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| **Radiocommunication Study Groups** |  |
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| Source: Document 5A/TEMP/350(Rev.1)  Question: Question ITU-R [205-5/5](http://www.itu.int/pub/R-QUE-SG05.205-5-2012) | **Annex 22 to  Document 5A/976-E** |
| **19 November 2018** |
| **English only** |
| Annex 22 to Working Party 5A Chairman’s Report | |
| Preliminary draft revision of Recommendation ITU-R M.2084-0 | |
| Radio interface standards of vehicle-to-vehicle and vehicle-to-infrastructure communications for Intelligent Transport System applications | |

(Question [ITU-R 205-5/5](https://www.itu.int/pub/R-QUE-SG05.205))

(2015)

Summary of the revision

The Recommendation is being revised to include updated standardisation information into Annexes 1 - 4 and additional new standards information found in Annexes 5 - 8.

Scope

This Recommendation identifies specific radio interface standards of vehicle-to-vehicle and vehicle-to-infrastructure communications for Intelligent Transport System applications. The technical and operational 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

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

V2X Vehicle-to-Everything

WAVE Wireless Access in Vehicular Environments

Related ITU Recommendations

Recommendation ITU-R [M.1453](http://www.itu.int/rec/R-REC-M.1453/en) Intelligent Transport Systems – dedicated short-range communications at 5.8 GHz

Recommendation ITU-R [M.1890](http://www.itu.int/rec/R-REC-M.1890/en) Intelligent Transport Systems – Guidelines and Objectives

[Preliminary draft new] Recommendation ITU-R M.[ITS\_FRQ] 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,

noting

that IMT networks operating in bands not listed in the Annexes of this Recommendation may complement Intelligent Transport System,

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 |
| Standardisation/ 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 | 5 855-5 925 MHz |
| RF channel bandwidth | 10 MHz |
| RF Transmit Power/EIRP | Typical limit of up to 33 dBm EIRP |
| 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 | 3 Mbit/s, 4.5 Mbit/s, 6 Mbit/s, 9 Mbit/s, 12 Mbit/s, 18 Mbit/s, 24 Mbit/s, 27 Mbit/s |
| 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 |
| 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 listed in Table 5.

TABLE 5

List of ETSI technical specifications transposed from 3GPP technical specifications supporting V2V   
and V2I communications

