Group Handover Strategy for Mobile Relays in LTE-A Networks

Olusegun O. Omitola and Viranjay M. Srivastava

[1,2] Department of Electronic Engineering,
Howard College, University of KwaZulu-Natal, Durban - 4041, South Africa.
Email: omitolasegun@gmail.com; viranjay@ieee.org

Abstract --Mobile cell is a new area emerging from the small cell technology that will dominate future networks. Mobile relay plays a major role in mobile cells allowing mobile user equipment (UE) to maintain network connectivity with good quality of experience to the macrocell base station during high speed vehicular movement. Group handover is an excellent solution to handle huge number of handovers associated with moving UEs in the mobile cell. In this paper, an efficient group handover strategy for mobile cell in LTE-Advanced system have been proposed. With the proposed group handover strategy, mobile relay node (MRN) attached to a high-speed train handover all UEs related communication from the source donor eNB (DeNB) to the target DeNB. In addition, unlike most work that uses fixed relay architecture, mobile relay architecture has been used in this work. By applying the proposed group handover strategy to the mobile cell, the number of handovers and call dropping probabilities in the system have been greatly reduced.

Index Terms—Donor eNB, group handover, mobile cell, mobile relay node, LTE-Advanced, small cell

I. Introduction

The rapid demand for data and voice services in the public transport vehicles has necessitated new dimensions to the development and adaptation of small cells to the present and future networks. Small cells are low powered [1] stations which provide excellent solutions to the coverage and capacity problems encountered in the homogeneous cellular networks i.e. without small cells. Small cells such as relays have been integrated to the LTE-Advanced system to serve hundreds of UEs on-board of high moving train [2]. To provide data and voice services to every UE inside the vehicles, the present architecture of LTE-A system has been redesigned to allow the mobile traffics to be handled by the mobile cell. New architecture such as the one proposed in [3] allows relay node to carry all the mobile traffic (UE traffic) and hand them over to the eNB as a group. To perform the handover effectively, an efficient group handover management algorithm is required to enhance the quality of experience of the moving UEs.

Relays are small cells with a wireless backhaul connection to the eNBs. Relay node (RN) can pass communication information between a mobile UE and eNB wirelessly and intelligently. The communication that takes place between eNB and RNs resembles the one between eNB and UEs and it uses point-to-point (PMP) connectivity. In other words, a wireless backhaul connectivity is maintained between the RNs and the eNB [4] same way femtocell IP backhaul connection to the core network in [5]. The RN will then establish PMP connection with the UEs to provide both uplink and downlink to the UEs. The eNB link to RN and the RS to eNB links, are termed relay links while the eNB to UE link and the RS to UE link are referred to as access links. In the cellular network, the importance of relay node includes: one, they provide increased capacity with the aid of frequency reuse. An increased capacity can be realized if eNB and RN communicate with different UEs using the same frequency [6]. Two, with a low deployment cost, they provide improved coverage and throughput enhancement [7], [8] because they are connected to the network using wireless backhaul. This aids the deployment of RN in ad-hoc manner in arears where the eNB cannot provide sufficient coverage (i.e. cell edges and shadowing areas). Also, better propagations i.e. reduced shadowing and path loss as well as good Line-of-Sight (LOS) are experienced when there is backhaul connection between the eNB and the RNs compared to direct connection between eNB and the UEs. Vehicle penetration loss at different frequencies, path loss and impact of LOS have been determined in [9], [10]. Additionally, RN can be shared by many operators to reduce the cost of building the networks.

Relays are categorized into fixed and mobile relays. Fixed relays have been standardized in 3GP LTE release 10 standards [11] and support many use cases. Mobile relay node (MRN) on the other hand, can support more use cases. Fixed relay nodes (FRNs) are usually deployed by the operators in a more deterministic manner i.e. in coverage holes while MRN can be deployed in a flexible way where especially FRNs are not available or not justifiable economically [12]. MRN addresses key network requirements such as low latency, reduced handover interruption time and high spectral efficiency. MRN, when deployed on top of a moving vehicle (such as train used in this work) can form its own cell inside the vehicle and serves vehicular UEs effectively [13]. MRN enhances signal strength to the UE and also reduces signaling overhead by simultaneously handling multiple service connections to the DeNB positioned along the train routes [14]. Vehicular penetration loss often

Manuscript received February 20, 2018; revised August 22, 2018.
Corresponding author email: omitolasegun@gmail.com.
doi:10.12720/jcm.13.9.505-511

characterized by vehicular communications can be reduced with proper placement of antenna in mobile relays. In addition, MRNs can use their smaller size and power to exploit smart antenna and advanced signal processing techniques [13] for better communications. MRNs however, are faced with various challenges such as designing efficient interference management technique and proper handover management scheme for the group handover.

