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Performance analysis of the LTE handover decision events for the high speed railway application

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***Abstract*— Providing high quality mobile internet service to passengers of high speed railway (HSR) has a key role to its market share. The LTE radio network has been raised as candidate for providing high data rate for this purpose. However, in the LTE radio network, handover (HO) becomes an important challenge at high moving speeds. The 3GPP standard body, has introduced several events for LTE HO decision making. To date, there has not been an analytical model to compare these events for using in HSR system. We have mathematically analyzed these events to compare their performances in which the effect of speed has also been considered. The results have been validated by comparison with simulation which shows close matching. The analytical model can be used for introducing new modified events which specially will be designed for HSR system.**

Index Terms- Railways, High Speed Railways (HSR), LTE, Handover, Handover Events.

I. INTRODUCTION

In past thirty years the mobile radio communication has a great advancement and up to now four generations of Radio Communication systems have been developed and fifth generation is on the way [1],[2]. By spreading the internet technology and more need for data communication the radio mobile communication tended to digital instead of analog communication with higher data rates.

Long Term Evolution (LTE) is an advanced radio mobile technology that is introduced by the 3rd Generation Partnership Project (3GPP) to develop high-data-rate, low-latency and packet-optimized radio access technology [3]. The LTE supportive standard has also been developed by 3GPPs and in first release, it did not really meet the requirements identified by the ITU in relation to the fourth generation, so it is considered to be one of the latest achievements of the third generation (3.9G.)[4],

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but in 2011, 3GPP Release 10 standard officially introduced this technology as the 4th generation of mobile telecommunication network [6].

On the other hand, with the more development of public transportation systems and the increase of their speed, high-speed mobile subscribers have also found a more important role. One of the most popular means of transportation is High Speed Railway (HSR) which is an advanced form of conventional railways system with speed more than 250 Km/h [7]. Despite the record speed of 575 Km/h that achieved on April 3, 2007 in France, the commercial speed of HSR around the world is about 350 Km/h [8]. HSR is in great competition with air transport, so providing extra services such as high-speed internet service and efficient train communication on trains is a determining factor. Up to now, the most common wireless communication system for railways has been GSM-R but according to restrictions such as low data transfer rate of 200 kbps, which is sufficient just only for train control and operation needs, so this system is replacing with LTE-R that is based on LTE technology [10], [11]. High data rate in LTE works best for low speed and for high speed mobility users there are yet important challenges[12]. In all mobile communications systems as well as LTE, mobility management of user equipment (UE) is of great importance. Mobility management has two aspects: position management and HO management [13]. HO is done when a UE link is transferred from serving base station (SeNB) to another (TeNB). The HO decision is done by SeNB based on some schemes which is called HO Events. The UE signal measurement feedback is main input to these events. The HO Events are standardized by 3GPP[14]. Some papers have investigated the LTE HO events individually in railway application just by simulation tools [19][20], [21]. To the best of our knowledge these HO events have not been analyzed and compared generally or for special case that we considered, i.e. HSR. Therefore, this paper aims to choose the best HO events for using in HSR by classification and analytical comparison of the events. The results are verified simulation results.

The remainder of this paper is organized as follows: Section II discusses HO events applicable to high speed railways, Section III presents the performance analysis of the events, Section IV presents the simulation and results and finally, section V presents the conclusion.

II. HO EVENTS APPLICABLE TO HIGH SPEED RAILWAYS

A. Handover (HO)

The HO is the process of the channel change (frequency, time slot, expansion code or a combination thereof) of the current communication session. In the texts, it is also called Handoff or automatic link transfer (ALT) [15]. Fig. 1 shows the HO process during which the UE is camped to the source base station (SeNB) and while data or voice session is up UE leaves source base station to camp to target base station without any sensed interruption [16].

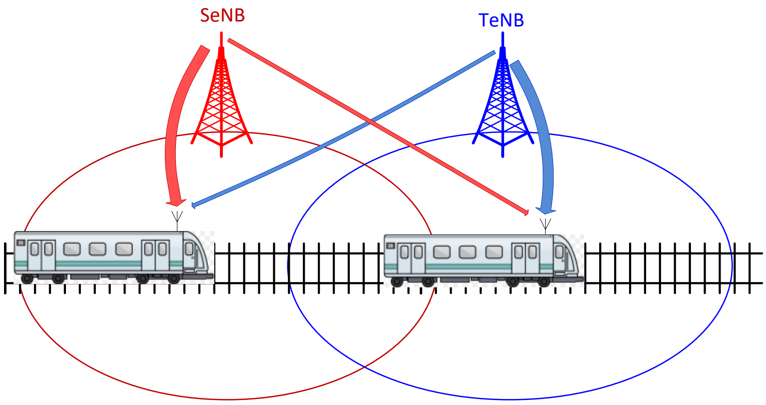

Fig. 1. System architecture

The HO usually takes place at the point where the two base stations overlap, while the UE receives the signal from both base stations in approximately the same condition. In simple words when the signal strength received from the SeNB weakens more than the signal strength received from the TeNB or a certain threshold, the UE communication transfers from SeNB to TeNB without user notice. What triggers HO is known as the HO event, which is standardized by 3GPP body[14].

