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METHODS TO IMPROVE EFFICIENCY OF HIGHLY-RELIABLE / ULTRA-RELIABLE APPLICATIONS USING COORDINATED MULTI-POINT TECHNIQUES

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ABSTRACT

Existing Coordinated Multi-Point (CoMP) mechanisms do not take into account reliability aspects of ongoing URC (or URLLC) services effectively. Presented herein are techniques that involve enhancing or optimizing CoMP mechanisms for applications that involve Ultra-Reliable Communication (URC) or Ultra-Reliable Low-Latency Communication (URLLC) services. These optimizations can also help to support a higher Highly Reliable Communication (HRC), URC, URLLC, and other Quality of Service (QoS) -aware applications in a network. Further, optimizations are proposed to provide URC or URLLC services over a single Protocol Data Unit (PDU) session in order to save Radio Access Network (RAN) and/or core network resources by tearing down redundant PDU sessions or for user equipment (UE) devices that do not support Redundancy Handler or Dual Connectivity capabilities but still require URC or URLLC services.

DETAILED DESCRIPTION

URLLC is key tenet of Third Generation Partnership Project (3GPP) Fifth Generations (5G) / next Generation (nG) systems. To ensure high reliability, redundant transmissions in a 5G core network system (5GS) are to be supported for mobile network deployments. In most cases, due to poor cell-edge radio conditions where a network cannot meet the requirements of reliability, redundant transmissions are applied on the user plane path between a UE and the network.

There are multiple solutions studied and concluded for providing high reliability message delivery for use cases involving normal PDU connections. One solution in 3GPP for URLLC involves creating two independent disjointed PDU connections by the UE towards the same data network (DN). Using these two PDU connections, the UE will receive duplicate packets and, even if some packets are dropped due to network issues, the UE still receives one copy of the packets due to the redundant PDU connections.

3GPP standards-defined Fourth Generation (4G)/5G networks use various techniques, such as CoMP Coordinated Scheduling (CoMP-CS), CoMP Joint Processing (CoMP-JP), and CoMP Coordinated Beamforming (CoMP-CB), to manage interference and improve performance at cell-edges. These methods apply the same techniques for all UEs without differentiating based on the capability of the devices (e.g., smartphones, Automatically Guided Vehicles (AGVs), Adaptive Multi-Rate (AMR) devices, robots, etc.) or the kind of services such devices may utilize (e.g. HRC, URC, URLLC) for different PDU sessions.

Current CoMP techniques (which are applied to UEs at cell-edges) are not optimized for HRC / URC / URLLC services. These current techniques typically do not have any visibility regarding the HRC / URC (or URLLC) PDU sessions and this can lead to suboptimal decision making for these and other UEs.

In this proposal, enhanced CoMP techniques are provided for via three potential solutions for applications that involve HRC / URC / URLLC services. These solutions involve selection of selection of a suitable inter-Base Station (inter-BS) coordination mechanism for mobility scenarios for applications involving HRC / URC / URLLC services.

In general, wireless networks utilize inter-BS coordination mechanisms to improve performance of cell-edge UEs. Consider an example scenario as shown in Figure 1, below.

