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Vertical Handover Triggering Condition Estimation for a Mobile Node Moving Out of a WiFi Cell

***Abstract**. In this work we estimate the handover trigger condition for a mobile node moving out of a WLAN cell roaming in a heterogeneous network environment by performing vertical handover using an end-to-end handover scheme. Determining the characteristics of the handover latency of the employed handover scheme we estimate the appropriate handover triggering instance so as to maximize the WiFi usage but limit the handover failure. The remaining time within the WiFi cell is determined through successive changes in received signal strength as the mobile node moves out of the WiFi coverage cell.*

***Streszczenie.** W pracy określono warunki trigera przełączania (handover) w mobilnym węźle komórki WLAN w środowisku sieci niejednorodnej. Określając opóźnienie przełączania określano sytuację przełączania tak aby maksymalizować użycie sieci WiFi ale ograniczać błąd przełączania. (**Określanie warunków trigera przełączania typu handover w mobilnym węźle komórki WiFi**)*

Keywords: Vertical handover, handover triggering condition estimation, handover failure probability.
Słowa kluczowe: przełączanie – handover, trigger

Introduction

Determination of optimum handover initiation time is particularly of prime importance in the context of optimization of vertical handover from the WiFi network, which is characterized by fast and low cost of access but limited coverage range. Desire to maximize its usage is obvious, however, handover triggering close to the boundary region may lead to handover failure. Delaying the handover trigger for a moving out mobile node increases the probability of handover failure due to insufficient time for handover completion. For a given probability of handover failure the instance of handover trigger is estimated. In this work we use a geometrical model for handover triggering condition estimation. This work aims to estimate the handover triggering condition of the mobile node using an end-to-end vertical handover scheme.

Geometrical and Analytical Model

1) Determination of remaining time in WiFi cell

In order to conserve the battery power of the limited power mobile node frequent monitoring of RSS is triggered only when the RSS falls below a predefined threshold value (P_{th}). Once the monitoring begins we record the changes in the successive readings of RSS. This helps us in determining the expected time after which requirement of handover would become inevitable. The change in the RSS embeds the information of direction, speed and the effect of the changing surroundings of the mobile node. Some suggested schemes in the literature determine the candidate target network by making use of GPS to get the position, speed and direction of the mobile node [4], [5], [6]. These schemes not only require availability of GPS on the mobile node, but also, the information does not take into account the impact of changing terrain of a mobile node.

Ignoring the shadowing effect, we assume circular WiFi cell and linear motion of the mobile node as it covers the length from the distance corresponding to P_{Th} and reaches the boundary of the WiFi Access Point (AP) corresponding to P_{min} as shown in Fig. 1.

Let t_{HO} is the mean handover delay and the observed power at time instance t_n is P_n. t_{rem}, the remaining time before the mobile node will have received signal strength below receiver sensitivity level of P_{min} is:

$$t_{rem} = \Delta t \left(\frac{P_n - P_{\min}}{\Delta P_n} \right)$$

(1)

Where,

$\Delta t = t_n - t_{n-1}$,

$\Delta P_n = (1-\alpha)\Delta P + \alpha \Delta P_{n-1}$; is the corrected value of change in the received power level.

$\Delta P = P_n - P_{n-1}$, and $0 \le \alpha \le 1$. Choosing α close to 0 will give maximum weightage to the last observed change in the received signal power.

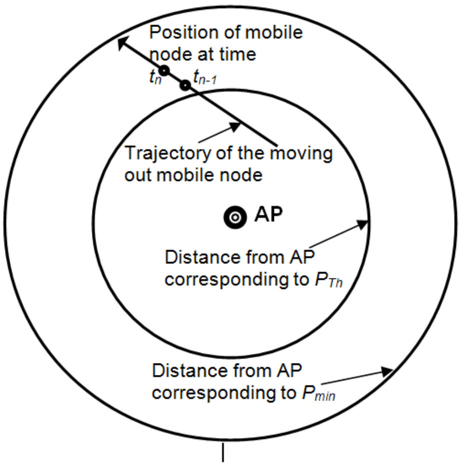

Fig.1. A mobile node moving out of a WiFi cell.

To model the system we also take into account the average handover time of the employed handover scheme, providing either horizontal or vertical handover.

