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TECHNICAL REPORT

**System Reference document (SRdoc);
DECT-2020 NR technology operating in
frequency bands below 6 GHz**

Reference

DTR/ERM-603

Keywords

DECT-2020, IMT-2020, NR, SRdoc, system

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Contents

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Foreword

This Technical Report (TR) has been produced by ETSI Technical Committee Electromagnetic compatibility and Radio spectrum Matters (ERM).

Modal verbs terminology

In the present document "**should**", "**should not**", "**may**", "**need not**", "**will**", "**will not**", "**can**" and "**cannot**" are to be interpreted as described in clause 3.2 of the ETSI Drafting Rules (Verbal forms for the expression of provisions).

"**must**" and "**must not**" are **NOT** allowed in ETSI deliverables except when used in direct citation.

Executive summary

The present document provides technical details and market information of DECT-2020 NR radio technology. DECT-2020 NR is part of IMT-2020 technology Recommendation ITU-R M.2150-1 [i.7]. DECT-2020 NR is developed and maintained by ETSI TC DECT group.

DECT-2020 NR design objectives are to provide wireless communication technology which can be used for various applications. It is application agnostic which enables rapid adoption thanks to flexible system topologies from simple point to point wireless links to traditional start topology to advanced multi-hop mesh topology for wide area and large-scale Internet of Things applications. It supports efficient shared spectrum operation for local area networks where several co-existing systems may be used in same area. See clauses 5 and 6.

DECT-2020 NR meets and exceeds the requirements set by the ITU-R for IMT-2020 technology for reliable low latency operation and massive machine type of communication. The DECT-2020 NR applies the modern wireless technologies such as OFDM based physical layer, efficient channel coding, fast physical layer re-transmission scheme (HARQ), MIMO and beamforming support. The Media Access Layer (MAC) supports advanced local interference management and spectrum access, radio link modulation and coding selection, HARQ management with physical layer and radio link security functions. The Data Link Layer (DLC) manages the radio link service types and routing functionality. The Convergence layer (CVG) manages functionalities such as end to end security and application adaptation such as IPv6 transport.

The DECT-2020 NR technology supports advanced functionalities for future needs such as autonomous and de-centralized operation, the support for high bit rates, low communication latencies, advanced diversity receivers. See clause 7 for details of the technology.

DECT-2020 NR standards series at present consists of 5 parts, harmonized standards for essential radio requirements for DECT-2020 NR and technical reports.

DECT-2020 NR access technology can operate in any suitable spectrum below 6 GHz. It is part of the terrestrial IMT technology recommendation and therefore is a viable option for local area networks for industry, local authority services, utilities to name few potential parties applying this technology. In addition to the generic IMT spectrum it is highlighted spectrum availability for 3,8 to 4,2 GHz which is considered for low and mid power local networks operating spectrum and potential use for 450 to 470 MHz band.

CEPT ECC (WGFM) is kindly requested to review, and amend where appropriate, ECC Decisions and Recommendations to ensure that the conditions contained therein do not unreasonably restrict the use of DECT-2020 NR, to maintain, as far as possible, the principle of technology neutrality.

Introduction

The present document has been developed by ETSI TC DECT, which is responsible for developing and maintaining DECT-2020 NR related standards, technical reports and essential radio requirements. The present document provides relevant technical and business information on DECT-2020 NR to support the co-operation between ETSI and the Electronic Communications Committee (ECC) of the European Conference of Post and Telecommunications Administrations (CEPT) for internal reference within ETSI.

Digitalization will have a profound impact on all areas of society, business, and even each person life in the future. The European Commission has made the 2021 Strategic Foresight Report, "The EU's capacity and freedom to act" [i.21], which analyses the global megatrends and Europe's strategic impact areas for the next decade.

The present document identifies key global megatrends: climate change and other environmental challenges, digital hyperconnectivity and technology transformation, pressure in democratic models and governance, and shifts in global order and demography. The first two megatrends, climate change and digital hyperconnectivity are areas where spearhead technology research and novel digitalization solutions can make a difference and impact our future challenges in the EU and globally. In the future, industrial digitalization solutions are targeted to improve productivity, reduce energy consumption, and production of waste in different industrial activities. Therefore, future digitalization will not only enable modernizing industrial procedures but will have a direct impact on the sustainability of the future industry and ways to mitigate and reduce climate change impacts. The challenge in the future is to provide digitalization solutions in all industry sectors so that they are viable and available for different sizes of industrial players including SMEs.

DECT-2020 NR technology is designed to operate on any suitable frequencies below 6 GHz for a large variety of different wireless applications. The autonomous, frequency agile operation supports multiple networks co-existing and sharing spectrum when necessary. It supports different network topologies from point-to-point connection, star topology to mesh topology enabling wide support for multiple applications from large scale utility systems such as smart meters and electricity grid to industry, healthcare, logistics and enterprise applications addressing industry digitalization for various size of business and finally is viable technology for advanced professional audios applications.

1 Scope

The present document provides information on the intended applications, markets and the technical parameters and functionalities of DECT-2020 NR technology and its deployment capabilities. The SRDoc contains information to support the CEPT activities e.g. for the EC mandate on technical conditions regarding the shared use of the 3,8 to 4,2 GHz frequency band. In addition, the present document contains information and proposals for operation on additional frequency bands outside the 1 880 to 1 900 MHz frequency band.

The present document includes the necessary information to support the co-operation between ETSI and the Electronic Communications Committee (ECC) of the European Conference of Post and Telecommunications Administrations (CEPT).

2 References

2.1 Normative references

Normative references are not applicable in the present document.

2.2 Informative references

References are either specific (identified by the date of publication and/or the edition number or the version number) or non-specific. For specific references, only the cited version applies. For non-specific references, the latest version of the referenced document (including any amendments) applies.

NOTE: While any hyperlinks included in this clause were valid at the time of publication ETSI cannot guarantee their long term validity.

The following referenced documents are not necessary for the application of the present document but they assist the user with regard to a particular subject area.

[i.1] ETSI TS 103 636-1 (V1.4.1): "DECT-2020 New Radio (NR); Part 1: Overview; Release 1".

[i.2] ETSI TS 103 636-2 (V1.4.1): "DECT-2020 New Radio (NR); Part 2: Radio reception and transmission requirements; Release 1".

[i.3] ETSI TS 103 636-3 (V1.4.1): "DECT-2020 New Radio (NR); Part 3: Physical layer; Release 1".

[i.4] ETSI TS 103 636-4 (V1.4.1): "DECT-2020 New Radio (NR); Part 4: MAC layer; Release 1".

[i.5] ETSI TS 103 636-5 (V1.4.1): "DECT-2020 New Radio (NR); Part 5: DLC and Convergence layers".

[i.6] ETSI EN 301 406-2 (V3.1.1): "Digital Enhanced Cordless Telecommunications (DECT); Harmonised Standard for access to radio spectrum; Part 2: DECT-2020 NR".

[i.7] Recommendation ITU-R M.2150-1 (February 2023): "Detailed specifications of the terrestrial radio interfaces of International Mobile Telecommunications-2020 (IMT-2020)".

[i.8] ETSI TR 103 810 (V1.1.1): "ETSI Evaluation group; Final Evaluation Report on DECT-2020 NR".

[i.9] Recommendation ITU-R M.2412-0: "Guidelines for evaluation of radio interface technologies for IMT-2020".

[i.10] NIST Special Publication 800-38B: "Recommendation for Block Chiper Modes of Operation: The CMAC Mode for Authentication".

[i.11] FIPS PUB 197: "Advanced Encryption Standard (AES)".

[i.12] IoT Analytics (May 2022): "Global IoT market Forecast".

[i.13] ABI Research (March 2022): "DECT-2020 NR: "A new 5G IoT standard; New applications and opportunities in smart cities, energy, industrial, and Supply chain"".

[i.14] ABI Research (September 2022): "DECT-2020 NR: "Sustainability and Scale for the IoT"".

[i.15] ReportLinker (January 2024): " 2028 Projections: Healthcare IoT - Detailed Breakdown by Segment and Region".

[i.16] PR Newswire (March 2022): "IoT in Manufacturing Market growing at a CAGR of 14.50% over 2022-2032, at to reach $ 399.08 billion by 2026, Says FMI".

[i.17] MARKETSandMARKETS (2020): "Smart Lighting Market global forecast to 2025".

[i.18] IoT Analytics (August 2019): "Industrial Connectivity Market Report 2019-2024".

[i.19] Research and Markets (2023): "Global Asset Tracking Market by Infrastructure (Platform, Software, Services), Connection Type, Mobility (Fixed, Portable, Mobile), Location Method (GPS, Beacons, RFID, Others), Solution Type, Supporting Technology and Industry Verticals 2023-2028".

[i.20] IoT Analytics (June 2019): "Predictive Maintenance - Market report 2019-2024".

[i.21] European Commission: "2021 Strategic Foresight Report".

[i.22] Council Directive 91/287/EEC of 3 June 1991 on the frequency band to be designated for the coordinated introduction of digital European cordless telecommunications (DECT) into the Community.

[i.23] Council Recommendation 91/288/EEC of 3 June 1991 on the coordinated introduction of digital European cordless telecommunications (DECT) into the Community.

[i.24] Mandate to CEPT on technical conditions regarding the shared use of the 3.8-4.2 GHZ frequency band for terrestrial wireless Broadband systems providing local-area network connectivity in the union.

[i.25] ETSI EN 300 175-2 (V2.9.1): "Digital Enhanced Cordless Telecommunications (DECT); Common Interface (CI); Part 2: Physical Layer (PHL)".

[i.26] ERC/DEC/(94)03: "ERC Decision of 24 October 1994 on the frequency band to be designated for the coordinated introduction of the Digital European Cordless Telecommunications system".

[i.27] ERC/DEC/(98)22: "Exemption from individual licensing and free circulation and use of DECT equipment".

[i.28] ECC Report 203: "Least Restrictive Technical Conditions suitable for Mobile/Fixed Communication Networks (MFCN), including IMT, in the frequency bands 3400-3600 MHz and 3600- 3800 MHz".

[i.29] ECC/DEC/(19)02: "Land mobile systems in the frequency ranges 68-87.5 MHz, 146-174 MHz, 406.1-410 MHz, 410-430 MHz, 440- 450 MHz and 450-470 MHz".

[i.30] ETSI EN 300 328 (V2.2.2): "Wideband transmission systems; Data transmission equipment operating in the 2,4 GHz band; Harmonised Standard for access to radio spectrum".

[i.31] ETSI EN 301 893 (V2.1.1): "5 GHz RLAN; Harmonised Standard covering the essential requirements of article 3.2 of Directive 2014/53/EU".

[i.32] Fortune Business Insights (2022): "The global wireless audio device market is projected to grow from $47.37 billion in 2022 to $143.41 billion by 2029, at a CAGR of 17.1% in the forecast period...".

[i.33] Recommendation ITU-R SM.329: "Unwanted emissions in the spurious domain".

[i.34] ETSI TS 103 636-2 (V1.5.1): "DECT-2020 New Radio (NR); Part 2: Radio reception and transmission requirements; Release 1".

[i.35] Directive 2014/53/EU of the European Parliament and of the Council of 16 April 2014 on the harmonisation of the laws of the Member States relating to the making available on the market of radio equipment and repealing Directive 1999/5/EC Text with EEA relevance.

3 Definition of terms, symbols and abbreviations

3.1 Terms

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

digital twin: digital representation of an intended or actual real-world physical product, system, or process

sink: Radio Device operating in FT role having internet connection

3.2 Symbols

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

Δf_{OOB}	Out of Band Frequency
dBi	deciBels relative to isotropic
dBm	deciBel relative to milliwatt
kHz	kiloHertz
MHz	MegaHertz
ppm	parts per million

3.3 Abbreviations

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

5G	5^{th} Generation
ACK	Acknowledgement of successful reception of the data
ACS	Adjacent Channel Selectivity
AES	Advanced Encryption Standard
AES-CTR	Advanced Encryption Standard-Counter mode
AGV	Automated Guided Vehicle
AI	Artificial Intelligence
AMR	Autonomous Mobile Robot
AMI	Advanced Metering Infrastructure
APAC	Asia Pacific
ARQ	Automatic Repeat and reQuest
BLER	Block Error Rate
BPSK	Binary Phase-Shift Keying
BW	Bandwidth
CAGR	Compound Averaged Growth Rate
CMAC	Cipher based Message Authentication Code
CRC	Cyclic Redundancy Check
CVG	Convergence layer
CP	Cyclic Prefix
CW	Continuous Wave
DECT	Digital Enhanced Cordless Telecommunications
DL	Data Layer Downlink (Forward Link)
DLC	Data Link Control
ETSI	European Telecommunication Standards Institute
ERC	European Radio communication Committee
FDMA	Frequency Division Multiple Access
FFT	Fast Fourier Transform
FHSS	Frequency Hopping Spread Spectrum
FT	Fixed Termination Point

GI	Guard Interval
HARQ	Hybrid ARQ
ID	Identification number
IE	Information Element
IMT	International Mobile Telecommunications
IoT	Internet of Things
IPv6	Internet Protocol version 6
ITU-R	International Telecommunication Union Radiocommunication Sector
LBT	Listen Before Talk (protocol)
LED	Light Emitting Device
LSA	Licensed Shared Access
MAC	Medium Access Control
MBW	Measurement Bandwidth
MCS	Modulation and Coding Scheme
MFCN	Mobile Fixed Communication Network
MIC	Message Integrity Check
MIMO	Multiple Input Multiple Output
mMTC	massive Machine Type Communication
NACK	Negative ACK
NR	New Radio
OFDM	Orthogonal Frequency Division Multiplexing
PHY	Physical
PDU	Protocol Data Unit
PMR	Private land Mobile Radio
PMSE	Programme Making and Special Events
PLMN	Public Landline Mobile Network
PT	Portable Termination point
QAM	Quadrature Amplitude Modulation
QPSK	Quadrature Phase-Shift Keying
RACH	Random Access Channel
RF	Radio Frequency
RD	Radio Device
RSSI	Received Signal Strength Indicator
RTLS	Real Time Location System
SME	Small and Medium size Enterprise
STF	Synchronization Timing Field
SCS	Subcarrier Spacing
TDD	Time Division Duplex
TDMA	Time Division Multiple Access
TCP	Transmission Control Protocol
TX	Transmission
UDP	User Datagram Protocol
UL	Up Link
ULE	Ultra Low Energy (Operational mode of DECT)
URLLC	Ultra Reliable Low Latency Communication
VoWiFi	Voice over WiFi® communication
WAN	Wide Area Networks

4 Comments on the System Reference document

No comments.

