Improved Handover Through Dual Connectivity in 5G mmWave Mobile Networks

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ABSTRACT

The next generation of mobile networks will likely use the communication at mmWave frequencies to reach a very high throughput with ultra low latency. However, the mmWave links are sensitive to blockage, thus the communication with the serving base station can be disrupted by any obstacle. Therefore, there is a need for a timely tracking of the channel quality and fast adaptation of the serving beam or base station. In this work we describe a solution based on dual connectivity to a mmWave network and a legacy one (e.g., LTE), and show how ns–3 can be used for an end-to-end performance evaluation of the proposed architecture.

1 INTRODUCTION

The new frontier of wireless communications is at mmWave frequencies, because they could be an enabler of the multi-gigabit-per-second throughput and ultra-low latency targets of 5G [1]. However, the communication at such high frequencies also introduces several issues that must be faced before mmWave cellular networks can be deployed. The first is the performance in high-density mobility scenarios. The link between the user equipment (UE) and a mmWave base station (BS) is extremely sensitive to blockage by obstacles and even by the human body. Thus, as the user moves, it may lose connectivity with respect to the serving mmWave BS, or it may even be in outage with respect to all of them. Therefore a solution to quickly restore connectivity is needed. Moreover, the coverage area of each mmWave cell is smaller than that of a sub-6 GHz cell, thus the number of handover events is expected to be higher in mmWave networks. In [2] we propose to use a dual connectivity (DC) solution to perform both the tracking of the UE, a quick fallback to a legacy Radio Access Technology (RAT) in case of outage and a fast handover between the mmWave base stations. We also implement the proposed solution in ns–3 and perform the first performance evaluation campaign of handover at mmWave frequencies.

2 PROPOSED ARCHITECTURE

In traditional cellular networks, the mobile terminal is connected to a single RAT at any given time, i.e., it is connected, for example, to a 4G LTE base station, or to a 3G one. With this single connectivity approach, the outage condition with respect to the serving base station would either trigger a Radio Link Failure (RLF), or an inter-RAT hard handover to another network. If this architecture is applied also to the mmWave Radio Access Network, then there would be extended service unavailability (i.e., throughput equal to zero) and consequently high latencies. Moreover, in traditional intra-RAT handover (e.g., from an LTE base station to another LTE base station) the UE has to interact with nodes such as the Mobility

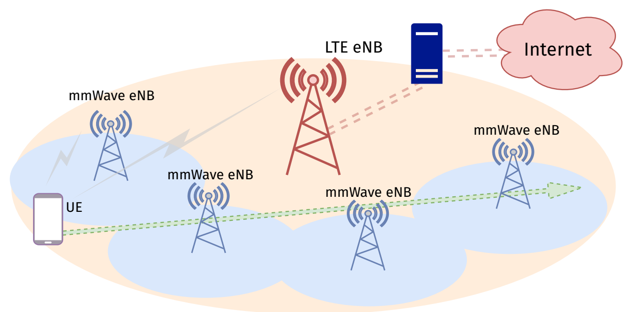


Figure 1: DC architecture in a mobility scenario.

Management Entity (MME) of the core network (CN) to complete the handover procedure. These nodes are generally located in a centralized datacenter and the additional delay involved in the communication with them increases the overall duration of the handover procedure.

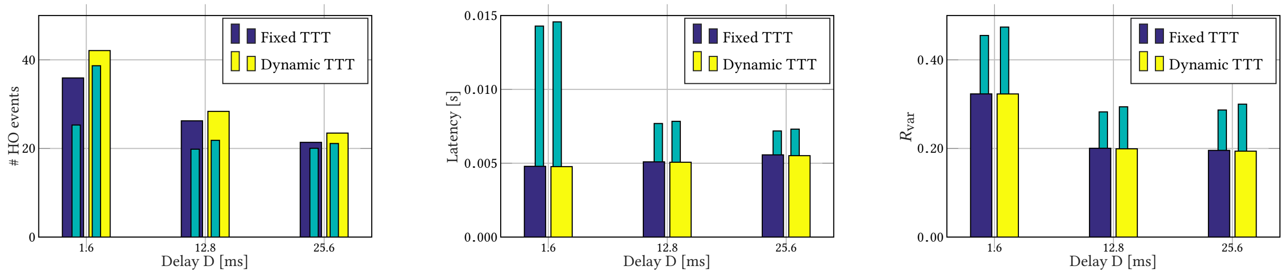
With the dual connectivity solution we propose in [2], the UE is connected to both the legacy LTE network and the mmWave network at the same time. An example of deployment using this architecture is shown in Figure 1. In this scheme, a local coordinator (which may be located in the LTE base station) acts as a mobility anchor for the mobile terminals, which do not have to interact with the MME for mobility involving cells under the control of the coordinator. The user plane is split at the PDCP layer, which is located in the coordinator, and packets are sent to the user via either the LTE (primary cell) or the mmWave (secondary cell) BS.