|  |  |
| --- | --- |
| Standard title | Standard number |
| **<Core network and UE protocol>** |  |
| Service requirements for V2X service | ETSI TS 122 185 |
|  |  |
| **<Core network and UE protocol>** |  |
| Numbering, addressing and identification | ETSI TS 123 003 |
| Restoration procedures. | ETSI TS 123 007 |
| Organization of subscriber data | ETSI TS 123 008 |
| Non-Access-Stratum (NAS) functions related to Mobile Station (MS) in idle mode | ETSI TS 123 122 |
| Policy and charging control architecture | ETSI TS 123 203 |
| Architecture enhancements for V2X service | ETSI TS 123 285 |
| Proximity-based services (ProSe); Stage 2 | ETSI TS 123 303 |
| Non-Access-Stratum (NAS) protocol for Evolved Packet System (EPS); Stage 3 | ETSI TS 124 301 |
| Proximity-services (ProSe) User Equipment (UE) to Proximity-services (ProSe) Function Protocol aspects; Stage 3 | ETSI TS 124 334 |
| V2X services Management Object (MO) | ETSI TS 124 385 |
| User Equipment (UE) to V2X control function; protocol aspects; Stage 3 | ETSI TS 124 386 |
| Representational state transfer over xMB reference point between content provider and BM-SC | ETSI TS 129 116 |
| Policy and Charging Control (PCC); Reference points | ETSI TS 129 212 |
| Evolved Packet System (EPS); Mobility Management Entity (MME) and Serving GPRS Support Node (SGSN) related interfaces based on Diameter protocol | ETSI TS 129 272 |
| V2X Control Function to Home Subscriber Server (HSS) aspects (V4); Stage 3 | ETSI TS 129 388 |
| Inter-V2X Control Function Signalling aspects (V6); Stage 3 | ETSI TS 129 389 |
| Group Communication System Enablers for LTE (GCSE\_LTE); MB2 reference point; Stage 3 | ETSI TS 129 468 |
| Characteristics of the Universal Subscriber Identity Module (USIM) application | ETSI TS 131 102 |
|  |  |
| **<Security>** |  |
| Security aspect for LTE support of V2X services | ETSI TS 133 185 |
|  |  |
| **<Device performance requirements>** |  |
| Evolved Universal Terrestrial Radio Access (E-UTRA); User Equipment (UE) radio transmission and reception | ETSI TS 136 101 |
| Evolved Universal Terrestrial Radio Access (E-UTRA); Requirements for support of radio resource management | ETSI TS 136 133 |
|  |  |
| **<Physical layer aspects>** |  |
| Evolved Universal Terrestrial Radio Access (E-UTRA); Physical channels and modulation | ETSI TS 136 211 |
| Evolved Universal Terrestrial Radio Access (E-UTRA); Multiplexing and channel coding | ETSI TS 136 212 |
| Evolved Universal Terrestrial Radio Access (E-UTRA); Physical layer procedures | ETSI TS 136 213 |
| Evolved Universal Terrestrial Radio Access (E-UTRA); Physical layer; Measurements | ETSI TS 136 214 |
|  |  |
| **<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 | ETSI TS 136 300 |
| Evolved Universal Terrestrial Radio Access (E-UTRA); Services provided by the physical layer | ETSI TS 136 302 |
| Evolved Universal Terrestrial Radio Access (E-UTRA); User Equipment (UE) procedures in idle mode | ETSI TS 136 304 |
| Evolved Universal Terrestrial Radio Access (E-UTRA); User Equipment (UE) radio access capabilities | ETSI TS 136 306 |
| Evolved Universal Terrestrial Radio Access (E-UTRA); Medium Access Control (MAC) protocol specification | ETSI TS 136 321 |
| Evolved Universal Terrestrial Radio Access (E-UTRA); Radio Link Control (RLC) protocol specification | ETSI TS 136 322 |
| Evolved Universal Terrestrial Radio Access (E-UTRA); Packet Data Convergence Protocol (PDCP) specification | ETSI TS 136 323 |
| Evolved Universal Terrestrial Radio Access (E-UTRA); Radio Resource Control (RRC); Protocol specification | ETSI TS 136 331 |
|  |  |
| **<Radio access network aspects>** |  |
| Evolved Universal Terrestrial Radio Access Network (E-UTRAN); M2 Application Protocol (M2AP) | ETSI TS 136 443 |
| Evolved Universal Terrestrial Radio Access Network (E-UTRAN); S1 Application Protocol (S1AP) | ETSI TS 136 413 |
| Evolved Universal Terrestrial Radio Access Network (E-UTRAN); X2 application protocol (X2AP) | ETSI TS 136 423 |

TABLE 6

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 |

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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 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 7.

TABLE 7

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 | 3 Mbit/s, 4.5 Mbit/s, 6 Mbit/s, 9 Mbit/s, 12 Mbit/s, 18 Mbit/s |
| Media access control | CSMA/CA |

Table 7 shows basic specifications of ARIB standard; ARIB STD-T109[[1]](#footnote-2), 700 MHz band Intelligent Transport Systems (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 Intelligent Transport System 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 Intelligent Transport System radiocommunications have the following features as shown in Table 8.

