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MEASUREMENT ANALYSIS FOR HANDOVER INITIATION PROCEDURE IN A HIGH SPEED TRAIN ENVIRONMENT

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ABSTRACT

High speed train has been the most prominent transportation that been used by the public to save the travel time due to the road congestion especially during the peak hour. Most of people travel by trains for about forty to fifty minutes to reach their destination. In parallel with the development of high speed trains nowadays as the trains' speed can reach up to 350km/h, there have been extensive researches to improve the data rates for mobile wireless communication. Higher data rate and reliable mobile communication are desirable when moving in high speed trains. The passengers on board usually play online application, surf internet, check emails, reading books and many more to kill time. As a solution, the latest LTE system seems to be a convincing platform to provide high data rates since it is expected to support high peak data rates of 1Gbps in downlink for low mobility and up to 100Mbps in high mobility environment. This paper provides the measurement analysis of current deployed network along high speed rail road. The results in this paper will be the pilot parameter to be analyzed further in order to improve mobile communication handover performance for high speed trains in LTE system.

Keywords: high speed train, handover, LTE.

INTRODUCTION

Nowadays, high speed railway is developed extensively worldwide in order to provide fast and convenient public transportation to the people. High speed railway in China has been developed to travel up to 350km/h and the speed of train is expected to increase up to 500km/h in the future (Q. Luo *et al.* 2012). High speed trains nowadays have become a popular choice of public transportation system since the passengers can avoid traffic congestion if travel by road.

Besides the extensive development of high speed railway transportation, the number of mobile broadband subscribers has been growing tremendously day by day. The passengers on board the train mostly using data service to surf website, playing online applications or games, reading online books, check email and many more to kill time during travelling.

With the development of high speed railway transportation and public demand on data traffic, network provider pay more attention to provide high data rate and reliable serbices under high mobility environment (W. Luo, Zhang, and Fang 2012). In order to provide seamless and reliable services, extensive researches to improve handover initiation in high speed environment had been studied.

Mobile wireless communication technology evolves from the introduction of 1G, which support voice communication to the latest LTE-Advanced system which is expected to support peak data rates up to 50Mbps in uplink and 1Gbps in downlink for low mobility (Ullah 2012). On the other hand, LTE-Advanced is an appealing solution to provide high data rate transmission compared to WCDMA/3G system. This is because LTE system is targets to achieve peak data rates of 100Mbit/s to support advanced services and applications for high mobility environment (Tu *et al.* 2012; V10.0.0 2011).

Global system for mobile communication for trains communication and control (GSM-R) has been adopted during these past years to adapt the railway transporting characteristics that need the integration of signal processing and communication techniques (Bhattacharya and De 2012; Fang, Luo, and Cheng 2012; Q. Luo *et al.* 2012). However, GSM-R cannot support demands for high data rate communication since it only provides maximum data rate of 200kbps, which satisfy for voice communication and railway control (Transportation *et al.* 2012).

High data rate wireless communication in high speed railway is desirable because of two main factors. One of it is the need of transmitting railway controlling information about security monitoring and maintenance. The other reason is the mobile users' demand to have access to the internet and reliable communication quality, regardless of their locations and speeds (Transportation *et al.* 2012).

However, it is challenging to achieve high data rate transmission in LTE system since the type of handover is hard handover. Hard handover means that the channel in source cell is released before being connected to the target cell. The data is being lost and higher call drop will occurred under this environment. Fast and reliable handover procedure must be deployed in high mobility environment, therefore users onboard the trains will not experience severe service interruption.

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HANDOVER IN HIGH SPEED RAILWAY COMMUNICATION SYSTEM

Challenges in high speed railway communication system

Many challenges arise during designing high speed railway communication. As been stated by (Huang *et al.* 2012), the cell radius in LTE system is smaller compared to GSM-R network. This is due to the deployment of high carrier frequency. Frequent handover is occurred since the size of cell is smaller and directly proportional to the high velocity of train lead. As the train moves at high speed, the high bandwidth that is requires to support online multimedia services decreases, because the user on board the trains unable to establish a direct link with the outside base station (Atat *et al.* 2012).

