Device-to-Device

Communications in 3GPP LTE

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Introduction
Introduction

• 3GPP Long Term Evolution (LTE) is the key technology for 4G wireless cellular communications

• Large user base makes it attractive for Public Safety (PS) applications as well
  • Economies of scale
  • Possible use of commercial networks
  • State-of-the-art technology available sooner
D2D communications is required to support Public Safety operation

- LTE is built upon the cellular model
  - No direct connection between devices before Release 12!
- PS is supposed to mostly use infrastructure-based communication
  - ...BUT device-to-device (D2D) communications MUST be supported as well
- D2D is supposed to cover critical use cases:
  - Out-of-coverage communications
  - Relaying for extended coverage
  - Communications in case of network failure, e.g. due to earthquakes
But can LTE support it?

- In any case, is it feasible to build such functionality into LTE?
- Pros: LTE is a flexible system
  - It is possible to multiplex signals in time and frequency domain
  - Base stations can coordinate devices in a very dynamic manner
  - LTE is designed to cope with different levels of interference
- Cons: D2D impact to cellular communications and to specifications
  - D2D transmissions may negatively impact cellular communications
  - LTE is flexible, but still there are limits to what can be changed
- Once defined, commercial customers may benefit from D2D as well where applicable, e.g. over-the-air direct discovery
General design principles
Scope of D2D in LTE

- LTE release cycles: Release 12 to be formally finalized this week
- Device-to-Device (D2D) = Proximity Services (ProSe)
- Rel-12 was the first release to include D2D/ProSe functionality
  - D2D communications
  - D2D discovery

<table>
<thead>
<tr>
<th></th>
<th>Within LTE network coverage</th>
<th>Outside LTE network coverage</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Discovery</strong></td>
<td>Non public safety &amp; public safety</td>
<td>Not supported</td>
</tr>
<tr>
<td><strong>Direct Communication</strong></td>
<td>Public safety only</td>
<td>Public safety only</td>
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</tbody>
</table>
General design

• Terminology: Uplink (UL) / Downlink (DL) / **Sidelink (SL)**

• D2D uses UL resources:
  - UL spectrum (in case of cellular FDD)
  - UL subframe (in case of cellular TDD)

• Half-duplex operation
  - D2D itself is TDD, even if cellular network is FDD

• D2D signals are mostly based on UL signal design
Synchronization

• Synchronized operation of D2D is assumed within a certain area (e.g. cell)
  - Allows efficient multiplexing of D2D transmissions

• Synchronization principles
  - In coverage, terminal synchronizes to the network
  - If out of coverage, device-based synchronization procedure

• Under some conditions, devices in edge-of-cell transmit synchronization signals to assist inter-cell and out-of-coverage synchronization and to align it with cellular network timing

• Different priority levels for different synchronization sources
**Resource pools**
New concept in LTE

- D2D is based on the concept of *resource pools*

- D2D can be added as a "plug-in" to LTE air interface enabling also legacy cellular terminal operation on that carrier

- Applies to both discovery and communications
Coexistence between D2D and cellular communications

- Some design principles that help with coexistence
  - Synchronization to cellular network
  - Resource pools
  - Scheduling by cellular network taking into account (potential) D2D

- Nevertheless, there is still impact to cellular Uplink
  - Inband emissions, near-far problem
  - Different air interface parameters

- Main solution to manage residual interference: power control, which is independently configured for different D2D signals
D2D Communications
D2D Communications in LTE

- Broadcast-based communications in physical layer
  - Same solution for broadcast, groupcast, and unicast
  - Full open loop operation: no control loops, no feedback, no HARQ, no link adaptation,…
  - Transmitter is not aware if there is a receiver around at all!

- Group/user identification based on higher layers

- Main requirements defining the way D2D broadcast operates:
  - Communications between two devices to be possible independently of network connection
  - Main focus: group communications with PTT (VoIP) applications or low data rate communications.
Resource allocation and coverage conditions

- Prior to data transmission, every transmitter sends a control signal with information on the data transmission format
  - Applies even if network is assigning resources to the transmitter
  - Receivers do not need to listen to cellular to be able to receive D2D

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<thead>
<tr>
<th></th>
<th>Network controlled</th>
<th>Autonomous</th>
</tr>
</thead>
<tbody>
<tr>
<td>Resource allocation</td>
<td>Device is assigned specific resources</td>
<td>Devices choose the resources</td>
</tr>
<tr>
<td>Resource pool</td>
<td>Control only</td>
<td>Control and data</td>
</tr>
<tr>
<td>In-coverage</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Out-of-coverage</td>
<td>No</td>
<td>Yes</td>
</tr>
</tbody>
</table>
D2D Discovery
D2D Discovery in LTE

• What does it mean
  - Devices are able to discover other devices in their surroundings using direct radio links
  - ‘Always-on’ type of operation: independent of ongoing or upcoming data communications between the devices
  - D2D discovery is NOT a required step for D2D communications

• Main requirements considered in the work
  - Standalone process or as an enabler for other services.
  - D2D discovery shall be able to accommodate potentially large numbers of devices
Basic functionality for D2D Discovery

• In Rel-12 discovery is available only for devices within network coverage.

• Similar to communications, two types of resource allocation exist:
  - Autonomous resource selection
  - Network allocation of resources

• Discovery resources are supposed to be concentrated in time, but separated by long periods of time (up to ~10s).

• Within the discovery period devices broadcast small messages of fixed size.
Challenges for D2D discovery

- Half-duplex operation brings challenges to discovery
  - Very large number of devices makes it difficult to multiplex in time domain only
  - In principle, all devices want to discover every other device

- Handled by devices transmitting at different times in next "discovery period"

*Half-duplex problem:* Device 1 can listen devices A, B, C, but not devices 2 and 3
Future prospects
3GPP LTE D2D story is not over yet – ongoing standardization

• Rel-12 was not the last release to introduce major D2D functionalities

• Main features that have been postponed to Rel-13 (approved already, to start in April):
  - Device-to-Network relay
  - Out-of-coverage discovery
  - Improvements to multi-operator support (mainly for commercial use cases)

• Other potential PS features that are not in scope of Rel-13:
  - Device-to-device relay
Other applications for D2D in 3GPP LTE beyond Rel-12 use cases

• New applications of Rel-12/13 D2D functionality are expected
  - Nevertheless, non-technical reasons may limit application of technology as well, e.g., legal interception requirements

• Potential new development: Vehicle-to-vehicle (V2V) communications
  - 3GPP is currently studying use cases and requirements for V2V, as well as vehicle-to-infrastructure and vehicle-to-pedestrian communications → Vehicle-to-X (V2X)
  - Technical work to support these features and use cases may start later on
Personal observation

D2D requires traffic that is truly local