Seamless QoS-Enabled Handover Scheme Using CoMP in Fast Moving Vehicular Networks

Sunghun Chae, Tuan Nguyen, and Yeong Min Jang

Department of Electronics Engineering, Kookmin University, Seoul 136-702, Republic of Korea

Correspondence should be addressed to Yeong Min Jang; yjang@kookmin.ac.kr

Received 18 July 2013; Accepted 15 November 2013

Copyright © 2013 Sunghun Chae et al. This is an open access article distributed under the Creative Commons Attribution License, which permits unrestricted use, distribution, and reproduction in any medium, provided the original work is properly cited.

Vehicular networks create new opportunities to develop innovative and enhanced solutions for generating reliable communication among vehicles. To widely deploy vehicular networks, it is needed to overcome several existing research challenges in such networks. Guaranteeing data transmission is one of the main challenges in vehicular networks that are specified by their large scale and high mobility. Recently, the effective deployment of femtocell networks inside high-speed moving vehicles, in order to improve the quality of data transmission, is an interesting topic for researchers. In this paper, we propose a novel handover scheme utilizing coordinated multiple point transmission (CoMP) in high-speed moving vehicular femtocell networks. The proposed scheme aims at a seamless, deployable, and efficient handover procedure for this specific environment. We take into account signal-to-interference-plus-noise ratio (SINR) and outage probability to evaluate the performance of our proposed handover scheme.

1. Introduction

Vehicular network is a new type of wireless network that has appeared along with the development in wireless technologies and the automotive industry. Vehicular networks are spontaneously formed among moving vehicles, which are equipped wireless interfaces in homogeneous or heterogeneous technologies, and infrastructure components. Compared to other communication networks, the vehicular networks have some attractive features, such as unlimited transmission power, higher computational capability, and predictable mobility of vehicles [1–3]. In recent years, a special type of mobile ad hoc network (MANET), called as vehicular ad hoc network (VANET) [4–6], is considered in vehicular environments. The VANET supports two types of communications, including vehicle-to-vehicle (V2V) and vehicle-to-infrastructure (V2I) communications. The characteristics of VANETs require distributed solutions that strongly depend on the vehicle density, the communication range, and the interference range of neighbor vehicles.

Regarding V2I communication, in inside-vehicle environments, cellular users face difficulties in receiving high-speed services due to low-quality signals from the outdoor base stations (eNodeBs). Femtocell has been considered as a new technology to overcome the drawbacks of cellular wireless communications in indoor environments. Femtocell has many advantages, such as improved coverage, low power, improved SINR (Signal-to-Interference-plus-Noise Ratio) level, low cost, reduced infrastructure and capital cost, and improved throughput [7–11].

Nowadays, femtocell technology is considered to be deployed not only in fixed environments but also in the moving vehicular environments, such as buses, trains, and subways, referred to as moving femtocells. In moving femtocell environments, especially femtocell deployed in fast-moving vehicles, handover is one of key issues that need to be solved effectively to make moving femtocell technology be possibly implemented in near future. The deployment of moving femtocell in high-speed vehicular environments generates lots of handovers, which are individual handovers or group handovers [12–14]. Handover brings about the interruption of data transmission of users and the scarcity of resource for allocating to users. This problem becomes more serious in case of group handover, in which network controllers have to handle handover situations of multiple users at the same time. Many researches have been proposed to cope with handover as well as group handover in femtocell environments. Reducing the handover delay, reducing handover control signal...
traffic, and mitigating unnecessary handovers are the main goals of handover schemes. Most of the works regarding group handover in wireless networks focus on modifying the processes of group handover procedure or handling resource allocation for group handover calls.

Coordinated multiple point transmission (CoMP) is one of the features defined in 3GPP Release-12 for LTE Advanced [15] to meet the requirements of IMT-Advanced framework and has been a key research area in high speed moving femtocell technology. CoMP gives many advantages to users as well as network operators, such as better network utilization, enhanced reception performance, increased overall received power, reduced intercell interference, and improved frequency spectral efficiency [16]. Besides, with the use of CoMP technique, handover is utilized with failure rate degradation, and the reliability of vehicles on ground communication is guaranteed.