In addition to the high velocity of trains, the service quality and performance is degraded severely due to the penetration loss of vehicle, Doppler frequency shift, shadowing and multi-path since the UE in train communicate directly to the outside base station (BS) (Li *et al.* 2012), (Atat *et al.* 2012), (Lu *et al.* 2011), (Qian & Wu 2012), (Huang *et al.* 2012), (Xiang & Yang 2009), (Q. Luo *et al.* 2012), (Cheng & Fang 2012). The vehicle penetration loss caused by the train's shield would be 15-25dB as state in (W. Luo *et al.* 2011) which attenuates the signal received by the UEs inside the train.

Handover seems to be an enormous challenge not only because the frequent handover, but also group handover which caused heavy implementation overhead to the system, as stated by (Tian *et al.* 2012). As the UEs inside the train in directly communicates with the outside base station, they requests handover process at the same during handover. It leads to network congestion as the handover must be executed simultaneously for hundreds of active users. If the handover fails, users will experience call drops and service interruptions (Zhao *et al.* 2011), (Tian *et al.* 2012), (Bhattacharya & De 2012).

Hence, extensive studies in improving handover performance have been conducted in recent years. Various handover schemes and system architecture are proposed by the researchers.

Handover schemes to optimize handover in high speed train

Generally, handover is triggered at the overlapping region between two neighbouring cell (Bakar 2014). Consequently, higher handover triggered probability is require at the cell edge/overlapping area.

An adaptive handover trigger scheme is proposed by authors in (J. Li *et al.* 2012) to guarantee a high handover triggered probability by configuring overlap area and measurement report period adaptively according to train speed. The proposed scheme is added by train location information and the speed of trains to calculate the adaptive report period. The adaptive report period, TS is calculated as in formula below.

$$T_S = \frac{R - x_0}{v.N} \quad (1)$$

R = cell radius
x_0 = location of train
v = train's velocity
N = handover decision number

The proposed scheme resulting high handover triggered probability at cell edges approaches to 99.8% while the number of the base stations is reduced by 17.6% compared to Global System for Mobile Communication for railway, GSM-R system. For high speed train whose velocity is below 540 km/h, it is verified that signal strength measurement report period can be configured to 200ms, same as LTE system. Thus, as the handover triggered probability increases when the size of the overlapped area gets larger and the report period becomes shorter.

Different approach to optimize handover performance in high speed train was proposed by authors in (Huang *et al.* 2012). Two reference points, which are pre-preparation and packet bi-casting were introduced to ensure handover in time. These two reference points are determined to reduce communication interruption time. A mobile relay node (MRN) is utilized to combat the high penetration loss of signal experience by the users onboard the train and focuses on group mobility challenge in high speed train environment.

Frequent delayed handover decrease the quality of service (QOS) experienced by users, thus handover trigger timing is an important issue. Necessary changes or modification of existing handover algorithms is needed to improve handover timing had been proposed by authors in (Choi *et al.* n.d.). In their approach, Time to Trigger (TTT) and hysteresis were been set as their control parameters to avoid ping-pong handover which occurred when the direction and speed of user equipment (UE) are not constant and the propagation environment is unstable. They used OPNET network simulator to simulate their analysis. The analysis focused on measurements when the UE approaches the target base station after it passed the serving base station. This is because the measurements at this point affect the handover trigger time. The simulation result indicated that the measurements are highly correlated with the resulted from the characteristics of high speed train rail road. Firstly, rail road tracks for the high-speed railway are installed in a relatively straight line in flat and open land for safety and cost-efficiency. Next, the speed of the train constantly changes. However in real deployment environment, the geographical area of high speed train railway is not constantly flat and open as been simulated.

In (Luan *et al.* n.d.) two rapid handover algorithms based on UE velocity and optimized time-to-trigger (TTT) were introduced. In this paper, 3GPP Spatial Channel Model, its extension (SCME) is adopted to analyse the effect of RSRP and RSRQ value under different parameters. The relation between RSRP and RSRQ value with SNR is drawn. The results show that RSRQ value change better when SNR value is increased. The rapid handover algorithm based on UE velocity shows

that the hysteresis and TTT value decreased accordingly as UE velocity is increased. The other rapid algorithm is proposed to prevent unnecessary or ping-pong handover by utilizing the number of RSRP value of source eNB higher than target eNB exceeds the hysteresis, denoted as N. TTT will be dynamic variable for the algorithms because handover is trigger when N Nthreshold. The proposed algorithms are then simulated and the results indicate handover success rate improved by both of algorithms.