As the high-speed train passes through the overlap area between the two cells, all mobile users handover to the new cell. Due to the issue of consecutive HOs, group HOs and QoS (Quality of Service) guarantee in some services, proper selection of appropriate HO event is one of the most important challenges in HSR radio communications [17].

B. HO Events

The 3GPP standard, No. TS 36.331, introduces HO Events and their Entry Condition (EC) and Leaving Condition are explained [14]. According to it, 13 events are introduced which are named as follows and conditions are explained:

- A1 to A6 events,
- B1 and B2 events,
- C1 and C2 events
- W1 to W3 events

As the events W1-W3 and events C1 and C2 are not considered in this paper because they are not applicable for HSR. Therefore, the total of 8 noticed HO events are considered here, which are practically reducible to three categories as is described in the next section.

C. Noticed HO events and their relations

The A1 event which acts based on base station's signals strength, is not directly HO, but is used to stop the UE consecutive and unnecessary measurements when the signal quality is good enough.

The A2 event acts functionally similar to A1, but vice versa. In this case, the signal strength of the serving base station is measured and if it is less than a specified threshold, this event will be activated.

It should be noted that events A1 and A2 are prologue for HOs, so we do not consider them in comparison

The A3 event is based on the comparison of strength of the signals from serving base station (SeNB) and the target base station (TeNB), and if the signal strength of the TeNB is stronger than the SeNB, HO will be triggered. The entry condition (EC) and leaving conditions (LC) for this event are defined according to relations (1) and (2), respectively:

$$R_n + Ofs_n > R_s + Ofs_s + Ofs_{A3} + Hys_{A3} \quad (1)$$

$$R_n + Ofs_n < R_s + Ofs_s + Ofs_{A3} - Hys_{A3} \quad (2)$$

Where:

R_n is Reference Signal Received Power (RSRP) of TeNB,

R_s is Reference Signal Received Power (RSRP) of SeNB,

Ofs_n is cell specific offset of TeNB,

Ofs_s is cell specific offset of SeNB,

Ofs_{A3} is the offset parameter for this event,

Hys_{A3} is the hysteresis parameter for this event

As the specific offset of both cells considered the same, Ofs_n and Ofs_s will be omitted.

The functional schematic of the A3 event has shown in Fig. 2.

The A4 event may be considered similar to the A1 event, except that it is used directly in the HO, and hysteresis and offset is also considered for it.

The entry condition (EC) and leave condition (LC) for the A4 event are given by equations (3) and (4), respectively:

$$R_n - Ofs_{A4} - Hys_{A4} > Thr_{A4} \quad (3)$$

$$R_n - Ofs_{A4} + Hys_{A4} < Thr_{A4} \quad (4)$$

Where:

R_n is received power (RSRP) of TeNB,

R_s is received power (RSRP) of SeNB,

Ofs_{A4} is the offset parameter for this event,

Hys_{A4} is the hysteresis parameter for this event,

Thr_{A4} is the threshold parameter for this event,

The functional schematic of the A4 event has shown in Fig. 3.

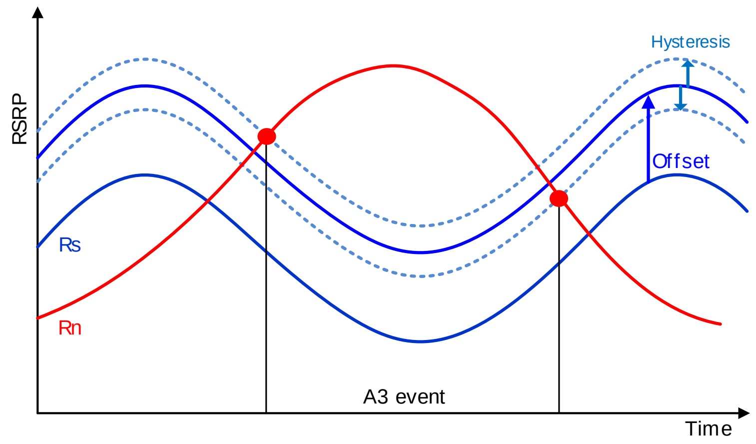

Fig. 2. Functional schematic of the A3 event

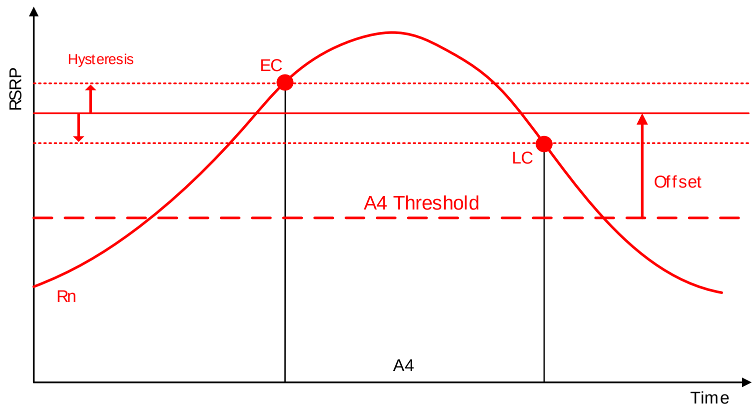

Fig. 3. Functional schematic of the A4 event

The A5 event is a relatively complex event with two thresholds. That is, the signal of the TeNB is compared with the threshold 1 and the signal of the SeNB is compared with the threshold 2. Another difference is that in the second comparison, an offset is also considered.

