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(Release 12)

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Foreword

This Technical Report has been produced by the 3rd Generation Partnership Project (3GPP).

The contents of the present document are subject to continuing work within the TSG and may change following formal TSG approval. Should the TSG modify the contents of the present document, it will be re-released by the TSG with an identifying change of release date and an increase in version number as follows:

Version x.y.z

where:

x the first digit:

1 presented to TSG for information;

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3 or greater indicates TSG approved document under change control.

y the second digit is incremented for all changes of substance, i.e. technical enhancements, corrections, updates, etc.

z the third digit is incremented when editorial only changes have been incorporated in the document.

1 Scope

The present document defines scope of the D2D study item.

The Feasibility Study on Proximity-based Services (FS_ProSe, TR 22.803 [2]) has identified services that could be provided by the 3GPP system based on UEs being in proximity to each other. The identified areas include services related to commercial services and Public Safety that would be of interest to operators and users.

The objectives of this feasibility study are to evaluate LTE device-to-device proximity services, as follows

	Within network coverage	**Outside network coverage**
Discovery	Non public safety & public safety requirements	Public safety only
Direct Communication	At least public safety requirements	Public safety only

In particular:

1. Define an evaluation methodology and channel models for LTE device-to-device proximity services, including scenarios to compare different technical options to realize proximal device discovery and communication, appropriate performance metrics, and performance targets (e.g. range, throughput, number of UEs supported). [RAN1]

2. Identify physical layer options and enhancements to incorporate in LTE the ability for devices within network coverage: [RAN1]

- to discover each other in proximity directly in a power-efficient manner

- to communicate directly, including enhancements to LTE interference management and scheduling that allow the LTE network to enable, manage, and continuously control all direct, over the air, device to device communications.

3. Identify and evaluate options, solutions and enhancements to the LTE RAN protocols within network coverage [RAN2 primary, RAN3 secondary]:

- to enable proximal device discovery among devices under continuous network management and control,
- to enable direct communication connection establishment between devices under continuous network management and control,
- to allow service continuity to/from the macro network

4. Consider terminal and spectrum specific aspects, e.g. battery impact and requirements deriving from direct device-to-device discovery and communication [RAN4]

5. Evaluate, for non public safety use cases, the gains obtained by LTE device-to-device direct discovery with respect to existing device-to-device mechanisms (e.g. WiFi Direct, Bluetooth), and existing location techniques for proximal device discovery (e.g. in terms of power consumption, and signaling overhead) [RAN1, RAN2]

6. The possible impacts on existing operator services (e.g. voice calls) and operator resources should be investigated [RAN1]

7. For the purposes of addressing public safety requirements, identify and study the additional enhancements and control mechanisms required to realize discovery and communication outside network coverage [RAN1, RAN2]

The identified options/enhancements should reuse the features of LTE as much as possible.

The study will cover:

- Single and multi-operator scenarios, including the spectrum sharing case where a carrier is shared by multiple operators (subject to regional regulation and operator policy)
- LTE FDD and LTE TDD operations

In this study item, the study of direct communication shall address at least public safety requirements and use cases..

It is assumed that aspects related to service authorization, system level architecture, security, and lawful interception are covered in the SA Working Groups.

2 References

The following documents contain provisions which, through reference in this text, constitute provisions of the present document.

- References are either specific (identified by date of publication, edition number, version number, etc.) or non-specific.
- For a specific reference, subsequent revisions do not apply.
- For a non-specific reference, the latest version applies. In the case of a reference to a 3GPP document (including a GSM document), a non-specific reference implicitly refers to the latest version of that document *in the same Release as the present document*.

[1] 3GPP TR 21.905: "Vocabulary for 3GPP Specifications".

[2] 3GPP TR 22.803: “Feasibility study for Proximity Services (ProSe)”

[3] 3GPP TS 36.814 V9.0.0, “Further advancements for E-UTRA physical layer aspects (Release 11)”

[4] R4-092042, “Simulation assumptions and parameters for FDD HeNB RF requirements”, Alcatel-Lucent, picoChip Designs, Vodafone

[5] 3GPP TS 36.101 V12.0.0, “Evolved Universal Terrestrial Radio Access (E-UTRA); User Equipment (UE) radio transmission and reception (Release 12)”

[6] WINNER II Channel Models, D1.1.2 V1.2

[7] D5.3: WINNER+ Final Channel Models

[8] Draft new Report ITU-R M.[IMT.EVAL] “Guidelines for evaluation of radio interface technologies for IMT-Advanced”, Document 5/69-E

[9] R1-132341, “Channel modelling for D2D”, NEC Group

[10] 3GPP TS 22.278 V12.3.0, “Service requirements for the Evolved Packet System (EPS) (Release 12)”

[11] R1-133186, “Typical Public Safety Use Cases, Performance Values, and E-UTRAN Characteristics for D2D ProSe Group Communication”, U.S. Department Of Commerce

[12] NPSTG Communications Report “Public Safety Broadband Push-to-Talk over Long Term Evolution Requirements”, 7/18/2013

3 Definitions, symbols and abbreviations

3.1 Definitions

Void

3.2 Symbols

Void

3.3 Abbreviations

For the purposes of the present document, the abbreviations given in TR 21.905 [1] and the following apply.

