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A Survey on Handover Techniques in High Speed Environment

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ABSTRACT: - In this fast moving world, the high speed railway plays an important role in making the people's life easier. Therefore, the communication in such a scenario is also highly demanded and it is dependent on fast and efficient handover. Handover is the process which changes the ongoing connection of mobile terminals when signal strength weakens. In high speed scenario, mobile terminal are moving faster and hence frequent handovers can occur which lead to call drops. This can adversely affect the Quality of Service provided to user. In this paper, different handover schemes used in high speed environment are studied and techniques to reduce these issues are presented

KEYWORDS: Handover (HO); High Speed Railway (HSR); Radio over Fiber (RoF); High Speed Train (HST)

I. INTRODUCTION

In present scenario, the term "Mobile" is a widely used and it became the part of our life. It refers to movement or, in general, it is used for mobile devices. Mobile devices became an essential requirement of day to day life which is unavoidable. New generation cellular mobile radio systems offering a range of innovative services which also demanding high Quality of Services (QoS) in communication along with the new features.

In cellular mobile networks, the land area is divided into number of cells. Each cell consists of a Base Station (BS) which serves the Mobile Nodes or Mobile Terminals (MTs) in that particular cell. MT means the users equipped with mobile devices. Each cell will be assigned with a frequency for communication, which will be different for adjacent cells. When a mobile user crosses the cell boundary or when the signal quality of the wireless link is unacceptable, a new connection needs to be established or initiated which is termed as handoff process.

Handoff is the process of changing the ongoing connection of mobile terminal from one BS to other. Handoff is also referred to as handover. Whenever a MT crosses a cell boundary or the signal strength weakens beyond a level, a connection has to be established with new BS with better signal strength in order to maintain network connectivity. However, since different wireless technologies differ in their characteristics, handoff is a critical process and should be handled carefully in order to ensure the continuity of connections and maintain the QoS.

In high speed environment like railway, the handover process is an important factor in deciding the QoS providing to end user. As within a short span of time, the train passes through different cells and many overlapped areas, which can cause frequent handovers and thereby call drops. Currently many heterogeneous networks are available which affects handover process. Therefore, adopting a correct handover technique has an important role in maintaining the QoS of the service. In this paper different handover techniques in high speed network are discussed.

II. HANDOVER PROCESS

Handover is described as a process of transferring data session an ongoing call from one access point to an- other in a homogeneous or heterogeneous wireless networks. Handover is also referred as Handoff. Both terms are used interchangeably in this article. It is a key element in a wireless network for maintaining continuous connections and QoS for the user. When user moves towards the end of the cell or moves through the cell overlapped area, handover occurs. In cellular systems, handover always occurs, as the whole area is divided into small cells, with different frequency for adjacent cells. Each single cell is having only a limited coverage area. The reasons for a handover can be either received signal level decreases continuously or the traffic in one cell is too high. In [1] the author explains the basic elements of handovers such as types of handoffs.

A. *Types of Handovers:*

Handover may be classified based on different criteria, like the kinds of the network involved, the number of active

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connections of the mobile nodes etc. Based on different access technology handoff can be classified into Horizontal and Vertical Handoff. Horizontal handoff occurs within a homogeneous network which involves only one wireless access technology. i.e. when mobile terminal crosses the boundary of cells which have same kind of network. For example, handover between Wi-Fi to Wi-Fi or 3G to 3G. Vertical handoff occurs when both source and destination network of mobile terminal is different, which means it changes the mobile active connection between different wireless technologies. For e.g., Wi-Fi to 3G or Wi-Fi to WiMAX.

Based on link transfer types, handoff can be classified into Hard and Soft handoff. In the case of hard handoff [5], a Mobile Terminal is connected to only one point or one BS at a time. It connects with the new BS or the new network only after breaking its connection with the serving BS. It is referred to as break before make connection. In soft handoff, the MT is connected to more than one point for a while. Soft handoff can be used to take a handoff decision without any loss of QoS because it establishes a new network connection without breaking the current one. It is referred to as make before break connection.

III. HANDOVER IN HIGH SPEED ENVIRONMENT

High speed railway (HSR) has an important role in transportation all over the world [4]. The development of high speed railways makes the commutation more convenient. Meanwhile, it put forward various requirements on services of high mobility users. As the technology is advancing in a fast pace, similar technological advancement is also required in HSR to cope with these technology.

