Mobile Relay Handover Procedure in Train For 4G LTE-Advanced Network

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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. 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 train. These are a challenge when moving in high speed mobile environment. The major concern is the handover process when travelling from one cell to the other is unable to complete successfully. This is due to the time delay allocates for the handover process to take place is lesser than the time taken for the train to travel across a cell area. Therefore, a solution is solution is required to maintain continuity of services for the passengers on board in order to avoid simultaneous call drop. LTE-Advanced technology seems to be a convincing platform to overcome the problem by proposing better handover signaling procedure when adapting mobile relay on top of the train. A mathematical equation has been derived in order to compare the differences of signaling cost of 3G and 4G networks. The proposed signaling solution is then used in simulation to analyze the number of handover calls between conventional and proposed scheme. The simulation results show that the proposed scheme has better performance in number of handover calls. Thus by adapting relay node in LTE-Advanced network, the problem of drop call can be reduced.**

***Index Terms*—Mobile Relay; Train; Signaling Cost; Handover; LTE-Advanced.**

I. Introduction

At the present, there is a numerous deployment of high train to ease the people to travel from one place to the other. For example, in Korea, the high-speed train operates around 300kmph, which cutting travel time from Seoul to Busan almost in half. Nowadays, Malaysia foresee there is a need to improve connectivity from Kuala Lumpur to Singapore with a development of High Speed Rail to meet growing demand of transportation, catalyzing economic growth and enhancing long term economic competitiveness while improving the quality of life of its people.

By taking considerations of current deployed trains in Malaysia such as KLIA Express and KTM Electric Train Service, which can travel up to 170km/h, together with future deployment of High Speed Train from Kuala Lumpur to Singapore, they initiate growth of demands for a reliable mobile communication and higher data rates. This is because when travelling on board, the passengers mostly kill the time by browsing internet, accessing their email, read online books or news, watching online video (i.e. Youtube), playing online games etc. These services demand high data rates and high level of Quality of Service (QoS) and also low latency which are applicable in normal mobility of users [1].

The performance of services decreased when moving in high speed mobility such as trains due to fast fading, Doppler frequency shift, penetration lost and fast handover. The handover rate increases as the speed of train is higher. In general, if the velocity of train is high, resulting the time taken to cross the handover area is less than the minimum handover delay, the handover process would not be completed, thus a call with drop causing service interruption [2].

In order to facilitate the increasing demands of high speed mobility users, more advance network architecture design is needed. The latest mobile network in Malaysia is 4G (LTE). As the time pass, there will be a need to upgrade the network architecture to solve network failure issues. The network design must have a good signaling cost to ensure service continuity to the users on board.

There are various researches and methods to overcome the handover problem [3]. One of the methods proposed is by having a heterogeneous cell to cover cell edges between two different macro cells [3]. This method reduces the rate of drop call and maintains the continuity of service. However, it could cause Intercell-Interference Coordination (eICIC) and unsuitable to be mounted on a train. Therefore, another method is proposed is by placing mobile relay node on top of the train [3].

The rest of this paper is as follows. Section 2 explains on signaling flow with adaption of signal node, Section 3 on research methodology, Section 4 on performance analysis and Section 5 on simulation result.

II. Signaling Flow With Adaptation of Mobile Relay Node

As been introduced in Section 1, handover failure in high speed mobility such as trains occurred mainly due to the time taken for handover process to take place is less than the time for minimum handover delay. Therefore, addition of mobile relay node is proposed to overcome this issue.

A study on mobile relay node is proposed in 3GPP Release 11 [4]. Recent work by 3GPP in [5] identifies the key properties of mobile relay and make benefits if it in fast-moving environment. Mobile relay on top of train can overcome penetration loss through carrier walls, reduces handover signaling overhead by implementing group mobility and reduce transmitting power of end users thus prolong the battery life [4].

Apparently, there are also challenges if adapting mobile relay in the network. A backhaul link and access link may operate in shared spectrum, resulting a requirement for duplexing operation. According to [4], high speed environment possesses challenges related to link adaptation when consider maximizing the backhaul link spectral efficiency. An author of [6] stating that the target eNodeB may not have enough resources to handle the moving relay executing a handover, thus leads to handover failure.

