VOL. 10, NO. 2, FEBRUARY 2015 ISSN 1819-6608
ARPN Journal of Engineering and Applied Sciences

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HANDOVER TRIGGER SCHEME FOR MOBILE COMMUNICATION IN HIGH SPEED MOBILE ENVIRONMENT

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ABSTRACT

High speed rail has been developed rapidly in recent years. The passengers travelled by trains demand for higher data rate and service continuity in order for them to access the Internet. The realization to provide reliable communication for the users in high speed mobility is challenging due to the frequent request for handover since the trains moving in high speed which resulting heavy overhead implementation. Since the User Equipment (UE) in trains communicates directly to the outside of the Base Station (BS), it reduced handover successful rate and hence, degraded the service quality. This research identified the system parameters to improve handover performance in high speed railway network. Moreover, mathematical equation has been derived by integrating the information of train speed and time travelled across the cell. This research has improved handover performances by reducing the probability of drop call rate and increasing the number of handover successful rate.

Keywords: receive signal strength (RSS), base station (BS), orthogonal frequency division multiplexing (OFDM), long term evolution (LTE), time to trigger (TTT), quality of service (QOS).

INTRODUCTION

LTE is a wireless broadband technology designed to support roaming on cell phones and handheld devices. LTE offers significant improvements over previous cellular communication standards. OFDM used in LTE systems make it possible to supply high-speed data service on railway (Li *et al*., 2012). But there are still many problems to be solved. In wireless systems for high speed rail, BS are deployed in a straight line along the rail (Mqose, 1994) and handover happens in the overlapped areas, whose performance, including handover probability, handover delay and unnecessary handover number caused by ping-pong effect will be degraded seriously. However, there are many problems still remain unsolved for the handover in wireless communications for high speed rail, such as the handover triggered probability, which is the probability of handover triggered before the train arrives at a specific position (Luo *et al*., 2011). A higher handover triggered probability is desirable at the cell edge to avoid communication interruptions and call drops to ensure continuous communication.

The authors in (Huang *et al*. 2012) state that the handover triggered probability increases when the size of the overlapped area gets larger and the report period becomes shorter. The proposed adaptive handover trigger scheme is to configure the report period adaptive to the train speed and the size of the overlapped area, which can provide a handover triggered probability of 99.8% when the velocity of train is below 540km/h (Huang *et al*. 2012). Currently, the train system in Malaysia travelled at 120km/h for Electric Train System (ETS) and 160km/h for KLIA Express which is also classify in high mobility environment.

The 3rd Generation Partnership Project (3GPP) LTE system has been designed to offer significantly higher data rates, higher system throughput and lower latency for delay critical services. This improved performance has to be provided and guaranteed under various mobility conditions (Dimou *et al*., 2009). Hence, handover and its performance are of high importance. Requirements for 3GPP LTE include the provision of peak cell data rates up to 100 Mbps in downlink and up to 50 Mbps in uplink under various mobility and network deployment scenarios. There is a requirement for mobility support with high performance up to speeds of 120 km/h (Report, 2010). Handover triggered probability is the probability of handover triggered before the train arrives at a specific position. A low handover triggered probability at the cell edge will results in serious communication interruptions and call drops. An adaptive handover trigger scheme is proposed to guarantee higher handover triggered probability by configuring overlapped area and measurement report period adaptively according to the train speed. Figure-1 shows the wireless coverage along railway where high speed train will pass through the cell in the track.

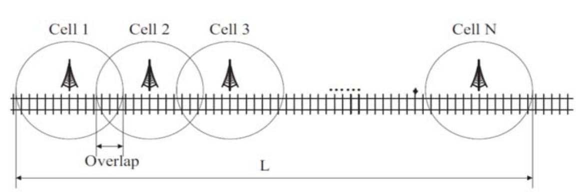

Figure-1. Wireless coverage along railway.

The handover triggered probability is decided by the number of handover decisions generated from the first user measurement results reported to when the train reaches the cell edge. The more decisions, the higher the handover triggered probability. The development of high-speed railway all over the world, the reliability and communication of bullet train depends on the wireless communication between train and BS along the railroad. The traditional handover scheme of LTE network on the neighbouring cell becomes better if performance the serving cell during TTT is increase (Report, 2010).

The rest of this paper is organized as follows. First, the data was collected by doing the drive test. Next parameter being identified where the handover threshold value is set based on speed of UE and distance to BS. Then, the drive test data and simulation results are compared. Finally the conclusion with recommendation are discussed.

