Abstract: In the evolution path towards the "Always-Connected" era and the trend for even more context-aware services, Device-to-Device communications (D2D) promise to be a key feature of the next-generation mobile networks. Despite remaining technical issues and uncertain business strategies, D2D-based services represent a new market opportunity for mobile operators that would manage to smoothly integrate these new technologies as a complement or even an efficient alternative to cellular communications. Existing research efforts on the integration of D2D technologies in cellular networks have mostly failed to meet user expectations for service simplicity and reliability along with operator requirements regarding lightweight deployment, control and manageability. This paper proposes a hybrid model for D2D communications assisted by mobile operators through the LTE network: it includes a lightweight D2D direct discovery phase and an optimized data communication establishment for proximity services. The proposed hybrid model is appraised against the existing solutions in literature and the current standardization effort on Proximity Services (ProSe) within the 3GPP.

Keywords: D2D communications, LTE networks, Proximity Services.

I. INTRODUCTION

TODAY’s mobile networking world facts are: the mobile industry is shipping more smartphones and tablets than PCs; success stories of social networking services like Facebook has become a social trend from which mobile users developed the need to be connected anywhere to their surroundings; statistics in [4] envision an exploding number of more than thousand billion wireless connections around the world in 2020. Meanwhile, revenues of mobile services have been growing at a much slower rate than the growth of mobile connections since 20111. The challenge for mobile opera- tors, who struggle each quarter to turn a profit on voice and SMS services, is yet to face the threat of Over-The-Top (OTT) providers who have put their foot down at the mobile market with apps that supply instant messaging, multimedia services like pho- to sharing and video conferencing and other popular services for free. In this context, Device-to-Device communications have become the new driver in wireless network- ing and mobile market. Defined as a short range direct communication between devices without the involvement of the network infrastructure, D2D communications have been proposed as an underlay to cellular networks. Such a solution will evolve cellular networks toward a layered topology in which multiple network layers (femto-network, D2D-network, Wifi-network…) would coexist with a main macro-cell layer. With these new types of communications mainly based on context and proximity information, a new generation of user-centric mobile services will rise, offering at the same time the opportunity for operators to extend their mobile networks’ capacities and to alleviate the traffic in their core networks; for instance, smart cities services, real-time social discovery of nearby persons, targeted and personalized hyper-local services (advertising, couponing/ticketing, restaurant/hotels booking, content down-load, etc.). Besides, when including group communications and relay mechanisms, D2D communications could be a relevant fallback alternative for the public safety services (police, firefighters, emergency services, etc…) in disaster situations (earth- quake, Fire, etc.): using a specific D2D-enabled Public safety device, an officer/agent can exchange data and transmit information to other devices through a D2D group communication. Moreover, in poor radio coverage areas, relay-based D2D mechanisms could be an efficient way to extend network connectivity. Surfing on the wave of the successful worldwide launch of 4G LTE (Long Term Evolution) mobile networks, a new short range technology based on LTE (LTE Direct) has been developed by Qualcomm2. Envisioned to be the next trendy D2D technology that best meets the requirements of the above mentioned types of services and successfully tested in are centre search work 3, 3 GPP (3rd Generation Partnership Project) has then initiated a standardization effort on the integration of LTE Direct in mobile networks [12]. If this effort first addresses Radio Access Network (RAN) requirements and technical issues for the support of D2D-based services, it comes also along with a feasibility study [5] and a technical specification on the architecture enhancements for the support of Proximity Services (ProSe)[6]. In literature, many research works have been done on D2D communications and their integration within LTE networks. The earliest ones addressed mainly the radio aspects such as D2D radio interference management with cellular communications, power control, radio resources allocation/sharing methods and spectrum regulatory aspects (use of a license do run licensed band for D2D). Studies have also been made on D2D discovery and communication mechanisms. However, the few proposed solutions in these fields are still immature and don’t answer basic user concerns for simplicity, reliability and QoS when using D2B-based services. Otherwise, if these requirements have been
answered by the recently standardized solutions proposed in 3GPP [6], the current specification is globally lacking from a more extensible and evolutionary vision of the D2D integration in current and next generation networks. This paper proposes a novel LTE-based D2D discovery and communication mechanism. The solution aims to integrate D2D as a new feature in the current LTE architecture in order to promote the new paradigm of decentralized and locally-scoped communications. It mainly includes a table Direct Discovery that as an end-to-end optimized communication establishment phase. In the following sections, we give an overview of D2D use cases classification and Proximity Services (ProSe) as well as discuss on existing D2D mechanisms. Then, we describe our D2D hybrid approach for discovery and communication and compare it to the current 3GPP standardized solution.

