

# An overview of D2D in 3GPP LTE standard

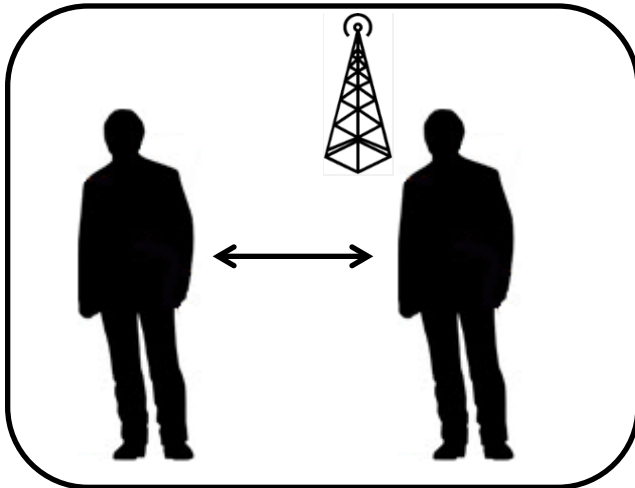
Sofia Martinez Lopez

21st June 2016

# Introduction

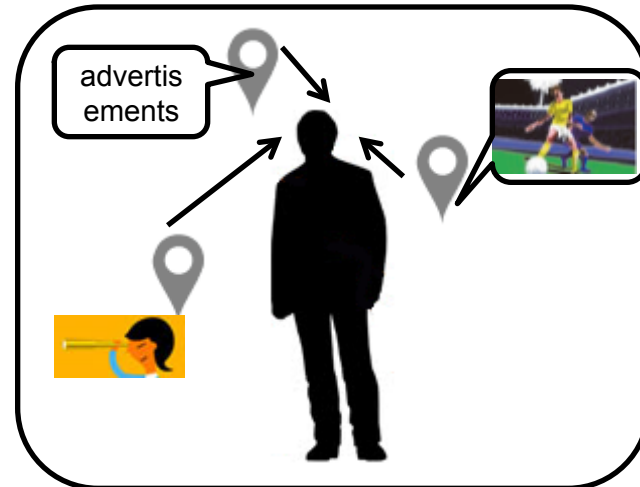
**ProSe** stands for 'Proximity Service'

## D2D communication



- Data and voice exchange among nearby user equipments

## D2D discovery



- Discovery of user equipments and/or services

# Outline

1. **Use cases**
2. **How does it work?**
3. **Comparison of D2D technologies**

# Outline

## 1. Use cases

- Public Safety D2D
- Commercial D2D Discovery
- Currently under study: V2V
- Beyond: wearables, IoT...

## 2. How does it work?

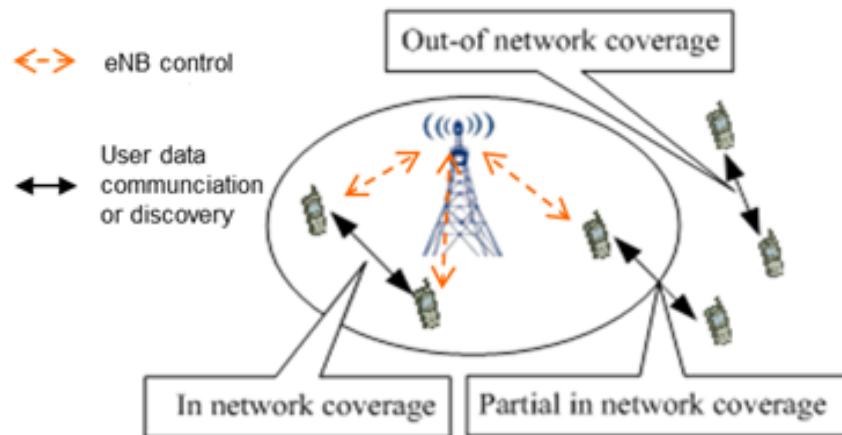
## 3. Comparison of D2D technologies

- The presented scenarios do not reflect Orange position

# Use cases (1)

## D2D for public safety applications

- The main motivation to define D2D communication in LTE Rel.12 is for Public Safety (PS) authorities such as police, firefighters and ambulances, to replace relatively old technology such as the TETRA system developed in the 90s
  - Reduce network deployment and operational cost
  - Support broadband
- Available when cellular networks are not available or fail (ex: disaster area after an earthquake) → **in/partial/out of coverage** (in Rel.12 only D2D communication can be done out of coverage)
- **Dedicated/Shared spectrum**



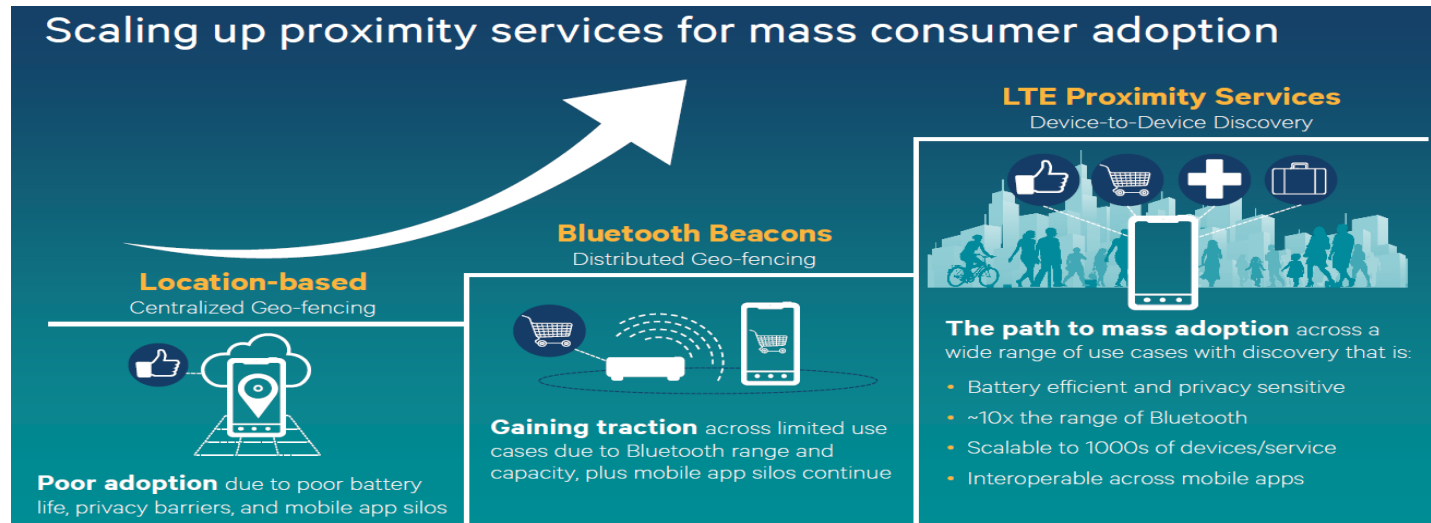
- **D2D Relays** (Rel.13)
- **Priority handling** (Rel.13)
- **D2D Discovery**

Rel.12: only within coverage

Rel.13: in/partial and out of coverage

## Use cases (2)

### D2D Discovery for commercial applications



[Creating a digital 6th sense with LTE Direct, Qualcomm]

**Examples:** finding friends nearby, hyper-local advertising, e-health etc

- **Open vs restricted discovery.** In the latter case explicit permission is required from the device that is being discovered (security and privacy)
- **Model A** ('I am here!') vs **Model B** ('Who is there?', 'Are you there?')

