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Radio interface standards of vehicle-to-vehicle and vehicle-to-infrastructure two-way communications for Intelligent Transport System applications

M Series
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Note: *This ITU-R Recommendation was approved in English under the procedure detailed in Resolution ITU-R 1.*

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RECOMMENDATION ITU-R M.2084-1

Radio interface standards of vehicle-to-vehicle and vehicle-to-infrastructure two-way communications for Intelligent Transport System applications

(Question ITU-R 205-5/5)

(2015-2019)

Scope

This Recommendation identifies specific radio interface standards of vehicle-to-vehicle and vehicle-to-infrastructure[1] communications for Intelligent Transport System applications. The technical characteristics described in this Recommendation are based on current Intelligent Transport Systems (ITS) applications in the mobile service.

Keywords

ITS, vehicle-to-vehicle communications, vehicle-to-infrastructure communications

Acronyms and abbreviations

3GPP	3rd Generation Partnership Project
ARIB	Association of Radio Industries and Businesses
ATIS	Alliance for Telecommunications Industry Solutions
ATS	Abstract test suite
BPSK	Binary phase shift keying
CCSA	China Communications Standards Association
CEN	European Committee for Standardization (Comité européen de normalisation)
CSMA/CA	Carrier sense multiple access/collision avoidance
DCC	Decentralized congestion control
DSRC	Dedicated short range communications
EFC	Electronic Fee Collection
eNB	E-UTRAN NodeB
ETSI	European Telecommunications Standards Institute
FDD	Frequency Division Duplex
FDM	Frequency Division Multiplexing
FEC	Forward error correction
GNSS	Global Navigation Satellite System
HARQ	Hybrid automatic repeat request
IEEE	Institute of Electrical and Electronics Engineers
IMDA	Infocomm Media Development Authority of Singapore

[1] Vehicle-to-infrastructure communications includes two-way communications between vehicle and infrastructure.

ITS	Intelligent transport systems
LTE	Long term evolution
OFDM	Orthogonal frequency-division multiplexing
OFDMA	Orthogonal frequency division multiple access
PICS	Protocol implementation conformance statement
PIXIT	Protocol Implementation eXtra Information for Testing
QAM	Quadrature amplitude modulation
QPSK	Quadrature phase shift keying
SC-FDM	Single carrier-frequency division multiplexing
SC-FDMA	Single-carrier frequency division multiple access
TDD	Time division duplex
TDM	Time division multiplexing
TSS & TP	Test suite structure and test purposes
TTA	Telecommunications Technology Association
UE	User equipment
V2I	Vehicle-to-infrastructure
V2N	Vehicle-to-network
V2P	Vehicle-to-pedestrian
V2V	Vehicle-to-vehicle
WAVE	Wireless access in vehicular environments

Related ITU Recommendations

Recommendation ITU-R M.1453	Intelligent Transport Systems – dedicated short-range communications at 5.8 GHz
Recommendation ITU-R M.1890	Intelligent Transport Systems – Guidelines and Objectives
Recommendation ITU-R M.2121	Harmonization of frequency bands for Intelligent Transport Systems in the mobile service

The ITU Radiocommunication Assembly,

considering

a) that standards development organizations (SDOs) are developing specific standards for vehicle-to-vehicle and vehicle-to-infrastructure communications in Intelligent Transport Systems (ITS);

b) that using the ITU-R Recommendation identifying these standards, manufacturers and operators should be able to determine the most suitable standards for their needs,

recommends

that the radio interface standards and technical specifications in Annexes 1 to 8 should be used for vehicle-to-vehicle and vehicle-to-infrastructure communications.

Table 1 provides a summary of the standards and technical specifications found in the respective Annexes.

TABLE 1

Standards and technical specifications

	Annex 1	**Annex 2**	**Annex 3**	**Annex 4**	**Annex 5**	**Annex 6**	**Annex 7**	**Annex 8**
Standardization/ technical specifications body	ETSI	IEEE	ARIB	TTA	IMDA	CCSA	3GPP	ATIS

NOTE – The technical characteristics of these standards and technical specifications are summarized in Annex 9.

Annex 1

ETSI standards

ETSI standards developed for the access and media layer are based on features such as:

– 5.9 GHz spectrum usage and spectrum access;

– multichannel operation;

– decentralized congestion control (DCC) and security;

– coexistence of ITS and EFC (using CEN DSRC) applications in the 5.8 GHz and 5.9 GHz bands; and

– ITS testing standards.

The technical characteristics of vehicle-to-vehicle and vehicle-to-infrastructure communications for ETSI ITS-G5 are shown in Table 2.

TABLE 2

Characteristics of the transmission scheme

Item	**Transmission characteristic**
Operating frequency range (MHz)	5 855-5 925
RF channel bandwidth (MHz)	10
RF Transmit Power/e.i.r.p.	Typical limit of up to 33 dBm e.i.r.p.
Modulation scheme	BPSK OFDM, QPSK OFDM, 16QAM OFDM, 64QAM OFDM
Forward error correction	Convolutional coding, rate = 1/2, 2/3, 3/4
Data transmission rate (Mbit/s)	3, 4.5 , 6 , 9 , 12 , 18 , 24 , 27
Media access control	CSMA/CA
Duplex method	TDD

TABLE 3

Base standards for the access and media layer

Standard title	Standard number
Intelligent Transport Systems (ITS); Radiocommunications equipment operating in the 5 855 MHz to 5 925 MHz frequency band; Harmonised Standard covering the essential requirements of article 3.2 of Directive 2014/53/EU	ETSI EN 302 571
Intelligent Transport Systems (ITS); Access layer specification for Intelligent Transport Systems operating in the 5 GHz frequency band	ETSI EN 302 663
Intelligent Transport Systems (ITS); Decentralized Congestion Control Mechanisms for Intelligent Transport Systems operating in the 5 GHz range; Access layer part	ETSI TS 102 687
Intelligent Transport Systems (ITS); Mitigation techniques to avoid interference between European CEN Dedicated Short-Range Communication (CEN DSRC) equipment and Intelligent Transport Systems (ITS) operating in the 5 GHz frequency range	ETSI TS 102 792
Intelligent Transport Systems (ITS); Harmonized Channel Specifications for Intelligent Transport Systems (ITS) operating in the 5 GHz frequency band	ETSI TS 102 724
Intelligent Transport Systems (ITS); Cross Layer DCC Management Entity for operation in the ITS G5A and ITS G5B medium	ETSI TS 103 175