Previous work in [15], [16] has shown that the quality of service (QoS) of UEs [17] inside a train can be improved significantly by deploying cooperative and coordinated relays on top of trains. Current solutions like layer 1 repeaters, WiFi access points and dedicated macro eNBs which serve the vehicular UEs were presented and compared with the dedicated MRN in [13]. It was shown in [13], [18] that the dedicated MRN deployments provide great improvement in the vehicular user experience compared to others. The authors also highlighted the challenges faced by the deployment of MRNs. These include the need for efficient interference and mobility management schemes to reduce interference and handover related problems. The authors in [11] adapted fixed relay architecture to the mobile relay and introduced global tunnel concept to reduce the number of signaling messages kept by the network nodes. A CoMP-based handover proposed in [19] aimed at reducing handover failure by allowing train to receive multiple signals from adjacent base stations when it travels through the overlapping areas. In [20], group handover management for moving cell based on LTE-A was proposed. In this work, moving cell architecture for future network was proposed and the protocol stacks of control and user plane for the group handover management were also described. In [3], the architecture for supporting mobile relay was presented but there was no group handover management scheme to support the mobile relay. It could be noticed that in most related work, fixed relay architecture was considered for group handover in mobile relay. Based on this, we present a group handover strategy for mobile relay node in LTE-A network. The proposed group handover will be based on the MRN architecture discussed in [3]. The main idea for the proposed group handover scheme is to reduce the number of handover associated with the MRNs while also maintaining the radio links between the UE and MRN throughout the handover process. The MRN change its point of attachment from source DeNB (S-DeNB) to the target DeNB (T-DeNB) as depicted in Fig. 1. For clarity, we have considered the scenario of MRN deployed on the public trains, however, the proposed work can be used by any high speed vehicular system.

This paper has been organized as follows. The architecture in support of the proposed group handover strategy for mobile relay in LTE-A has been described in the Section II. The proposed group handover strategy to handle the process of handover between MRN and eNBs with enhanced QoS for moving large UEs in the vehicle have been analyzed in the Section III. Analysis of the proposed group handover strategy with MRN has been performed in the Section IV. The proposed work has been tested against the schemes with Fixed Relay Node (FRN) and direct UE to DeNBs in terms of number of handovers and call dropping probability in the Section V. Finally, the Section VI concludes the work and recommends the future aspects.

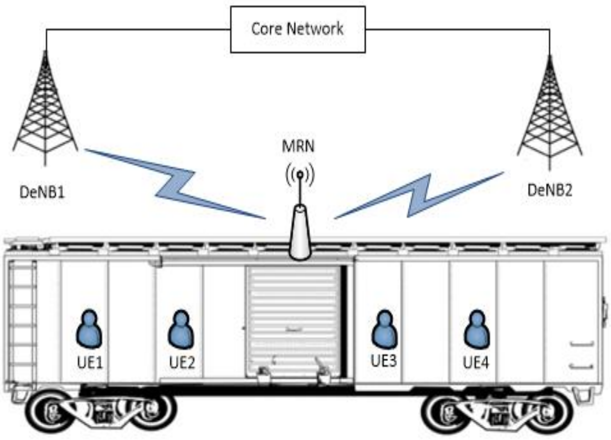

Fig. 1. Group handover scenario in high-speed train

II. Mobile Relay Architecture

The motivation for this work came after studying small cells such as femtocells, relays and mobile cells for future networks and the need for efficient handover management for moving cells in LTE-A network. In mobile relay, two architectures are possible due to changes in DeNB serving the MRN caused by the mobility. These architectures proposed in [2] are known as initial GW and relocated GW architectures as shown in Fig. 2.

