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Foreword

This Technical Report (TR) has been produced by ETSI Technical Committee Digital Enhanced Cordless Telecommunications (DECT).

The present document presents a study of a new radio interface named DECT-2020. DECT-2020 is a state of the art radio interface based on OFDM with options for MIMO and is intended as long-term evolution of DECT technology.

The present document is focused on the Physical layer.

Modal verbs terminology

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Introduction

The current DECT radio interface was designed in the early 1990's and is based on TDMA/TDD with Gaussian Frequency Shift Keying (GFSK) modulation. Although this interface is able to provide a cost-effective solution for cordless telephony applications with an appropriate reuse of the spectrum, it cannot provide the high data rates and bandwidth efficiency required by most modern evolution scenarios. In addition, promising applications such as Audio-Streaming and Wireless Industrial Automation in Internet of Things (IoT) domain introduces Ultra Reliability and Low Latency requirements that have to be taken into account in any technology evolution.

IMT-2000 is the term used by the International Telecommunications Union (ITU) for a set of globally harmonised standards for third generation (3G) mobile telecoms services and equipment. 3G services are designed to offer broadband cellular access at speeds of 2Mbps, which will allow mobile multimedia services to become possible.

DECT is, and will continue to be, one of the IMT-2000 technologies. However, the ITU work continued, first with IMT-Advanced, and it is now going further with IMT-2020. The term IMT-2020 was coined in 2012 by the ITU and means International Mobile Telecommunication system with a target date set for 2020, with the intention of addressing fifth generation (5G) mobile telecoms services and equipment.

The ETSI DECT Technical Committee and the industry body DECT Forum are currently supporting activities to develop DECT to meet the IMT-2020 requirements. This will require major changes to the existing DECT standards, and specifically to the MAC and PHL layers.

For the purpose of the present document the terms "DECT-2020", "DECT-2020 New Radio", "DECT-2020 NR" or "PHL-2020" have all the same meaning and all of them refer to the new radio interface based on OFDM outlined in the present document. This new radio interface is targeted to meet the IMT-2020 requirements.

The terms FP-2020 or PP-2020 refer to FP and PP (respectively) devices supporting DECT-2020.

The present document is motivated by recent efforts to identify new ways of utilizing efficiently DECT frequency bands and potentially additional bands. New modes of operation are defined to target a more diverse set of use cases, while addressing 5G requirements for low latency, high spectral efficiency and large numbers of client nodes.

1 Scope

The present document aims on studying "DECT-2020: New Radio", a new radio interface based on state of the art paradigms able to offer the required data rates, propagation characteristics and spectrum efficiency, while maintaining compatibility with the carrier and time structure of the DECT band.

The present document is focused on the Physical layer.

DECT-2020, as defined by the present document, will be based on OFDM and may support space multiplexing (MIMO).

The study focuses on:

1) Review of use cases and key application areas for DECT-2020.

2) Identification of methodology, initial sources, simulation tools and models.

3) Initial definition of "DECT-2020: New Radio" PHY layer, providing guidance for a following technical specification.

4) Preliminary simulation results and preliminary study on spatial multiplexing (MIMO).

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 date of publication and/or edition number or 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 EN 300 175-1: "Digital Enhanced Cordless Telecommunications (DECT); Common Interface (CI); Part 1: Overview".

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

[i.3] ETSI EN 300 175-3: "Digital Enhanced Cordless Telecommunications (DECT); Common Interface (CI); Part 3: Medium Access Control (MAC) layer".

[i.4] ETSI EN 300 175-4: "Digital Enhanced Cordless Telecommunications (DECT); Common Interface (CI); Part 4: Data Link Control (DLC) layer".

[i.5] ETSI EN 300 175-5: "Digital Enhanced Cordless Telecommunications (DECT); Common Interface (CI); Part 5: Network (NWK) layer".

[i.6] ETSI EN 300 175-6: "Digital Enhanced Cordless Telecommunications (DECT); Common Interface (CI); Part 6: Identities and addressing".

[i.7] ETSI EN 300 175-7: "Digital Enhanced Cordless Telecommunications (DECT); Common Interface (CI); Part 7: Security features".

[i.8] ETSI EN 300 175-8: "Digital Enhanced Cordless Telecommunications (DECT); Common Interface (CI); Part 8: Speech and audio coding and transmission".