In order to ensure reliable and successful handover, a modification at mobile relay is proposed to ensure dedicated signaling handover procedure. The idea of designing a signaling procedure includes relay node function in handover is implemented by authors in [7]. A smart forwarding method is used in the signaling flow, ensuring the communication takes place between the UE-RN and RN-eNodeB always stay connected to each other, reducing drop calls and ensure continuity of service.

This paper proposes simplified signaling flow scheme compared to the current conventional signaling flow scheme in Malaysia. Therefore, handover delay of the proposed scheme should be less than the conventional scheme. The overall performance of the proposed scheme in terms of signal cost and latency will be discussed in performance analysis section.

III. RESEARCH METHODOLOGY

In order to analyze total handover cost for both proposed and conventional schemes, several assumptions and parameters are identified as listed below, using same principal of measuring signaling cost as in [8]:

c = transmission cost between database
a = cost of database access
p = probability of UE stay or move to neighboring cell
α = weight factor for the transmission cost
β = weight factor of the access cost of database
Case 1 = Communication happens between two eNodeB
Case 2 = UE remains at same place

The total cost of handover can be calculated as in Equation (1):

$$C^K = p_1K_1^r + p_2K_2^r + \cdots p_nK_n^r \tag{1}$$

where:
p_{1-n} = probability of each case, but for proposed scheme only use one probability
K_{1-n}^r = α (c1+c2+c3…cn) +β (a1+a2+a3…an) = cost of handover of each case.

The latency of handover can be calculated as in Equation (2):

$$s(.) = \frac{1}{\mu(.)} + w(.) \tag{2}$$

where:
s(.) = delay of accessing database
$\frac{1}{\mu(.)}$ = average processing time for each database
$w(.)$ = average waiting time

While average waiting time, $w(.)$ is as per Equation (3):

$$w(.) = \eta(.)\frac{\mu(.) + \sigma_n^2}{2(1-\frac{\eta(.)}{\mu(.)})} \tag{3}$$

where:
$\eta(.)$= average arrival rate for each of database
σ_n^2 = variance of processing time

Total latency formula is as in Equation (4):

$$D^r = p_0s(0) + p_1s(1) + \cdots \ldots p_ns(n) \tag{4}$$

Based on the assumptions and parameters used, the proposed scheme is analyzed. The data for total cost of handover and handover latency is simulated using Matlab software. A mathematical equation is derived and implemented using the software to evaluate it.

IV. THEORETICAL PERFORMANCE ANALYSIS

Table 1, 2 and 3 contain the parameter values used in analyzing the performance of the proposed signaling scheme for total cost of handover and handover latency. Both of the proposed scheme and conventional scheme are analyzed using different value of α value which are at α = 0.5, α = 0.7 and lastly at α = 0.9.

Table 1
Total handover signaling cost and its probability

Case	Probability	Latency D^r
1	P1	Srn + Ssn + Stn + Smme +Ssgw
2	P2	0

Table 2
Handover latency and its probability

Database Access cost	asgw 8	amme 5	atn 5	asn 5	arn5
Average Processing Time (msec)	$\frac{1}{\mu(sgw)}$ 1.0	$\frac{1}{\mu(mme)}$ 0.5	$\frac{1}{\mu(tn)}$ 0.5	$\frac{1}{\mu(sn)}$ 0.5	$\frac{1}{\mu(rn)}$ 0.5
Signaling Transmission Cost	C_1=C_2=C_3=C_4=C_5=1				
Database Access Cost	a_{rn}=a_{sn}=a_{tn}=1; a_{mme}=5; a_{sgw}=8;				
Proposal Average Arrival Rate(msec^{-1})	$\eta(sgw)$ 0.001	$\eta(mme)$ 0.001	$\eta(tn)$ 0.001	$\eta(sn)$ 0.001	$\eta(rn)$ 0.001
Variance of Processing Time (msec)	σ_{sgw}^2 0.04	σ_{mme}^2 0.01	σ_{tn}^2 0.01	σ_{sn}^2 0.01	σ_{rn}^2 0.01