5 Presentation of the technology

5.1 General

DECT-2020 NR as a technology foundation is targeted for local area wireless applications, which can be deployed anywhere by anyone at any time. The technology supports autonomous and automatic operation with minimal maintenance effort. Where applicable, interworking functions to Wide Area Networks (WAN). e.g. PLMN, satellite, fibre, and internet protocols foster the vision of a network of networks.

DECT-2020 NR can be used as a foundation for:

- very reliable Point-to-Point and Point-to-Multipoint Wireless Links provisioning (e.g. cable replacement solutions);
- local area Wireless Access Networks following a star topology as in the DECT family of standards deployment supporting URLLC use cases; and
- self-organizing Local Area Wireless Access Networks following a mesh network topology, which enables to support mMTC use cases.

DECT-2020 NR applies similar design principles as in the DECT family of standards. Especially the inherent feature of automatic interference management allows deployments without extensive frequency planning. The Mesh networking capability of DECT-2020 NR enables application-driven network topologies and deployments in e.g. IoT and mMTC use scenarios such that the link budget of classical cellular base-station to user equipment constellations is no longer a limiting factor. This enables local and large area (e.g. city wide) deployments without cellular base station infrastructure. Moreover, overall system coverage is constantly improved by adding new devices to the system thanks to direct device to device communication.

DECT-2020 NR (i.e. PHY layer numerology and MAC algorithms) is designed to coexist with the DECT family of standards and DECT evolution in current frequency bands allocated to DECT.

5.2 Use case examples

DECT-2020 NR is designed to provide a slim but powerful technology foundation for wireless applications deployed in various use cases and markets. This radio interface technology supports all kind of applications including, but not limited to cordless telephony, audio streaming applications, professional audio applications, consumer and industrial applications of Internet of Things (IoT) such as industry and building automation and monitoring, utility and smart city applications, and in general solutions for local area deployments (indoor or outdoor) for Ultra-Reliable Low Latency Communication (URLLC) and massive Machine Type Communication (mMTC) as envisioned for IMT-2020.

ETSI TC DECT is developing a standard that contains DECT-2020 NR radio access profiles for various application protocols such as DLMS/CoSEM (www.dlms.com) for smart metering, Matter (www.csa-iot.org), OPC/UA (www.opcfoundation.org), Profinet (profibus.com), BacNet (www.bacnet.org), I/O, and many more. The application-specific parts are impacting DECT-2020 NR radio parameter configurations supported by the DECT-2020 NR standards.

The use cases relevant for DECT-2020 NR technology could be divided by multiple aspects such as the deployment area, device density and/or latency performance. Some examples of the use case are listed below:

- Connectivity of battery-powered mobile robotic systems like Autonomous Mobile Robots (AMRs).
- Asset tracking of tools, pallets, containers, and other equipment in industrial facilities.
- Telemetry of fixed and mobile sensor units (e.g. Electricity smart metering, integration of distributed energy production, or environmental sensing in cities at a larger scale).
- Condition-based monitoring, such as occupancy detection in buildings or machine or tool level condition monitoring.
- Mission-critical communication for the organization and coordination of rescue services in case of disasters.

- Large area environmental monitoring such as early warning systems for wildfires, flooding, or monitoring systems in the crop and cattle growth.
- Factory automation with deterministic cyclic-traffic requirements and latency.
- Healthcare use, both institutional and home applications.
- Mission-critical connectivity islands.
- Professional media content production.
- Unified Communications for enterprises: high-quality audio, messaging (alarm, control), positioning.

More detailed information on use cases is available in annex A in the present document.

5.3 DECT-2020 NR Architecture and Network topologies

5.3.1 Deployment flexibility

The autonomous, frequency agile operation of DECT-2020 NR supports multiple co-existing networks and sharing spectrum when necessary. It can operate in different network configurations such as point-to-point connection, star and mesh topology networks, and combinations of these topologies, enabling wide support for multiple applications, for example smart grids and smart metering, healthcare, logistics and enterprise applications to deliver industry digitalization.

Within a DECT-2020 NR network, radio device can have following roles based on their location and capabilities in the network:

- Sink node: this is the gateway between the back-end network and the DECT-2020 NR cluster(s), for example the gateway to the internet or local back-end. The sink node is always a fixed terminal radio device (RD_{FT}) role.
- Router node: extends the network by routing messages to other devices or clusters. The router node operates as RD_{FT} role for its cluster members, and it operates as a RD_{PT} role in the next cluster heading to a sink node.
- Leaf node: the end point of the network and can only send and/or receive data. A leaf node is RD_{PT} device.

In all network topologies discussed below, the support of broadcast and multicast messages from one point to multiple points is possible. In this scenario, RD_{FT} has multiple RD_{PT}s associated to it.

5.3.2 Wireless Point-to-Point links

Point-to-Point connection refers to a dedicated communication link between two endpoints or devices. The simplest network consists of two radio devices, one acting as the FT mode (RD_{FT}) and the other as a PT mode (RD_{PT}). To extent the range of a point-to-point link, or to improve the signal-to-noise ratio, one or more routers can be added between the RD_{FT} and $_{the}$ RD_{PT}.

Connection between the devices is enabled by one RD selecting to operate in FT mode (RD_{FT}) which will initiate radio resource coordination and beacon transmissions, and the other RD will operate in PT mode (RD_{PT}) which will associate with the (RD_{FT}) via the appropriate association protocols.

5.3.3 Star topology

Conceptually, the star topology is similar to that of a typical cellular base station -to -user equipment configuration. DECT-2020 NR can be configured for a single-cluster or multiple star topology network. In a star topology, multiple RD_{PT}s will associate with single RD_{FT}.

A star network topology involves, in principle, two types of RDs:

- An RD_{FT} which may be connected to the fixed network infrastructure e.g. the internet or alternatively a local back-end system is the 'sink'. This RD_{FT} coordinates the radio resources and routing of associated device data in uplink and downlink directions.
- Other RDs which are operating in a non-routing role, i.e. operating in RD_{PT} mode.

A multiple star topology is a deployment of multiple RD_{FTs}, where each RD_{FT} is serving its own dedicated area. RD_{PTs} may associate with more than one RD_{FT} enabling mobility between areas or, alternatively, can be restricted to associate with a single RD_{FT} to limit operation within a single area.

5.3.4 Mesh network topology

In mesh network DECT-2020 NR devices can form a complex communication network and route other devices' data. This can increase the resilience and reliability of the network by operating with higher signal-to-noise ratio conditions and can provide alternative paths for data packets. If needed (and in accordance with local spectrum access rules), devices can be added to the mesh (operating as routers) to extent the range of the network.

The mode of the radio devices can change autonomously depending on the context of the communication. One or more devices can operate as gateways to the backend, e.g. connect to the internet, while other devices can operate as either routers to forward messages or as a leaf nodes.

Within a mesh network, if one route becomes unavailable, devices can reroute packets to the destination, minimizing the probability of outage. These autonomous routing decisions provide the ability to adapt dynamically to mobile users and changes in network performance, for example due to interference.

For mMTC, operation in a mesh network is scalable to a very high number of devices and routing is based on cost value without the need to maintain routing tables in each device. Network scalability is achieved by the following:

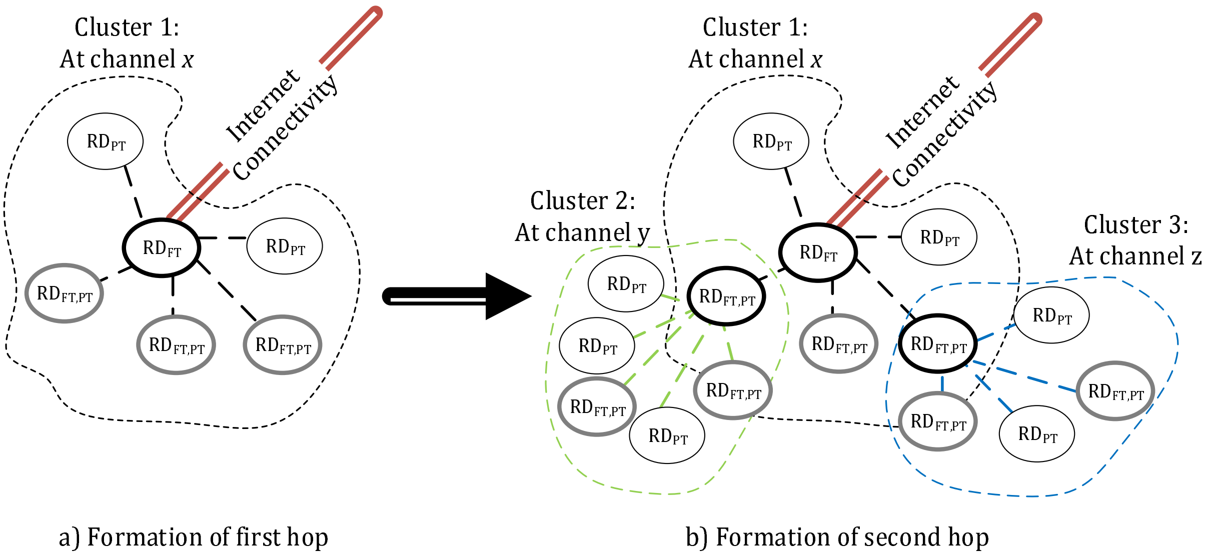
- The mesh network does not assume a central coordinator and decisions are taken locally by RDs. This enables massive scalability.
- The mesh network can support multiple gateways via 'sink' devices operating in FT mode. PT devices can route data to the backend via any connected gateway.
- All RDs can route data based on its own autonomous decisions. It is possible to configure a RD to a non-routing mode.
- Routing devices can change their operating mode autonomously between FT mode (routing RD), PT mode (non-routing RD), or supporting both FT and PT modes simultaneously.
- RDs can operate with multiple channels (based on FDMA and TDMA) and take local decisions on use of the radio resource, e.g. modulation and coding scheme used.

In DECT-2020 NR, the mesh network is based on a cluster tree topology where each RD decides the next hop individually based on available routes towards and from the RD_{FT} providing the connection to the backend/internet. The formation of cluster tree topology has the following steps:

- The sink, operating in FT mode selects the operating frequency (or frequencies) and initiates beacon transmission indicating it has a route to the external world. The beacon transmission provides all necessary parameters to allow other RDs detect and associate with the sink. Once the RD has associated with the sink it may initiate its own association information to allow other RDs to associate with it, and through it to the sink or other RDs in the cluster.
- RD detecting a beacon from another RD evaluates the connection based on the information included in the received beacon and the signal quality. RD monitors its neighbourhood and may autonomously initiate an association process towards another RD_{FT} or $RD_{FT,PT}$.

- Once the RD has established a connection with another device it can start send and receive data through the network. It can simply use a specific address value to indicate that the data is addressed to a backend.

Process outlined above continues throughout each subsequent hop in the network as illustrated in Figure 5.3.4-1.



NOTE 1: At the formation of the first hop a) one or more RD_{PT} or $RD_{FT,PT}$ associates with an RD_{FT}.

NOTE 2: The second hop b) is formed by RD_{PT} or $RD_{FT,PT}$ that associate with the first hop $RD_{FT.PT}$.

NOTE 3: Black thick circle: RD with associated members, grey thick circle: RD that is available routing, but has no associated members, black thin circle: RD in PT only mode.

Figure 5.3.4-1: Formation of the cluster tree mesh network topology

The network can have multiple backends sharing the same mesh network connectivity. The system operation with multiple RDs in FT mode (*sinks*) is illustrated in Figure 5.3.4-2. The process of forming clusters is identical and an RD may choose to change its association to the next hop RD regardless of the next hop RD will provide connectivity to a different RD_{FT} having the backend connection. Figure 5.3.4-2 also illustrates the case when there is $RD_{FT,PT}$ that does not yet have any associated RD_{PT}.

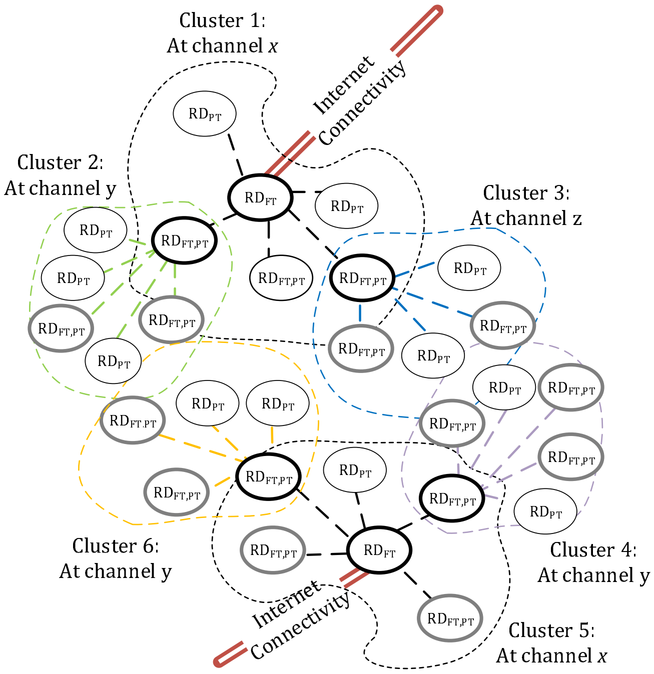


Figure 5.3.4-2: Example formation of the clusters in multiple RD_{FT} scenario

Association and routing in between RDs is based on the received beacons´ quality attributes such as Received Signal Strength Indicator (RSSI) measurement to determine the pathloss and cost values to a sink. If both DL pathloss and UL pathloss are such that connection can be established, the RD transmitting this beacon is considered as *potential next hop*.