[i.9] ETSI TS 102 939-1: "Digital Enhanced Cordless Telecommunications (DECT); Ultra Low Energy (ULE); Machine to Machine Communications; Part 1: Home Automation Network (phase 1)".

[i.10] ETSI TS 102 939-2: "Digital Enhanced Cordless Telecommunications (DECT); Ultra Low Energy (ULE); Machine to Machine Communications; Part 2: Home Automation Network (phase 2)".

[i.11] Draft new Report ITU-R M.[IMT-2020.TECH PERF REQ].

[i.12] ETSI TR 103 515: "Digital Enhanced Cordless Telecommunications (DECT); Study on URLLC use cases of vertical industries for DECT evolution and DECT-2020".

[i.13] 3GPP TR 22.804 (V1.0.0) (2017-12): "Study on Communication for Automation in Vertical Domains (Release 15)".

[i.14] ITU Radiocommunication Study Groups; Working Party 5D; draft new Report ITU-R M.[IMT-2020.EVAL]: "Guidelines for evaluation of radio interface technologies for IMT-2020".

[i.15] ITU Radiocommunication Study Groups; Working Party 5D; Attachment 7.4 to Document 5D/758; Liaison Statement to External Organizations; Further information related to draft new Report for IMT-2020 evaluation.

[i.16] Guidelines for evaluation of radio interface technologies for IMT-2020, ITU, Revision 2 to Document 5D/TEMP/347-E, 20 June 2017.

[i.17] IEEE Transactions on Communications: "Robust Frequency and Timing Synchronization for OFDM"; Timothy M. Schmidl and Donald C. Cox,, Vol. 45, No. 12, December 1997, pp 1613-1621.

[i.18] ETSI TS 136 211 (V10.7.0): "LTE; Evolved Universal Terrestrial Radio Access (E-UTRA); Physical channels and modulation (3GPP TS 36.211 version 10.7.0 Release 10)".

[i.19] 3GPP TS 38.211 (V1.0.0) (2017-09): "NR; Physical channels and modulation".

[i.20] IEEE P802.11ah™/D10.0, Part 11: "Wireless LAN Medium Access Control (MAC) and Physical Layer (PHY) Specifications, Amendment 2: Sub 1 GHz License Exempt Operation", September 2016.

[i.21] IEEE Std 802.11ac™-2013, Part 11: "Wireless LAN Medium Access Control (MAC) and Physical Layer (PHY) Specifications, Amendment 4: Enhancements for Very High Throughput for Operation in Bands below 6 GHz".

[i.22] IEEE P802.11ax™/D1.4, Part 11: "Wireless LAN Medium Access Control (MAC) and Physical Layer (PHY) Specifications, Amendment 6: Enhancements for High Efficiency WLAN", August 2017.

[i.23] IEEE 802.11-03™/940r4: "TGn Channel Models", May 2004.

[i.24] ETSI TS 136 212 (V10.9.0): "LTE; Evolved Universal Terrestrial Radio Access (E-UTRA); Multiplexing and channel coding (3GPP TS 36.212 version 10.9.0 Release 10)".

[i.25] 3GPP TS 38.212 (V1.0.0) (2017-09): "NR; Multiplexing and channel coding".

[i.26] IEEE 802.15-04-0585-00-004b: "Multipath Simulation Models for Sub-GHz PHY Evaluation", October 2004.

3 Definitions, symbols and abbreviations

3.1 Definitions

For the purposes of the present document, the terms and definitions given in ETSI EN 300 175-1 [i.1] and the following apply:

beacon bearer packet types: packet formats intended for use in beacon bearers and C/L downlink bearers

NOTE: They include synchronization fields and do not need to support MIMO.

DFT bandwidth (MHz): maximum theoretical bandwidth that can be handled by the DFT in a given configuration

"HE" packet types: packet formats intended for continuous data transmission over several frames

NOTE: They may support circuit-mode traffic, URLLC traffic as well as packet mode traffic, and may implement MIMO.

"Legacy" DECT: current DECT technology as defined by ETSI EN 300 175 parts 1 [i.1] to 8 [i.8]

occupied bandwidth (MHz): bandwidth really occupied by a given configuration

NOTE: It is typically less than the DFT bandwidth due to the insertion of null sub-carriers at bandwidth edges.