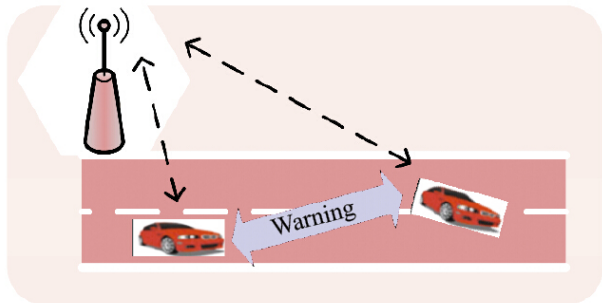
#### Deployment aspects:

- Multiple carriers and Inter-PLMN
- Only enabled for the **in-coverage** scenario

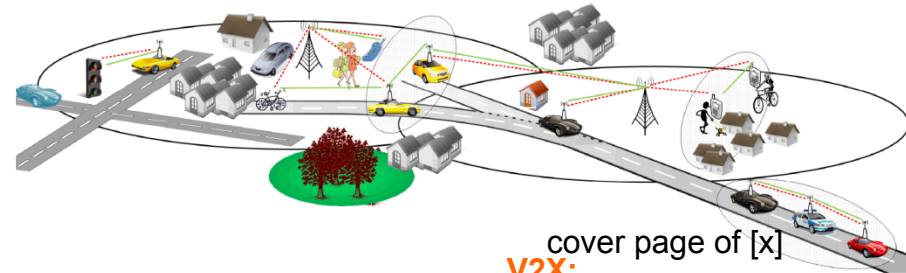
## Use cases (3)

### V2V

- Connected cars



## 5G Automotive Vision



### V2X:

**V2V:** Vehicle to Vehicle

**V2I/N:** Vehicle to Infrastructure/Network

**V2P:** Vehicle to Pedestrian

- The market for V2V communication is time sensitive
  - Direct Short Range Communication (DSRC), based on IEEE 802.11p is already standardized. 75 MHz of bandwidth in the 5.9 GHz region
- Not specified yet** but a feasibility study has been conducted in Rel.13 (TR 36.885)
- Possible (not decided yet! ) scenarios** to be considered in the next **Rel.14:**
  - In and out of coverage
  - Dedicated and shared carrier
  - Relative speed of up to 500 km/h
  - Other V2X services, especially V2I/N and V2P services could be considered
  - V2V based on not only LTE D2D interface but also LTE cellular or a combination of both



## Use cases (4)

### V2V

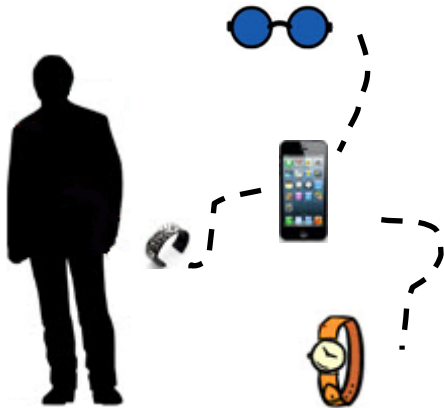
- Missing features for V2V over LTE-D2D have been identified, to be solved during next Release, Rel.14

	ProSe limitations / missing features
Primary (consensus at 3GPP)	1. Collision risk in sidelink transmission mode 2 (UE autonomous resource selection) as a result of random resource selection from (pre)configured resource pool.
	2. Time Resource Pattern (TRP) length (8 bits for FDD mode) for PSSCH subframe allocation insufficient for high density situations involving many simultaneous transmission sources within close proximity, due to half-duplex constraint (i.e., a UE cannot transmit and receive on sidelink in the same subframe).
	3. Handover of Mode 1 resource allocation needs further optimization. This is key as many vehicles will cross cell boundaries at any given time.
	4. Suboptimal pilot scheme for sidelink channel estimation in highly time-variant channels.
	5. Limitations of ProSe security mechanisms. ProSe security as well as LTE security, are not yet applicable for V2X due to the differences in use cases (this may change in Rel-14). Therefore, new mechanisms may need to be adopted.

## Use cases (5)

Beyond 3GPP Release 13...

- **D2D wearables networks and other low-cost IoT?**

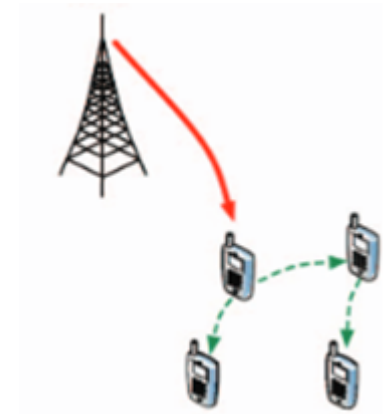


- **Ultra-low latency??**

tactile internet?



- **Cellular offload??**



ex: caching strategies

# Outline

## 1. Use cases

## 2. How does it work?

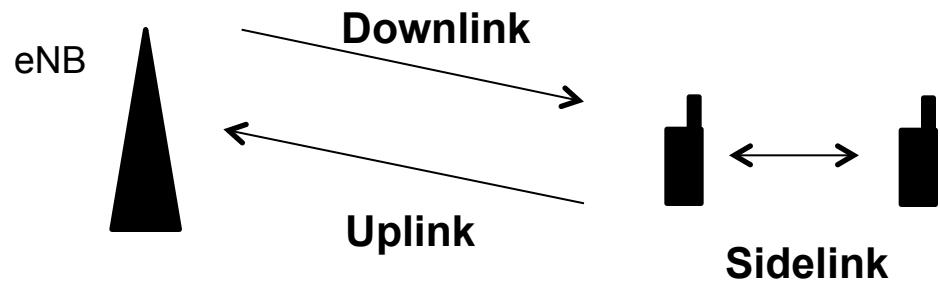
- General
- Resource allocation: scheduled mode vs autonomous mode
- Procedures: Synchronization, Relaying operation
- Physical Layer issues and Solutions

## 3. Comparison of D2D technologies

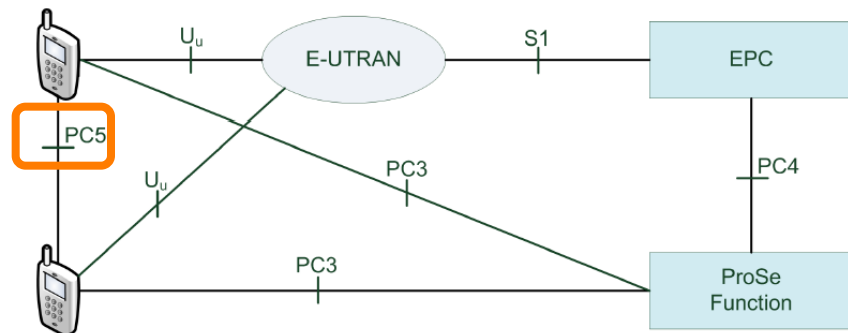
# General (1)

## System Aspects

- D2D in LTE standard is called **Sidelink**.