6 Market information

6.1 General

The global IoT market size is estimated in [i.12], indicating that the total active IoT connections are growing from 12,2 billion connection by 2021 to 27 billion connection by 2025. The annual growth of active connections is approximately 4 billion connections. This market forecast also indicates that the Wireless Local Area Networks and Wireless personal area networks covers 1/3rd of the total connections indicating the importance of easy spectrum access for IoT.

DECT-2020 NR is initially intended to professional use, and consumer application are also viable but it is more difficult to assess addressable market size in the consumer markets. The market information presented in the present document is based on professional applications.

6.2 Industry applications and market information

6.2.1 Market information

ABI research has done industrial IoT market size studies in [i.13] and [i.14]. In [i.13] the analysed use case segments are:

- Asset tracking/goods location monitoring.
- Logistics and supply chain, mobile robotics.
- Smart/Micro city applications.
- Smart energy, metering, and telemetry.

IoT Analytics in [i.18] discusses the industrial applications markets. [i.22] report indicates that wireless connections will grow from 195 million units in 2020 to 1 151 million units in 2023, from 2022 to 2023 the growth is estimated 450 million units annually, indicating rapid growth in this sector.

6.2.2 Asset Tracking and logistics supply chain

The manufacturing process is a complex interaction of moving objects such as raw materials, sub-assemblies, parts, personnel, and tools that together perform steps in a defined sequence. The monitoring of all moving elements is essential to prevent deviations from the manufacturing process and improving the quality. Asset management is relevant for various industries and markets:

- Healthcare.
- Retail.
- Hospitality.
- Transportation and Logistics.
- Industrial manufacturing.
- Process industry.

According to [i.19] analysis, global asset tracking market will reach $72,4B by 2028, growing at 18,3 % CAGR. Global asset tracking market for AI-embedded devices to grow at 33,1 % through 2028. While fleet comprises over 77 % of the market, non-fleet asset tracking is growing 18 % faster. The asset management and logistics market will witness considerable vendor consolidation through 2030. Leading companies will integrate asset management, logistics and connected-device security as combined solutions IoT supported asset tracking market will account for over 90 % of all connected enterprise and industrial solutions by 2030.

The total connection estimate by 2026 is approximately 2 billion wireless connections according [i.13]. The largest industry sector is automotive industry approximately 420 million connections followed by Food & Beverage with 260 million and electronics and machinery sectors both approximately 170 million connections.

6.2.3 Smart city

For smart cities the smart lighting is predicted the first application where the digitalization in this context is starting.

The smart lighting market was valued at $11 040 million in 2019 and is projected to reach $30,598 million by 2025 [i.17] and it is expected to grow at a CAGR of 18,0 % during the forecast period. The smart lighting market is segmented based on communication technology into wired and wireless technologies. It is estimated that wireless communication technologies market value will grow from 3 608 million in 2019 to 12 894 million in 2025.

Based on regions, the wireless smart lighting market in Europe is estimated to be 4 363 million in 2025, North America 2 631 million, APAC 4 039 million and rest of the world 1 860 million in 2025 [i.17].

6.2.4 Smart Energy and smart metering

The energy sector electrification is currently ongoing to reduce the use of fossil fuels, and transfer to renewable and distributed energy production is rapidly growing. The demand and response requirement to keep the electricity network stable and future energy market having millions of producers and consumers requires cost effective communication services.

Smart electricity metering, Advanced Metering Infrastructure (AMI), plays a crucial role in modernizing and improving the efficiency of the electricity distribution system. Smart electricity metering is essential for creating a more efficient, responsive, and sustainable energy ecosystem which is valued high in the EU Commission strategy initiatives.

DECT-2020 NR technology provides excellent communication distances, reliability, and scalability for wide area deployments such as smart metering services. The autonomous operation provides reliability in the field which is necessary for utilities responsible for service quality and reliability.

The electricity meters deployments are one of the biggest markets for next years. In [i.13] the annual smart meter market is in 2021 770 million units and growing up to 1,2 billion units by 2026. This covers both wired and wireless communication solutions. Approximately half of the volumes are based on wireless communication. It is estimated that 30 % i.e. 380 million in 2026 meters could be addressable market for DECT-2020 NR.

6.2.5 Enterprise and Industrial IoT market

In the industrial environments of the future, robots, sensors, and other industrial devices will have to communicate autonomously and in a robust and efficient manner with each other, relying to an increasingly large extent on wireless communication links, which will expand and supplement the existing wired/Ethernet connections.

With the number of networked sensors increasing across production, supply chain, and products, manufacturers are entering into a new generation of systems that enable automatic and real-time interactions among machines, systems, assets, and things. The pervasiveness of connected devices is finding applicability across multiple segments of the manufacturing and supply chain, throughout the value chain.

These uses cases could be categorized into several classes.

- Production optimization by increasing automation.
- Process and production modelling with "Digital Twin" with massive amount of measurement points.
- Asset and production material monitoring.
- Preventive maintenance applications enabling new service models.

In [i.20] the estimated preventive maintenance cumulative market size is $23 536 million in 2024 and the estimated cumulative savings in maintenance costs in the same year is $188 billion.

The IoT in Manufacturing Market is growing at a CAGR of 14,50 % over 2022 to 2032, at to reach $399,08 billion by 2026 [i.16].

6.3 Wireless Audio Market

6.3.1 Wireless Audio

Wireless audio is the transmission of audio via wireless technologies in applications such headphones & headsets, earphones, microphones, speaker systems & soundbars. DECT based equipment currently play an important role in headsets market and for wireless microphones for presentation and lecturing purposes.

The global wireless audio devices market was valued at $40 billion in 2021. The market is projected to grow from $47 billion in 2022 to $143 billion in 2029, at a CAGR of 17 % during the forecast period [i.32].

6.3.2 Content Creation and Production

Equipment for audio content creation and professional audio production is used to support broadcasting, news gathering, theatrical productions and special events, such as culture events, concerts, sport events, conferences, and trade fairs.

Programme Making and Special Events (PMSE) is a term used, typically in Europe to describe the wireless communication links that allow the creative industries to transport the captured audio and video content from performers and presenters on location to audiences, either at the venue, at home, or increasingly, on the move. PMSE content capture sits at the start of the supply and value chains for a wide range of products, and consequently, it is expected to provide the highest quality possible.

According to information available to audio industry stakeholders involved in ETSI TC DECT the market for wireless audio production tools continues to show a healthy growth with a worldwide market revenue generated as a result of these events of around $2,03 billion in 2021 and with an expected increase of 6 % CAGR out until 2026.

6.4 Healthcare

Healthcare institutions comprise hospitals for short-term, acute care as well as long-term care homes for elderly people or psychiatric care. In all of these institutions there are use cases and applications that can be effectively addressed by DECT-2020 NR.

Key factors driving the growth of the IoT in healthcare market are the rising focus on active patient engagement and patient-centric care, growing need for adoption of cost-control measures in the healthcare sector and growth of high-speed network technologies for IoT connectivity and increasing focus on patient-centric service delivery through various channels.

The global IoT in healthcare market size is projected to grow from $127,7 billion in 2023 to $289,2 billion by 2028, at a Compound Annual Growth Rate (CAGR) of 17,8 % during the forecast period [i.15].

7 Technical information

7.1 Detailed technical description

7.1.1 Introduction

DECT-2020 NR system design objectives are targeted to meet industry network deployment challenges. These objectives are:

- The simplicity of deployment by supporting autonomous operation minimizing network planning and configuration tasks by network self-forming and -healing capabilities.
- Radio technology enables reliable communication and devices can route data further providing reliability for challenging radio environment and wider area coverage.
- The operational freedom by keeping the physical and logical protocol layers application agnostic.
- The network operational model can be selected freely in terms of local on-premises data consumption or alternatively using public clouds matching the use case and service requirements.
- Technology can operate both shared and licensed spectrum. The polite spectrum access, i.e. the device ability to sense the spectrum use prior its own transmission to avoid collision with other transmissions.
- When operating in licensed spectrum, the technology offers capability to share the spectrum between different networks.

The smallest radio transmission bandwidth, radio frame, and transmission slot lengths in DECT-2020 NR are aligned with classic DECT and DECT ULE to ensure efficient spectrum use and to minimize interference at DECT core bands (1 880 to 1 900 MHz in Europe). Initial results with DECT-2020 NR in RF band 1, defined in Table 7.1.5-1, with 1,728 MHz channel bandwidth indicates an operating range up to 6 km with open space conditions and 19 dBm output power.

The inherent features of automatic interference management such as operating channel selection, LBT for random access transmission, transmission power control, and capability to detect and decode physical control information from other devices transmission allows locally selecting frequencies with lowest interference and thus deployments without extensive frequency planning. The mesh networking capability of DECT-2020 NR enables application-driven network topologies and deployments in, e.g. IoT and mMTC scenarios such that a single link budget is no longer limiting factor for the communication. This enables local and large area (e.g. city wide) deployments without cellular base station infrastructure. Moreover, overall system coverage is constantly improved by adding new devices to the system thanks to direct device to device communication.

7.1.2 Radio Protocols

The DECT-2020 NR radio protocol architecture consists of Physical Layer (ETSI TS 103 636-2 [i.2] and ETSI TS 103 636-3 [i.3]), Medium Access layer (MAC) (ETSI TS 103 636-4 [i.4]), Data Link Control layer (DLC), and Convergence (CVG) layer (ETSI EN 301 406-2 [i.6]). Physical layer, MAC, and DLC -layers are completely agnostic to the application data types.

The standard supports different protocol configuration options that can be enabled depending on use case and application requirements. The packet routing is performed at the DLC layer, as shown in Figure 7.1.2-1. This allows any RD routing other RD's data without understanding the content of the transferred data.

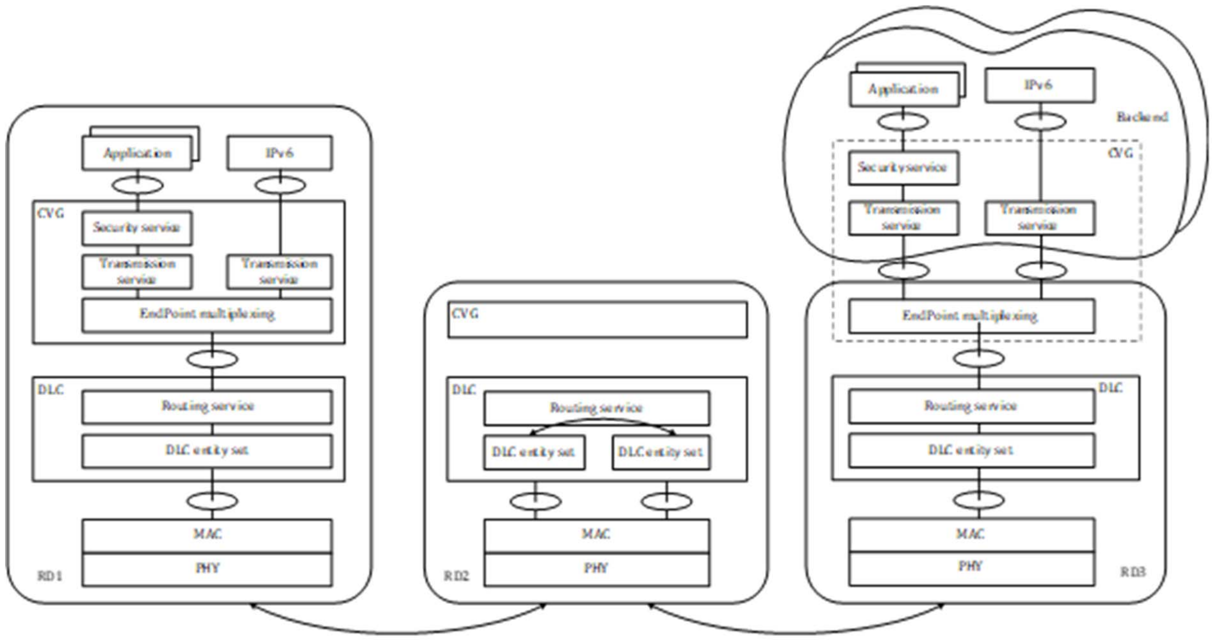


Figure 7.1.2-1: DECT-2020 NR Overall protocol architecture
Source: Figure 4.2.1-3 in ETSI EN 301 406-2 [i.6]

In DECT-2020 NR, the Convergence Layer (CVG) provides adaptation between different application data layers and DECT-2020 NR radio protocol layers. CVG also supports the Endpoint multiplexing function where different applications are using different application endpoint values, i.e. identification code. These values identify the used application between the source and destination of the data introducing a unique data flow for the given application. This enables standard application protocols such as OPC-UA or DLMS (device language message specification) operation with IPv6/UDP/TCP or directly over the DECT-2020 NR radio interface, while also allowing vendor-specific data formats when desired.

With the definition of different endpoint values, a single network can transfer data from many different applications at the same time. This can enable, when desired e.g. in smart city or building application to use same network and each transfer data to their own backend server. In addition to endpoint multiplexing, CVG supports several optional functionalities that can be used when desired. These functions are end-to-end segmentation and reassembly, flow control, end-to-end Automatic Repeat reQuest (ARQ), and end-to-end security. Further CVG architecture has been defined in such a manner that different functions above Endpoint multiplexing functionality can be implemented in different location in RD_{FT} (gateway) or in backend, as shown in Figure 7.1.2-1.

The purpose of the end-to-end segmentation and reassembly is to ensure that the PDU size being routed in the mesh network does not exceed device communication capabilities; for this purpose, the application PDUs may be segmented to fit into the transmission and routing processes of the devices. The segmented PDUs will then be reassembled at the destination before they are delivered to the application, and the application layer, such as IPv6/UDP/TCP protocol layer, can use their normal PDU structures and sizes.