TABLE 4

Testing standards for the access and media layer

Testing Standard title	Standard number
Intelligent Transport Systems (ITS); Test specifications for the channel congestion control algorithms operating in the 5.9 GHz range; Part 1: Protocol Implementation Conformance Statement (PICS)	ETSI TS 102 917-1
Intelligent Transport Systems (ITS); Test specifications for the channel congestion control algorithms operating in the 5.9 GHz range; Part 2: Test Suite Structure and Test Purposes (TSS & TP)	ETSI TS 102 917-2
Intelligent Transport Systems (ITS); Test specifications for the channel congestion control algorithms operating in the 5.9 GHz range; Part 3: Abstract Test Suite (ATS) and partial Protocol Implementation eXtra Information for Testing (PIXIT)	ETSI TS 102 917-3
Intelligent Transport Systems (ITS); Test specifications for the methods to ensure coexistence of Cooperative ITS G5 with RTTT DSRC; Part 1: Protocol Implementation Conformance Statement (PICS)	ETSI TS 102 916-1

TABLE 4 (*end*)

Testing Standard title	Standard number
Intelligent Transport Systems (ITS); Test specifications for the methods to ensure coexistence of Cooperative ITS G5 with RTTT DSRC; Part 2: Test Suite Structure and Test Purposes (TSS&TP)	ETSI TS 102 916-2
Intelligent Transport Systems (ITS); Test specifications for the methods to ensure coexistence of Cooperative ITS G5 with RTTT DSRC; Part 3: Abstract Test Suite (ATS) and partial Protocol Implementation eXtra Information for Testing (PIXIT)	ETSI TS 102 916-3

Radio interface technologies supporting Vehicle-to-Everything (V2X) communications for ITS applications have been developed as part of 3GPP technical specifications. As a founding partner of 3GPP, ETSI automatically transposes technical specifications and technical reports developed in 3GPP to ETSI deliverables. ETSI technical specifications that are transposed from 3GPP technical specifications supporting V2V and V2I communication are described in Annex 7.

TABLE 5

Base standards for security

Standard title	Standard number
Intelligent Transport Systems (ITS); Security; Security header and certificate formats	ETSI TS 103 097
Intelligent Transport Systems (ITS); Security; ITS communications security architecture and security management	ETSI TS 102 940
Intelligent Transport Systems (ITS); Security; Trust and Privacy Management	ETSI TS 102 941

The deployment of any radio interface technology based on standards listed in Tables 3, 4 and 12 has to follow the regional and national regulations.

Annex 2

IEEE standards

IEEE Standards developed for the access and media layer are based on features such as:

– 5.9 GHz spectrum usage;

– multichannel operation;

– coexistence of ITS and other existing services in the 5 850-5 925 MHz band.

The requirement for use of multi-channel wireless communications is based on IEEE Std 802.11p™-2010 – IEEE Standard for Information technology – Local and metropolitan area networks – Specific requirements – Part 11: Wireless LAN Medium Access Control (MAC) and Physical Layer (PHY)

Specifications Amendment 6: Wireless Access in Vehicular Environments, originally developed as an amendment to IEEE 802.11™-2007 that has been incorporated into the revision of IEEE 802.11™-2016 – IEEE Standard for Information technology – Telecommunications and information exchange between systems Local and metropolitan area networks – Specific requirements Part 11: Wireless LAN Medium Access Control (MAC) and Physical Layer (PHY) Specifications. The upper layer protocols and services requirements are described in the IEEE 1609 family of standards that use IEEE Std 802.11. Standardization of the upper layer protocols and services support the vehicle-to-vehicle and vehicle-to-roadside communication requirements of the National ITS Architecture and the Joint Program Office initiatives. Benefits for the ITS program in enabling wireless communications is for vehicle operators, dispatch centres, traffic management centres, emergency response centres, route guidance, safety and amber alerts, and response to traveller emergencies, traceable to the National ITS Architecture.

The published IEEE Std 802.11-2016 is available for free download at the IEEE Get program: http://standards.ieee.org/about/get/802/802.11.html

A list of the IEEE 1609 family of standards is as follows:

IEEE 1609.0™-2013 – IEEE Guide for Wireless Access in Vehicular Environments (WAVE) – Architecture

IEEE 1609.2™-2016 – IEEE Standard for Wireless Access in Vehicular Environments – Security Services for Applications and Management Messages

IEEE 1609.3™-2016 – IEEE Standard for Wireless Access in Vehicular Environments (WAVE) – Networking Services

IEEE 1609.4™-2016 – IEEE Standard for Wireless Access in Vehicular Environments (WAVE) – Multi-channel Operation

IEEE 1609.11™-2010 – IEEE Standard for Wireless Access in Vehicular Environments (WAVE) – Over-the-Air Electronic Payment Data Exchange Protocol for Intelligent Transportation Systems (ITS)

IEEE 1609.12™-2016 – IEEE Standard for Wireless Access in Vehicular Environments (WAVE) – Identifier Allocations

Annex 3

ARIB standard

In Japan, for the use of the safe driving support systems, a part of the 700 MHz band (755.5-764.5 MHz) has been assigned in a new spectrum allocation on a primary basis in the digital dividend band. The technical characteristics of vehicle-to-vehicle and vehicle-to-infrastructure communications for safe driving support systems are shown in Table 6.

TABLE 6

Characteristics of the transmission scheme

Item	Technical characteristic
Operating frequency range	755.5-764.5 MHz (Single channel)
Occupied bandwidth	Less than 9 MHz
Modulation scheme	BPSK OFDM, QPSK OFDM, 16QAM OFDM
Forward error correction	Convolutional coding, rate = 1/2, 3/4
Data transmission rate (Mbit/s)	3, 4.5, 6, 9, 12, 18
Media access control	CSMA/CA

Table 6 shows basic specifications of ARIB standard; ARIB STD-T109[2], 700 MHz band ITS which have been developed in February 2012.

A 9 MHz channel width in the 700 MHz radio frequency band will be used for the safe driving support systems.

Data transmission rate is variable based on the selection of modulation scheme and coding rate (R) as follows:

– 3 Mbit/s (BPSK OFDM, R = 1/2), 4.5 Mbit/s (BPSK OFDM, R = 3/4);

– 6 Mbit/s (QPSK OFDM/, R = 1/2), 9 Mbit/s (QPSK OFDM, R = 3/4);

– 12 Mbit/s (16QAM OFDM, R = 1/2), 18 Mbit/s (16QAM OFDM, R = 3/4).

The single channel accommodates both vehicle-to-vehicle and vehicle-to-infrastructure communications based on CSMA/CA media access control.

Annex 4

TTA standards

1 Technical characteristics

The advanced ITS radiocommunications have to consider the described V2V/V2I communications and its service requirements and WAVE standards for international harmonization. In V2V applications, it is required to consider the low packet latency because the life-saving time of safety message is useful in the span of 100 ms. Also it requires a highly activated radio channel when many vehicles try to activate radio channel simultaneously. In V2I applications, it needs to adopt the long packet transmission which includes a short message, map information and image information to be order of 2 Kbytes in a packet size in high mobility condition.