II. OVERVIEW ON D2D USE CASES

Similarly to location based services, a D2D communication benefits from the proximity of devices in order to establish a direct link between them for a local data exchange. Basically, devices could be any device equipped with a D2D technology suitable for short range communication such as smartphones, tablets, laptops, network printers, cameras, or even connected vehicles. When dealing with devices proximity”, the definition of “proximity” becomes questionable and different proximity levels could be defined (e.g. geographical proximity, network topology, proximity of devices within the same subnet, radio range, etc.). Formobile operators with a ready-to-use amount of valuable rdata, context and proximity information are assets that need to be empowered to offer new value-added services to users and apace mainstream D2D services.

2.1 D2D use cases classification

D2D-based services is a business opportunity for operators and present multiple attractive use cases going from public/commercial services to more specific fields like public safety and military services. Generally, D2D applications aim at improving local services for users while optimizing the throughput over the radio network, reducing the overall network load and enhancing connection delays. Multiple use case classifications were made in[2],[5] and[6]. Generally, D2D-based services can be classified into three main categories like described in Table 1.

<table>
<thead>
<tr>
<th>Use case category</th>
<th>Applications</th>
</tr>
</thead>
<tbody>
<tr>
<td>Commercial and Social Proximity Services: An evolution of LBS services through hyper-local and dynamic proximity data.</td>
<td>Discovery-centric services: Context-aware applications, Social networking applications, location enhancement applications, Social gaming, and smart Cities services… Communication-centric services: content and video sharing services.</td>
</tr>
<tr>
<td>Public safety services based on group and relay</td>
<td>Direct communication between public safety agents in or outside network coverage: push-to-talk,</td>
</tr>
</tbody>
</table>

2.2 Operator role in D2D

D2D communications are definitely a business opportunity for mobile operators. Operators' strengths consist in having a powerful network in infrastructure that will allow the deployment of new D2D-based services while assuming their original contractual duty on keeping data security and users' privacy. Despite these technical issues and challenges that operators may face with the integration of D2D in their LTE net-works, they still have rich valuable assets that meet user expectations toward new D2D services. Operators' important assets include:

- Service security and QoS through secure and uninterrupted connections.
- Identity management, authentication and Privacy when using a D2D service.
- Context information exposure for more attractive services and better QoE.
- Devices management: user's cellular and non-cellular devices are associated to his user profile and included into the operator's subscriber database and automatically associated with the owner's cellular devices.
- Ensure the consistency of the user experience including reachability and mobility aspects (seamless off load, seamless handover, etc.).

III. D2D PEER DISCOVERY AND COMMUNICATION ESTABLISHMENT

<table>
<thead>
<tr>
<th>Data-path for EPC communications</th>
<th>Control-path</th>
</tr>
</thead>
<tbody>
<tr>
<td>Data-path for Direct D2D services</td>
<td>Data-path for network-assisted D2D communications through NB</td>
</tr>
</tbody>
</table>
A D2D communication has mainly two phases: A discovery phase in which devices are aware of their location detect surrounding devices/services, and a Communication phase in which D2D Peer exchange data on a D2D link.