Data Link Control (DLC) defines 4 different service type modes for link specific functionalities as well as routing functionality. Link specific functionalities are called DLC service types and are numbered from 0 to 3. Different service types can be initiated for each DLC entity. DLC service type 0 provides transparent operation, whereas link specific segmentation is supported in DLC type 1. DLC service type 2 provides ARQ operation based on HARQ feedbacks and finally DLC service type 3 combines the support of link specific segmentation with ARQ operation respectively.

Routing functionality operates on top of the DLC service layer in mesh system configuration. The routing is supported by using 32 bit long Radio Devices Long RD Identities (Long RD-ID) and placing the source and the destination Long RD-IDs into PDU header. The DECT-2020 NR packet routing functionality is defined separately for packet routing in uplink, i.e. packets transmitted from RDs to backend, downlink, i.e. packets transmitted from backend to RD, multicast group or to all RDs and packet routing between RD, with unicast, multicast or broadcast address.

The packet routing in uplink is based on cluster tree routing topology, where RD sends data to the backend using a specific address reserved for the backend. As all RDs including RDs routing data, i.e. operating in both FT and PT mode, maintain constantly valid and most optimum route towards RD that has an external interface towards backend (RD_{FT}), each node does not have to know exact data path, rather they just maintain best next hop selection and send uplink data to their next hop, i.e. to RD_{FT} that they are associated with. This enables efficient uplink packet routing, even in changing radio environment where individual RD may select and update the most optimum path for uplink data, which typically vast majority of all data transferred in typical IoT systems.

The *route cost* expresses the cost of the route to deliver data to the *sink,* the RD_{FT} that has a backend connection to the internet. RD may select the RD_{FT} or $RD_{FT,PT}$ for association having the smallest *cost*. Route cost value will increase at least 1 in every hop. The *route cost* is dependent on multiple factors, such as RD capabilities, data rate, interference and BLER, own load i.e. data amount to be delivered, available battery energy, etc.

The packet routing from backend (downlink) is based on selective flooding in cluster tree, where each router forwards downlink data towards to all routing RDs or RD that is target device of the data. This method provides robust method for delivering data from backend to RDs without routing tables route registration signalling. Further, this is also only option for infrequent DL data traffic without constant routing updates that would create constant signalling traffic to wireless mesh network. TC DECT is currently working for more advance methods for TC DECT Release 2 for improving DL packet routing to support especially bi-directional data transmissions.

Finally, packet routing between RDs, is based on hop limited flooding between devices. This operation has been defined for local use cases, where single RD sends typically command to one or more devices configured in a multicast group. Typical use case being outdoor or indoor lighting where RD device with control button or with presence indication detector can send command to group of lights to turn on or off. With hop limiting functionality the flooding can be controlled so that command is received by all desired devices, but message is not distributed to complete network.

DECT-2020 NR MAC and physical layer can perform fast re-transmissions at link-level which improves the reliability of data delivery. The basic principle of the HARQ is based on functionality when a receiver is not able to decode a data packet correctly, it stores the received packet in memory and sends a negative acknowledgement (NACK) to the transmitter. When the transmitter receives the NACK, it initiates re-transmission and when the receiver recognizes the re-transmission, it combines the original transmission and re-transmission together which is improving the reception quality significantly (approximately 5 dB in the case of the DECT-2020 NR design). The RX to TX transition time is performed within the Guard Interval (GI), enabling a very competitive low latency operation even with hybrid ARQ.

When reception of the transmission is successful, the receiver sends an Acknowledgement (ACK) to the transmitter indicating successful reception of the data. HARQ latency characteristics are illustrated in Table 7.1.2-1.

Table 7.1.2-1: User plane Latency in ms (Source: ETSI TR 103 810 [i.8])

<table>
<tr><th>Mode and channel bandwidth</th><th>Data TX duration</th><th>MCS (modulation and coding rate) and transport block size</th><th colspan="2">One way user plane latency</th></tr>
<tr><td rowspan="3">27 kHz SCS, with 1,728 MHz</td><td rowspan="3">416,667 µs (10 symbols)</td><td rowspan="3">MCS1 (QPSK 1/2) 296 bits</td><td>No HARQ</td><td>0,90 ms</td></tr>
<tr><td>10 % HARQ retransmissions</td><td>1,05 ms</td></tr>
<tr><td>Max delay with one HARQ</td><td>2,44 ms</td></tr>
<tr><td rowspan="3">54 kHz SCS, with 3,456 MHz</td><td rowspan="3">208,333 µs (10 symbols)</td><td rowspan="3">MCS2 (QPSK 3/4) 368 bits</td><td>No HARQ</td><td>0,45 ms</td></tr>
<tr><td>10 % HARQ retransmissions</td><td>0,53 ms</td></tr>
<tr><td>Max delay with one HARQ</td><td>1,22 ms</td></tr>
<tr><td rowspan="3">54 kHz SCS, with 6,912 MHz</td><td rowspan="3">208,333 µs (10 symbols)</td><td rowspan="3">MCS0 (BPSK 1/2) 288 bits</td><td>No HARQ</td><td>0,45 ms</td></tr>
<tr><td>10 % HARQ retransmissions</td><td>0,53 ms</td></tr>
<tr><td>Max delay with one HARQ</td><td>1,22 ms</td></tr>
<tr><td rowspan="3">108 kHz SCS, with 6,912 MHz</td><td rowspan="3">104,166 µs (10 symbols)</td><td rowspan="3">MCS2 (QPSK 3/4) 368 bits</td><td>No HARQ</td><td>0,22 ms</td></tr>
<tr><td>10 % HARQ retransmissions</td><td>0,26 ms</td></tr>
<tr><td>Max delay with one HARQ</td><td>0,61 ms</td></tr>
</table>

The above values represent each link's transmission latency for reliable communications. The one-way end-to-end latency in mesh topology operation increase latency due to multi-hop characteristics. In massive Machine Type Communication (mMTC) system simulations for IMT-2020 scenarios, as defined in Recommendation ITU-R M.2412-0 [i.9], the end-to-end latency results were below 100 ms. The end-to-end latency is use case dependent, and hence it can be influenced by deployment choices.

In addition, it is possible to utilize end-to-end ARQ to provide lossless data delivery between the original source and destination of the data.

DECT-2020 NR supports two separate security layers, namely MAC security for link level encryption and CVG layer security for end-to-end security.

MAC provides the first security layer for link-level encryption and integrity protection of the data and MAC signalling. This ensures that any eavesdropping third party cannot extract the data content, and the receiver can verify that the received data is legitimate and unchanged. For this purpose, MAC security mode 1 is defined, which utilizes AES-128 counter mode (AES-CTR) for encryption as defined in FIPS PUB 197 [i.11] and CMAC (OMAC-1) message authentication algorithm as defined in NIST Special Publication 800-38B [i.10] for integrity protection.

The second security layer is at CVG, CVG security mode 1, which provides the end-to-end security between the original source and destination of the data. The CVG security mode 1 uses the same AES-128 and CMAC ciphering and integrity protection algorithms as the MAC layer in a fully independent processes with different security keys.

Both MAC and CVG layer security functions are defined in such a manner that new security algorithms can be introduced in the future based on application and use case requirements.

7.1.3 Spectrum access capabilities

DECT-2020 NR supports polite spectrum operation, i.e. the device senses the spectrum use prior its own transmission to avoid collision with other transmissions by enabling operation on least interfered channels by supporting Listen Before Talk (LBT) protocol. Further, DECT-2020 NR complies with different spectrum licensing rules, including licensed access, Licensed Shared Access (LSA), Primary/Secondary access and unlicensed spectrum access.

The advanced spectrum management functions that are further assisting the coexistence of DECT-2020 NR systems with, either classic DECT technologies or any other technologies co-existing in any frequency bands:

- Local, device-based interference management:
  - Operating channel and timeslot selection is local and subject to the lowest interference levels.
  - The connection association decision is local, enabling a device to initiate an association to the optimum neighbouring device and minimize spectrum utilization and interference.
  - Active transmitter power control minimizes the used TX (transmission) power use and interference caused to other users/systems.

For shared spectrum operation DECT-2020 NR enables:

- Capability to detect interference from any other system sharing the same spectrum or adjacent spectrum with the DECT-2020 NR device.
- Listen Before Talk (LBT) with the exponential back-off operation for transmitting random access resources.

Capability to identify other DECT-2020 NR systems operating in same spectrum:

- Advanced capability to detect and perform measurement on DECT-2020 NR transmissions from the same network devices or from devices belonging to other DECT-2020 NR networks operating in the same area.
- The standard supports advanced features enabling autonomous, time-accurate interference avoidance schemes over the air between DECT-2020 NR devices and even between DECT-2020 NR devices belonging to another network minimizes interference.

- With the coexistence between DECT-2020 NR systems and classic DECT technologies (e.g. DECT, DECT evolution, DECT ULE), the following design choices were explicitly made in DECT-2020 NR:
  - The nominal channel bandwidth is the same as the nominal channel bandwidth in DECT systems, i.e. 1,728 MHz, and wider nominal channel bandwidths are multiples of 1,728 MHz. The operating channel centre frequencies are aligned with classic DECT frequencies.
  - DECT-2020 NR radio frame and slot lengths are aligned with the DECT family of standards, and transmission lengths are multiples of them.

7.1.4 Physical layer details

Supported subcarrier Spacing (SCS) and Cyclic Prefix (CP) values are found to be suitable even for urban macro type of deployments. Furthermore, as used SCS directly impacts the OFDM symbol duration in time and thus the inherent physical layer transmission latency, higher numerology options can be used for very delay sensitive applications.

The physical layer supports advanced channel coding for both control and physical channels and Hybrid ARQ with incremental redundancy, enabling fast re-transmission schemes in physical layer. Advanced channel coding together with Hybrid ARQ functionality ensures very reliable communication for URLLC use cases. Additionally, the physical layer can support both transmit and receiver diversity and MIMO operations up to 8 streams.

Subcarrier spacing is defined by the subcarrier scaling factor μ, resulting in either 27 kHz, 54 kHz, 108 kHz, or 216 kHz OFDM subcarrier spacing. The Fourier transform scaling factor β can be set to allow different transmission bandwidths for each configuration of the subcarrier spacing. These capabilities enable to support nominal RF bandwidth from 1,728 MHz, 3,456 MHz, 6,912 MHz up to 221,184 MHz, as shown in Table 7.1.4-1.

Table 7.1.4-1: Different transmission bandwidth options composed from ETSI TS 103 636-4 [i.4]

SCS scaling factor μ	SCS [kHz]	FFT scaling factor β	FFT size	Nominal RF bandwidth [MHz]
1	27	1	64	1,728
		2	128	3,456
		4	256	6,912
		8	512	13,824
		12	768	20,736
		16	1 024	27,648
2	54	1	64	3,456
		2	128	6,912
		4	256	13,824
		8	512	27,648
		12	768	41,472
		16	1 024	55,296
3	108	1	64	6,912
		2	128	13,824
		4	256	27,648
		8	512	55,296
		12	768	82,944
		16	1 024	110,592
4	216	1	64	13,824
		2	128	27,648
		4	256	55,296
		8	512	110,592
		12	768	165,888
		16	1 024	221,184

Supported modulation schemes are BPSK, QPSK, 16-QAM, 64-QAM, 256-QAM, and 1024-QAM used to carry channel-coded bits. The channel coding scheme is Turbo Coding which combines error detection, error correction, rate matching, and interleaving. The turbo encoder uses a coding rate of R = 1/3, with two 8-state constituent encoders and one turbo code internal interleaver. Coding rates are 1/2, 2/3, 3/4, and 5/6 depending on the used modulation scheme. The physical layer error detection is supported by the use of 16 or 24-bit CRC (ETSI TS 103 636-4 [i.4]).

In ETSI TS 103 636-4 [i.4], annex C provides examples of 1, 2 and 4 slot single spatial stream user plane bitrates available to the MAC layer. The available data rates to the MAC layer are increasing when the number of slots in a single physical layer packet is increased. The present specification allows up to 16 slots (6,6 ms) for a single continuous transmission.

The transmitter's maximum output power is +23 dBm for bands 1, 2, 3 and 4, see Table 7.2.2.1.1-1. The transmitter output power can be adapted to support use cases like battery-powered devices with lower output power levels down to -40 dBm for applications to support for high equipment densities.

The receiver requirement defines the minimum performance for the radio device with hybrid ARQ support. The reference sensitivity levels for single RX devices are scaling depending on the operating bandwidths from -99,9 dBm @1,728 MHz, -96,9 dBm @3,456 MHz, and 93,9 dBm @6,912 MHz (ETSI TS 103 636-3 [i.3]). With the use of more receiver structures such as RX diversity, the receiver sensitivity can be further improved when needed.

The physical layer specification [i.4] considers also operating bandwidths numerology up to 221,184 MHz as illustrated in Table 7.1.4-1. The radio performance requirements defined in ETSI TS 103 636-3 [i.3] including receiver and transmitter requirements, receiver sensitivity and selectivity, maximum output power, emission masks for operating bandwidths above 6,912 MHz are considered in future releases based on regulation of addressable bands.

Radio device measurements are defined for channel access purposes and to support radio environment quality reporting for mobility and mesh routing purposes. The requirements are defined keeping in mind the state of art performance, low power consumption, and enabling affordable implementation.

7.1.5 Current Spectrum support

The radio channel numbering scheme assigns of transmission frequencies from 450 MHz up to 5 875 MHz organized into 21 different operating bands (ETSI TS 103 636-3 [i.3]).

The system is designed to operate in Time Division Duplex (TDD) bands where reception and transmission occur on the same frequency channel. The operating band numbering is shown in Table 7.1.5-1.

The physical and MAC layers are defined in a frequency-independent manner, and a RD may support one or more bands depending on its capabilities and use case requirements.