The total handover signaling cost for the proposed scheme is as in (5):

$$C^K = \alpha(6c1+5c2+6c3+2c4+2c5) \\ \beta(arn+asn+atn+amme+asgw) \tag{5}$$

where:
c1 = transmission cost between UE & Relay

c2 = transmission cost between Relay & Source eNodeB
c3 = transmission cost between Source eNodeB & Target eNodeB
c4 = transmission cost between Target eNodeB & MME.
c5 = transmission cost between MME & SGW
arn = database for access relay node
asn = database for access source eNodeB
atn = database for access target eNodeB
amme = database for access MME
asgw = database for access SGW

The total latency for the proposed scheme is as in (6):

$$D^r = Srn + Ssn + Stn + Smme + Ssgw \qquad (6)$$

where:
Srn = Delay for accessing relay node database
Ssn = Delay for accessing source eNodeB database
Stn = Delay for accessing target eNodeB database
Smme = Delay for accessing MME database
Ssgw = Delay for accessing SGW database

Table 3
Parameter used for proposed scheme

Case	1	2
Probability	P1	P2
Signaling cost	6c1+5c2+6c3+2c4+2c5	0
Cost of Database	arn+asn+atn+amme+asgw	0
Cost of handover	α(6c1+5c2+6c3+2c4 + 2c5 β(arn+asn+atn+amme+asgw)	0

where:
$\frac{1}{\mu(sgw)}$ = average processing time for SGW
$\frac{1}{\mu(mme)}$ = average processing time for MME
$\frac{1}{\mu(tn)}$ = average processing time for target eNodeB
$\frac{1}{\mu(sn)}$ = average processing time for source eNodeB
$\frac{1}{\mu(rn)}$ = average processing time for relay node
$\eta(sgw)$ = arrival rate for SGW
$\eta(mme)$ = arrival rate for MME
$\eta(tn)$ = arrival rate for target eNodeB
$\eta(sn)$ = arrival rate for source eNodeB
$\eta(rn)$ = arrival rate for relay node
σ^2_{sgw} = variance of processing time for SGW
σ^2_{mme} = variance of processing time for MME
σ^2_{tn} = variance of processing time for target eNodeB
σ^2_{sn} = variance of processing time for source eNodeB
σ^2_{rn} = variance of processing time for relay node

Based on the parameters listed in Table 1, 2 and 3 the total handover cost and latency are analyzed using Matlab software. Figure 1 until Figure 3 show the result of total handover signaling cost when the value of α varies at 0.5, 0.7 and 0.9, where α is the weight factor for the transmission cost.

Based on all three figures, Figure 1, Figure 2 and Figure 3, the total cost of handover increased when the value of α increased. The figures also indicate that total cost of handover using proposed scheme is lower than the conventional handover scheme. As observed, the addition of relay node in the network architecture reduces the signaling cost, thus lowering the handover cost and rate of drop calls.

The parameters were then analyzed to compare the performance of proposed scheme at α = 0.5 with conventional scheme at α = 0.5, 0.7 and 0.9. The result is shown in Figure 4.

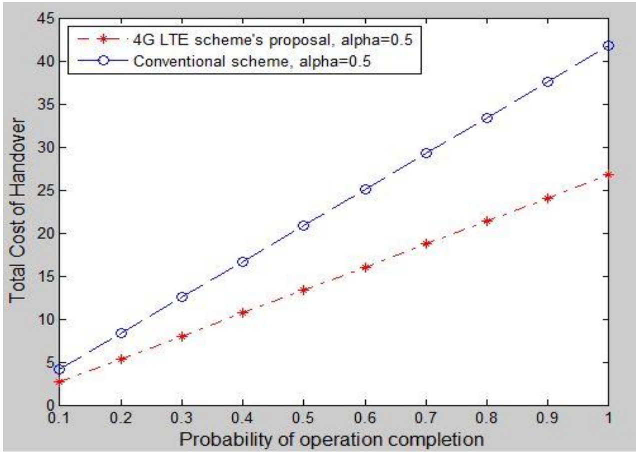

Figure 1: Relationship between total cost of handover against probability of operation completion at α = 0.5