Since the high speed railway is in distributed along the track, the wireless access network features are also distributed in similar fashion, i.e. It covers the whole railway through a lot of cells. Currently Base Stations are deployed densely along the tracks of rail, in order to provide sufficient network access throughout the rail. Due to these BS, signal strength is obtained but it also creates large cell overlapping area which can lead to frequent and unnecessary handovers. Therefore to provide QoS to the users, handover performance is a bottleneck which has to be considered and processed carefully for the HSR environment.

Base Stations (eNodeB) deployed along a high speed railway line is shown in Fig 1 [2].

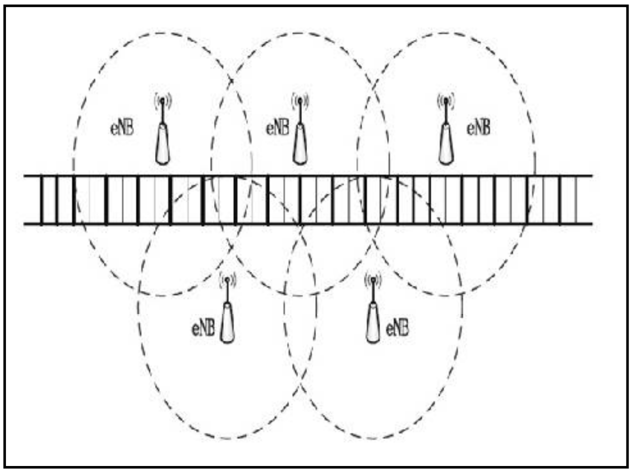

Fig.1. A high speed railway scenario which deploys eNodeB along the railway line [2]

A. *Challenges in Mobility:*

The wireless connection between the high-speed train (HST) and the ground network is the crucial factor to improve the QoS of train passengers [4]. For a given cell size, the HST will take small amount of time to pass through the overlapping region. The wireless access problems in high speed mobile scenarios given in [4] are as follows:

1 Frequent handover: **-** The high speed of the train can cause frequent handover when the cell size is small. Also, when the minimum time for processing handover is larger than the time interval for the HST takes to pass through an overlapping region, then call drops can occur as handover process didn't complete. It can also cause packet loss. Therefore a fast handover needs to be achieved.

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2 Doppler frequency shift and fast fading: The signal frequency shift at the receiver due to the movement is known as Doppler frequency shift [4].Fast channel variation in one Orthogonal Frequency Division Multiplexing (OFDM) block will the orthogonality between the sub-carrier signals which results in Inter-carrier Interference [9]. It can cause difficulty in initiating handover, and cause handover failures. In order to reduce Doppler frequency effect base station needs to be deployed far away from the track but which not a good practical solution as it can lead to penetration problem [4].

3 Penetration loss: - When MT communicate with base station directly, the radio signal experience penetration loss when signal propagating through the train carriages. Most of the high speed trains are made of metal bodies with single or multi-layer glass windows which can cause penetration loss. To overcome this problem, two-hop model can be used. In this model, wireless signals are fed to the antenna on the top of train and then signals reach the user equipment.

IV. HST COMMUNICATION HANDOVER SCHEMES

Handover is a mechanism that an ongoing call is transferred from one cell to another when user moves through the coverage area of different cells. It is considered as the one of the most important functionality of a mobile system, especially in case of HST where the high speed mobility of user terminal causes the mobile terminal to be passed through many overlapping cell area within a short span of time. Therefore handover procedure has to be designed according to the type of the network architecture and it determines which handover models to be used. [3] [4].

A. *Satellite to Ground*

In [4] it is given that satellite communication has large coverage, and requires less ground equipment next to the tracks. A transmitter and receiver which is mounted on top of a train can use the positioning information of the next base station and thereby identifying target BS for handover can be a scope of this communication. Due to the height of the satellite, handover is not at all required in most cases. However, there exist some spots in its coverage area where there are tall buildings, mountains, tunnel like obstacles are present which block the line of sight of satellite signals. So handovers are required in such cases. The delay in the satellite communication and bandwidth limitation is not suitable for satisfying high demands of users [9]. Also, satellite signal suffers high losses in bad weather conditions and its high costs are some other disadvantages.