Table 7.1.5-1: Operating band numbering

Band number	Receiving and Transmitting band [MHz]
1	1 880 to 1 900
2	1 900 to 1 920
3	2 400 to 2 483,5
4	902 to 928
5	450 to 470
6	698 to 806
7	716 to 728
8	1 432 to 1 517
9	1 910 to 1 930
10	2 010 to 2 025
11	2 300 to 2 400
12	2 500 to 2 620
13	3 300 to 3 400
14	3 400 to 3 600
15	3 600 to 3 700
16	4 800 to 4 990
17	5 725 to 5 875
18	5 150 to 5 350
19	5 470 to 5 725
20	3 800 to 4 200
21	3 700 to 3 800
NOTE 1: Some bands may not be available in all CEPT countries. NOTE 2: Frequency bands 20 and 21 support are added to ETSI TS 103 636-2 [i.34] draft based on agreed CR's DECT(23)000036 and DECT(23)000154.	

7.2 Technical parameter and implications on spectrum

7.2.1 Status of technical parameter

This clause provides relevant technical information transmitter, receiver, and spectrum access behaviour of DECT-2020 NR.

7.2.2 Transmitter parameter

7.2.2.1 Transmitter Output Power / Radiated Power

7.2.2.1.1 Transmitter maximum power

Transmitter maximum output characteristic are defined in ETSI TS 103 636-3 [i.3].

Transmitter characteristics are specified at the antenna connector of the Radio Device (RD) with single antenna transmissions. The RD having integral antenna, a reference antenna gains of 0 dBi is assumed.

The maximum output power is defined as the mean power of the transmitted packet. The maximum transmitter output power for Radio Device is defined in Table 7.2.2.1.1-1.

Table 7.2.2.1.1-1: Maximum output power

RD power class	Operating channel bandwidth (MHz)		
	1,728	3,456	6,912
	Output power (dBm)		
Class I	23	23	23
Class II	21	21	21
Class III	19	19	19
Class IV	10	10	10
NOTE 1: The measurement bandwidth equals to the transmission bandwidth of the operating channel bandwidth defined in Table 5.3.2-1 in ETSI TS 103 636-3 [i.3]. NOTE 2: Common test parameters are defined in Table A.2.1-1 for 1,728 MHz operating channel bandwidth, Table A.3.1-1 for 3,456 MHz operating channel bandwidth and Table A.4.1-1 for 6,912 MHz operating channel bandwidth operation as defined in ETSI TS 103 636-3 [i.3]. NOTE 3: Transmission output power tolerance is defined in Table 6.3.1-1 in ETSI TS 103 636-3 [i.3].			

Current standards power classes are based on existing regulation limits. Standard defines output power control scheme where the transmit power can be adjusted based on each radio link. The minimum transmission power is -40 dBm. DECT 2020 NR access can support higher output power classes which may be allowed by regulation and may be added in later releases.

7.2.2.1.2 Transmitter minimum power

The minimum controlled output power of the radio device is defined as the power in the channel bandwidth when the power is set to a minimum value.

The minimum output power, excluding the power tolerance, is less than value specified in Table 7.2.2.1.2-1.

Table 7.2.2.1.2-1: Minimum output power

Parameter/Unit	Channel bandwidth/MHz		
	1,728	3,456	6,912
Minimum output power/ dBm	-40		

7.2.2.1.3 Out of band emissions

The Out of band emissions are unwanted emissions immediately outside the assigned channel bandwidth resulting from the modulation process and non-linearity in the transmitter but excluding spurious emissions.

The spectrum emission mask of the RD applies to frequencies (Δf_{OOB}) starting from the ± edge of the assigned channel. For frequencies offset greater than Δf_{OOB} as specified in Tables 7.2.2.1.3-1, 7.2.2.1.3-2 and 7.2.2.1.3-3 the spurious emission requirements are applicable.

Table 7.2.2.1.3-1: Spectrum emission limit for 1,728 MHz channel bandwidth

Spectrum emission limit (dBm)		
Δf_{OOB}/MHz	**1,728 MHz channel bandwidth**	**Measurement BandWidth (MBW)**
±0 to 0,0945	-10	30 kHz
±0,0945 to 1,6335	-10	1 MHz
±1,6335 to 1,8225	-13	1 MHz
±1,8225 to 3,3615	-20	1 MHz
±3,3615 to 3,456	-23	1 MHz
NOTE 1: The first and the last measurement position with a 30 kHz filter is at Δf_{OOB} equals to ±0,015 MHz and ±0,0795 MHz. NOTE 2: The first and the last measurement position with a 1 MHz filter is at Δf_{OOB} equals to ±0,5945 MHz and ±3,8615 MHz.		

Table 7.2.2.1.3-2: Spectrum emission limit for 3,456 MHz channel bandwidth

Spectrum emission limit (dBm)		
Δf_{OOB}/MHz	**3,456 MHz channel bandwidth**	**Measurement BandWidth (MBW)**
±0 to 0,2025	-10	30 kHz
±0,2025 to 3,2535	-10	1 MHz
±3,2535 to 3,6585	-13	1 MHz
±3,6585 to 6,7095	-20	1 MHz
±6,7095 to 6,912	-23	1 MHz
NOTE 1: The first and the last measurement position with a 30 kHz filter is at Δf_{OOB} equals to ±0,015 MHz and ±0,1875 MHz. NOTE 2: The first and the last measurement position with a 1 MHz filter is at Δf_{OOB} equals to ±0,7025 MHz and ±7,2095 MHz.		

Table 7.2.2.1.3-3: Spectrum emission limit for 6,912 MHz channel bandwidth

Spectrum emission limit (dBm)		
Δf_{OOB}/MHz	**6,912 MHz channel bandwidth**	**Measurement BandWidth (MBW)**
±0 to 0,4185	-10	30 kHz
±0,4185 to 6,4935	-10	1 MHz
±6,4935 to 7,3305	-13	1 MHz
±7,3305 to 13,4055	-20	1 MHz
±13,4055 to 13,824	-23	1 MHz
NOTE 1: The first and last measurement position with a 30 kHz filter is at Δf_{OOB} equals to ±0,015 MHz and ±0,4035 MHz. NOTE 2: The first and the last measurement position with a 1 MHz filter is at Δf_{OOB} equals to ±0,9185 MHz and ±13,9055 MHz.		

7.2.2.2 Antenna Characteristics

Equipment's antenna characteristics varies based on intended use and deployment requirements. DECT-2020 NR system design is based on identical radio designs in each equipment, which is simplifying and reducing the cost of the deployments. The simplest equipment may support single antenna with radiation pattern close to omni antennas.

Multi-antenna operation with MIMO and beamforming is possible with DECT-2020 NR technology when use case requires it. In these use cases the antenna design is more complex, and directivity is better.

In general, the deployment are local area networks in and outdoors and antenna heights in general are between 1,5 m to 4 m.

7.2.2.3 Operating Frequency

Radio device operating band numbering is defined in Table 7.2.2.3-1. Radio device may implement one or more band support depending on its capabilities.

Table 7.2.2.3-1: Operating band numbering

Band number	Receiving band (MHz)	Transmitting band (MHz)
1	1 880 to 1 900	1 880 to 1 900
2	1 900 to 1 920	1 900 to 1 920
3	2 400 to 2 483,5	2 400 to 2 483,5
4	902 to 928	902 to 928
5	450 to 470	450 to 470
6	698 to 806	698 to 806
7	716 to 728	716 to 728
8	1 432 to 1 517	1 432 to 1 517
9	1 910 to 1 930	1 910 to 1 930
10	2 010 to 2 025	2 010 to 2 025
11	2 300 to 2 400	2 300 to 2 400
12	2 500 to 2 620	2 500 to 2 620
13	3 300 to 3 400	3 300 to 3 400
14	3 400 to 3 600	3 400 to 3 600
15	3 600 to 3 700	3 600 to 3 700
16	4 800 to 4 990	4 800 to 4 990
17	5 725 to 5 875	5 725 to 5 875
18	5 150 to 5 350	5 150 to 5 350
19	5 470 to 5 725	5 470 to 5 725
20	3 800 to 4 200	3 800 to 4 200
21	3 700 to 3 800	3 700 to 3 800
NOTE: Some bands may not be available in all CEPT countries.		

The minimum channel spacing is 1,728 MHz between adjacent channels centre to centre frequencies. In wider operating bandwidth cases the channel centre frequencies can be adjusted with 0,864 MHz in bands 1 to 12. For bands 13 to 16 and 20, the minimum channel centre frequency step size is 1,728 MHz. For bands 17 to 19 the minimum channel centre frequency step size is 2 MHz.

The absolute channel numbering range and respective band edge channel frequency are shown in Table 7.2.2.3-2 The absolute channel numbers are possible to assign by MAC Resource Allocation IEs independently for receiving and transmitting frequencies, to support e.g. DL or UL only traffic in given frequencies.

Table 7.2.2.3-2: Absolute channel number range

Band number	Channel centre frequencies/MHz	Absolute channel frequency numbering
1	1 881,792 to 1 899,072	1 657 to 1 677
2	1 901,664 to 1 918,994	1 680 to 1 700
3	2 401,056 to 2 482,272	2 258 to 2 352
4	902,88 to 927,072	524 to 552
5	451,008 to 469,152	1 to 22
6	698,976 to 805,248	288 to 411
7	717,12 to 727,488	309 to 321
8	1 432,512 to 1 516,32	1 137 to 1 234
9	1 911,168 to 1 928,448	1 691 to 1 711
10	2 010,528 to 2 024,352	1 806 to 1 822
11	2 300,832 to 2 399,328	2 142 to 2 256
12	2 501,28 to 2 619,648	2 374 to 2 511
13	3 301,268 to 3 399,764	3 126 to 3 183
14	3 401,492 to 3 598,484	3 184 to 3 298
15	3 600,212 to 3 698,708	3 299 to 3 356
16	4 801,172 to 4 989,524	3 994 to 4 103

Band number	Channel centre frequencies/MHz	Absolute channel frequency numbering
17	5 726 to 5 874	4 392 to 4 466
18	5 152 to 5 348	4 105 to 4 203
19	5 472 to 5 724	4 265 to 4 391
20	3 802,388 to 4 198,1	3 416 to 3 645
21	3 700,436 to 3 798,932	3 357 to 3 414

The radio device modulated transmitter carrier frequency accuracy observed over the transmitted packet is defined to be within ±10,0 ppm compared to the selected absolute carrier centre frequency as defined in Table 7.2.2.3-2.

7.2.2.4 Bandwidth

DECT-2020 NR supports flexible physical layer numerology defined in ETSI TS 103 636-4 [i.4] clause 4.3, Table 4.3-1. For release 1 bandwidths up to 6,912 MHz are defined. Next releases larger communication channel bandwidths radio performance requirements may be added.

Table 7.2.2.4-1: Channel bandwidth

Parameter	Operating channel bandwidth I	Operating channel bandwidth II	Operating channel bandwidth III
Nominal channel bandwidth (MHz)	1,728	3,456	6,912
Transmission channel bandwidth (MHz)	1,539	3,051	6,075

7.2.2.5 Unwanted emissions

Spurious emissions are emissions which are caused by unwanted transmitter effects such as harmonics emission, parasitic emissions, intermodulation products and frequency conversion products, but exclude out of band emissions unless otherwise stated. The spurious emission limits are specified in terms of general requirements in-line with Recommendation ITU-R SM.329 [i.33].

The spurious emissions are measured during the time period where the transmitter is active excluding any transient periods. The spurious emission limits apply for the frequency ranges that are more than F_{OOB} (MHz). The spurious emission limits in Table 7.2.2.5-1 apply for all transmitter bands and channel bandwidths.

Table 7.2.2.5-1: Spurious emission limits

Frequency Range	Maximum Level	Measurement BandWidth
9 kHz ≤ f < 150 kHz	-36 dBm	1 kHz
150 kHz ≤ f < 30 MHz	-36 dBm	10 kHz
30 MHz ≤ f < 1 000 MHz	-36 dBm	100 kHz
1 GHz ≤ f < 12,75 GHz	-30 dBm	1 MHz
12,75 GHz ≤ f < 5th harmonic of the upper frequency edge in GHz	-30 dBm	1 MHz

7.2.3 Receiver parameters

7.2.3.1 Reference sensitivity

DECT-2020 NR reference sensitivity level is the minimum mean power applied to RD antenna port when received signal data throughput meets or exceeds 90 % of reference measurement channel data rate.

Table 7.2.3.1-1: Minimum receiver reference sensitivity ($RX_{sensitivity}$) requirement

Bands	Channel bandwidth (MHz)			Unit
	1,728	**3,456**	**6,912**	
1-12	-99,7	-96,7	-93,7	dBm
13 - 15 and 20	-97,7	-94,7	-91,7	dBm
16 -19	-95,7	-92,7	-89,7	dBm

7.2.3.2 Adjacent Channel Selectivity

DECT-2020 adjacent channel selectivity is 25 dB for interfering signal which has same signal characteristics and bandwidth as the wanted signal is. The wanted signal throughput is maintained same as in reference sensitivity requirement. The ACS performance is defined as in Table 7.2.3.2-1.

Table 7.2.3.2-1: Adjacent Channel Selectivity requirement

Rx Parameter	Channel bandwidth (MHz)			Units
	1,728	**3,456**	**6,912**	
Own signal input level	$RX_{sensitivity}$ + 14 dB			dBm
$P_{Interferer}$	$RX_{sensitivity}$ + 39 dB	$RX_{sensitivity}$ + 39 dB	$RX_{sensitivity}$ + 39 dB	dBm
$BW_{Interferer}$	1,728	3,456	6,912	MHz
$F_{Interferer}$ (offset)	1,728 or -1,728	3,456 or -3,456	6,912 or -6,912	MHz
NOTE 1: The interferer signal characteristic is same as the wanted signal modulated with data. NOTE 2: The interferer offset is from own signal centre frequency to interferer centre frequency.				

7.2.3.3 In band blocking characteristics

DECT-2020 NR in-band blocking is defined for an unwanted interfering signal falling into the RD operating band or into the first adjacent channel below or above the RD receive band at which the received signal throughput is 90 % of the maximum received signal throughput. Each operating bandwidth requirement is defined in Table 7.2.3.3-1.