In this paper, we propose a novel eNodeB-to-eNodeB handover scheme utilizing CoMP for high speed vehicular networks deploying femtocell. In our proposed scheme, when an outside transceiver needs to perform handover, the data transmission between mobile users, which have been currently using that outside transceiver, and the current serving eNodeB are now temporarily handled by other outside transceivers under the management of central control femtocell access point (CCF). After the outside transceiver is successfully connected to the target eNodeB, those mobile users return to use this transceiver. The information of this target eNodeB is used by other transceivers to simplify their handover procedures.

The rest of this paper is organized as follows. Section 2 introduces some proposed approaches regarding handover in vehicular networks. In Section 3, the moving vehicular system model and conventional eNodeB-to-eNodeB backhaul handover procedure are represented. Our proposed scheme is described in Section 4. Section 5 represents numerical results of our proposed scheme. Finally, Section 6 concludes our work.

2. Related Works

Due to the importance of handover in vehicular networks, a large number of approaches have been proposed to optimize the handover performance. Tian et al. [14] proposed a seamless handover scheme to minimize the communication interruption during handover procedure. In this scheme, to keep the communication without interruption during handover, two antennas are deployed in a train. Besides, to avoid the data forwarding delay between the serving eNodeB and the target eNodeB, the bicasting process is utilized. Luo et al. [16] proposed an optimized handover scheme in which the coordinated multiple point transmission (CoMP) technology and dual vehicle station coordination mechanism are applied to improve the traditional hard handover performance of LTE. Their proposed scheme can receive signals from adjacent eNodeBs at the same time and obtain diversity gain when the trains pass by overlapping areas; since then the quality of the received signal can be increased and the high QoS for communication between high speed vehicles and eNodeBs is provided. The proposed scheme in [17] utilizes sensor technologies to capture the train movement status used to assist handover decision. This proposed scheme uses simple and cheap optical switch units to carry out the handover action. Although it can support seamless handover for high speed train users without disruption, this proposed scheme still leaves some drawbacks, such as fast fading, multipath, and Doppler shift. Lee et al. [18] proposed an interdomain handover scheme for Proxy Mobile IPv6 (PMIPv6) with a new network entity, called intermediate mobile access gateway (iMAG). This proposed scheme is a proactive handover approach that performs the inter-domain L3 handover before the inter-domain L2 handover while the mobile node (MN) is still connected to the iMAG in the home domain. To support high-throughput wireless access for high speed train users, Karimi et al. [19] proposed a novel infrastructure and scheduling algorithms. This work is based on a cell array organization to effectively predict upcoming LTE cells in service. Zhang and Liu [20] proposed a group handover scheme in heterogeneous vehicular networks. This proposed scheme not only seeks the maximize system throughput but also makes sure that the load of all candidate access networks is maintained at the target load level. As a one-sided multiassignment problem, group users can select the most appropriate networks with mobility prediction information. In [21], a high speed scenario with mobile relay integrated is presented to analyze some special issues for LTE Advanced system. This proposed scheme can improve the throughput of the system as well as achieve higher handover success ratio with a decrease in link failure ratio.

3. System Model

3.1. Moving Femtocell System Architecture. To help easily understanding of our idea, we explain a moving vehicular system model deploying femtocell with high-speed trains, as shown in Figure 1. In the LTE based vehicular network environment in which femtocell technology is deployed, a femtocell access point FAP, a.k.a. HeNB, is deployed on the ceiling of the each compartment. A transceiver is deployed outside of each compartment for transmitting/receiving data to/from eNodeBs with backhauling network. Compared to direct connection between eNodeBs and mobile users, the use of outside transceivers achieves stronger received signal; since then the Quality of Service (QoS) is improved.

The uplink data of users inside the vehicle are forwarded to the outside transceivers by the FAPs, and then the outside transceivers transmit the data to eNodeBs. On the other hand, the downlink data received by the outside transceivers from eNodeBs are forwarded to the mobile users by the FAPs. All the FAPs and outside transceivers are managed by a CCF, as shown in Figure 2.