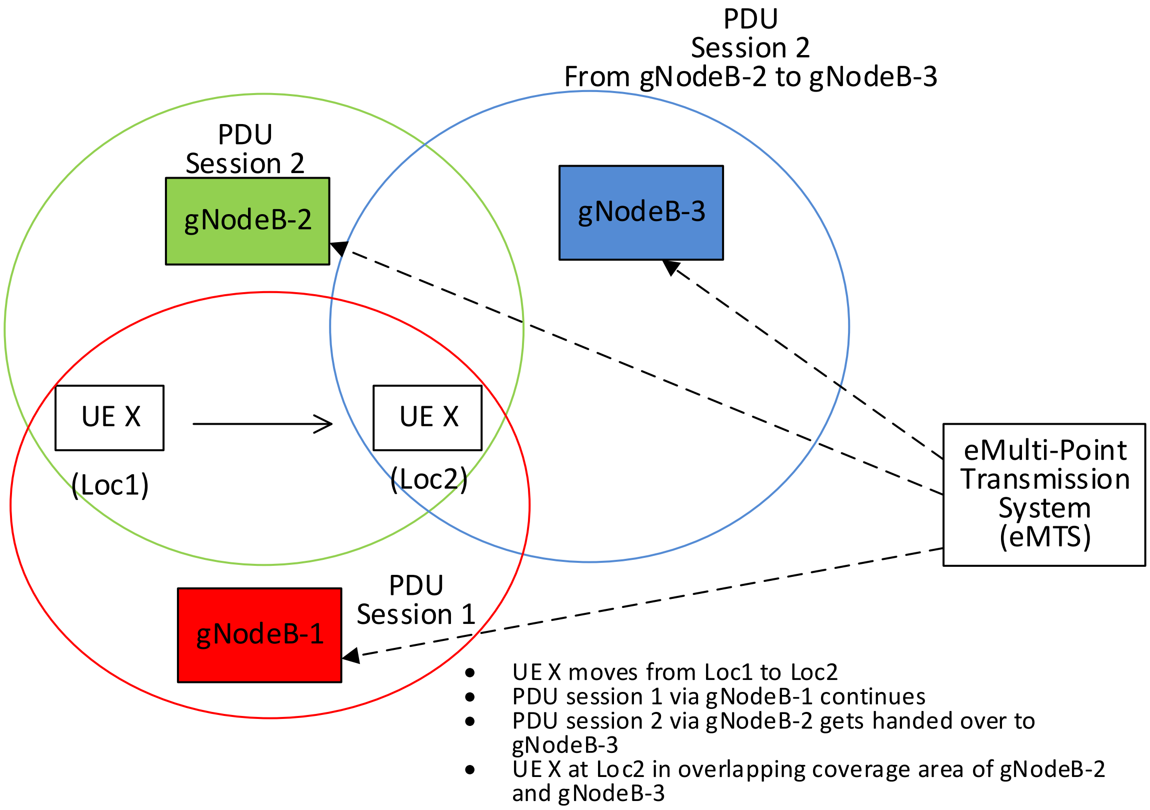

Figure 1: Example UE Handover Scenario

As shown in Figure 1, as a UE 'x' moves from a first location (Loc1) to a second location (Loc2), its PDU session 2 is handed over from a first next Generation Node B (gNodeB-2) to another gNodeB (gNodeB-3). At Loc2 (e.g., a cell-edge), the UE is in an overlapping coverage area for both gNodeB-2 and gNodeB-3 and a suitable inter-gNodeB coordination mechanism is utilized to be utilized to coordinate service for the UE.

Figure 2, below, illustrates an example monolithic RAN architecture in which an enhanced capability may be provided via an enhanced Multi-Point Transmission System (eMTS) in order to facilitate various solutions discussed herein. The eMTS may be provided internal or external to a 5G Core (5GC). Although Figure 2 illustrates a monolithic RAN architecture, solutions discussed herein may also be implemented for disaggregated virtualized RAN (vRAN) architectures, such as Open RAN (O-RAN) architectures.

