Relay assisted D2D communication in 3GPP

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Abstract

Wireless relaying in cellular networks has attracted considerable attention because of its capability of extending coverage and improving transmission reliability. The Third Generation Partnership Project (3GPP) had standardized the relaying functionality in Release 10. In Release 13, the concept of relaying has been evolved to combine it with device-to-device communications for extending network coverage further. In this paper, a state-of-the-art 3GPP relay technology called the UE-to-Network relay that provides a novel approach of extending network coverage will be introduced briefly.

1. Introduction

Over the last decade, tremendous amount of research efforts has been made in the area of device-to-device (D2D) communication underlying cellular networks. The potential benefits and challenges of D2D communication technologies were presented in earlier works [1,2], and power control and D2D session management were studied in [3]. More detailed D2D protocols based on operator control were proposed in [4–6]. On the fruitful ground of research outcomes and growing interest in proximity service, the Third Generation Partnership Project (3GPP) introduced a set of new technologies called ProSe as proximity service enabler in Release 12 (Rel-12). Among the new technologies, ProSe direct communication and ProSe direct discovery enable the data to be transferred between UEs without traversing the eNB, using LTE radio technologies.

Even though Rel-12 ProSe direct technologies empower UEs to communicate directly with each other, the connectivity enabled by these technologies is limited to inter-UE connectivity. UEs that are out of network coverage cannot have connectivity to infrastructure network, i.e., Internet/infrastructure-based application services. To address the limitation, a relaying functionality based on ProSe technologies has been introduced in 3GPP Rel-13, and is called the ProSe UE-to-Network relay. This paper discusses the coverage scenarios, network architecture, protocol stack, procedures for the ProSe UE-to-Network relay, and potential enhancements.

2. Comparison of 3GPP relay technologies
Based on the ProSe UE-to-Network relay specified in 3GPP Rel-13, a UE can provide other UEs (called remote UEs) that could experience coverage problems with internet protocol (IP) connectivity. The UE-to-Network relay effectively extends network coverage by relaying IP traffic between the network and remote UEs. The relay communicates with remote UEs using UE-to-UE direct communication while connecting to the network using existing cellular communication technologies.

Besides the UE-to-Network relay, 3GPP has specified relay service technologies in Rel-10 to extend network coverage. In Rel-10, the network node providing relay service is called the Relay Node (RN) [7]. The Rel-10 RN and the Rel-13 UE-to-Network relay commonly support the relay of IP traffic. In spite of the basic commonality of the RN and the UE-to-Network relay performing layer-3 relaying, differences between the two can be observed as follows:

• The Rel-10 RN acts as the eNB to serve other UEs connected to the RN; hence, the RN should support generic eNB functionalities. The Rel-13 ProSe-UE-Network relay is, in contrast, a UE merely supporting relay functions.

• The Rel-10 RN communicates with other UEs using an existing Uu interface (UL/DL), whereas the Rel-13 relay communicates with other UEs using a UE-to-UE direct interface newly defined for direct communication between UEs.

For the rest of the paper, the UE-to-Network relay is often simply referred to as the relay UE. The UE connected to the relay UE for facilitating relay service is called the remote UE.

3. 3GPP direct communication

3.1. Protocol stack for sidelink

As the relay UE utilizes a direct interface called sidelink (SL) to communicate with remote UE(s), understanding how direct communication works are essential. Let us assume that the application of a UE (e.g., remote UE or relay UE) generates user data to be transmitted to another UE. This user data is packetized at the IP layer into an IP packet. The IP packet then passes down to access stratum (AS) layers. The functions of the AS for the SL are described below.

PDCP [8]: The packet data convergence protocol (PDCP) supports header compression of the received IP service data unit to reduce the size of the IP packet header. The PDCP establishes an SL radio bearer (SLRB) to carry data over the SL.

RLC [9]: Only unacknowledged mode (UM) radio link control (RLC) is supported for the SL, and therefore, no retransmission is performed at this level. The support of only UM RLC for the SL is reasonable as long as the application for the SL targets delay-sensitive and error-tolerant traffic
such as real-time voice/video.

**MAC** [10]: The medium access control (MAC) layer performs logical channel prioritization by considering the priority of each SL logical channel corresponding to the SLRB. The MAC header includes source ID and destination ID fields. The MAC at the receiving side uses the destination ID for packet filtering. Each MAC protocol data unit has one new transmission and up to three retransmissions so that the receiving UE performs HARQ combining. Note that HARQ feedback is not supported for SL, and hence, the number of retransmissions is configured.

**PHY** [11]: Data transmission involves the transmission of a physical control channel carrying SL control information (SCI), and a physical data channel. For each new transmission, the UE transmits SCI that indicates the layer-1 destination ID, modulation and coding scheme, and time–frequency location of the data. Then, the UE transmits the actual data on the physical data channel that immediately follows the control channel. Note that the control channel and the data channel are separated only in the time domain.

### 3.2 Radio resource control for sidelink

The general principle of radio resource control for the SL is simple [12]: the UE in coverage follows the radio resources explicitly signaled by the network; however, once the UE moves out of network coverage, it switches to using preconfiguration stored in the UE.

For SL reception, the UE is configured with the reception pool(s) that the UE should monitor for reception, and the radio resources in the reception pool(s) should cover all the concerned transmission resources used in proximity.