The EC for the A5 event is defined as:

$$R_s < Thr1_{A5} - Hys1_{A5} \quad \& \quad R_n > Thr2_{A5} - Ofs_{A5} + Hys2_{A5} \tag{5}$$

The LC is also defined for event A5 as:

$$R_s > Thr1_{A5} + Hys1_{A5} \quad \& \quad R_n < Thr_{A5} - Ofs_{A5} - Hys2_{A5} \tag{6}$$

Where:

R_n is received power (RSRP) of TeNB,

R_s is received power (RSRP) of SeNB,

Ofs_{A5} is the offset parameter for this event,

$Hys1_{A4}$ is the hysteresis parameter #1 for this event,

$Thr1_{A4}$ is the threshold parameter #1 for this event,

$Hys2_{A4}$ is the hysteresis parameter #2 for this event,

$Thr2_{A4}$ is the threshold parameter #2 for this event,

The functional schematic of the A5 event has shown in Fig. 4

The B1 event is analogous to event A1, except that the frequency offset parameter is added to its threshold.

The last event that is considered, B2 is analogous to A5.

The last two events have two twins in their previous incidents, and since they are related to Inter-RAT, they have not been investigated here.

It is worth noting; hysteresis parameter in above relations that always is positive is intended to prevent the ping pong effect, but the offset parameter that can be both positive or negative is intended to adjust the HO time, for example even if the power of received signal from the SeNB is good enough, but since its capacity is full, the offset can be adjusted so the HO take place sooner.

III. PERFORMANCE ANALYSIS

In this section, the main events will be analyzed that have major differences in decision making. The structure used for the analysis is shown in Fig. 5. The received signal strength from the base stations SeNB and TeNB can be denoted as [8]:

$$R_s = 10\log_{10}\left(P_d \cdot A \cdot W\right) - 10\gamma\log_{10} D_s + 10\log_{10} sh_s^2 \tag{7}$$

$$R_n = 10\log_{10}\left(P_d \cdot A \cdot W\right) - 10\gamma\log_{10} D_n + 10\log_{10} sh_n^2 \tag{8}$$

Where $P_d = E\left[\left|d_m\right|^2\right]$, in which d_m is the transmitted data, A is constant, $W = \sum_{l=0}^{L-1}\sigma_l^2\int_{-1}^{1} J_0\left(2\pi f_D T_s x\right)\left(1-x\right)dx$ is independent of the distance to the base station in which L is the number of path fading. J_0 is a zero-order Bessel function and $f_D = v f_c / c$ is the maximum Doppler frequency, in which v is the train speed, f_c is the carrier frequency and c is the speed of light. T_s is an effective OFDM symbol duration. sh_n indicates shadow fading related to TeNB with zero mean and standard deviation of σ_n and sh_s indicates shadow fading related to SeNB with zero mean and standard deviation of σ_s. D_s and D_n are also the distance between train and SeNB and TeNB, respectively and at last γ is the path loss exponent.

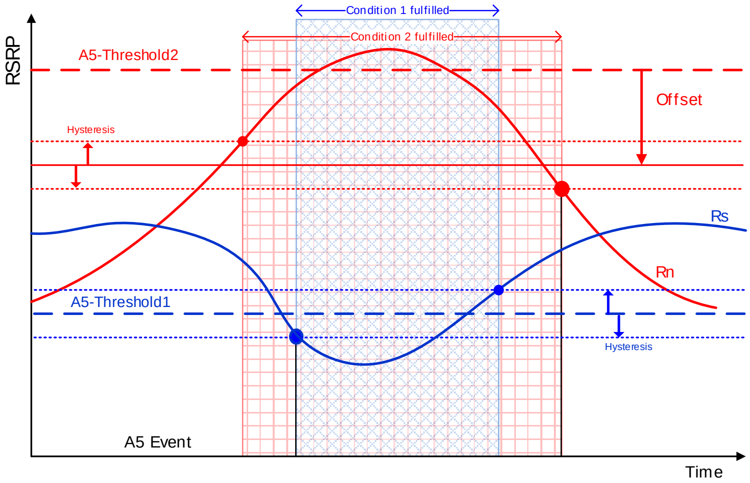

Fig. 4. Functional schematic of the A5 event

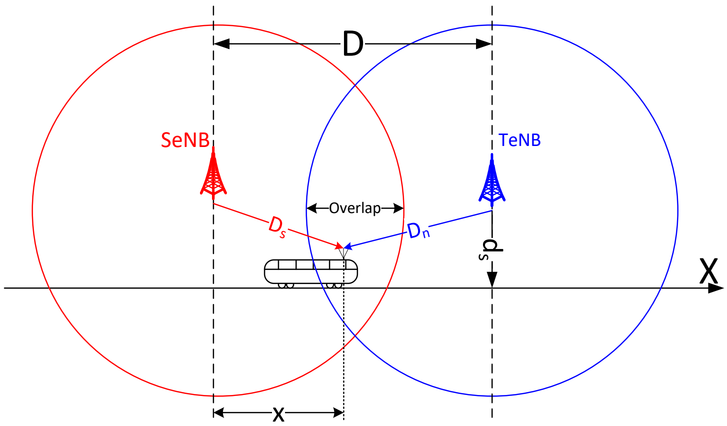

Fig. 5. Analytical schematic

A. A3 Event Analysis

1) HO probability of A3 Event

As mentioned before, A3 is one of the main events and unlike the other events it works by comparing the two signal levels of the SeNB and TeNB. Therefore, the HO probability of A3 Event can be written as follows:

