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ANALYSIS OF HYSTERESIS MARGIN FOR EFFECTIVE HANDOVER IN 4G WIRELESS NETWORKS

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Abstract
The integration of various cellular networks; wireless Local Area Networks, Worldwide interoperability for Microwave Access (WiMAX), Long Term Evolution (LTE), mobile ad-hoc networks and personal area networks utilizing all IP-based architecture constitutes 4G wireless networks. The mobile users roam across the boundaries of different access networks which gives rise to the requirement of effective handover algorithms. The basic criteria, while designing handover algorithms, is link quality, measured in terms of signal strength. In case of received signal strength based handover algorithms, the threshold signal strength and hysteresis margin play an important role. This paper gives an analysis of hysteresis margin for effective handover in 4G wireless networks. The impact of handover margin on handover delay and number of handovers is also investigated. Simulation results are obtained to find appropriate handover margin for users moving with different velocity.

Keywords:
Handover Delay, Hysteresis Margin, Handover Rate, 4G

1. INTRODUCTION

The wireless technologies, one of the fastest ever growing technologies, keep on developing facilities for mobile users. A number of competitive network providers as well as operators are involved in improving the available systems and enhancing the user satisfaction. An individual network is incapable of providing expected services to the customers. To fulfill the user demands in various aspects, the cooperation of different access technologies is required. The wireless technologies, including Worldwide Interoperability for Microwave Access (WiMAX), UTRAN, WiFi, cellular networks and LTE are proven to be beneficial for subscribers. The fourth generation (4G) wireless networks [1] utilize these technologies by integrating them in order to meet the user requirements which would not be possible by any individual network. In 4G technologies, these networks are supposed to perform seamless and smooth handover to have maximum utilization of the resources [2][3]. Handover is a process which is performed either by network or by the mobile station to provide continuous services with promising quality. The mobile initiated handover procedure is mainly due to insufficient signal strength received from serving cell while the network generally initiates the handover to avoid the call drop probability that may arise due to network congestion. The active connection is maintained for users, irrespective of their location or point of attachment. Broadly, two types of handovers are defined, namely, vertical handover and horizontal handover. The handover between base stations associated with same access technologies is known as horizontal handover or intra technology handover. On the other hand, the handover between base stations using different access technologies is referred as vertical handover or Inter-technology handover. In 4G technology, both types of handover are performed to converge these networks. It is highly desirable to initiate handover at the appropriate time and to get connected to the most preferred network to improve the perceived QoS [4]. The handover takes place in three steps: Handover initiation, handover decision and handover execution. The handover intiation deals with correct estimation about necessity of handover and generating triggers to start handover process. The second step is for taking appropriate decion about selection of most suitable target cell. In the last step i.e. handover execution, the mobile station actually connects to the target network after performing handover activities.

In this paper, signal strength and hysteresis margin based algorithm is considered for handover. Choosing suitable threshold values of handover parameters is a challenging task. The impact of hysteresis margin on handover performance is studied which may help in determining suitable parameters. Mobile users moving with different velocity are also considered during simulation which may be useful for choosing appropriate handover parameters in dynamic environments.

The rest of the paper is organized as follows: Section 2 describes the related work in this research area. Section 3 presents the proposed system model for analyzing signal strength and hysteresis margin based handover algorithm. Finally, extensive simulation experiments are carried out to study the effect of hysteresis margin on handover delay and number of handovers in section 4. In this section, it is shown that by making use of simulation results, the handover parameters can be optimized for users moving with different velocity. Finally concluding remarks and future scope is mentioned in section 5.