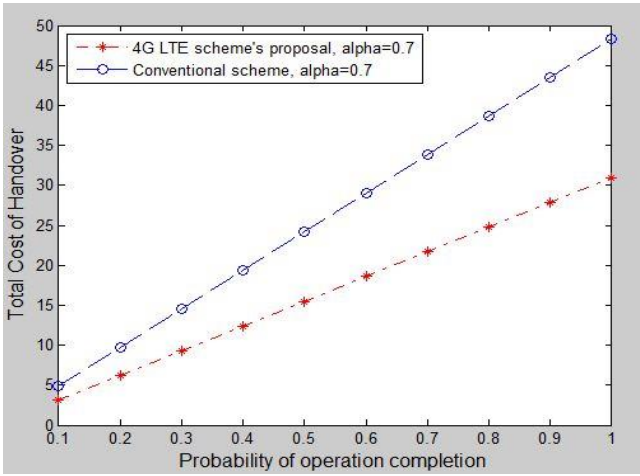

Figure 2: Relationship between total cost of handover against probability of operation completion at α = 0.7

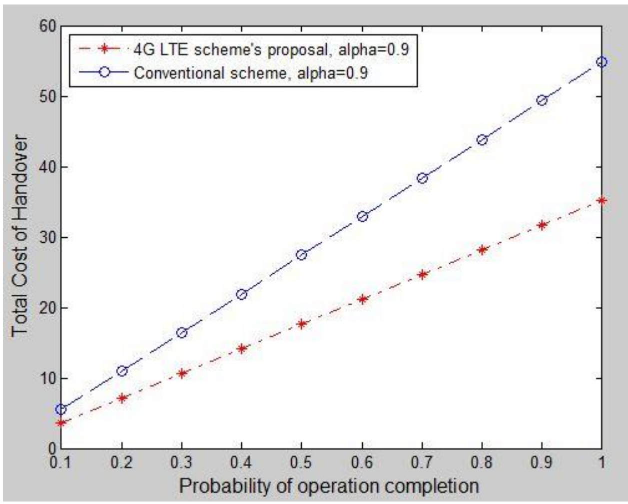

Figure 3: Relationship between total cost of handover against probability of operation completion at α = 0.9

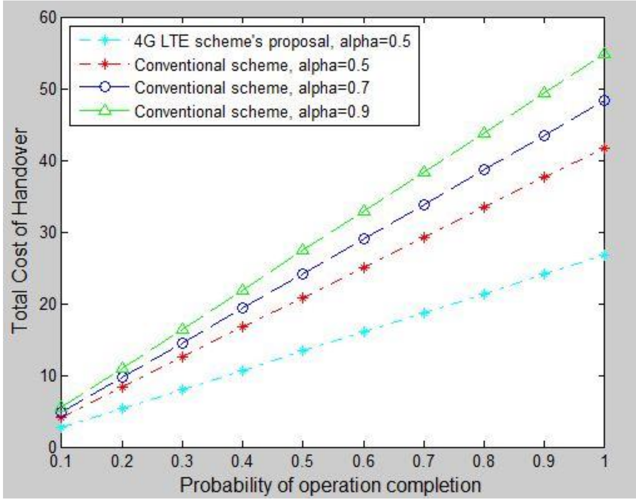

Figure 4: Relationship between total cost of handover against probability of operation completion, compared with proposed scheme at α = 0.5 and conventional scheme at at α = 0.5, 0.7 and 0.9

As shown in Figure 4, total cost of handover for the proposed scheme shows better performance compared to the conventional scheme. This is due to the 4G network architecture. According to 3GPP standard, 4G is the simplified network architecture compared to the conventional scheme [1]. The database or element uses in new 4G network is less than the conventional scheme therefore the time taken to accessing the database is shorter. This also leads to shorter time to initiate the call within 4G network which resulting faster and better performance compared to the conventional scheme.

