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Adaptive TTT Scheme to Optimize Handover in High Speed Environment

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Abstract— In high speed railway environment, to provide efficient communication handover plays an important role. Handover is the process of changing the connection of mobile terminal from one base station to other. In high speed railway environment, base stations are deployed along the tracks and due to this large cell overlapping area is created. This can cause frequent and unnecessary handover which can lead to connection loss. In order to reduce the handover issues in high speed environment, an optimized A3 algorithm is used in LTE. In the existing system, if the condition of A3 event has failed, then instead of resetting the handover, the signal quality of target cell is considered for further process. This results in unnecessary handovers in high speed environment. In this paper, another approach is used where the time to trigger value is adjusted when the serving cell is sufficient to maintain connection.

Index Terms— Handover, Handover Margin (HOM), High Speed Railway (HSR), LTE (Long Term Evolution), Reference Signal Received Power (RSRP), Reference Signal Received Quality (RSRQ), Time to Trigger (TTT).

1 Introduction

HIGH speed railway has rapidly developed and trains have been widely deployed in recent year. To satisfy the higher data transmission rate requirements of passengers in high-speed railway network, the handover (HO) should be done in faster and seamless manner, since its success rate is an indicator of user satisfaction [8]. In current railway networks, HO parameters configured are time-consuming and in error-prone manner. In addition to this, the corresponding operations costs are significant because of the large network coverage in high-speed railway networks.

Handover is the process of changing the connection of the mobile terminal from one base station to another in a homogeneous or heterogeneous wireless networks in order to maintain connectivity. It is also referred as Handoff [3]. It is a key factor for maintaining continuous network connections and QoS for the user. When user moves towards the cell edge or moves through the cell overlapped area, handover occurs. In cellular systems, handover always occurs, as the whole area is divided into number of small cells, with different frequency for the adjacent cells. Each cell has a limited coverage area only. The reasons for a handover can be either received signal strength level decreases continuously or the traffic in one of the cells is too high.

It can be classified to Hard and Soft handover based on radio link transfer type [7]. In hard handover mobile terminal is connected to one Base Station (BS) at a time. In order to perform handover, connection to the serving base station is disconnected and then new connection to target base station is established. i.e. 'break before make' policy is adopted. In case of soft handover, a mobile terminal can be connected to more than one BS at a time. i.e. before breaking the connection to the serving cell, connection to new base station is made. So 'make before break' policy is adopted in this case. In LTE network, there is only hard handover, so the handover performance in terms of success rate and delay of execution is of high importance [6].

In high speed railway environment, base stations are deployed along the tracks in order to provide sufficient network access throughout the rail. Due to these base stations, good signal strength is obtained but it also creates large cell overlapping area that leads to continuous handover. When the mobile terminal moves in high speed, it passes through many cells overlapping area within a short span of time. This can cause many frequent and unnecessary handover which can lead to connection loss. Therefore, extreme care should be taken in order to perform handover in such environment. The base station deployment pattern along rail track is shown in Fig. 1 [4], [9]

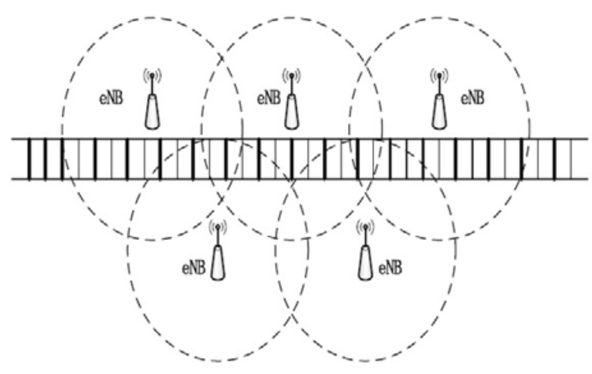

Fig.1 Base stations deployed along the railway tracks [9]

In this paper, a handover optimizing algorithm for high-speed railway networks is given, to modify the time to trigger parameter efficiently, to reduce the handover occurrence frequency.

The rest of the paper is organized as follows. In Section 2,

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overview of LTE handover and basic handover process is briefly explained. Section 3 explains the existing system along with traditional A3 handover algorithm. The proposed handover algorithm is given in Section 4. The simulation results and its analysis are presented in Section 5. Finally, the conclusion is given in Section 6.