3.2. eNodeB-to-eNodeB Backhaul Handover. Figure 3 shows the call flow of eNodeB-to-eNodeB backhaul handover procedure in moving femtocell network [13]. An outside transceiver has to select the proper backhaul network. If the outside transceiver detects that the received signal is going down, it sends the measurement report to the serving
eNodeB (Steps 1 and 2). After that, the outside transceiver searches for the new signals from the neighbor eNodeBs (Step 3). Then it carries out the preauthentication to all the access networks that are included in the neighbor cell list (Step 4). The outside transceiver and its serving eNodeB make handover decision together based on the preauthentication and the received signal levels for handover to the target eNodeB (Step 5). The serving eNodeB sends a handover request to the target eNodeB for starting handover process (Steps 6, 7, and 8). The target eNodeB and target RNC perform CAC and RRC to admit the handover call (Step 9). Then the target eNodeB responds the handover request to serving eNodeB (Steps 10, 11, 12, 13, and 14). A new link is established between the T-RNC and target eNodeB (Steps 15, 16, and 17). The outside transceiver resetting a channel with the target eNodeB disconnects from the serving eNodeB and synchronized with the target eNodeB (Steps 19, 20, 21, and 22). After that, the outside transceiver sends a handover complete message to T-RNC (Steps 23 and 24). Finally the serving eNodeB deletes the old link with S-RNC (Steps 25, 26, 27, 28, and 29). Now the packets are forwarded to outside transceiver through the target eNodeB.

4. Proposed Handover Scheme

4.1. A Novel Handover Using CoMP Technique. During the conventional eNodeB-to-eNodeB handover scheme explained in the previous section, the outside transceiver can receive signals from only one base station at a certain time. This problem results in the interruption of data transmission and can reduce the quality of service. In this paper, we utilize a CoMP technique to overcome this problem.

CoMP allows vehicles to receive signals from both eNodeBs at the same time. In our paper, the use of CoMP to support handover follows 4 steps as shown in Figure 4.

Step 1. When the train moves towards the boundary area of its serving eNodeB, the received signal strength of outside transceivers becomes weak. When the outside transceiver of the first compartment needs to perform handover, it starts the scanning process to find out the best neighbor eNodeB. To guarantee the data transmission of mobile users inside the first compartment, the CCF now connects the FAP of the first compartment to one of the remaining outside transceivers which are still communicating with the current serving eNodeB.

Step 2. After the scanning process, the first outside transceiver decides and starts connecting to the best neighbor eNodeB. The information regarding this target eNodeB is then sent to the CCF. After successfully connecting to the target eNodeB, the first outside transceiver now starts data transmission with this one. Then the mobile users inside the first compartment are back to use the first outside transceiver.
Step 3. When the outside transceiver of the second compartment needs handover, by using the information of the best neighbor eNodeB saved in CCF, this outside transceiver starts connecting the target eNodeB without the scanning process.

Step 4. Step 3 is repeated for the remaining outside transceivers. The handover procedure is complete when all the outside transceivers are connected to the target eNodeB.

4.2. Outage Probability Analysis. To analyze outage probability in moving femtocell networks, we consider the affection of interference and noise for the system. Moving femtocell users receive signal from FAPs which are deployed inside trains. The path loss between a mobile user and FAP \(i\) inside the train can be expressed as follows:

\[
L_{f,c}(i) = 20 \log f_{c,f} + 28 \log d_i - 28 \text{ [dB]},
\]

(1)

where \(L_{f,c}(i)\) is the loss, \(f_{c,f}\) is the center frequency in MHz of the moving femtocell, and \(d_i\) is the distance between FAP and moving femtocell users in meters.

The ICI inside vehicles, denoted as \(I_{\text{inj}}\), is given by:

\[
I_{\text{inj}} = \sum_{j=1}^{N_{\text{FAP}}} S_{T,\text{FAP}} 10^{L_{f,c}(i)/10},
\]

(2)

where \(S_{T,\text{FAP}}\) is the transmitted power of FAPs, \(N_{\text{FAP}}\) is the number of neighbor FAPs, and \(j\) is the identity of a neighbor FAP.

The SINR value of mobile users inside trains can be calculated as

\[
\text{SINR}_{\text{FAP}} = \frac{S_{T,\text{FAP}} 10^{-L_{f,c}(i)/10}}{I_{\text{inj}} + \text{AWGN}},
\]

(3)
where AWGN is additive white Gaussian noise. We assume that the intracell interference does not affect the system performance and can be neglected in this paper.