The time accessing the database does affect the handover latency. In conventional scheme, a longer processing time is needed to access larger database, while in the proposed scheme is processing time is shorter. Therefore, it can be observed that the handover latency for proposed scheme is lower than the conventional scheme. The result is illustrated in Figure 5.

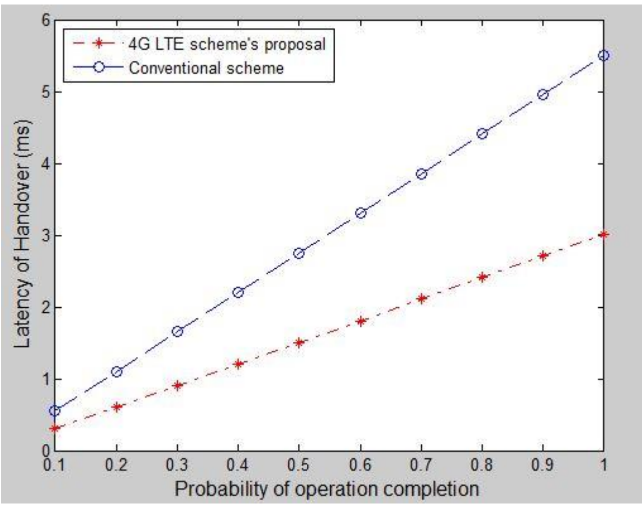

Figure 5: Relationship between handover latency against probability of operation completion at α = 0.5

Based on the simulation result, theoretically it clearly shows that the proposed scheme has better performance in terms of total handover cost and handover latency as compared to the conventional scheme.

V. Simulation Result and Discussion

A simulation for proposed signaling flow scheme is done to simulate the effect of adding mobile relay node in 4G network architecture. Figure 6 below indicates the initial position and the movement of UE to next position. The red dots refer to initial position of UE and the black cross refers to the position of moving UE. At same time, the position of relay node is maintained at distance of 500m in mobile environment. This process is repeated for simulation time of 1000s at speed of train fixed at 100kmph.

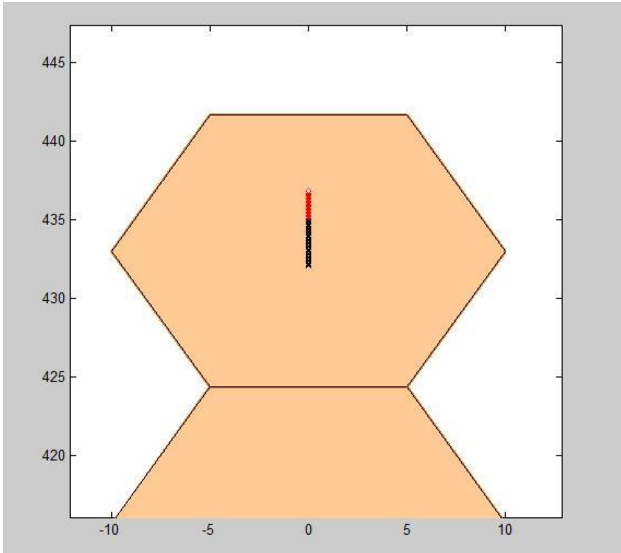

Figure 6: UE in one cell before it moves to another cell

Besides that, due to the high velocity of train, a set of long track consists of 50 hexagon cell has been set up to collect the measurement of handover call during the simulation time. The long track is illustrates in Figure 7 with a condition that the simulation is only focusing the center tracks only.