METHODOLOGY

Drive test

Firstly, the data is collected by using NEMO Handy as a drive test tool, to measure signal strength and signal quality. The data obtained from NEMO handy then be transferred to NEMO Outdoor and analyzed. NEMO Handy is portable engineering tools for advanced measurement on wireless air interface and mobile application Quality of Services (QoS) (Luan *et al*. 2011).

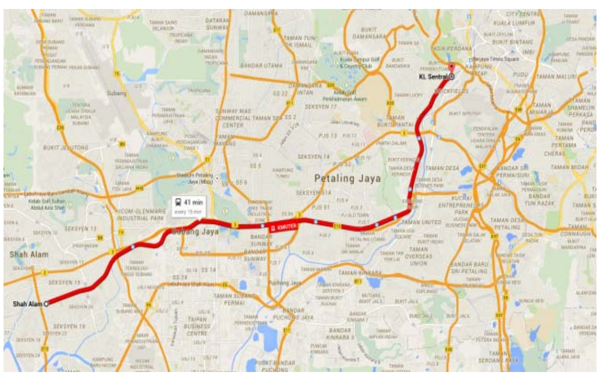

Figure-2. Route taken from KTM Shah Alam- KL Sentral and KL Sentral-KTM Shah Alam.

Figure-2 shows the measurement starting point which is located at KTM Shah Alam and finish point at KL Sentral and return back. This Drive Test covered of 26.9km with duration of approximately 60 minutes. This test has been conducted for three different times, which is morning (8am-10am), afternoon (11am-1pm) and evening (4pm-6pm). This drive test was conducted in a train. The log file obtained from the drive test has been saved and transferred to NEMO Outdoor for analysis purpose.

Parameter on handover performance

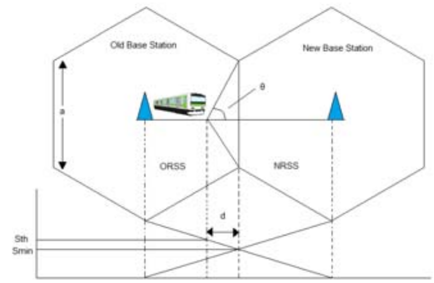

Figure-3. Analysis of handover process.

Figure-3 shows the analytical framework of handover process. The current BS is labeled as Old BS (OBS) and the target BS as New BS (NBS) with the following parameter:

- Sth: The Threshold value of the Receive Signal Strength (RSS) to initiate the handover process. Therefore, when the RSS at OBS referred as ORSS. When RSS drop below Sth, the Mobile Switching Center (MSC) registration are initiated for UE handover to NBS.
- Smin: The minimum value of RSS required for successful communication between an UE and OBS.
- a: The cell size.

After receiving the handover information message, the proper threshold value should be carefully selected in order to initiate the handover process. In this algorithm, mathematical equations have been derived to control the handoff time according to the train speed as follows:

$$Pa = 1 - (1/\pi) * \theta \quad (1)$$

Where

$$\Theta = \text{atan}\,(a/2d) \quad (2)$$

$$Pf = a\cos(d/vt) / a\tan(a/2d) \quad (3)$$

The above equation (1-3) used to calculate probability of false handoff initiation, (pa) and probability of handoff failure, (pf). First, the value of d is calculated for desired value of pf using (3). The value of d is the distance of UE from boundary of serving BS, t is the handoff signaling delay, where 'a' is cell size as shown in Figure-3. Then equation (4) is used to select RSS threshold. From path loss model, equation (4) was derived where RSS min is the minimum RSS required for the mobile to communicate with new BS, β is the path loss coefficient and ε is the standard deviation of shadow fading. In order not to degrade the QOS of other users, RSS min value should be carefully selected. By using adaptive threshold value, too early or to late handoff initiation process (registration) can be avoided.

$$Sth = RSS\ min + 10\,\beta \log[(a(R-d)] + \varepsilon \quad (4)$$

RESULTS AND DISCUSSIONS

Drive test results

The data collection has being taken and analyzed. All the data has being transfer to computer and transform to graph. Figures 4 and 5 shows the comparison of RSS value for average three different sessions, morning, afternoon and evening.

