A Novel Approach to Reduce the Handover Probabilities due to Wrong Decision

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Abstract: ***In this work a novel method is proposed to compute the wrong decision probability, unnecessary handover probability and missing handover probability. Three different criteria, namely, bandwidth, BER and signal strength are considered in different combinations to determine the handover probabilities. The simulations are conducted for 5 node network model. Probability equations are inferred for a general handover models. Signal strength is added to the criteria to reduce the probabilities and BER is added to capture the uncertainties better in the data transmission, while bandwidth is a network parameter. The decision times are varied to understand the effect on the handover probabilities. Results are presented for a case 16 channels in the networks. It has been demonstrated with the simulations that handover probabilities can be reduced by adding signal strength to the list of criteria while retaining all the uncertainties in the data transmission.***

Keywords: Unsuccessful handovers, wrong decision, unnecessary handover, missing handover

1. Introduction

Mobile nodes are handed over from one network to another network based on certain criteria like available bandwidth, signal strength or speed of movement of the mobile device. For example, if the available bandwidth is higher in the target network than that of the host network then handover is initiated. If the free bandwidth in target network is less than the host network, then handover is not started. The algorithms used in handovers based on available bandwidth are presented in ref [1-3]. Similarly, signal strength can also be used as the criteria for the handover. The algorithms based on the signal Strength as the criteria are presented in [4-8]. Nie et al developed an algorithm that utilized both free bandwidth and signal strength as the criteria. Authors [6] considered IEEE 802.11 and IEEE 802.16a as the benchmark to test the performance of the algorithms. At each network node both the free bandwidth and the signal strength are sampled to verify between the hosts and target network.

Sudipta Patowary et al. presented an algorithm in which signal interference/noise ratios as well as free bandwidth are used as the criteria [8]. In this method the signal interference/noise ratio of the GPRS is converted to the is known as missing handover probabilities. The total of unnecessary and missing handover probabilities is known as wrong decision probability.

In ref [10] authors used three network nodes instead of two. The probability equations were derived for the Markov chain model of three node network. The equations were derived by extending the equations of the two node network. In this work authors used only free bandwidth as the handover criteria. In another research work [11] authors extended the models developed in [10] to larger bandwidth networks based on the same handover criteria. The problem

equivalent factors of the Wi-Fi. Similarly the factors of Wi-Fi were also converted to the equivalent factors of GPRS for the purpose of comparison. A limitation of this approach is if the variation in the criteria is too high then the number of handovers is very high resulting in the ping-pong effect [9].

One of the important works in the space of handovers based on probability models was developed by Chi et al. [2]. Authors introduced the concepts of missing handover probability, unnecessary handover probability and wrong decision probability. These probability definitions were explained with the help of a Markov chain model. A two node network was modeled and the hand over criterion process, if the free bandwidth in the target network is higher than that of the host network, handover is started. But there is a possibility of change of conditions in the target or host network by the time the handover actually happens. If the conditions reverse, i.e. the free bandwidth is less in the target network than host network, it results in unnecessary handover. Similarly if the decision of handover is not initiated based on the fact that free bandwidth at the target network is less than that of the host network but if the condition gets reversed at the end of decision time then the handover is missed to happen. This type of probability of computing the factorials that appear in the probability equations was addressed in this work.

The models were further extended to consider the signal strength also as the criteria for handover [12]. The models were developed for three node networks. The models were developed for free bandwidth and signal strength separately. Also the combined criterion was considered for handovers as a third case. It was proved that missing handover probability; unnecessary handover probability and wrong decision probability were reduced when both free bandwidth and signal strength were considered as the handover criteria instead of considering free bandwidth alone. The two node network was extended to mobile nodes which are in multiple states and the details are presented in ref [13]. The numerous states considered in the exploration work were selfish state, cooperative state, malicious state and failed state. Later the probability models created as a major aspect of the prior research work [2, 10] was extended to a five node network. The handover criterion was again founded on free bandwidth available in the network. The approach was similar to that of ref [10] but the equations are very complex since the models were extended to 5 nodes from 2 nodes.