$$P_{P_{HO\_A3}} = P\left\{(R_n - R_s) > Hys_{A3} + Ofs_{A3}\right\} = P\begin{Bmatrix} -10\gamma\log_{10} D_n + 10\log_{10} sh_n^2 + 10\log_{10}\left(P_d \cdot A \cdot W\right) + \\ 10\gamma\log_{10} D_s - 10\log_{10} sh_s^2 - 10\log_{10}\left(P_d \cdot A \cdot W\right) > Hys_{A3} + Ofs_{A3} \end{Bmatrix} \quad (9)$$

With the definitions; $SD_n = 10\log_{10} sh_n^2$ and $SD_s = 10\log_{10} sh_s^2$, we will have:

$$P_{HO\_A3} = P\left\{10\gamma log_{10} D_s - 10\gamma log_{10} D_n + SD_n - SD_s > Hys_{A3} + Ofs_{A3}\right\} \tag{10}$$

Given that SD_n and SD_s both have Gaussian distributions with zero mean and standard deviations of σ_n and σ_s [23]. Since the sum of random variables with Gaussian distribution has a Gaussian distribution, so $SD = SD_s + SD_n$ will have Gaussian distribution with zero mean and standard deviation of $\sigma = \sqrt{\sigma_n^2 + \sigma_s^2}$. So we will have:

$$P_{HO\_A3} = P\left\{10\gamma log_{10} D_s / D_n + SD > Hys_{A3} + Ofs_{A3}\right\} = Q\left(\left(Hys_{A3} + Ofs_{A3} - 10\gamma log_{10} \frac{\sqrt{x^2 + d_s^2}}{\sqrt{(D-x)^2 + d_s^2}}\right) / \sigma\right) \tag{11}$$

2) HO failure probability of A3

The handover failure (HOF) happens if in duration between HO trigger and connection transfer to TeNB, the signal received by SeNB drops below the acceptable limit and so the HO fails. We define the handover failure probability to measure it [21]. Considering Fig. 6, let's assume that the first UE measurement was made at distance x_T corresponding to time t_T. The probability of an HO occurring at x_T is $P_{HO\_A3}\big|_{x_T}$. We suppose the next measurement at point x_o corresponds to t_o. Then $t_o - t_T = TTT$.

Since the random variables of two consecutive measurements at point x_T and x_o can be considered independent, so the HOF probability of A3 event will be the product of two, denoted as:

$$P_{HOF\_A3} = P_{HO\_A3}\big|_{x = x_T} \times P\left\{R_s < T_{fail}\big|_{x = x_o}\right\} \tag{12}$$

In which T_{fail} is acceptable limit of received signal. Now, after HO trigger (at time t_T and $x = x_T$), the *TTT* (time to trigger) timer starts and the next measurement will be performed as soon as *TTT* is over at $t = t_o$. According to Fig. 6, $t_o = t_T + TTT$, so with train speed of v,we will have $x_o - x_T = v \times TTT$, therefore:

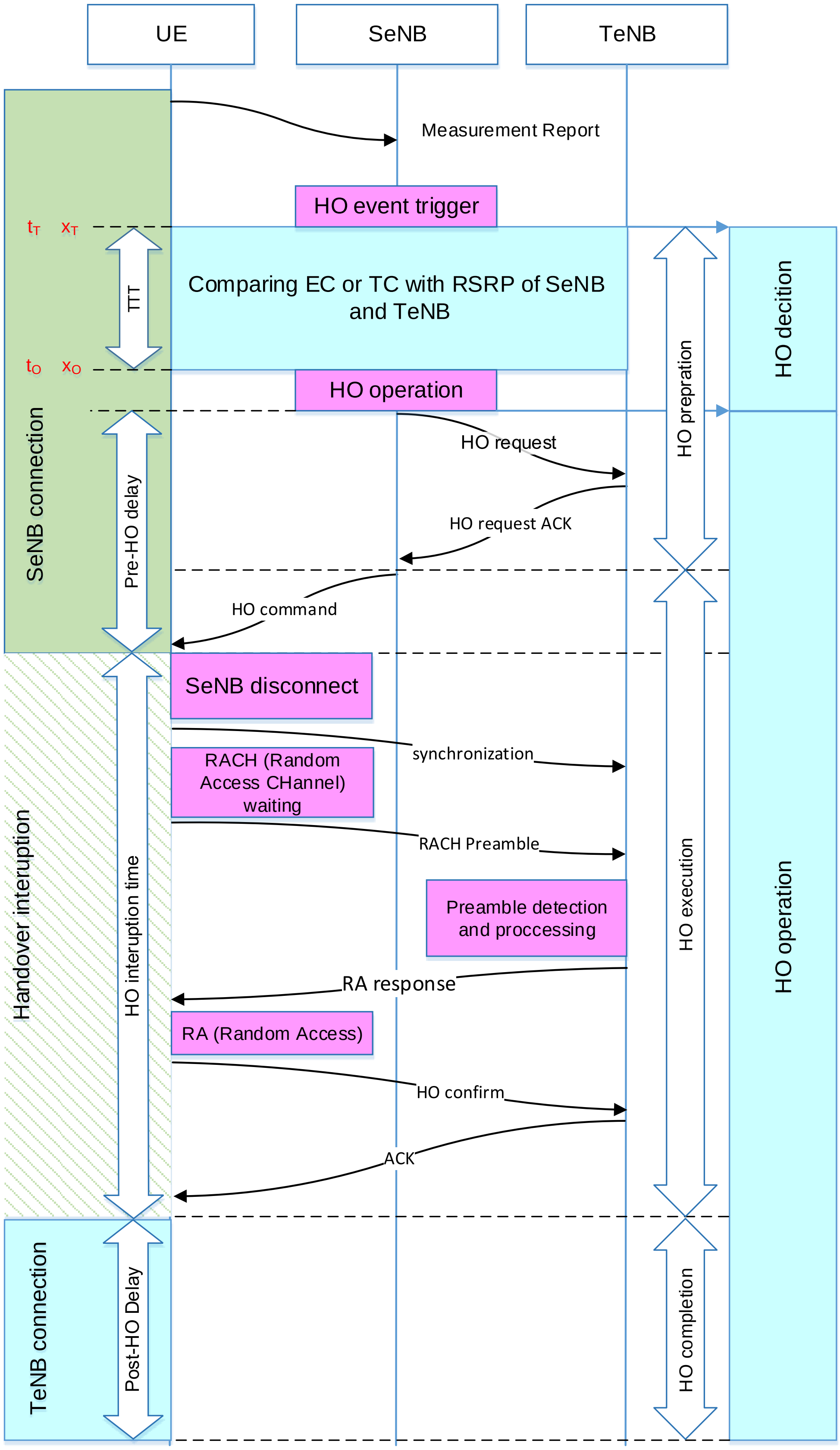

Fig. 6. HO Signaling process in LTE

$$
\begin{aligned}
&P\left\{R_s < T_{fail}\big|_{x=x_o}\right\} = P\left\{10log_{10}\left(P_d \cdot A \cdot W\right) - 10\gamma log_{10} D_n\big|_{x=x_o} + SD_n < T_{fail}\right\} = \\
&P\left\{SD_n - 10\gamma log_{10} D_n\big|_{x=x_o} < T_{fail} - 10log_{10}\left(P_d \cdot A \cdot W\right)\right\} = \\
&1 - P\left\{SD_n - 10\gamma log_{10} D_n\big|_{x=x_o} > T_{fail} - 10log_{10}\left(P_d \cdot A \cdot W\right)\right\} = \\
&1 - Q\left(\left(T_{fail} - 10log_{10}\left(P_d \cdot A \cdot W\right) - 10\gamma log_{10} D_n\big|_{x=x_o}\right) / \sigma_s\right) = \\
&1 - Q\left(\left(T_{fail} - 10log_{10}\left(P_d \cdot A \cdot W\right) + 10\gamma log_{10}\sqrt{\left(x_T + v \times TTT\right)^2 + d_s^2}\right) / \sigma_s\right)
\end{aligned}
\tag{13}
$$

Now, according to the equations 11 and 12, we will have:

$$
\begin{aligned}
&P_{HOF\_A3} = Q\left(\left(Hys_{A3} + Ofs_{A3} - 10\gamma log_{10}\frac{\sqrt{x^2 + d_s^2}}{\sqrt{\left(D - x_T\right)^2 + d_s^2}}\right) / \sigma\right) \times \\
&\left[1 - Q\left(\left(T_{fail} - 10log_{10}\left(P_d \cdot A \cdot W\right) + 10\gamma log_{10}\sqrt{\left(x_T + v \times TTT\right)^2 + d_s^2}\right) / \sigma_s\right)\right]
\end{aligned}
\tag{14}
$$

B. A4 Event Analysis

1) HO probability of A4 Event

Based on before mentioned definition of A4 event:

$$
\begin{aligned}
&P_{HO_{A4}} = P\left\{R_n > Thr_{A4} + Hys_{A4} + Ofs_{A4}\right\} \xrightarrow{R_n\ def} \\
&P_{HO_{A4}} = P\left\{10\log_{10}\left(P_d \cdot A \cdot W\right) - 10\gamma\log_{10} D_n + 10\log_{10} sh_n^2 > Thr_{A4} + Hys_{A4} + Ofs_{A4}\right\}
\end{aligned}
\tag{15}
$$

According to previous mentioned definitions, we will have:

$$
\begin{aligned}
&P_{HO\_A4} = P\left\{SD_n - 10\gamma log_{10} D_n > Thr_{A4} + Hys_{A4} + Ofs_{A4} - 10log_{10}\left(P_d \cdot A \cdot W\right)\right\} = \\
&Q\left(\left(Thr_{A4} + Hys_{A4} + Ofs_{A4} - 10log_{10}\left(P_d \cdot A \cdot W\right) - 10\gamma log_{10}\sqrt{\left(D - x\right)^2 + d_s^2}\right) / \sigma_n\right)
\end{aligned}
\tag{16}
$$

