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TECHNICAL REPORT

LTE;
5G;
Overall description of Radio Access Network (RAN) aspects for Vehicle-to-everything (V2X) based on LTE and NR
(3GPP TR 37.985 version 16.0.0 Release 16)

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Contents

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:

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where:

x the first digit:

1 presented to TSG for information;

2 presented to TSG for approval;

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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.

In the present document, certain modal verbs have the following meanings:

shall indicates a mandatory requirement to do something

shall not indicates an interdiction (prohibition) to do something

NOTE 1: The constructions "shall" and "shall not" are confined to the context of normative provisions, and do not appear in Technical Reports.

NOTE 2: The constructions "must" and "must not" are not used as substitutes for "shall" and "shall not". Their use is avoided insofar as possible, and they are not used in a normative context except in a direct citation from an external, referenced, non-3GPP document, or so as to maintain continuity of style when extending or modifying the provisions of such a referenced document.

should indicates a recommendation to do something

should not indicates a recommendation not to do something

may indicates permission to do something

need not indicates permission not to do something

NOTE 3: The construction "may not" is ambiguous and is not used in normative elements. The unambiguous constructions "might not" or "shall not" are used instead, depending upon the meaning intended.

can indicates that something is possible

cannot indicates that something is impossible

NOTE 4: The constructions "can" and "cannot" shall not to be used as substitutes for "may" and "need not".

will indicates that something is certain or expected to happen as a result of action taken by an agency the behaviour of which is outside the scope of the present document

will not indicates that something is certain or expected not to happen as a result of action taken by an agency the behaviour of which is outside the scope of the present document

might indicates a likelihood that something will happen as a result of action taken by some agency the behaviour of which is outside the scope of the present document

might not indicates a likelihood that something will not happen as a result of action taken by some agency the behaviour of which is outside the scope of the present document

In addition:

is (or any other verb in the indicative mood) indicates a statement of fact

is not (or any other negative verb in the indicative mood) indicates a statement of fact

NOTE 5: The constructions "is" and "is not" do not indicate requirements.

Introduction

The 3GPP platform was first expanded to the automotive industry by the introduction of support for V2V and V2X services in Release 14. This support forms Phase 1 of 3GPP's ongoing project relating to V2X, and was intended to support a set of requirements sufficient for basic road safety services. Vehicles containing UEs with these features can use the uplink, downlink and sidelink to exchange information on their own status, such as position, speed, and heading with other nearby vehicles, infrastructure nodes, and pedestrians. Phase 2 of the V2X project was standardised in Release 15, and adds a number of new features to the sidelink intended to enhance efficiency and exploit developments in UE and network designs. These enhancements include sidelink carrier aggregation, higher-order modulation, and reduced latency.

Phase 3 of V2X, in Release 16, adds support to NR (and also 5GC, not addressed in this TR) for advanced V2X use cases, and includes introduction of the NR sidelink. The use-cases are broadly grouped to enable vehicular platooning, exchange of extended sensor information, advanced driving, and remote driving. Phase 3 also allows either RAT's sidelink to be operated under control of the other RAT's Uu interface, as well as permitting connection to EPC or 5GC, to enable usage in the main MR-DC deployment scenarios.

In the following clauses, LTE-V2X is described first, then NR-V2X, and finally certain aspects which have a degree of commonality to both RATs.

Although this TR deals with RAN aspects, note that the core network architectures also have many adaptations to support V2X in both EPC and 5GC. These are referred to only as needed for other explanations in this TR, and details can be found in the relevant specifications.

1 Scope

The present document provides an overall description of the features introduced by 3GPP to LTE and NR in support of V2X services, starting from Rel-14. The purpose of this TR is to give an overview across the RAN specifications of how the features have been designed, and how they operate together. This document addresses LTE V2X and NR V2X via both sidelink, i.e. the PC5 interfaces, and via the cellular uplink/downlink, i.e. the Uu interfaces. It covers V2V, V2I/N, and V2P, as well as the eNB/gNB, UE, and RSU nodes. The intention is to provide descriptions at approximately the Stage 2 level of detail, and thus references are provided to RAN specifications for the reader to obtain precise details.