The probability modeling of multi node wireless networks is exhibited in the ref [14]. Number of network nodes considered in this was five. As the quantity of nodes expanded, the complexity of probability equation additionally turns out to be increasingly complex. The models were pertinent for cellular networks. It is again the expansion of the probability models proposed in [2] and [10]. In this work, the availability of free bandwidth in five nodes is considered as the paradigm for handover. Comparison between 2 nodes, 3 nodes and 5 nodes was presented in [15] and it has been shown that probabilities are lower in 5 nodes network and hence the lesser ping pong effect.

In [16], authors modeled the variation in signal strength with Gaussian distribution and normalized probabilities along with the free bandwidth. The unnecessary handover probabilities have reduced and hence this approach can be used to reduce the overall wrong decision probabilities. The modeling approach was further improved by considering multiple states like selfish state, cooperative state, malicious state and failed state [17, 18]. It has been demonstrated that the wrong decision probabilities could be reduced with the multiple states approach.

2. Physical Model and Handover Approach

If there are n network nodes [2] then the probability that a mobile node continue to present in the current network node can be represented as complement of all the probabilities of mobile node moving from network node n to any other node. The probability equation can be expressed as,

$$P_{n/n} = 1-\left(P_{1/n} + P_{2/n} + \ldots\ldots + P_{n-1/n}\right) \quad (1)$$

Probability that the mobile device present in the network node n is given by,

$$P_n = \frac{P_{n/1} + P_{n/2} + \ldots. + P_{n/n-1}}{P_{1/n} + P_{n/1} + \ldots\ldots + P_{n-1/n} + P_{n/n-1}} \quad (2)$$

Where

$$P_n = \frac{\sum_{i=1}^{n-1}\left[P_{n/i}\right]}{\sum_{i=1}^{n-1}\left[P_{n/i} + P_{i/n}\right]} \quad (3)$$

The probability of mobile device moving from network node 1 to network node 2 is equal to the probability of (BWidth2-BWidth1 >L _threshold), where L is the threshold limit. That means if the BWidth2 is greater than BWidth1 by L_threshold number of free channels, then the decision for handover happens.

$$P_{n-1/n} = P\left\{BWidth_{n-1} - BWidth_n \geq L\_threshold\right\} \quad (4)$$

Handover probabilities for such an arrangement are given by,

$$P_{handover} = \frac{1}{n}\left\{\sum_{i=1}^{n} P_i\left[\sum_{\substack{j=1\\ j\neq i}}^{n} P_{j/i}\right]\right\} \quad (5)$$

Let, the probability of occupied bandwidth is expressed by,

$$\Pi_{n,k} = \frac{\left[\rho_i^k\right]}{k!\sum_{j=0}^{A_i}\left[\frac{\rho_n^j}{j!}\right]} \quad (6)$$

Where ρ_i is the load in network node *i*.

For an M/M/B process, the call arrival rate follows a Poisson's distribution with a parameter representing the mean of the distribution λ_i and service rate is given by,

$$\Psi_i = \lambda_i\left[BWidth_i - k\right]/\left[BWidth_i\right] \quad (7)$$

$$P_{unnecesary} = \sum_{i=1}^{n}\sum_{\substack{j=1\\ j\neq i}}^{n} P_i P_{j/i} \sum_{m=X}^{BWidth_j} \Pi_{j,BWidth_j-m}$$
$$\sum_{k=0}^{m-X} \Pi_{i,BWidth_i-k}\, \Omega_i\left(k,r,t\right) \bullet \sum_{n=0}^{A_i} \Pi_{i,BWidth_i-n}$$
$$\sum_{k=n+X}^{BW_j} \Pi_{j,BWidth_j-k}\, \Phi_j\left(k,r,t\right) \quad (8)$$

Where $P_{unnecesary}$ the probability that handover has happened unnecessarily, while the conditions are not favorable in the target network node.