2) HO failure probability of A4

According on the descriptive explanations given for calculation of HOF probability of A3 event, we will have:

$$
P_{HOF\_A4} = P_{HO\_A4}\Big|_{x=x_T} \times P\left\{R_s < T_{fail}\big|_{x=x_o}\right\}
\tag{17}
$$

The left side of the above relation was calculated in the previous section, and the right side was calculated in the section of A3 HOF calculation. So we will have:

$$P_{HOF\_A4} = Q\left(\left(Thr_{A4} + Hys_{A4} + Ofs_{A4} - 10\log_{10}\left(P_d \times A \times W\right) + 10\gamma\log_{10}\sqrt{\left(D - x\right)^2 + d_s^2}\right)/\sigma_n\right) \times \left[1 - Q\left(\left(T_{fail} - 10\log_{10}\left(P_d \times A \times W\right) + 10\gamma\log_{10}\sqrt{\left(x_T + v \times TTT\right)^2 + d_s^2}\right)/\sigma_s\right)\right] \quad (18)$$

A. A5 Event Analysis

1) HO probability of A5 Event

According to the definition of A5 event, we will have:

$$P_{HO\_A5} = P\left\{R_n > Thr2_{A5} + Hys2_{A5} + Ofs_{A5} \,.\, R_s < Thr1_{A5} - Hys1_{A5}\right\} \quad (19)$$

Since the R_n and R_s are independent, so:

$$P_{HO\_A5} = Q\left(\left(Thr2_{A5} + Hys2_{A5} + Ofs_{A5} - 10log_{10}\left(P_d \cdot A \cdot W\right) - 10\gamma log_{10}\sqrt{\left(D - x\right)^2 + d_s^2}\right)/\sigma_n\right) \times \left[1 - Q\left(\left(Thr1_{A5} - Hys1_{A5} - 10log_{10}\left(P_d \cdot A \cdot W\right) + 10\gamma log_{10}\sqrt{x^2 + d_s^2}\right)/\sigma_s\right)\right] \quad (20)$$

2) HO failure probability of A5

According to the description given for calculation of HOF probability of A3 event, HOF probability of A5 event can be mentioned as follows:

$$P_{HOF_{A5}} = Q\left(\left(Thr2_{A5} + Hys2_{A5} + Ofs_{A5} - 10log_{10}\left(P_d \cdot A \cdot W\right) + 10\gamma log_{10}\sqrt{\left(D - x_T\right)^2 + d_s^2}\right)/\sigma_n\right) \times \left[1 + Q\left(\left(Thr1_{A5} - Hys1_{A5} - 10log_{10}\left(P_d \cdot A \cdot W\right) + 10\gamma log_{10}\sqrt{x^2 + d_s^2}\right)/\sigma_s\right)\right] \times \left[1 - Q\left(\left(T_{fail} - 10log_{10}\left(P_d \cdot A \cdot W\right) + 10\gamma log_{10}\sqrt{\left(x_T + v \times TTT\right)^2 + d_s^2}\right)/\sigma_s\right)\right] \quad (21)$$

IV. SIMULATION AND RESULTS

The simulation was performed in the MATLAB environment. The HSR conditions for the test of the physical layer performance are two non-fading propagation channels [24]. We set a non-zero value for the Doppler shift in order to model a high-mobility flat-fading channel [25]. In order to account for the rapid fading effect due to the Doppler shift, we used the method used in Z. Liu and P. Fan [22]. Also, the constellation of the received signal resembles a 64QAM (Quadrature Amplitude Modulation) modulation. The simulation parameters are given in Table I.

The diagrams of HO probability of three events (theory and simulation) are shown in Fig. 7. As the figure presents, the simulation results confirm the theoretical results.

As shown in Fig. 7, at first glance, A3 event shows the best behavior in terms of the HO probability, closer to ideal behavior (ideal behavior is a step function that changes from 0 to 1 at optimum location of HO that is 1300m in our example). But for comprehensive comparison, other behaviors need to be evaluated. One of the most important indicators in this regard is the HO failure probability. According to previous obtained relations, this indicator is speed dependent, so the effect of train speed can be taken to account. The diagrams of HOF probability of three events (theory and simulation) for low speed and high speed are shown respectively in Fig. 8 and Fig. 9.

Fig. 8 and Fig. 9 depict that events A3 and A4 show similar behavior in handover failure probability (HOF). In a position farther from the ideal HO location (here 1300m), the A4 event shows slightly higher HOF probability than the A3 event, but close to the ideal HO location, both are very close to each other. However, the A5 event has significantly lower HOF probability than the other ones.

Despite of the obtained result in this regard is in favor of A5 event but for the final judgment, probability density function (Pdf) of HO success will be discussed. This parameter is a distance indication of the most took placed HOs from the ideal HO location. The analytical charts of probability density function (Pdf) of HO success for main three events are depicted in Fig. 10.