The document is a 'living' document, i.e. it is permanently updated and presented to TSG-RAN meetings.

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 36.885: "Study on LTE-based V2X Services".

[3] ETSI EN 302 637-2: "Specification of Cooperative Awareness Basic Service".

[4] SAE J2735: "Dedicated Short Range Communications (DSRC) Message Set Dictionary".

[5] ETSI EN 302 637-3 "Specifications of Decentralized Environmental Notification Basic Service".

[6] 3GPP TS 22.185: "Service requirements for V2X services".

[7] 3GPP TS 22.186: "Enhancement of 3GPP support for V2X scenarios".

[8] 3GPP TS 36.211: "Evolved Universal Terrestrial Radio Access (E-UTRA); Physical channels and modulation".

[9] 3GPP TS 36.212: "Evolved Universal Terrestrial Radio Access (E-UTRA); Multiplexing and channel coding".

[10] 3GPP TS 36.331: "Evolved Universal Terrestrial Radio Access (E-UTRA); Radio Resource Control (RRC)".

[11] 3GPP TS 36.101: "Evolved Universal Terrestrial Radio Access (E-UTRA); User Equipment (UE) radio transmission and reception".

[12] 3GPP TS 36.214: "Evolved Universal Terrestrial Radio Access (E-UTRA); Measurements".

[13] 3GPP TS 36.300: "Evolved Universal Terrestrial Radio Access (E-UTRA) and Evolved Universal Terrestrial Radio Access Network (E-UTRAN); Overall description; Stage 2".

[14] 3GPP TS 36.321: "Evolved Universal Terrestrial Radio Access (E-UTRA); Medium Access Control (MAC)".

[15] 3GPP TS 36.323: "Evolved Universal Terrestrial Radio Access (E-UTRA); Packet Data Convergence Protocol (PDCP)".

[16] 3GPP TS 38.211: "NR; Physical channels and modulation".

[17] 3GPP TS 38.331: "NR; Radio Resource Control (RRC) protocol specification".

[18] 3GPP TS 38.213: "NR; Physical layer procedures for control".

[19] 3GPP TS 37.340: "Evolved Universal Terrestrial Radio Access (E-UTRA) and NR; Multi-connectivity; Stage 2".

[20] 3GPP TS 38.300: "NR; NR and NG-RAN Overall Description; Stage 2".

[21] 3GPP TS 38.321: "NR; Medium Access Control (MAC) protocol specification".

3 Definitions of terms, symbols and abbreviations

3.1 Terms

For the purposes of the present document, the terms given in TR 21.905 [1] and the following apply. A term defined in the present document takes precedence over the definition of the same term, if any, in TR 21.905 [1].

example: text used to clarify abstract rules by applying them literally.

3.2 Symbols

For the purposes of the present document, the following symbols apply:

<symbol> <Explanation>

3.3 Abbreviations

For the purposes of the present document, the abbreviations given in TR 21.905 [1] and the following apply. An abbreviation defined in the present document takes precedence over the definition of the same abbreviation, if any, in TR 21.905 [1].

Where the same abbreviation is used for LTE V2X and NR V2X, which is meant can be derived from the clause within which it appears, unless otherwise stated.