TABLE 8

Technical characteristics

| Item | Technical characteristic |
| --- | --- |
| RF frequency | 5 855-5 925 MHz |
| RF channel bandwidth | 10 MHz |
| RF Transmit power | 20 dBm |
| Modulation type | OFDM (BPSK, QPSK, 16QAM, 64QAM) |
| Data rate | 3, 4.5, 6, 9, 12, 18, 24, 27 Mbit/s |
| 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 Intelligent Transport System radiocommunications

In the Republic of Korea, Telecommunication Technology Association (TTA) established four standards for advanced Intelligent Transport System radiocommunications. The detailed information of these standards is shown in Table 9.

TABLE 9

Base standards related to advanced Intelligent Transport System radiocommunications

|  |  |
| --- | --- |
| Standard title | Standard number |
| Vehicle communication system Stage 1: Requirements | TTAK.KO-06.0175/R1 |
| Vehicle communication system Stage 2: Architecture | TTAK.KO-06.0193/R1 |
| Vehicle communication system Stage 3: PHY/MAC | TTAK.KO-06.0216/R1 |
| Vehicle communication system State 3: Networking | TTAK.KO-06.0234/R1 |

Annex 5  
  
IMDA standards

Infocomm Media Development Authority of Singapore (IMDA) had set the required communication standards for Intelligent Transport System 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 Intelligent Transport Systems 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 10.

TABLE 10

Characteristics of the transmission scheme

|  |  |
| --- | --- |
| Item | Transmission Characteristic |
| Operating frequency range | 5 855-5 925 MHz |
| RF channel bandwidth | 10 MHz |
| RF Transmit Power/EIRP | Typical limit of up to 33 dBm EIRP |
| 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 | 3 Mbit/s, 4.5 Mbit/s, 6 Mbit/s, 9 Mbit/s, 12 Mbit/s, 18 Mbit/s, 24 Mbit/s, 27 Mbit/s |
| 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

CCSA (China Communications Standards Association) 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 information is presented in Table 11.

TABLE 11

Standards of LTE-V2X in CCSA

|  |  |
| --- | --- |
| **Standard title** | **Standardization Item Number** |
| General technical requirements of LTE-based vehicular communication | 2015-1616T-YD |
| Technical requirements of air interface of LTE-based vehicular communication | 2016-1853T-YD |

CCSA Standards of LTE-V2X 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 GNSS (Global Navigation Satellite System) 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 MBMS(Multimedia Broadcast Multicast Service) in downlink;

– multiple SPS(Semi-Persistent Scheduling) configuration in uplink.

The technical characteristics of LTE-V2X standards in CCSA are summarized in Table 12.

TABLE 12

Technical characteristics of LTE-V2X standards in CCSA

|  |  |  |
| --- | --- | --- |
| Parameter | Technical characteristic | |
| 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 trial. | 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/EIRP | 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 Mbps for 20 MHz; 78.7 Mbps for 15 MHz; 52.7 Mbps for 10 MHz;  26.4 Mbps for 5 MHz.  DL with one layer:  Maximum 97.9 Mbps for 20 MHz; 75.4 Mbps for 15 MHz; 48.9 Mbps for 10 MHz;  24.5 Mbps for 5 MHz.  DL with two layers:  Maximum 195.8 Mbps for 20 MHz; 149.8 Mbps for 15 MHz; 97.9 Mbps for 10 MHz;  48.9 Mbps for 5 MHz.  Broadcast:  Maximum 60% of unicast. |
| 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 | FDM(Frequency Division Multiplexing) and TDM (Time Division Multiplexing) | Frequency Division Multiplexing (FDM)   and Time Division Multiplexing (TDM) |
| Retransmission | HARQ (Hybrid Automatic Repeat Request) | 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 Uu interface which provides communication between the cellular network, road infrastructure, pedestrians and vehicles using uplink and downlink via eNB. The other is PC5 interface which has been developed to provide direct communication among vehicles and road infrastructure. Uu interface always uses centralized scheduling which means that base station (eNB) controls medium access and radio resource management. PC5 interface supports two scheduling options; one is the centralized scheduling similar to that used for 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 PC5 interface with distributed scheduling can operate both inside and outside cellular coverage and does not require cellular operator support. While PC5 interface only support broadcast transmissions, Uu interface supports unicast, multicast, and broadcast transmissions.