The outage probability of a mobile user inside the train, denoted as $P_{in}$, can be calculated as

$$P_{in} = P(\text{SINR}_\text{FAP} < \gamma_{in})$$

(4)

where $\gamma_{in}$ is the threshold value for indicating the acceptable reception.

When the train is at location $x$, the path loss between an outside transceiver and an eNodeB $k$, denoted as $A(k, x)$, can be calculated as

$$A(k, x) = r_{k, x}^{-\frac{1}{l}} 10^{\xi(k, x)/10}$$

(5)

where $r_{k, x}$ is the distance between the outside transceiver and eNodeB $k$, $l$ is the path loss exponent, and $\xi(k, x)$ is the Gaussian distributed random variable with zero mean.

Regarding eNodeBs, the ICI, denoted as $I_{out,k}$, can be expressed as

$$I_{out,k} = \sum_{m=1}^{N_{\text{NodeB}}} S_{T,eNodeB} A(m, x)$$

(6)

where $S_{T,eNodeB}$ is the transmitted power of eNodeBs, $N_{T,eNodeB}$ is the number of neighbor eNodeBs, and $m$ is the identity of a neighbor FAP.

Similarly to FAP case, the SINR value of the outside transceivers can be calculated as

$$\text{SINR}_{eNodeB}(k) = \frac{S_{T,eNodeB} A(k, x)}{I_{out,k} + \text{AWGN}}$$

(7)

In our proposed scheme, the two adjacent eNodeBs communicate with the vehicle simultaneously in the overlapping area. So the outage happens if and only if both signals are of unacceptable quality. The outage probability of connection between outside transceivers and eNodeBs using our proposed scheme can be expressed as

$$P_{out,\text{proposed}} = P(\max(\text{SINR}_{eNodeB}(k), \text{SINR}_{eNodeB}(m)) < \gamma_{out})$$

(8)

where $\gamma_{out}$ is a predefined threshold for indicating the acceptable reception; $k$ and $m$ are identities of neighbor eNodeBs, respectively.

Equation (8) can be further derived into (9):

$$P_{out,\text{proposed}} = \left(\int_{-\infty}^{\infty} P[\text{SINR}_{eNodeB}(k) < \gamma_{out} | \xi(k, x) = \xi_0] \cdot P[\xi(k, x) \xi_0] d\xi_0\right)$$

Figure 4: The procedure of handover using CoMP technique.
\[
\begin{align*}
\cdot \left( \int_{-\infty}^{\infty} P \left[ \text{SINR}_{\text{NodeB}} (m) < y_{out} \mid \xi (m, x) = \xi_0 \right] \cdot P \left[ \xi (m, x) = \xi_0 \right] d\xi_0 \right) \\
= \left( \int_{-\infty}^{\infty} P \left[ \text{SINR}_{\text{NodeB}} (k) < y_{out} \mid \xi (k, x) = \xi_0 \right] \cdot \frac{1}{\sqrt{2\pi}\sigma} e^{-\xi_0^2/2\sigma^2} d\xi_0 \right) \\
\cdot \left( \int_{-\infty}^{\infty} P \left[ \text{SINR}_{\text{NodeB}} (m) < y_{out} \mid \xi (m, x) = \xi_0 \right] \cdot \frac{1}{\sqrt{2\pi}\sigma} e^{-\xi_0^2/2\sigma^2} d\xi_0 \right).
\end{align*}
\] (9)

Substituting (7) into (9), we can obtain in detail the outage probability of our proposed scheme that is expressed by (10):

\[
P_{\text{out, proposed}} = \left( \int_{-\infty}^{\infty} P \cdot \frac{A (k, x)}{\sqrt{\text{S}_T}} < \frac{y_{out} (I_{out,k} + \text{AWGN})}{\text{S}_T} \mid \xi (k, x) = \xi_0 \right) \cdot \frac{1}{\sqrt{2\pi}\sigma} e^{-\xi_0^2/2\sigma^2} d\xi_0
\]

\[
\cdot \left( \int_{-\infty}^{\infty} P \cdot \frac{A (m, x)}{\sqrt{\text{S}_T}} < \frac{y_{out} (I_{out,m} + \text{AWGN})}{\text{S}_T} \mid \xi (m, x) = \xi_0 \right) \cdot \frac{1}{\sqrt{2\pi}\sigma} e^{-\xi_0^2/2\sigma^2} d\xi_0.
\] (10)