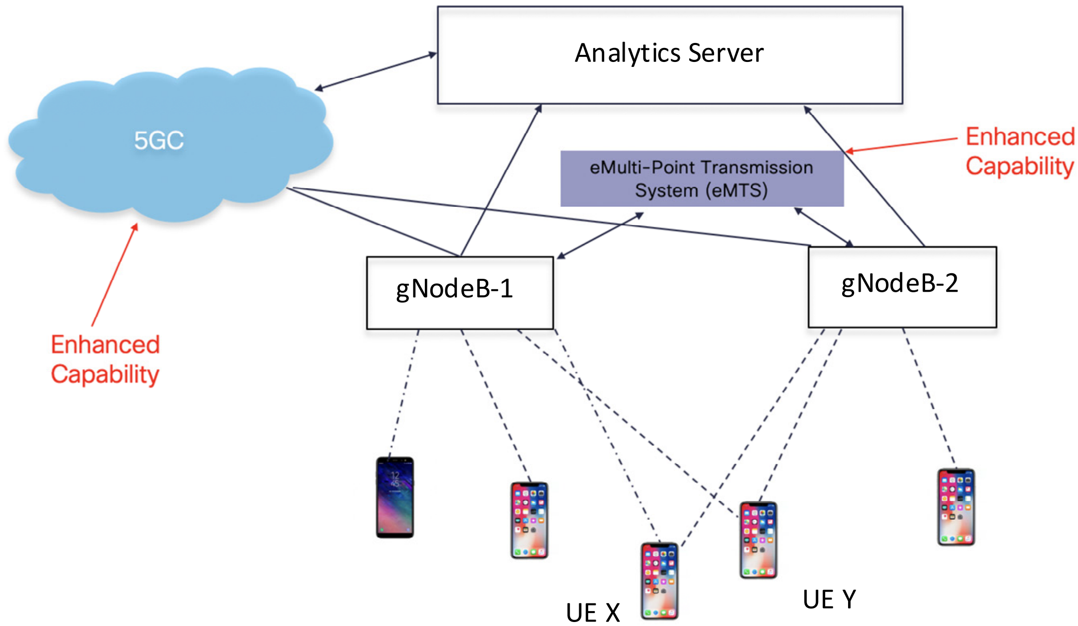

Figure 2: Example Implementation Architecture

Consider a first potential solution in which an inter-BS (or inter-gNodeB) coordination entity (such as a CoMP server) is made aware of the identity of UEs that are using two (or more) PDU sessions for applications that involve URC or URLLC services. For this solution, performance indicators (e.g., a count of acknowledgments of packets successfully received at UE/gNodeB in a rolling time window) can be sent to the CoMP server are used by the CoMP server to infer the performance of these PDU sessions. The CoMP server uses this information (along with its regular mechanisms) to select suitable inter-BS coordination technique for UEs. Example details for this first solution are illustrated below in Figure 3 and discussed in further detail below.

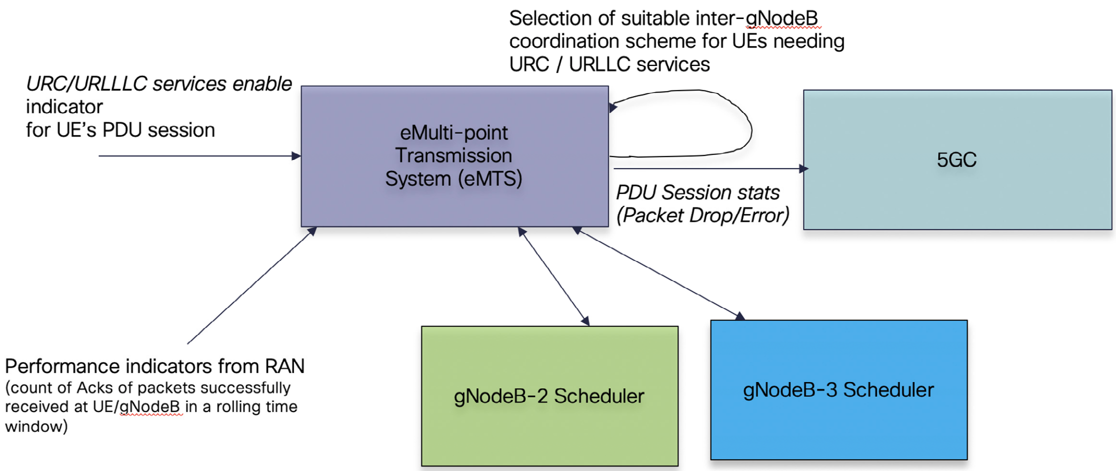

Figure 3: Optimizations to Aid Inter-BS Coordination Mechanisms

Consider various key steps that may be associated with the first solution. For example, consider that two redundant PDU sessions, PDU1 over gNodeB-1 and PDU2 over another gNodeB-2, are established. The PDU1 session over gNodeB-1 may utilize a first User Plane Function (UPF1) in the 5GC and the PDU2 session over gNodeb2 may utilize a second UPF (UPF2) in the 5GC.

When a redundant PDU session is established, the Session Management Function (SMF) in the 5GC informs the gNodeB-1/gNodeB-2 that the redundant PDU session is URC/URLLC enabled using Retransmission Sequence Number (RSN) parameters. Additionally, the gNodeB-1 and the gNodeB-2 notifies the CoMP Server that this PDU session is URC/URLLC enabled in order for the CoMP server to apply additional techniques to these PDU sessions to improve URC/URLLC application performance. The gNodeb-1 and the gNodeB-2 also send Key Performance Indicators (KPIs) and/or any other statistics about the user traffic to the CoMP Server (e.g., count of acknowledgements of packets successfully received at UE/gNodeB in a rolling time window).

As the UE moves to a cell-edge boundary, the PDU2 session is handed over from gNodeB-2 to gNodeB-3. Based on the KPIs/statistics received from gNodeB-1 and gNodeB-3, the CoMP server may determine that there is packet loss to the UE from gNodeB-3.

The CoMP server can determine additional neighboring gNodeBs that can send/receive packets to the (URC/URLLC) UE and consider them in CoMP techniques. In other words, additional CoMP techniques via multiple neighboring gNodeBs (at the cell-edge) are applied to (URC/URLLC) UE, whereas normal UEs, such as smartphones, can continue to be served through normal CoMP techniques.

There are multiple CoMP techniques available, such as CoMP-CS (coordinated scheduling involving signal transmissions by a single gNodeB), CoMP-JP (joint processing involving signal transmissions from multiple gNodeBs), CoMP-DPS (dynamic point selection involving signal transmission by a single gNodeB), etc. The CoMP-JP is costly technique in terms of radio resources because it involves multiple gNodeBs sending a packet as compared to CoMP-CS where only one gNodeB sends packets towards a UE.