Thus the advanced ITS radiocommunications have the following features as shown in Table 7.

[2] ARIB standard; ARIB STD-T109, 700 MHz band intelligent transport systems (https://www.arib.or.jp/english/std_tr/telecommunications/std-t109.html).

TABLE 7

Technical characteristics

Item	Technical characteristic
RF frequency (MHz)	5 855-5 925
RF channel bandwidth (MHz)	10
RF Transmit power (dBm)	20
Modulation type	OFDM (BPSK, QPSK, 16QAM, 64QAM)
Data rate (Mbit/s)	3, 4.5, 6, 9, 12, 18, 24, 27
MAC	CSMA/CA, Option: Time Slot based CSMA/CA
Networking	IPv4/IPv6, VMP(WSMP compatible)
Multi-hop	Location information based routing

2 TTA Standards related to advanced ITS radiocommunications

In the Republic of Korea, Telecommunication Technology Association (TTA) established six standards for advanced ITS radiocommunications. The detailed information of these standards is shown in Table 8.

TABLE 8

Base standards related to advanced ITS radiocommunications

Standard title	Standard number
Vehicle communication system Stage 1: Requirements	TTAK.KO-06.0175/R2
Vehicle communication system Stage 2: Architecture	TTAK.KO-06.0193/R2
Vehicle communication system Stage 3: PHY/MAC	TTAK.KO-06.0216/R1
Vehicle communication system Stage 3: PHY/MAC(LTE-V2X)	TTAK.KO-06.0479
Vehicle communication system State 3: Networking	TTAK.KO-06.0234/R1
Vehicle communication system State 3: Application Protocol Interface	TTAK.KO-06.0242/R1

Radio interface technologies supporting Vehicle-to-Everything (V2X) communications for ITS applications have been developed as part of 3GPP technical specifications. As a founding partner of 3GPP, TTA regularly transposes technical specifications and technical reports developed in 3GPP to TTA technical specifications.

TTA technical specifications transposed from 3GPP technical specifications supporting V2X communication are described in Annex 7.

Annex 5

IMDA standards

Infocomm Media Development Authority of Singapore (IMDA) had set the required communication standards for ITS with the advice from the Telecommunication Standards Advisory Committee (TSAC). The detailed information of the standards could be found in IMDA TS DSRC document – Technical Specification for Dedicated Short-Range Communications in Intelligent Transport Systems.

The Specification was intended for developing ITS for improving traffic management, transportation safety and mobility, and an ITS architecture for Vehicle-to-Vehicle (V2V) and Vehicle-to-Infrastructure (V2I) communications. The technical characteristics used have the following features as shown in Table 9.

TABLE 9

Characteristics of the transmission scheme

Item	Transmission characteristic
Operating frequency range (MHz)	5 855-5 925
RF channel bandwidth (MHz)	10
RF Transmit Power/e.i.r.p.	Typical limit of up to 33 dBm e.i.r.p.
Modulation scheme	BPSK OFDM, QPSK OFDM, 16QAM OFDM, 64QAM OFDM
Forward error correction	Convolutional coding, rate = 1/2, 2/3, 3/4
Data transmission rate (Mbit/s)	3, 4.5 , 6 , 9 , 12 , 18 , 24 , 27
Media access control	CSMA/CA
Duplex method	TDD

The DSRC use cases of the Specification may be broadly categorised as follows:

a) Localisation;

b) Electronic Parking Management;

c) Traffic Signal Control Management;

d) Traffic Information;

e) Safety Applications;

f) Emergency Applications;

g) Kiosk Related Services;

h) Other ITS Application and Services.

Annex 6

CCSA standards

China Communications Standards Association (CCSA) has finished the general technical requirements standard and air interface requirements standard of LTE-based vehicular communication (LTE-V2X), which includes V2V (Vehicle-to-Vehicle), V2I (Vehicle-to-Infrastructure), V2P(Vehicle-to-Pedestrian) and V2N (Vehicle-to-Network). The detailed standard numbers are presented in Table 10.

TABLE 10

Standards of LTE-V2X in CCSA

Standard title	Standard item number
General technical requirements of LTE-based vehicular communication	YD/T 3400-2018[3]
Technical requirements of air interface of LTE-based vehicular communication	YD/T 3340-2018[4]

CCSA Standards of LTE-V2X which are derived from the transposed 3GPP technical specifications listed in Table 12, Annex 7 support two operation modes, which are:

1) Direct communication mode between UEs in sidelink, supporting V2V, V2I and V2P, main features:
   - operating in 5.9 GHz spectrum;
   - direct communication between UEs;
   - enhanced physical layer structure;
   - enhanced resource allocation mechanism supporting distributed mode (Mode 4) and centralized mode (Mode 3);
   - synchronization procedure with Global Navigation Satellite System (GNSS) and/or eNB;
   - decentralized congestion control;
   - vehicle-to-pedestrian transmission with power saving.
2) Cellular communication mode between UE and eNB in uplink/downlink, supporting V2N and also supporting V2V/V2I/V2P via cellular network relay. Main enhanced features comparing with traditional cellular communication:
   - shorter repetition/modification period for Multimedia Broadcast Multicast Service (MBMS) in downlink;
   - multiple Semi-Persistent Scheduling (SPS) configuration in uplink.

The technical characteristics of LTE-V2X standards in CCSA are summarized in Table 11.

[3] http://www.ptsn.net.cn/standard/std_query/show-yd-5502-1.htm.

[4] http://www.ptsn.net.cn/standard/std_query/show-yd-5394-1.htm.