- The new radio interface is called **PC5**



**ProSe** stands for  
'Proximity Service'

Simplified architecture for ProSe (not roaming)

## General (2)

### System Aspects

- LTE D2D uses **Uplink** resources
  - Sidelink LTE reuses part of the Uplink phy layer design  
ex: SC-FDMA, reference signals etc
- LTE-D supports both **FDD** and **TDD**
- **Network synchronization** is not required but enhances performance (inter-cell)
- No cluster head
- Only **broadcast D2D** communication/discovery from phy layer perspective
  - There is no feedback channel for sidelink communication
  - One-to-one sidelink communication can be established by higher layer
- **Steps for D2D Communication/D2D Discovery :**
  - Synchronization and radio parameter acquisition
  - D2D Communication/D2D Discovery/D2D relay procedure ← resource allocation

## General (3)

### New physical channels and signals

- **Synchronization signals:**

- Sidelink Primary Synchronization Signal (SPSS)
- Sidelink Secondary Synchronization Signal (SSSS)

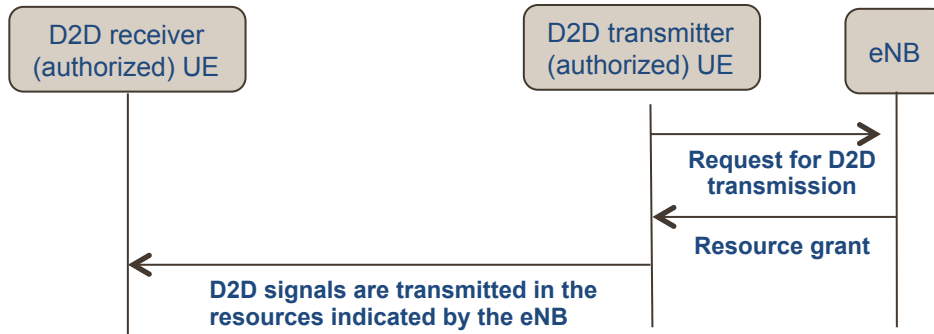
- **Physical channels defined in the sidelink:** TS 36.201

- Physical Sidelink Broadcast Channel (PSBCH),
- Physical Sidelink Control Channel (PSCCH),
- Physical Sidelink Shared Channel (PSSCH)
- – Physical Sidelink Discovery Channel (PSDCH),

+ two new System Information Blocks (RRC signaling): SIB18, SIB19

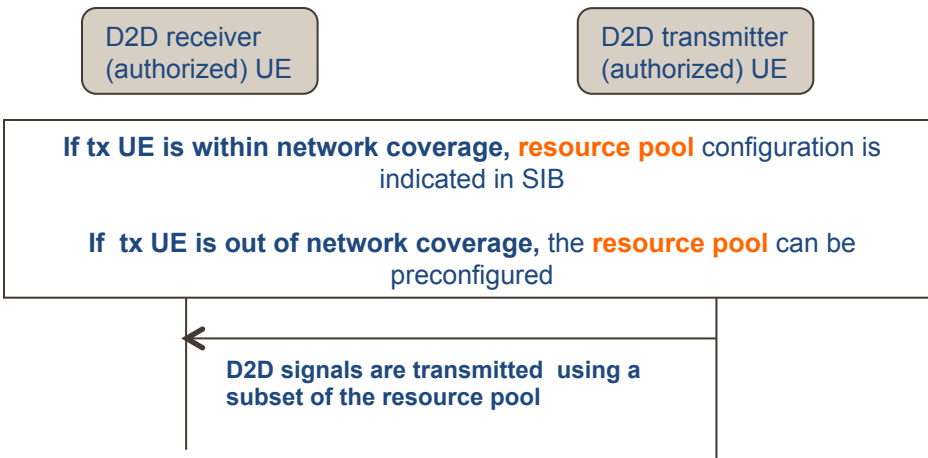
# Resource allocation (1)

## Scheduled mode versus Autonomous mode



- **Scheduled** mode: eNB indicates the physical resources to be used on a UE-specific basis

→ Collision avoidance



- **Autonomous** mode: A UE on its own selects resources from resource pools allocated on a non-UE specific basis

→ Immunity to network failure

D2D UEs can be in **RRC-CONNECTED mode** or **RRC-IDLE mode**, if authorized by the network. Except for scheduled mode, where the tx D2D UE needs to be RRC-CONNECTED

## Resource allocation (2)

Both modes can be applied to D2D Com. and D2D Discovery

### ▪ Scheduled

### ▪ Autonomous

#### ▪ D2D Communication

##### Mode 1

- Only in-coverage
- Resources for transmission on PSCCH and PSSCH are indicated using Downlink Control Information from eNB

##### Mode 2

- In coverage and out of coverage
- Resource pools config. for D2D transmission and reception on PSCCH and PSSCH (up to 8)

#### ▪ D2D Discovery

##### Type 2b\*

semi-persistent allocation

- Only in-coverage
- Resources for transmission on PSDCH are indicated using Downlink Control Information from eNB

##### Type 1

- In coverage and out of coverage
- Resource pools configurations for D2D transmission and reception on PSDCH

\* During standardization, Type 2a (non-semi-persistent) was discussed but only Type2b became relevant to be specified



## Resource allocation (3)

Switch between scheduled (Mode 1) and autonomous (Mode 2) for D2D communication

- In coverage, the UE uses only the resource allocation mode **indicated by the eNB**
- Exceptionally, UE can autonomously **switch from scheduled to autonomous mode** when (as required by public safety organizations) one of the following timers are running:
  - T311: RRC connection re-establishment procedure)
  - T301: transmission of RRCConnectionReestablishmentRequest)
  - T310: physical layer problems