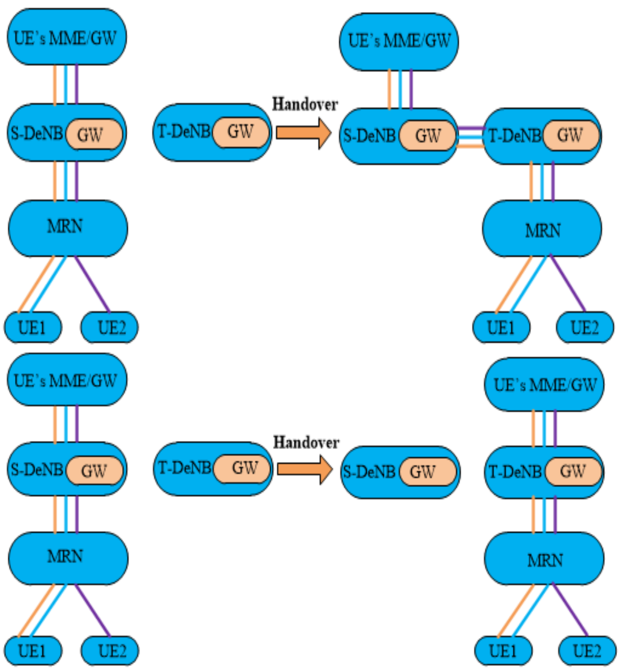

Fig. 2. (a) Initial GW architecture and (b) GW relocation architecture for MRN [3]

In Fig. 2(a) the initial GW architecture, the MRN PGW/SGW is always at the S-DeNB (initial DeNB) for normal operation of mobile relay. The S-DeNB performs the function of keeping the MRN and UE's content, as well as forwarding packets of data between S-DeNB and T-DeNB. No additional signalling is required for handover in the network during MRN mobility.

In Fig. 2(b) the GW relocation architecture, there is relocation of SGW/PGW and Relay GW to the T-DeNB. If a handover occurs from the S-DeNB to T-DeNB, the MRN's SGW/PGW and Relay GW are relocated to T-DeNB. If the MRN travels long distance from the S-DeNB, there is a very long routing path in the initial GW architecture [3]. Also, if the GW relocation occurs each time a handover is performed by the MRN as in the GW relocation architecture, an additional signalling overhead is ensured. A combine solution has been provided in [3].

