D2D –
Time has Come for Proximity-based Applications

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Definition (3GPP)

Device-to-Device (D2D)  
Proximity Service (ProSe) / D2D def. of 3GPP TR 21.905 / TR 22.803:

- **Discovery / Proximity Service (ProSe)**
  - a process that identifies that a UE is in proximity of another, using E-UTRA or EPC

- **ProSe (Direct/D2D) Communication**
  - a communication between two UEs in proximity
  - the communication path could be established directly between the UEs or routed via local eNB(s)
Two main groups of use cases: 1. **Commercial** 2. **Public Safety**

### Commercial
- Discovery of partner
- Enhance Location / Presence info
- ProSe API to 3rd party app. developer
- Handover support
- ProSe for M2M
- Offloading (WLAN, disaster)

### Public Safety
- ProSe Group / (local) Broadcast
- Implicit discovery
- Discovery within / outside NW coverage
- Relay / Range extension
- WLAN support
Use Cases

Diverse service requirement - examples

Traffic Safety

Offloading

Fast data transfer between devices

Advertisements to terminals for by-passers

Automation

NSPS

Proximity based social networking, gaming

Proximity-enabled communication between a group of terminals

Diversity in terms of use cases, requirements, terminal capabilities, ...
Description

Topology Scenarios & Use Cases

Pure D2D architecture

D2D Multicast Archit.

D2D Relaying Archit.

Localized data service

- M2M (V2V)
- Content sharing
- Multi-user gaming
- Mobile advertising
- Local voice service

Localized data service

- Content sharing
- Multi-user gaming
- Mobile advertising

Localized data service

Relaying

- Relay-functionality
- Sensor networks: UE as gateway to sensors

+ Intra/inter-cell D2D

Data

Control signals
Description
RAN support & Frequency Bands

<table>
<thead>
<tr>
<th>Network controlled (RAN support)</th>
<th>UE controlled (No RAN support)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Licensed band</strong></td>
<td><strong>Disaster case</strong></td>
</tr>
<tr>
<td>eNB</td>
<td></td>
</tr>
<tr>
<td>![eNB diagram]</td>
<td>![eNB diagram]</td>
</tr>
<tr>
<td>![UE diagram]</td>
<td>![UE diagram]</td>
</tr>
<tr>
<td>![Data diagram]</td>
<td>![Data diagram]</td>
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<tr>
<td>![Control signals diagram]</td>
<td>![Control signals diagram]</td>
</tr>
<tr>
<td><strong>Unlicensed band</strong></td>
<td><strong>Ad-hoc mode</strong></td>
</tr>
<tr>
<td>eNB</td>
<td></td>
</tr>
<tr>
<td>![eNB diagram]</td>
<td>![eNB diagram]</td>
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<tr>
<td>![UE diagram]</td>
<td>![UE diagram]</td>
</tr>
<tr>
<td>![Data diagram]</td>
<td>![Data diagram]</td>
</tr>
<tr>
<td>![Control signals diagram]</td>
<td>![Control signals diagram]</td>
</tr>
</tbody>
</table>

Legend:
- eNB: Evolution Node B
- UE: User Equipment
- Data: Data signals
- Control: Control signals
- "Typical D2D": Normal D2D communication
- "Cellular assistance": Cellular assistance
- Ad-hoc mode: Ad-hoc mode communication
- Disaster case: Disaster case communication
### Description

**D2D Discovery & Communication**

<table>
<thead>
<tr>
<th></th>
<th><strong>with NW coverage</strong></th>
<th><strong>w/o NW coverage</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>D2D discovery</strong></td>
<td>Required both for commercial and public safety</td>
<td>Public safety only</td>
</tr>
<tr>
<td>eNB</td>
<td>Control signals</td>
<td>Discovery signal</td>
</tr>
<tr>
<td>UE</td>
<td>Discovery signal</td>
<td>UE</td>
</tr>
</tbody>
</table>

**D2D communication**

**I. Control signals**

**II. Data**

**Public safety only**

**Control signals**

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Relationship between Discovery & Communication

1) Step 1: Discovery
   - D2D Discovery / Proximity Service

2) Step 2: Data exchange
   - Communication (via eNB)
   - D2D Communication (direct link)\(^1\)
   - Implicit Discovery\(^2\)
   - D2D Communication between devices

3) Service Update\(^3\) (client-server)

Benefits for user, operator & service provider due to new information & communication service

- 1) Including LTE direct-link and direct connection via different RAT, e.g. WiFi
- 2) Public Safety Implicit Discovery (D2D communication w/o explicit ProSe Discovery event)
- 3) D2D discovery resp. proximity information could be utilized for applications, too (e.g. as friend-finder, nearest printer or in general device / M2M, targeted advertisement, etc.)
### M2M (Machine to Machine) / MTC (Machine Type Com.)

*(3GPP TR 22.368)*

**Definition:** M2M/MT Communication is a form of data communication between entities that do not necessarily need human interaction.