# Resource allocation (4)

## Resource pools

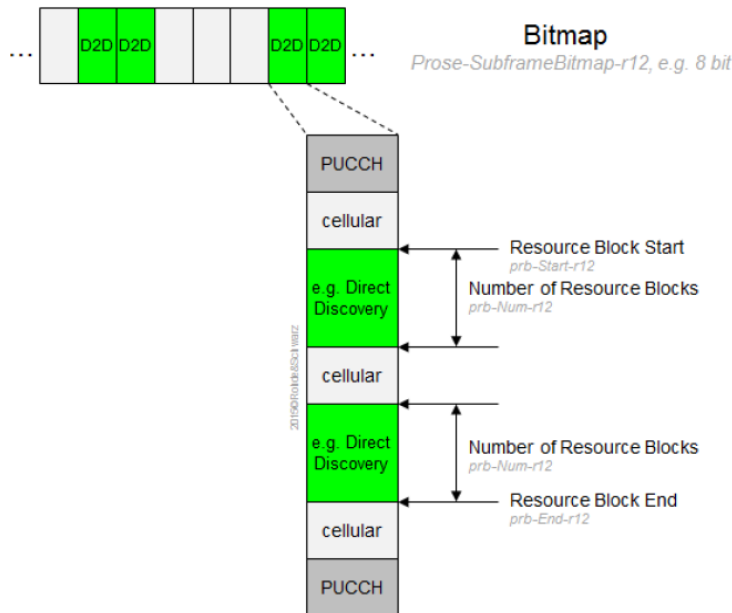


Fig. 2-19: Resource Block Allocation for LTE D2D ProSe (Example: Direct Discovery)

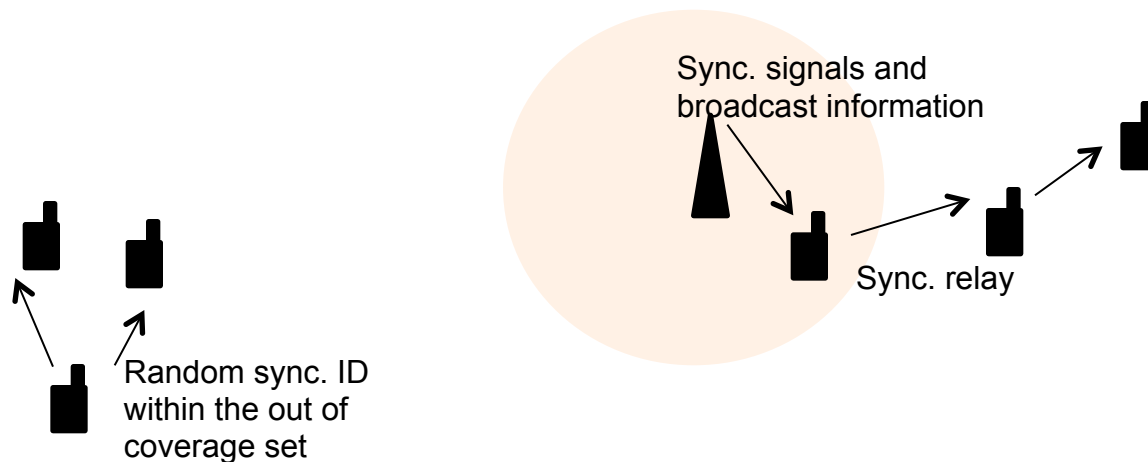
- In **coverage**, resource pool configuration is signaled in **broadcast information** (RRC signaling, SIBs) transmitted from the eNB
- In **out of coverage**, the UE uses **preconfigured parameters** for D2D
- up to 8 transmission pools for D2D communication. Each pool can have one or more PPPP (ProSe Per-Packet Priority) associated with it
- Operator can **dimension** resource pools depending on the expected traffic (shared spectrum)

[‘Device to Device Communication in LTE Whitepaper’ Rohde & Schwarz ]

# Procedures (1)

## Synchronization

- In order to demodulate the D2D data, the receiver has to **synchronize in time and frequency** to the sender
- The synchronization procedure **depends on the coverage situation** of the transmitting UE:
  - Both UEs are in coverage of the same cell or of two synchronized cells  
→ cellular synchronization provided by eNBs
  - UEs are in different non-synchronized cells or at least one UE is out of coverage  
→ new synchronization where some UEs will transmit sync signals.



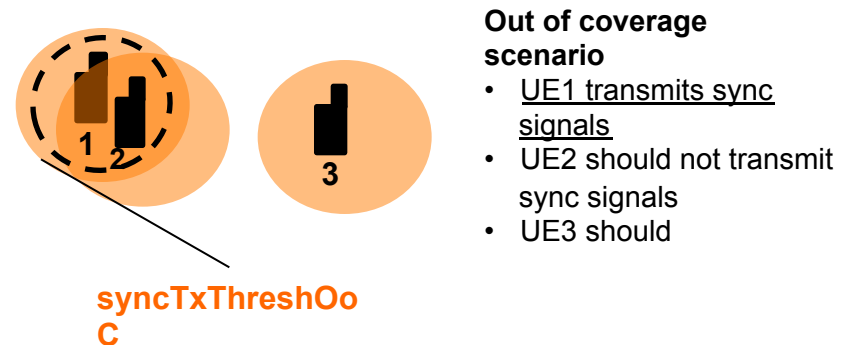
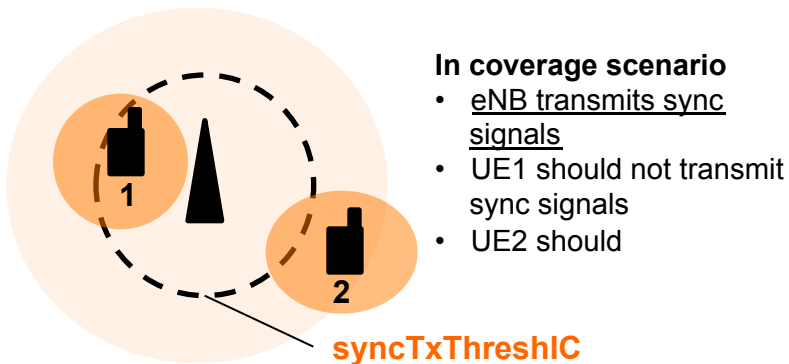
The arrows indicate the transmission of the sync. signals