2. RELATED WORK

Many researchers have elaborated the deployment of various handover algorithms to provide ubiquitous access to the network services. Effective algorithms can be designed by taking handover parameters into account. Some of the authors have shown the impact of few factors on handover performance. The authors of [5] proposes a predictive method to estimate received signal strength. Afterwards, the time to trigger handover is estimated with the help of predicted signal strength. The authors of [6] show that the number of unnecessary handover can be minimized by considering the effect of signal thresholds on handover performance. The effect of signal averaging time on hysteresis margin can be found in [7][8]. However, the radio channel characteristics are assumed as static contrary to the real time scenario. The authors of [9] provide a detailed study of signal averaging and handover margin as a function of velocity of mobile user. It also reveals the influence of users with extremely high velocities over cell size in WLAN. The authors of [10] show the impact of average window size and time to trigger on the outage probability. In addition, the handover performance is also optimized by tuning the parameters. In [11], the authors investigate the effect of an application based signal strength threshold on an adaptive preferred network lifetime based handover strategy. The analytical derivations are done for different performance metrics. In [12], the handover required time is calculated for given neighbor network conditions followed by predictive link triggering mechanism. This technique minimizes the handover costs in terms of signaling load. In self organizing network based LTE systems, various time to trigger mechanisms are applied in [13]. It shows that by choosing a suitable time to trigger, ping pong effect can be mitigated along with acceptable radio link failure rate. For this purpose, two methods, referred as adaptive and grouping, are investigated. A data rate based handover triggering mechanism is proposed in [14]. Here, vertical handover is performed between WLAN and cellular network by making use of IEEE 802.21 functionalities. The network capacity is proved to be enhanced by applying the time to trigger mechanism. Similarly, RSS, available bandwidth and type of application are considered as basis for triggering handover in [15]. The Markov model is utilized to minimize wrong decision probability and missing handover probability. In [16], the effect of L2 trigger due to velocity of mobile user and cell size is studied in handover procedure. In this paper, the MIPv6 handover protocol is implemented between 802.16 and 802.11 networks. The length of dynamic boundary area is derived mathematically as a function of mobile node speed in [17]. This estimation is further utilized to choose the adaptive value of signal strength. This results in improved handover performance in next generation cellular networks.

3. RSS AND HYSTERESIS MARGIN BASED HANDOVER ALGORITHM

Conventionally, the handover is performed mainly on the basis of link quality of the network with which mobile station is associated. The basic terminology used in the handover algorithm is given below.

Signal Strength: Signal strength is the measure of link quality of the physical channel through which mobile station is connected to base station. It is measured in decibels and it is the basic requisite to sustain a call.

Threshold signal strength: It is the minimum signal strength required to maintain a link to a particular network. The mobile is unable to access a network if the received signal level goes below threshold level.

Hysteresis margin: Hysteresis margin is the margin provided for maintaining the minimum difference between the signal strength received from the current base station and the target base station.

Handover delay: Handover delay is the time difference between the link down time and the time where handover is actually performed.

Handover rate: Handover rate is defined as the number of handovers performed during one trajectory of the mobile station across the boundary of the cell.

The algorithm considered in this paper is acapable of taking decision for performing handover from BS_1 to BS_2 on the basis of the following conditions.

- The signal strength received by mobile station from current base station BS_1 is less than the predefined threshold signal strength (minimum signal strength required to maintain a link).
- The signal strength received by mobile station from neighboring base station BS_2 is greater than the signal strength received from BS_1 by Hysteresis margin H dB.

Similarly, the handover from BS_2 to BS_1 is performed if reverse conditions get satisfied as given below.

- The signal strength received by mobile station from the base station BS_2 is less than the predefined threshold signal strength (minimum signal strength required to maintain a link).
- The signal strength received by mobile station from neighboring base station BS_1 is greater than the signal strength received from BS_2 by Hysteresis margin H dB.

The Fig.1 shows the simulation model to implement the above mentioned algorithm. Two adjacent cells of hexagonal shape are considered for simulation and are supported by BS_1 and BS_2 respectively. The mobile station is assumed to be moving with velocity 'v' away from BS_1 towards adjacent cell. The distance between two BSs is D. The target network is assumed to be having sufficient resources. The received signal strength is an indication of the link quality at a particular instant and can be obtained using log distance path loss formula. According to the log distance path loss formula, it can be observed in Fig.2 that the link is deteriorating with an increase in distance from the current base station. On the other hand, the signal received from BS_2 gets stronger as depicted in Fig.2. The handover necessity is ensured by monitoring the received signal strength regularly at an interval of nTs, where n is an integer measured by $[D/vTS]$ and Ts is the sampling interval. The signal strength received by mobile station from BS_1 and BS_2 at n^{th} interval is calculated by Eq.(1) and Eq.(2), respectively.

$$Pr_1(nT_s) = P_t - 10\gamma\log_{10}(nvT_s) + A(nvT_s) \quad (1)$$

$$Pr_2(nT_s) = P_t - 10\gamma\log_{10}(D\text{--}nvT_s) + B(nvT_s) \quad (2)$$

Here, P_t is the transmitted power and γ represents the path loss exponent. A and B are zero mean stationary Gaussian random process that model log normal shadowing. To eliminate the effect of random fluctuations due to shadow fading, averaging of the samples of the received signal is performed. The average signal strength, calculated using exponential window is given by Eq.(3),

$$Pr_i(n) = zPr(n\text{-}1) + (1\text{-}z)\, Pr(n) \text{ for } i = 1,2 \quad (3)$$

where, z is the auto-correlation function between two adjacent shadowing samples. Another effect, that should be taken into account while measuring signal strength in real time, is fast fading. However, by suitable averaging method and parameters like correlation distance, it can be neglected.

