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Reliability Oriented Dual Connectivity for URLLC services in 5G New Radio

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***Abstract*—Novel solutions are required to meet the stringent reliability and latency requirements targeted for the Ultra Reliable Low Latency Communication service class, which emerged with the introduction of 5G new radio. This paper analyses *reliability-oriented multi-Connectivity* - where the same data packet is independently transmitted through multiple links - as such a solution. Multi-connectivity is first presented at a conceptual level. We then propose a novel admission mechanism to control the number of users operating in multi-connectivity mode. Finally, the reliability and latency enhancement with multi-connectivity in heterogeneous network scenario with multi-service traffic is evaluated via system level simulation. Up to 23% latency reduction and 57% reliability improvements over the single connectivity solution are observed. However such gains are sensitive to the configuration criteria, and the average gains are more modest.**

***Index Terms*—Dual Connectivity, multi-Connectivity, 5G, new radio, PDCP duplication, URLLC.**

I. Introduction

THE 5G new radio is marked by the introduction of multi-service support catering to key vertical sectors. Alongside enhanced Mobile Broadband (eMBB) services, 5G introduces new service classes such as Ultra Reliable Low Latency Communication (URLLC) and massive Machine Type Communication (mMTC) [1].

The recently released 5G new radio (NR) standard - also known as 3GPP Release-15 - particularly focuses on eMBB and URLLC services. The most challenging URLLC service target is 99.999% reliability at millisecond level latency. Examples of novel solution proposals to meet such challenging design requirements include flexible frame structure design with shorter (and variable) transmission time intervals (TTI) [2], [3], preemptive scheduling for critical low latency data [4] and diversity as a reliability improvement feature [5].

Focusing on diversity as a solution for URLLC services, it has been demonstrated in [5], [6] that macro diversity along with micro-level diversity through multiple antennas is required to guarantee high reliability. Hence, macro-level diversity through multi-channel access (MCA), such as multi-connectivity (MC), is foreseen as a potential solution for URLLC applications [7], [8].

In this paper, we specifically focus on MC as a solution for URLLC services. MC is an extension of the dual connectivity (DC) feature introduced in Long Term Evolution (LTE), which allows a UE to simultaneously send/receive data from/to two different base stations [9]. The initial goal in LTE was throughput enhancement via data split. In 5G NR, MC has additionally been extended as a reliability enhancement solution using data duplication [7], with the aim of reducing the packet failure probability by transmitting the same data packet to the target UE from multiple base stations independently.

Reliability-oriented MC via data duplication is a novel feature, and therefore not well investigated yet in the literature. This paper details the potentials and challenges of reliability-oriented MC. Moreover, we propose a novel solution attempting to answer the question - 'when and how to configure MC?'. The presented MC evaluation considers a heterogeneous network (HetNet) scenario, which is also a specific contribution of this paper compared to the mentioned literature (e.g., [5], [6]) where URLLC provisioning is investigated via diversity in macro only scenarios.

The 'first drop' of 5G NR Release-15 standard still restricts the number of cells in MC to two (i.e., DC). Therefore, all MC concepts discussed in this paper are presented for the special case of DC. However, the proposed solutions are readily applicable to the general MC scenario.

The rest of the paper is organized as follows. A discussion on the status of MC in light of 5G NR standardization activities is presented in Section II. We then delve deeper into MC by demonstrating reliability improvement through MC, along with the associated cost in terms of reduced network spectral efficiency in Section III. Section IV addresses in details the design challenges in configuring MC. Finally, system level simulation results validating the role of MC in reliability enhancement are presented and discussed in Section V. Concluding remarks and future outlook are drawn in Section VI.

II. Dual-Connectivity Overview

5G NR inherits the DC design from LTE, which allows a UE configured with split bearer to send/receive data from/to two distinct evolved nodeBs (eNB) simultaneously. The data is split at the packet data convergence protocol (PDCP) layer, transmitted via the two radio paths and aggregated at the receiver PDCP layer, resulting in an end user throughput boosting [10]. In addition to data split, 5G NR DC extends LTE DC towards reliability enhancement by allowing data duplication in which the same data packet is independently transmitted through two different base stations.

