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Design of Side Link Protocol for D2D Communications in VANETs using LTE-A

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Abstract

Increasing demands for highly efficient proximity networks led to the derivation of LTE-A (LTE-Advanced) by 3GPP (3rd-Generation-Partnership-Project).Its superior characteristics in terms of capacity and data rates make it a user-friendly option to realize the pipe dream of efficient communication for several communication modules. Device to Device (D2D) communication is one such scheme that adopted the features of LTE-A to ensure the quality of experience and services for the users. D2D aims at establishing device connectivity by interlinking devices in the vicinity. Direct connectivity and connectivity via ENodeB (eNB) are the advisable schemes of D2D Communication. Further enhancement is D2D is realized in the form of side-link which ensures direct connectivity of devices by eliminating eNB routing. This achievement by 3GPP enhances the co-existence of side-link and D2D,which makes it adoptable in various value added services. One such value added service exists as VANETS (Vehicular ad-hoc networks), designed for inter vehicular communication to elevate quality of living of the people by ensuring public safety. This paper mainly focuses on Radio Resource Controller (RRC), Media Access Control (MAC) and ProSe layers of 3GPP protocol stack.

Keywords: D2D, LTE-A, Proximity Services, Side-Link, VANET

1. Introduction

The growth and need of user data traffic in the last few years has been phenomenal. According to CISCO global mobile traffic forecast, the Global mobile data traffic reached 7.2 exabytes per month at the end of 2016[1] (One exabyte is equivalent to one billion gigabytes, and one thousand petabytes). Apart from this, around 30 percent of the smartphones generate more than 95 percent of the overall data traffic, which is too huge to be handled by a network. It is thus pushing the industries and engineers to design a better network architecture, which can accommodate such a huge need of data traffic.

With the 4G being already implemented and the fact that it cannot fulfill the huge gap between the required and the actual performances, 3GPP has been working on a new enhanced version of LTE called as LTE-Advanced. LTE-A enhances many requirements such as system capacity, peak data rates, end to end delay, throughput, etc., which is been achieved by embedding techniques like millimeter wave, Massive MIMO, spectrum sharing using cognitive radio, D2D Communication, Carrier Aggregation etc[2]. D2D communication is been considered as a key innovate feature for next-generation cellular networks. One of the main operation of eNB in the LTE network is to handle traffic between UE's, while in D2D the data traffic is bypassed and directly communicated to the neighboring device without the involvement of eNB thus reducing latency[3]. D2D communication was introduced in 3GPP specification in release 12 focusing on public safety applications and has been upgraded in successive releases[4].

IEEE 802.11p and LTE are the conventional solutions for V2V communication. The drawbacks of IEEE802.11p for V2V is low mobility with intermittent connectivity[12] and the drawbacks of LTE for V2V by authors of[13] is that

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the performance in terms of reliability and latency does not meet the Quality of Service (QoS) for Critical safety applications. D2D technology which is part of LTE-A (LTE-Advanced) that promises to fulfill QoS requirements for low latency and reliability for V2V communication.

2. D2D Communication With and Without eNB

Necessity of central hubs for building up association between gadgets is been viewed as the soonest methods of correspondence with the development of LTE-Advanced (LTE-A). LTE-A will be a better correspondence plot planned than meet the expanding needs of limit in information exchange. In D2D, the prime motivation is setting up association among gadgets in the region. This is a short territory arrange which can be additionally extended with the establishment of progressive hubs. Prior methods of correspondence in D2D favored the focal center point or eNB approach for information steering which now is been supplanted with an immediate association without the inclusion of eNB. This accomplishment is acknowledged by

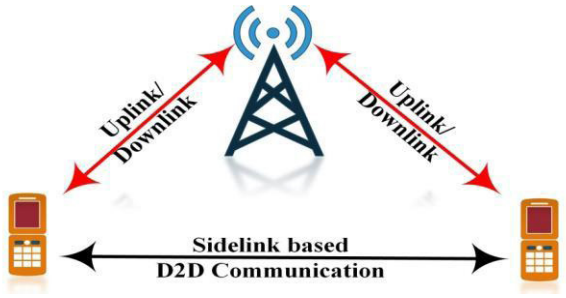

Figure 1. Illustration of sidelink based D2D communication in uplink, downlink and direct modes.