Two communication modes were identified in [1],[2],[3] and [6]: the D2DDirect mode or the D2D network-assisted mode. As both D2D discovery and communication phases could be relatively independent, different models can be derived from each D2D model according to the role of the operator in D2D phases. In a network-assisted D2D mode, two schemes could be derived: a fully-controlled scheme in which the operator has a full control on discovery and communication phases, and a loosely-controlled scheme in which discovery and communication Phases are partially assisted by the operator, for instance with authentication mechanisms and radio resource allocation.

3.1 D2D Peer discovery approaches

D2D peers need to discover each other before initiating a D2D communication. This discovery phase could be done directly between devices in an ad-hoc manner or with the support of the operator network that can either control the entire discovery phase by detecting D2D candidates at the core network level or only assist in a trusted third-party. Two main discovery approaches were identified in [1],[2],[3]:

- **Direct discovery approach:** According to 3GPP, D2D direct discovery is defined as the process of detecting and identifying devices in proximity using E-UTRA direct radio signals [6]. Two discovery models were identified in ProSe: the “I’m here” model (A) and the “who is there?” (model B). In model A, a UE(Equipment) could be an_announcing UE that broadcasts some information to its surrounding at predefined discovery intervals, or a monitoring UE that monitors certain information of interest from devices in proximity. In model B, the discovery model is more accurate about what is sexually interested to discover and thus, defines two roles for the UE: a discovery UE which sends certain information about what it is interested to discover and a discoveree UE which replies with some information to the discoverer. The Direct Discovery approach has the advantage of flexibility and scalability as it can adapt to the increasing number of D2D connections and handover needs without the load of core network traffic.

3.2 D2D Communication Establishment

After the discovery phase, the D2D peers establish a communication link for data exchange. As shown in Figure 1, the exchange of data can be done either directly between D2D devices or using an AN of the operator network. Basic communication types in [8],[11],[13] consist of the establishment of an EPS bearer composed of a radio bearer (E-UTRAN) and a UE (An EPS bearer and a packet filter). There are two types of EPS bearers: the default bearer and dedicated bearers. The default bearer uses the network attachment of the UE, while the dedicated bearer connects with a PDN Gateway and the allocation of an IP address to the UE. In the case of a D2D Communication, a dedicated bearer is used, which is optimized for D2D Communications. Since the D2D UE has already an IP address associated with it, the default bearer is used for all bearers within the same PDN connection including the D2D dedicated bearer. Based on the concept of the Roaming aggregator, multiple D2D flows corresponding to simultaneous D2D connections could be carried within the same D2D dataradio bearer. According to the current 3GPP standard, the D2D Communication is considered as a whole and only when devices are out of coverage and only for public safety services and bearer mechanisms are not yet defined for these types of communications. In [8], a D2D dedicated bearer mechanism is proposed for the D2D Offloading service. Generally, existing D2D literatures lack detailed mechanisms for D2D bearer establishment and other than public safety offload.
3.3 Existing solutions
Several solutions were proposed in the literature for D2D discovery and communication establishment mechanisms. They are summarized as follows:

Solution 1: An EPC-based D2D discovery through MME using the Session Initiation Protocol (SIP). In this solution, the D2D bearer control mechanism is proposed. The implementation of this solution is that the dedicated bearer setup procedure is done in EPC while the handover takes place directly between eNBs. Also, the traditional IP address allocation for the dedicated EPC bearer would break the session at the handover from eNB to D2D link.

Solution 2: A direct D2D discovery through a dedicated ProSe server. A ProSe authorization mechanism is proposed before the direct D2D discovery. The Direct D2D discovery is implemented through a ProSe protocol that is defined in 3GPP.