TABLE 11

Technical characteristics of LTE-V2X standards in CCSA

Parameter	Technical characteristic[5]	
	Direct communication mode	**Cellular communication mode**
Operating frequency range	5 855-5 925 MHz Note: China officially approved 5 905-5 925 MHz for LTE-V2X.	The bands used in combination with direct communication mode. For FDD UL: 1710-1785 MHz; DL: 1 805-1 880 MHz UL: 880-915 MHz; DL: 925-960 MHz For TDD 1 880-1 920 MHz 2 496-2 690 MHz
RF channel bandwidth	10/20 MHz	1.4/3/5/10/15/20 MHz
RF transmit power/e.i.r.p.	Maximum 23 dBm	Maximum 23 dBm
Modulation scheme	QPSK SC-FDM, 16QAM SC-FDM	UL: QPSK SC-FDM, 16QAM SC-FDM, 64QAM SC-FDM, 256QAM SC-FDM DL: QPSK OFDM, 16QAM OFDM, 64QAM OFDM, 256QAM OFDM
Forward error correction	For control channel: Tail biting convolutional coding, rate = 1/8. For data channel: Turbo coding with rate up to 0.86. Rate can be controlled with a fine granularity.	UCI (Uplink Control Information): Tail biting convolutional coding / Block code UL-SCH (Uplink Shared channel): Turbo coding DCI (Downlink Control Information): Tail biting convolutional coding DL-SCH (Downlink Shared channel): Turbo coding MCH (Multicast channel):Turbo coding
Data transmission rate	Up to 15.8 Mbit/s for 10 MHz channel bandwidth. Up to 31.7 Mbit/s for 20 MHz channel bandwidth. Rate can be controlled with a fine granularity.	Unicast: UL: Maximum 105.5 Mbit/s for 20 MHz; 78.7 Mbit/s for 15 MHz; 52.7 Mbit/s for 10 MHz; 26.4 Mbit/s for 5 MHz. DL with one layer: Maximum 97.9 Mbit/s for 20 MHz; 75.4 Mbit/s for 15 MHz; 48.9 Mbit/s for 10 MHz; 24.5 Mbit/s for 5 MHz. DL with two layers: Maximum 195.8 Mbit/s for 20 MHz; 149.8 Mbit/s for 15 MHz; 97.9 Mbit/s for 10 MHz; 48.9 Mbit/s for 5 MHz. Broadcast: Maximum 60% of unicast.

[5] The deployment of any radio interface technology in China based on standards has to follow the Chinese national regulations.

TABLE 11 (*end*)

Parameter	Technical characteristic[5]	
	Direct communication mode	**Cellular communication mode**
Media access control	For Mode4: Sensing with semi persistent transmission, random selection. For Mode3: eNB scheduling.	eNB scheduling
Duplex method	TDD	TDD/FDD
Resource multiplexing across UEs	Frequency Division Multiplexing (FDM) and Time Division Multiplexing (TDM)	Frequency Division Multiplexing (FDM) and Time Division Multiplexing (TDM)
Retransmission	Hybrid Automatic Repeat Request (HARQ)	Hybrid Automatic Repeat Request (HARQ)

Annex 7

3GPP technical specifications

For Intelligent Transport Systems, 3GPP has developed its technical specifications for vehicle-to-everything (V2X), which includes vehicle-to-vehicle (V2V), vehicle-to-infrastructure (V2I), vehicle-to-pedestrian (V2P), vehicle-to-network (V2N), as a part of the Long Term Evolution (LTE) specifications from Release 14. 3GPP technical specifications for V2X cover physical layer signals/channels, medium access and radio resource management protocols, radio access network, core network and user equipment (UE) protocol, security, use cases and service requirements, and device performance requirements.

3GPP technical specifications support two different interfaces for V2X communications. One is the Uu interface which provides communication between the cellular network, road infrastructure, pedestrians and vehicles using uplink and downlink via eNB. The other is the PC5 interface which has been developed to provide direct communication among vehicles and road infrastructure. The Uu interface always uses centralized scheduling which means that base station (eNB) controls medium access and radio resource management. The PC5 interface supports two scheduling options; one is the centralized scheduling similar to that used for the Uu interface and the other is distributed scheduling where each vehicle on its own determines the suitable time and frequency resources to use for its transmissions. It is noted that the PC5 interface with distributed scheduling can operate both inside and outside cellular coverage and does not require cellular operator support. While the PC5 interface only supports broadcast transmissions, the Uu interface supports unicast, multicast, and broadcast transmissions.

The LTE downlink uses orthogonal frequency division multiple access (OFDMA), and the LTE uplink and PC5 interfaces use single-carrier frequency division multiple access (SC-FDMA).

Frequency bands envisaged for the LTE-V2X Uu interface and the PC5 interface[6] are found in Table 13.

All 3GPP technical specifications listed in Table 12 have been transposed by 3GPP Organizational Partners[7] into their relevant deliverables (e.g. standards). The detailed standards transposed by 3GPP Organizational Partners are listed in Table 12.

TABLE 12

List of the 3GPP technical specifications and transposed standards related to V2X

Specifications title	Reference number	Standard number			
		ATIS	CCSA[8]	ETSI	TTA
<Core network and UE protocol>					
Service requirements for V2X service	3GPP TS 22.185	ATIS.3GPP.TS 22.185V1430	CCSA TS 22.185 v14.3.0	ETSI TS 122 185	TTAT.3G-22.185(R14-14.3.0)
<Core network and UE protocol>					
Numbering, addressing and identification	3GPP TS 23.003	ATIS.3GPP.TS 23.003V1460	CCSA TS 23.003 v14.6.0	ETSI TS 123 003	TTAT.3G-23.003(R14-14.5.0)
Restoration procedures.	3GPP TS 23.007	ATIS.3GPP.TS 23.007V1440	CCSA TS 23.007 v14.4.0	ETSI TS 123 007	TTAT.3G-23.007(R14-14.3.0)
Organization of subscriber data	3GPP TS 23.008	ATIS.3GPP.TS 23.008V1440	CCSA TS 23.008 v14.4.0	ETSI TS 123 008	TTAT.3G-23.008(R14-14.3.0)
Non-Access-Stratum (NAS) functions related to Mobile Station (MS) in idle mode	3GPP TS 23.122	ATIS.3GPP.TS 23.122V1440	CCSA TS 23.122 v14.4.0	ETSI TS 123 122	TTAT.3G-23.122(R14-14.4.0)
Policy and charging control architecture	3GPP TS 23.203	ATIS.3GPP.TS 23.203V1450	CCSA TS 23.203 v14.5.0	ETSI TS 123 203	TTAT.3G-23.203(R14-14.5.0)
Architecture enhancements for V2X service	3GPP TS 23.285	ATIS.3GPP.TS 23.285V1450	CCSA TS 23.285 v14.5.0	ETSI TS 123 285	TTAT.3G-23.285(R14-14.4.0)
Proximity-based services (ProSe); Stage 2	3GPP TS 23.303	ATIS.3GPP.TS 23.303V1410	CCSA TS 23.303 v14.1.0	ETSI TS 123 303	TTAT.3G-23.303(R14-14.1.0)
Non-Access-Stratum (NAS) protocol for Evolved Packet System (EPS); Stage 3	3GPP TS 24.301	ATIS.3GPP.TS 24.301V1460	CCSA TS 24.301 v14.6.0	ETSI TS 124 301	TTAT.3G-24.301(R14-14.5.0)
Proximity-services (ProSe) User Equipment (UE) to Proximity-services (ProSe) Function Protocol aspects; Stage 3	3GPP TS 24.334	ATIS.3GPP.TS 24.334V1400	CCSA TS 24.334 v14.0.0	ETSI TS 124 334	TTAT.3G-24.334(R14-14.0.0)

6 The published 3GPP technical specifications are available at 3GPP Portal: http://www.3gpp.org/ftp/Specs.

7 The Organizational Partners of 3GPP are ARIB, ATIS, CCSA, ETSI, TSDSI, TTA and TTC (http://www.3gpp.org/partners).

8 http://www.ccsa.org.cn/english/files.php?docpath=/ITU-R/M.1457/M.1457-14/DS/Rel-14.