<table>
<thead>
<tr>
<th>D2D</th>
<th>M2M</th>
</tr>
</thead>
<tbody>
<tr>
<td>Describes connectivity service</td>
<td>Defines a class of devices &amp; is application oriented</td>
</tr>
<tr>
<td>Main target</td>
<td>Discovery and local communication</td>
</tr>
<tr>
<td>Type of device</td>
<td>Not defined (arbitrary)</td>
</tr>
<tr>
<td>Number of devices</td>
<td>Typically two or a few</td>
</tr>
<tr>
<td>Location</td>
<td>Proximity</td>
</tr>
<tr>
<td>Communication</td>
<td>Between devices (D2D)</td>
</tr>
</tbody>
</table>
Business Impacts of D2D Discovery

D2D Discovery creates *new proximal end-to-end communication pairs*

➔ opens new service opportunities and creates new end-to-end traffic

Operator KPI: Unified & easy AAA/charging
Business Impacts of D2D Communication

D2D Communication can efficiently handle new large amount of end-to-end traffic enabled by D2D Discovery.

Benefits:
- Higher throughput
- Shorter delay
- Higher spectral efficiency
- Traffic offloading
- etc.
Business Impacts
Competitive Advantages of Mobile Network Operators

• **QoS**: Guarantee of QoS (assignment of dedicated spectrum / resources)
  – Low latency, high bandwidth,
• **Reliability**: Stable Proximity Service (discovery and communication)
  – Carrier-grade infrastructure & network elements
  – Different communication paths (diversity) → availability / coverage
• **Mobility management** / handover support (infrastructure / D2D mode)
• **Security**: Apply security schemes known from cellular system
• **Legacy voice service**: Conventional numbering scheme & QoE
  – No pairing like used for BT, WiFi, ...
• **Energy** consumption: Support of power management
• **Provisioning & scalability**: Availability of infrastructure for management of high number of devices
• ...

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Trends & Drivers

Technical Trends

TDD for 5G

TDD for D2D communication

D2D as “connectivity mode” for M2M

D2D for energy saving (Green IT)

D2D enabled UE for wireless backhaul

D2D increases resource efficiency

Social communities and sharing within small groups

Social / Economic

Public safety → supports discovery AND communication

Standardization

Public safety and commercial service are developed jointly

Standardization of ProSe in RAN1 and SA1
• Hybrid usage of lower & higher frequency bands (e.g. 2 GHz & 3.5 GHz)

• Proposed macro-assisted small cell – “Phantom cell”
  – Split of C-plane and U-plane between macro & small cells in different bands
  – Phantom cells likely to be dynamic TDD as it is the case for D2D
  – Link between UE and Phantom cell is similar to D2D link

2 GHz (Example)
✓ No coverage issue anymore

3.5 GHz (Example)
✓ High throughput
✓ Big offloading gain
Challenges

Challenges for efficient **D2D Discovery**
- Half-duplex scheme (TDD)
  - Discovery signals might collide
  - UE cannot listen to others while it is transmitting

Challenges for **D2D Communication**
- if UE controlled: Collisions problem, critical for latency-sensitive D2D service & local sub-optimal due to the lack of NW support
- If NW controlled: spatial re-use not possible (e.g. w/o GPS info.); high RRC signaling overhead; not applicable out of NW coverage
- D2D between devices subscribed to different operators
  - Which spectrum to use (for direct communication)?
- Lawful interception
  - How to monitor direct communication?
- Charging
  - How to perform (content-based) charging?
  - How to charge if D2D communication is supported w/o NW coverage?
- Privacy, Security, Authentication, Out-of-the-box operation (for public safety), ... etc.
Approach: (1) Introduce resource group (RG) patterns, (2) allocate UEs to a RG, (3) let each UE arbitrarily select one discovery resource (DR) within the allocated RG

Definition
• RG pattern is a set of RGs
• RG is a set of DRs or only one DR

Each UE deterministically select allocated DR

Fully centralized

Partially centralized

Fully distributed

Each UE arbitrarily select 1 DR out of 16 DRs in RG4
From radio propagation point of view, UE group A and B have good spatial separation
⇒ The entire radio resource can be used by Group A and B simultaneously.
⇒ Further improve the spectrum efficiency of D2D discovery

⇒ New signaling and procedures are needed for Smart Discovery Resource Allocation that enables spatial resource re-use
• Proximity Services / D2D offer plenty of potential use cases and business opportunities
• Many drivers exist for D2D
  – With increasing importance of TDD the basic communication mode will be provided as part of the next generation network
  – With the introduction of D2D for public safety also commercial services will become reality
→ Time has come for Proximity-based applications - D2D

• Phantom Cell - Architecture including D2D
• Many challenges to be solved for: D2D Discovery and D2D communications
  – Resource Groups: Solution for efficient D2D Discovery

…. Still a lot of research to be performed!
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Topology Scenarios
D2D Communication Options

- D2D Communication Paths

  via Gateway
  
  via eNB
  
  Direct Communication

Ia.

Ib.

II.
Device Status

- Policy and user choice can set the ProSe feature to enable a ProSe-enabled device (UE) (TR 22.803):
  - to discover others in its proximity but **not be discoverable**;
  - to be discoverable but **not be able to discover others** in its proximity;
  - to **discover others** in its proximity and **be discoverable**;
  - to **disable discovery** (disable ability to be discoverable and to discover others).
  - to **revoke being discoverable** by others (i.e. be discoverable by a UE at one time, and then not discoverable by the same UE at another time);
  - to **discover others of interest**, or to restrict discoverability to others of interest, where interest is defined in a ProSe-enabled application per user, group of users, or category of users;

- Operator policy and user choice can be different for licensed vs. unlicensed spectrum.
3GPP MTC Architecture

- 3GPP Architecture for Machine-Type Communication (TS 23.682 v11)