2 Background

2.1 LTE

LTE has a network architecture which is simple when compared to universal mobile telecommunications system (UMTS) [4]. The LTE network architecture consists of three elements: evolved NodeB (eNodeB/eNB), mobile management entity (MME), and serving gateway (S-GW). The eNB performs all radio interface related functions such as packet scheduling and handover mechanism. MME manages mobility, user equipment (UE) identity, and security parameters. S-GW is a node that terminates the interface towards E-UTRAN (Evolved Universal Terrestrial Access Network).

In [1] LTE specification is briefed as follows. The LTE access network is simply a network of base stations, eNB, generating a flat architecture**.** There is no centralized intelligent controller, and the eNBs are normally inter-connected via the X2-interface and towards the core network by the S1-interface**.** The reason for distributing the intelligence amongst the base stations in LTE is to speed up the connection set-up and reduce the time required for a handover. For an end-user, the connection set-up time for a real time data session is crucial in many cases**.** The time for a handover is essential for real-time services where end-users tend to end calls if the handover takes too long.

2.2 LTE Handover Overview

An overview of LTE handover is given in [5] which describes the measurement configuration is the information regarding a connection reconfiguration message sent by serving cell to a UE. Whenever an event occurs at UE, the received signal strength of serving cell and neighboring cells is reported. When the collected values of signal strength meet conditions of any events, a measurement report is generated and the serving cell is informed. Suppose, if an A3 event is reported, then the UE determines the neighboring cell to which handover to be done during handover decision step. Then the serving cell forwards the handover request to the corresponding neighboring cell to prepare for the handover.

A path is then created to send a control message and download the packet forwarding. The HO execution step performs the real HO steps. UE break the wireless link to serving cell and establishes new wireless link to the chosen cell. If the UE fulfills the connection with new cell successfully, handover is completed.

When UE speed is high, it will experience longer distance and more severe degradation of signal quality during TTT which is the original value configured in cell causing too late handover. Thus it is reasonable to set a lower TTT value for high speed UEs according to [10].

3 Existing System

3.1 A3 Handover

The traditional A3 handover [4] algorithm in LTE (shown in Fig. 2) is a basic and efficient algorithm which consists of two variables: handover margin (HOM) and time to trigger (TTT) timer. Handover margin is a constant variable that represents the threshold for the difference in signal strength between serving cell and target cell. It finds the appropriate cell to which handover can be done. TTT is the time during which the specific criteria for an event need to be met in order to trigger a measurement report. The procedure of A3 event is that it checks whether the difference in the signal strength of the serving cell and target cell is greater than HOM value.

$$RSRP_T > RSRP_S + HOM$$

where $RSRP_T$ and $RSRP_S$ are the Reference Signal Received Power received by UE from the target cell and serving cell respectively.

If this condition satisfies for the entire TTT duration, handover event is triggered and when the condition fails the handover process will be reset.

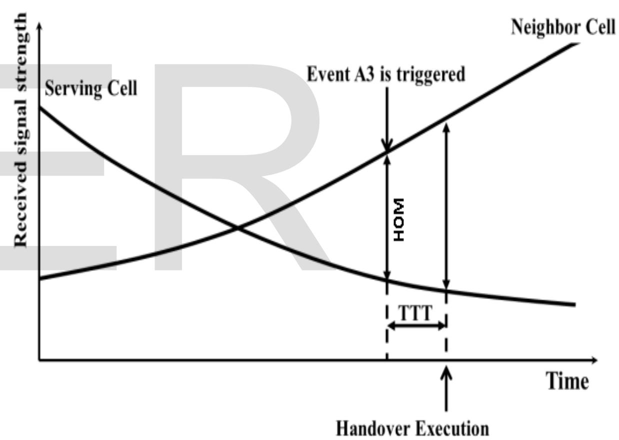

Fig.2 The traditional A3 handover algorithm

3.2 Existing Handover Algorithm

In the existing system, A3 handover along with optimization, i.e. signal threshold check, is done even after A3 event condition is failed. It will check RSRQ of serving cell against the signal quality Threshold of adjacent cells, where $RSRQ_T$ is the Reference Signal Received Quality of each target cell.