NR-NR Dual-Connectivity: To enable a faster introduction of 5G NR, Release-15 supports Multi-radio access technology (RAT) Dual Connectivity (MR-DC), i.e., DC between NR and LTE [7]. However, the general single RAT 5G NR DC between two next generation node Bs (gNB), known as NR-NR DC, is assumed in this paper. In particular, we consider the inter-frequency case in a HetNet scenario between a 5G NR macro layer and a 5G NR small cell layer operating at two different frequencies.

A. Dual-Connectivity Setup

In DC, the UE is connected to a master node (MN) and a secondary node (SN), which are interconnected via an Xn interface. For the control plane, the MN establishes the control interface to the core network, whereas both the MN and SN have Radio Resource Control (RRC) connections to the UE. The MN's RRC connection preexists the DC setup and is used for the MN to instruct the UE to perform channel measurements and for the UE to report the detected cell(s) back to the MN thus facilitating SN selection and DC configuration.

DC connectivity setup can only be initiated by the MN. Based on UE's channel measurements, the MN requests the SN to allocate resources to the UE, along with providing all information necessary to establish the connection. If the SN is able to admit the request, it allocates respective resources, and acknowledges the request back to the MN. After the setup of DC is complete, the SN RRC further enhance the control link reliability by allowing signaling to be conveyed to the UE through MN and/or SN.

Contrary to the control plane, both MN and SN can potentially establish the user-plane interface to the core network. However, the data for a user is transferred from the core network to either MN or SN, but not both. This concept is referred to as a 'bearer split'.

B. Reliability-Oriented Dual Connectivity

Reliability-oriented DC utilizes the two connections to improve reliability and consequently reduce the packet latency. Once reliability-oriented DC is set up, the MN duplicates the incoming data destined for the user and forwards the duplicates to the SN via the Xn-U interface for transmission to the UE. Independent scheduling of the duplicated packets through the two links implies that the acknowledgement of the physical transmissions (via ACK/NACK signaling) and HARQ mechanisms are independent.

At the receiver side, the UE will perform PDCP packet re-ordering and forward the first successfully received PDCP packet to the higher layers, while discarding any later copies which may be received. 5G NR DC operation with data duplication in the downlink direction is schematically presented in Figure 1.

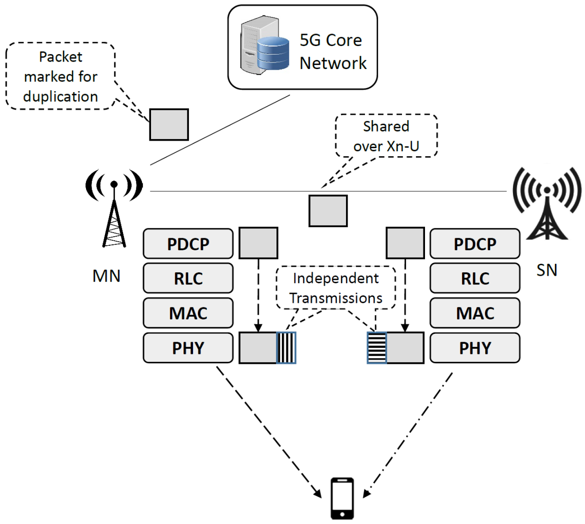


Fig. 1: Schematic of reliability-oriented DC in the downlink direction.

III. Multi-Connectivity as a Reliability Enhancement Concept

Dense HetNet deployment is identified as a promising solution towards meeting the targeted higher data rates in 5G NR [11]. As cells get denser and more heterogeneous, multiple strong links become available to many of the UEs. Such availability of multiple strong links can be harnessed for URLLC applications through MC.

Reliability-oriented DC introduces an additional diversity order. Ideally, the resulting reliability of duplicating a packet through two independent nodes with respective outage probabilities P_1^{out} and P_2^{out} is $r_{DC} = (1 - P_1^{out} P_2^{out})$. As a simple numerical example, 99.99% reliability can be obtained for $P_1^{out} = P_2^{out} = 0.01$ (corresponding to 99% reliability with single connectivity (SC) - when served by a single base station).

In order to demonstrate the advantages of reliability-oriented MC and its associated costs, we numerically evaluate reliability-oriented MC in a simple setting in this section. To this end, we consider a simple HetNet scenario as shown in Figure 2. A single macro cell operating at the 2 GHz band and a single small cell at the 3.5 GHz band, separated by a distance of 300 meters, are considered. A target UE of interest is co-linearly placed along the macro and the small cell, with its distance from the macro cell (d) being a variable. The macro and small cell transmit powers are 46 dBm and 30 dBm respectively.