In contrary to the HOF behavior that was depicted in Fig. 8 and Fig. 9, it is clear from this figure that A4 event has the worst behavior in this index. Additionally due to the poor behavior of A4 event for HO probability that was shown in Fig. 7, this event will be last choice. In terms of probability of HOF, A3 and A4 events have a close behavior. In terms of the HO probability that was shown in Fig. 7, the A3 event due to being closer to the ideal state is more favorable. Therefore, it can be claimed that according to these above mentioned discussions, that generally the A3 event is considered to be the best and most efficient event.

In respect of high speed railway (HSR), Fig. 8 and Fig. 9 show that in high speed comparing to low speed, the HOF probability of selected A3 event is decreased about -1.89dB. Fig. 11 shows how the HOF probability of three main events change by train speed.

Table I. List of parameters used in simulation

Parameter	**Symbol**	**Value**
Carrier frequency	f_c	2 GHz
Cell radius	R	1500 meters
Overlap	-	400 meters
The distance between the base station and the railway line	d_s	100 meters
Standard deviation related to SeNB	σ_s	4 dB
Standard deviation related to TeNB	σ_n	4 dB
Train speed	v	500 Km/h
signal failure threshold	T_f	-60 dB
A4 event threshold	T_{A4}	-54 dB
The first threshold of A4 event	$T1_{A5}$	-57 dB
The second threshold of A4 event	$T2_{A5}$	-51 dB
A3 event offset	Ofs_{A3}	0
A4 event offset	Ofs_{A4}	0
A5 event offset	Ofs_{A5}	0
Time To Trigger	TTT	1280 ms
Number of subcarriers	M	1024
Subcarriers bandwidth	-	15 *kHz*

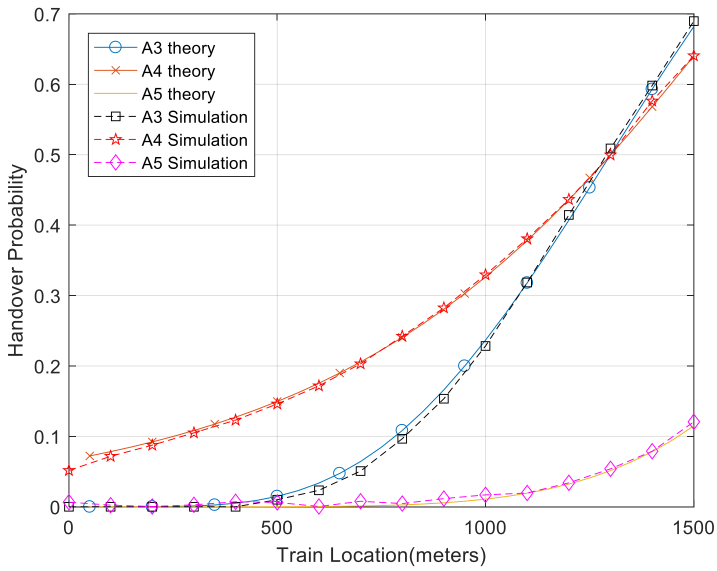

Fig. 7. Probability of handover (HO) for the three main events (theatrical and simulation)

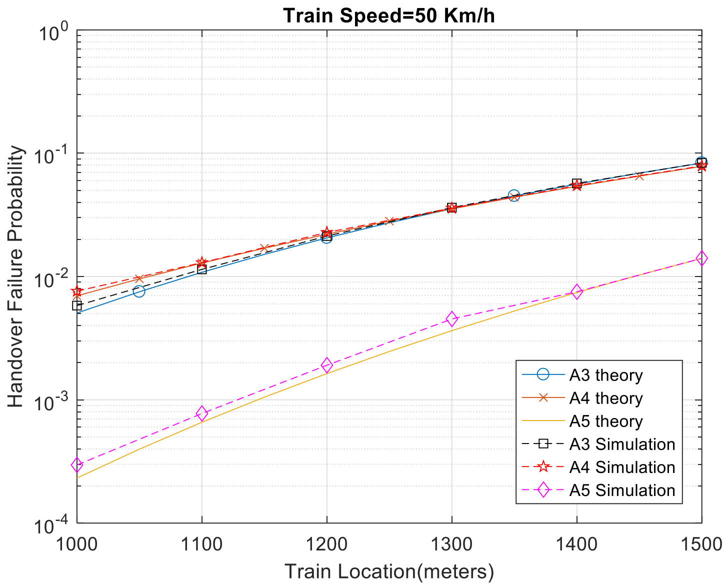

Fig. 8. HOF Probability of the three main events (low speed)