Table 7.2.3.3-1: In-band blocking requirement

Rx Parameter	Channel bandwidth (MHz)			Units
	1,728	**3,456**	**6,912**	
Own signal input level	$RX_{sensitivity}$ + 6 dB			dBm
$P_{Interferer}$	$RX_{sensitivity}$ + 52 dB	$RX_{sensitivity}$ + 52 dB	$RX_{sensitivity}$ + 52 dB	dBm
$BW_{Interferer}$	1,728	3,456	6,912	MHz
$F_{Interferer}$ (offset from operating channel edge)	2,592 + additional channel frequency step or -2,592 - additional channel frequency step	5,184 + additional channel frequency step or -5,184 - additional channel frequency step	10,368 + additional channel frequency step or -10,368 - additional channel frequency step	MHz

7.2.3.4 Out of band blocking characteristics

Out-of-band band blocking is defined for an unwanted CW interfering signal falling more than adjacent channel below or above the RD receive band. For the first adjacent channel below or above the receive band the appropriate in-band blocking or Adjacent Channel Selectivity is valid. Out of band blocking are defined in Tables 7.2.3.4-1, 7.2.3.4-2 and 7.2.3.4-3 for respective operating channel bandwidth.

Table 7.2.3.4-1: Out of band blocking requirement for 1,728 MHz channel bandwidth

Band	Rx Parameter	Channel bandwidth (MHz)			Units
		1,728			
1, 2, 3, 4	Own signal input level	$RX_{sensitivity}$ + 6 dB			dBm
	$F_{Interferer}$ (CW)	Range 1	Range 2	Range 3	
		$Band_{low\ edge}$ - 15 to $Band_{low\ edge}$ - 60	$Band_{low\ edge}$ - 60 to $Band_{low\ edge}$ - 85	$Band_{low\ edge}$ - 85 to 1	MHz
		$Band_{high\ edge}$ + 15 to $Band_{high\ edge}$ + 60	$Band_{high\ edge}$ + 60 to $Band_{high\ edge}$ + 85	$Band_{high\ edge}$ + 85 to 12 750	MHz
	$P_{Interferer}$	-44	-30	-15	dBm

Table 7.2.3.4-2: Out of band blocking requirement for 3,456 MHz channel bandwidth

Band	Rx Parameter	Channel bandwidth (MHz)			Units
		3,456			
1, 2, 3, 4	Own signal input level	$RX_{sensitivity}$ + 6 dB			dBm
	$F_{Interferer}$ (CW)	Range 1	Range 2	Range 3	
		$Band_{low\ edge}$ - 15 to $Band_{low\ edge}$ - 60	$Band_{low\ edge}$ - 60 to $Band_{low\ edge}$ - 85	$Band_{low\ edge}$ - 85 to 1	MHz
		$Band_{high\ edge}$ + 15 to $Band_{high\ edge}$ + 60	$Band_{high\ edge}$ + 60 to $Band_{high\ edge}$ + 85	$Band_{high\ edge}$ + 85 to 12 750	MHz
	$P_{Interferer}$	-44	-30	-15	dBm

Table 7.2.3.4-3: Out of band blocking requirement for 6,912 MHz channel bandwidth

Band	Rx Parameter	Channel bandwidth (MHz)			Units
		6,912			
1, 2, 3, 4	Own signal input level	$RX_{sensitivity}$ + 6 dB			dBm
	$F_{Interferer}$ (CW)	Range 1	Range 2	Range 3	
		$Band_{low\ edge}$ - 15 to $Band_{low\ edge}$ - 60	$Band_{low\ edge}$ - 60 to $Band_{low\ edge}$ - 85	$Band_{low\ edge}$ - 85 to 1	MHz
		$Band_{high\ edge}$ + 15 to $Band_{high\ edge}$ + 60	$Band_{high\ edge}$ + 60 to $Band_{high\ edge}$ + 85	$Band_{high\ edge}$ + 85 to 12 750	MHz
	$P_{Interferer}$	-44	-30	-15	dBm

7.2.4 Channel access parameters

7.2.4.1 Introduction

DECT-2020 NR channel access is defined in ETSI TS 103 636-4 [i.4] clauses 5.1. "Spectrum management procedures", 5.2. "Broadcast procedures", 5.3. "Random access procedure" and 5.4. "Scheduled access data transfer". Furthermore, the clause 5.1 "Spectrum management procedures" are defined in subclauses on operating channel(s) and subslot(s) selection, last minute scan, selecting RD for association, beaconing transmissions, and power control.

In each connection between two RDs, one RD is in FT mode and the other RD is in PT mode. The RD in FT mode, RD with backend connection as well as RDs that are routing data, coordinates local radio resources and provides information on how other RDs may connect and communicate with it, whereas the RD in PT mode performs functions based on information provided by the RD in FT mode. This enables that each routing RD or RD with backend connection selects locally most optimum radio channels based on local interference conditions. Further this enables trunking and efficient resource utilization of the RD in FT mode.

The radio resource coordination in an RD in FT mode is performed with the following functions:

- Operating carrier(s) and subslot(s) selection by using a background scan.
- Transmitting beacon(s) to enable other RDs to identify, measure and initiate association with the RD in FT mode.

- Providing and configuring radio communication parameters of the connections with associated RDs.
- Selecting the optimum power level for communication.

An RD in PT mode operates based on information provided by RDs in FT mode and performs the following functions:

- Selecting RD in FT mode for the association.
- Performing configured measurements for channel access before initiating transmissions to an RD in FT mode.
- Selecting the optimum power level for communication.

A single RD can operate both in FT and PT modes simultaneously, i.e. in FT mode it coordinates radio resources for other RDs connecting to it as well as in PT mode it is connected to another RD, which operates in FT mode.

7.2.4.2 Spectrum access and monitoring

When an RD initiates FT mode operation, it initiates the background scan process for finding the operating channels and sub slots, which are suitable for operation.

The background scan may be done in any order on the supported band(s) and channel(s). The RD measures each channel the duration of the variable *SCAN_MEAS_DURATION* to obtain the RSSI-1 value for each measured subslot.

RSSI-1 measurement is an average received power observed during 1 OFDM symbol and measurement over the transmission channel bandwidth. This measurement observes interference caused by other radio transmissions in the monitored channel. For DECT band 1 as defined in Table 7.1.5-1 the *RSSI_THRESHOLD_MIN* is -85 dBm and *RSSI_THRESHOLD_MAX* is -52 dBm-maximum transmitter power of RD.

For each measured subslot on the channel, the RD evaluates whether the subslot is "free", "possible" or "busy".

- "free" if max(RSSI-1) ≤ *RSSI_THRESHOLD_MIN*;
- "possible" if *RSSI_THRESHOLD_MIN* <max(RSSI-1) ≤ *RSSI_THRESHOLD_MAX*;
- "busy" if max(RSSI-1) > *RSSI_THRESHOLD_MAX*.

After measuring channels, the RD selects an operating channel(s)in the following manner:

- Select the channel where all subslots are "free.
- Otherwise select the channel that has the lowest number of "busy" subslots.

After selecting the operating channel(s) the RD starts the timer *scanStatusValid*, which defines when the RD does the channel scan again. The RD may re-initiate the Operating Channel(s) and Subslot(s) selection procedure at any time when channel conditions are changing.

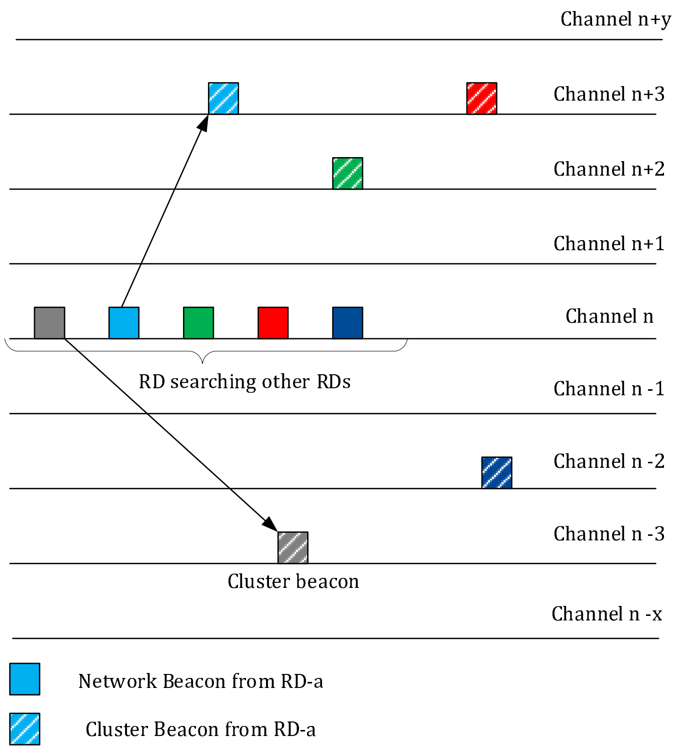
After selecting operating channels and subslots the RD in FT mode initiates Beacon transmissions to enable other RDs to identify, measure and initiate association with the RD.

There exist two types of beacon messages that are transmitted periodically by the FT:

- Network Beacon message.
- Cluster Beacon message.

The Network Beacon message is used to allow RDs to find the network rapidly. The Network Beacon message can be transmitted on a limited set of channel(s) to reduce other RDs' search time.

The Network Beacon message indicates the operating channel of the RD in FT mode and the next transmission timing of the Cluster Beacon message as illustrated in Figure 7.2.4.2-1.



NOTE: Different colours represent different RDs sending Network and Cluster Beacon messages.

Figure 7.2.4.2-1: Examples of Network and Cluster Beacon transmissions

The Cluster Beacon message is used to provide frame and slot timing used by the RD in FT mode. The Cluster Beacon provides the parameters for initiating association with the RD and it is used to coordinate radio resources in the cluster. The MAC PDU carrying the Cluster Beacon Message can be amended with additional optional IEs.

7.2.4.3 Selecting RD for association and association procedure

When an RD wishes to establish a connection with another RD it scans frequency channels to detect network and/or cluster beacon messages containing the desired network ID(s).

When an RD detects cluster beacons from another RD it evaluates by RSSI-2 measurement from the detected beacon whether it meets the minimum quality level for radio connection. The minimum quality level is defined as RSSI-2 ≥ MIN_SENSTIVITY_LEVEL + *MIN_QUALITY.*

RSSI-2 is the demodulated OFDM signal strength measurement which is intended for DECT-2020 NR transmissions monitoring and radio co-ordination purposes. This measurement can detect in range DECT-2020 NR signals from any network within the monitored channel.

If the RD has detected multiple beacons from different RDs, it will locally decide based on predetermined rules and route cost information to which RD in FT mode to associate. The association process starts by using random access channel transmission.

The association signalling procedure is shown in Figure 7.2.4.3-1. This procedure initiates the unicast data exchange between two RDs. The association request information is transferred with random access recourses and based on service type in association request, the RD in FT mode allocates resources for contention or scheduled data operation. A single RD may have an active association to multiple other RDs simultaneously. When an association is established, it is maintained until it is explicitly released by either party or radio conditions prevents to maintain association.

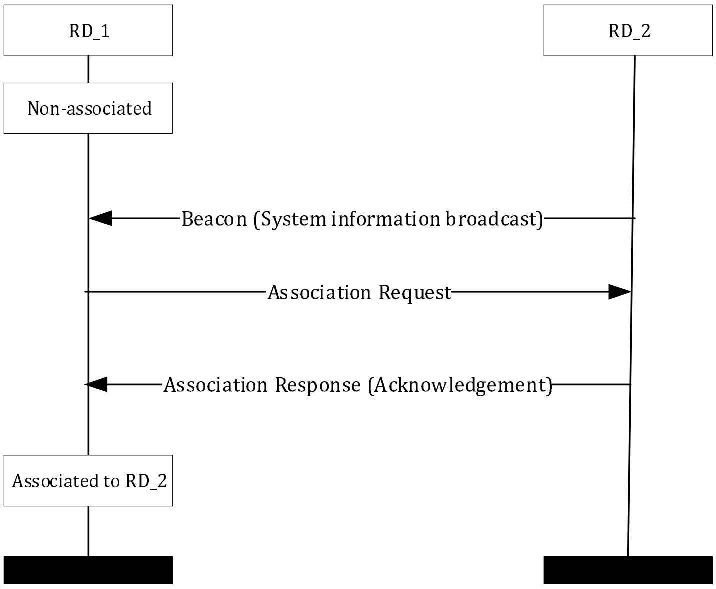


Figure 7.2.4.3-1: Association signalling

RD_2 enables the association procedure by broadcasting beacon messages. The reception of a beacon message allows other RDs to associate with RD_2. The beacon message has at least the following parameters:

- Fixed Control Header (type 1).
- Short RD ID of RD_2 in the PHY control field of the beacon frame as the transmitter address of the frame.
- The rest of the PHY control fields defines the physical layer information of the beacon message.
- MAC PDU of the beacon message contains the Network ID and the Long RD ID of RD_2 in beacon header, which is transmitted as plain text or encrypted.

The beacon content of the MAC PDU can be transmitted as plain text without MIC or ciphered with the inclusion of the MIC provided by the MAC security.

If the beacon content is sent plain text RD_2 provides association for any other RDs that may or may not have MAC security key(s) available from authentication with the backend.

If the beacon content is ciphered the association is only possible for RDs that already have MAC security keys available.

RD may support only the contention-based data transfer after the association.

7.2.4.4 Random access

Random access resources are broadcasted in beacons by RDs in FT mode. Random access resources have following parameters:

- **RACH resources slots:** Indicates slot index of the first and last slot in a frame for RACH resources.
- **Repetition:** Defines how often RACH resources are repeated in coming frames.
- **RACH Period:** Defines how many frames RACH allocation is valid after the frame where the beacon was transmitted.
- **Maximum Random Access TX time:** Defines the maximum Packet length for a single RACH transmission.
- **Response Window:** Time window when a RACH response can be expected by the RD sending the Random access transmission. If not received, the transmitting RD considers that the RACH transmission failed.
- ***CW_MIN*:** Defines the minimum value where the *CW_CURRENT* can be reduced.