When RSRQ is better, i.e. when this condition is satisfied, it will further proceed to check the number of successful handover for each target cells against a Threshold, $N_{Threshold}$ [4]. If this condition also satisfied then it will proceed to perform handover even after A3 event condition is failed. The brief of algorithm is given in Table 1.

This can cause the increase in number of handover, which is not at all a benefit for the high speed railway. When signal strength of adjacent cell does not meet expected value throughout TTT, the signal quality threshold of adjacent cell may be better than Threshold at some point of time. This can

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create HO initiation when UE approaches each eNBs which results in frequent and more number of handovers in high speed railway environment.

TABLE 1
EXISTING HANDOVER ALGORITHM

Step 1	Check the velocity > 120km/hr If true, goto Step 2 else do A3 handover algorithm
Step 2	Compute and check $RSRP_T > RSRP_S + HOM$ is satisfied for the entire TTT duration. If satisfied, goto Step 4 else goto Step 3
Step 3	Check $RSRQ_T$ > Threshold If true, goto Step 4 else goto Step 6
Step 4	N = N+1 where N is the number of satisfied handover condition for each target cell
Step 5	Check $N > N_{Threshold}$, If satisfied trigger handover else Step 6
Step 6	Search for the next cell and goto Step 2

4 PROPOSED SYSTEM

In proposed system, for each measurement report, the threshold for the cell is checked against $RSRP_s$ – HOM at first [5].

$$RSRP_S - HOM > Threshold$$

If this condition holds, i.e. the serving cell is still having sufficient signal strength to maintain fair network connection, TTT is increased to delay the handover trigger otherwise the TTT is decreased to perform handover immediately. Only after setting the TTT value, the A3 condition is checked. After each measurement interval time to trigger value can change.

When A3 event check is done and if satisfied then it will proceed for number of successful handover check in each target cell with an $N_{Threshold}$. When satisfied it computes the rate of resource change of neighboring cells. Only after the entire neighbor cells are searched and computed, the cell of smallest rate of change in resource is selected to trigger handover as given in [4]. Here, when A3 event condition is failed, it will not further proceed to handover which helps in avoiding too many handovers. The algorithm is briefly given in Table 2.

The first part of this proposed system will delay the handover occurrence thereby reducing the number of handovers by adjusting the TTT. The second part gives stability in connection by performing handover to a cell which is having smallest rate of resource change.

5 SIMULATION RESULTS AND ANALYSIS

The simulation work is implemented in NS-3(Network Simulator). An LTE network is created with 5 eNBs, i.e. 5 cells, and 1 UE moving in high speed which is assumed to be a high speed train. The UE is sending measurement report in every 0.2 seconds. It contains the RSRP, RSRQ of the neighboring cells and the serving cell information.

Simulation is done for the three algorithms: the traditional A3 algorithm, the existing system and for the proposed system algorithm. For each case the number of handover occurred is computed against different velocities and HOM values.

TABLE 2
PROPOSED HANDOVER ALGORITHM

Step 1	Check the velocity > 120km/hr If true, goto Step 2 else do A3 handover algorithm
Step 2	Compute and check $RSRP_S$ – HOM > Threshold, if true increase TTT else decrease TTT
Step 3	Compute and check $RSRP_T > RSRP_S + HOM$ is satisfied for the entire TTT duration. If satisfied, goto Step 4 else goto Step 7
Step 4	N = N+1 where N is the number of satisfied handover condition for each target cell
Step 5	Check $N > N_{Threshold}$, If satisfied add the cell to list and find the cell with smallest rate of resource change else goto Step 7
Step 6	Check whether all cells are searched, if yes trigger handover to best cell selected in Step 5 else Step 7
Step 7	Search for the next cell and goto Step 2

When UE is running in high speed, HOM should be set to low. Similarly, when UE velocity is low, HOM value can be increased in order to maintain sufficient time for the existing connection. Here the path loss model considered is Cost231PropagationLossModel [2]. The simulation parameters are shown in Table 3.