3GPP with the guide of side link correspondence. In D2D communication side-link is a direct communication radio air interface used to have communication between UE's without going through eNB as opposed to cellular communication as shown in Figure 1. Side-link based transmission is carried out in two different modes Scheduled and Autonomous modes. The assets required for Scheduled method of operation is helped by eNB. Autonomous mode has a pool of assets that are preconfigured in view of the correspondence/autonomous necessity. Gadget-to-gadget (D2D) correspondence innovation for fifth era (5G) portable systems empowers User Equipment's (UE) to discuss specifically with different UEs without or with incomplete contribution of the system foundation, for example, universal access for UE's or for base stations. The resources to be utilized for side-link based D2D communication are preconfigured in to UE's Universal-Subscriber-Identity-Module (USIM) for out of coverage scenario and will be receiving from eNB through system information block-19 (SIB-19) messages for in-coverage scenario. When both the UE's are out of coverage the UE will broadcast its preconfigured SIB-19 messages to proximity devices and will become sync reference UE and will be coordinating further process of D2D communication. D2D enhances the data transfer exceptionally well and expand the unearthly effectiveness of the system. All things considered, the benefits of D2D interchanges are not just constrained to improve ghostly proficiency. D2D correspondences can possibly enhance throughput, vitality effectiveness, deferral, and decency. LTE D2D interchanges is a distributed connection which does not utilize the cell arrange framework, but rather empowers LTE based gadgets to discuss straightforwardly with each other when they are in nearness.

3. Sidelink Introduction in VANETs

Vehicular-Ad-Hoc-Network or VANET is a sub-form of Mobile-Ad-Hoc-Network or MANET that gives correspondence amongst vehicles and between vehicles and road side units with a point of giving effective and secured transportation. A vehicle in VANET is thought to be a wise versatile hub prepared to communicate with its neighbors and different vehicles in the system. VANET presents more difficulties viewpoints as contrasted with MANET in light of high portability of hubs and rapid topology changes in VANET. Different steering accords have been outlined and exhibited by scientists subsequent to considering the real difficulties associated with VANETs. To protect a VANET, broad examinations have been directed on creating confirmation frameworks and recognizing getting out of hand vehicles. The adequacy of such endeavors intensely relies upon the fundamental correspondence organize.

For Vehicle to Vehicle (V2V) communication using D2D, the important implementation is in its Layer-2 and 3 also termed as "Side-link Communication". The below figure shows the Side-link Communication performed in

LTE D2D. Just like uplink and downlink communication available in LTE, here for direct communication between devices, a side-link is introduced. The new interface between them is called ProSe Control 5 [PC5] as shown in Figure 2. These side-link are established between vehicles that communicate using D2D as in the case of V2V.

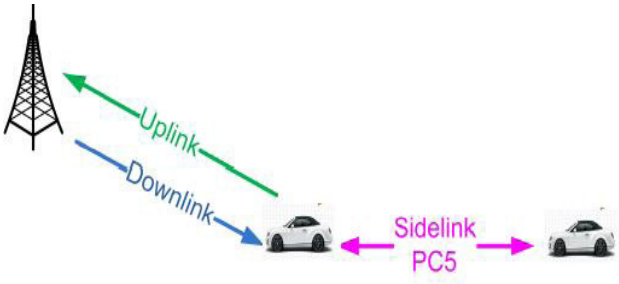

Figure 2. Illustration of sidelink based D2D communication in uplink, downlink and direct modes in VANETS.

4. Client and Server Implementation

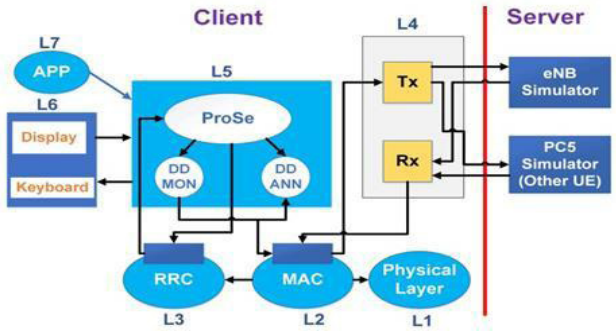

Figure 3. Overall architecture of side-link based D2D communication server and client side implementation.