LTE downlink uses orthogonal frequency division multiple access (OFDMA), and LTE uplink and PC5 interface use single-carrier frequency division multiple access (SC-FDMA). Frequency bands envisaged for LTE-V2X Uu interface and PC5 interface[[2]](#footnote-3) are found in the Table 14.

TABLE 13

List of the 3GPP technical specifications related to V2X

|  |  |
| --- | --- |
| Specifications title | Reference number |
| **<Core network and UE protocol>** |  |
| Service requirements for V2X service | 3GPP TS 22.185 |
|  |  |
| **<Core network and UE protocol>** |  |
| Numbering, addressing and identification | 3GPP TS 23.003 |
| Restoration procedures. | 3GPP TS 23.007 |
| Organization of subscriber data | 3GPP TS 23.008 |
| Non-Access-Stratum (NAS) functions related to Mobile Station (MS) in idle mode | 3GPP TS 23.122 |
| Policy and charging control architecture | 3GPP TS 23.203 |
| Architecture enhancements for V2X service | 3GPP TS 23.285 |
| Proximity-based services (ProSe); Stage 2 | 3GPP TS 23.303 |
| Non-Access-Stratum (NAS) protocol for Evolved Packet System (EPS); Stage 3 | 3GPP TS 24.301 |
| Proximity-services (ProSe) User Equipment (UE) to Proximity-services (ProSe) Function Protocol aspects; Stage 3 | 3GPP TS 24.334 |
| V2X services Management Object (MO) | 3GPP TS 24.385 |
| User Equipment (UE) to V2X control function; protocol aspects; Stage 3 | 3GPP TS 24.386 |
| Representational state transfer over xMB reference point between content provider and BM-SC | 3GPP TS 29.116 |
| Policy and Charging Control (PCC); Reference points | 3GPP TS 29.212 |
| Evolved Packet System (EPS); Mobility Management Entity (MME) and Serving GPRS Support Node (SGSN) related interfaces based on Diameter protocol | 3GPP TS 29.272 |
| V2X Control Function to Home Subscriber Server (HSS) aspects (V4); Stage 3 | 3GPP TS 29.388 |
| Inter-V2X Control Function Signalling aspects (V6); Stage 3 | 3GPP TS 29.389 |
| Group Communication System Enablers for LTE (GCSE\_LTE); MB2 reference point; Stage 3 | 3GPP TS 29.468 |
| Characteristics of the Universal Subscriber Identity Module (USIM) application | 3GPP TS 31.102 |
|  |  |
| **<Security>** |  |
| Security aspect for LTE support of V2X services | 3GPP TS 33.185 |
|  |  |
| **<Device performance requirements>** |  |
| Evolved Universal Terrestrial Radio Access (E-UTRA); User Equipment (UE) radio transmission and reception | 3GPP TS 36.101 |
| Evolved Universal Terrestrial Radio Access (E-UTRA); Requirements for support of radio resource management | 3GPP TS 36.133 |
|  |  |
| **<Physical layer aspects>** |  |
| Evolved Universal Terrestrial Radio Access (E-UTRA); Physical channels and modulation | 3GPP TS 36.211 |
| Evolved Universal Terrestrial Radio Access (E-UTRA); Multiplexing and channel coding | 3GPP TS 36.212 |
| Evolved Universal Terrestrial Radio Access (E-UTRA); Physical layer procedures | 3GPP TS 36.213 |
| Evolved Universal Terrestrial Radio Access (E-UTRA); Physical layer; Measurements | 3GPP TS 36.214 |
|  |  |
| **<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 |
| Evolved Universal Terrestrial Radio Access (E-UTRA); Services provided by the physical layer | 3GPP TS 36.302 |
| Evolved Universal Terrestrial Radio Access (E-UTRA); User Equipment (UE) procedures in idle mode | 3GPP TS 36.304 |
| Evolved Universal Terrestrial Radio Access (E-UTRA); User Equipment (UE) radio access capabilities | 3GPP TS 36.306 |
| Evolved Universal Terrestrial Radio Access (E-UTRA); Medium Access Control (MAC) protocol specification | 3GPP TS 36.321 |
| Evolved Universal Terrestrial Radio Access (E-UTRA); Radio Link Control (RLC) protocol specification | 3GPP TS 36.322 |
| Evolved Universal Terrestrial Radio Access (E-UTRA); Packet Data Convergence Protocol (PDCP) specification | 3GPP TS 36.323 |
| Evolved Universal Terrestrial Radio Access (E-UTRA); Radio Resource Control (RRC); Protocol specification | 3GPP TS 36.331 |
|  |  |
| **<Radio access network aspects>** |  |
| Evolved Universal Terrestrial Radio Access Network (E-UTRAN); M2 Application Protocol (M2AP) | 3GPP TS 36.443 |
| Evolved Universal Terrestrial Radio Access Network (E-UTRAN); S1 Application Protocol (S1AP) | 3GPP TS 36.413 |
| Evolved Universal Terrestrial Radio Access Network (E-UTRAN); X2 application protocol (X2AP) | 3GPP TS 36.423 |