D2D	Device to device
ProSe	Proximity based services

4 Synchronization

In cases when at least one external synchronization reference exists, which is always the case at least within NW coverage:

- A UE begins to transmit a D2D signal at the time instance of T1-T2.
  - T1 is the reception timing of the synchronization reference
  - T2 is an offset which is positive, negative, or zero.
- Option 1: The synchronization reference is derived from the timing of a cell (not precluding the possibility that different cells may be used at different times).
  - In this option, the cell may or may not be the serving cell of the UE
  - Option 1.1: T2 is fixed in the specification.
  - Option 1.2: T2 is configurable by the network.
  - Option 1.3: T2 is derived from the PUSCH transmit timing associated with the cell (this option is only applicable in cases when the UE knows the PUSCH timing).
- Option 3: The synchronization reference is a synchronization signal transmitted by one UE
  - Option 3.1: T2 is fixed in the specification.
  - Option 3.2: T2 is obtained from the one UE
- Option 4: The synchronization reference comprises synchronization signals transmitted by more than one UE
  - Option 4.1: T2 is fixed in the specification.
  - Option 4.2: T2 is obtained from the UEs
- Option 5: The synchronization reference is transmitted by an external source, e.g. GNSS
- Other options are not precluded.
- For D2D discovery signal within NW coverage, Options 1&5 are considered for further study.
- For D2D discovery signal outside NW coverage, Options 3, 4&5 are considered for further study.
- For D2D communication signal, Options 1, 3, 4 & 5 are considered for further study.
  - At least option 1.3 is supported for within NW coverage

Further study is required for the transmission timing in cases when a synchronisation reference does not exist.

Note that a full definition of "within" and "outside" NW coverage is needed; revisit the relation between the above options and within/outside NW coverage after such a definition is clarified.

5 Discovery

- It is assumed that D2D operates in UL spectrum (in the case of FDD) or UL sub-frames of the cell giving coverage (in the case of TDD except when out of coverage)

    - Use of DL sub-frames in the case of TDD can be studied further
- It is assumed that D2D transmission/reception does not use full duplex on a given carrier

5.1 Types of Discovery

At least the following two types of discovery procedure are defined for the purpose of terminology definition for use in further discussions/studies (note that these definitions are intended only to aid clarity and not to limit the scope of the study):

- Type 1: a discovery procedure where resources for discovery signal transmission are allocated on a non UE specific basis
    - Note: Resources can be for all UEs or group of UEs
- Type 2: a discovery procedure where resources for discovery signal transmission are allocated on a per UE specific basis
    - Type 2A: Resources are allocated for each specific transmission instance of discovery signals
    - Type 2B: Resources are semi-persistently allocated for discovery signal transmission

Note that further details of how the resources are allocated and by which entity, and of how resources for transmission are selected within the allocated resources, are not restricted by these definitions.

6 Communication

Discovery is not a required step for groupcast and broadcast communication.

For groupcast and broadcast, it is not assumed that all receiving UEs in the group are in proximity of each other.

Annex A: Simulation model

A.1 Link simulation Scenarios

A.2 System simulation Scenarios

A.2.1 System simulation assumptions

A.2.1.1 Reference system deployments

Two classes of scenarios are defined: General Scenarios & Public Safety Scenarios.

The layout for the scenarios shall be a hexagonal grid. There shall be 3 sectors per macro site. There shall be either with 19 or 7 macro sites in the layout.

Following are the layout options that shall be used.

Option 1: Urban macro (500m ISD) + 1 RRH/Indoor Hotzone per cell

Option 2: Urban macro (500m ISD) + 1 Dual stripe per cell

Option 3: Urban macro (500m ISD) (all UEs outdoor)

Option 4: Urban macro (500m ISD) + 3 RRH/Indoor Hotzone per cell

Option 5: Urban macro (1732m ISD)

Option 6: Urban micro (100m ISD)

Options 1, 2, 3, 4 and 6 layout shall use parameters specified for 3GPP case 1 defined in Table A.2.1.1.1 of [3] unless specified otherwise.

Options 5 layout shall use parameters specified for 3GPP case 3 defined in Table A.2.1.1.1 of [3] unless specified otherwise.