The baseline SC case considers two different UEs. The designated UE of interest is served by the cell with the strongest average signal strength, while the other UE (with eMBB traffic) is randomly located within the service area of the cell that doesn't serve the target UE. We assume an URLLC user operating at a target signal to interference plus noise ratio (SINR) as the UE of interest, whereas the random UE is considered to be a best effort eMBB user. Note that, the eMBB UE is not served in the DC scenario, since both gNBs serve the designated UE of interest. The URLLC transmission is considered successful if the target SINR is fulfilled through any one of the connections in this case.

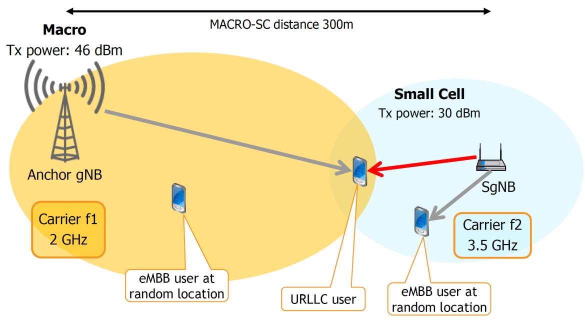


Fig. 2: The simple HetNet scenario with a single macro and small cell serving a target URLLC user considered for evaluating the gains and costs of MC.

Two different performance metrics are considered, namely the outage probability for the target URLLC user, and the network spectral efficiency, i.e., the normalized Shannon throughput summed across the active users (which is one for DC, and two for SC). The latter is the sum of the spectral efficiencies of the target UE and the random UE (when available). The performance curves, considering a 2 dB target SINR for the target UE, are presented in Figure 3.

We observe a reduction of the outage probability with DC compared to SC. In particular, the highest gain of *around two orders of magnitude* is seen when the UE experiences similar signal strengths from both the MN and the SN. However, this reliability enhancement comes at the cost of reduced network spectral efficiency. Since DC mode utilizes the resources of both the nodes in serving the target UE operating at a fixed target SINR, the overall network spectral efficiency is significantly reduced with DC. Note however that, a highly idealized scenario is considered in this exercise, which overlooks other practical challenges of operating DC, such as the selection of an appropriate SN, expected queuing delay at high network load etc.

IV. Optimizing Multi-Connectivity Configuration

In Section III, we stated that MC operation needs to balance the trade-off between performance gain and

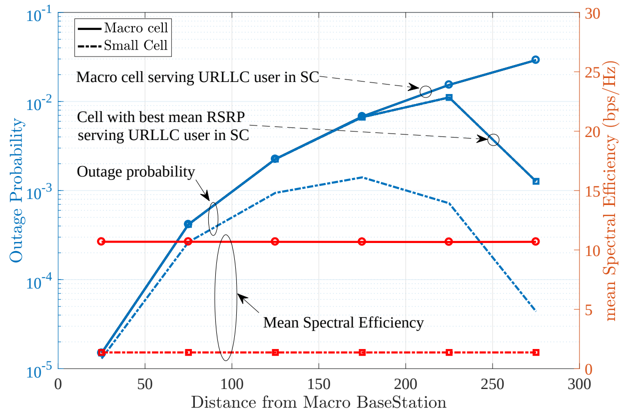


Fig. 3: The outage Probability of target URLLC UE and sum network spectral efficiency for DC and SC case.

increased resource usage. This section explores this trade-off in the context of when to operate a particular UE in DC mode. We first detail the challenge and then propose a promising solution, which is then numerically evaluated in the following section.

A. When to Operate DC for Reliability Enhancement?

DC data duplication increases the resource utilization in the network since resources from multiple nodes are used to serve the same UE. Hence, it should only be configured for the UEs that actually need it. Ideally, those are the URLLC users with a tight latency budget that cannot be met by SC. It is also observed that the best outage probability reduction is observed when the received signals from the MN and the SN are at similar level of strength.

Two factors primarily impact DC configuration, namely the user's channel quality, and the network load. Under light network load conditions a user with relatively poor channel quality can be allocated more resources (e.g., resource blocks) and transmitted with a low modulation and coding scheme (MCS). This allows meeting the high reliability and low latency requirements easily with SC.