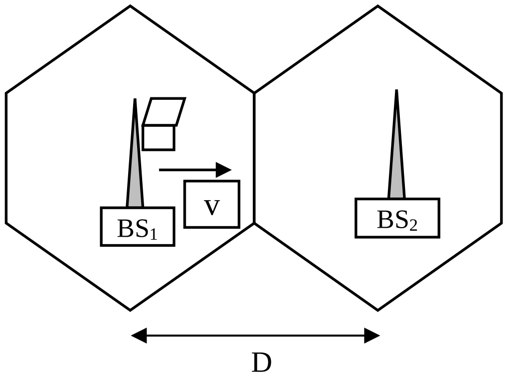

Fig.1. System model

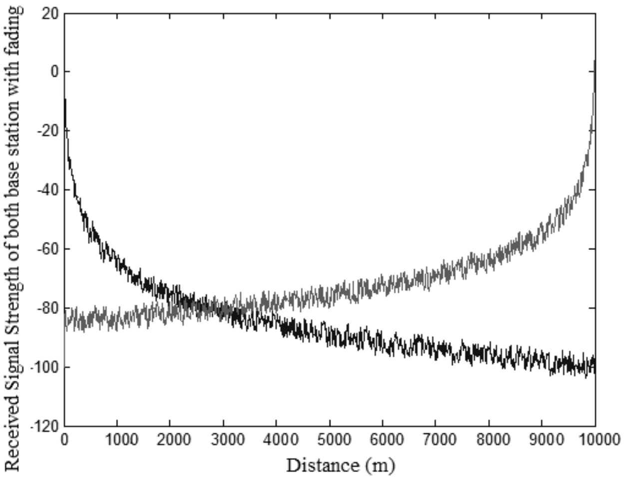

Fig.2. Signal strength received from BS$_1$ and BS$_2$ with distance

4. SIMULATION RESULTS AND DISCUSSION

This section gives a detailed discussion about simulation results obtained through Matlab simulator. The effect of hysteresis margin on different parameters is observed.

4.1 EFFECT OF HYSTERESIS MARGIN ON HANDOVER DELAY

The Fig.3 shows how handover delay gets affected with variation in hysteresis margin. As hysteresis margin increases, the handover delay increases and vice-versa. This is due to the fact that a larger value of hysteresis margin can be achieved later as compared to the smaller value of hysteresis. As the mobile user is moving away from the current base station towards target base station, the signal strength received from BS$_1$ gets degraded while received from BS$_2$ gets stronger. This results in larger value of hysteresis margin. On the other hand, a relatively lesser value of hysteresis invokes handover earlier than the boundary of the cell. Both the extremities of hysteresis margin are undesired due to the reason that the ideal handover is supposed to be performed at the boundary of the cell.

Another important observation made through this plot is the shifting of the graph with respect to change in velocity of mobile user. The velocity of mobile user ranges from 10m/s to 60m/s. The mobile users moving with low velocity suffer from high handover delay as compared to the fast moving users for a given value of hysteresis margin. After a certain value of hysteresis margin (6dB approximately), the velocity does not affect handover delay because the required condition for signal strength is very high which is not achieved very soon even for fast users.

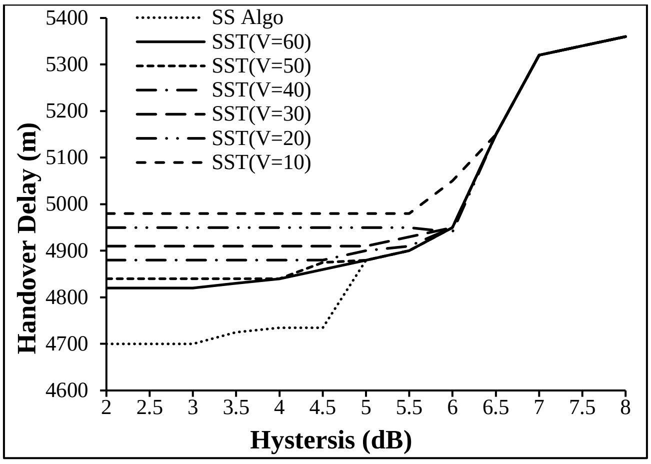

Fig.3. Variation of handover delay with hysteresis margin for variation in velocity of user