See A.2.1.1.5 in [3] for details on RRH/Indoor Hotzone.

See 4.2.1 in [4] for details on Dual Stripe model.

Table A.2.1.1-1: Details of Deployment Scenarios

	General Scenarios	Public Safety Scenarios
LTE Layout	Option 1 shall be mandatory Others layouts are optional in order of decreasing priority: Option 2 / Option 3 Option 4 Option 6	Option 5 shall be mandatory Others layouts are optional in order of decreasing priority: Option 3 Option 1
Carrier Frequency (Note: The performance at 2GHz is expected to be different from the performance at 700MHz.)	2GHz	700 MHz
System bandwidth	10MHz Uplink and 10MHz Downlink for FDD, 20 MHz for TDD	10MHz Uplink and 10MHz Downlink for FDD, 20MHz for TDD for in-coverage and partial coverage scenarios, 10MHz dedicated spectrum for out-of-coverage scenarios
Network operation	100% eNodeBs enabled	0% eNodeBs enabled 100% eNodeBs enabled 3-site clustered eNodeB enabling pattern for 19 cells layout as shown in Figure A.2.1.1 for partial network coverage[a]
UE out of coverage criterion	N/A	Average SINR < -6 dB over system bandwidth.
Network synchronization	All cases shall be treated with equal priority: - all eNodeBs synchronized - eNodeBs on different carriers not synchronized - eNodeBs on a given carrier not synchronized	
UE mobility (only for channel models)	3 km/hr	60km/h for outdoor UEs in Option 5. 3km/h for all other cases.

UE RF parameters	Max transmit power of 23 dBm for non public safety, 23 dBm, 31 dBm for public safety 1 Tx (2 Tx optional for public safety only), 2 Rx antenna, Antenna gain 0 dBi, Noise figure 9 dB	
eNodeB RF parameters	As specified in 3GPP Case 1, except for Option 5 which uses parameters as specified in 3GPP Case 3 (Table A.2.1.1.1 of [3])	
Non D2D traffic	With probability {X}, a D2D UE has non D2D (downlink & uplink) traffic. WAN traffic source shall be FTP2.	
Total number of active UEs[b] per cell area[c]	Layout Option 1 Indoor-outdoor mix: 25	Layout Option 5 Indoor-outdoor mix: 10 Uniform (outdoor): 10 Hotspot: 10
Total number of UEs (including active UEs[b]) for discovery per cell[c]	Layout Option 1 Indoor-outdoor mix: 150	Layout Option 5 Indoor-outdoor mix: 150 Uniform (outdoor): 150 Hotspot: 150
Number of UEs participating in a D2D communication session	Unicast : 2 Groupcast: N/A Broadcast: N/A	Unicast: 2 Groupcast: 10 (One transmitter UE and 9 (N_{gr}) receiver UEs) Broadcast: One transmitter UE and variable number of receiver UEs based on the association procedure defined in Section A.2.1.1.3
Average number of communication sessions per cell[c]	Unicast: 12(N_u) Groupcast: N/A Broadcast: N/A	Unicast : 12 (N_u) Groupcast: 3 (N_g) Broadcast: 3 (N_b)

UE drop for all UEs, for both discovery and communication evaluations	For layout options 1,2, 4:
	• 2/3 UEs randomly and uniformly dropped within the clusters of small cell(s).
	• Remaining 1/3 UEs randomly and uniformly dropped throughout the macro geographical area.
	• 20% UEs are outdoor, and 80% UEs are indoor.[d]
	
	For layout option 3, 5, 6:
	• Uniform drop : all UEs are randomly and uniformly dropped throughout the macro geographical area
	• Hotspot drop :
	    o Randomly select an area within each macro geographical area.
	    o Randomly and uniformly drop 2/3 UEs within 40 m of the selected area.
	    o Randomly and uniformly drop the remaining 1/3 UEs to the entire macro geographical area of the given macro cell.	

	Additionally for layout option 5: • Drop 2 RRH buildings (without RRHs) in each macro geographical area. (See A.2.1.1.5 in [3]) • All UEs randomly and uniformly dropped throughout the macro geographical area such that 20% UEs are outdoor, and 80% UEs are indoor.	
UE association for unicast D2D communication	Refer to Section A.2.1.1.1	
UE association for groupcast D2D communication	N/A	Refer to Section A.2.1.1.2
UE association for broadcast D2D communication	N/A	Refer to Section A.2.1.1.3
UE association for Relay D2D communication	N/A	First UE is randomly selected from all UEs without eNodeB coverage and 2nd UE is selected from the UEs within eNodeB coverage
Minimum distance between UE and eNodeB	>=35m (except for Option 6 where it shall be 5m)	
Minimum distance between UEs	>= 3m	
Wraparound	Wraparound is used for all cases except partial network coverage, for which no wraparound is used.	
Minimum association RSRP for D2D communication (X) (baseline)	-112dBm	

a) To ensure sufficient number of out-of-coverage UE in partial NW coverage, use ITU UMa model (Table B.1.2.1-1 in [3]) for eNodeB-to-UE channel model in D2D evaluations.

b) Active UEs are UE with WAN traffic.

c) Note that a cell refers to a sector of the geographical macro-cell (hexagon).

d) In order to ensure that 80% of the UEs are indoor some of the UEs that are not dropped inside a building will be declared as indoor UEs. We will call them virtual indoor UEs.