As the URLLC traffic load in a cell increases, it has less available resources per user, and therefore the service requirements cannot be fulfilled easily. Under such conditions, a user is set to benefit from the ability to utilize the diversity of DC. On the contrary, at peak network loads, the increased resource usage by DC and the resulting queuing delay outweighs its benefit since the network becomes very resource-limited.

The goal of specifying the selection criteria for operating in DC mode is to optimize the number of UEs that should be configured with the DC mode, and get the best performance gains while minimizing the impact of the increased resource utilization.

B. Proposal to Tightly control DC Mode Selection

Conventionally, a UE's association to a cell is done based on the reference signal received power (RSRP). The

RSRP from the macro cell is usually greater than that from the small cell over a large part of the coverage area, mainly due to the higher macro transmit power. On the other hand, since a macro cell serves a larger area, it is most often the resource-constrained cell. Hence, cell selection based on the RSRP alone results in an imbalance between the macro and the small cell resource usage. Cell range extension (CRE) offset can be applied to improve the load-balance between the macro cell and the small cells [12]. CRE is an offset applied to the small cell RSRP to favor connection to the small cell.

We have identified that DC should only be applied to cell-edge users connected to the small cell layer. The motivation is two-fold: firstly, cell-edge users usually suffer from a poor channel quality due to their distance from the serving base station; and secondly, small cell-edge users usually have a stronger or similar strength signal from the macro cell due to the CRE offset, and hence are best suited to benefit from DC.

To achieve such an objective, we introduce a new parameter called DC_{range}, which controls the size of the logical DC area, as shown in Figure 4. The implementation is done based on the NR A3 event, which is triggered when a neighbouring cell becomes better than the serving cell by an offset [13]. UEs logically located in DC area (based on their RSRP) will operate in DC mode. Thus, for all UEs with small cell as their primary cell, the DC configuration condition is given as:

$$RSRP_s < RSRP_m - CRE + DC_{range},$$

where $RSRP_m$ and $RSRP_s$ are the RSRPs from the macro cell and small cell, respectively.

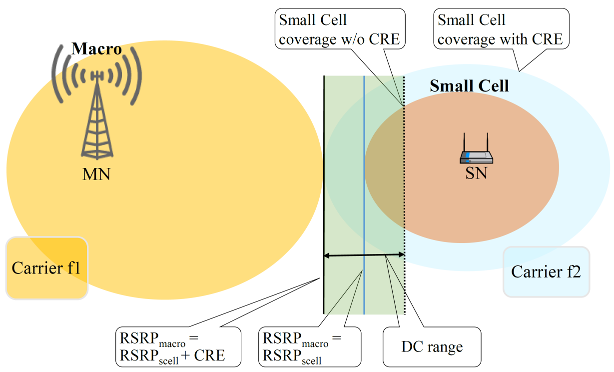


Fig. 4: DC configuration area in HetNet scenario.

V. Performance Evaluation and Discussion

A. Simulation Methodology

System level simulation results analysing the performance of the proposed DC configuration criteria are presented and discussed in this section. The presented simulation results are generated using a system level simulator emulating a high degree of realism. The 5G NR frame structure proposed in [14] with a short transmission time interval of 0.143 ms, corresponding to 2 OFDM symbols, is assumed.

Radio resource management functionalities such as packet scheduling (proportional fair in this case), packet duplication and re-ordering at the PDCP level, radio link control unacknowledged mode, Hybrid automatic repeat request (HARQ) and link adaptation at MAC layer are implemented in the simulator. HARQ round trip time is set to 4 TTIs, thus accommodating a maximum of one retransmission within the 1 ms latency budget for URLLC. The resource blocks are scheduled at each TTI. Link adaptation to select the MCS corresponding to the desired block error rate (BLER) target is done based on the user reported channel quality indicator, which is then further adjusted through Outer Loop Link Adaptation mechanisms [15].

We assume a fixed 50 bytes payload URLLC traffic with a Poisson distributed arrival having different arrival rates. In addition, a mixed traffic scenario with background full-buffer eMBB traffic is also considered in some use cases. Only downlink traffic is considered. For the case of DC users, packets arriving at the MN are duplicated at the PDCP layer of the SN via an ideal Xn interface which does not incur any delay. The 3GPP 2A deployment scenario [16] consists of 7 macro sites having 3 sectors each, with four small cells in a cluster within each macro sector area. On average 30 UEs are randomly deployed within each macro-cell area. We assume 2×2 Multiple Input Multiple Output (MIMO) configuration with single stream transmission, and interference rejection combining (IRC) receiver at the UE [17]. The simulation parameters are summarized in Table I.

