 6 shows the missing probabilities for the Two and Three networks for the case with a decision time of 4 ms. By comparing Figs. 5 and 6,it can be concluded that with increase in decision time, the probability of missing handover increases for both the networks with an increased D. It is obvious that with more delay in the decision making, the probability that the available bandwidth in the present network itself changes will be more.

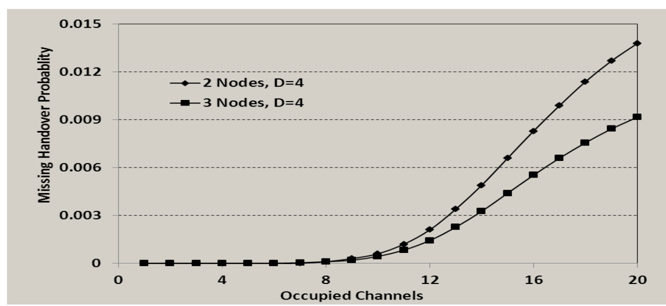

Figure 6: Missing Handover Probability Vs Occupied number of channels for Two and Three network models for D = 4 ms.

3.3. Wrong Decision Probability

The WDP is calculated by combining the probability of unnecessary and missing handovers. $WDP = UHP + MHP$

The proposed algorithm is able to reduce the WDP and balance the traffic load with increase in choice of available neighboring networks.
Figs. 7 and 8 shows the probabilities for the Wrong decision probability vs the occupied number of channels when the maximum channel band widths available in both the networks are 21. Higher the decision time, more the probability of wrong decision making. Assuming For a set threshold of 0.9% of WDP (fig 7) it is seen that there is a significant reduction of wrong decisions as the choice of available network increases.

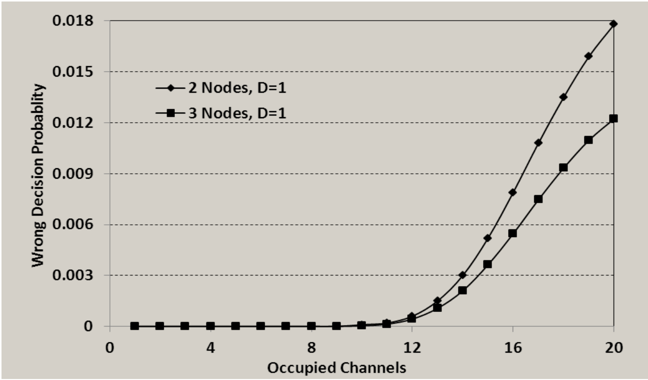

Figure 7: Wrong Decision Probability Vs Occupied number of channels for Two and Three network models for D = 1 ms.

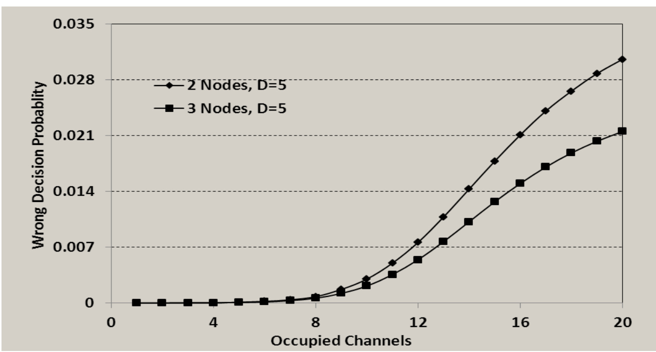

Figure 8: Wrong Decision Probability Vs Occupied number of channels for Two and Three network models for D = 5 ms.

Alternatively, the following algorithm may be used to further reduce the Wrong Decision Probabilities:

1. Assume that mobile in the network n_1 and wants to move to another network assuming the networks n_2 and n_3 can provide the service where the user wants to move to.
2. Define the threshold value as *L*.
3. If the mobile is at n_1, then decision is made to switch over when $b2 - b1 \geq L$, else verify $b3 - b1 \geq L$ and switchover to n_3 if $b3 - b1 \geq L$ is true.
4. In case $b2 - b1 \geq L$, then verify $b3 - b1 \geq L$. If both are true, then calculate the WDP for both the network and switch over to that network which has least WDP and at least less by 50% than the other.
5. In case the difference between WDP of both the network links less than 50%, the reduce the decision time by $1/10^{th}$ and calculate the WDP and take decision.
6. Repeat the same until the decision to handover is achieved.

4. CONCLUSIONS

In this work, WDP has been used to predict the probabilities of missing handovers and unnecessary handovers for different decision times, different bandwidths and larger number of available networks for performing handover leading to an increase in the thruput. The focus is on minimization of WDP (UHO/MHO). Through continuous monitoring of Bandwidth, Decision times and number of neighboring networks it is possible to estimate WDP in order to limit call dropping and minimizing network load. Higher the decision time, more the probability of wrong decision making due to the obvious reason that with more delay in the decision making, more the probability that the available bandwidth in both the present and other network changes which leads the wrong decision making. There is significant improvement in the reduction of wrong decision making when two network models is replaced by a three network model and also the ping-pong effect caused due to unnecessary handoff has been reduced which indicates that with increase in choice of neighboring networks effect of WDP can be minimized but with an obvious tradeoff between cost and number of networks. Further, parameters like Signal Strength and Mobility can be considered for analyzing the effect of WDP on handover decision algorithms.

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