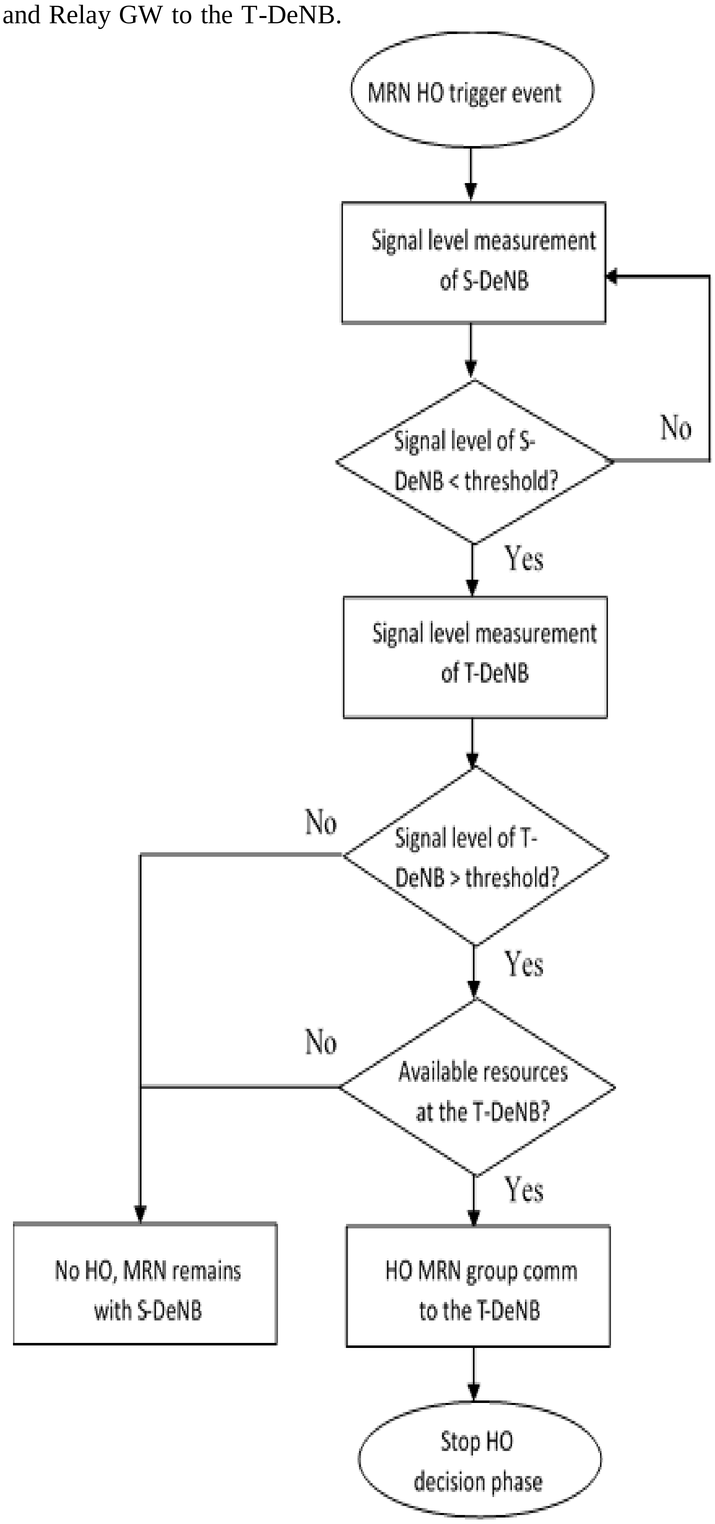

Fig. 3. The proposed group handover flowchart

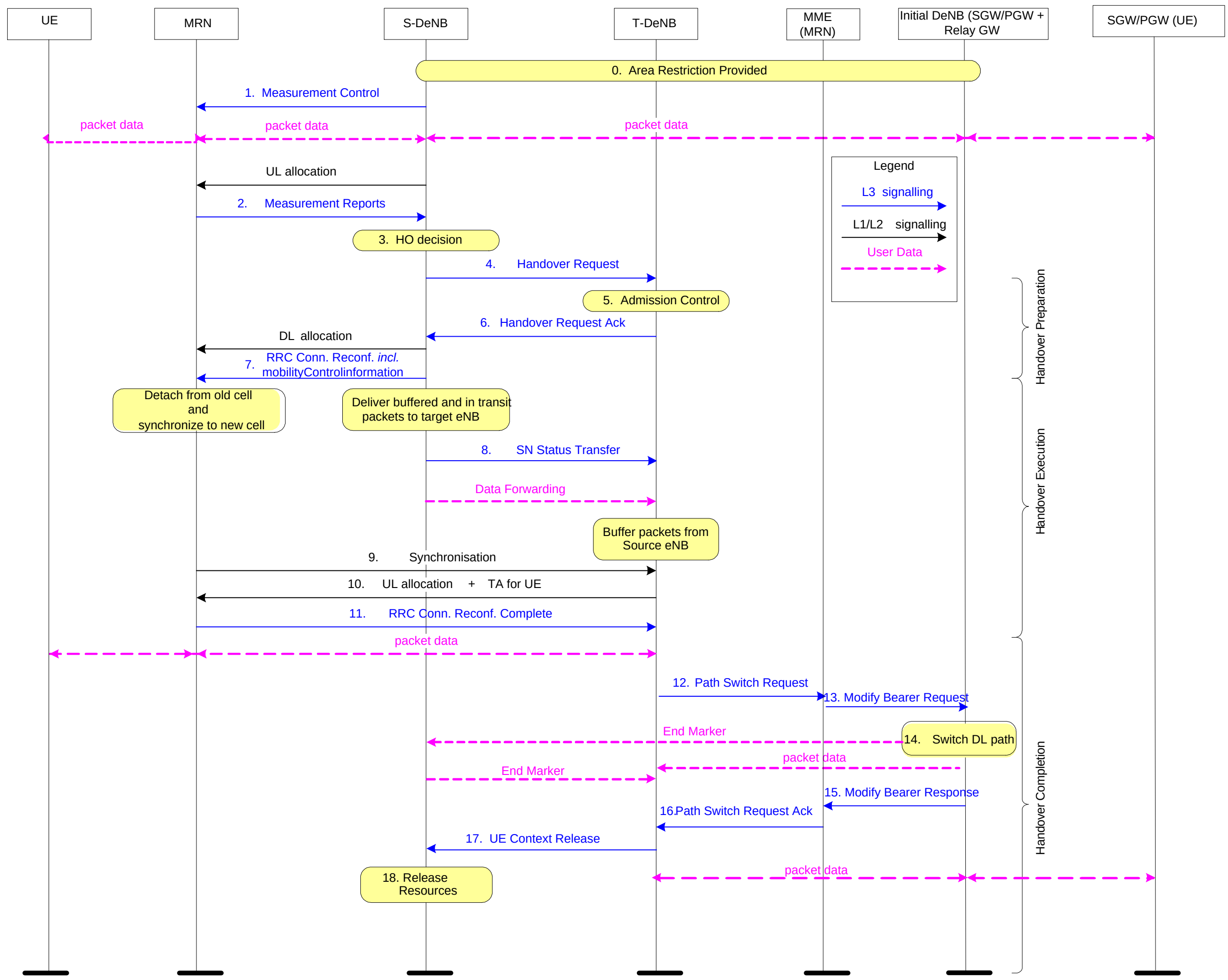

Fig. 4. MRN handover procedure

III. Proposed Group Handover Strategy

In this section, the proposed group handover for the MRN can be represented by the flowchart in Fig. 3. As shown in Fig. 1, relay node mounted on a high-speed train with wireless backhauls can enable group handovers of in-train users. In this way, a single group handover procedure shown in Fig. 4 will ensure proper handover of users served by the MRN between two DeNBs. Group handover apart from reducing the number of handovers and call droppings, can greatly lower the radio interface overheads as well as overheads on the network and subsequently lead to reduced latency for all users.

