Abstract of the Thesis

Algorithms for Handover Management in Dense LTE Networks under Vehicular Mobility

Soumadip Biswas
(Roll No. 14CS91R02)

LTE (Long-Term Evolution) and LTE-A (LTE-Advanced) standards have been the basis for providing 4G network services for more than a decade. In LTE/LTE-A networks, the end-user devices, known as User Equipment (UE), get connected to a cellular base station, known as evolved NodeB (eNB). At any point in time, a *user association* defines the binding of a UE with one eNB, called it's *serving eNB*, with which it communicates directly. An underlying handover mechanism changes the user association of a mobile UE if the signal from its serving eNB is no longer adequate. Proper choice of when to trigger a handover and the eNB to handover to is very important in a handover mechanism to ensure seamless communication and efficient resource utilization. To cater to increasing number of users and growing bandwidth demands of applications, dense deployments of eNBs are adopted in many network scenarios. The handover management problem becomes more challenging in such dense LTE networks as a UE may have more than one candidate target eNBs for handover; choosing the wrong target eNB can cause spurious handovers that unnecessarily waste resources. The problem is expected to be more evident when the mobility of the UEs is higher, such as in a vehicular mobility scenario. In this thesis, we address these issues and investigate algorithms for handover management in dense LTE networks in vehicular mobility scenarios.

In the first work of the thesis, we present a detailed performance evaluation of four existing handover algorithms in a vehicular environment. Two of these algorithms are based only on signal strength measurement and the associated events. In contrast, the third algorithm considers speed of the UEs and the nature of the data transfer, while the fourth algorithm also considers the direction of movement and load along with the received signal strength. It is shown that the existing algorithms fail to properly balance between spurious handovers and signal strength drops. This analysis paves the path for designing the handover algorithms presented next in this thesis.

In the second work of the thesis, we address the problem of minimizing the number of handovers of a single mobile UE placed in a vehicle. We propose two graph-based algorithms that use a novel idea of using look-ahead signal strength in reducing the number of handovers while maintaining good overall signal quality. The first algorithm, called *UE Association based on Complete Signal Strength Look-ahead* (USSL-C), assumes that exact signal strengths that the UE will receive at future timeslots are known. However, this algorithm is not implementable in practice. The second algorithm, *UE Association based on Approximate Signal Strength Look-ahead* (USSL-A), is based on the same basic idea as in USSL-C; however, it uses estimated signal strengths for future timeslots over the travel path instead of the exact signal strengths. We present detailed

performance evaluation of the algorithms in three different city scenarios, one each in Paris, Amsterdam, and New York to show that they can significantly reduce the number of handovers compared to four other existing algorithms, while still maintaining good signal quality.

In a dense LTE deployment scenario, a UE may get similar signal strengths from multiple eNBs in its vicinity at any point in time and a handover algorithm purely based on signal strength look-ahead may result in an unbalanced distribution of UEs to eNBs, causing degradation in the system's spectral and energy efficiency. In the third work of the thesis, we propose a framework, and a specific load balancing algorithm based on this framework, that can be invoked periodically on top of any existing handover algorithm for balancing the load across the available eNBs. The proposed load balancing algorithm is evaluated by invoking it periodically on top of USSL-A (proposed in the first work of the thesis) and four other existing algorithms, using the same simulation setup used earlier. It is seen that the algorithm can reduce the load imbalance among eNBs significantly while maintaining good signal quality. However, the number of handovers are increased, though the increase is not large.

In the fourth and final work of the thesis, we investigate a different approach for load balancing by considering the load directly while making handover decisions. We first formulate the problem of jointly minimizing the average number of handovers per UE and maximizing the number of eNBs that are not highly loaded while maintaining good signal quality. We then propose a greedy framework, referred to as *LB-USSL*, that modifies USSL-A to also consider load while deciding the target eNB for handover. We then propose and evaluate a set of algorithms based on this framework using the same simulation setup as before. The proposed algorithms are compared with two other existing algorithms. The results indicate that some of the algorithms are significantly improve system load performance at a comparable number of handovers compared to one of the existing algorithms. The other existing algorithm has a better load performance, but incurs a significantly higher number of handovers. The proposed algorithms also outperform the handover-independent load balancing algorithms discussed in the third contribution of the thesis. This indicates that integrated load-aware handover algorithms can give better load performance than performing load balancing and handover separately and independently.