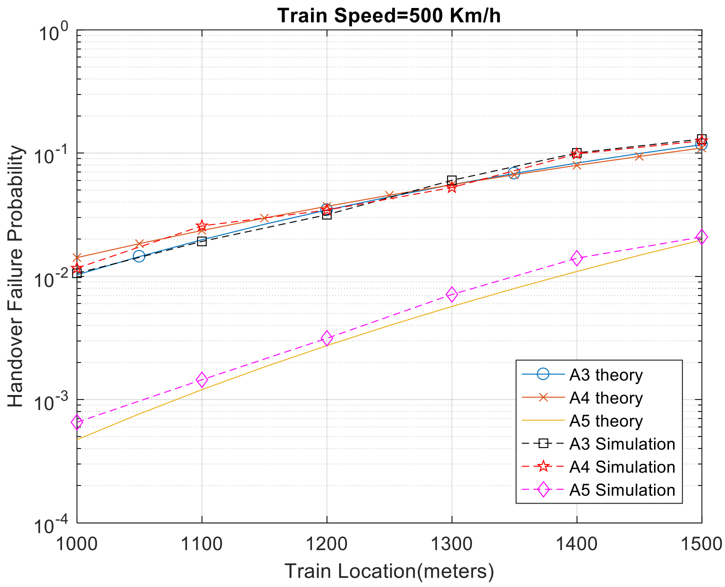

Fig. 9. HOF Probability of the three main events (high speed)

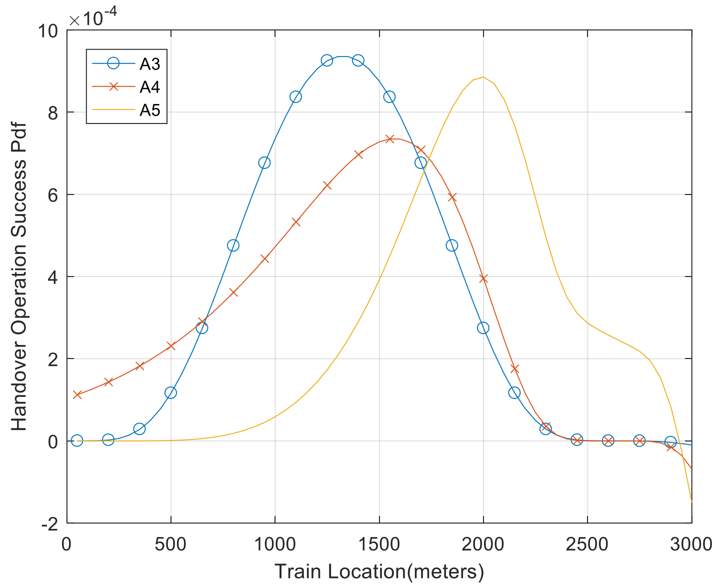

Fig. 10. Pdf of HO success for main three events

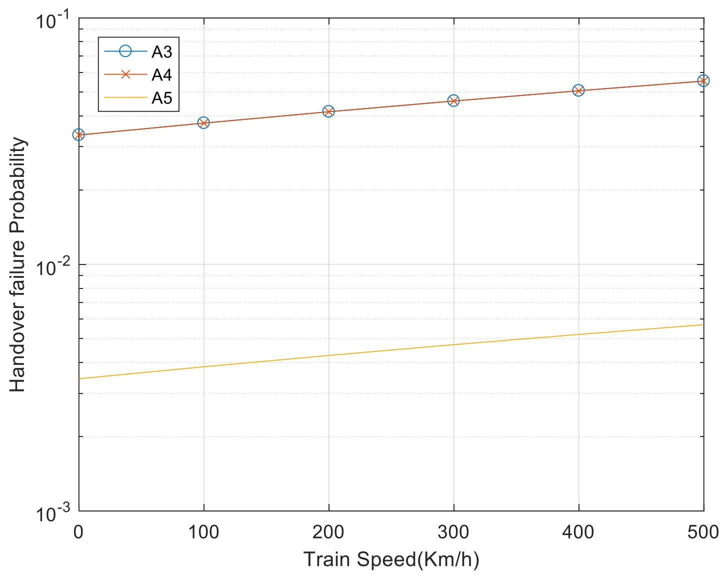

Fig. 11. HOF probability of main events with respect to train speed

It can be seen that the result of A3 event preeminence is valid for higher speed. Since LTE as the communication network should support and high speed data services for passengers and safety functionalities for HSR which travels at speeds up to 350 km/h now and 500 km/h in the near future, it is very important that the LTE network can stay connected to the train at all times. This is especially important in HSRs because the train moves very fast, and handover (HO) occurs very frequently. Due to its importance, the European Telecommunication Standards Institute (ETSI) requires a minimum HO success rate of 0.995 for railway communications [26]. As seen in Fig. 11 A3 and A4 events don't meet this requirement and A4 event even though meet the condition, it has not a favorable behavior for Pdf of HO success.

V. CONCLUSION

According to the 3GPP standards, several handover (HO) events for LTE network have been defined. In this paper, these events, especially which have found applicable for use in high-speed rail (HSR), were investigated and categorized. To the best of our knowledge, these events have not been analyzed, so in this paper we have analyzed them based on some best known indicators such as handover (HO) probability, handover failure (HOF) probability and Pdf of handover (HO) success, to choose the most efficient one. Analytical results have been verified by simulation tools. The results show that A3 has the best behavior in terms of defined indicators. Furthermore, as we were looking for most suitable events applicable to HSR, the behavior of the HO events in terms of speed have been investigated. It is shown that increasing the speed from low speed to high speed of 500 Km/h will decrease the handover failure (HOF) probability by 1.89dB. Anyway, A3 and A4 events don't meet the standard requirement. A4 event even though meet the condition, it has not a favorable behavior for Pdf of HO success so introduction of an efficient handover event for HSR is of great importance

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