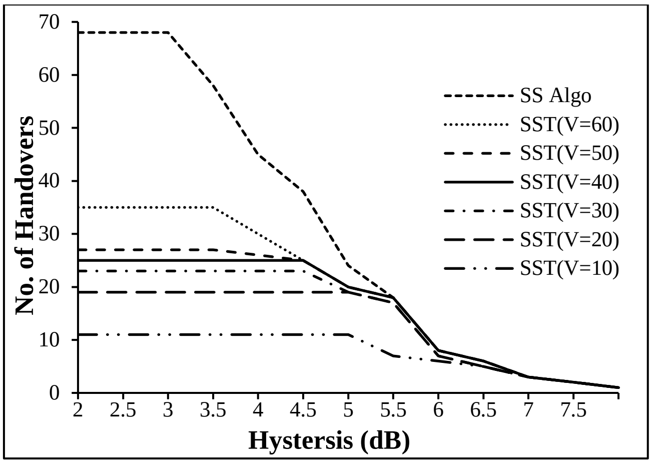

Fig.4. Variation of number of handovers with hysteresis margin for variation in velocity of user

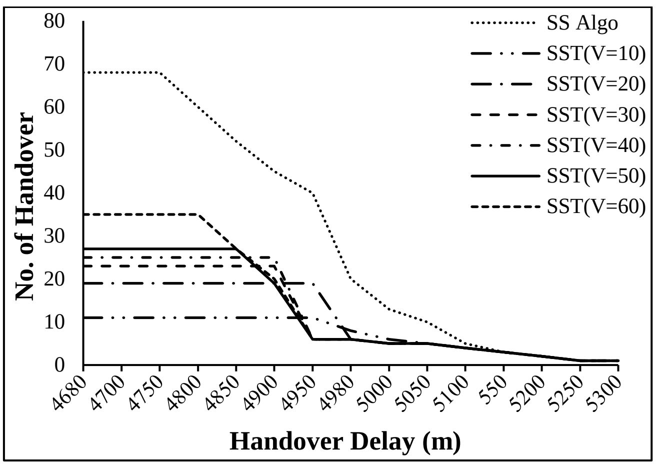

Fig.5. Number of handovers versus handover delay for variation in velocity of user

4.2 EFFECT OF HYSTERESIS MARGIN ON NUMBER OF HANDOVERS

The hysteresis margin has a great impact on number of handovers as depicted in Fig.4. The number of handovers varies inversely with hysteresis margin. It may be analyzed with the results that by keeping hysteresis margin low, the conditions for handover get satisfied for BS_1 and BS_2 very frequently due to random nature of signal strength. Thus, even small variations in signal can cause handover to be invoked. As a result, the mobile will keep on oscillating between the two stations referred to as ping-pong effect. To mitigate the ping-pong effect, the hysteresis margin should be kept reasonably high evidenced by Fig.4. Another factor, which affects the number of handovers for a particular value of hysteresis margin, is velocity of mobile user. Thus, the fast moving users are more sensitive to ping-pong effect however, after a ceratin value of hysteresis margin, saturation occurs and the velocity of mobile does not affect the handover rate.

From the above two graphs (Fig.3 and Fig.4) obtained through Matlab simulation, it is clear that a high value of hysteresis margin gives benefit in terms of handover rate while a lesser value of hysteresis margin gives benefit in terms of handover delay. The appropriate hysteresis margin is to be determined for different values of velocity of mobile user. An efficient handover algorithm is supposed to provide less handover delay as well as less handover rate. These two parameters are contrary to each other. This paper proposes an effective solution to this issue which is supported by Fig.5. The Fig.5 shows graph between handover delay and number of handovers for different values of velocity. A tradeoff can be achieved with the help of this graph. It can be observed that the two factors get compromised in a region of 4900m-5000m approximately (can be treated as optimum point) which is near to the boundary of current cell. Moreover, the optimum point gets shifted towards left of the boundary as velocity increases. This is due to the reason that a fast moving user will reach the boundary earlier than a slow moving user. Thus, handover is required to be invoked earlier in former case.

5. CONCLUSION AND FUTURE SCOPE

This paper presents an insight to the signal strength and hysteresis margin based handover algorithm. The hysteresis margin is analyzed to improve the performance of 4G wireless networks during handover. It may be concluded that the choice of hysteresis margin has a great impact on the handover delay as well as the number of handovers. In addition, the results also vary with variation in velocity of mobile user. A trade off curve between handover delay and number of handovers is drawn in order to support the analysis. In future work, more handover factors can be analyzed for different mobility environments. Also, test bed implementation can be done to experience the real time scenario.