This approach presents several benefits:

- it allows to collect channel measurements from the mmWave BSs and track the optimal BS-UE pair with the procedure described in [3]. The mobile equipments periodically transmit uplink pilots scanning all the possible transmission directions, and the mmWave BSs use these pilots to estimate the SINR in the different directions of arrival. Then, the optimal direction and SINR for each user is reported to the coordinator, that is able to decide which is the optimal BS for each UE.
- the DC architecture allows to change the base station which is serving the UE with procedures which are faster than the traditional hard handover of the single connectivity architecture: (i) *fast switching* between LTE and mmWave and (ii) *secondary cell handover* (SCH) between mmWave BSs (without interactions with the CN).

3 NS–3-BASED PERFORMANCE EVALUATION

In order to analyze the performance of the proposed DC architecture we extended the implementation of the ns–3 mmWave module described in [5] in order model the features needed for mobility



(a) Number of handover/switch events **(b) Latency** **(c) Throughput standard deviation/mean**

Figure 2: Performance of the proposed architecture in randomly generated scenarios. The narrow bars refer to a single connectivity architecture with hard handover, while the blue and yellow bars represent the performance of DC with two different SCH algorithms.

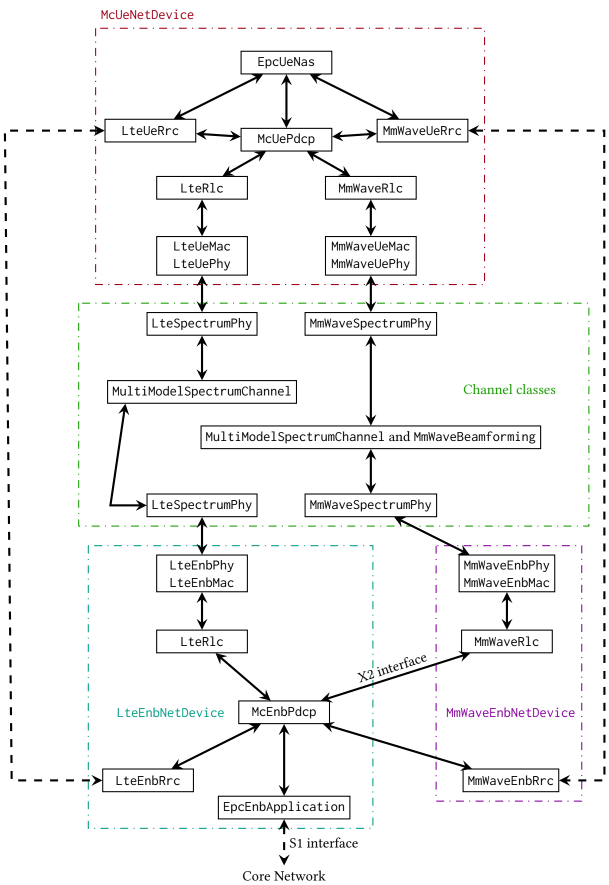


Figure 3: Block diagram of a dual-connected device, an LTE eNB and a MmWave eNB [4].

management, either with single or with dual connectivity. This extension is described in [4] and a comprehensive overview of the whole mmWave framework is given in [6]. The core of the implementation is shown in Figure 3, which describes the classes implementing the different layers of the UE (called `McUeNetDevice`) and of the mmWave and LTE BSs. For the channel model, we used the NYU statistical channel model [7], and added randomly generated obstacles in the simulation scenario to model buildings and other obstacles. We also modeled the transition from Line of Sight to Non Line of Sight conditions using experimental traces of a blockage event, in order to capture the real dynamics of the system.

The results shown in Fig. 2 compare the performance of DC with a the single connectivity baseline. The DC architecture is able to better adapt to the dynamic mmWave channel conditions, thanks to a larger number of faster handover and switch events. At the same time, DC shows a lower latency and smaller throughput variations, thus allowing to increase the robustness of the network with respect to outage events and the quality of experience of the mobile user.

4 CONCLUSIONS

In this work, we described the benefits of a dual connectivity solution for the mobility management of mmWave networks. Moreover, we described how ns–3 can be extended in order to assess the performance of the proposed architecture with respect to a single connectivity baseline.

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