TABLE 14

Characteristics of the transmission scheme

|  |  |  |
| --- | --- | --- |
| **Item** | **Transmission Characteristic** | |
|  | Uu interface | PC5 interface |
| Operating frequency range | All the bands specified in TS 36.101[[3]](#footnote-4) support operation with the Uu interface, except Band 47.  Bands for Uu interface when used in combination with PC5[[4]](#footnote-5)  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–2025 MHz                  DL: 2010 MHz –2025 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 | 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/EIRP | 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. These standards 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.

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

LTE downlink uses orthogonal frequency division multiple access (OFDMA), and LTE uplink and PC5 interface use single-carrier frequency division multiple access (SC-FDMA). Frequency bands envisaged for LTE-V2X Uu interface and PC5 interface[[5]](#footnote-6) are found in the Table 16.

TABLE 15

List of the ATIS standards related to V2X

|  |  |
| --- | --- |
| Standards title | Reference number |
| **<Core network and UE protocol>** |  |
| Service requirements for V2X service | ATIS.3GPP.TS 22.185V1430 |
|  |  |
| **<Core network and UE protocol>** |  |
| Numbering, addressing and identification | ATIS.3GPP.TS 23.003V1460 |
| Restoration procedures. | ATIS.3GPP.TS 23.007V1440 |
| Organization of subscriber data | ATIS.3GPP.TS 23.008V1440 |
| Non-Access-Stratum (NAS) functions related to Mobile Station (MS) in idle mode | ATIS.3GPP.TS 23.122V1440 |
| Policy and charging control architecture | ATIS.3GPP.TS 23.203V1450 |
| Architecture enhancements for V2X service | ATIS.3GPP.TS 23.285V1450 |
| Proximity-based services (ProSe); Stage 2 | ATIS.3GPP.TS 23.303V1410 |
| Non-Access-Stratum (NAS) protocol for Evolved Packet System (EPS); Stage 3 | ATIS.3GPP.TS 24.301V1460 |
| Proximity-services (ProSe) User Equipment (UE) to Proximity-services (ProSe) Function Protocol aspects; Stage 3 | ATIS.3GPP.TS 24.334V1400 |
| V2X services Management Object (MO) | ATIS.3GPP.TS 24.385V1430 |
| User Equipment (UE) to V2X control function; protocol aspects; Stage 3 | ATIS.3GPP.TS 24.386V1430 |
| Representational state transfer over xMB reference point between content provider and BM-SC | ATIS.3GPP.TS 29.116V1430 |
| Policy and Charging Control (PCC); Reference points | ATIS.3GPP.TS 29.212V1460 |
| Evolved Packet System (EPS); Mobility Management Entity (MME) and Serving GPRS Support Node (SGSN) related interfaces based on Diameter protocol | ATIS.3GPP.TS 29.272V1460 |
| V2X Control Function to Home Subscriber Server (HSS) aspects (V4); Stage 3 | ATIS.3GPP.TS 29.388V1410 |
| Inter-V2X Control Function Signalling aspects (V6); Stage 3 | ATIS.3GPP.TS 29.389V1410 |