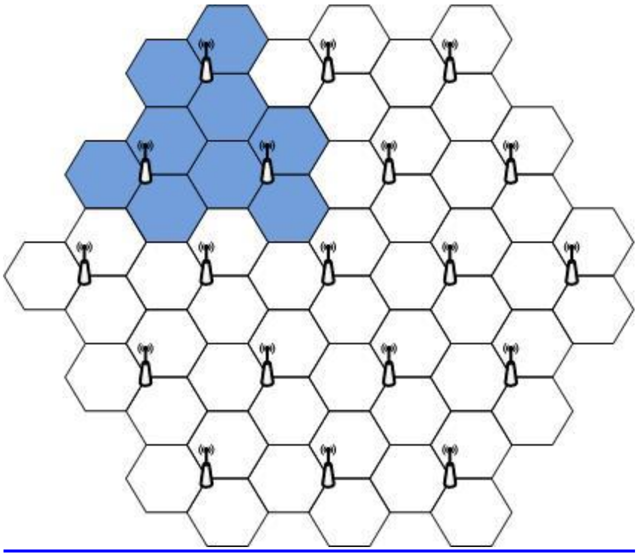

Figure A.2.1.2: 3-site clustered eNodeB enabling pattern for partial network coverage.

For simulation purpose the following assumptions shall be made

- Only one type of D2D communication (Groupcast, Broadcast and Unicast) per simulation
- [The unicast traffic will flow from the first selected UE to the second selected UE]
- Groupcast is unidirectional communication from a first UE to all other UEs in the group
- Broadcast is unidirectional communication from a first UE to all other UEs

A.2.1.1.1 Dropping and Association for Unicast

Following shall be procedure for dropping and association for unicast.

1. Create 19 or 7 macro sites (hexagon) with 3 cells each.
2. [150] UEs will be dropped per cell using the UE dropping procedure described in Table A.2.1.1-1 for different layout options.
3. Start association of unicast links, set NUM_LINKS_ASSOCIATED = 0.
4. First UE is randomly selected from all UEs within the entire 19 or 7 macro sites that are not part of a unicast link.
5. Second UE is randomly selected from the remaining UEs (i.e., are not part of a unicast link and are not the first UE) within the entire 19 or 7 macro sites.
6. If second UE is not within RSRP* of X dBm of the first UE then randomly reselect the second UE among the UEs that are within the RSRP of X dBm of the first UE and are not part of a unicast link already.
7. If no second UE is found then discard the first UE and go to Step 4, else NUM_LINKS_ASSOCIATED = NUM_LINKS_ASSOCIATED + 1.
8. If the NUM_LINKS_ASSOCIATED < (N_u * (19 or 7)*3) then go to Step 4.

Note: If simulation is not leading to the required number of links then re-dropping can be performed.

*RSRP is calculated for transmit power of 23dBm by the transmitter UE and is the received power at the receiver UE calculated after accounting for large scale path loss and shadowing. Additionally note that wrap around is used for path loss calculations except for the case of partial network.

Values of X and N_u are specified in Table A.2.1.1-1.

A.2.1.1.2 Dropping and Association for Groupcast

Following shall be the procedure for dropping and association for groupcast.

1. Create 19 or 7 macro sites (hexagon) with 3 cells each.
2. [150] UEs will be dropped per cell using the UE dropping procedure described in Table A.2.1.1-1 for different layout options.
3. Start association of groupcast links, set NUM_GROUPS_ASSOCIATED = 0.
4. Transmitter UE is randomly selected from all UEs within the entire 19 or 7 macro sites that are already not selected as transmitter or receiver UEs.
5. Start selecting the receiver for the transmitter, set NUM_RECEIVERS_ASSOCIATED = 0.
6. Receiver UE is randomly selected from the remaining UEs (i.e., not already part of a group) within the entire 19 or 7 macro sites.
7. If receiver UE is not within RSRP* of X dBm of the transmitter UE then randomly reselect the receiver UE among the UEs that are within the RSRP of X dBm of the transmitter UE and are not part of a group already.
8. If no receiver UE is found then discard the transmitter UE and go to Step 4, else NUM_RECEIVERS_ASSOCIATED = NUM_RECEIVERS_ASSOCIATED + 1.
9. If the NUM_RECEIVERS_ASSOCIATED < N_{gr} then go to Step 6 else NUM_GROUPS_ASSOCIATED = NUM_GROUPS_ASSOCIATED + 1
10. If NUM_GROUPS_ASSOCIATED < (N_g*(19 or 7)*3) then go to Step 4.