# Procedures (2)

## Synchronization

### Global/system synchronization

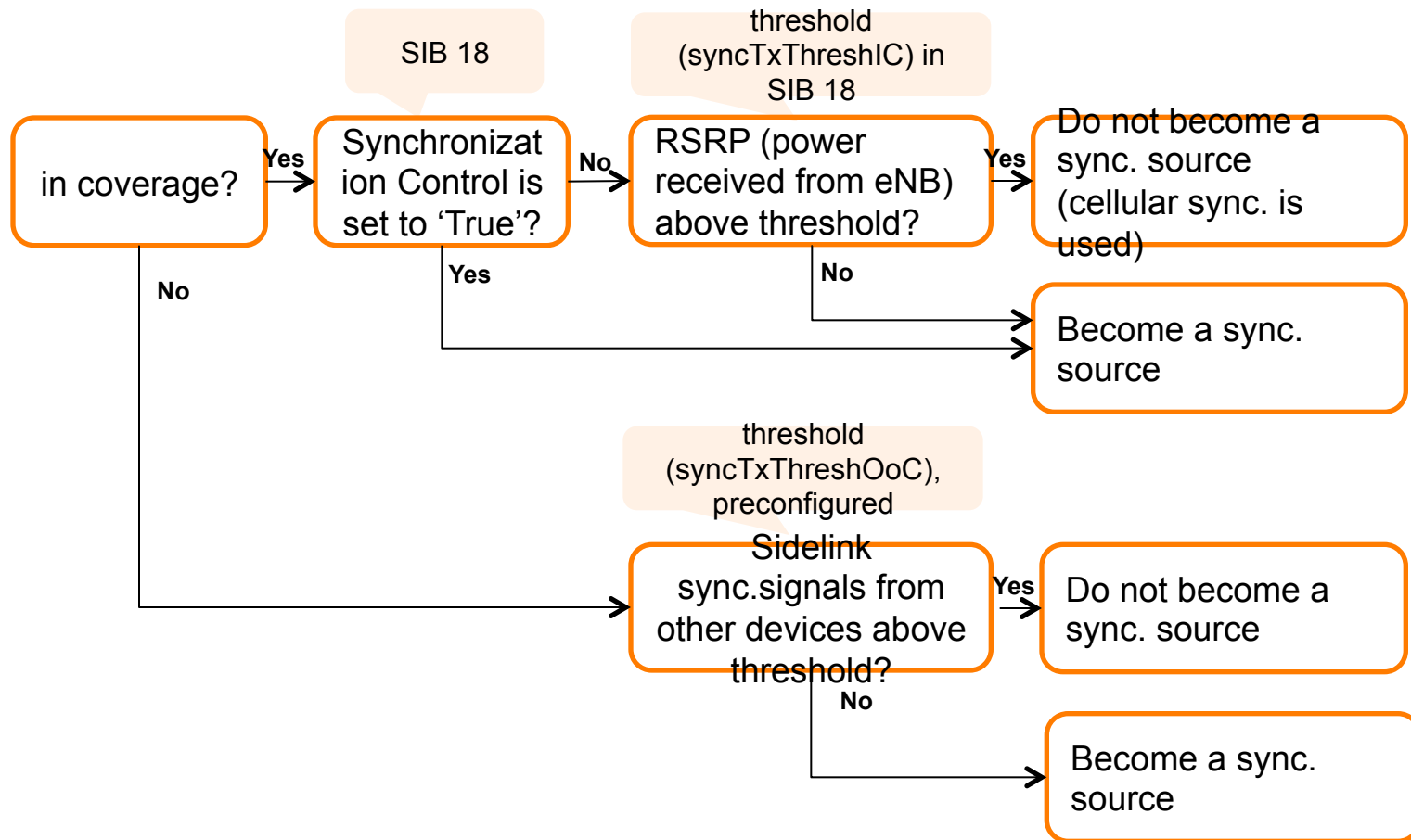
- The number of different synchronization sources should be minimized (interf., battery consumption)
- UEs that are close to a synchronization source do not transmit sync. signals (syncThreshIC and syncThreshOoC)



# Procedures (3)

## Synchronization

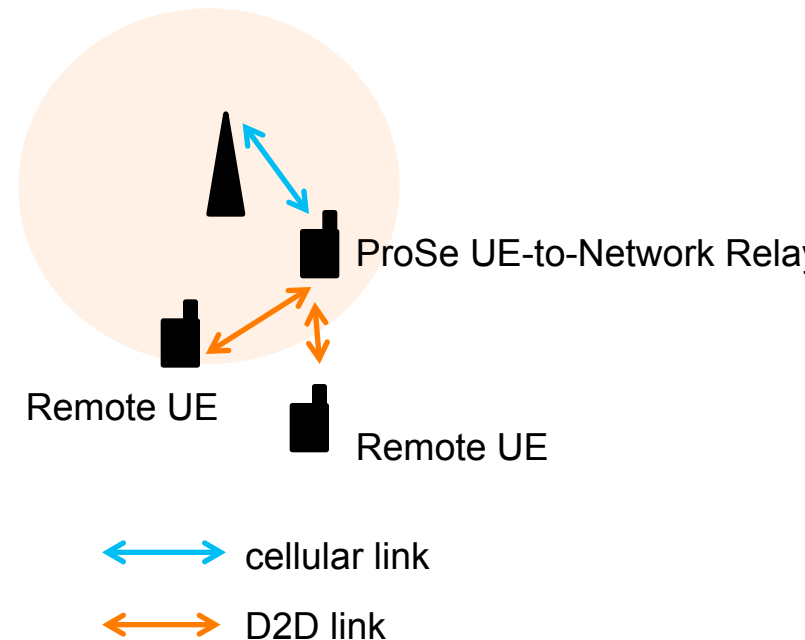
When should a tx D2D UE become a **synchronization source**?



# Procedures (4)

## D2D Relay

- Range extension
- L3 forwarding function
- The **ProSe UE-to-Network Relay** is always in-coverage.
- The **remote UE** can be in-coverage (service continuity) or out of coverage.
- The **eNB** provides:
  - Transmission/reception resources
  - A min/max threshold on cellular link quality that the D2D Relay UE needs to respect
  - A max threshold on cellular link quality that the remote UE needs to respect before it can transmit Relay discovery solicitation messages
  - A threshold on D2D link quality for reselection



# Procedures (5)

## D2D Relay

Release 13

101

3GPP TS 23.303 V13.3.0 (2016-03)