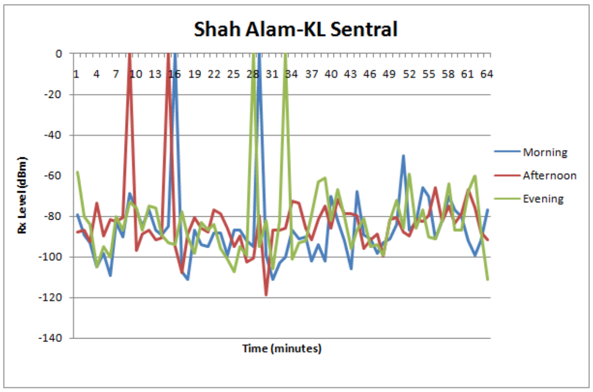

Figure-4. Comparison of three sessions from Shah Alam to KL Sentral.

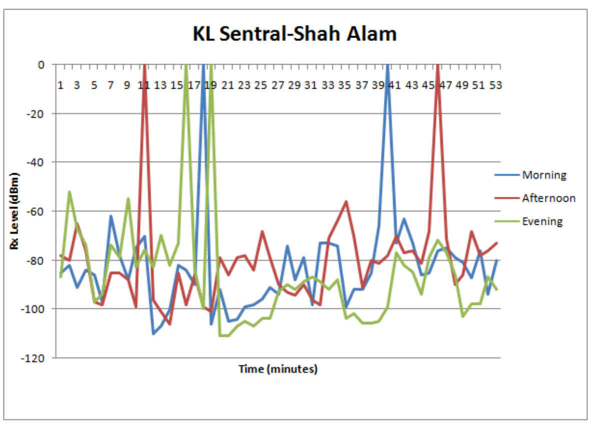

Figure-5. Comparison of average three sessions from KL Sentral to Shah Alam.

Table-1. Dropped call location on three sessions.

	Shah Alam-KL	KL-Shah Alam
Dropped call location	-Batu 3 -Subang Jaya -Setia Jaya	-Kg Dato Harun -Batu 3 -Subang Jaya

From these three figures the value of 0dBm for the RSS indicates the dropped call. The location of dropped call shows on Table-1. The most dropped call happen at Subang Jaya and Batu Tiga. Subang Jaya and Batu Tiga had become hot location dropped call happen from three different sessions.

There are many factors that could affect RSS and cause dropped call to happen. During the drive test session, the terrain and surrounding geographical area of Subang Jaya KTM Commuter Station is filled with buildings. Empire Subang is the main building that could affect RSS due to multi-path propagation caused by signal bouncing off building which dampens the signal. The height of Empire Subang is 50 meters tall from ground. Thus, these are the reason why dropped call always happens on that location.

The geographical area at Batu Tiga KTM Commuter Station is not same as Subang Jaya Station. There is no big building like Empire Subang that could affect the RSS. However, dropped call still happens on this location. The distance between Batu Tiga KTM Commuter Station with Subang Jaya Station is only 3.5 kilometers. Research from (Bhattacharya, 2012) state that RSS with hysteresis allow a UE to handover only if the new BS signal is sufficient stronger by the current one. Geographical area at Subang Jaya Station will also affect the RSS at Batu Tiga Station. Thus, the location of Batu Tiga Staion that is nearby with Subang Jaya Station also caused dropped call to happen.

On these three sessions of drive test, Subang Jaya and Batu Tiga Station became hot location that dropped call happens. However, there are others location that dropped call also happens. These locations are Kg. Dato Harun and Setia Jaya Station. These dropped calls happen on morning and afternoon sessions. High density of users could cause the line to be slower, increase interference and dropped call rate as well. On morning session, there are many people to use the train for going to work. Hence, these will increase the number of user on train at the same time. The other factor that could effects dropped call to occur is temperature. The high temperature on the afternoon could affect the RSS performance (Mason, 2008). On afternoon session, between 11am-1pm, the temperature is high. The probability interference of RSS is high due to this temperature.

One of the biggest frustrations in everyday life is dropped calls. In a recent study by the (Karimi *et al*. 2012) dropped calls were cited as the biggest complaint by cell phone owners. According to the study, 72% of cellphone owners experienced dropped calls at least occasionally, and 32% experience this at least a few times a week (Karimi *et al.* 2012). An excellent cellular telephone communication system is described having operational steps which prevent a call from being dropped due to a UE not receiving a handoff instruction from its new BS. Handoff is processed if the signal strength from one of the new BS proves to be higher than the signal strength from the old BS. When UE moves from one BS to another, on the way signal from old BS get reduced whereas threshold value from new BS increased. So, UE should be served by the new BS when signal from old BS reduced below a specified level. On the next section simulation results by adapting the handoff threshold in a high speed mobile communication system will be explained.