- ***CW_MAX*:** Defines the maximum value where the *CW_CURRENT* can be increased.

Allowed parameter value ranges for the above parameters are operating band specific with possible default values.

Slots indicated as random-access resources are divided into multiple start positions where the transmission can be initiated. Start positions are counted from the beginning of a random-access slot, and are 0, 1, 2, 3… times the duration of STF and GI field, i.e. a fraction of the sub-slot length. Transmissions to random access resources are controlled by a Listen Before Talk (LBT) protocol, with exponential back off delay. The minimum LBT duration is 2 OFDM symbols. 1,728 MHz channel bandwidth LBT duration is 83,4 µs, and decrease with higher numerologies, with a 6,912 MHz channel BW being 20 µs. The timer *rachBackOff* is started with a random value picked by the RD and it has uniform distribution between 0 and *CW_CURRENT*, taking values multiple of the sum of the STF and the GI. Transmission to the random access is allowed after timer *rachBackOff* expires and the channel is detected as "free" or "possible" at least *MINIMUM_LBT_PERIOD* before this. The *MINIMUM_LBT_PERIOD* is the duration of the sum of the STF, and the GI.

The LBT and random delay is depicted in Figure 7.2.4.4-1.

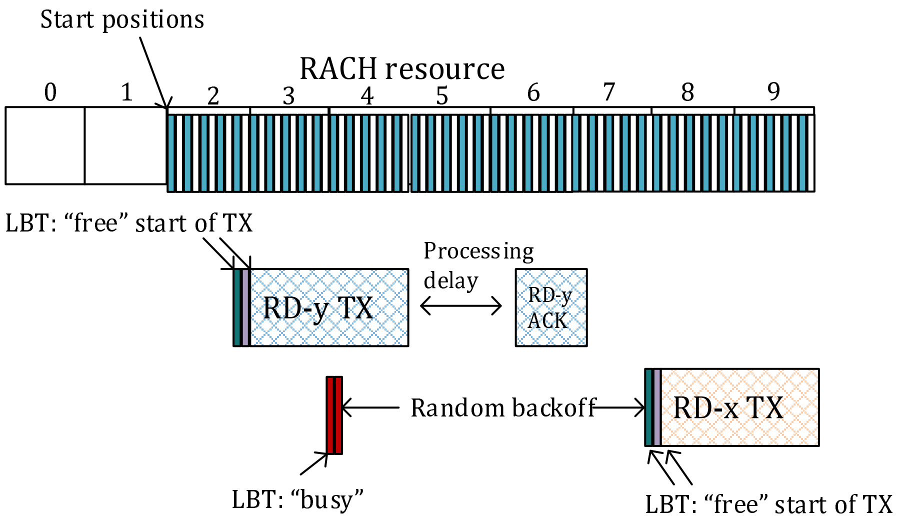


Figure 7.2.4.4-1: Illustration of Random-Access transmissions

7.2.4.5 Scheduled access

An RD in FT mode is in control of scheduled access by allocating resources for a communication between RD in PT mode and itself. RD in FT mode can do that after it has selected operating channel(s) and while timer *scanStatusValid* is valid and RD in PT mode has associated with it.

In the scheduled transmission allocation, the RD in FT mode selects most suitable frequency channel as subslots for RD in PT mode to receive and transmit and signals selected resources by Resource allocation IE to the RD in PT mode. Figure 7.2.4.5-1 illustrates an example how resource allocation can be performed.

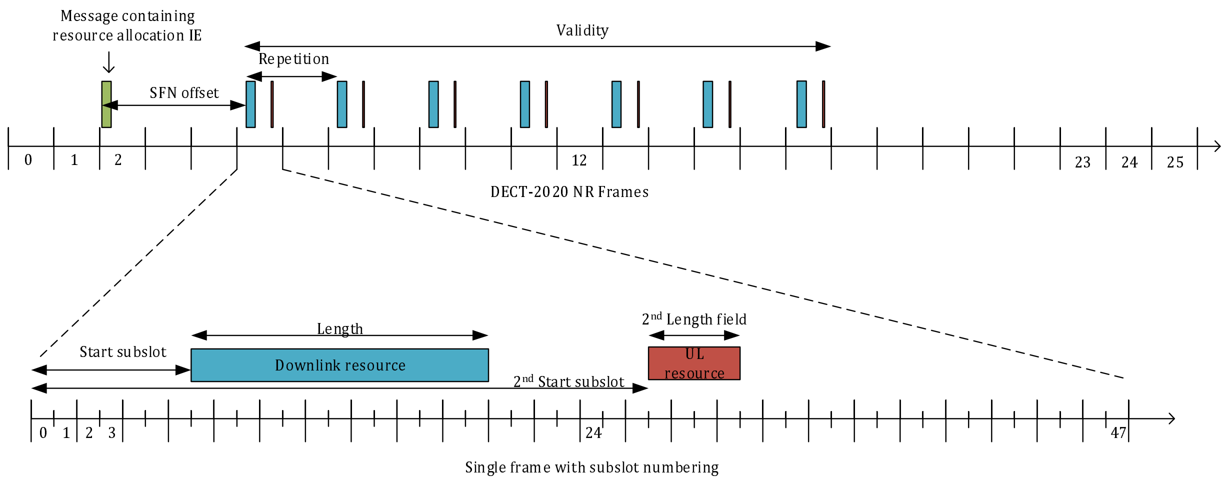


Figure 7.2.4.5-1: Example resource allocation with downlink and uplink resource assignment, with μ = 1

7.2.4.6 Parameter ranges for spectrum access

Spectrum access parameters are defined in ETSI TS 103 636-4 [i.4] in clause 6 "Protocol Data Units, formats and parameters" and clause 7 "Variables and Timers".

7.3 Information on relevant standard(s)

DECT-2020 NR technical standards at present time consist of the following parts:

1) ETSI TS 103 636-1 [i.1] presents the system and functional overview.

2) ETSI TS 103 636-2 [i.2] establishes the minimum RF requirements for DECT-2020 (NR) Radio Devices.

3) ETSI TS 103 636-3 [i.3] specifies the physical layer (PHY) and interaction between PHY and MAC layer.

4) ETSI TS 103 636-4 [i.4] specifies MAC layer functionality and its interaction physical layer and higher layers.

5) ETSI TS 103 636-5 [i.5] specifying the Data Link Control (DLC) and Convergence layer.

6) ETSI EN 301 406-2 [i.6] specifying the essential requirements for EC Directive 2014/53/EU [i.35] on efficient spectrum operation.

ETSI TS 103 636 series [i.1] to [i.5] will be accompanied by a feature and/or application-driven technical specification set, which is organized as a set of access profiles for application-specific solutions for various use cases.

8 Radio spectrum request and justification

8.1 General

DECT as a technology has developed and can support applications other than cordless telephony, for example sensors, alarms, Machine-to-Machine (M2M) applications and industrial automation. As a recognized in Recommendation ITU-R M.2150-1 [i.7] as a part of 5G, IMT-2020 technology, the DECT-2020 NR standard is targeted at local area wireless applications, including URLLC and mMTC. When considering DECT-2020 NR, the range of use cases it supports, and that it is a recognized 5G IMT technology, it is clear that it has evolved beyond the initial scope of cordless telephony.

Consequently, DECT-2020 NR lends itself to different applications in different radio spectrum bands, analogous to Private Mobile Radio. For this purpose, DECT-2020 NR bands identified for IMT, in particular Band 20 (3 800 to 4 200 MHz) and Band 5 (450 to 470 MHz) are important in future.

DECT, as a technology was originally envisaged to support cordless telephony as a specific application. To enable European wide interoperability and a single market for cordless telephony, the band 1 880 to 1 900 MHz was harmonised for DECT in the European Union, see Council Directive 91/287/EEC [i.22] and Council Recommendation 91/288/EEC [i.23]. Similarly, other countries also identified specific spectrum bands for DECT. On this basis DECT as a technology standard has become synonymous with DECT the application. It is, therefore, necessary to separate DECT the (standardized) technology from DECT the cordless telephony application.

Table 7.1.5-1 provides a list of frequency bands in which DECT-2020 NR is expected to initially operate. DECT-2020 NR is designed to operate alongside the DECT family of standards, and therefore Band 1 (within Europe), Band 2 and Band 9 align with the most common spectrum allocations for DECT. The other Bands identified reflect spectrum allocations to the Mobile Service, including bands identified for IMT technologies use.

8.2 Spectrum in 450 to 470 MHz

DECT-2020 NR applications which would benefit these frequencies are related to public services requiring good coverage and low building penetration losses. These are utilities applications, electricity and energy grid control, public safety uses such as fire brigades, security, and safety personnel communication to name just a few examples.

The wireless communication does not require any infrastructure support and can be set up quickly wherever needed or when the operation have to be autonomous from fixed infrastructure. In the context of the 450 to 470 MHz band, with narrower channel bandwidths and TDD operation, DECT-2020 NR could be considered an alternative to other PMR technologies that operate in the band, particularly for wireless data connectivity.

8.3 Spectrum for local area applications in 3 800 to 4 200 MHz

The European Commission has identified 5G connectivity as a key enabler of the digitalisation of vertical industries (such as transport, logistics, automotive, health, energy, smart factories media and entertainment). The European Commission also identified a need to identify suitable spectrum for locally licensed low/medium power networks and issued a Mandate to CEPT [i.24] on technical conditions regarding the shared use of the 3,8 to 4,2 GHz band.

DECT-2020 NR can operate both shared and licensed spectrum, and when operating in licensed spectrum the technology offers the capability to share the spectrum between different networks. At 3,8 to 4,2 GHz high signal attenuation, especially indoor use, results in shorter communication distances. DECT-2020 NR with mesh support can enable wider area coverage in these frequencies with reliable communication thanks to multi hop device to device connectivity.

The system can operate in flexible spectrum sizes, however the reliability and interference avoidance point of view it would be beneficial to operate 20 MHz or wider spectrum blocks. This would allow some frequency channel adaptation locally to mitigate possible interference. DECT-2020 NR supports MIMO technologies and wider bandwidths which can convey higher bitrates and operate even lower latencies.

Multiple local area applications can be supported such as industry condition monitoring, low latency control application, building management, logistics applications in distribution centres, various healthcare, and hospital applications which business and operational autonomy.

8.4 IMT spectrum access

DECT-2020 NR is acknowledged as an IMT-2020 technology fulfilling the technical requirements set by ITU for mMTC and URLLC operation. Globally assigned spectrum for IMT technologies is significant, and DECT-2020 NR technology enables an alternative wireless connectivity strategy for local autonomous network operations. DECT-2020 NR technology in these frequencies should be possible in future.

8.5 Other frequency bands

DECT-2020 NR is designed for shared spectrum access and technology also covers frequency bands 2,4 to 2,4835 GHz, 5,15 to 5,35 GHz and 5,47 to 5,725 GHz bands. Essential requirements for operation in these frequency bands are defined in ETSI EN 300 328 [i.30] and ETSI EN 301 893 [i.31] respectively which with a suitable configuration can be met. DECT-2020 NR technology spectrum access with LBT is introduced in clause 7.2.4 and this functionality is also applicable in these frequency bands.

For 2,4 to 2,4835 GHz, DECT-2020 NR adheres to requirements in ETSI EN 300 328 [i.30], clause 4.3.2 Wideband data transmissions (non-FHSS equipment). DECT-2020 NR standard defines 4 maximum transmitter power classes in clause 7.2.2.1.1. 10 dBm output power class, which is especially intended for battery operated devices adheres to the EN 300 328 requirement without the adaptivity capability. Higher transmitter output classes are also possible with LBT functionality and radio frame configuration with 24 slot granularities in a 10 ms radio frame.

For 5,15 to 5,35 GHz and 5,47 to 5,725 GHz, requirements defined in ETSI EN 301 893 [i.31] are met with 6,912 MHz or higher channel bandwidth. DECT-2020 NR supports 20 MHz channel raster defined in ETSI TS 103 636-2 [i.2] for this frequency band. The minimum LBT time is 20 µs fulfilling the minimum *Observation slot* time for channel access.

In clause 7.2.4 the channel access functionalities of DECT-2020 NR are introduced and the roles of RD in FT mode as a radio link control entity to RD PT mode is explained.

The DECT-2020 NR physical layer is based on comparable OFDM receiver with different numerologies than the incumbent technologies and it can detect radar system signals as defined in ETSI EN 301 893 [i.31], clause 4.2.6 in a similar manner as incumbent technologies with RSSI-1 measurements explained in clause 7.2.4.2. Operation in the RD FT mode results in scanning the available spectrum prior to initiate the beacon transmissions for the selected radio channel and controlling the RDs in PT mode radio configuration.

9 Regulations

9.1 Current regulation

DECT is a worldwide technology based on the DECT family of standard. DECT carriers are specified in ETSI EN 300 175-2 [i.25], annex F for the whole frequency range 1 880 MHz to 1 980 MHz and 2 010 MHz to 2 025 MHz. Within Europe, the most common spectrum allocation is 1 880 MHz to 1 900 MHz.

Within CEPT, two regulatory Decisions relate specifically to the DECT family of standards, ERC/DEC/(94)03 [i.26] and ERC/DEC/(98)22 [i.27]. In addition, Member States of the European Union have implemented the Council Directive 91/287/EEC [i.22] and Council Recommendation 91/288/EEC [i.23].

The smallest radio transmission bandwidth (1,728 MHz), radio frame, and transmission slot lengths in DECT-2020 NR are aligned with the DECT family members to ensure efficient spectrum use and to minimize interference in the DECT core band at 1 880 MHz to 1 900 MHz in Europe. Wider bandwidths of 3,456 MHz and 6,912 MHz in DECT-2020 NR can also be used under the ERC Decisions noted above in accordance with Table 2 in ETSI EN 301 406-2 [i.6].