ProSe UE-to-NW  
Relay must be in  
RRC-CONNECTED  
mode

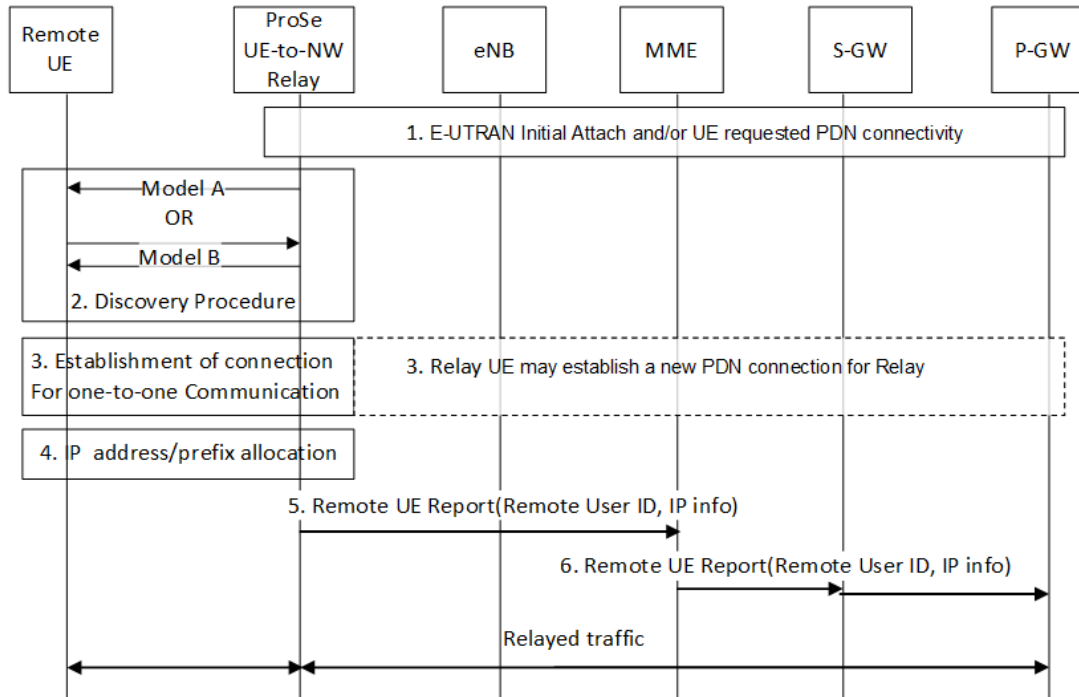


Figure 5.4.4.1-1: ProSe UE-to-Network Relay

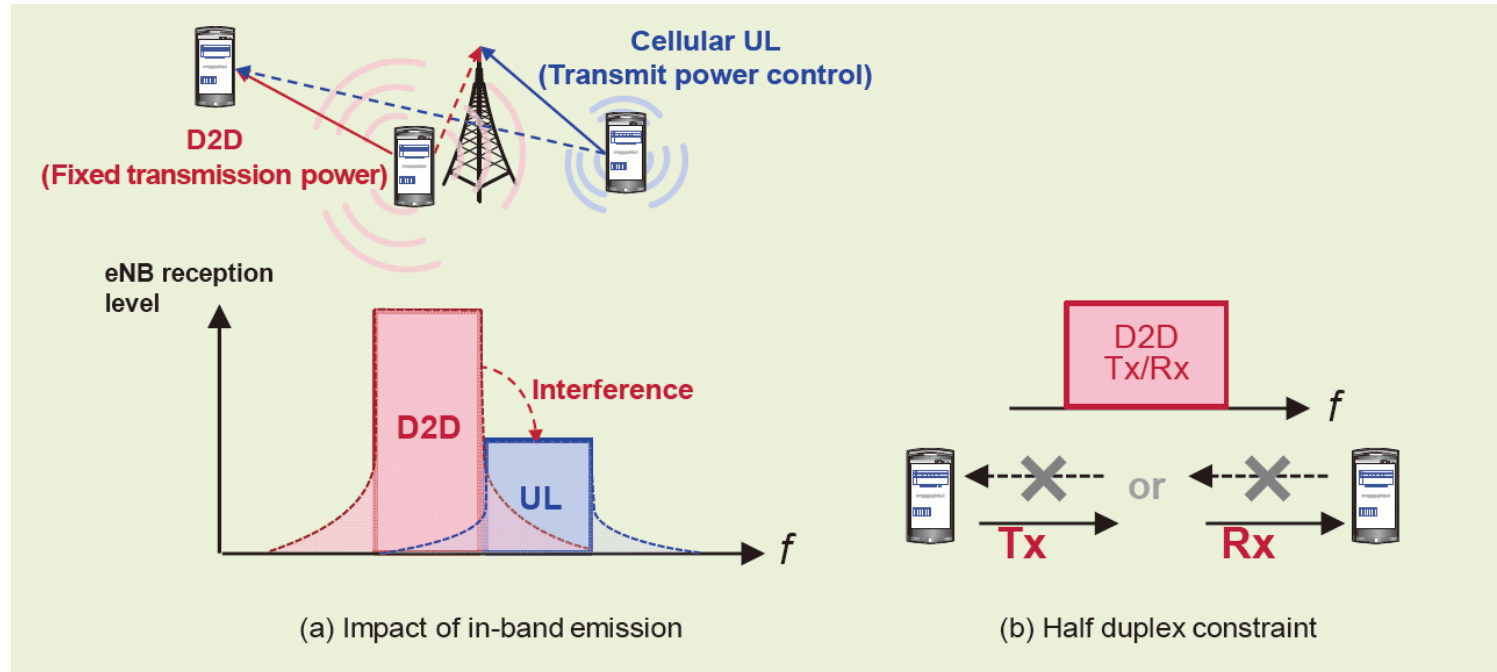
Discovery announcement message (for channel monitoring)

Relay channel measurements

relay channel is weaker  
than threshold?

Relay reselection

# Physical Layer Issues and Solutions (1)



## Physical layer issues in LTE D2D

figure taken from 'D2D Communications in LTE-Advanced Release 12', NTT Docomo Technical Journal Vol.17, No. 2

- Problem of in-band emission → solution: **Open loop transmit power control** of D2D link (next slide)
- Problem of half duplex constraint → solution: **Repetition Transmission and Time&Frequency hopping**, with a different pattern for each UE



# Physical Layer Issues and Solutions (2)

## Power control of D2D link

typically 23 dBm

- $P_{\text{tx cellular,subframe } i} + P_{\text{tx D2D,subframe } i} < P_{\text{cmax}}$
- **3 range classes for D2D discovery** have been defined for different applications: low/medium/high range.
  - Applications are matched to one of these range classes using the operator ProSe Function.
  - Then the range class is translated into actual maximum transmit power at RAN level: Maximum allowed transmission power for each range class is broadcasted by eNB (in

Note that transmission power modifies the range but a precise range cannot be guaranteed, since it depends on the channel propagation at a given frequency carrier.

P <sub>max</sub> (example)	31 dBm*	23 dBm	12 dBm	0 dBm
Median range (outdoor NLOS @ 2 GHz with -107 dBm sensitivity)	~500m	~350 m	~170m	~75m

Example of D2D range depending on transmission power [5]

\* Maximum transmit power for LTE UEs is 23 dBm, except for some bands where 31dBm can be used for PS

# Physical Layer Issues and Solutions (3)

## Power control of D2D link

- For in coverage, **open loop power control** can be applied to D2D communication and D2D discovery, for both resource allocation modes
  - Can be applied to PSCCH (Control CHannel for com.), PSSCH (D2D Data Communication), PSDCH (D2D Discovery) and synchronization signals, separately

$$P = \min \left\{ P_{\text{MAX}}, 10 \log_{10}(M) + \underbrace{P_0 + \alpha}_{\text{}} \cdot PL \right\}$$

Bandwidth of the channel expressed in number of resource block. Ex: for discovery M=2.