$$P_{missing} = \sum_{i=1}^{n}\sum_{\substack{j=1\\ j\neq i}}^{n} P_i\left(1-P_{j/i}\right) \sum_{n=0}^{BWidth_i} \Pi_{i,BWidth_i-n}$$
$$\sum_{k=0}^{n+X-1} \Pi_{j,BWidth_j-k}\, \Omega_j\left(k,r,t\right) \bullet \sum_{m=X-1}^{BWidth_J} \Pi_{j,BWidth_j-m}$$
$$\sum_{k=m-X+1}^{BWidth_i} \Pi_{i,BWidth_i-k} \Phi_i\left(k,r,t\right) \quad (9)$$

Where $P_{missing}$ the probability that handover has missed to happen while the conditions are favorable in the target network node.

Where,

$$\Omega_i\left(k,r,t\right) = \sum_{p=0}^{BWidth_i-k} \frac{\left(\Psi_i t\right)^p}{p!} e^{-\Psi_i t} \bullet \sum_{q=0}^{p+k-r} \frac{\left(\lambda_i t\right)^q}{q!} e^{-\lambda_i t} \quad (10)$$

And

$$\Phi_i\left(k,r,t\right) = \sum_{p=0}^{BWidth_i-k} \frac{\left(\Psi_i t\right)^p}{p!} e^{-\Psi_i t} \bullet \left[1 - \sum_{q=0}^{p+k-r} \frac{\left(\lambda_i t\right)^q}{q!} e^{-\lambda_i t}\right] \quad (11)$$

The unsuccessful handover probability due to incorrect decision is given by,

$$P_{wrong} = P_{unnecessary} + P_{missing} \quad (12)$$

In mobile networks, the serious issue occurs because of the interference of signals originating from the mobile units.

From this interference between the signals and because of blurring of the signal, the strength of the signal is lost and the information stored in the form of data packets will get disturbed and hence the original data packet sent and the one received will be totally different. For instance, if a specific packet of 1 0 1 0 0 0 1 1 1 0 is sent by the access point and if the received packet is 1 1 0 0 0 0 0 1 1 1, which has the bits at positions 2, 3, 7 and 10 are disturbed and distorted due to interference between the signals and due to fading. The distortion of the packets received with respect to packets sent may be approximated with the help of the Bit Error Rate (BER).

The Bit Error Rate may be defined as proportion between no. of wrong bits received to the total number of actual bits transmitted. BER provides estimate as the percentage of wrong bits received.

$$\text{BER} = \frac{\text{Number of incorrect bits received}}{\text{Total number of bits transmitted}} \tag{13}$$

Or

$$\text{BER} = \frac{\text{Number of incorrect bits received per sec}}{\text{Total number of bits transmitted per sec}}$$

It can be considered as an incorrect bit if 1 was transmitted, and 0 was received in its place. It is also considered as an incorrect bit if 0 was transmitted and 1 was received in its place. The noise in the signal is assumed to follow the Gaussian distribution, and the signals have means I_1 and I_0 for 1 and 0 respectively; and $\sigma 0$ and $\sigma 1$ are standard deviations of 1 and 0. Assume that there is a threshold for the

$$BER = \frac{1}{2}[P(0/1) + P(1/0)] \tag{14}$$

Where,

$P(0/1)$: Probability that 0 was received instead of 1

$P(1/0)$: Probability that 0 was received instead of 0.

Probabilities $P(0/1)$ and $P(1/0)$ are given by,

$$P(0/1) = \frac{1}{\sigma_1\sqrt{2\pi}}\int_{-\infty}^{I_{th}} exp\left[\frac{(I-I_1)^2}{\sigma_1^2}\right] dI \tag{15}$$

$$= \frac{1}{2} erf\left[\frac{(I_1-I_{th})}{\sigma_1\sqrt{2}}\right]$$

$$P(1/0) = \frac{1}{\sigma_0\sqrt{2\pi}}\int_{I_{th}}^{\infty} exp\left[\frac{(I-I_0)^2}{\sigma_0^2}\right] dI \tag{16}$$