Note: If simulation is not leading to the required number of groups then re-dropping can be performed.

*RSRP is calculated for transmit power of 23dBm by the transmitter UE and is the received power at the receiver UE calculated after accounting for large scale path loss and shadowing. Additionally note that wrap around is used for path loss calculations except for the case of partial network.

Values of X, N_{gr} and N_g are specified in Table A.2.1.1-1.

A.2.1.1.3 Dropping and Association for Broadcast

Following shall be the procedure for dropping and association for broadcast.

1. Create 19 or 7 macro sites (hexagon) with 3 cells each.
2. 32 UEs will be dropped per cell using the UE dropping procedure described in Table A.2.1.1-1 for different layout options.
3. Start selecting the receiver for the transmitter, set NUM_TRANSMITTERS_SELECTED = 0.
4. Transmitter UE is randomly selected from all UEs within the entire 19 macro sites that are already not selected as transmitter UEs.
5. NUM_TRANSMITTERS_SELECTED = NUM_TRANSMITTERS_SELECTED + 1
6. If the NUM_TRANSMITTERS_SELECTED < (N_b*(19 or 7)*3) then go to Step 4
7. Start associating receivers with the transmitters
8. For each remaining UE (, i.e., UEs that are not transmitter) calculate the RSRP* from each of the selected transmitter. If the RSRP is greater than X dBm for a transmitter then associate the UE with the transmitter.

*RSRP is calculated for transmit power of 23dBm by the transmitter UE and is the received power at the receiver UE calculated after accounting for large scale path loss and shadowing. Additionally note that wrap around is used for path loss calculations except for the case of partial network.

Values of X and N_b are specified in Table A.2.1.1-1.

A.2.1.2 Channel models

Following channel models shall be used for D2D.

	Outdoor to Outdoor	Outdoor to Indoor	Indoor to Indoor
Pathloss[a]	PL_B1_tot(d) = max($PL_{freespace}$(d), PL_B1(d)) where d is distance between UEs $PL_{freespace}$ is free space path loss (Eq. 4.24 in [6]), PL_B1 is the Winner + B1[b] ([7] Table 4-1) channel model for hexagonal layout with the following offsets a. LOS offset = 0 dB[c] b. NLOS offset = -5 dB[c] While calculating Winner + B1 pathloss the following values shall be used h_BS = h_MS = 1.5m, h_BS' = h_MS' = 0.8m	Dual strip ([3] Table A.2.1.1.2-8) for Layout Option 2 Remaining Layout Options a. LOS: PL_B1_tot (d_{out} + d_{in}) + 20.0 + 0.5*d_in b. NLOS: PL_B1_tot(d_{out} + d_{in}) + 20.0 + 0.5*d_{in} – 0.8*h_MS where d_{out} and d_{in} are defined by Note 1 after Table 4-1 in [7] for true indoor UEs d_{in}=1.5m and d_{out}=d-d_{in} for virtual indoor UEs h_MS = 1.5m	Dual strip ([3] Table A.2.1.1.2-8) for Layout Option 2 InH ([3] Table A.2.1.1.5-1) for remaining layout options[d]
LOS Probability[e]	Winner II-B1 ([6] Table 4-7)	ITU-R IMT UMi ([8] Table A1-3)	ITU-R IMT UMi ([8] Table A1-3) for InH N/A for Dual Strip
Shadowing standard deviation	7 dB log-normal	7 dB log-normal	UEs are in same building: LOS: 3 dB log-normal NLOS: 4 dB log-normal UEs are in different building: 10 dB log-normal

Shadowing correlation	i.i.d.		
Fast Fading[f]	ITU-R IMT UMi ([8] Annex 1.3.2) LOS and NLOS	ITU-R IMT UMi O2I ([8] Annex 1.3.2)	ITU-R IMT InH ([8] Annex 1.3.2) LOS and NLOS

a) Pathloss should be defined for 700 MHz in addition to 2 GHz (by applying 20log(fc) correction for 700 MHz if not otherwise specified)

b) Winner+B1 is assumed to be valid up to a minimum distance of 3m

c) The offsets are assumed to be valid for all the frequencies of interest.

d) For calculating the indoor to indoor path loss between a virtual indoor UE and another virtual indoor UE or indoor UE use the InH model for UEs inside different buildings

e) LOS probability: some pathloss models do not specify a LOS/NLOS region – the LOS Probability would not be used for such models

f) Additional modifications needed to incorporate changes in Doppler modeling due to dual mobility are described in Section A.2.1.2.1. Further study can be undertaken on the dual-scattering described in [9].