For SL transmission, two resource selection schemes are supported: (i) eNB-scheduled resource selection and (ii) UE-autonomous resource selection [11]. If the eNB-scheduled resource selection scheme is configured, the UE uses the radio resources assigned by its serving cell. If UE-autonomous resource selection is used, the UE randomly selects transmission resources from the transmission resource pool(s). When the UE is out of dedicated network control such as being in RRC IDLE or out of coverage, only UE-autonomous resource selection is applicable.

### 3.3 Sidelink synchronization

The synchronization for the SL is achieved in such a manner that a transmitting UE sends the synchronization information over the SL, and then, a receiving UE becomes synchronized [12]. The synchronization information includes both the physical synchronization signal (called SLSS) and the RRC message (called MIB-SL). For SL transmission including SLSS, the UE in coverage uses network synchronization that is related to UL/DL synchronization. If the UE out of coverage detects suitable synchronization information transmitted by the other UE, which is called the synchronization
reference UE (SyncRef UE), the former UE uses the detected synchronization information. A UE that cannot detect any suitable SyncRef UE becomes a SyncRef UE by transmitting the synchronization information.

For SL reception, the UE uses the synchronization information associated with the reception pool. The network may explicitly include the synchronization information when signaling the reception pool. If the resource pool does not have any explicit synchronization information, the UE uses network synchronization.

4. UE-to-Network relay

4.1. Protocol stack for UE-to-Network relay

The relay UE has two radio interfaces to the eNB and the remote UE, respectively, and it relays IP packets between the remote UE and the network at the IP layer.

4.2.1. Traffic mapping between Uu and PC5

The relay UE relays the traffic between Uu and PC5 interfaces, and hence should perform traffic mapping. More specifically, it should map UL/DL bearers on SL bearers and vice versa, and this mapping is essential for proper packet routing and quality-of-service (QoS) treatment. For SL to UL mapping, which occurs when the relay UE receives traffic from the remote UE over the SL, the relay UE uses uplink traffic flow templates (TFTs) to select uplink bearers to carry the received traffic over UL. For DL to SL mapping, which occurs when the relay UE receives traffic from the eNB, it identifies whether the packet has to be relayed, by referring to the destination IP address of the packet. The relay UE then assigns a priority value called ProSe per packet priority (PPPP) to the received packet to be relayed. The priority assignment is based on the mapping information representing the association between the QoS class identifier (QCI) values of DL bearers and the priority values. The QCI-to-priority mapping information is provisioned to the relay UE by the network.

4.2.2. Addressing

To facilitate the transmitting UE and the receiving UE to unambiguously address each other, SL communication introduces ProSe UE ID and ProSe Group ID, each of which are 24-bit long, for unicast and groupcast. In the MAC header, the full length of the ProSe UE ID and the truncated ProSe UE ID/ProSe Group ID (16-MSBs) are included in the source and destination fields, respectively. The remaining 8-LSBs for the destination ProSe UE ID/Group ID are indicated in the SCI at the physical layer. The destination UE ID of each UE can be obtained by the other during relay discovery.

4.3. QoS support for relay service
In conventional LTE networks, QoS differentiation is realized by establishing evolved packet service (EPS) bearer(s) and provisioning proper QoS parameters to the EPS bearer(s). As there is no EPS bearer defined for the SL, the existing QoS differentiation mechanism cannot be applied to the SL.

In Rel-13, PPPP is introduced to enable QoS differentiation across different traffic streams corresponding to different SL logical channels. PPPP has eight values ranging from one to eight, and each PPPP value represents the priority at which the associated traffic should be treated over the SL. Each data packet to be transmitted is assigned a PPPP value selected by the application layer. The UE then performs logical channel prioritization such that the transmission of the data associated with higher PPPP is prioritized. PPPP is also applied to transmission pool selection in the case of UE-autonomous resource selection. The network can configure one or multiple PPPP for each transmission pool in the list of pools. Then, for each MAC protocol data unit to transmit on the SL, the UE selects a transmission pool associated with the PPPP.

4.4. Broadcast traffic relaying

In addition to relaying unicast traffic, the relay UE supports relaying multimedia broadcast multicast service (MBMS) traffic. For MBMS relaying, the remote UE may inform the relay UE of temporary mobile group ID (TMGI) and service area ID (SAI), which jointly identify the desired MBMS service. The relay UE then checks if the serving cell broadcasts the service and, if so, starts to monitor the MBMS contents from the MBMS traffic channel of the serving cell and broadcast it over SL. Meanwhile, the relay UE responds to remote UEs whether it can support relaying the desired MBMS service. If the response is positive, the remote UEs start to monitor the MBMS service via the relay over the SL.

5. Conclusion and further enhancement

In this paper, the state-of-the-art 3GPP relay technology called the UE-to-Network relay was discussed. While the new relaying technologies open up novel approaches of extending network coverage, relaying performance may not be satisfactory in that tight service continuity for the relayed traffic is not guaranteed. The reason is that (i) the network has a limited control for relay services and (ii) SL performance is considerably below optimum.

Naturally, the key objective of future work could be to enable the network to have a tighter control for relay procedures, which could include, e.g., network-controlled relay (re-)selection and sophisticated resource management with better QoS treatment. Another objective would be to enhance SL performance by introducing, e.g., closed-loop power control, feedback-based retransmissions, coordination between UEs for transmissions, and redesign of the structure of
physical SL channels together with a scheduling scheme. In addition, the UE-to-UE relay function, if introduced, could considerably increase the relaying range, by allowing multihop relaying.

References


