Device-to-Device Communications in 3GPP LTE

Cássio Ribeiro

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Outline

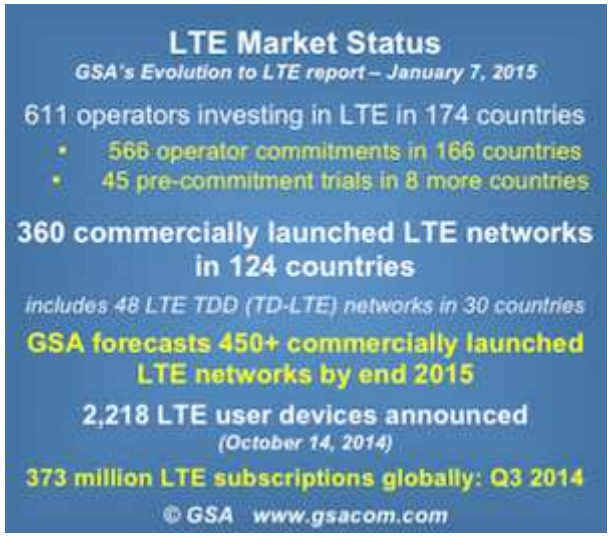
- Introduction
- General design principles
- D2D Communications
- D2D Discovery
- Future prospects

Introduction

Introduction

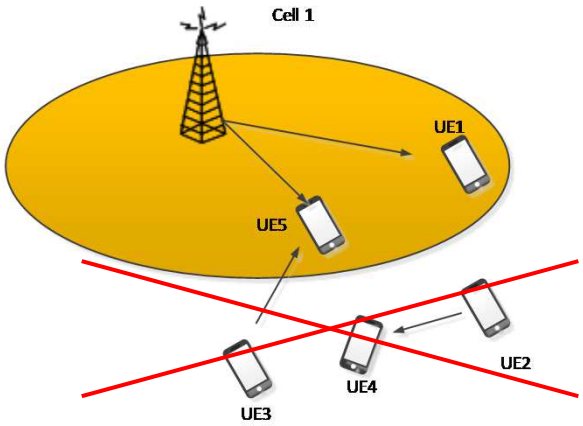
- 3GPP Long Term Evolution (LTE) is the key technology for 4G wireless cellular communications

- 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

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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

	Within LTE network coverage	**Outside LTE network coverage**
Discovery	Non public safety & public safety	Not supported
Direct Communication	Public safety only	Public safety only

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

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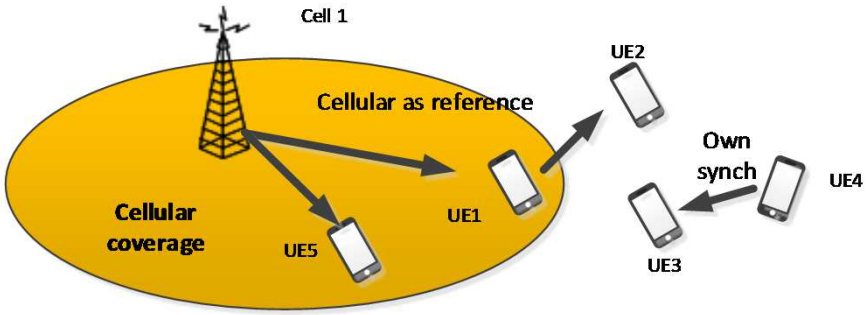
Synchronization

- 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

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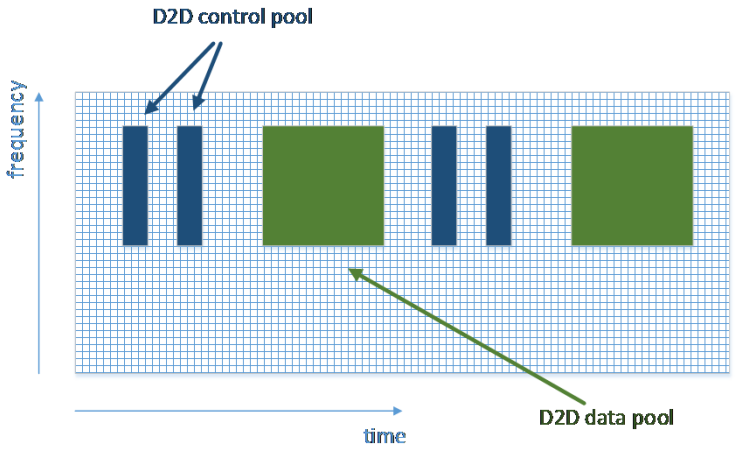
Resource pools

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

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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.

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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

	Network controlled	Autonomous
Resource allocation	Device is assigned specific resources	Devices choose the resources
Resource pool	Control only	Control and data
In-coverage	Yes	Yes
Out-of-coverage	No	Yes

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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

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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

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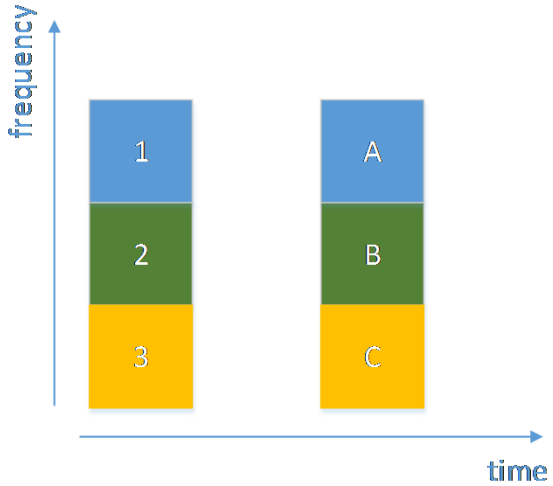
Challenges for D2D discovery

- 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

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Future prospects

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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

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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

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Personal observation

D2D requires traffic that is truly local

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