The higher the PL (pathloss), the higher the UE is allowed to transmit D2D, since interference is lower

- Tradeoff interference protection/D2D range
- For D2D communication mode 1 (scheduled mode), open loop power control can be deactivated (TPC command set to 0).

**Example of use case:** maximize range for Public Safety

$$P_{\text{PSSCH}} = P_{\text{MAX}}$$

# Outline

1. Use cases
2. How does it work?
3. Comparison of D2D technologies

## Comparison with other D2D technologies

	<b>LTE D2D</b>	<b>Wifi-Direct and Wifi-NAN (Neighbor Awareness Networking)</b>	<b>Bluetooth Low Energy</b>
Spectrum	Licensed *	Unlicensed	Unlicensed
Range	Around 500 m at 2GHz	Around 50m indoors and 100m outdoors	Up to 50m but most devices only achieve 10m
Energy consumption	Low global sync, idle mode operation	Medium	Low
Cluster head	No	Yes – Group owner/ Group formation phase	Yes - One master device can serve up to 7 active (255 passive) slaves in a star topology

\*Operators can control the devices and beacons that can access that spectrum, which gives better control, management and privacy.

# Conclusion

- D2D Discovery / D2D Communication / D2D Relay
- Public Safety / Commercial applications
- In coverage / Partial / Out of coverage
- Dedicated / Shared spectrum
- 2 resource allocation modes for LTE sidelink: scheduled/ autonomous
- Global synchronization
- Advantages of LTE D2D over other D2D technologies: integration over LTE, licensed spectrum, range

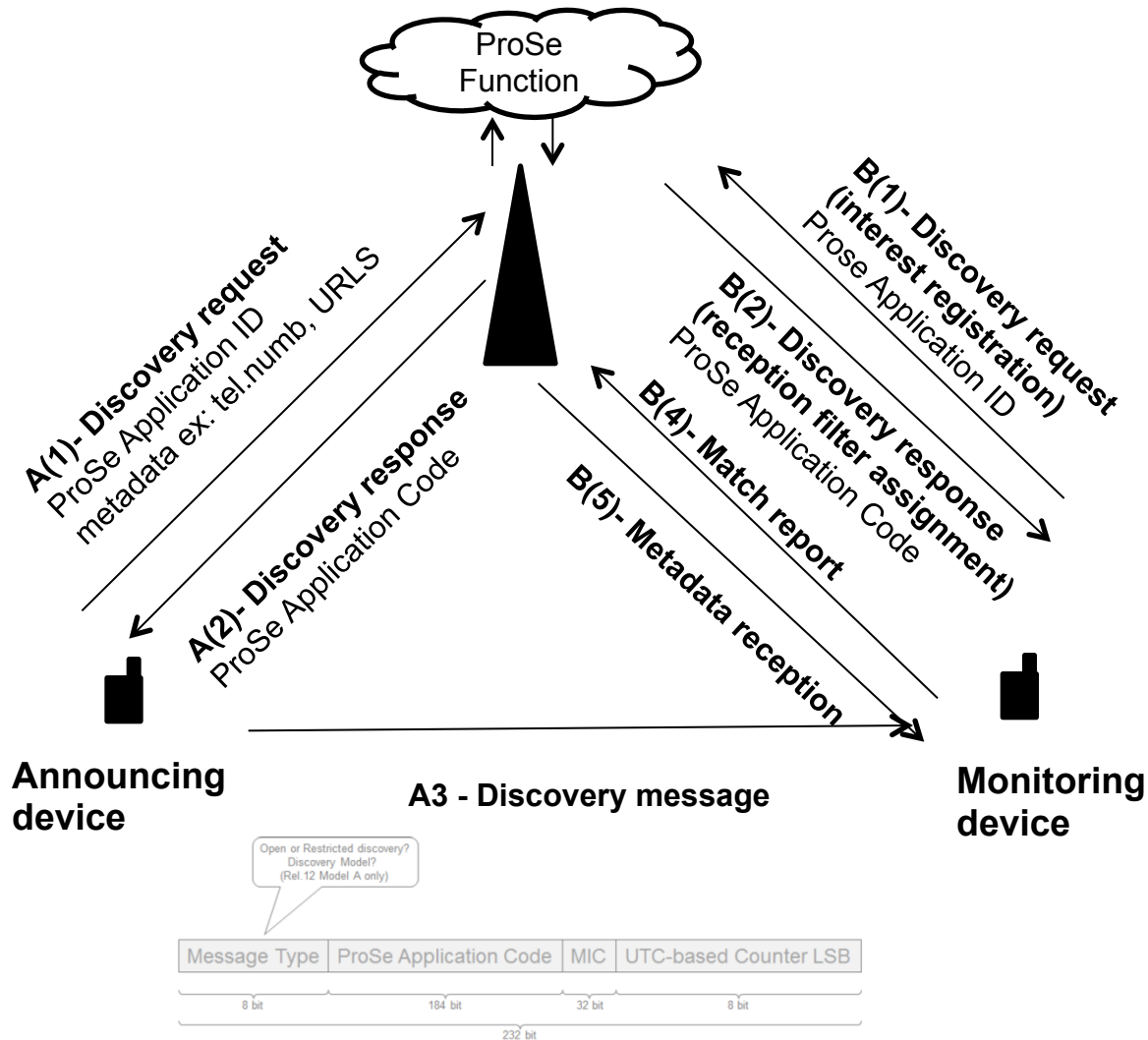
# To go further...

- Work Item Descriptions
  - Release 12: RP-122009
  - Release 13: RP-150441
- TS 36.300 “” – RAN2
- TR 22.803 “Feasibility study for Proximity Services (ProSe)” – SA1
- TR 23.703 “Study on architecture enhancements to support Proximity-based Services (ProSe) (Rel. 12)” – SA2
- TS 23.303 “Proximity-based services (ProSe); Stage 2 (Release 12)” – SA2
- TR 33.833 “Study on security issues to support Proximity Services” – SA3
- TR 36.843 “Study on LTE Device to Device Proximity Services - Radio Aspects” – RAN1
- TS 36.211, TS 36.212, TS 36.213, TS 36.214 for details on physical layer design – RAN1
- TS 24.333 “Proximity-services Management Object (MO)” - CT1
- TS 24.334 “Proximity-services (ProSe) User Equipment (UE) to Proximity-services (ProSe) Function aspects (PC3); Stage 3” - CT1
- TR 36.375/TR 36.877/TR 36.785/TR 36.843 “V2V “ – RAN4
- Device to Device Communication in LTE Whitepaper’ Rohde &Schwarz
- ‘D2D Communications in LTE-Advanced Release 12’, NTT Docomo Technical Journal Vol.17, No.2
- Expanding your horizons with LTE Direct, September 2015, Signals Research Group