VOL. 10, NO. 2, FEBRUARY 2015 ISSN 1819-6608
ARPN Journal of Engineering and Applied Sciences

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Simulation Results

A. Probability of false handoff initiation

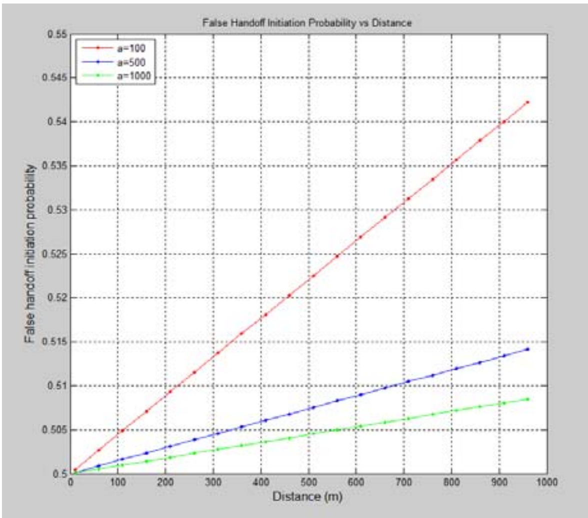

Figure-6. Relationship between false handoff probability and distance with different value of cell size.

Figure-6 shows the relationship between false handoff probability and distance with different value of cell size. Handoff initiation is the process by which a handover is started as a consequence of the fact that the old BS threshold value unacceptably degraded or another new BS can provide a better communication link (Alam, 2013). From the graph above, the value of 'a' is represent cell size. When the value of 'a' is increase, the probability of false handoff initiation also increase. The probability of false handoff initiation increases if irrelevant large value of distance is used. The delay in handoff initiation time causes disruption in service while an early handoff initiation results in wastage of resources of current network (Pahal *et al*. 2013). For this reason, it is very important to select an appropriate value of distance to reduce the probability of false handoff initiation.

B. Probability of handover failure vs velocity (t = 1sec)

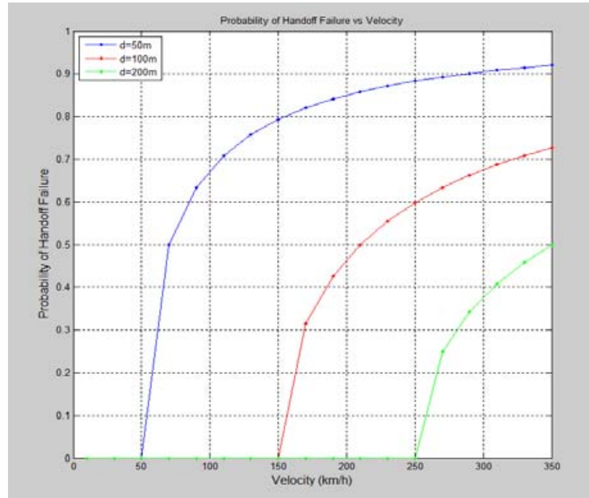

Figure-7. Relationship between handoff failure and speed for intra system with t=1sec.

C. Probability of handover failure vs velocity (t = 3sec)

Figures 7 and 8 shows the relationship between handoff failure and speed for intra and inter system. There are two types of handover namely inter-handover and intra-handover. Inter-Handover is the process where UE changes between two cells belonging to different BS under the same network. In this case the old BS will take the decision and initiate the handover process. Intra-Handover is a process where MS changes between two cells, belonging to the same network (Alam, 2013).

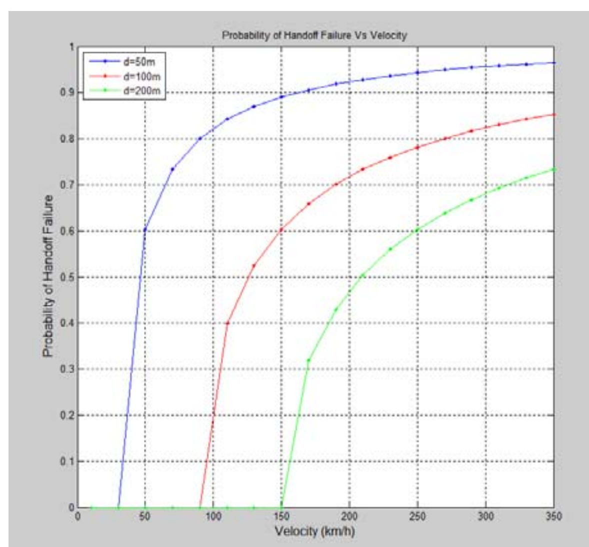

Figure-8. Relationship between handoff failure probability and speed for inter system with t=3sec.