Continuing with the present solution, the CoMP server will receive packet statistics and performance indicators related to the PDU1 packet delivery status from the gNodeB-1. These statistics/performance indicators can be sent periodically. For example, the statistics/performance indicators may be sent based on any combination of: a number of successful packets being delivered in a given time duration, after some threshold number of packets are delivered successfully, determining packet errors/drops occurring for the PDU1 session; and/or determining a packet sequence range that are successfully delivered to the UE for the PDU1 session.

The CoMP server will use the packet statistics/performance indicators to choose the CoMP techniques by employing following strategy that involves one method for choosing a specific mode for CoMP operation below, as follows:

1. If packets are successfully delivered for the PDU1 session (and if this number is above a threshold in a given time interval), the CoMP server will prefer CoMP-CS (over CoMP-JP) for delivering packets for the PDU2 session.
2. If some errors/drops are encountered for the PDU1 session (and if this number is above a threshold in a given time interval), the CoMP server will prefer CoMP-JP (over CoMP-CS) for delivering packets for the PDU2 session.
3. Additionally, if gNodeB-1 has provided a notification that all packets are already delivered to the PDU1 session, the CoMP server may not provide resources for these packets for the PDU2 session.

Consider additional example details involving a second potential solution for optimizations to aid inter-BS coordination mechanisms. For the second solution, consider that a UE has established redundant PDU sessions for URC/URLLC services. The second solution provides optimizations that involve removing one of the redundant PDU sessions, thereby optimizing resource utilization by evaluating feedback provided to the core network regarding radio performance at the cell-edge for URC / URLLC PDU sessions.

For example, consider that a given UE has established a redundant PDU session and the RAN (e.g., gNodeB) has indicated to the CoMP server that the UE session is a URLLC PDU session. In this solution, the CoMP server sends feedback to the RAN indicating that radio reliability can be ensured using currently deployed CoMP techniques. Thereafter, the RAN sends KPIs/statistics to the SMF (via the Access and Mobility Management Function (AMF) in the core network) and the SMF forwards all the KPIs/statistics to an analytics server. The analytics server analyzes the received KPIs/statistics and determines whether two PDU sessions are required for the UE or whether a single PDU session is enough to ensure reliability.

Upon determining that a single PDU session is enough to ensure reliability, the SMF, based on obtaining a trigger from the analytics server, terminates the second (redundant) PDU session and triggers release of the second PDU session resources. The SMF triggers signaling with the corresponding gNodeB and UPF to create a duplicate N3/N9 tunnel for the UE session. The SMF also notifies the UPF to not drop duplicate uplink packets, but rather to send duplicate uplink packets towards the N6 side. When a downlink packet is received at the UPF, the UPF will duplicate the packet and send it towards gNodeB on both N3/N9 tunnels and the gNodeB will drop the duplicate packets.

A side effect benefit of the second solution (and the third solution, discussed below) is that the network can provide URLLC services (through enhanced CoMP techniques with additional visibility) even to UEs that do not have a Redundancy Handling (RH) capability or a capability to create redundant PDU sessions.

The third potential solution for optimizations to aid inter-BS coordination mechanisms is provided to handle a scenario in which the core network (5GC) is ultra-reliable but the radio network (RAN) is not ultra-reliable or a UE in the RAN does not support the RH capability. Currently, none of the 3GPP solutions for URLLC handles such a scenario. Further, the redundant PDU session solution assumes that UE has RH functionality, which may not always be true. Additionally, the redundancy PDU solution consumes more resources because for every PDU session such that one extra redundant PDU session is established that consumes resources on core network as well as RAN.

Thus, for the third potential solution, consider a scenario in which a core network is sufficiently reliable but the RAN-UE connectivity is not reliable or the UE does not have or support Dual Connectivity capabilities. In this scenario, the Policy Control Function (PCF) in the core network notifies the SMF that the PDU session for the UE is URLLC. The AMF, based on obtaining radio capabilities for the UE, determines that UE does not support Dual Connectivity. The SMF can notify the gNodeB that the session is a URLLC PDU session and the gNodeB can send a URLLC indication for the PDU session to the CoMP server. Based on obtaining the indication regarding the session, the CoMP server can trigger one of the CoMP strategies on the gNodeB for ensuring reliability between the gNodeB and the UE using only a single PDU session.

In summary, technique herein provide for enhancing or optimizing CoMP mechanisms for applications that may involve HRC/URC/URLLC and/or any other QoS-aware services. Further, optimizations are proposed to provide URC or URLLC services over a single PDU session in order to save RAN and/or core network resources by tearing down redundant PDU sessions or for UEs that that do not support Redundancy Handler or Dual Connectivity capabilities but still require URC or URLLC services.