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| **Radiocommunication Study Groups** |  |
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| Source: Document [5A/TEMP/263](https://www.itu.int/md/R15-WP5A-C-0369/en)Question: Question ITU-R [205-5/5](http://www.itu.int/pub/R-QUE-SG05.205-5-2012) | **Annex 30 toDocument 5A/650-E** |
| **20 November 2017** |
| **English only** |
| Annex 30 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 |

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

ATS Abstract Test Suite

BPSK Binary Phase Shift Keying

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

FEC Forward Error Correction

IEEE Institute of Electrical and Electronics Engineers

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-FDMA Single-Carrier Frequency Division Multiple Access

TDD Time Division Duplex

TSS & TP Test Suite Structure and Test Purposes

TTA Telecommunications Technology Association

UE User Equipment

V2I Vehicle-To-Infrastructure

V2N Vehicle-To-Network

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

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,

recognizing

a) that Recommendation ITU-R M.1453 recommends dedicated short-range communications (DSRC) operating at 5.8 GHz,

recommends

that the radio interface standards and technical specifications in Annexes 1 to 6 should be used for vehicle-to-vehicle and vehicle-to-infrastructure communications.

NOTE – The technical characteristics of these standards and technical specifications are summarized in Annex 7.

Annex 1

ETSI standards

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

– 5.9 GHz spectrum usage;

– multichannel operation;

– decentralized congestion control (DCC);

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

TABLE 1

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 |

TABLE 2

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 |

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 ITS program is managed by the United States Federal Highway Administration Joint Program Office for ITS. 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 3.

TABLE 3

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 3 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 4.

TABLE 4

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 5.

TABLE 5

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 6.

TABLE 6

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

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 8.

TABLE 7

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 8

**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-14Band 3: UL: 1 710-1 785 MHz DL: 1 805-1 880 MHzBand 7: UL: 2 500-2 570 MHz DL: 2 620-2 690 MHzBand 8: UL: 880-915 MHz DL: 925-960 MHzBand 39: 1 880-1 920 MHzBand 41: 2 496-2 690 MHz | For Rel-14Band 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 eNBMax 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 channelDownlink: 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 7

Summary of the technical characteristics of the standards and technical specifications

Technical characteristics of each standard and technical specifications are shown in Table 9.

TABLE 9

Technical characteristics

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Parameter | ETSI (Annex 1) | IEEE (Annex 2) | ARIB (Annex 3) | TTA (Annex 4) | IMDA(Annex 5) |
| Operating frequency range | 5 855-5 925 MHz | 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 | 10 MHz or 20 MHz | Less than 9 MHz | Less than 10 MHz | 10 MHz |
| RF Transmit Power/EIRP | Max 33 dBm EIRP |  | – | 20 dBm | Typical limit of up to 33 dBm EIRP |
| RF transmit power density |  |  | 10 dBm/MHz |  |  |
| Modulation scheme | BPSK OFDM, QPSK OFDM, 16QAM OFDM, 64QAM OFDM | 64-QAM-OFDM 16-QAM-OFDMQPSK-OFDMBPSK-OFDM52 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, 2/3 | 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 Mbit/s, 4.5 Mbit/s, 6 Mbit/s, 9 Mbit/s, 12 Mbit/s, 18 Mbit/s, 24Mbit/s, 27Mbit/s | 3, 4.5, 6, 9, 12, 18, 24 and 27 Mbit/s for 10 MHz channel spacing6, 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 | CSMA/CA,Option: Time Slot based CSMA/CA | CSMA/CA |
| Duplex method | TDD | TDD | TDD | TDD | TDD |

|  |  |
| --- | --- |
| **Parameter** | **3GPP (Annex 6)** |
| **Uu interface** | **PC5 interface** |
| Operating frequency range | Bands for Uu interface when used in combination with PC5, for Rel-14Band 3: UL: 1 710-1 785 MHz DL: 1 805-1 880 MHzBand 7: UL: 2 500-2 570 MHz DL: 2 620-2 690 MHzBand 8: UL: 880-915 MHz DL: 925-960 MHzBand 39: 1 880-1 920 MHzBand 41: 2 496-2 690 MHz | For Rel-14Band 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 eNBMax 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 channelDownlink: 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)