2) Handover execution technique and handover latency

Various end-to-end handover techniques exist in literature [1,2,3], we consider a vertical handover scheme of [1]. The scheme is based on simple address translation mechanism at the communicating ends. A lookup table is maintained at both ends for address translation. As the mobile node initiates the call it also registers its home IP address with the correspondent node. When the need for handover arises the mobile node acquires the foreign IP address in the foreign network and updates its new location to the correspondent node. The correspondent starts translating the packets before delivering it to the network. A reverse address translation is performed at the receiving end to preserve the context of the connection. This results in minimum service disruption with low packet loss and also direct routing of packets from source to destination without requiring tunnelling or rerouting. Marked by no network modification, simplicity and efficiency the handover latency in this mechanism is dependent on the delay between the mobile node and the correspondent node. As the mobile node moves away from the correspondent node the handover delay increases due to end-to-end signalling involved in the handover process. In HaMAT handover latency is dependent on the round trip time (RTT).

The distribution of end-to-end delay in TCP/IP network is assumed as truncated normal distribution owing to [4]. Using the pdf of RTT we predict the handover latency and find the optimum handover triggering time (t_t), prior to hitting the WiFi boundary in order to keep probability of handover failure within limits.

(2)

$$f(x;\mu,\sigma,a,b)=\begin{cases}\dfrac{\frac{1}{\sigma}\phi\left(\frac{x-\mu}{\sigma}\right)}{\Phi\left(\frac{b-\mu}{\sigma}\right)-\Phi\left(\frac{a-\mu}{\sigma}\right)}, a<X<b\\ 0, elswhere\end{cases}$$

Where, $\phi(.)$, $\Phi(.)$ are respectively the pdf and cdf of standard normal distribution. μ is the mean, σ^2 is the variance of normal distribution, however, it is truncated between a and b as handover delay is bounded in [a, b].

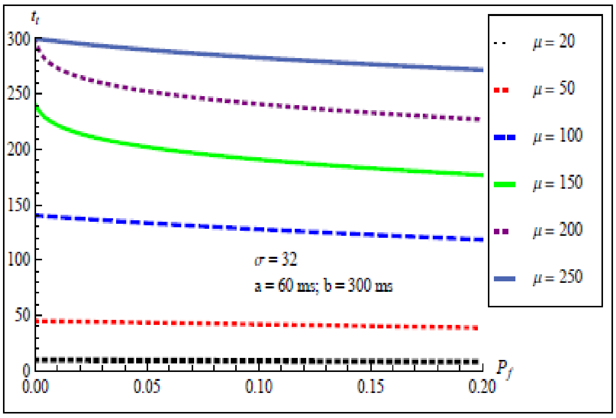

Fig.2. value of t_t for a given P_f for different values of μ.

Handover Triggering Condition Estimation

An early triggering of a handover would transfer the live session of the mobile node to a less desired network before it is actually needed. On the other hand if handover triggering is delayed beyond a certain point the handover may fail due to insufficient time to complete the handover[5].

A handover failure occurs when the remaining time for the mobile node inside the coverage region is less than handover latency [6], so the probability of handover failure at handover triggering time (t_t) is $P_f = \Pr[t_t < \tau]$

(3) $$P_f = 1-\Pr[\tau \le t_t] = 1-\int_0^{t_t} f(\tau)d\tau$$

For a given probability of handover failure we find the handover triggering time as given in equation (4). In order to keep the probability of handover failure within desired limits the handover must be triggered no later than t_t for the accepted value of P_f.

(4)

$$t_t = \mu + \sqrt{2\sigma^2}\, InvErf\left(\begin{array}{l} Erf\left(\frac{b-\mu}{\sqrt{2\sigma^2}}\right) - Erf\left(\frac{b-\mu}{\sqrt{2\sigma^2}}\right) - \\ Erf\left(\frac{\mu}{\sqrt{2\sigma^2}}\right) + P_f\left(\begin{array}{l} Erf\left(\frac{a-\mu}{\sqrt{2\sigma^2}}\right) - \\ Erf\left(\frac{b-\mu}{\sqrt{2\sigma^2}}\right)\end{array}\right)\end{array}\right)$$

where, Erf and $InvErf$ are Gauss error function and inverse error function respectively.

Handover latency is bounded in $[a,b]$. Value of a is the minimum time in which the handover can be completed and for the considered handover scheme of HaMAT [7] it is at least the end-to-end link delays in both directions and sum of processing and buffering delays in the network and in the end nodes when they are facing minimum load. Value of b is the handover delay when the network and nodes are facing peak load.

We evaluate the behaviour of t_t with respect to changes in mean (μ) and variance (σ^2) of RTT. Fig. 2 shows the variation in handover triggering time as the probability of handover failure increases for different values of μ. As the mean value of handover delay increases the mobile node is required to trigger the handover earlier for the same probability of handover failure. Alternatively, the mobile node can delay the handover triggering instance close to the WiFi cell boundary at the cost of higher probability of handover failure.