Note: These models are being adopted for the purpose of relative comparisons of D2D techniques, without necessarily having measurement support.

A.2.1.2.1 Doppler modelling

Following are the working assumptions for Doppler modelling.

- [Symmetric angular spread distribution and dual mobility corrections]
- [Doppler is determined by path AOA/AOD]
- [Uniform AOA spread of 104 degrees]
- [Direction of travel (velocity vector) independent and random]
  - [Amend the ITU-R UMi/InH model to incorporate dual mobility]
    - [V_{TX} (UE1) and V_{RX} (UE2) parameters separately with phase change per sub-path]
    - [Equation (21) in [8] shall be modified to]

$$\upsilon_{n,m} = \frac{\|v_{rx}\|\cos(\varphi_{n,m} - \theta_{vrx}) + \|v_{tx}\|\cos(\phi_{n,m} - \theta_{vtx})}{\lambda_0}$$

[For equation (23) in [8], υ_{LOS} shall be modified similar to above.]

A.2.1.3 Traffic models

User full buffer, VoIP and FTP2 from [3].

A.2.1.4 Performance evaluation metrics

A.2.1.4.1 Metrics for discovery

For evaluation of proposed discovery schemes the following metrics shall be considered.

- The metrics related to performance targets aspect of Open ProSe discovery are
    - Number of UEs discovered as a function of time. This shall be a system level metric.
    - CDF of number of UEs discovered as a function of time. This shall be a system level metric.
- The metric related to performance targets aspect of Restricted ProSe discovery is
    - Probability of discovery as a function of time. Zero time penalty shall be assumed for each false alarm. This shall be a system level metric.
- The metrics related to range and reliability aspects of discovery are
    - Probability of discovery vs. pathloss. This shall be both a link & system level metric.
    - Probability of false alarm. This shall be both a link & system level metric.
- The metrics related to impact on WAN aspect of discovery are
    - Amount of resource used for discovery per cell if in network coverage. This shall be a system level metric.
    - FFS metrics related to throughput loss and/or interference.
- The metrics related to power consumption aspect of discovery is
    - Power consumption should be calculated using the model described in Section A.2.1.6.

Points to note:

- Time shall be measured from start of simulation without prior synchronisation.
- Unless explicitly stated same metrics shall be used for in-network, partial network and out of network coverage scenarios with possibly different emphasis.
- Same metrics shall be used for public safety and non-public safety cases with possibly different emphasis.

A.2.1.4.2 Metrics for communication

For evaluation of proposed communication schemes the following metrics shall be considered.

- The metrics related to D2D throughput aspects of communication are
    - For full buffer traffic model; mean, 5%, and CDF of user throughput. This shall be a system level metric.
    - For FTP2 traffic model; mean, 5%, and CDF of perceived user throughput. This shall be a system level metric.
    - For VOIP traffic model; VOIP system capacity. The VOIP delay requirement shall be ~~{X}~~200 ms for Unicast, Broadcast, Groupcast and 100ms per hop for Relays. This shall be a system level metric.
- The metrics related to range and reliability aspects of communication are
    - Performance versus pathloss or distance. Performance shall be in terms of either user throughput, perceived user throughput, or probability of satisfied VOIP user depending on traffic model. This shall be both a link and system level metric. For link level performance use only full buffer.
- The metrics related to call setup latency aspect of communication is

    - Physical layer latency for call setup for out of coverage only. This should only model L1 related aspects; higher layer aspects should be considered in RAN2. This shall be both a link and system metric.

- The metrics related to impact on WAN aspects of communication are
    - Change in cell throughput/cell spectral efficiency for full buffer traffic model. This shall be a system level metric.
    - CDFs of perceived per-user throughput for FTP2 with and without D2D. This shall be a system level metric.

- The metrics related to power aspect of communication is
    - Power consumption should be calculated using the model described in Section A.2.1.6.

Points to note:

- Same metrics shall be used for in-network, partial network and out of network coverage scenarios.
- Same metrics shall be used for public safety and non-public safety cases with possibly different emphasis.
- Same metrics shall be used for unicast, groupcast and broadcast with each receiver counted separately.

A.2.1.5 In-band emissions model

Following two models will be used.

- [Option B: In-band emissions are modelled as specified in [5], Section 6.5.2.3.]
- [Option C': Assume emission noise floor -36 dBc relative to PSD for the transmitted resource blocks.]

A.2.1.6 Power consumption model

Following power consumption model shall be used.