5GC	Fifth Generation core network
AGC	Automatic gain control
AMBR	Aggregate maximum bit rate
BSM	Basic safety message
BWP	Bandwidth part
CA	Carrier aggregation
CAM	Cooperative awareness message
CBR	Channel busy ratio
CR	Channel usage ratio
DENM	Decentralized environmental notification message
DMRS	Demodulation reference signal
EPC	Evolved packet core
MBSFN	Multicast-broadcast single-frequency network
MNO	Mobile network operator
PPPP	ProSe per-packet priority
PPPR	ProSe per-packet reliability
PSBCH	Physical sidelink broadcast channel
PSCCH	Physical sidelink control channel
PSSCH	Physical sidelink shared channel
PSSS, S-PSS	Primary sidelink synchronization signal (LTE), sidelink primary synchronization signal (NR)
PT-RS	Phase-tracking reference signal
P-UE	Pedestrian UE

RSU	Roadside unit
SA	Scheduling assignment
SCI	Sidelink control information
SC-PTM	Single-cell point-to-multipoint
SL-BCH	Sidelink broadcast channel
SLSS	Sidelink synchronization signal
S-RSSI	Sidelink received signal strength indicator
S-SSB	Sidelink synchronization signal block
SSSS, S-SSS	Secondary sidelink synchronization signal (LTE), sidelink secondary synchronization signal (NR)
V2I	Vehicle-to-infrastructure
V2P	Vehicle-to-pedestrian
V2V	Vehicle-to-vehicle
V2X	Vehicle-to-everything

4 Services and requirements

LTE-V2X is designed with BSM, CAM, and DENM particularly in mind. BSMs and CAMs have the characteristic of generating periodic messages at intervals, whereas DENMs are event-triggered. As an illustration of the different message types, in TR 36.885 [2], BSM/CAM were modelled, for evaluation purposes, as periodically occurring sets of one 300-byte message followed by four 190-byte messages. These types of message regularly broadcast information such as the vehicle's heading, speed, latitude/longitude, etc. ETSI EN 302 637-2 [3], SAE J2735 [4]. In TR 36.885 [2], DENMs were modelled, for evaluation purposes, as Poisson distributed initiations of six 800-byte messages spaced by 100 ms. DENMs can contain various different messages depending on the cause for their transmission, such as imminent collision, sudden braking, or detection of a traffic jam, amongst others ETSI EN 302 637-3 [5]. The requirements relating to traffic size and pattern for LTE-V2X set in TS 22.185 [6] can be summarized as follows, although they do not limit the usage of LTE-V2X. Other requirements relating to general system function are also included in TS 22.185 [6].

- Support for periodic broadcast messages with payloads of 50-300 bytes.
- Support for event-triggered messages with payloads of up to 1200 bytes.
- Up to 10 messages per second transmitted by a UE.
- V2V and V2P latency of maximum 100 ms, or for V2V pre-crash sensing, maximum 20 ms.
- V2I latency, i.e. between a UE and RSU, of maximum 100 ms.
- V2N latency, i.e. when transferring messages via the cellular network, of maximum 1000 ms.
- Maximum relative velocity between two vehicles of 500 km/h, and maximum absolute velocity of 250 km/h for V2V and V2P UEs, and of a UE communicating with an RSU.
- Requirements relating to security, integrity, authorization, and privacy.

NR V2X is designed with a broader set of more advanced V2X use cases in mind. These were specified in TS 22.18 [7], and are broadly arranged into four use case groups: vehicular platooning, extended sensors, advanced driving, and remote driving.

1) Vehicles Platooning enables the vehicles to dynamically form a platoon travelling together. All the vehicles in the platoon obtain information from the leading vehicle to manage this platoon. These information allow the vehicles to drive closer than normal in a coordinated manner, going to the same direction and travelling together.

2) Extended Sensors enables the exchange of raw or processed data gathered through local sensors or live video images among vehicles, road site units, devices of pedestrian and V2X application servers. The vehicles can increase the perception of their environment beyond of what their own sensors can detect and have a more broad and holistic view of the local situation. High data rate is one of the key characteristics.

3) Advanced Driving enables semi-automated or full-automated driving. Each vehicle and/or RSU shares its own perception data obtained from its local sensors with vehicles in proximity and that allows vehicles to synchronize and coordinate their trajectories or manoeuvres. Each vehicle shares its driving intention with vehicles in proximity too.