We have assumed that the deployed MRN is embedded with a small device (called mdev) which is used to predict the location and direction of DeNBs, and also to prepare the MRN for timely handover to the DeNBs. Since MRNs act as regular eNBs, they are capable of supporting multiple radio access technologies [13]. The required steps for the proposed strategy is as follows:

a. MRN measures the signal level to the S-DeNB and compares it with a threshold signal.
b. If the signal in (a) above is less, MRN with the embedded mdev measures its signal level to the T-DeNB and compare it with the threshold signal.
c. If the signal in (b) above is greater than the threshold, the resources at the T-DeNB are determined.
d. If resources are available, then MRN handover UEs group communication information to the T-DeNB otherwise MRN remains with the S-DeNB and repeats the steps until the new T-DeNB is found.

To determine the available resources at the target DeNB, equation (1) is used as follows:

$$C_{users} + C_{req} \subseteq C \quad (1)$$

where C is the total system capacity, C_{req} is the capacity requested by the group handover call, and C_{users} is the actual capacity needed for the connected users.

IV. Performance Analysis and Results

The performance of the proposed group handover strategy on UEs communication can be verified against, one: scenario where the UEs communicate and handover to the T-DeNB directly (i.e. no group handover) and two: scenario where FRN nodes (with group handover) are used instead of MRN (with group handover).

With metrics such as number of handover and call dropping probability, the evaluation can be made using the event-based simulator we have developed in C#. We assumed that the train moves in a straight line with DeNBs deployed alongside the railway line. FRN and MRN were deployed on top of the train separately to represent different scenarios. Also, in another scenario, the UEs were made to communicate directly to the DeNBs. For our strategy, mdev in MRN monitors and detects signals from DeNBs every few seconds. If the condition in the proposed strategy is satisfied, the mdev embed in the MRN triggers the group measurement report and prepares the MRN for timely handover. Threshold and other parameters were set by referring to the [21]. The default parameters used are as presented in Table I.

TABLE I: UNITS FOR MAGNETIC PROPERTIES

Parameter	Conversion from Gaussian and CGS EMU to SI [a]
Bandwidth	10 MHz
Frequency	2.6 GHz
Train speed	Up to 300 km/h
Transmit power (eNB/DeNB)	46 dBm
Transmit power (Relay)	10 dBm
Path Loss Model	32.4 + 20 log (f) + 20 log (d) dB

The two DeNBs: S-DeNB and T-DeNB discussed earlier in this work can be represented by *Bs* and *Bt* respectively. The distance from *Bs* to *Bt* is denoted as *D* and the train velocity as *V*. Let *d* be distance from mdev in MRN to DeNB *v* where *v* ε (*Bs* and *Bt*). The signal strength from mdev to DeNB can be given as:

$$R(v,d) = K - 10y\log(d) + \varpi \quad (2)$$

where K is a constant and denotes the revised transmit power of v. ϖ is a zero-mean Gaussian-random variable with a shadowing fading represented by deviation σ .

We have assumed that the MRN through the mdev can receive messages about signal strength from DeNBs and vice versa. Furthermore, measurement report can be triggered immediately in the MRN if the mdev knows the quality of signal in T-DeNB to be higher than a threshold *U* in *dB*. The two relay protocols for forwarding signal have been discussed in [22]. After the measurement report is triggered, mdev awaits the radio resource connection (RRC) reconfiguration from Bs, which replies in a time *Td*. If the message is lost, the message is resubmitted within a fixed interval *Tr* by the *Bs*. Finally, the mdev receives the RRC configuration or else the failure of the radio link occurs.