| Group Communication System Enablers for LTE (GCSE\_LTE); MB2 reference point; Stage 3 | ATIS.3GPP.TS 29.468V1430 |
| Characteristics of the Universal Subscriber Identity Module (USIM) application | ATIS.3GPP.TS 31.102V1440 |
|  |  |
| **<Security>** |  |
| Security aspect for LTE support of V2X services | ATIS.3GPP.TS 33.185V1410 |
|  |  |
| **<Device performance requirements>** |  |
| Evolved Universal Terrestrial Radio Access (E-UTRA); User Equipment (UE) radio transmission and reception | ATIS.3GPP.TS 36.101V1460 |
| Evolved Universal Terrestrial Radio Access (E-UTRA); Requirements for support of radio resource management | ATIS.3GPP.TS 36.133V1460 |
|  |  |
| **<Physical layer aspects>** |  |
| Evolved Universal Terrestrial Radio Access (E-UTRA); Physical channels and modulation | ATIS.3GPP.TS 36.211V1450 |
| Evolved Universal Terrestrial Radio Access (E-UTRA); Multiplexing and channel coding | ATIS.3GPP.TS 36.212V1451 |
| Evolved Universal Terrestrial Radio Access (E-UTRA); Physical layer procedures | ATIS.3GPP.TS 36.213V1450 |
| Evolved Universal Terrestrial Radio Access (E-UTRA); Physical layer; Measurements | ATIS.3GPP.TS 36.214V1440 |
|  |  |
| **<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 | ATIS.3GPP.TS 36.300V1450 |
| Evolved Universal Terrestrial Radio Access (E-UTRA); Services provided by the physical layer | ATIS.3GPP.TS 36.302V1440 |
| Evolved Universal Terrestrial Radio Access (E-UTRA); User Equipment (UE) procedures in idle mode | ATIS.3GPP.TS 36.304V1450 |
| Evolved Universal Terrestrial Radio Access (E-UTRA); User Equipment (UE) radio access capabilities | ATIS.3GPP.TS 36.306V1450 |
| Evolved Universal Terrestrial Radio Access (E-UTRA); Medium Access Control (MAC) protocol specification | ATIS.3GPP.TS 36.321V1400 |
| Evolved Universal Terrestrial Radio Access (E-UTRA); Radio Link Control (RLC) protocol specification | ATIS.3GPP.TS 36.322V1450 |
| Evolved Universal Terrestrial Radio Access (E-UTRA); Packet Data Convergence Protocol (PDCP) specification | ATIS.3GPP.TS 36.323V1410 |
| Evolved Universal Terrestrial Radio Access (E-UTRA); Radio Resource Control (RRC); Protocol specification | ATIS.3GPP.TS 36.331V1451 |
|  |  |
| **<Radio access network aspects>** |  |
| Evolved Universal Terrestrial Radio Access Network (E-UTRAN); M2 Application Protocol (M2AP) | ATIS.3GPP.TS 36.443V1401 |
| Evolved Universal Terrestrial Radio Access Network (E-UTRAN); S1 Application Protocol (S1AP) | ATIS.3GPP.TS 36.413V1441 |
| Evolved Universal Terrestrial Radio Access Network (E-UTRAN); X2 application protocol (X2AP) | ATIS.3GPP.TS 36.423V1450 |

TABLE 16

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/EIRP | 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 9  
  
Summary of the technical characteristics of the standards   
and technical specifications

Technical characteristics of each standard and technical specifications are shown in Table 17.