Another handover optimization scheme in LTE for a variety of velocities was presented by (Kim, Lee, and In 2014). The proposed algorithm changed the time to trigger adaptively to the received signal strength level of the serving cell. TTT algorithm is adjusted based on RSS replacing the user's position. Based on this algorithm, the location and speed of UE are not important. The simulation was done using OPNET, and the result indicates that the data link failures of traditional handover scheme reach 12% which leads to significant amount of data and packet losses in the network while the proposed algorithm enhanced the ping-pong handover rate due to the control of TTT, therefore unnecessary handover near cell border do not happened.

As referred to previous studies on handover optimization scheme in high speed environment, most of the researches relied on simulation result of different simulator.

Therefore, performance analysis of current deployed network system was done in order to improve handover initiation procedure to result in faster and seamless handover in high speed train environment. The results of the performance measurement then can be the pilot parameter or can be reference to be analysed further in order to improve handover in LTE system in real environment when deployed in Malaysia in the future.

PERFORMANCE ANALYSIS

Measurement of received signal strength in high speed train

In order to improve handoff initiation when travelling in high speed trains, the performance of calls using current deployed network has been measured. A better handoff initiation procedure will resulting lower number of dropped call.

The measurement was taken along 6 KLIA transit routes which consists of 6 stations, approximately 36 minutes of journey. The results were measured when travelling along KLIA transit using Electric Train Service (ETS) that moves up to 160km/h speed. Figure-1 shows the area of the signal measurement for high speed train along KLIA transit rail road.

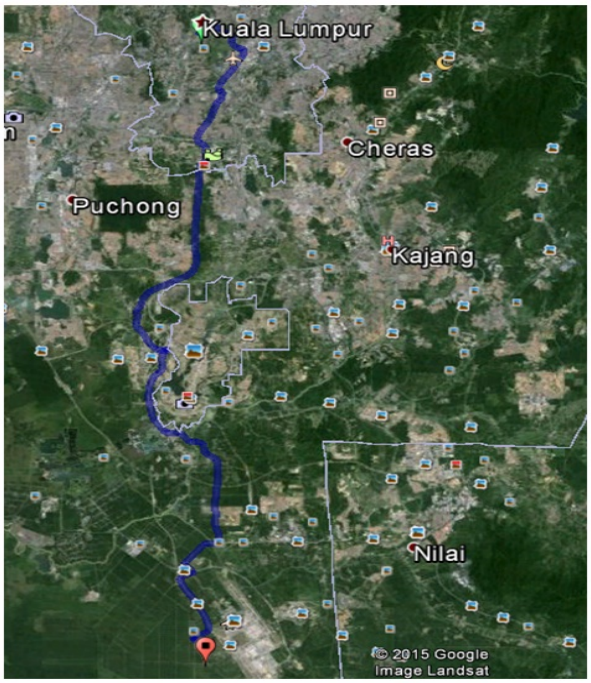

Figure-1. Map of signal measurement along KLIA transit railway (source, Google maps).

Figure-2 shows the 6 stations along KLIA transit which starts from KL Sentral and ends at KLIA2 station.

Figure-2. Stations of KLIA transit (KL Sentral-Bandar Tasik Selatan-Putrajaya & Cyberjaya-Salak Tinggi-KLIA-KLIA2).

Nemohandy is the tool to collect the performance of mobile communication and the result is generated using Nemo Outdoor Software. During this measurement the network operator being used is Celcom. The main focus of the measurement is to measure the average received signal strength along the KLIA transit rail road at three different times which are at morning, evening and night.

Average received signal strength at morning

By using Nemohandy tool, the coverage of the KLIA transit rail road mostly covered by GSM network which from KL Sentral-Seri Kembangan-Serdang-Dengkil-Bandar Baru Salak Tinggi-KLIA and KLIA2, while Cyberjaya and Putrajaya area are covered by WCDMA coverage.

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Figure-3 is a graph indicating the received signal strength taken from KL Sentral to KLIA2 from 9.03am to 9.40am.