Table 2: Existing D2D solutions

<table>
<thead>
<tr>
<th>Direct or EPC-based discovery?</th>
<th>Solution 1</th>
<th>Solution 2</th>
<th>Solution 3</th>
<th>Solution 4</th>
</tr>
</thead>
<tbody>
<tr>
<td>EPC-based discovery</td>
<td>No</td>
<td>No</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>EPC-level discovery for offloading</td>
<td>No</td>
<td>No</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>EPC-level discovery for offloading</td>
<td>No</td>
<td>No</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>D2D bearer mechanism?</td>
<td>No</td>
<td>No</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>EPC impacted entities</td>
<td>MME</td>
<td>PGW, SGW, eNB</td>
<td>ProSe, HSS</td>
<td>MME, eNB</td>
</tr>
<tr>
<td>Support for D2D Authorization?</td>
<td>No</td>
<td>No</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>Support for session continuity at handover?</td>
<td>No</td>
<td>No</td>
<td>Yes</td>
<td>No</td>
</tr>
</tbody>
</table>

As described in Table 2 below, most of the existing solutions propose EPC-based discovery mechanisms with weak contribution to the communication establishment mechanisms. D2D authentication and authorization are not seriously considered except the 3GP ProSe solution. Besides, IP session continuity at handover from EPC-based communication to D2D is not yet discussed in many of the above-mentioned solutions. Generally, the proposed LTE improvements are not supported.

D2D communications lack from long-term vision to the viability of the EPS architecture readding complexity to a system without considering its evolution into the future and regardless to economic and scientific advances. May lead to fast obsolescence. In next sections, we expose a long-term vision of the deployment of D2D communications through the hybrid LTE network assisted D2D solution for D2D communication.

IV. A HYBRID MODEL FOR D2D DISCOVERY AND COMMUNICATION

4.1 Motivations and proposal
Thematic motivation for D2D based services was originally to offload local communications through an optimized data path (D2D path) in order to alleviate the traffic overload in the core network. With the expansion of context-aware applications in the market, the migration towards new types of mobile services based on proximity information in the vision of future cellular networks, studies have demonstrated the tendency to move towards architecture in which core networks realize the functionalities of interest in the network and enhance the performance and reduce cooperation costs of core network extensions for operators. In this context, Cloud Radio Access Network (CRAN) has been proposed as an enhancement to the LTE RAN. It consists mainly of an optimization of NE deployment through he virtualization of some of its functions. Composed of a BBU (Baseband Unit) and a RRH (Remote Radio Head), the NE BBU function is virtualized and centralized in the core network to reduce deployment costs in urban areas, efficiently use processing resources, limit interference issues, and improve scalability of the RAN through collaborative radio mechanisms. In the following, we introduce a hybrid LTE vision of the D2D integration within the LTE EPS architecture.

4.2 Enhanced eNB for local D2D services
From network design point of view, the closest network entity is the eNB. Being the anchor point between the RAN and the EPC, the eNB is responsible for the location information of each UE in the cell (for device in active mode). Assuch, a proper session setup and handoff mechanism is needed in the D2D service. The solution is based on a new D2D discovery mechanism. The eNB is assisted by the operator for the authentication and service authorization aspects. The eNB is responsible for the session continuity at handover. Besides, before the proposal of EPC entities (MME and HSS), the new D2D discovery mechanism is introduced in the LTE protocol stack and to implement the following functions as an evolution to the current NB
4.3 A reliable Direct Discovery mechanism

Before initiating the D2D procedure, we assume that D2D enabled UEs have registered to a specific D2D service through a service platform. AD2D service registration phase consists basically of granting access credentials for a specific CD2D service from an Application Server (AS) using an agent applet. The agent applet is executed on the UE. This bearer is configured through the NASAttach Procedure.

* **network data service (D2D):**

  - The bearer is set up to support real-time services.
  - The bearer is configured through the NASAttach Procedure.

* **Dedicated D2D bearer establishment with D2D resource allocation:**

  - The dedicated D2D bearer is set up to support real-time services.
  - The bearer is configured through the NASAttach Procedure.