- Sleep power = 0.01 unit per sub-frame
- RX Power = 1 unit per sub-frame
- TX power
    - 20 unit per sub-frame for 31 dBm
    - 1 unit per sub-frame for 0 dBm and below
    - Linearly scaled with transmit power between 1mW and 10^3.1mW
- Assume 8 sub-frames are accumulated for synchronization with WAN
    - Synchronization is assumed to be reliable for 0.5s
- GPS power = 0.08 unit per sub-frame
    - Average power consumption when GPS is used
    - Always on independently of other communications

This model is valid for both in coverage, partial coverage and out of coverage scenarios. Same values are to be used for D2D discovery, D2D communication, WAN signaling for D2D and non-D2D-related WAN signaling.

While stating power consumption state the number of sub-frames assumed for each type of power usage.

Paging cycle of 1.28 seconds is assumed.

A.2.2 System level simulator calibration

A.3 Detailed simulation results

A.4 Public Safety ProSe Communication Use Cases

This is an informative appendix included for providing background on the use cases discussed in the TR.

In this appendix, the input provided in [11] is included based on ProSe Communication definitions in [10], that read as:

ProSe Communication: a communication between two or more ProSe-enabled UEs in proximity by means of a ProSe Communication path. Unless explicitly stated otherwise, the term "ProSe Communication" refers to any/all of the following:

- ProSe E-UTRA Communication between only two ProSe-enabled UEs; or
- ProSe Group Communication or ProSe Broadcast Communication among Public Safety ProSe-enabled UEs; or
- ProSe-assisted WLAN direct communication.

ProSe E-UTRA Communication: a ProSe Communication using a ProSe E-UTRA Communication path.

ProSe Group Communication: a one-to-many ProSe E-UTRA Communication, between more than two Public Safety ProSe-enabled UEs in proximity, by means of a common ProSe E-UTRA Communication path established between the Public Safety ProSe-enabled UEs.

ProSe Broadcast Communication: a one-to-all ProSe E-UTRA Communication, between all authorized Public Safety ProSe-enabled UEs in proximity, by means of a common ProSe E-UTRA Communication Path established between these Public Safety UEs.

A.4.1 Typical Public Safety Use Cases and Scenarios of ProSe Communication

According to definitions and requirements in [10], Device-to-Device (D2D) ProSe Communication (1) is directly between Public Safety ProSe-enabled UEs using E-UTRA regardless of whether or not a priori ProSe Discovery is used, and (2) can be autonomously enabled by Public Safety users when authorized. This section identifies typical public safety use cases of D2D ProSe Communication.

A.4.1.1 General Description of Public Safety ProSe Communication Scenarios

PTT voice is the most critical means of communications for first responders in emergency situations and cannot be compromised. Although the focus of applications over D2D ProSe Communication is PTT voice communications, other forms of ProSe Communication applications are important too. In [12], general descriptions of scenarios for PTT off-network communications are following:

> "*While the NPSBN (National Public Safety Broadband Network) will be a primary, reliable transport of public safety voice and data, there are many situations where voice and data communications will be required in areas where the NPSBN is not available. NPSBN Users (NPSBN-U) may be outside of the range of the fixed network, such as first responders in a rural area assisting in a response to a plane crash or police officers inside a residence responding to a domestic issue. Off-network voice communications must be immediately accessible to users in the absence of the NPSBN. This includes areas and locations where the ability to access non-terrestrial communications can be impaired such as within building and other enclosed areas where non-terrestrial communications may not be available. Additionally, there may be times when users may wish to communicate off-network. Today, firefighters often join a local communications network, which does not leverage the fixed network, but rather, relies on either direct communications between the user devices or communications via a local repeater on-scene. Firefighters can voluntarily leave the fixed network either due to the unpredictable coverage of the fixed network, or if the coverage of direct communications or the local repeater is well known, based on experience.*

There will be occasions where a user may be within network coverage and will need to communicate with users who are on the network and off-network, such as an Incident Commander (IC) supporting fire response activities. These users must be able to communicate to users on the fixed network, such as dispatch, as well as the local users who are off-network or when it is desirable to provide voice, data and video connections between users without connection to the network even if within network coverage.

A relay function is critical for off-network communications when NPSBN coverage is not sufficient to support the public safety mission. In the case of firefighters who are responding to a wildfire while outside of the coverage of the fixed network, if one user becomes encircled by the wildfire and is beyond the range of the IC, but within the range of another device that can act as a relay, the endangered firefighter can still update his status to the IC."

A.4.1.2 Typical Use Cases of Public Safety ProSe Communication

The **D2D ProSe Communication** are "communications in Direct Mode" that is separate from ProSe Communications via the network infrastructure as noted above. D2D ProSe Communication is a critical public safety need overall.