TABLE I: Summary of Simulation Parameters.

Parameter	Macro Layer	SC Layer
Layout	7 sites ×3 sectors	4 SC/macro
Inter-BS dist.	500 m	cluster
Tx Power	46 dBm	30 dBm
Pathloss model	3D-Uma	3D-UMi
Antenna Ht.	32 m	10 m
UE Ant. Ht.	1.5 m	
Carrier Freq.	2 GHz	3.5 GHz
Bandwidth	10 MHz	
URLLC packets	5 million	

B. Results and Discussions

1) URLLC Only Traffic Use Case: We first consider a URLLC-only low traffic, low-interference scenario targeting 10^{-5} reliability at 1 ms latency. A moderate load of 2 Mbps, along with 1% and 10% BLER target, and 10 and 15 dB DC range values, is considered. This scenario represents use cases where URLLC users usually have enough resources at their disposal to meet the challenging design target through SC itself.

The performance is evaluated in terms of the complimentary cumulative distribution function (CCDF) of the latency, as presented in Figure 5. The CCDF shows a staircase like shape, emanating from the processing time and HARQ retransmissions. The first slope ending at around 0.3 ms (= 2 TTIs) corresponds to the successful transmission at first attempt. The following plateau of about 0.4 ms is the aggregate time spent for receiver processing, NACK feedback and HARQ retransmission. Note that, all use cases except DC with 10% BLER target and 15 dB DC range result in zero outage probability (which does not show on log-scale) after the first retransmission, as indicated by the ending of the curves in Figure 5 at ~ 0.7 ms latency.

We observe that the achieved BLER after the first transmission is far lower than the BLER target. For example, at 15 dB DC_{range} and 10% BLER target, the achieved BLER is $\sim 10^{-3}$. Such large gap between the target and the achieved BLER is a result of the considered scenario. The sporadic URLLC traffic leads to a high variance in the perceived interference, which makes the link adaptation module select a conservative MCS. This, coupled with the abundantly available resources, leads to transmission with over-provisioned resources; which in turn results in the very low achieved BLER target. Furthermore, most of the curves are discontinued after the first retransmission, i.e., there are no outage outage at all following the first retransmission and subsequent HARQ combining.

Comparing SC with DC, we observe that SC outperforms DC for both DC range values. Under the relatively low load condition, the users are neither resource constrained (i.e., they can be scheduled immediately), nor do they experience much interference. Hence, SC is sufficient to meet the URLLC requirements. The increased load with DC (due to DC users being scheduled duplicate copies from the SC and the macro cell) results in the slight performance deterioration with DC. Consequently, DC with a higher DC range (more DC users) leads to the worst performance. A BLER target of 1% expectedly results in lower latencies compared to that of 10%, and as such we fix the BLER target at 1% for the remaining investigations. We thus deduce that DC is only beneficial in scenarios where the URLLC requirements can not be met with SC. This corroborates the conceptual findings presented in Section III.

2) Mixed URLLC and eMBB Traffic Use Case: In order to stabilise the interference condition, full buffer background eMBB traffic is considered along with URLLC traffic in this use case. The URLLC traffic has a higher priority and are always scheduled before any eMBB traffic. Close to 100% of the available RBs are utilized in this case , implying that the URLLC requirements cannot be fulfilled at all instances. URLLC loads of 500 Kbps, 2 Mbps and 6 Mbps, along with DC range of $5, 10$ and 15 dB are considered.

