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Abstract of Doctoral Dissertation

Study on Mobility Management Scheme of Moving Relay Nodes in LTE Network

LTE ネットワークにおける移動中継ノードの移動管理方式に関する研究

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Summary

In the past, cellular networks were primarily used for voice and short message services. Today, this has changed and these networks are mainly used for data transferring services such as live video streaming, online gaming, and social application data. Hence, the development of next-generation wireless networks focuses on addressing the increasing bandwidth usage and mobile data traffic in order to provide a good quality of service, low end-to-end latency, data reliability, efficient bandwidth management, and more secure connections. Achieving these goals is an important challenge cellular network operators need to overcome. The growth of the amount of mobile data traffic and the number of Internet-connected devices is presented in Cisco's Visual Networking Index [2014-2019] and the Ericsson Mobility Report (June 2015): (i) global mobile data traffic grew by 69 percent in 2014, which reflects the impact of smartphone and powerful operating systems. In addition, it is expected to increase nearly tenfold by 2019, reaching 24.3 Exabytes per month by 2019, (ii) the increasing number of devices connected to the Internet such as smartphones, tablets, laptops, game consoles, and portable devices, and (iii) the increase in the amount of sensitive data traffic, for example, mobile video traffic comprised 45 percent of mobile data traffic in 2014. (iv) on-board mobile devices generate a considerable amount of mobile data traffic. In addition, applications need to be targeted at mobile users and their devices.

One promising solution is to use a moving relay that focuses on the provision of high-quality service within trains as a new issue. Consequently, it is necessary to provide a good quality connection for the passenger that satisfies the wireless network configuration for high-speed scenarios. To address this need, moving relay nodes (MRN) were introduced in Release 12 (TS 38.836) of the LTE standard to support data services in fast moving environments.

Furthermore, MRN is a feature enhancement and one of the typical solutions involving an indoor, mobile, small base station capable of supporting communication to users traveling on public transportation, providing a wireless backhaul connection via the base station by an outer antenna. This solution can bypass the following difficulties: vehicular penetration loss, increased power consumption of user equipment, more handover frequency, and signaling overhead.

Although the MRN solution improves indoor coverage and performance, it also creates a single point of failure because, if MRN fails to handover, the connections of mobile users will be dropped. MRN architecture is designed such that passengers' devices do not execute the handover procedure; instead, only the MRN takes handover to the target cell via the outer antenna located on the front of the train. However, MRN mobility management used a conventional hard handover scheme without any changes in the handover preparation step. The problems associated with current mobility management schemes in fast-moving trains are increased Radio Link Failures (RLFs), more frequent handovers, service interruption, and a reduced handover success rate. This is because from the viewpoint of a core network, MRN handover triggering and decision-making is the same as that of regular UE,i.e., it is static and configured manually in LTE standards.

Our first study commences with an investigation of a handover scheme, parameters, and call admission control for MRNs in LTE networks. Specifically, we proposed an adaptive handover hysteresis scheme based on a cost function to influence handover triggering and to increase handover performance. The function effectively adjusts handover hysteresis as the main parameter of the handover procedure between cells in a homogeneous network. The cost function is based on important factors, namely the current speed of the vehicle relative to the MRN, the load on the candidate cells, and the service types of the active users. Moreover, the proposed handover can increase the duration of the handover procedure, including the time required by the security policy and data re-routing, during fast movement of trains and buses in the overlapping area between neighboring cells. Second, the probability of handover call blocking is reduced by introducing a proposed call admission control scheme to support the radio resource reservation for handover calls that prioritizes MRN handover calls over UE handover calls and new calls. The proposed solution in which adaptive handover is combined with call admission control is evaluated by system level simulation. Our simulation results illustrate an increased handover success rate and reduced RLFs.

In our second study, we present the self-optimization of handover parameters that can auto-tune hysteresis and offset in order to reduce the number of RLFs and connection interruptions that occur during handover procedures. The two parameters are the current speed of the train based on automatic hysteresis and the handover performance indicator based on the individual offset of a macrocell. This scheme focuses on the handover performance and triggering that can define a starting point of the handover procedure at the correct time. Further, in order to reduce service interruption, we present a handover procedure with dual MRNs in which cooperative outer antennas are installed on the front of the train. Only one of these antennas, referred to as the main outer antenna, produces a measurement report for its handover decision by the serving cell. The other antennas begin a handover procedure that emulates the successful handover of the main antenna. In the simulation, the proposed self-optimization scheme was compared to that of a conventional handover scheme with manually configured parameters for high-speed environments. The simulation results show that the proposed scheme reduced handover delay, RLFs, and communication interruption.