B. *Leaky Coaxial Cable*

Leaky coaxial cable (LCX) scheme mentioned in [4] [9] can provide a uniform coverage of radio signals without any mutual interference. LCX is a cable, that has a small portion of copper is stripped away to enable signal transmission and electromagnetic wave radiation, which acts as an antenna for data transmission and reception. It can reuse several frequency points in the long segment of the HSR with high bandwidth efficiency. So the signal quality is good and transmission power is low. However, for the slot size there are some stringent requirements, which make the cable cost very high. Also, due to heavy loss of radio signal, several repeaters needs to be installed, making the relay cost high. Its initial investment cost could be very high which makes it not suitable for entire line of HSR. But it can be used for some specific situations like wireless communications in tunnels.

C. *Radio over Fiber*

Radio over Fiber (RoF) is a framework which is very suitable for HST broadband wireless access. In [6] the authors explain RoF. A RoF system is a fiber-fed distributed antenna network. Its aim is to transmit complicated signal processing functions from BS to a centralized control unit along the railway. Multiple Remote Antenna Units (RAUs) are placed along the railway and connected via a fiber ring to a control center. The expensive signal processing equipment at control station can be shared among several RAUs. The RAUs are grouped over a distance and several RAUs are associated with a single control center. A ring topology is used for this. All RAUs under a same ring are supervised by a centralized control station, where all the processing is done (shown in Fig 2). Each RAU is linked with a fixed BS in the control center and it also has a fixed radio frequency. At control center, the electrical signals are converted into optical signals and then transmitted to RAUs via the fiber. Then they are radiated by the antennas from RAU after converted back to electrical signals.

The RoF model is cost effective because one control center can associate with multiple RAUs. The transmission power is also saved as the antennas are linearly radiated. Moreover, handover is not required when the train moves from one RAU to another which is under the same control center. In this way, RoF model can reduce the number of handovers to a great extend.

The Distributed Antenna System (DAS) is an important application of RoF scheme. It provides high data rate services and excellent coverage in short-range communications. In this, cell is divided into sectors and RAUs are

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geographically distributed in the cell. Since all RAUs are connected to control unit spatial diversity and frequency reuse can be exploited. DAS in conjunction with RoF technologies have been used to HST communications.

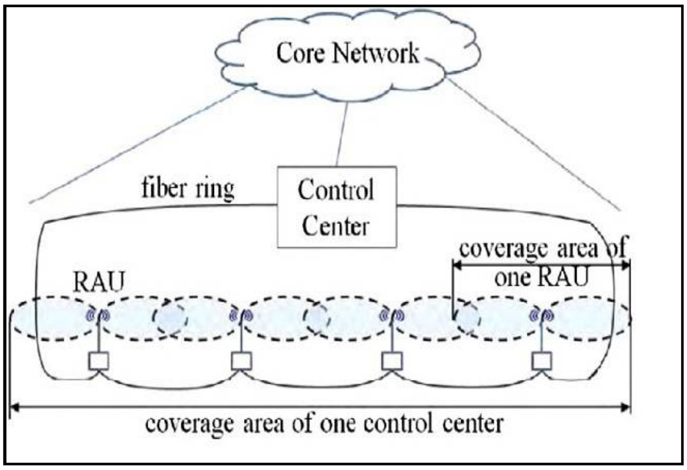

Fig. 2. Linear cell planning based on RoF [4]

D. *Moving Cell Concept*

In [6] the authors Lannoo et al. introduce a moving cell concept. According to the author, instead of the train moving along a fixed repeated cell-pattern, the authors suggest that a cell pattern moves along with the train and thereby using same frequency all over connection, helps in avoiding handover possibilities. These moving cells can be implemented by re-configuring the optical network serving the RAU. However, all base stations are grouped under a control station and normally only one train will be in range of a single RAU. The RAU deployed along the rails will track the movement of train and reconfigure its operating frequency. In this way speed of the cells are synchronized with that of the train. In this concept, each BS is no longer associated with a fixed RAU, moreover the number of BSs can be lot smaller than the number of RAU [6]. Control station can sufficiently equip with as many BS as train antenna that are within its range. The only action to be done is that output of BS has to be transmitted to another RAU by an optical switch for completing the handover.