TABLE 12 (*continued*)

Specifications title	Reference number	Standard number			
		ATIS	CCSA[8]	ETSI	TTA
V2X services Management Object (MO)	3GPP TS 24.385	ATIS.3GPP.TS 24.385V1430	CCSA TS 24.385 v14.3.0	ETSI TS 124 385	TTAT.3G-24.385(R14-14.2.0)
User Equipment (UE) to V2X control function; protocol aspects; Stage 3	3GPP TS 24.386	ATIS.3GPP.TS 24.386V1430	CCSA TS 24.386 v14.3.0	ETSI TS 124 386	TTAT.3G-24.386(R14-14.2.0)
Representational state transfer over xMB reference point between content provider and BM-SC	3GPP TS 29.116	ATIS.3GPP.TS 29.116V1430	CCSA TS 29.116 v14.3.0	ETSI TS 129 116	TTAT.3G-29.116(R14-14.2.0)
Policy and Charging Control (PCC); Reference points	3GPP TS 29.212	ATIS.3GPP.TS 29.212V1460	CCSA TS 29.212 v14.6.0	ETSI TS 129 212	TTAT.3G-29.212(R14-14.5.0)
Evolved Packet System (EPS); Mobility Management Entity (MME) and Serving GPRS Support Node (SGSN) related interfaces based on Diameter protocol	3GPP TS 29.272	ATIS.3GPP.TS 29.272V1460	CCSA TS 29.272 v14.6.0	ETSI TS 129 272	TTAT.3G-29.272(R14-14.5.0)
V2X Control Function to Home Subscriber Server (HSS) aspects (V4); Stage 3	3GPP TS 29.388	ATIS.3GPP.TS 29.388V1410	CCSA TS 29.388 v14.1.0	ETSI TS 129 388	TTAT.3G-29.388(R14-14.1.0)
Inter-V2X Control Function Signalling aspects (V6); Stage 3	3GPP TS 29.389	ATIS.3GPP.TS 29.389V1410	CCSA TS 29.389 v14.1.0	ETSI TS 129 389	TTAT.3G-29.389(R14-14.1.0)
Group Communication System Enablers for LTE (GCSE_LTE); MB2 reference point; Stage 3	3GPP TS 29.468	ATIS.3GPP.TS 29.468V1430	CCSA TS 29.468 v14.3.0	ETSI TS 129 468	TTAT.3G-29.468(R14-14.2.0)
Characteristics of the Universal Subscriber Identity Module (USIM) application	3GPP TS 31.102	ATIS.3GPP.TS 31.102V1440	CCSA TS 31.102 v14.4.0	ETSI TS 131 102	TTAT.3G-31.102(R14-14.3.0)
<Security>					
Security aspect for LTE support of V2X services	3GPP TS 33.185	ATIS.3GPP.TS 33.185V1410	CCSA TS 33.185 v14.1.0	ETSI TS 133 185	TTAT.3G-33.185(R14-14.1.0)
<Device performance requirements>					
Evolved Universal Terrestrial Radio Access (E-UTRA); User Equipment (UE) radio transmission and reception	3GPP TS 36.101	ATIS.3GPP.TS 36.101V1460	CCSA TS 36.101 v14.6.0	ETSI TS 136 101	TTAT.3G-36.101(R14-14.5.0)
Evolved Universal Terrestrial Radio Access (E-UTRA); Requirements for support of radio resource management	3GPP TS 36.133	ATIS.3GPP.TS 36.133V1460	CCSA TS 36.133 v14.6.0	ETSI TS 136 133	TTAT.3G-36.133(R14-14.5.0)
<Physical layer aspects>					

TABLE 12 (*continued*)

Specifications title	Reference number	Standard number			
		ATIS	CCSA[8]	ETSI	TTA
Evolved Universal Terrestrial Radio Access (E-UTRA); Physical channels and modulation	3GPP TS 36.211	ATIS.3GPP.TS 36.211V1450	CCSA TS 36.211 v14.5.0	ETSI TS 136 211	TTAT.3G-36.211(R14-14.4.0)
Evolved Universal Terrestrial Radio Access (E-UTRA); Multiplexing and channel coding	3GPP TS 36.212	ATIS.3GPP.TS 36.212V1451	CCSA TS 36.212 v14.5.1	ETSI TS 136 212	TTAT.3G-36.212(R14-14.4.0)
Evolved Universal Terrestrial Radio Access (E-UTRA); Physical layer procedures	3GPP TS 36.213	ATIS.3GPP.TS 36.213V1450	CCSA TS 36.213 v14.5.0	ETSI TS 136 213	TTAT.3G-36.213(R14-14.4.0)
Evolved Universal Terrestrial Radio Access (E-UTRA); Physical layer; Measurements	3GPP TS 36.214	ATIS.3GPP.TS 36.214V1440	CCSA TS 36.214 v14.4.0	ETSI TS 136 214	TTAT.3G-36.214(R14-14.3.0)
<Medium access and radio resource management protocols>					
Evolved Universal Terrestrial Radio Access (E-UTRA) and Evolved Universal Terrestrial Radio Access Network (E-UTRAN); Overall description; Stage 2	3GPP TS 36.300	ATIS.3GPP.TS 36.300V1450	CCSA TS 36.300 v14.5.0	ETSI TS 136 300	TTAT.3G-36.300(R14-14.4.0)
Evolved Universal Terrestrial Radio Access (E-UTRA); Services provided by the physical layer	3GPP TS 36.302	ATIS.3GPP.TS 36.302V1440	CCSA TS 36.302 v14.4.0	ETSI TS 136 302	TTAT.3G-36.302(R14-14.3.0)
Evolved Universal Terrestrial Radio Access (E-UTRA); User Equipment (UE) procedures in idle mode	3GPP TS 36.304	ATIS.3GPP.TS 36.304V1450	CCSA TS 36.304 v14.5.0	ETSI TS 136 304	TTAT.3G-36.304(R14-14.4.0)
Evolved Universal Terrestrial Radio Access (E-UTRA); User Equipment (UE) radio access capabilities	3GPP TS 36.306	ATIS.3GPP.TS 36.306V1450	CCSA TS 36.306 v14.5.0	ETSI TS 136 306	TTAT.3G-36.306(R14-14.4.0)
Evolved Universal Terrestrial Radio Access (E-UTRA); Medium Access Control (MAC) protocol specification	3GPP TS 36.321	ATIS.3GPP.TS 36.321V1400	CCSA TS 36.321 v14.5.0	ETSI TS 136 321	TTAT.3G-36.321(R14-14.4.0)
Evolved Universal Terrestrial Radio Access (E-UTRA); Radio Link Control (RLC) protocol specification	3GPP TS 36.322	ATIS.3GPP.TS 36.322V1450	CCSA TS 36.322 v14.1.0	ETSI TS 136 322	TTAT.3G-36.322(R14-14.1.0)
Evolved Universal Terrestrial Radio Access (E-UTRA); Packet Data Convergence Protocol (PDCP) specification	3GPP TS 36.323	ATIS.3GPP.TS 36.323V1410	CCSA TS 36.323 v14.5.0	ETSI TS 136 323	TTAT.3G-36.323(R14-14.4.0)
Evolved Universal Terrestrial Radio Access (E-UTRA); Radio Resource Control (RRC); Protocol specification	3GPP TS 36.331	ATIS.3GPP.TS 36.331V1451	CCSA TS 36.331 v14.5.1	ETSI TS 136 331	TTAT.3G-36.331(R14-14.4.0)