REFERENCES

[1] IEEE LAN/MAN Standards Committee, "IEEE Standard for local and metropolitan area networks Part 16: Air interface for fixed and mobile broadband wireless access systems amendment 2: Physical and medium access control layers for combined fixed and mobile operation in licensed bands and corrigendum 1", IEEE Std 802.16-2004/Cor 1-2005 (2006).

[2] J. Mcnair and Fang Zhu, "Vertical Handoffs in Fourth-Generation Multi-network Environments", *IEEE Wireless Communications*, Vol. 11, No. 3, pp. 8-15, 2004.

[3] N. Nasser, A. Hasswa and H. Hassanein, "Handoffs in Fourth Generation Heterogeneous Networks", *IEEE Communications Magazine*, Vol. 44, No. 10, pp. 96-103, 2006.

[4] Sudesh Pahal, Brahmjit Singh and Ashok Arora, "Performance Evaluation of Vertical Handover based on Signal Strength and Residual Time in Heterogeneous Wireless Networks", *International Journal of Computing and Network Technology*, Vol. 2, No. 1, pp. 25-31, 2014.

[5] Sudesh Pahal, Brahmjit Singh, Ashok Arora, "A Predictive Handover Initiation Mechanism in Next Generation Wireless Networks", *WSEAS Transactions on Communications*, Vol. 12, No. 6, pp. 271-281, 2013.

[6] N. Zhang and J. Holtzmann, "Analysis of Handoff Algorithms using both Abosute and Relative Measurements", *IEEE Transactions on Vehicular Technology*, Vol. 45, No. 11, pp. 174-179, 1996.

[7] A. Murase, I. Symington and E. Green, "Handover Criterion for Macro and Microcellular Systems", *Proceedings of IEEE Conference on Vehicular Technology*, pp. 542-530, 1991.

[8] M. Zonoozi and P. Dassanayake, "Handover Delay in Cellular Systems", *Proceedings of IEEE International Conference on Personal Wireless Communications*, pp. 24-27, 1997.

[9] Cheng-Shong Wu, Yan-San Chu and Chia-Hung Fang, "The Periodic Scan and Velocity Decision Handover Scheme for Next Generation Femtocell/Macrocell Overlay Networks", *Proceedings of International Conference on ICT Convergence*, pp. 201-206, 2013.

[10] Brahmjit Singh, "Outage Probability Analysis in Soft Handover for 3G Wireless Networks", *Proceedings of 6th IEEE International Conference on 3G and Beyond*, pp. 1-5, 2005.

[11] A.H. Zahran, B. Liang and A. Saleh, "Signal Threshold Adaptation for Vertical Handoff in Heterogeneous Wireless Networks", *Mobile Networks and Applications*, Vol. 11, No. 4, pp. 625-640, 2006.

[12] Sang-Jo Yoo, David Cypher and Nada Golmie, "Timely Effective Handover Mechanism in Heterogeneous Wireless Networks", *Wireless Personal Communications*, Vol. 52, No. 3, pp. 449-475, 2010.

[13] Yejee Lee, Bongjhin Shin, Jaechan Lim and Daehyoung Hong, "Effects of Time-to-Trigger Parameter on Handover Performance in SON-based LTE Systems", *Proceedings of 16th Asia-Pacific Conference on Communications*, pp. 492-496, 2010.

[14] Sueng Jae Bae, Jungmin So and Min Young Chung, "Handover Triggering Mechanism Based on IEEE 802.21 in Heterogeneous Network with LTE and WLAN", *Proceedings of IEEE International Conference on Information Networking*, pp. 399-403, 2011.

[15] Uthman Baroudi and Faisal Al-naseer, "Performance Evaluation Study on a Multiple Parameter Handoff Algorithm", *Proceedings of IEEE International Conference on Information Networking*, pp. 273-277, 2011.

[16] Kyungtae Kim, Young-June Choi, Junghoon Jee and Eunah Kim, "L2-Triggered Mobility Management in Heterogeneous IP Wireless Networks", *Proceedings of 3rd International Conference on Ubiquitous and Future Networks*, pp. 375-380, 2011.

[17] Azita Laily Yusof, Norsuzila Yaacob and Mohd Tarmizi Ali, "Handover Initiation across Heterogeneous Access Networks for Next Generation Cellular Network", *Proceedings of IEEE Symposium on Wireless Technology and Applications*, pp. 78-83, 2011.