# Development of Device-to-Device Communication in LTE-Advanced System

MiJeong Yang, KwangRyul Jung, SoonYong Lim, and JaeWook Shin
Electronics and Telecommunications Research Institute
mjyang@etri.re.kr

***Abstract*-- Device-to-Device communication in 3GPP LTE-Advanced cellular network has been proposed as a means to provide high data rate, low delay, and low power consumption for mobile consumer equipments. In this paper, we propose an enhanced LTE-advanced system which incorporates the D2D communication, and describe the experimental result to show the feasibility of the D2D technology.**

## I. INTRODUCTION

In recent years, mobile data traffic has grown explosively due to the popularity of smart phones and mobile devices. This indicates that mobile devices suffer from lower spectrum utilization, higher power consumption and unsatisfied user experience. As one of solutions to improve the performance of cellular networks, the Third Generation Partnership Project (3GPP) has been discussing Device-to-Device (D2D) communication technology in its Release 12 work[1].

The D2D communication means that user devices adjacent to each other within the coverage of cellular network set up a direct D2D radio link instead of device-to-base station links. The user devices can exchange data directly through the D2D radio link. The D2D technology aims for, without increasing cost for infrastructures, improving the data transmission rate for users in cell-edge areas and increasing system capacity by reducing interference. Specifically, the D2D technology is becoming more important due to its advantages of providing high data rate, low delay, and low power consumption for mobile consumer equipments.

To extend the conventional 3GPP cellular system to incorporate the D2D communication functionalities, the architectural enhancements are required[2]. In this paper, we propose an enhanced LTE-Advanced (LTE-A) system based on network architecture including a D2D server and D2D discovery/communication mechanism. We also show the first-ever implementation results of D2D technology in LTE-A.

## II. ARCHITECTURE FOR D2D IN LTE-ADVANCED

This section proposes the enhanced network architecture for LTE-A based D2D communications which includes new reference points and functional features.

We propose a new enhanced LTE-A network architecture which is required for D2D technology including a new logical entity named D2D server as shown in Fig. 1. The D2D server is introduced to support the D2D operation within the Evolved Packet Core (EPC) network. It provides the following functionalities: managing the D2D discovery identities for D2D enabled UEs, D2D service control, policy and charging related functions, D2D discovery control, and coordinating the establishment of D2D links. The D2D server interfaces with the Packet Data Network Gateway (P-GW) to perform the above functionalities.

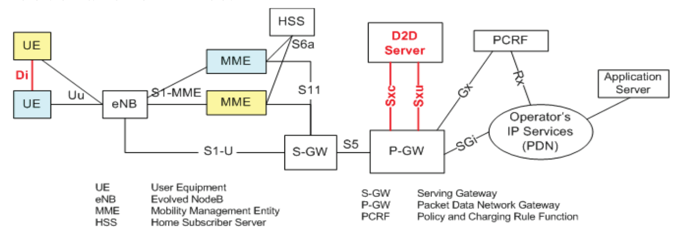


Fig. 1. Network Architecture for LTE-Advanced based D2D Communications

Also, we introduce a new reference point between D2D enabled UEs named Di interface using enhanced radio protocols and procedures as a UE connecting to an Evolved NodeB (eNB). The following D2D specific functionalities are supported: proximity measurement and report, D2D channel state measurement and report, and D2D data transmission. Data transmission between D2D enabled UEs is performed using D2D physical shared channels. The functional split between the D2D enabled UE and other network entities, are briefly outlined in Fig. 2. The policy and charging control is performed between the D2D server and the Policy and Charging Rule Function (PCRF) through the P-GW.

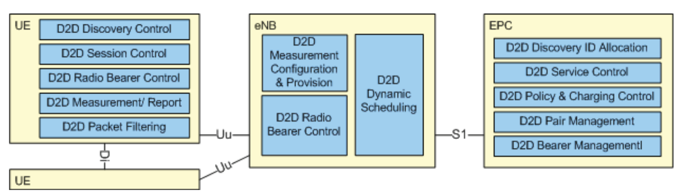


Fig. 2. Functional Split Diagram

The PCRF also indicates the appropriate Quality of Service (QoS) configuration for the D2D connection. The P-GW cooperates with the D2D server in order to manage the measurement for the discovery and the proximity assurance. The D2D server initiates the establishment of D2D connections and then the P-GW and the Mobility Management Entity (MME) perform the D2D bearer setup procedure.

## III. DESIGN AND IMPLEMENTATION

In this section, we describe our proposed procedures for discovering the nearby UEs and establishing the D2D communication connections between them. And then, we

This paper is drawn from the research supported by the IT R&D program of MKE/KEIT in Republic of Korea [K10038765, Development of beyond 4G technologies for smart mobile services].

present the experimental results. The discovery procedure is defined as a continuous process which identifies neighboring UEs in proximity. There are two types of discovery: open and restricted. Open discovery is the case where there is no explicit permission needed from the UE being discovered. Whereas restricted discovery only takes place with explicit permission from the UE being discovered. The information obtained from the discovery procedure may be used for initiating D2D communication.