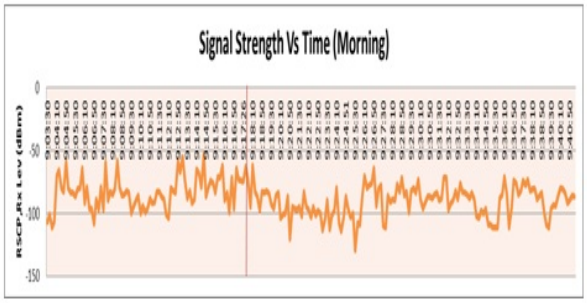

Figure-3. Average received signal strength along KLIA transit rail road at morning.

From the measurement, a better signal quality was taken during 9:14:40 am which located around Taman Seri Serdang. Since this is a residential area, the coverage may be better than the other area because there are a lot of users need to be served, so the network providers will provide better network quality with better infrastructure. The lowest signal strength was observed at 9:25:30 am. This might happen based on the geographical area. The area is surrounded by hills and the signal breakdown may be occurred due to the blockage of tall apartment building nearby Taman Selatan.

Besides the signal strength level, the dropped call also been observed during the measurement of signal strength level. Figure-4 illustrates the details of dropped calls occurred along the rail road.

Dropped Calls - 1. HTC/HTC Sensation Z710e (Filtered)

Event name	Time	CS call disconnect status
Call disconnect	09:17:26.614	Dropped call (i.e. network release)
Call disconnect	09:24:51.940	Dropped call (i.e. network release)
Call disconnect	09:25:41.787	Dropped call (i.e. network release)
Call disconnect	09:27:50.018	Dropped call (i.e. network release)
Call disconnect	09:36:34.987	Dropped call (i.e. network release)
Call disconnect	09:39:14.273	Dropped call (i.e. network release)

Figure-4. Call disconnect status along KLIA rail road at morning.

The dropped calls occurred six times along the rail road resulting from many reasons. One of the reason of drop call is network release.

Average received signal strength at evening

In order to get precise readings on received signal strength, the measurement was taken again at different time. For second measurement, the reading was taken at evening time started from 16:13:50 to 16:41:50. Figure-5 is a graph showing the received signal strength along the 38 minutes journey from KL Sentral to KLIA2.

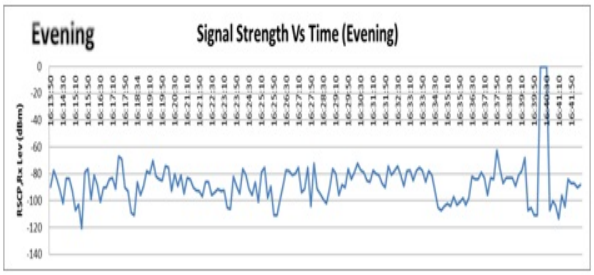

Figure-5. Average received signal strength along KLIA transit rail road at evening.

Figure-6 indicates the statistic of dropped calls occurred along the rail road.

Event name	Time	CS call disconnect status
Call disconnect	16:17:40.748	Dropped call (i.e. network release)
Call disconnect	16:18:34.182	Dropped call (i.e. network release)
Call disconnect	16:19:26.666	Dropped call (i.e. network release)
Call disconnect	16:21:15.330	Dropped call (i.e. network release)
Call disconnect	16:40:06.078	Dropped call (i.e. network release)

Figure-6. Call disconnect status along KLIA rail road at evening.

There are five dropped calls been detected along the rail road. From the observation, the dropped calls happened when the train moving at area that covered by hills, oil palm plantation and dead zone areas (subway lines and basement). Besides that, the blockage of signal from vicinity high mountains also may be a factor of dropped calls since it degraded the signal received from nearby Base Station.

Average received signal strength at night

The received signal strength was then observed at night, this time taken from KLIA2 to KL Sentral. Most of the areas are covered by WCDMA coverage, while area from KL Sentral to Kampung Malaysia Raya, nearest to Bandar Tasik Selatan station are covered by GSM network. Based on the different network coverage along the rail road, it showed varies and inconsistent reading of the received signal strength. Since the area of last two stations are covered by GSM network, it is understandable why the level of received signal strength is dropped to a lower level. Figure-7 illustrates the reading of received signal strength level along 40 minutes started at 20:18:40 until 20:58:40.