Since \(A(k, x)\) is a random variable with normal distribution, \(P_{\text{out, proposed}}\) can be calculated using Q-function:

\[
Q (\alpha) = \frac{1}{\sqrt{2\pi}} \int_{\alpha}^{\infty} e^{-x^2/2} dx.
\] (11)

By using Q-function, (10) can be derived from (12), where \(A(k, x)\) and \(A(m, x)\) are, respectively, the average values of the path loss between a mobile user and two eNodeBs \(k\) and \(m\) at location \(x\):

\[
P_{\text{out, proposed}} = \left( \int_{-\infty}^{\infty} Q \left( \frac{A (k, x) - \gamma_{out} (I_{out,k} + \text{AWGN}) / S_T}{\sigma} \right) \cdot \frac{1}{\sqrt{2\pi}\sigma} e^{-\xi_0^2/2\sigma^2} d\xi_0 \right)
\]

\[
\cdot \left( \int_{-\infty}^{\infty} Q \left( \frac{A (m, x) - \gamma_{out} (I_{out,m} + \text{AWGN}) / S_T}{\sigma} \right) \cdot \frac{1}{\sqrt{2\pi}\sigma} e^{-\xi_0^2/2\sigma^2} d\xi_0 \right).
\] (12)

\[
P_{\text{out, conventional}} = \left( \int_{-\infty}^{\infty} Q \left( \frac{A (k, x) - \gamma_{out} (I_{out,k} + \text{AWGN}) / S_T}{\sigma} \right) \cdot \frac{1}{\sqrt{2\pi}\sigma} e^{-\xi_0^2/2\sigma^2} d\xi_0 \right)
\]

\[
\cdot \left( \int_{-\infty}^{\infty} Q \left( \frac{A (m, x) - \gamma_{out} (I_{out,m} + \text{AWGN}) / S_T}{\sigma} \right) \cdot \frac{1}{\sqrt{2\pi}\sigma} e^{-\xi_0^2/2\sigma^2} d\xi_0 \right).
\] (13)

Using the same calculation, in case of conventional handover scheme which does not use CoMP concept, the outage probability of connections between outside transceivers and eNodeBs can be expressed as in (13). Finally, the outage probability of the system is as follows:

\[
P_{\text{outage}} = P_{in} + P_{\text{out}}
\]

\[
\begin{align*}
P_{\text{outage}} &= P_{in} + P_{\text{out, conventional}} \\
&= \begin{cases} P_{in} + P_{\text{out, conventional}} & \text{conventional scheme} \\
P_{in} + P_{\text{out, proposed}} & \text{proposed scheme.} \end{cases}
\]

5. Performance Evaluation

In this section, we evaluate the performance of our proposed scheme in terms of outage probability and SINR. We compare the outage probability between our proposed scheme and conventional handover scheme that does not utilize CoMP concept. The outage probabilities are calculated and evaluated by varying the distance, calculated between FAPs and mobile users inside trains, and the outage threshold. Table 1 shows the parameters assumption. The height of a FAP is set to be 2 meters, the transmitted power of FAPs is set to be 20 mW, and the transmitted power of eNodeBs is set to be 60 W.

Figures 5 and 6 show the SINR values of mobile users inside trains and outside transceivers, respectively, according to distances. Due to the effect of intercell interference, the values of SINR in these two situations are quite small. In case of mobile users inside trains, the value of SINR with respect to one-meter distance is 0.69. Figure 7 shows the comparison of outage probability between our proposed scheme and conventional handover scheme, which does not use CoMP technique, according to distance. In this experiment, the outage probability of mobile users inside trains is taken into account. The outage threshold value is set to be 6 (dB). By utilizing CoMP, our proposed scheme effectively reduces the outage probability. When the distance between mobile users and FAPs is not larger than 10 meters, the outage probability of our proposed scheme is smaller than 0.03. Figure 8 shows the outage probabilities of two schemes according to outage threshold variance. The increment of outage threshold brings about the decrement of outage probability, and our proposed scheme provides the improvement in outage probability compared to the conventional scheme that can be obtained from the figure.
6. Conclusion

Vehicular network is a new type of wireless network that has appeared along with the development in wireless technologies and the automotive industry. Handover is an essential issue to guarantee the seamless connectivity or to improve the QoS in vehicular networks. In high speed moving femtocell environments where handover can occur frequently, it is necessary to provide an effective handover process. In this paper, we propose a novel eNodeB-to-eNodeB handover scheme utilizing CoMP for high speed moving vehicular femtocell networks. The CoMP concept is handled by multiple outside transceivers and a CCF. With the use of CoMP, the connections between outside transceivers and eNodeBs are maintained seamlessly, and the outage probability is reduced compared to conventional handover scheme. Our proposed scheme is expected to be a suitable candidate for practical handover deployment.