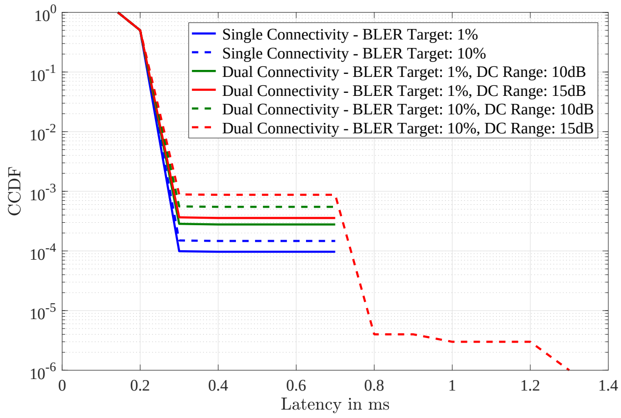


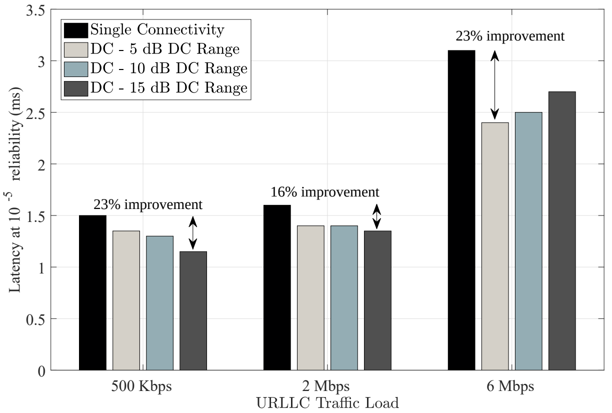
Fig. 5: CCDF of the latency with URLLC only traffic for 1% and 10% BLER target, and DC range $\in \{10, 15\}$ dB.

Figure 6a compares the latency at $1-10^{-5}$ reliability target for different DC range values, and different loads. It is observed that the introduction of background eMBB traffic makes it impossible to meet the stringent 1 ms latency requirement at $1-10^{-5}$ reliability target. However, contrary to the observation with URLLC only traffic, small cell URLLC users benefit from DC operation in this scenario.

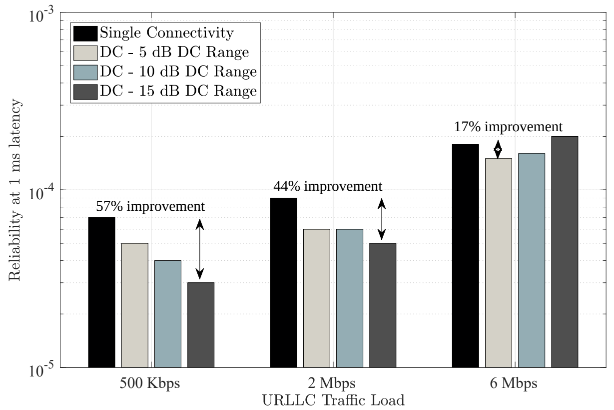
The latency at $1-10^{-5}$ reliability target is found to improve with the DC range value for low (500 kbps) to medium (2 Mbps) URLLC load. At these loads, having more users in DC mode leads to a better latency performance. In particular, the latency is reduced by up to 23% and 16% respectively. On the other hand, the best latency reduction of 23% at high URLLC load (6 Mbps) is observed for a DC range of 5 dB. Due to the high URLLC load, the cost of operating in DC mode, i.e., increased resource usage, outweighs its benefits. Thus having more users in DC mode (i.e., a higher DC_{range} value) reduces the gains observed with DC.

The reliability at 1 ms latency for different URLLC loads and different DC range values are presented in Figure 6b. A similar trend as that observed when comparing the latency is seen. However, the improvement factors are much higher compared to the improvements observed for the latency at $1-10^{-5}$ reliability target.

In general, we observe performance benefits in terms of the latency and reliability with DC, even though the targeted URLLC requirements cannot be met under the investigated scenario. It is worth mentioning that 3GPP has also identified URLLC use cases where the latency target is more than 1 ms [18], for which DC can be a promising solution. In particular, the latency reduction is very promising at high load, high interference scenarios. To reap the best gains from DC, the number of DC users, as characterized by the proposed DC_{range} parameter, has to be optimized.



(a) The latency at 10^{-5} reliability for SC and DC with different DC range values at different URLLC loads.



(b) The reliability at 1 ms latency for SC and DC with different DC range values at different URLLC loads.

Fig. 6: Performance evaluation of dual connectivity in a multi-service scenario at different URLLC loads.

VI. Conclusions and Outlook

The application of dual connectivity as a reliability enhancement solution for URLLC services is investigated in this paper. We have first presented the conceptual framework of DC in light of its potential gains and corresponding costs. In order to balance the trade-off between the cost and the benefits of DC and have only the most vulnerable users operate in DC mode, we then proposed a mechanism to control the UEs in DC mode which relies on the introduced novel DC_{range} parameter.