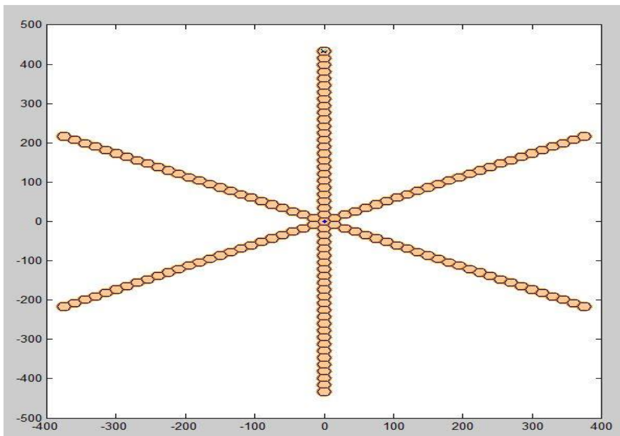

Figure 7: Long track of 50 hexagon cell in a straight line, considering center track only

The simulation results of proposed and conventional scheme with simulation times of 200s and 1000s are shown in Figure 8 and Figure 9 respectively. The simulation time is done up to 1000s in order to obtain precise and accurate result. Based on the results, the proposed scheme show higher number of handover call compared to the conventional scheme. This is because propose scheme provides larger channel than the normal macro cell 4G architecture.

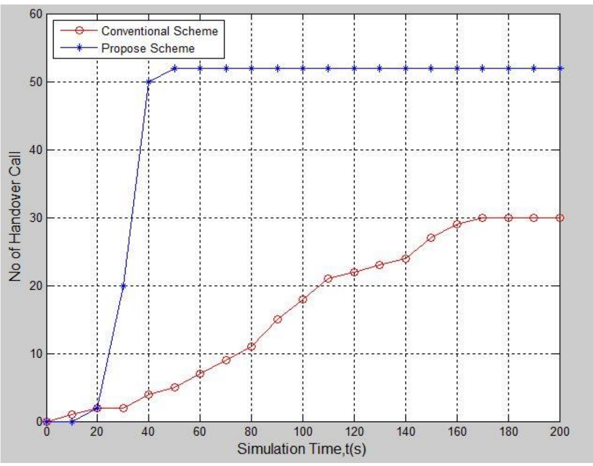

Figure 8: Number of handover call against the simulation time (t = 200s)

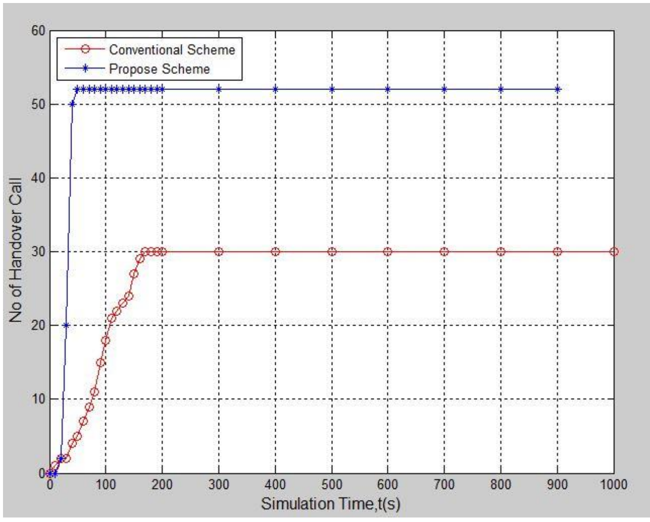

Figure 9: Number of handover call against the simulation time (t = 1000s)

As observed from the results, higher number of handover call indicates better quality of network. This is because addition of relay node provides more channel to the users. Therefore, number of successful handover is increased compared to conventional scheme. In conventional scheme, the handover failure rate is higher since because the handover process cannot be completed in time [6].

VI. Discussion

Adapting a mobile relay node in LTE-Advanced network is one of the methods to overcome handover failure in high speed mobility environment. Mobile relay node supports group handover which reducing the rate of handover failure, and ensure service continuity. Since LTE network is simpler than 3G architecture, the processing time to access the database also shorter. In the propose scheme by adapting mobile relay node in the network, it shows significant result where the total handover cost and handover delay is lower as compared to the conventional scheme. From the simulation results, the proposed scheme shows higher number of handover call compared to the conventional scheme. This is because by adapting mobile relay node in the network provides more channel, thus reducing the drop call during the handover process.

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