TABLE 12 (*end*)

Specifications title	Reference number	Standard number			
		ATIS	CCSA[8]	ETSI	TTA
<Radio access network aspects>					
Evolved Universal Terrestrial Radio Access Network (E-UTRAN); M2 Application Protocol (M2AP)	3GPP TS 36.443	ATIS.3GPP.TS 36.443V1401	CCSA TS 36.443 v14.0.1	ETSI TS 136 443	TTAT.3G-36.443(R14-14.0.1)
Evolved Universal Terrestrial Radio Access Network (E-UTRAN); S1 Application Protocol (S1AP)	3GPP TS 36.413	ATIS.3GPP.TS 36.413V1441	CCSA TS 36.413 v14.4.1	ETSI TS 136 413	TTAT.3G-36.413(R14-14.4.0)
Evolved Universal Terrestrial Radio Access Network (E-UTRAN); X2 application protocol (X2AP)	3GPP TS 36.423	ATIS.3GPP.TS 36.423V1450	CCSA TS 36.423 v14.5.0	ETSI TS 136 423	TTAT.3G-36.423(R14-14.4.0)

TABLE 13

Characteristics of the transmission scheme

Item	Transmission characteristic	
	Uu interface	**PC5 interface**
Operating frequency range	All the bands specified in TS 36.101[9] support operation with the Uu interface, except Band 47. Bands for Uu interface when used in combination with PC5. Band 3: UL: 1 710-1 785 MHz DL: 1 805-1 880 MHz Band 5: UL: 824 MHz – 849 MHz DL: 869 MHz – 894 MHz Band 7: UL: 2 500-2 570 MHz DL: 2 620-2 690 MHz Band 8: UL: 880-915 MHz DL: 925-960 MHz Band 20: UL: 832 MHz – 862 MHz DL: 791 MHz – 821 MHz Band 28: UL: 703 MHz – 748 MHz	For Rel-14 Band 47: 5 855-5 925 MHz

[9] TS 36.101 “Evolved Universal Terrestrial Radio Access (E-UTRA); User Equipment (UE) radio transmission and reception” http://www.3gpp.org/DynaReport/36-series.htm .

TABLE 13 (*end*)

Item	Transmission characteristic	
	Uu interface	**PC5 interface**
	DL: 758 MHz – 803 MHz Band 34: UL: 2 010 MHz – 2 025 MHz DL: 2 010 MHz – 2 025 MHz Band 39: 1 880-1 920 MHz Band 41: 2 496-2 690 MHz Band 71: UL: 663 MHz – 698 MHz DL: 617 MHz – 652 MHz	
RF channel bandwidth	1.4, 3, 5, 10, 15, or 20 MHz per channel	10 or 20 MHz per channel
RF Transmit Power/e.i.r.p.	Max 43 dBm for eNB Max 23 or 33 dBm for UE	Max 23 or 33 dBm
Modulation scheme	Uplink: QPSK SC-FDMA, 16QAM SC-FDMA, 64QAM SC-FDMA; Downlink: QPSK OFDMA, 16QAM OFDMA, 64QAM OFDMA	QPSK SC-FDMA, 16QAM SC-FDMA
Forward error correction	Convolutional coding and turbo coding	Convolutional coding and turbo coding
Data transmission rate	Uplink: From 1.4 Mbit/s to 36.7 Mbit/s for 10 MHz channel Downlink: From 1.4 Mbit/s to 75.4 Mbit/s for 10 MHz channel	From 1.3 Mbit/s to 15.8 Mbit/s for 10 MHz channel
Media access control	Centralized scheduling by eNB	Centralized scheduling or distributed scheduling
Duplex method	FDD or TDD	TDD

Annex 8

ATIS Standards

3GPP Intelligent Transport Systems technical specifications have been transposed and standardized by ATIS for vehicle-to-everything (V2X), which includes vehicle-to-vehicle (V2V), vehicle-to-infrastructure (V2I), vehicle-to-pedestrian (V2P), vehicle-to-network (V2N), as a part of

the Long Term Evolution (LTE) Release 14. ATIS standards that are transposed from 3GPP technical specifications supporting V2X communications are described in Annex 7.

Frequency bands envisaged for the LTE-V2X Uu interface and the PC5 interface[10] are found in Table 14.

TABLE 14

Characteristics of the transmission scheme

Item	Transmission Characteristic	
	Uu interface	**PC5 interface**
Operating frequency range	Bands for Uu interface when used in combination with PC5, for Rel-14 Band 3: UL: 1 710-1 785 MHz DL: 1 805-1 880 MHz Band 7: UL: 2 500-2 570 MHz DL: 2 620-2 690 MHz Band 8: UL: 880-915 MHz DL: 925-960 MHz Band 39: 1 880-1 920 MHz Band 41: 2 496-2 690 MHz	For Rel-14 Band 47: 5 855-5 925 MHz
RF channel bandwidth	1.4, 3, 5, 10, 15, or 20 MHz per channel	10 or 20 MHz per channel
RF Transmit Power/e.i.r.p.	Max 43 dBm for eNB Max 23 or 33 dBm for UE	Max 23 or 33 dBm
Modulation scheme	Uplink: QPSK SC-FDMA, 16QAM SC-FDMA, 64QAM SC-FDMA; Downlink: QPSK OFDMA, 16QAM OFDMA, 64QAM OFDMA	QPSK SC-FDMA, 16QAM SC-FDMA
Forward error correction	Convolutional coding and turbo coding	Convolutional coding and turbo coding
Data transmission rate	Uplink: From 1.4 Mbit/s to 36.7 Mbit/s for 10 MHz channel Downlink: From 1.4 Mbit/s to 75.4 Mbit/s for 10 MHz channel	From 1.3 Mbit/s to 15.8 Mbit/s for 10 MHz channel
Media access control	Centralized scheduling by eNB	centralized scheduling or distributed scheduling
Duplex method	FDD or TDD	TDD

[10] The published ATIS standards are available at: https://www.atis.org/docstore/default.aspx .