E. *Relay Station-Assisted*

Relay station (RS) is used in communication systems to increase capacity along with the network coverage and enhance the weak-field zone [3]. The purpose of the relay assisted handover model is to satisfy the minimum requirements for the reliable communication, by ensuring the signal coverage and strength in the overlapping area where the relay station is placed in middle of the overlapping area. In another relay scheme given in [10], one or more antenna is mounted outside the train which is connected to one or more relays. It helps in availability of signals inside train. Due to this mode of signal transmission, attenuation will be less. Moreover, this set up will reduce the number of handovers, because in this set up relay can be configured in such a way that it appears to be a single User Equipment (UE) to the BS. But the performance of this scheme depends on the number of relays or antenna per train/carriage.

F. *SFN*

In [4] it is given that, the Single Frequency Network (SFN), is having cells that operate at the same frequency. The aim of SFN is to extend the coverage area without using any additional frequencies. It simplifies the handover process as the whole train can be considered as a single user terminal. Assuming that all the BSs in the SFN are synchronized, and then there is no need for a new low-layer connection. When there is more than one HST, each HST can be allocated with different orthogonal resources.

In [8] Luo et al. discussing about another scheme Coordinated MultiPoint (CoMP). In this, transmission and reception allows different BSs to send or receive data to or from on terminal jointly. Two or more adjacent cells form a Cooperative Transmission Set (CTS), where the each eNBs in the same CTS are cooperatively working. i.e. this scheme allows the train to receive signals from both the adjacent BSs in overlapping area. Here, the total bandwidth is divided to two portion of equal size. The HST moving in any one direction is assigned with one part of the bandwidth. Within the CTS, same frequency is used to send the data to one HST. Therefore at cell boundary, soft handover is

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possible. The CTS reconstructs continuously along with the moving direction of HSTs. HST can achieve diversity gain and seamless handover because only a single portion of the bandwidth is used.

G. *Dual-Soft*

In [3], the Dual-soft handover model, instead of eliminating the multi-path effects it utilizes to increase the throughput while multiple antennas are used. Here, two antennas are installed, one in the front and other at the rear end of the HST. When the HST reaches the cell boundary, the antenna at the front of HST performs handover to the target BS, and the antenna at rear end is still connected with the source BS, this helps in maintaining the connection during the handover process. This helps in achieving seamless soft handover and also in reducing handover interruption time.

Bi-casting is used to support fast handover in standard LTE system. It is used to eliminate the delay in data forwarding between the serving BS and the target BS. It maintains a set of cell which is having fair signal strength with having values greater than some threshold. From this information dynamic cell selection is done in a faster manner. Of course, it creates an overhead of storing data in buffer but in case of linear path of HST, a set with information regarding two cells is enough. Dual-soft handover model takes advantage of combining bi-casting and dual antennas, thereby forms a multiple input multiple output system in which system can have the benefit of a seamless soft handover and diversity gain.

V. CONCLUSION

An overview of different handover schemes for wireless communication that can be used in high speed environment are given in this paper. Most of the broadband wireless communication technologies currently used is designed for low speed mobile environments. The aim of all the schemes is to overcome the technical issues such as frequent handovers, Doppler frequency shift and penetration loss which occurs during handover in high speed railway environment and to provide higher QoS for the end users.

Satellite related scheme still exist since it provide direct links and there no requirement of ground station. But as it does not meet the current requirements of high-speed train communications, it can be considered for some special scenario like either ground systems were destroyed or for emergency situations. LCX can be considered for wireless communications in tunnel or similar specific cases but not suitable for the whole HSR communication. RS can help in enhancing signal strengths in weak fields along railway and assist handover but too much interference can occur also cost of establishing new stations are very high. The Single Frequency Network is beneficial in avoiding interference and the Dual handover along with bi-casting is possible two cell and three cell configuration but the proper time to cast the stored data is not a well-defined procedure. The RoF together with the moving cell concept can be a more efficient idea that can reduce costs of the remote antenna units and also limits the number of handovers. However, designing a specific handover algorithm in high-speed environment can be done by considering the current advancement in technology and real time requirement along with the reliability.

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