RAC packet types: packet types formats intended for use in Random Access Channels (RAC)

NOTE: They may be used for initially accessing a channel, carry only C-plane traffic, and do not need to support MIMO.

"Standard" packet types: packets intended for IP data packet-mode transmissions

NOTE: They are self-detectable packets usable in either synchronous or asynchronous way and may implement MIMO. The design of these packets is closer to the designs used in other WLAN technologies.

ULE packet types: packet formats intended for use in ULE (Ultra Low Energy) packet data transmissions

NOTE: They may be used for initially accessing a channel, are able to carry both U-plane and C-plane traffic, and do not need to support MIMO.

Ultra-Low Energy (ULE): ultra-low power consumption packet data technology based on DECT intended for M2M communications and defined by ETSI TS 102 939 parts 1 [i.9] and 2 [i.10]

3.2 Symbols

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

N_{BPSC}	Number of Bits Per SubCarrier
N_{CBPS}	Number of Coded Bits Per Symbol
N_{CTF}	Number of channel training symbols
N_{DBPS}	Number of data bits per symbol
N_{DC}	Number of null subcarriers at or surrounding DC
N_{DFT}	Discrete Fourier transform size
N_{SD}	Number of data subcarriers per OFDM symbol
$N_{SERVICE}$	Number of bits in the SERVICE subfield of the Data field
N_{SN}	Number of null subcarriers
N_{SP}	Number of pilot subcarriers per OFDM symbol
N_{SR}	Highest data subcarrier index per OFDM symbol
N_{SS}	Number of Spatial Streams
N_{ST}	Total number of used subcarriers per OFDM symbol,
N_{SYM}	Number of data SYMbols
N_{TAIL}	Number of TAIL bits for BCC encoder
RX	Receiver
T_{CTF}	Channel Training Field Time

T_{DFT}	DFT period
T_{FRAME}	Frame Time
T_{GT}	Guard field Time
T_{HF}	Header Field Time
T_{HFS}	Short Header Field Time
T_{SLOT}	Slot Time
T_{STF}	Synchronization Training Field Time
T_{STFS}	Short Synchronization Training Field Time
T_{SYM}	Symbol Time
TX	Transmitter
W_{BC}	Basic Channel Bandwidth / Spacing

3.3 Abbreviations

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

AGC	Automatic Gain Control
ARQ	Automatic Retransmission Query
ARQ	Automatic Repeat-reQuest
AWGN	Additive White Gaussian Noise
BCC	Binary Convolutional Codes
BCN	BeaCoN bearer
BPSK	Binary Phase Shift Keying
BS	Base Station (a.k.a FP, AP)
BW	BandWidth
BW_{DFT}	BandWidth DFT
BWO	BandWidth Occupied
CFO	Carrier Frequency Offset
CP	Cyclic Prefix
CTF	Channel Training Field
D	Downlink
DC	Direct Current
DECT	Digital Enhanced Cordless Telecommunications
DECT-2020	Physical Layer for DECT-2020
DECT-2020 NR	Physical Layer for DECT-2020
DF	Data Field
DFT	Discrete Fourier Transform
eMBB	enhanced Mobile BroadBand
EVM	Error Vector Magnitude
EXPP	EXponential Power Profile channel
FC	Full Carrier
FCS	Frame CheckSum
FDMA	Frequency Division Multiple Access
FEC	Forward Error Correction
FFS	For Further Study
FP	Fixed Part (a.k.a BS, AP)
FP-2020	PP implementing DECT-2020
FS	Full Slot
GF	inter-slot Guard Field
GFSK	Gaussian Frequency Shift Keying
HARQ	Hybrid Automatic Repeat-reQuest
HC	Half Carrier
HE	High Efficiency
HF	Header Field
HS	Half Slot
iDFT	inverse Discrete Fourier Transform
IP	Internet Protocol
ITU	International Telecommunication Union
ITU-R	International Telecommunication Union, Radiocommunication sector
LL-ULE	Low Latency-ULE
LP	Long Preamble
MAC	Medium Access Control

MCS	Modulation and Coding Scheme
MIMO	Multiple Input/Multiple Output
mMTC	massive Machine Type Communications
MRC	Maximal Ratio Combining
MU	Multi-User
NR	New Radio

NOTE: Refers to DECT-2020 radio interface as described in the present document.