However, as a technology, DECT-2020 NR is an evolution of the DECT family of standards and is a candidate technology for various wireless applications and use cases (see clause 5) in a range of operating bands (see Table 7.1.5-1). These bands are subject to different international (including Harmonising Decisions of the EU) and national regulations and technical conditions. Even though technology neutrality is envisioned national licensing conditions and EC Decisions which are binding on EU Member States, may contain regulatory and technical conditions that may preclude the use of DECT-2020 NR and other technologies in some bands unintentionally.

NOTE: Use of DECT technology in the 1 880 to 1 900 MHz band is exempted from individual licensing (ERC/DEC/(98)22 [i.27]). However, in other bands where use of spectrum is subject to individual licensing, DECT-2020 NR could be used under an appropriate national licensing system.

9.2 Proposed regulation and justification

As a technology, DECT-2020 NR can be used for a variety of applications that are 'mobile' and hence part of the Mobile Service or that are ´fixed´ and therefore part of the Fixed Service. In addition, DECT-2020 NR is a recognized IMT-2020 technology. On this basis, therefore, DECT-2020 NR complies with the definition of a mobile and fixed communications network in ECC Report 203 [i.28]. CEPT/ECC (Working group FM) is kindly requested to consider inclusive and technology neutral regulation for bands 20 and 5 as discussed in clause 8.1.

However, many of the technical and regulatory conditions provided in ECC Decisions and Recommendations associated with MFCNs are mainly derived from one family of technology standards, i.e. 3GPP, which may not be applicable to DECT-2020 NR. Also, in other bands such as those allocated to the Land Mobile service, conditions may exist that inadvertently inhibit the use of DECT-2020 NR, for example technical conditions in ECC/DEC/(19)02 [i.29] (for land mobile systems) do not include parameters relevant to DECT-2020 NR.

CEPT/ECC (Working group FM) is also kindly requested to consider, and amend where appropriate, ECC Decisions and Recommendations to ensure that the conditions contained therein do not unreasonably restrict the use of DECT-2020 NR, to maintain, as far as possible the principle of technology neutrality. Consequentially, similar consideration may be needed for EC Decisions as they relate to bands listed in Table 7.1.5-1.

Annex A: Additional application information

A.1 Industry applications

A.1.1 Asset Tracking and logistics supply chain

The manufacturing process is a complex interaction of moving objects such as raw materials, sub-assemblies, parts, personnel, and tools that together perform steps in a defined sequence. The monitoring of all moving elements is essential to prevent deviations from the manufacturing process and improving the quality. RealTime Location Systems (RTLS) will help tracking work-in-process carriers, containers, and valuable equipment in real time.

With the growing emphasis on increasing productivity and operation efficiency, along with remaining flexible, manufacturers are increasingly adopting smart factory solutions. A smart factory involves various elements-ranging from smart devices to innovative processes. RTLS solutions provide an organization with location data (both asset and personnel). RTLS solutions are being installed in industrial manufacturing sectors including automotive, aerospace, tire, glass, and heavy engineering to significantly increase the production throughout, enable efficient utilization of resources, reduce scrap, and enhance quality. RTLS helps industrial manufacturing plants to overcome challenges in terms of locating assets and the visibility of manufacturing processes or operations for manufacturers.

Asset management is relevant for various industries and markets:

- Healthcare.
- Retail.
- Hospitality.
- Transportation and Logistics.
- Industrial manufacturing.
- Process industry.
- And other areas.

A.1.2 Smart city

For smart cities the smart lighting is predicted the first application where the digitalization in this context is starting. Smart city projects are presenting a huge opportunity for technology companies, technology service providers, utility service providers, etc., companies. In this context the main objective of smart city infrastructure is to use electricity more efficiently. Smart cities are driving factors for sustainable economic growth which is strongly attributed by the rapid urbanization globally. The smart lighting application is expected to play a significant role in achieving sustainability and energy savings. The smart city applications are spreading fast as the benefits of them are apparent for increasing energy efficiency and reducing energy cost, maintenance cost, and carbon emissions.

Smart lighting operates with the help of a variety of sensors, gateways, relays, programmed LED drivers and ballasts, and various other light switches, depending on the desired function. Smart lighting controls consist of automated controls, which can adjust the lighting based on criteria such as occupancy, daylight., events, alarms, or manual override. The more there are sensors and alarms connected to lighting system, the more the wireless connection of them becomes relevant to easy adoption and deployment. Street lighting accounts for a major portion of the total energy consumption across lighting applications.

A.1.3 Smart energy, smart metering

The energy sector electrification is currently ongoing to reduce the use of fossil fuels, and transfer to renewable and distributed energy production is rapidly growing. The demand and response requirement to keep the electricity network stable and future energy market having millions of producers and consumers requires cost effective communication services.

Smart electricity metering, Advanced Metering Infrastructure (AMI), plays a crucial role in modernizing and improving the efficiency of the electricity distribution system. Smart electricity metering provides essential functionalities for consumers and society such as:

- Accurate billing: Consumer energy billing based on up to date real measurement data.
- Real-Time data: This data can be used by both consumers and utilities to monitor energy usage patterns, allowing for informed decisions on energy conservation and management.
- Reduced operational costs: Smart meters automate the meter reading and information delivery for billing system.
- Dynamic pricing policy: Smart meters supports dynamic energy pricing models, where prices can vary based on the time of day or demand. This encourages consumers to shift their energy usage to off-peak hours, contributing to grid load balancing and stability.
- Remote disconnect and reconnect: Utilities can remotely disconnect and reconnect electricity delivery.
- Efficient outage detection: Smart meters can detect power outages and voltage fluctuations more accurately and promptly than traditional meters. This helps utilities identify issues faster and minimizing downtimes of service.
- Grid optimization and load management: Utilities are monitoring load patterns using the data collected from smart meters to identify areas of high demand and to prevent overloads and blackouts. Utilities can use this information for better infrastructure planning, capacity expansion, and long-term resource management.
- Renewable energy: Smart meters facilitate the integration of renewable energy sources, such as solar panels, by providing data on both energy consumption and generation.
- Firmware updates: Smart meters can receive firmware updates remotely, allowing utilities to enhance functionality, security, and performance without needing to replace physical meters.

The energy production and consumption and climate change are global megatrends. Smart electricity metering is essential for creating a more efficient, responsive, and sustainable energy ecosystem which is valued high in the EU Commission strategy initiatives.

DECT-2020 NR technology provides excellent communication distances, reliability, and scalability for wide area deployments such as smart metering services. The autonomous operation provides reliability in the field which is necessary for utilities responsible for service quality and reliability.

A.1.4 Industrial IoT market

The industrial IoT applications are numerous. The main motivation for these applications is to improve processes and save resources, energy and reduce costs.

These uses cases could be categorized into several classes:

- Production optimization by increasing automation.
- Process and production modelling with "Digital Twin" with massive amount of measurement points.
- Asset and production material monitoring.
- Preventive maintenance applications enabling new service models.

Example use cases could be the "Digital Twin" where numerous sensors are collecting the data from real machine(s) and processes for the purpose of building "Digital Twin "of the real process. This capability enables more accurate modelling of the machines and process behaviour benefitting the system and/or process optimization.

Preventive maintenance applications can be anything which is impacting the production reliability minimizing the costly service breaks as well as improving the personal safety in production facilities. Obvious use cases for preventing maintenance is various machines by monitoring vibration, heat, pressure, etc., sensors in massive scale and collect this information to plan service breaks in advance to prevent failures and production breaks.

A.2 Wireless Audio Market

A.2.1 Wireless Audio

Wireless audio is the transmission of audio via wireless technologies in applications such headphones & headsets, earphones, microphones, speaker systems & soundbars. DECT based equipment currently play an important role in headsets market and for wireless microphones for presentation and lecturing purposes.

A.2.2 Content Creation and Production

Equipment for audio content creation and professional audio production is used to support broadcasting, news gathering, theatrical productions and special events, such as culture events, concerts, sport events, conferences, and trade fairs.

Programme Making and Special Events (PMSE) is a term used, typically in Europe to describe the wireless communication links that allow the creative industries to transport the captured audio and video content from performers and presenters on location to audiences, either at the venue, at home, or increasingly, on the move. PMSE content capture sits at the start of the supply and value chains for a wide range of products, and consequently, it is expected to provide the highest quality possible.

DECT's easy configuration makes it ideal for ad-hoc deployment, which is enabled by the automatic frequency and interference management functionalities. In the production and contribution of media content, classic DECT is primarily used for conferencing, audio for video, intercoms, talkback and wireless microphones for presentations and lectures, but not for musicians.

In addition to the use cases of classic DECT, DECT-2020 NR will enable further use cases by delivering a quality of service already demanded by audio professionals and audio hobbyists with professional requirements.

The market for wireless audio production tools continues to show a healthy growth with a worldwide market revenue generated as a result of these events of around $2,03 billion in 2021 and with an expected increase of 6 % CAGR out until 2026.

A.3 Healthcare

Healthcare institutions comprise hospitals for short-term, acute care as well as long-term care homes for elderly people or psychiatric care. In all of these institutions there are use cases and applications that can be effectively addressed by DECT-2020 NR.

Hospitals form a highly demanding work environment, facing big challenges to improve staff efficiency as well as patient security and satisfaction. Staff needs to stay reliably connected anywhere, anytime: every second counts and important decisions are taken on the spot. Optimized communications improve productivity, generate cost savings and create an environment where efficiency and responsiveness foster best possible patient outcomes. The hospital is a mission-critical environment requiring messaging solutions that deliver reliability, scalability, sufficient bandwidth and instant location of people and resources. In addition, to ensure the ongoing safety of patients, caregivers and visitors, hospital management teams have to offer contingency plans should an on-site emergency occur; emergency notification solutions have to quickly communicate the source and severity of a situation and seamlessly notify personnel and public safety officials for optimal on-site response and wellbeing of all within the facilities. Classic DECT has effectively met many of these requirements over the past decades but DECT DECT-2020 NR, with its reliable low-latency (URLLC) and high density (mMTC) capabilities, will open up for further improvements to existing solutions as well as enabling entirely new use cases.

Examples of such new use cases include:

- Connectivity for medical equipment: Patient Monitors, Infusion pumps, Ventilators and many other medical devices are often mobile and therefore cable connections can be a hurdle. A robust and low-latency wireless communication standard can reliably cut the cable and increase efficiency.
- Automated Guided Vehicles (AGVs): in North America there are already examples of AGVs being used for delivering meals around hospitals. It is quite easy to imagine how AGVs can be used to carry many other things like medication, medical equipment, clean bed sheets etc. around hospitals freeing up valuable time of care staff for more important and useful tasks.
- Tracking and tracing: to improve staff efficiency a reliable tracking and tracing solution can be based on DECT-2020 NR. Here the high scalability as well as long battery autonomy are features that make DECT-2020 NR the best technology option.
- Surveillance and monitoring: cameras for security as well as air quality sensors and smoke detection devices are abundant in hospitals. The long battery autonomy offered by DECT-2020 NR opens up for wireless connectivity of such devices.
- Smart lighting solutions can be operated on schedules by means of server solutions or triggered by audio or motion. Here also the easy scalability and battery autonomy are key factors for using DECT-2020 NR.
- Staff communication devices. In today's hospitals wireless staff devices include pagers, cordless DECT or VoWiFi phones and smartphones communicating over WiFi® and Cellular. The mission-critical nature of staff communication has meant that DECT has been a favourite choice because of its robustness, protected frequency band and easy deployment. The limited bandwidth of classic DECT has limited the more advanced type of applications that staff want to use on smartphones and tablets. But the higher bandwidths offered by DECT DECT-2020 NR position it as a perfect choice for wireless connectivity of hospital staff communication devices.

Key factors driving the growth of the IoT in healthcare market are the rising focus on active patient engagement and patient-centric care, growing need for adoption of cost-control measures in the healthcare sector and growth of high-speed network technologies for IoT connectivity and increasing focus on patient-centric service delivery through various channels.

A.4 Enterprise

In the industrial environments of the future, robots, sensors, and other industrial devices will have to communicate autonomously and in a robust and efficient manner with each other, relying to an increasingly large extent on wireless communication links, which will expand and supplement the existing wired/Ethernet connections.

With the number of networked sensors increasing across production, supply chain, and products, manufacturers are entering into a new generation of systems that enable automatic and real-time interactions among machines, systems, assets, and things. The pervasiveness of connected devices is finding applicability across multiple segments of the manufacturing and supply chain, throughout the value chain.

IoT in manufacturing can facilitate the production flow in a plant, as IoT devices automatically monitor development cycles and manage warehouses and inventories. It is one of the reasons that investments in IoT devices have skyrocketed, over the past few decades.

Most IoT has been based on wired connections and wireless technologies have to date seen limited deployment in manufacturing, despite the flexibility that wireless connectivity can bring; this has been because past solutions have been unable to deliver the highly robust and reliable communications needed for "wire-like wireless connections". DECT-2020 NR specifications are designed to overcome these shortcomings and with its low latency, highly robust and reliable (URLLC) capabilities as well as high densities (mMTC) its inherent structure is well suited to meet the requirements of the manufacturing environment.

Examples of use cases that can effectively be addressed by DECT-2020 NR include:

- Robots and other Production and Packaging Machines will benefit from the low-latency and high reliability features.
- AGVs: the market for AGVs is expected to grow substantially over the coming years. The high reliability and scaling properties of DECT-2020 NR will make it an attractive option for this use case.
- Tracking and tracing of goods and equipment are essential in the manufacturing environment and lead to major efficiency gains. Here the high scalability as well as long battery autonomy are features that make DECT-2020 NR the best technology option.
- Surveillance and monitoring: cameras for security as well as air quality sensors and smoke detection devices are standard in the manufacturing environment. The long battery autonomy offered by DECT-2020 NR opens up for wireless connectivity of such devices.
- Smart lighting solutions can be operated on schedules by means of server solutions or triggered by audio or motion. Here also the easy scalability and battery autonomy are key factors for using DECT-2020 NR.

Annex B:
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History

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