* **Initial NAS Attach, D2D Authentication & Authorization:**

  - The UE requests the establishment of a dedicated D2D bearer through the NASAttach Procedure.
  - The bearer is set up to support real-time services.
  - The bearer is configured through the NASAttach Procedure.

* **D2D service registration based on the D2D bearer establishment:**

  - The D2D bearer is set up to support real-time services.
  - The bearer is configured through the NASAttach Procedure.

* **Initialization of D2D service registration:**

  - The D2D bearer is set up to support real-time services.
  - The bearer is configured through the NASAttach Procedure.

* **Mode selection by the UE:**

  - The UE selects the mode it will use for the D2D communication.
  - The mode selection is based on the type of service required.

* **Resource allocation for D2D discovery:**

  - The resource allocation is based on the type of service required.
  - The allocation is set up through the NASAttach Procedure.

* **Direct D2D discovery over E-UTRA:**

  - The D2D discovery is carried out over the E-UTRA network.
  - The discovery is initiated through the NASAttach Procedure.

* **PDN connection & default bearer establishment:**

  - The default bearer is set up to support real-time services.
  - The bearer is configured through the NASAttach Procedure.

* **Interoperability between D2D and LTE networks:**

  - The D2D bearer is set up to support real-time services.
  - The bearer is configured through the NASAttach Procedure.

* **PDN connection & default bearer establishment:**

  - The default bearer is set up to support real-time services.
  - The bearer is configured through the NASAttach Procedure.

* **Interoperability between D2D and LTE networks:**

  - The D2D bearer is set up to support real-time services.
  - The bearer is configured through the NASAttach Procedure.
In figure 4, we propose a signaling call flow for the establishment of the D2D communication after the discovery phase. Both discovered UE and eNB directly communicate with each other and maintain D2D radio bearer context. The role of the MME is to maintain context information and route the D2D bearers. The eNB will allocate an IP address to the UE. The IP address is used in the D2D bearer context for the establishment of the D2D bearer. Using the established IP address, the D2D data is transferred between the UE and eNB. The UE side, D2D traffic is sent to the eNB, and the eNB sends the data back to the UE through the IP network.

Fig. 4. eNB-assisted D2D communication establishment

V. DISCUSSION

The hybrid mechanism proposed above brings new features compared to existing D2D solutions proposed in literature. First, the direct discovery approach is combined with network-assisted communication establishment approach. Thereasonsoft his combination is that operator network has important role to play in the deployment of D2D-based services as trusted parties that can satisfy users' concerns about security and privacy. It is then proposed a control plane signaling for D2D authentication and authorization during the initial attach to the network: this SS0 based mechanism reduces the number of exchanged messages between the UE and the EPC network. From this point of view, we proposed to evolve the current eNB functionalities to support D2D functions: including D2D mechanisms at the EPC level would be contradictory to the basic concept of D2D communication, which offloads D2D traffic to local communications. One of the main objectives of four approaches is to route D2D traffic to the lowest network entity, i.e., the closest entity to the UE.

VI. CONCLUSION

This paper proposes a long-term operator-assisted D2D communication mechanism through a trusted procedure for a Direct D2D discovery over E-UTRA. The operator role in assisting the D2D authentication and authorization of the D2D users is highlighted. Then, a dedicated and optimized signaling for D2D communication establishment was proposed with a specific mechanism to apply a per service QoS. In a more global view, the solution envisages a more active role of the eNB in the EPS architecture for in-network-meeting emerging local and proximity service deployment requirements. Ongoing simulation and modeling work is planned to further investigate and compare the performance of the proposed solution in terms of delays and security in the operator's D2D-oriented RAN and EPC entities.

REFERENCES


elessWorldResearchForum Looks to the Future,"


[7] 3GPP TR 22.803 "Feasibility study for Proximity Services (ProSe)”, 2013

[8] 3GPP TS 23.303 "Architecture enhancements to support Proximity Services (ProSe)”, 2014