4) Remote Driving enables a remote driver or a V2X application to operate a remote vehicle for those passengers who cannot drive by themselves or remote vehicles located in dangerous environments. For a case where variation is limited and routes are predictable, such as public transportation, driving based on cloud computing can be used. High reliability and low latency are the main requirements.

The most demanding requirements set in TS 22.186 [7] are for a maximum sidelink range of 1000 m, a maximum throughput of 1 Gbps, a shortest latency of 3 ms, a maximum reliability of 99.999%, and a maximum transmission rate of 100 messages/second. However, there is not a use case which, on its own, demands all of these bounding requirements. The communication scenarios described in TS 22.186 [7] include a mixture of periodic and aperiodic services. Similar to LTE-V2X, there are also requirements relating to security, integrity, authorization, and privacy.

5 LTE V2X

5.1 V2X sidelink physical layer

The LTE V2X sidelink supports broadcast transmission of messages in the physical layer, since this is a suitable approach for delivery BSM, CAM, DENM and similar traffic. In the MAC layer, a broadcast address can be mapped to a single UE or a group of UEs by implementation. Such implementation techniques have no particular specification support in LTE, and are transparent to the physical layer.

5.1.1 Physical sidelink channels and signals

The LTE V2X sidelink uses the following physical channels and signals:

- Physical sidelink broadcast channel (PSBCH), specified in TS 36.211 [8, clause 9.6]
- Physical sidelink control channel (PSCCH), specified in TS 36.211 [8, clause 9.4]
- Physical sidelink shared channel (PSSCH), specified in TS 36.211 [8, clause 9.3]
- Primary and secondary sidelink synchronization signals (PSSS and SSSS) specified in TS 36.211 [8, clause 9.7]. These can be referred to jointly as the sidelink synchronization signal (SLSS).
- A demodulation reference signal (DMRS) associated with each of the three physical channels, specified in TS 36.211 [8, clause 9.8]

LTE-V2X sidelink physical channels are transmitted using SC-FDMA.

PSBCH transmits the SL-BCH transport channel, which carries the sidelink V2X Master Information Block (MIB-V2X) from the RRC layer. When in use, PSBCH transmits MIB-V2X every 160 ms in the central 72 subcarriers of the SL bandwidth. DMRS associated with PSBCH are transmitted in the 5th, 7th, and 10th symbols of the subframe.

PSSS and SSSS are transmitted to allow other UEs to achieve sidelink synchronization when they do not have another source of synchronization available. They jointly convey the SLSS ID selected by the UE. For further details of SLSS and synchronization, refer to Clause 5.1.2. PSSS/SSSS also allow UEs to detect the sidelink subframe boundary, with subframe number and frame number signalled in MIB-V2X.

PSSCH transmits the SL-SCH transport channel, which carries the TBs of data for transmission over SL. The resources in which PSSCH is transmitted can either be scheduled by an eNB and granted to the UE by a DCI (termed resource allocation mode 3, see Clause 5.2.2.1) or determined through a sensing procedure conducted autonomously by the transmitting UE (termed resource allocation mode 4, see Clause 5.2.2.2). A given TB can be transmitted once or twice, with a second transmission occurring a time gap after the first which is indicated in the scheduling SCI.

PSCCH transmits physical layer sidelink control information (SCI), also known as a scheduling assignment (SA). For V2X, PSCCH is transmitted in two frequency-adjacent PRBs, and always carries SCI format 1, defined in TS 36.212 [9, clause 5.4.3.1.2]. To receive PSCCH, a UE has to monitor each defined pair of PRBs to determine whether PSCCH has been transmitted in them. PSCCH is transmitted in the same subframe(s) as the associated PSSCH, and can be transmitted in PRBs that are either frequency adjacent or frequency non-adjacent to the PSSCH.

DMRS associated with PSSCH and PSCCH are transmitted in the 3rd, 6th, 9th, and 12th symbols of a subframe.