The overall design and working procedure of client and server modules are explained on the basis of Figure 3.

4.1 Client Module

The interface, Transmitter (Tx)/Receiver (Rx) and sockets refer to layer 4 entities i.e transport layer. The side-link Prose (SLP), DD-Monitor (DD-MON) and DD-Announcer (DD-ANN) correspond to layer 5. While the side-link RRC (SL-RRC) and side-link MAC (SL-MAC) from the layer 3 and layer 2 entities of 3GPP protocol stack respectively. Prose module exchanges the control information related to prose communication between the ProSe-enabled UE and ProSe function in the form of PC3 messages. It is also responsible for all the D2D related activities between the UE's handling the messages for initial registration of UE's to have D2D communication. It has two important modules. DD monitor and DD announce module the purpose of monitor module is to configure the monitor mode for the UE. While the DD announce module handles the announce functionalities and its associated parameters. RRC module mainly handles the resource allocation of UE in both in-coverage and out of coverage scenarios. It acts as a gateway between the higher and lower layers and plays a vital role in side-link based communication. Through the messages sent by the client side RRC. eNB will decide whether the particular UE is interested to perform a side-based communication or not. RRC will always sent its readiness status to the ProSe layer and to the MAC layer. At the client side, all PC5 messages are handled by MAC protocol. The announcement and Monitoring of these messages from the ProSe are first passed to the MAC before sending it to RX. For out of coverage case, the messages sent by sync ref UE is handled and processed by the MAC. The MIB messages from the sync ref UE is also sent by MAC to other UE's. Keyboard and display form the two modules of presentation layer. For demonstration purpose, we are considering the keyboard to accept user input. At application module, initially UE will send a request though an app to the client ProSe, the SLP in turn sends registration request to the server. If the server sends the positive response to UE, then the client UE will get an update to perform global registration to authorize communication through that particular application.

4.2 Server Module

When the devices are in-coverage the highest priority is given to the eNB rather than to sync reference UE, and for the proposed work from demonstration view point, we are considering eNB simulator. The eNB will broadcast all the messages related to resource allocation and utilization to the UEs. For D2D communication, various interfaces have been introduced, among which PC5 and PC3 are important ones. The PC5 interface is between two UEs under D2D communication and a PC3 interface is used to a connect ProSe function with a newly defined node.

For in-coverage scenario, eNB will transmit all radio broadcast messages and also will be functional. The Rx will receive all these broadcast messages and forwards the messages to MAC module which in-turn passes it on to RRC module. After receiving RRC readiness mes-

sage, SLP module requests RRC module to know whether DD announcement/monitor operation is to be executed. Based on the received parameters, RRC module will then send information to SLP to perform DD announcement/monitoring. The SLP in turn activates DD announcement/monitor module based on information received from the RRC module. Finally, the DD announcement/monitor module transmits the information message(s) to MAC to be transmitted to eNB through transmitter.

5. Operational Sequential Flow

The operational sequence flow and procedures have is been explained considering Figure 4.

5.1 User Equipment and Service Registration

The first and foremost thing that is inevitable is the registration process. There are two modes of registration, one is the new device that is introduced to the network and the other is subscription renewal of the existing registered user. When a new device is introduced, it should sync with the server in order to establish a link. The process includes filing user credentials to the network database as a proof. Process of registration happens from the moment the device is switched on and there exists a scheduled time limit within which the registration process has to be completed. The second scenario includes the renewal