TABLE 17

Technical characteristics

|  |  |  |  |
| --- | --- | --- | --- |
| Parameter | ETSI  (Annex 1, Table 3 and Table 4) | ETSI (Annex 1, Table 5)[[6]](#footnote-7) | |
| Uu interface | PC5 interface |
| Operating frequency range | 5 855-5 925 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 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 and Rel-15  Band 47:5 855-5 925 MHz |
| RF channel bandwidth | 10 MHz | 1.4, 3, 5, 10, 15, or 20 MHz per channel | 10 or 20 MHz per channel  (10+10MHz and 10+20MHz carrier aggregation are supported) |
| RF Transmit Power/EIRP | Max 33 dBm EIRP | 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/EIRP |  | – | 20 dBm | Typical limit of up to 33 dBm EIRP |
| RF transmit power density |  | 10 dBm/MHz |  |  |
| 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, ¾ | 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, 27Mbit/s |
| Media access control | CSMA/CA | CSMA/CA | CSMA/CA, Option: Time Slot based CSMA/CA | CSMA/CA |
| Duplex method | TDD | TDD | TDD | TDD |

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Parameter** | **CCSA(Annex 6)** | | **3GPP (Annex 7)** | |
| Cellular communication mode | Direct communication mode | Uu interface | PC5 interface |
| Operating frequency range | 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 | 5 855-5 925 MHz  Note: China officially approved 5 905-5 925 MHz for LTE-V2X trial. | Bands for Uu interface when used in combination with PC5[[7]](#footnote-9)  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–2025 MHz                    DL: 2010 MHz –2025 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 | For Rel-14  Band 47: 5 855-5 925  MHz |
| RF channel bandwidth | 10/20 MHz | 1.4/3/5/10/15/20 MHz | 1.4, 3, 5, 10, 15, or 20 MHz per channel | 10 or 20 MHz per channel |
| RF Transmit Power/EIRP | Maximum 23 dBm | Maximum 23 dBm | Max 43 dBm for eNB  Max 23 or 33 dBm for UE | Max 23 or 33 dBm |
| RF transmit power density |  |  |  |  |
| Modulation scheme | QPSK SC-FDM, 16QAM SC-FDM | QPSK SC-FDM, 16QAM SC-FDM, 64QAM SC-FDM, 256QAM SC-FDM | 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 | 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 | PUCCH(Physical Uplink Control channel):Tail biting convolutional coding / Block code  PUSCH(Physical Uplink Shared channel):Turbo coding | Convolutional coding and turbo coding | Convolutional coding and 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 | Maximum 105.5 Mbps | 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 | For Mode 4: Sensing with SPS, random selection.  For Mode 3: eNB scheduling. | eNB scheduling | Centralized scheduling by eNB | Centralized scheduling or distributed scheduling |
| Duplex method | TDD | TDD/FDD | FDD or TDD | 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/EIRP | 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 |

1. ARIB standard; ARIB STD-T109, 700 MHz band intelligent transport systems  
   (https://www.arib.or.jp/english/std\_tr/telecommunications/std-t109.html). [↑](#footnote-ref-2)
2. The published 3GPP technical specifications are available at 3GPP Portal: <http://www.3gpp.org/ftp/Specs>. [↑](#footnote-ref-3)
3. 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 [↑](#footnote-ref-4)
4. [↑](#footnote-ref-5)
5. The published ATIS standards are available at: https://www.atis.org/docstore/default.aspx. [↑](#footnote-ref-6)
6. [ The deployment of any radio interface technology based on standards has to follow the regional and national regulations.] [↑](#footnote-ref-7)
7. [↑](#footnote-ref-9)