$$= \frac{1}{2} erf\left[\frac{(I_{th}-I_0)}{\sigma_0\sqrt{2}}\right]$$

The error function is defined as,

$$erf(p) = \frac{2}{\sqrt{\pi}}\int_x^{\infty} exp[q^2]\, dq \tag{17}$$

Hence, the BER can be written as,

$$BER = \frac{1}{4}\left[\frac{1}{2} erf\left[\frac{(I_1-I_{th})}{\sigma_1\sqrt{2}}\right] + \frac{1}{2} erf\left[\frac{(I_{th}-I_0)}{\sigma_0\sqrt{2}}\right]\right] \tag{18}$$

$$\text{Let, } Q = \frac{I_1-I_0}{\sigma_1+\sigma_0} \tag{19}$$

Q may be defined as the fractional noise margin.

The BER can be approximated as,

$$BER \approx \frac{1}{Q\sqrt{2\pi}} exp\left[-\frac{Q^2}{2}\right] \tag{20}$$

The Received signal strength is given by,

$$s(t) = \rho(t) \bullet \cos(2.\pi.f_c.t + \theta(t)) \tag{21}$$

$$\rho(t) = \sqrt{I^2(t) + Q^2(t)} \tag{22}$$

Where *I (t)* and *Q (t)* are In-phase and Quadrature components. Probability of amplitude of received signal strength is

$$\Pr(\rho) = \frac{\rho}{\sigma^2} e^{\frac{-\rho^2}{2\sigma^2}} \tag{23}$$

Total probabilities are the products of probabilities due to parameters like bandwidth difference, BER and Signal strength.

3. Simulation Results

Simulations are run for three cases, namely, unnecessary handover, missing handover and total handover due to wrong decisions. The number of channels is set to be 16. The decision time has been varied at from 1ms to 5ms at an interval of 1ms. The simulations are run for three criteria:

1) Bandwidth (BW)
2) Bandwidth and BER (BW+BER)
3) Bandwidth, BER and Signal Strength (BW+BER+SIG)

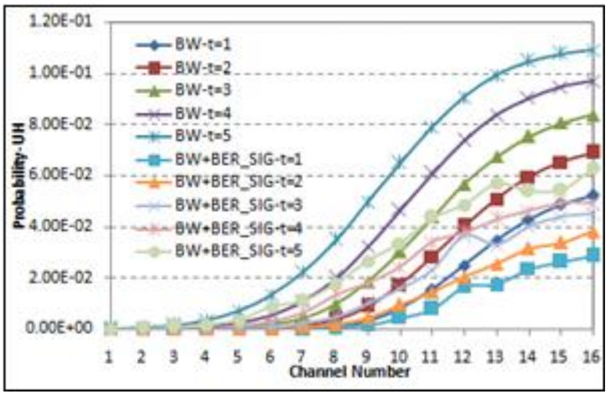

Figure 1: Probability of the handover that has happened unnecessarily based on BW and BW+BER+SIG

Fig. 1 shows the probability of the handover that has happened unnecessarily based on Bandwidth (BW) and Bandwidth, BER and Signal Strength (BW+BER+SIG) with respect to number of occupied channels. It can be observed that unnecessary handover probability increases as the number of occupied channels increase. Also, the unnecessary handover probability increases as the decision time increases. When the number of occupied channels increases, number of free channels becomes less and hence there is a chance for more unnecessary handovers. When there is more time available for decision making, there is more chance that the condition will change on the other side. Therefore the unnecessary handover probability increases with number occupied channels and decision time. When only bandwidth is considered as criteria, the maximum unnecessary handover probability is 0.1 and it is 0.062 when Bandwidth, BER and Signal Strength (BW+BER+SIG) are considered as criteria. Therefore it is possible to reduce the unnecessary handovers by adding BER and Signal Strength as criteria.