Annex 9

Summary of the technical characteristics of the standards and technical specifications

Technical characteristics of each standard and technical specifications are shown in Table 15.

TABLE 15

Technical characteristics

Parameter	ETSI (Annex 1, Table 3 and Table 4)	ETSI (Annex 7, Table 12)[11]	
		Uu interface	PC5 interface
Operating frequency range	5 855-5 925 MHz	All the bands specified in ETSI TS 136 101[12] support operation with the Un interface, except band 47. Bands for Uu interface when used in combination with PC5[13] Band 3: UL: 1 710-1 785 MHz DL: 1 805-1 880 MHz Band 5: UL: 824 MHz – 849 MHz DL: 869 MHz – 894 MHz Band 7: UL: 2 500-2 570 MHz DL: 2 620-2 690 MHz Band 8: UL: 880-915 MHz DL: 925-960 MHz Band 20: UL: 832 MHz – 862 MHz DL: 791 MHz – 821 MHz Band 28: UL: 703 MHz – 748 MHz DL: 758 MHz – 803 MHz Band 34: UL: 2010 MHz – 2 025 MHz DL: 2010 MHz – 2 025 MHz Band 39: UL: 1 880-1 920 MHz DL: 1 880-1 920 MHz Band 41: UL: 2 496-2 690 MHz DL: 2 496-2 690 MHz	For Rel-14 and Rel-15 Band 47: 5 855-5 925 MHz

[11] The deployment of any radio interface technology based on standards has to follow the regional and national regulations.

[12] ETSI TS 136 101 V15.4.0 (2019-01) LTE; Evolved Universal Terrestrial Radio Access (E-UTRA); User Equipment (UE) radio transmission and reception (3GPP TS 36.101 version 15.4.0 Release 15), clause 5.5. https://www.etsi.org/deliver/etsi_ts/136100_136199/136101/15.04.00_60/ts_136101v150400p.pdf.

[13] ETSI TS 136 101 V15.4.0 (2019-01) LTE; Evolved Universal Terrestrial Radio Access (E-UTRA); User Equipment (UE) radio transmission and reception (3GPP TS 36.101 version 15.4.0 Release 15), clause 5.5G. https://www.etsi.org/deliver/etsi_ts/136100_136199/136101/15.04.00_60/ts_136101v150400p.pdf.

TABLE 15 (*continued*)

Parameter	ETSI (Annex 1, Table 3 and Table 4)	ETSI (Annex 7, Table 12)[11]	
		Uu interface	PC5 interface
		Band 71: UL: 663 MHz – 698 MHz DL: 617 MHz – 652 MHz	
RF channel bandwidth	10 MHz	1.4, 3, 5, 10, 15, or 20 MHz per channel	10 or 20 MHz per channel (10+10 MHz and 10+20 MHz carrier aggregation are supported)
RF Transmit Power/e.i.r.p.	Max 33 dBm e.i.r.p.	Max 43 dBm for eNB Max 23 or 33 dBm for UE	Max 23 or 33 dBm
RF transmit power density			
Modulation scheme	BPSK OFDM, QPSK OFDM, 16QAM OFDM, 64QAM OFDM	Uplink: QPSK SC-FDMA, 16QAM SC-FDMA, 64QAM SC-FDMA; Downlink: QPSK OFDMA, 16QAM OFDMA, 64QAM OFDMA	QPSK SC-FDMA, 16QAM SC-FDMA 64QAM SC-FDMA
Forward error correction	Convolutional coding, rate = 1/2, 3/4, 2/3	Convolutional coding and turbo coding	Convolutional coding and turbo coding
Data transmission rate	3 Mbit/s, 4.5 Mbit/s, 6 Mbit/s, 9 Mbit/s, 12 Mbit/s, 18 Mbit/s, 24Mbit/s, 27Mbit/s	Uplink: From 1.4 Mbit/s to 36.7 Mbit/s for 10 MHz channel Downlink: From 1.4 Mbit/s to 75.4 Mbit/s for 10 MHz channel	From 1.3 Mbit/s to 24.5 Mbit/s for 10 MHz channel
Media access control	CSMA/CA	Centralized scheduling by eNB	Centralized scheduling or distributed scheduling
Duplex method	TDD	FDD or TDD	TDD

Parameter	IEEE (Annex 2)	ARIB (Annex 3)	TTA (Annex 4)	IMDA (Annex 5)
Operating frequency range	5 850-5 925 MHz	755.5-764.5 MHz (Single channel)	5 855-5 925 MHz	5 855-5 925 MHz
RF channel bandwidth	10 MHz or 20 MHz	Less than 9 MHz	Less than 10 MHz	10 MHz
RF Transmit Power/e.i.r.p.		–	20 dBm	Typical limit of up to 33 dBm e.i.r.p.
RF transmit power density		10 dBm/MHz		

Parameter	IEEE (Annex 2)	ARIB (Annex 3)	TTA (Annex 4)	IMDA (Annex 5)
Modulation scheme	64-QAM-OFDM 16-QAM-OFDM QPSK-OFDM BPSK-OFDM 52 subcarriers	BPSK OFDM, QPSK OFDM, 16QAM OFDM	BPSK OFDM, QPSK OFDM, 16QAM OFDM, 64QAM	BPSK OFDM, QPSK OFDM, 16QAM OFDM, 64QAM OFDM
Forward error correction	Convolutional coding, rate = 1/2, 3/4	Convolutional coding, rate = 1/2, 3/4	Convolutional coding, rate = 1/2, 3/4	Convolutional coding, rate = 1/2, 2/3, 3/4
Data transmission rate	3, 4.5, 6, 9, 12, 18, 24 and 27 Mbit/s for 10 MHz channel spacing 6, 9, 12, 18, 24, 36, 48 and 54 Mbit/s for 20 MHz channel spacing	3 Mbit/s, 4.5 Mbit/s, 6 Mbit/s, 9 Mbit/s, 12 Mbit/s, 18 Mbit/s	3, 4.5, 6, 9, 12, 18, 24, 27 Mbit/s	3 Mbit/s, 4.5 Mbit/s, 6 Mbit/s, 9 Mbit/s, 12 Mbit/s, 18 Mbit/s, 24Mbit/s, 27 Mbit/s
Media access control	CSMA/CA	CSMA/CA	CSMA/CA	CSMA/CA
Duplex method	TDD	TDD	TDD	TDD