OFDM	Orthogonal Frequency-Division Multiplexing
PAPR	Peak to Average Power Ratio
PDF	Probability Density Function
PER	Packet Error Rate
PHL	PHysical Layer
PHL-2020	PHysical Layer for DECT-2020
PHY	PHYsical
PMSE	Programme-Making and Special Events
PP	Portable Part (a.k.a UE)
PP-2020	PP implementing DECT-2020
QAM	Quadrature Amplitude Modulation
QPSK	Quadrature Phase Shift Keying
R	code Rate
RAC	Random Access Channel
RIT	Radio Interface Technology
RMS	Root Mean Square
RPF	Reference Pilot Field
RRM	Radio Resource Management
SFM	Shadow Fading Margin
SISO	Single Input / Single Output
SNR	Signal to Noise Ratio
STF	Synchronization Training Field
SU	Single User
TCP	Cyclic Prefix Time
TDMA	Time Division Multiple Access
TFM	Time/Frequency Map
U	Uplink
UE	User Equipment (a.k.a PP)
ULE	Ultra-Low Energy
UR	Ultra-Reliable
URLLC	Ultra-Reliable and Low Latency Communications
WLAN	Wireless LAN

4 Introduction to DECT-2020 Use Cases and their Requirements

4.1 Introduction

A separate study on DECT evolution and DECT-2020 use cases and requirements has been conducted and published as ETSI TR 103 515 [i.12]. According to ETSI TR 103 515 [i.12], the following three major application areas have been identified as target for DECT-2020 radio technologies. These are:

- Home and Building Automation, including Smart Living.
- Industry automation - Factories of the Future, Industry 4.0.
- Media and entertainment industry - Programme Making and Special Events (PMSE).

Nevertheless, DECT-2020 application areas will not be restricted to these three major domains and additional applications and use cases may be supported. In particular, any Machine Type Communication, including massive M2M are considered candidate areas for the technology.

4.2 Summary of Use Cases and Requirements

ETSI TR 103 515 [i.12] has identified a set of Use Cases candidate for implementation using DECT-2020. Most of the identified use cases have Low Latency or Ultra Reliability requirements and therefore are part of the URLLC definition as given by ITU-R [i.14], [i.15] and [i.16]. ETSI TR 103 515 [i.12] is consistent with and reuses material from a contemporary TR published by 3GPP as TR 22.804 (V1.0.0) [i.13].

Table 1 summarizes the work done by ETSI TR 103 515 [i.12].

Table 1: Classification of the use cases regarding Reliability and Latency and feasibility for DECT implementation

Clause (s) of ETSI TR 103 515 [i.12]	Use Case	DECT feasibility		Possible Implementation path		URLLC classification			
		By range	*By license regimen*	*DECT-2020*	*DECT evolution*	*UR*	*LL*	*Synchronicity*	*Other requirements*
Home and building automation									
5.2.2	Environmental monitoring	Y	Y	Y	Y	Y	N	N	
5.2.3	Fire detection	Y	Y	Y	Y	Y	< 10 ms	N	
5.2.4	Feedback control	Y	Y	Y	Y	Y	< 10 ms	maybe (1 ms jitter)	
Industry Automation - Factories of the Future									
5.3.2	Motion control	Y	Y	Y	w/ restrictions	Y + $(1 - 10^{-8})$	Y + (0,5 ms)	Y (1 µs)	
5.3.3	Motion control - transmission of non-real-time data	Y	Y	Y	Y	N	N	N	
5.3.4	Motion control - seamless integration with Industrial Ethernet	Y	Y	Requires further study	Requires further study				
5.3.5	Control-to-control communication (motion subsystems)	Y	Y	Y	w/ Restrictions	Y + $(1 - 10^{-8})$	Y (4 ms cyclic)	Y (1 µs)	
5.3.6	Mobile control panels with safety functions	Y	Y	Requires further study	Requires further study				
5.3.7	Mobile robots	Y	Y	Probably, but requires further study	N	Y	Y	probably	
5.3.8	Massive wireless sensor networks	Y	Y	Probably, but requires further study	Requires further study	Y + $(1 - 10^{-8})$	10 ms	N	High bit rate Low power operation required (see clause 5.3.8 for details)