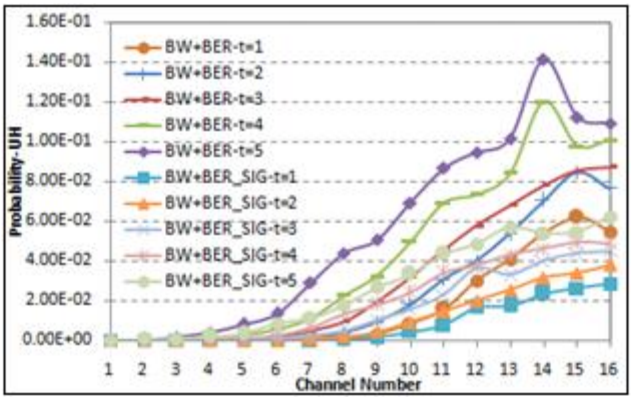

Figure 2: Probability of the handover that has happened unnecessarily based on BW+BER and BW+BER+SIG

Fig. 2 shows the probability of the handover that has happened unnecessarily based on Bandwidth and BER (BW+BER) and Bandwidth, BER and Signal Strength (BW+BER+SIG) with respect to number of occupied channels. When only bandwidth was considered as criteria, the maximum unnecessary handover probability was 0.1, with bandwidth and BER, it is 0.14 and it is 0.062 when Bandwidth, BER and Signal Strength (BW+BER+SIG) are considered as criteria. By adding the BER to the BW criteria, the maximum probability increased from 0.1 to 0.14, which is due to the reason that BER adds more uncertainty.

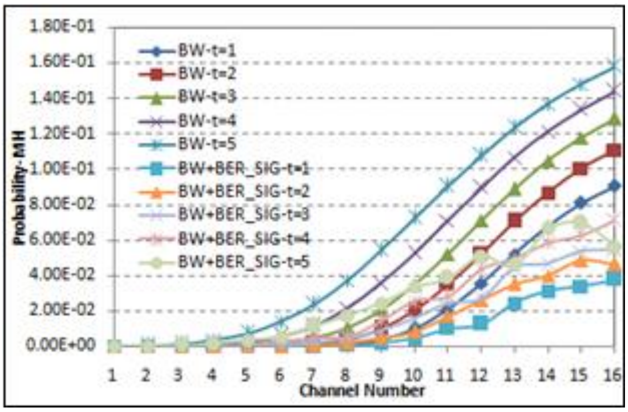

Figure 3: Probability of the handover that has missed to happen based on BW and BW+BER+SIG

Fig. 3 shows the probability of the handover that has missed to happened which is based on Bandwidth (BW) and Bandwidth, BER and Signal Strength (BW+BER+SIG) with respect to number of occupied channels. It can be observed that missing handover probability increases as the number of occupied channels and decision time increase. When only bandwidth is considered as criteria, the maximum missing handover probability is 0.155 and it is 0.075 when Bandwidth, BER and Signal Strength (BW+BER+SIG) are considered as criteria. With BER and Signal strength, the missing handover probability reduced by around 50%. Therefore it is possible to reduce the missing handovers by adding BER and Signal Strength as criteria.

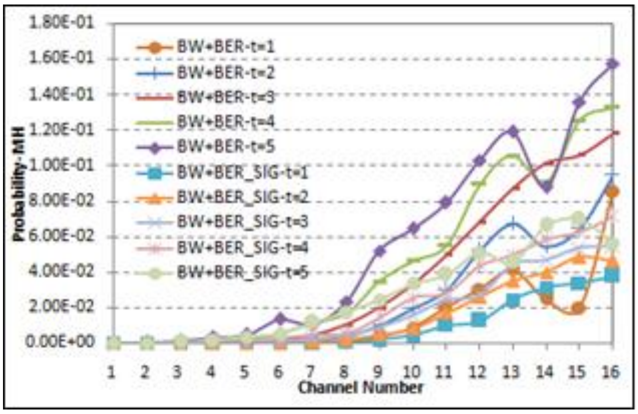

Figure 4: Probability of the handover that has missed to happen based on BW+BER and BW+BER+SIG

Fig. 4 shows the probability of the handover that has missed to happen based on Bandwidth and BER (BW+BER) and Bandwidth, BER and Signal Strength (BW+BER+SIG) with respect to number of occupied channels. When only bandwidth is considered as criteria, the maximum missing handover probability is 0.155, 0.158 and 0.075 when Bandwidth; Bandwidth and BER; and Bandwidth, BER Signal Strength (BW+BER+SIG) are considered as criteria respectively. With BER and Signal strength, the missing handover probability reduced by around 50%. Therefore it is possible to reduce the missing handovers by adding BER and Signal Strength to Bandwidth as criteria.