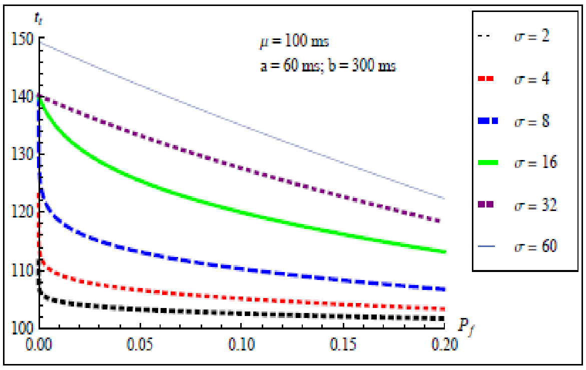

Fig.3. Value of t_t for a given P_f for different values of σ.

Pattern of P_f are identical in Fig. 3. For a particular value of μ, a and b as the standard deviation (σ)

increases the requirement of an earlier handover trigger also increases.

For an acceptable level of probability of handover failure, using the updated values of a, b, μ and σ we can determine the optimum handover triggering time and enable the MN to maximize the connectivity with the preferred network.

Determination of a, b, μ and σ

This model trades-off connectivity with the preferred network for higher probability of failure. The success of this model is dependent on the precise determination of the remaining time in the WiFi coverage region and exact knowledge of the instantaneous values of a, b, μ and σ. Since in HaMAT the handover is executed by exchange of messages between the mobile node and the correspondent node, which are already exchanging messages, we can keep record of end-to-end delays of these recently exchanged packets to estimate the handover latency. The values of a, b, μ and σ can be obtained from the statistics of the data collected from the record of previously received packets.

Using the Monte-Carlo simulation we have found that value of μ is best predicted by using two samples when utilizing minimum or average of the RTT of the last few packets for handover triggering condition. Increasing the number of samples does not help in prediction for truncated normal distribution of RTT. As for using the maximum value of the RTT of last few packets for HTCE the handover failure probability continues to decrease with increase in the number of previous samples. Obviously reduction in handover failure is trade-off with an early handover from the preferred network. Fig. 4 shows handover failures for different number of previous samples for predicting the handover latency, which in turn is used for estimating the handover triggering time.

Conclusion

In this work we have modeled a system to determine the appropriate time of handover initiation in a heterogeneous network environment. Based on successive changes in the RSS the remaining time in the network is estimated for a mobile node moving out of a WiFi cell. The handover latency in an end-to-end handover scheme is estimated through the previously exchange packets between the two communicating ends. Applying the probabilistic model the optimum value of the handover triggering instance is determined for a given probability of handover failure. We have observed the trend of handover triggering time with changing mean, variance and probability of handover failure. The handover is triggered as soon as:

$$t_{rem} \to t_t \tag{5}$$

By tuning α and Δt we can further optimize the handover initiation time. We can also allow to dynamically change the values of α and Δt. For instance, if the velocity, reflected by successive readings of the received power, of the mobile node, is high, then value of Δt should be small otherwise it should be large to minimize load on battery and processing resources. This work is limited to consideration of RSS only. The idea can be extended to consider other factors pertinent to handover decision in heterogeneous network environment. These factors include user preferences, load on the target network, access cost, available bandwidth and QoS required etc. — for achieving Always Best Connected (ABC), anywhere and anytime [7]. The model can be further refined by considering Carrier to Interference Ratio (CIR), Signal to Interference Ratio (SIR), bit error rate (BER) etc. The model ensures minimal battery and processing resources consumption, yet it imbeds the information of speed, direction and surroundings of the MN without requiring any additional equipment.

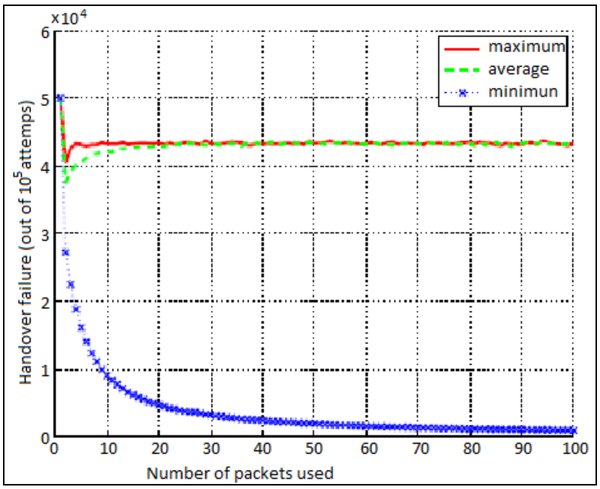

Fig.4. Effect of sample size on handover failure.

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