TABLE 3
SIMULATION PARAMETERS

Parameter	Values
UE number	1
eNodeB number	5
Height of eNodeB	50m
Height of UE	3m
Distance between eNodeBs	100m
Distance between eNodeB and railway	100m
Velocity of UE	10 ~ 100 m/s
Transmitting Power	53dBm
Measurement interval	0.2 s
HOM	2 ~ 6 dB
TTT	180ms
$N_{Threshold}$	3
Path loss model	COST231

After the simulation in Ns3, the following are the major observations regarding the number of handovers from each of the algorithms:

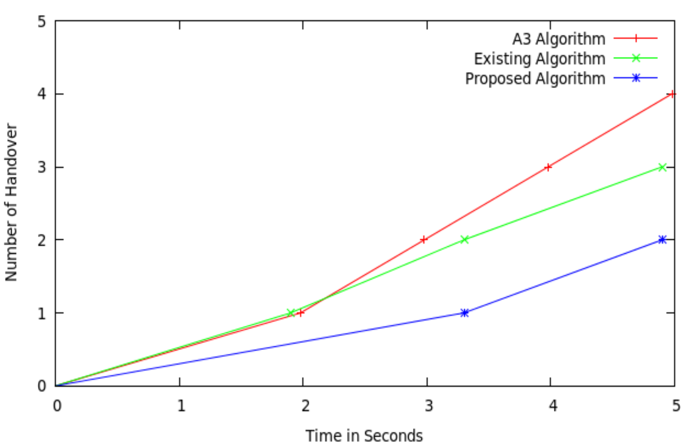
In traditional A3 algorithm, the UE performs handover whenever the event condition is satisfied. It perform handover in the following pattern 1 ⇨ 2 ⇨ 3 ⇨ 4 ⇨ 5. i.e. HO occurs from cell 1 to cell 2 and so on. Therefore the total number of handover is 4, which means it performs handover to each eNBs available in its path seeking for better signal power. This can result in ping pong (repeated) handover.

In the existing systems algorithm, where the signal quality threshold is checked for the target cells which is having better handover success rate along with A3 event condition, the handover pattern is as follows: 1 ⇨ 2 ⇨ 4 ⇨ 5. Here the number of handover is reduced by one i.e. total number of handover occurred is 3.

Finally in the proposed algorithm, the signal quality check is avoided after A3 event condition. Instead it will check whether the threshold of the cell is still sufficient to maintain the fair quality connection and the TTT is increased to delay the handover initiation. Otherwise TTT is reduced to perform handover. Only after setting the TTT, the event condition is checked. On satisfying the event condition, the cell with smallest rate of change in resource is identified among the cells which is having good handover success rate is then selected for the handover process. Here the handover pattern obtained is 1 ⇨ 4 ⇨ 5 i.e. the total number of handover is now reduced to 2.

Therefore in this proposed algorithm, the handover count is reduced. This result is obtained because in each of the measurement report obtained, the TTT is set to a value based on the signal strength. Only after this process only the handover check is done and this delays or avoids unnecessary handovers. Moreover, when handover is required it checks for the cells with smallest change in resources continuously and this helps in attaining the stability for the obtained connection. For the cells with change in resource is frequent, there is a possibility of loss of connection or immediate handover requirement.

Fig. 3 Simulation Result



From the simulation result shown in Fig. 3 shows that the proposed algorithm avoids unnecessary handover compared to other two algorithms. Also, another factor that can be seen from the above result is the time at which the handover occurred is also delayed. In A3 algorithm and existing system, first HO occurred before 2s, but in proposed system is delayed and only after 3s HO occurred which shows that the proposed algorithm has better performance. Therefore, it is clear that the proposed algorithm is performing better when compared to the existing one and the traditional handover algorithm in high speed railway environment.

6 Conclusion

Handover is one of the important factors that provide better QoS and seamless connection in mobile communication. In high speed railway environment handover plays a crucial role in maintaining network connection for efficient communication. Therefore selection of handover algorithm is very important and it should be decided based on the environment where it is used. In this paper, the proposed algorithm reduces the unnecessary handovers that occur in HSR. The algorithm selects the time to trigger value based on the signal strength dynamically rather than using a static value and also handover is done carefully to cells that having less rate of resource change. The simulation results clearly indicate that the proposed method has better performance than the existing system and traditional A3 handover algorithm. Therefore this algorithm can improve the performance of handover in high speed railway environment.

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