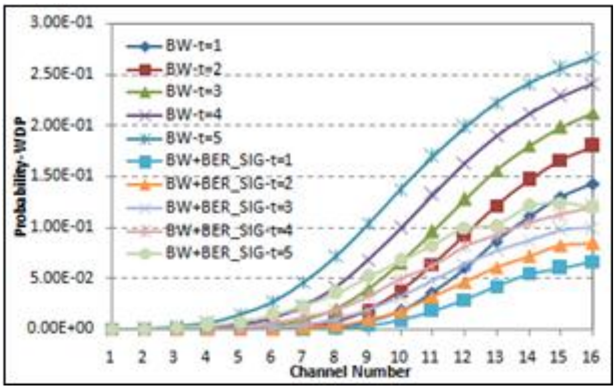

Figure 5: Probability of the handover that has happened due to wrong decision based on BW and BW+BER+SIG

Fig. 5 demonstrates the probability of the handover due to wrong decision dependent on Bandwidth (BW); and Bandwidth, BER and Signal Strength (BW+BER+SIG) with respect to number of occupied channels. It can be observed that handover probability due to wrong decision increases as the quantity of involved channels and decision time increase. When only bandwidth is considered as criteria, the maximum handover probability due to wrong decision is 0.255 and it is 0.137 when Bandwidth, BER and Signal Strength (BW+BER+SIG) are considered as criteria. With BER and Signal strength, the missing handover probability reduced by around 53%.

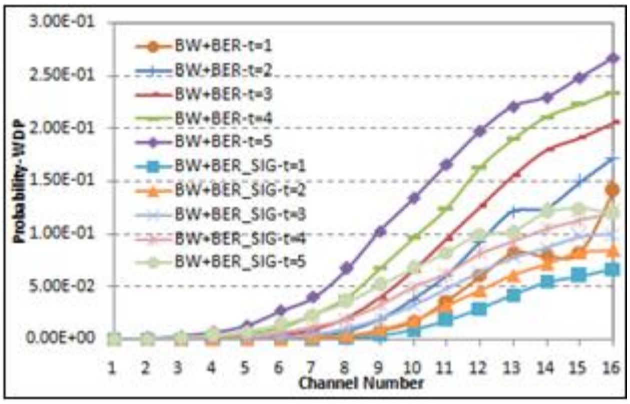

Figure 6: Probability of the handover that has happened due to wrong decision based on BW+BER and BW+BER+SIG

Fig. 6 shows the probability of the handover due to wrong decision based on Bandwidth and BER (BW+BER) and Bandwidth, BER and Signal Strength (BW+BER+SIG) with respect to number of occupied channels. When only bandwidth is considered as criteria, the maximum probabilities of the handover due to wrong decision are 0.255, 0.275 and 0.137 when Bandwidth; Bandwidth and BER; and Bandwidth, BER Signal Strength (BW+BER+SIG) are considered as criteria respectively. With BER and Signal strength, the missing handover probability reduced by around 49%.

4. Conclusion

In this work, simulation are performed for the unnecessary handover, missing handover and total probability of handover due to wrong decision for the criteria bandwidth alone, bandwidth and BER; bandwidth, BER and Signal strength. The bandwidth is a network dependent criterion, BER is a data transmission criterion and signal strength is the environmental and noise criterion. When BER is added to criteria of bandwidth alone, the probabilities increase. In order to reduce the probabilities, it has been demonstrated that signal strength also can be considered in the criteria along with bandwidth and BER. With bandwidth, BER and Signal strength, the total probabilities due to unnecessary handover, missing handover and wrong decision drops by about 50%. Hence it can be concluded that signal strength can be added to the criteria to reduce the probabilities and BER can be added to capture the uncertainties better in the data transmission.

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