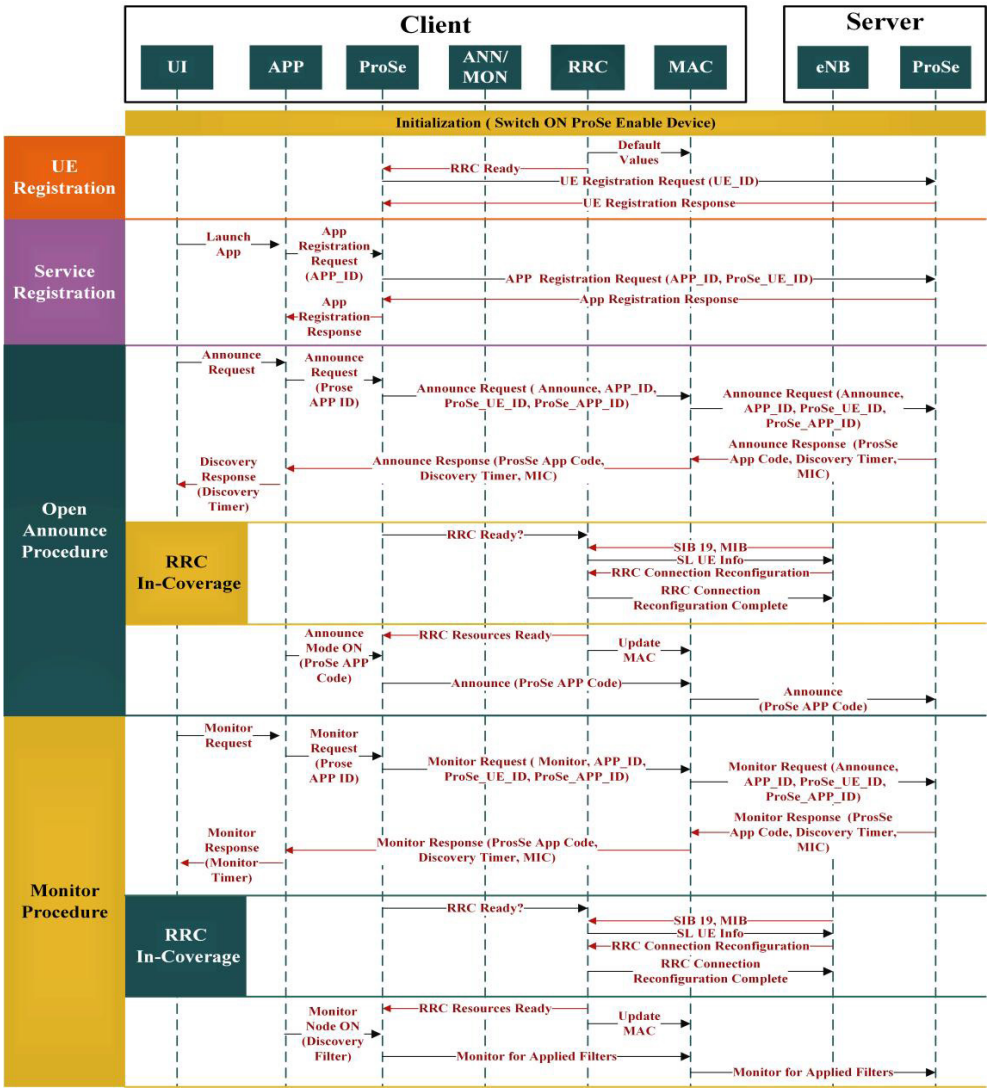

Figure 4. Operational sequence flow for side-link based D2D communication. UI, APP, ANN, MON represent User Interface, Application, Announcer and Monitor respectively.

of subscription period of a registered user on expiry. The expiry is notified by the server in the form of a message to the user. Based on this message the user can opt new subscription scheme.

5.2 Open Announce Procedure

ProSe application turns to be the source of open announcement made from the user equipment side. For every open announcement there exists an App-code that should match the Prose-App-ID. It is the function of SLP module to ensure the existence of the APP-code that match the Prose-APP-ID. This mechanism acts as private key that enhances the privacy of data transfer. In case if there is no App-Code available, a message namely 'PC3' will be forwarded to the Prose server. This message acts a discovery request for the App-ID. As an acknowledgement form the Prose-server a 'Discovery response' is forwarded which is responsible for the creation of PC5 message. Once the successful retrieval of APP-Code achieved, mapping of App-ID and App-Code is stored within the user equipment until the next discovery-timer expires.

5.3 RRC Layer Procedure

In In-coverage scenario, RRC informs its readiness state to SLP and MAC once User-Equipment is switched on using preconfigured data stored in USIM7.