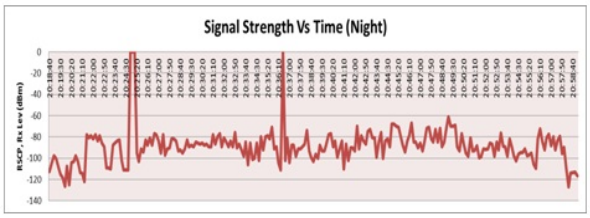

Figure-7. Average received signal strength along KLIA transit rail road at evening.

Compared to morning and evening measurements, call dropped are highly occurred at night which occurred seven times in 40 minutes duration. The frequent call dropped indicates a poor handover procedure,thus need to be improved for better call experience and minimizing service interruption.

Figure-8 shows the detail of dropped calls that occurred at night. The call was dropped three times within three minutes period indicates a poor handover procedure resulting unsuccessful handover process that leads to dropped call.

Event name	Time	CS call disconnect status
Call disconnect	20:18:58.986	Dropped call (i.e. network release)
Call disconnect	20:23:25.237	Dropped call (i.e. network release)
Call disconnect	20:24:43.912	Dropped call (i.e. network release)
Call disconnect	20:36:27.834	Dropped call (i.e. network release)
Call disconnect	20:55:48.925	Dropped call (i.e. network release)
Call disconnect	20:56:53.354	Dropped call (i.e. network release)
Call disconnect	20:58:27.354	Dropped call (i.e. network release)

Figure-8. Call disconnect status along KLIA rail road at night.

As been observed during the measurement, it can be summarized that most of the users are using data mobile and make the call at night. From the map, most of Kuala Lumpur areas are covered by WCDMA coverage which has better signal quality and higher data rate compared to GSM network. People in urban area mostly served with WCDMA coverage to satisfy their usage need and their demand to have a higher data rates. By referring to the indicator of WCDMA, it can be seen that Mid Valley has the weakest signal strength level. This might due to tall buildings in the vicinity area blocking the received signal strength by the users onboard the train.

Besides that, the highest number of dropped call at night also can be happened due to the peak hour of the coverage usage by the users. First dropped call occurred at 20:18:58 PM, second at 20:23:25 PM, third at 20:24:43 PM, fourth at 20:36:27 PM, fifth at 20:55:48 PM, sixth at 20:56:53 PM and lastly at 20:58:27 PM.

The first dropped call is due to basement or subway line or called as dead zone where there is no coverage available. Some of the dropped calls are due to the local environment as there are some construction area been developed along rail road of KLIA transit. Besides that, the reinforced concrete is one of the main factor of bad reception in local area.

SUMMARY AND DISCUSSIONS

The measurements taken at three different times showed that the poor network condition occurred at night, as the highest dropped call was measured at night. The highest possible main reason of this condition is because most of people is home during this time and they consume high usage of data transmission. Compared to morning and evening environment, most of people are out to work or at school, therefore network usage during this hour is lesser. As been observed from the measurement results, the density of users connected to a base station in a cell also affect the network quality.

Other than that, poor signal reception also caused by the geographical area along KLIA transit rail road. The signal was blocked mainly by the tall office or apartment buildings at the urban area, or by the dead zones which are subway or basements. In addition, the hills along the rail road also caused poor received signal strength level since it blocked the signal transmitted from base station. Poor received signal strength level is directly proportional to the number of dropped call. This is because handover is generally initiated when the same signal power strength is detected between two adjacent cells.

If the received signal level is detected to be same as adjacent signal level transmitted by adjacent base station, at wrong handover point, it will leads to premature handover. Thus, call drops will occur with higher probability. An ideal handover point between two adjacent cells must be determined precisely, therefore unnecessary handover trigger can be avoided and handover success rate can be increased accordingly.

CONCLUSIONS

As the speed of high speed train is increasing extensively to meet public need in transportation, it is also a challenge in mobile communication system to provide reliable communication quality and satisfy users' demand to have access to the internet, regardless of locations and speeds. From the results, network quality along high speed trains in Malaysia is not satisfying enough to meet the users' demand. Besides that, higher data rates also need to be considered and improve in the future as data rate transmission using GSM and WCDMA network is not sufficient to meet the future demand.

For future work, the results from this measurement will be a reference point to improve handover initiation procedure in LTE system.

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