Assuming the measurement report is triggered at a location *X* of the mdev (or MRN), if *Bs* sends an RRC connection reconfiguration, the mdev with MRN would have moved with the train to location X_1.

$$\text{Where } X_1 - X = V * T_d \quad (3)$$

If RRC connection reconfiguration is not received correctly by the mdev, the *Bs* can resend the message when mdev is in location X_2.

$$\text{Where } X_2 - X_1 = V * T_r \quad (4)$$

Since the handover can be triggered between *Bs* and *Bt*, the probability of successful handover performed by mdev during handover procedure can be given as:

$$P = \frac{1}{D}\int_0^D P\{R(B_t, X_t) + R \supseteq U\} * \left(1 - \sum_{X_s \in \{X_1, X_2 \dots\}} P\{R(B_s, X_s) \subset S\} d(X)\right) \quad (5)$$

From Eq. (5), when mdev is at *Bs*, the handover procedure will be triggered provided the signal quality detected plus *R* is greater than or equal to *U*. Where *R* is known as a reward parameter used by mdev when moving towards a nearby DeNB to speed up the triggering process of a measurement report. Also the handover is successful if the signal quality in *Bs* is greater than *S* at any point in set *Xs*. Assuming a fixed distance *D*, the distance *Xt* in Fig. 5 becomes shorter, and the probability of mdev trigeering a handover is higher. However, the probability of mdev receiving the RRC connection reconfiguration correctly becomes lower.

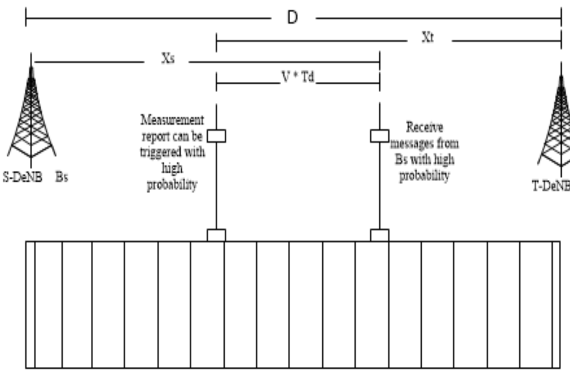

Fig. 5. The proposed group handover flowchart

V. PERFORMANCE EVALUATION OF PROPOSED GROUP HANDOVER STRATEGY

A. *Handover Number (HON)*

The number of handovers recorded in the three cases is illustrated in Fig. 6. The number of handovers in existing works, i.e. Direct-HO and FRN GRP-HO increases as the train moves further distance because UEs can no longer maintain connection with the S-DeNB due to signal loss and inability of the MRN to detect the T-DeNB to communicate with. The number of handovers is the same and much less in MRN GRP-HO because the UEs remain connected to the MRN throughout the train sojourn. Thus, the control signalling overhead using MRN GRP-HO is significantly reduced compared to the overhead in both Direct-HO and FRN GRP-HO. The number of handover in FRN GRP-HO however, is less than that of Direct-HO because with FRN, better connection is provided especially at the edges of the cell compared to direct UE connection to the DeNB.