User-Equipment waits for the SIB19 messages as illustrated in the figure. If any eNB broadcasted message is detected, SIB19 messages are captured by Side-Link-

RRC and forwards Side-link UE information message to eNB on received SIB19 configuration. Client side RRC waits for RRC connection reconfiguration message from eNB. It acknowledges, once it is readyto react on the reconfiguration message received previously from eNB. For out-of-coverage scenario, operational procedures illustrated in the figure given will replace the operational procedures of RRC in the in-coverage scenario as illustrated in the given diagram. As eNB will not be activel, RRC will be receiving all the messages from reference UE. In-order to enhance D2D communication

UE forwards the Side-Link Synchronization Signal (SL-SS) and Side-Link MIB (SL-MIB). SL-MIB and SL-SS is preferred by UE to transmit to other UE's in the region to have D2D communication, if received signal is below threshold and it is configured to be reference UE. After the RRC layers indication for its lower layers readiness, the App code is sent to announce module, which forms a PC5 message and sends to SL-MAC. This marks the on state of announce module. Based on the frequency transmission of PC5 message, SL-MAC will send this data to its lower layer. For critical applications, the frequency of PC5 message could be configured as 10Hz. This 10kHZ remains a constant frequency for PC5.

5.4 Match Report for Side Link

The matching on applied discovery filters match to a PC5 message that is sent from SL-MAC to monitor module. The matched App-Code is sent to SLP module, if APP code is matched has a mapping Prose-App-ID. If the Prose-App-ID-App code mapping is not present, a Match report PC3 message is initiated by SLP to get the corresponding Prose-APP-ID and indicated to application layer of the match.

For in-coverage scenario, usually all the five procedures are initiated. In out-of - coverage case, the Prose App ID-App code mapping would be available and monitor discovery filters will be preconfigured. Hence, such services need not communicate with Prose Server and PC3 interface will not be applicable.

5.5 Monitor Procedure

RRC layer for its lower layer readiness procedure, the APP code is sent to announce module that forms a PC5 message and sends to SL-MAC. The announce mode is now ON and based on frequency of transmission. Any device wanting to monitor a device/application/message sends a monitor request triggered by the application layer to SLP module. The ProSe APP ID is the main parameter in this message that uniquely identifies the application/service that triggered it. Similar to the announce procedure, SLP checks if there is a mapping discovery filter for this ProSe APP ID. If there is no mapping available, a PC3 'Discovery Request' message asking the discovery filters are sent to the server. After successful 'Discovery Response' from the server, the discovery filters received is applied to monitor module until the monitor timer expires.

5.6 Side Link based Communication in VANETs

The overall implementation of the prototype for D2D communication has been implemented to establish communication between two Linux machines (Ubuntu), one acting as server and another as client. The sequence flow in

the figure between the server and client has been observer using terminal for both cases. A separate external control is given to the terminal to make UE to be either in in-coverage otout-of coverage.

Server has three display terminals PC5, Tx/Rx and Prose function. Server Tx/Rx terminal displays the log information captured when UE is switched on and also the messages exchanged between server and client. PC5 simulator acts as air interface between SyncRefUE and normal UE. PC5 terminal displays the MIB messages broadcasted. The Prose function terminal displays the users under eNB. It also displays UE-ID and registration details. Client side has one terminal displaying log of message transmitted/received to/from the server.

The following design assumptions are considered for this work. UE is considered as client and eNB as server for in-coverage scheme. New D2D UE pair is considered as client(s) and UE which is capable of transmitting MIB as SyncrefUE, for out of coverage scenario. UE will not be considering all the DL resources coming from server eNB for side-link operation. For in-coverage cases, only SIB19 and MIB are decoded instead of SIB1, SIB2 till SIB18 to reduce signaling overhead as compared to normal RRC operations. The side-link process is faster in out of-coverage case as compared to uplink and downlink in coverage scenario. Since UE will not be communicating with eNB. The pre configurations are stored in USIM of the user device. The communication is different compared to RRC and MAC operation of conventional cellular communication.

6. Conclusion

In this work, a brief overview of Side link based D2D communication for both in-coverage and out-of-coverage scenarios is been presented Further extension of side-link based design for VANETS has been realized and experimented. A brief research carried out on the implementation of RRC, MAC and ProSe layers of 3GPP stack is been proposed for all communications scenarios suggested by 3GPP for VANETS using Side-link based communication for ensuring public safety. Along with operational flow sequences, the important elements which are communicated between UE (Client) and eNB (Server) for each message has been detailed out. The procedures also specified on how the devices discover each other in out-of-coverage scenario. Ad hoc nature of D2D communications to conduct V2V communication can compensate LTE's inadequate capability of supporting a high density of vehicles.

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