For **D2D ProSe Group Communication** involving more than two Public Safety ProSe-enabled UEs, the Incident Commander will assign team members to specific groups of users (detailed to perform a specific task) where each group is having independent ProSe Group Communication. This bifurcating of each team allows the incident commander to manage these groups more effectively and ensures that their communications are exclusive/pre-empted to their task. In current Public Safety LMR systems, off-network (Direct Mode) operations are often a method used for on-scene communications, in particular by the Fire Service, whether their existing trunked network is operational and has coverage in this particular area or not.

Furthermore, when a task force is manually switched to off-network (D2D ProSe Group Communication) that has had one or more of its team members move off D2D ProSe Communication-coverage (whether it was intentional or not), if a UE will provide the user an opportunity to determine which users are in- D2D ProSe Communication-coverage at any given time, users could use this capability to determine if the user they need to reach by seeing his status of availability and, if the user is not in- D2D ProSe Communication-coverage, a procedure is triggered to deterministically establish an alternative communication path to try to reach him. Additionally, UEs that are switched to D2D ProSe Communication (while being in-network-coverage) requires continuous LTE connectivity to EPC for messages, maps, pictures, video exchanges with group communications via the infrastructure LTE network. For those UEs that are out-off-network-coverage the EPC connectivity is provided by UE-to-Network Relays wherever feasible.

It is noteworthy that in a D2D (off network) environment, the incident commander could configure two users for private communication by setting them up with **D2D ProSe E-UTRA Communication** in Direct mode. D2D ProSe E-UTRA Communication is necessary and critical to Public Safety, which is mimics the Private Call in today's Land Mobile Radio (LMR) trunked systems. This often is communication between a supervisor and one of the people under his command that is a member of the larger group. One use case could be Team Leader/supervisor of a police group operating off network communicating to a sniper on the roof giving a "shoot" or "don't shoot" message at a critical moment. They may determine that immediate dialogue might not be beneficial to a larger group during that critical moment. Moreover, this feature is purposely used sparingly and only specific individuals/devices are assigned to D2D ProSe E-UTRA Communication, such that sharing information among the group of incident members is not jeopardized.

A.4.2 Typical Performance Values and E-UTRAN Characteristics for Public Safety of ProSe Communication

Typically needed performance values and E-UTRAN characteristics for Public Safety of D2D ProSe Communication are following.

A.4.2.1 Basic operations

- With concurrent on-network operation, there would not be more than 6-8 D2D ProSe Group Communication groups at an incident scene.
- With concurrent on-network operations, there should not be more than 12-16 users assigned to each D2D ProSe Group Communication group but the group size could be expanded to 50-70 users to accommodate a search and rescue team.
- With concurrent on-network operations, two incident service members may have an authorized "private call" using D2D ProSe E-UTRA Communication.
- Geographic area of operations for D2D ProSe Communication could be up to 1.5 mile radius per incident scene.

A.4.2.2 Coverage

- D2D ProSe Communication for Public Safety ProSe-enabled UEs is needed among in-network-coverage UEs, out-of-network-coverage UEs and a mixture of UEs in and out of network coverage.
- Determination is needed regarding within the D2D ProSe Communication which user(s) are in-D2D ProSe Communication-coverage at any given time.
- Maintaining concurrent D2D ProSe Communication (off-network) and LTE connectivity to EPC is required regardless of whether UEs are in network coverage or out-of-network-coverage (see [10]). The LTE connectivity to EPC for out-of-network-coverage UEs are provided via UE-to-Network Relays.

A.4.2.3 Applications

- The applications to be supported by D2D ProSe communication for Public Safety are voice, location, low speed data (SMS, report/query, sensor, etc.), and pictures (optional video if possible) with voice as the most critical means of communications.
- Emergency Alert is required. The alert would be sent to either the group leader or all other group members (undercover law enforcement operations, fireground operations).
- Locate Team Member is required. That is the ability for the Team Leader to send a query to acquire the location of an unresponsive team member, the UE if functional would respond automatically, providing the location of the unresponsive team member to the team leader.

A.4.2.4 System Aspects

- D2D ProSe Communication for Public Safety needs to consider cases of in-network coverage, out-of-network coverage as well as a mix of UEs within and outside network coverage.
- ProSe Communication for Public Safety can be directly between the ProSe-enabled UEs using E-UTRA regardless of whether or not a priori ProSe Discovery, and could be enabled by Public Safety ProSe-enabled users when authorized.

Annex B: Change history

Change history							
Date	TSG #	TSG Doc.	CR	Rev	Subject/Comment	Old	New
04 2013	R1#72bis	R1-131717			TR Skeleton		0.1.0
10 2013	R1#74bis	R1-13xxxx			Added text proposals R1-132719, R1-134025, and R1-133917.		0.2.0