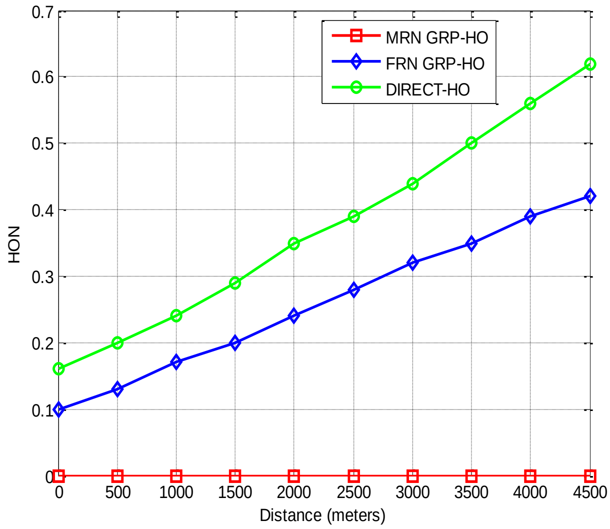

Fig. 6. The handover number

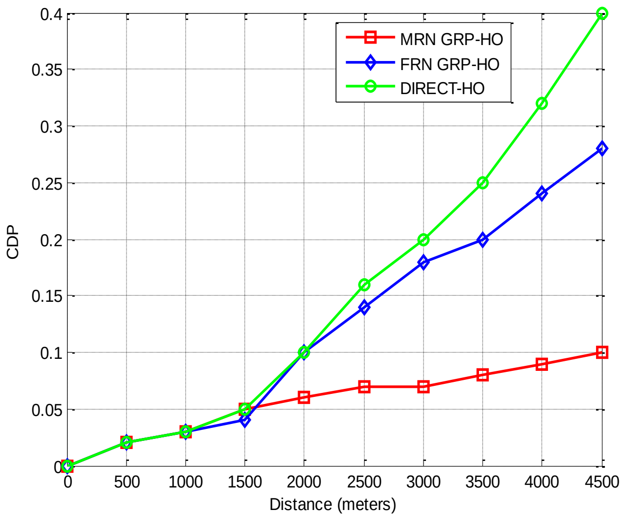

Fig. 7. Call dropping probability

B. Call Dropping Probability (CDP)

In the DIRECT-HO i.e. where UE communicates directly with the DeNBs, all UEs try to perform handover to the T-DeNB individually and since there is no strategy to prepare each UE for handover beforehand, and to determine the availability of resources at the T-DeNB, majority of the UEs call are dropped. The same is noticed in FRN GRP-HO. When the UEs were initially connected to the S-DeNB, there were little call drops as the train moves certain distance as shown in Fig. 7. However, as the train moves further around 1500m, we noticed highest call drops from this point and throughout the rest of the train sojourn in DIRECT-HO because UEs could not handover on time to the T-DeNB and no mechanism to prepare handover before time. The call dropped in the FRN GRP-HO is lower compared to DIRECT-HO because of the group handover scheme but no strategy to help prepare the group to handover to the T-DeNB on time. However, the lowest reduction in call drop is noticed in the MRN GRP-HO because of the proposed strategy which determines the closeness of the MRN to the T-DeNB and prepares the MRN for timely handover to the T-DeNB.

VI. Conclusions

In this work, an efficient group handover strategy for UEs in LTE-A high speed train systems have been proposed. It has been observed that in the conventional handover procedure, where UEs communicate directly to the DeNBs, the handover frequency is very high. Also, the recent LTE-A fixed relay node and mobile relay node solutions which brought about group handover management though reduces the frequency of handover and probability of call drops to some extent, however, it is not efficient without an additional strategy or mechanism to prepare the group information for timely handover due to the speed of the train. Therefore, the group handover management procedure has been enhanced with our strategy to make it more robust. Consequently, the number of handover and call dropping probability in the system reduced with our strategy.

In the future, we plan to investigate on how more calls can be accepted into the T-DeNB using dynamic borrowing strategy to admit more real-time calls while maintaining the ongoing non-real calls.

References

[1] O. O. Omitola and V. M. Srivastava, "An enhanced handover algorithm in LTE-advanced network," *Wireless Personal Communications*, vol. 97, pp. 2925-2938, 2017.

[2] K. M. Addali, A. BenMimoune, F. A. Khasawneh, A. M. Saied, and M. Kadoch, "Dual-Backhaul links in LTE-A mobile relay system for high-speed railways," in *Proc. IEEE International Conference on Future Internet of Things and Cloud Workshops*, 2016, pp. 98-102.

[3] L. Chen, Y. Huang, F. Xie, Y. Gao, L. Chu, H. He, *et al.*, "Mobile relay in LTE-advanced systems," *IEEE Communications Magazine*, vol. 51, pp. 144-151, 2013.

[4] R. Balakrishnan, X. Yang, M. Venkatachalam, and I. F. Akyildiz, "Mobile relay and group mobility for 4G WiMAX networks," in *Proc. Wireless Communications and Networking Conference*, 2011, pp. 1224-1229.

[5] O. O. Omitola and V. M. Srivastava, "A robust speed-based handover algorithm for dense femtocell/macrocell LTE-A network and beyond," *Journal of Telecommunication, Electronic and Computer Engineering*, vol. 8, pp. 121-129, 2016.

[6] I. F. Akyildiz, E. Chavarria-Reyes, D. M. Gutierrez-Estevez, R. Balakrishnan, and J. R. Krier, "Enabling next

generation small cells through femtorelays," *Physical Communication*, vol. 9, pp. 1-15, 2013.

[7] H. Lin, D. Gu, W. Wang, and H. Yang, "Capacity analysis of dedicated fixed and mobile relay in LTE-Advanced cellular networks," in *Proc. IEEE International Conference on Communications Technology and Applications*, 2009, pp. 354-359.

[8] Y. Jiang, G. Zhu, and Z. Wang, "A specific mobile relay with Doppler diversity in OFDM system for high-speed railway scenario," in *Proc. 2nd IEEE International Conference on Network Infrastructure and Digital Content*, 2010, pp. 742-747.

[9] E. Tanghe, W. Joseph, L. Verloock, and L. Martens, "Evaluation of vehicle penetration loss at wireless communication frequencies," *IEEE Transactions on Vehicular Technology*, vol. 57, pp. 2036-2041, 2008.

[10] A. Alsharoa, H. Ghazzai, E. Yaacoub, and M. S. Alouini, "Energy-efficient two-hop LTE resource allocation in high speed trains with moving relays," in *Proc. 12th International Symposium on Modeling and Optimization in Mobile, Ad Hoc, and Wireless Networks*, 2014, pp. 528-533.