Conflict of Interests

All the funding sources for this work are listed in the acknowledgement section of the paper. None of the authors
of this work have a significant financial relation or affiliation with any product or trademark mentioned nor any potential bias against another product.

Acknowledgment

This work was supported by the IT R&D program of MKE/KEIT [10035362, Development of Home Network Technology based on LED-ID].

References

[1] A. Lehner, R. Garcia, and T. Strang, “On the performance of TERA DMO short data service in railway VANETs,” Wireless Personal Communications, vol. 69, no. 4, pp. 1647–1669, 2013.

[2] S. Annese, C. Casej, C.-F. Chiasserini, N. Di Maio, A. Ghittino, and M. Reineri, “Seamless connectivity and routing in vehicular networks with infrastructure,” IEEE Journal on Selected Areas in Communications, vol. 29, no. 3, pp. 501–514, 2011.

[3] L. Shan, F. Liu, and K. Yang, “Performance analysis of group handover scheme for IEEE 802.16j-enabled vehicular network,” in Proceedings of the Joint International Conferences on Advances in Data and Web Management, pp. 653–658, April 2009.

[4] M. Saini and S. Mann, “VANET: handoff schemes, application and challenges,” International Journal of Innovative Research and Studies, vol. 2, no. 4, pp. 516–525, 2013.

[5] M. A. Wasnik and S. S. Dorle, “Analysis of handover scheme for VANETS,” International Journal of Science and Research, vol. 2, no. 2, pp. 73–76, 2013.

[6] M. N. Majeed, S. P. Chatta, A. A. Akram, and M. Zafullah, “Vehicular Ad-hoc networks history and future development arenas,” International Journal of Information Technology and Electrical Engineering, vol. 2, no. 2, pp. 25–29, 2013.

[7] S. H. Chae, M. Z. Chowdhury, T. Nguyen, and Y. M. Jang, “A dynamic frequency allocation scheme for moving femtocell networks,” in Proceedings of the International Conference on ICT Convergence (ICTC ’12), pp. 125–128, October 2012.

[8] http://www.femtoforum.org/.

[9] V. Chandrasekhar, J. G. Andrews, and A. Gatherer, “Femtocell networks: a survey,” IEEE Communications Magazine, vol. 46, no. 9, pp. 59–67, 2008.

[10] H. Claussen, L. T. W. Ho, and L. G. Samuel, “An overview of the femtocell concept,” Bell Labs Technical Journal, vol. 13, no. 1, pp. 221–245, 2008.

[11] H.-S. Jo, C. Mun, J. Moon, and J.-G. Yook, “Self-optimized coverage coordination in femtocell networks,” IEEE Transactions on Wireless Communications, vol. 9, no. 10, pp. 2977–2982, 2010.

[12] W. Lee and D.-H. Cho, “Enhanced group handover scheme in multiaccess networks,” IEEE Transactions on Vehicular Technology, vol. 60, no. 5, pp. 2389–2395, 2011.

[13] M. Z. Chowdhury, N. Saha, S. H. Chae, and Y. M. Jang, “Handover call admission control for mobile femtocells with free-space optical and macrocellular backbone network,” Journal of Advanced Smart Convergence, vol. 1, no. 1, pp. 19–26, 2012.

[14] L. Tian, J. Li, Y. Huang, J. Shi, and J. Zhou, “Seamless dual-link handover scheme in broadband wireless communication systems for high-speed rail,” IEEE Journal on Selected Areas in Communications, vol. 30, no. 4, pp. 708–717, 2012.

[15] 3GPP TR 36.836, “Mobile Relay for Evolved Universal Terrestrial Radio Access (E-UTRA),” 2012.
Submit your manuscripts at http://www.hindawi.com