Results showed that the value of velocity is directly proportional to the value of Pf for both intra and inter handover. This is because when the speed increases, more time required crossing the coverage area from OBS

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to NBS. For intra and inter handover, the Pf value for inter handover higher as compared to intra handover. This is because inter handover need to make a new registration to the new network and hence require fast handover initiation time to make sure the data or calls links is not drop. From both Figure, it show that when the speed varies, the value of distance for handover initiation need to adaptive. Therefore, an adaptive value of RSS is required to initiated handover for inter and intra system in high speed train.

D. Relationship between adaptive RSS vs velocity

Relationship between Adaptive RSS and UE speed is shows in Figure-9. To determine these relationships, the value of d is required by using equation (2). The value of pf is assumed to be 0.02. Once d is calculated, the corresponding value of Sth is calculated using analytical framework model as shown in Figure-3.

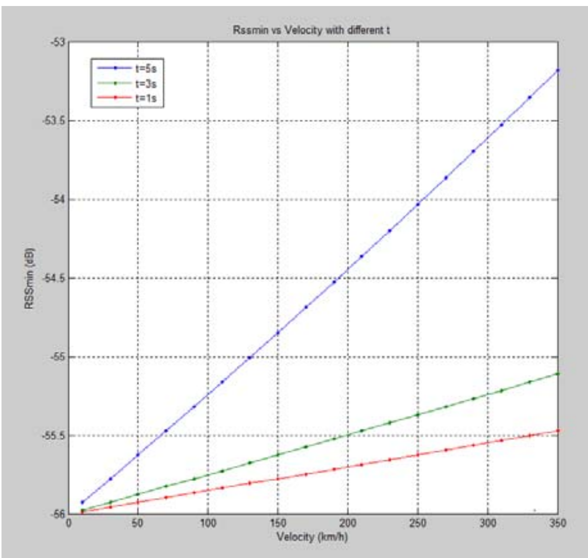

Figure-9. Relationship between adaptive RSS threshold value with different speed.

Figure-9 shows the proposed Adaptive RSS min increase as UE speed increase for different value of t. From this graph it can be seen that the required time to initiate handoff for high speed UE is faster compared to slower UE. Research in (Tian *et al*. 2012) stated that the great challenge for high speed train environment is handover due to the frequent request for handover since the trains moving in high speed trains may experience one handover for each 10-20s if it travels with speed of 350km/h. As the train moves at high velocity, the time taken for a train to move across the cell is very fast, shorter than the minimum handover delay. This scenario leads to increasing call drops since the UEs in the train do not have enough time to execute handover while travel across the cell. According to (Tian *et al*. 2012), the wireless channel condition in high speed train scenario changes drastically, result in disturbing the data rate. Besides that, the network in high speed train environment also faces severe Doppler frequency shift and high penetration loss due to fast moving vehicle and well shield carriage. The faster the speed of UE the faster time should be handoff to initiate. Thus, the faster time UE to initiate handoff, the higher the probability of handoff to success.

CONCLUSIONS

This paper focuses on the fast handover trigger scheme for mobile communication in high speed train. The influencing factor such as speed, distance to initiate handoff and location of dropped call has been analyzed on this paper. After that the performance of handoff that uses an adaptive value of RSS threshold to initiate the handoff process is analyzed. In drive test result, the location of dropped call is almost on the same location. Through the analysis, the reason that dropped call happens is because of interference on that location and time to initiate handoff is longer that make the process of handover failed. In the simulation results, a proper threshold value to control the handover initiation time based on UE speed and handover type are proposed. For the future work about fast handover, having detail information from few network providers such as the base station location would greatly help during the analysis stage. This project can be continued to simulate the performance for both intra and inter system handoff at different location. The adaptive value of RSS can be implemented since it can avoid too early or too late initiation of handover process.

ACKNOWLEDGMENT

This paper is part of research work that supported by the FRGS grant no. FRGS/1/2014/TK03/UITM/02/5 funded by the Kementerian Pendidikan Malaysia and Faculty of Electrical Engineering, UiTM Shah Alam.

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