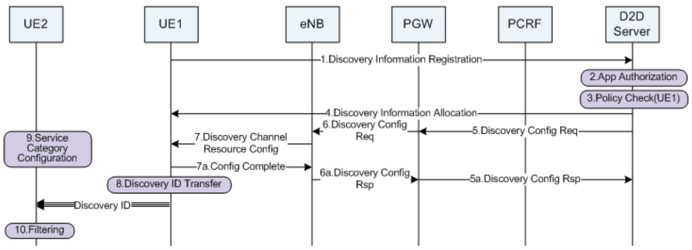

Fig. 3. Open Discovery Procedure

We design a new discovery procedure to implement D2D technology based on the proposed network architecture. Fig. 3 illustrates the open discovery procedure for short. A discoverable UE1 can be allocated a device discovery identity using Discovery Registration and Discovery Information Allocation messages through the default bearer. Discovery mechanism is performed by which the UE1 sends out physical probes including the discovery identity and the nearby UE2 that is interested in the service category of the UE1 acquires the UE1's discovery identity. We define Physical Discovery Channel (PDCH) which carries UE-specific discovery identity and occupies the same time-frequency resources among cells. The coordination of the time, frequency and reference signal sequence allocations for sending and scanning for the physical probes is performed by the eNB.

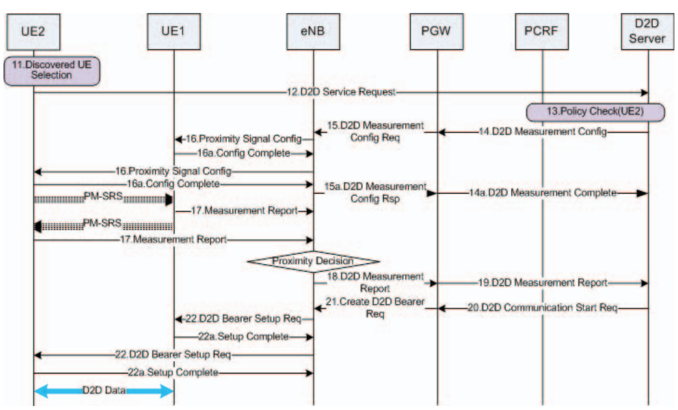

Fig. 4. D2D Communication Procedure

The UE2 can use the discovered UE1's identity for subsequent direct communication as shown in Fig. 4. Each UE exchanges D2D link establishment signaling with the P-GW, MME, and eNB by triggering from the D2D server. We use Proximity Measurement – Sounding Reference Signal (PM-SRS) to measure the degree of proximity, to estimate the received timing, and to estimate the path loss between the UEs that are going on D2D communication. We define D2D-Physical Shared Channel (D2D-PSCH) based on the LTE-A physical uplink shared channel since we use the uplink frequency for D2D communication. Also, we employ D2D-Physical Control Channel (D2D-PCCH) for exchanging the control information for D2D-PSCH.

We adopt DSP boards to develop the D2D enhanced LTE-A system efficiently. The implemented test-bed is shown in Fig. 5. TI TMS320C6670/6678 with multi-CorePac[3] are chosen for platforms for UEs and eNB. We verify our proposed D2D technology with this test-bed and demonstrate various D2D services on it. Table 1 lists up our targeted D2D services and Fig. 6 presents several demonstration scenes of the implemented services.

Fig. 5. LTE-Advanced based D2D Communication Test-bed

TABLE I
IMPLEMENTED D2D SERVICES

| Category | Service |
|---|---|
| Open Discovery | Store finding, Alerting |
| Restricted Discovery | Friend finding , Geo-fencing |
| Communication | N:N Document/voice/video sharing, Reservation and confirmation, Gaming |


Fig. 6. Service Demonstration

## IV. CONCLUSIONS

In this paper, we propose a D2D solution based on LTE-A system and introduce our test-bed verifying the proposed D2D technology. The demonstration including the open/restricted discovery and D2D communication shows that our D2D technology is well-designed and works well. This test-bed also shows the feasibility of the LTE-A system built by multi-core DSPs.

## REFERENCES

[1] 3GPP TR 22.803, 3GPP TSG SA; Feasibility Study for Proximity Services (ProSe) (Release 12), Jun. 2013.
[2] 3GPP TS 24.301, 3GPP TSG Core Network and Terminals; Non-Access-Stratum (NAS) protocol for Evolved Packet System (EPS); Stage 3(Release 11), Jun. 2013.
[3] TI, TMS320C6670/ TMS320C6678 Multicore Fixed and Floating-Point System-on-Chip, Mar. 2012.