[11] Y. Chen and X. Lagrange, "Analysis and Improvement of mobility procedures for mobile relays in LTE networks," in *Proc. 26th Annual International Symposium on Personal, Indoor, and Mobile Radio Communications*, 2015, pp. 1769-1774.

[12] O. Bulakci, "Multi-hop moving relays for IMT-advanced and beyond," arXiv preprint arXiv:1202.0207, 2012.

[13] Y. Sui, J. Vihriala, A. Papadogiannis, M. Sternad, W. Yang, and T. Svensson, "Moving cells: A promising solution to boost performance for vehicular users," *IEEE Communications Magazine*, vol. 51, pp. 62-68, 2013.

[14] S. N. Mane and P. C. Sayankar, "Handover scheme for mobile relays in LTE-A high speed rail network: A Review," *International Journal of Innovative Research in Computer and Communication Engineering*, vol. 4, pp. 6933-6936, 2016.

[15] V. Van Phan, K. Horneman, L. Yu, and J. Vihriala, "Providing enhanced cellular coverage in public transportation with smart relay systems," in *Proc. Vehicular Networking Conference*, 2010, pp. 301-308.

[16] W. Li, C. Zhang, X. Duan, S. Jia, Y. Liu, and L. Zhang, "Performance evaluation and analysis on group mobility of mobile relay for LTE advanced system," in *Proc. Vehicular Technology Conference*, 2012, pp. 1-5.

[17] Y. Sui, A. Papadogiannis, W. Yang, and T. Svensson, "Performance comparison of fixed and moving relays under co-channel interference," in *Proc. Globecom Workshops (GC Wkshps)*, 2012, pp. 574-579.

[18] Y. Sui, A. Papadogiannis, and T. Svensson, "The potential of moving relays-A performance analysis," in *Proc. IEEE 75th Vehicular Technology Conference (VTC Spring)*, 2012, pp. 1-5.

[19] W. Luo, R. Zhang, and X. Fang, "A CoMP soft handover scheme for LTE systems in high speed railway," *EURASIP Journal on Wireless Communications and Networking*, vol. 2012, p. 196, 2012.

[20] Y. Hwang and J. Shin, "Group handover management for V2x in moving cell based LTE-Advanced system," in *Proc. International Conference on Information and Communication Technology Convergence*, 2015, pp. 1054-1057.

[21] M. S. Pan, T. M. Lin, and W. T. Chen, "An enhanced handover scheme for mobile relays in LTE-A high-speed rail networks," *IEEE Transactions on Vehicular Technology*, vol. 64, pp. 743-756, 2015.

[22] A. Papadogiannis, A. Saadani, and E. Hardouin, "Exploiting dynamic relays with limited overhead in cellular systems," in *Proc. GLOBECOM Workshops*, 2009, pp. 1-6.

Olusegun O. Omitola received M.Sc. in Mobile Computing and Communications from the University of Greenwich, London, UK and B.Tech degree in Computer Engineering from Ladoke Akintola University of Technology (LAUTECH), Nigeria, in 2007. He is a lecturer at the department of Electrical, Electronic and Computer Engineering, Afe Babalola University, Nigeria. He is currently pursuing his PhD in Electronic Engineering at the University of KwaZulu-Natal, South Africa. His interests include mobile and wireless communications, femtocells, LTE/LTE-A, and mobile ad-hoc networks.

Viranjay M. Srivastava is a Doctorate (2012) in the field of RF Microelectronics and VLSI Design, Master (2008) in VLSI design, and Bachelor (2002) in Electronics and Instrumentation Engineering. He has worked for the fabrication of devices and development of circuit design. Presently, he is a faculty in Department of Electronic Engineering, Howard College, University of KwaZulu-Natal, Durban, South Africa. He has more than 13 years of teaching and research experience in the area of VLSI design, RFIC design, and Analog IC design. He has supervised various Bachelors, Masters and Doctorate theses. He is a senior member of IEEE, and member of IEEE-HKN, IITPSA, ACEEE and IACSIT. He has worked as a reviewer for several Journals and Conferences both national and international. He is author/co-author of more than 110 scientific contributions including articles in international refereed Journals and Conferences and also author of following books, 1) VLSI Technology, 2) Characterization of C-V curves and Analysis, Using VEE Pro Software: After Fabrication of MOS Device, and 3) MOSFET Technologies for Double-Pole Four Throw Radio Frequency Switch, Springer International Publishing, Switzerland, October 2013.