Backup slides

# Procedures

## D2D Discovery

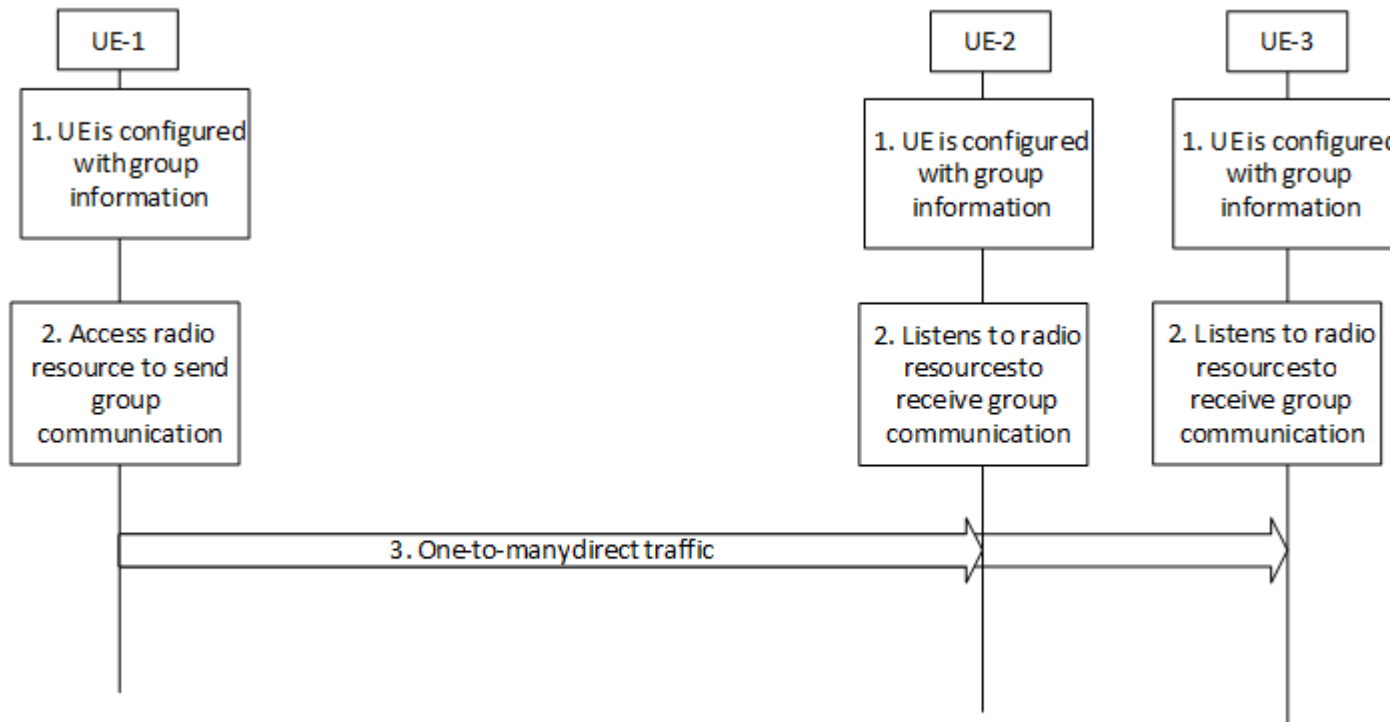




# Procedures

## D2D Communication

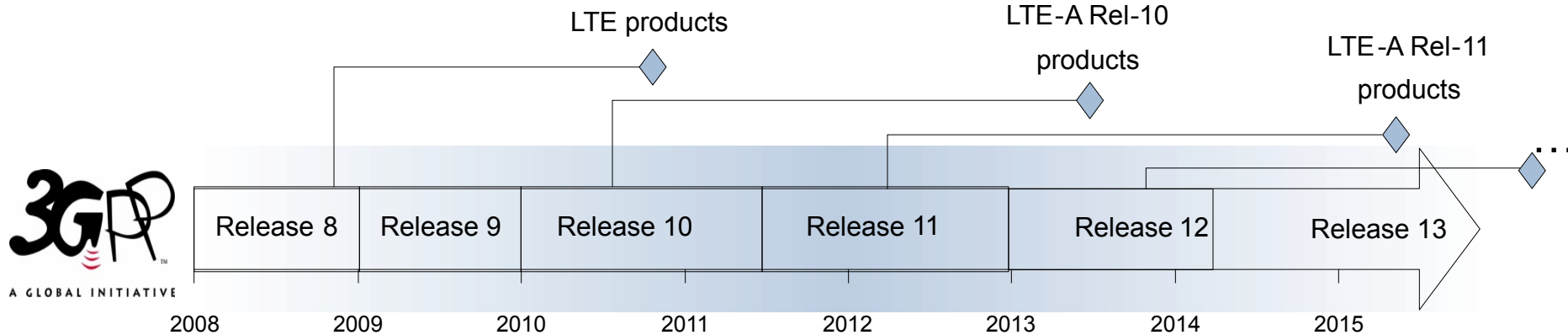
3GPP TS 23.303 V13.3.0 (2016-03)



**Figure 5.4.2-1: One-to-many ProSe Direct Communication transmission**

- One-to-one sidelink communication can be established by higher layer

# 3GPP timeline and main features per Release - Physical level



## Rel.8

- OFDM in DL and SC-FDMA in UL
- Channel dependent scheduling and rate adaptation
- Frequency domain Inter-Cell Interference Coordination (ICIC)
- Multi-Antenna transmission (up to 4 layers in DL)
- MU-MIMO (TM5), based on a limited UE codebook based feedback

## Rel.9

- Multicast and Broadcast Support (MBSFN)
- Positioning
- Dual –layer beamforming (no tests for FDD)

## Rel.10

- Carrier Aggregation and cross-carrier scheduling
- Non-codebook-based beamforming (thanks to UE-specific reference signals, TM9)
- Enh. DL MIMO (extension to 8 layers and non codebook based precoding)
- Enh. UL MIMO (extension to 4 layers and UL SU-MIMO)
- Time domain eICIC for HetNets
- Inband Relays

## Rel.11

- CoMP (ideal backhaul)
- ePDCCH
- Further enhanced eICIC
- Multiple TA for inter-band carrier aggregation

## Rel.12

- MTC
- D2D
- Advanced receivers
- CoMP with non-ideal backhaul
- FDD – TDD joint operation
- Small Cells enh (Dual connectivity, 256QAM in DL, on/off, radio-based sync...)

## Rel.13

- MTC
- D2D enhanc.
- Massive MIMO
- LAA-LTE
- Indoor positioning
- ...