In URLLC traffic only scenarios, where SC is sufficient to meet the URLLC target, DC does not provide a latency gain at 10^{-5} reliability. However, under mixed service scenarios where the background eMBB traffic makes it difficult to achieve high-reliability and low-latency, there is a performance improvement with DC. By optimizing the DC range - i.e., the number of users in DC mode - for different load conditions, DC can improve the latency at 10^{-5} reliability target by up to 23%. Similarly, the reliability at 1 ms latency is improved by up to 57%, though such gains are sensitive to the configuration criteria. The average gains are more modest, whereas higher gains can be expected if DC range is optimized.

In the light of the findings, DC is considered a promising reliability enhancing solution, especially in scenarios where the latency requirements is not tight at 1 ms. As future work, we will investigate optimizing DC operation to ensure that it can achieve the URLLC target. As an example, intra-layer interference management techniques can be applied to improve its performance in high-load scenarios.

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References

[1] 3GPP TS 38.300, "NR; Overall description; Stage-2," Jun. 2018, v:15.2.0.

[2] K. Pedersen *et al.*, "A flexible 5G frame structure design for frequency-division duplex cases," *IEEE Comm. Mag.*, vol. 54, no. 3, pp. 53–59, Mar. 2016.

[3] N. H. Mahmood *et al.*, "A novel centimeter-wave concept for 5G small cells," in *Opportunities in 5G Networks*, F. Hu, Ed. CRC Press, Apr. 2016, pp. 391–424.

[4] K. Pedersen, G. Gerardino, J. Steiner, and S. Khosravirad, "Punctured scheduling for critical low latency data on a shared channel with mobile broadband," in *IEEE VTC-Fall*, Sep. 2017.

[5] F. Kirsten, D. Ohmann, M. Simsek, and G. P. Fettweis, "On the utility of macro- and microdiversity for achieving high availability in wireless networks," in *Proc. IEEE PIMRC*, Sep. 2015.

[6] G. Pocovi *et al.*, "Signal quality outage analysis for ultra-reliable communications in cellular networks," in *Proc. IEEE Globecom Workshops*, USA, Dec. 2015.

[7] 3GPP TS 37.340, "E-UTRA and NR; Multi-connectivity; Stage-2," Dec. 2017, v:15.0.0.

[8] N. H. Mahmood *et al.*, "Multi-channel access solutions for 5G new radio," *IEEE Wireless Comm. Mag.*, 2018, submitted.

[9] 3GPP TS 36.300, "E-UTRA and E-UTRAN; Overall description; Stage 2," Mar. 2018, v:13.11.0.

[10] C. Rosa *et al.*, "Dual connectivity for lte small cell evolution: functionality and performance aspects," *IEEE Comm. Mag.*, vol. 54, no. 6, pp. 137–143, Jun. 2016.

[11] J. G. Andrews *et al.*, "What will 5G be?" *IEEE JSAC*, vol. 32, no. 6, pp. 1065–1082, Jun. 2014.

[12] F. Muhammad, Z. H. Abbas, and F. Y. Li, "Cell association with load balancing in nonuniform heterogeneous cellular networks: Coverage probability and rate analysis," *IEEE Transactions on Vehicular Technology*, vol. 66, no. 6, pp. 5241–5255, Jun. 2017.

[13] 3GPP TS 36.331, "E-UTRA; Radio Resource Control; Potocol specification," Mar. 2018, v:13.9.1.

[14] K. Pedersen, G. Pocovi, J. Steiner, and A. Maeder, "Agile 5G scheduler for improved E2E performance and flexibility for different network implementations," *IEEE Comm. Mag.*, vol. 56, no. 3, pp. 210–217, Mar. 2018.

[15] M. G. Sarret *et al.*, "Dynamic outer loop link adaptation for the 5G centimeter-wave concept," in *Proc. of European Wireless*, May 2015.

[16] 3GPP TR 36.872, "Small cell enhancements for E-UTRA and E-UTRAN - physical layer aspects," Dec. 2013, v:12.1.0.

[17] N. H. Mahmood *et al.*, "Radio resource management techniques for eMBB and mMTC services in 5G dense small cell scenarios," in *Proc. IEEE VTC-Fall*, Montreal, Canada, Sep. 2016, pp. 1–5.

[18] 3GPP TS 23.501, "System Architecture for the 5G System, Release-15," Jun. 2018, v:15.2.0.