Parameter	CCSA (Annex 6)[14]	
	Cellular communication mode	Cellular communication mode
Operating frequency range	The bands used in combination with direct communication mode. For FDD UL: 1 710-1 785 MHz; DL: 1 805-1 880 MHz UL: 880-915 MHz; DL: 925-960 MHz For TDD 1 880-1 920 MHz 2 496-2 690 MHz	The bands used in combination with direct communication mode. For FDD UL: 1 710-1 785 MHz; DL: 1 805-1 880 MHz UL: 880-915 MHz; DL: 925-960 MHz For TDD 1 880-1 920 MHz 2 496-2 690 MHz
RF channel bandwidth	1.4/3/5/10/15/20 MHz	1.4/3/5/10/15/20 MHz
RF Transmit Power/e.i.r.p.	Maximum 23 dBm	Maximum 23 dBm
RF transmit power density		
Modulation scheme	QPSK SC-FDM, 16QAM SC-FDM, 64QAM SC-FDM, 256QAM SC-FDM	QPSK SC-FDM, 16QAM SC-FDM, 64QAM SC-FDM, 256QAM SC-FDM

[14] The deployment of any radio interface technology in China based on standards has to follow the Chinese national regulations.

Parameter	CCSA (Annex 6)[14]	
	Cellular communication mode	**Cellular communication mode**
Forward error correction	PUCCH (Physical Uplink Control channel): Tail biting convolutional coding / Block code PUSCH (Physical Uplink Shared channel): Turbo coding	PUCCH (Physical Uplink Control channel): Tail biting convolutional coding / Block code PUSCH (Physical Uplink Shared channel): Turbo coding
Data transmission rate	Maximum 105.5 Mbits	Maximum 105.5 Mbits
Media access control	eNB scheduling	eNB scheduling
Duplex method	TDD/FDD	TDD/FDD

Parameter	3GPP (Annex 7)	
	Uu interface	**Uu interface**
Operating frequency range	Bands for Uu interface when used in combination with PC5 Band 3: UL: 1 710-1 785 MHz DL: 1 805-1 880 MHz Band 5: UL: 824 MHz – 849 MHz DL: 869 MHz – 894 MHz Band 7: UL: 2 500-2 570 MHz DL: 2 620-2 690 MHz Band 8: UL: 880-915 MHz DL: 925-960 MHz Band 20: UL: 832 MHz – 862 MHz DL: 791 MHz – 821 MHz Band 28: UL: 703 MHz – 748 MHz DL: 758 MHz – 803 MHz Band 34: UL: 2 010 MHz – 2 025 MHz DL: 2 010 MHz – 2 025 MHz Band 39: 1 880-1 920 MHz Band 41: 2 496-2 690 MHz Band 71: UL: 663 MHz – 698 MHz DL: 617 MHz – 652 MHz	Bands for Uu interface when used in combination with PC5 Band 3: UL: 1 710-1 785 MHz DL: 1 805-1 880 MHz Band 5: UL: 824 MHz – 849 MHz DL: 869 MHz – 894 MHz Band 7: UL: 2 500-2 570 MHz DL: 2 620-2 690 MHz Band 8: UL: 880-915 MHz DL: 925-960 MHz Band 20: UL: 832 MHz – 862 MHz DL: 791 MHz – 821 MHz Band 28: UL: 703 MHz – 748 MHz DL: 758 MHz – 803 MHz Band 34: UL: 2 010 MHz – 2 025 MHz DL: 2 010 MHz – 2 025 MHz Band 39: 1 880-1 920 MHz Band 41: 2 496-2 690 MHz Band 71: UL: 663 MHz – 698 MHz DL: 617 MHz – 652 MHz
RF channel bandwidth	1.4, 3, 5, 10, 15, or 20 MHz per channel	1.4, 3, 5, 10, 15, or 20 MHz per channel
RF Transmit Power/e.i.r.p.	Max 43 dBm for eNB Max 23 or 33 dBm for UE	Max 43 dBm for eNB Max 23 or 33 dBm for UE
RF transmit power density		
Modulation scheme	Uplink: QPSK SC-FDMA, 16QAM SC-FDMA, 64QAM SC-FDMA; Downlink: QPSK OFDMA, 16QAM OFDMA, 64QAM OFDMA	Uplink: QPSK SC-FDMA, 16QAM SC-FDMA, 64QAM SC-FDMA; Downlink: QPSK OFDMA, 16QAM OFDMA, 64QAM OFDMA
Forward error correction	Convolutional coding and turbo coding	Convolutional coding and turbo coding

Parameter	3GPP (Annex 7)	
	Uu interface	Uu interface
Data transmission rate	Uplink: From 1.4 Mbit/s to 36.7 Mbit/s for 10 MHz channel Downlink: From 1.4 Mbit/s to 75.4 Mbit/s for 10 MHz channel	Uplink: From 1.4 Mbit/s to 36.7 Mbit/s for 10 MHz channel Downlink: From 1.4 Mbit/s to 75.4 Mbit/s for 10 MHz channel
Media access control	Centralized scheduling by eNB	Centralized scheduling by eNB
Duplex method	FDD or TDD	FDD or TDD

Parameter	ATIS (Annex 8)	
	Uu interface	PC5 interface
Operating frequency range	Bands for Uu interface when used in combination with PC5, for Rel-14 Band 5: UL: 824-849 MHz DL: 869-894 MHz Band 7: UL: 2 500-2 570 MHz DL: 2 620-2 690 MHz Band 41: 2 496-2 690 MHz Band 71: UL: 663-698 MHz DL: 617-652 MHz	For Rel-14 Band 47: 5 855-5 925 MHz
RF channel bandwidth	1.4, 3, 5, 10, 15, or 20 MHz per channel	10 or 20 MHz per channel
RF Transmit Power/e.i.r.p.	Max 43 dBm for eNB Max 23 or 33 dBm for UE	Max 23 or 33 dBm
RF transmit power density		
Modulation scheme	Uplink: QPSK SC-FDMA, 16QAM SC-FDMA, 64QAM SC-FDMA; Downlink: QPSK OFDMA, 16QAM OFDMA, 64QAM OFDMA	QPSK SC-FDMA, 16QAM SC-FDMA
Forward error correction	Convolutional coding and turbo coding	Convolutional coding and turbo coding
Data transmission rate	Uplink: From 1.4 Mbit/s to 36.7 Mbit/s for 10 MHz channel Downlink: From 1.4 Mbit/s to 75.4 Mbit/s for 10 MHz channel	From 1.3 Mbit/s to 15.8 Mbit/s for 10 MHz channel
Media access control	Centralized scheduling by eNB	Centralized scheduling or distributed scheduling
Duplex method	FDD or TDD	TDD