# DECT-2020 NR Technology

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Wirepas

# Outline

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# Foreword

# What has Shannon to do with IoT?

# What one can do to improve communication performance?

1. **Increase *B*, the bandwidth for communication**
   - **Use wider transmission bandwidth**

Wider BW transmissions tends to lower the received S/N values.

2. **Increase the *S/N* value**
   - **Higher S/N enables higher bitrate**

For high S/N short communication distances are needed.

3. **Increase number of independent channels**
   - **Diversity, beamforming and MIMO techniques with multiple TX and RX chains.**

Multiple TX and RX increase complexity

# Shannon- Hartley theorem

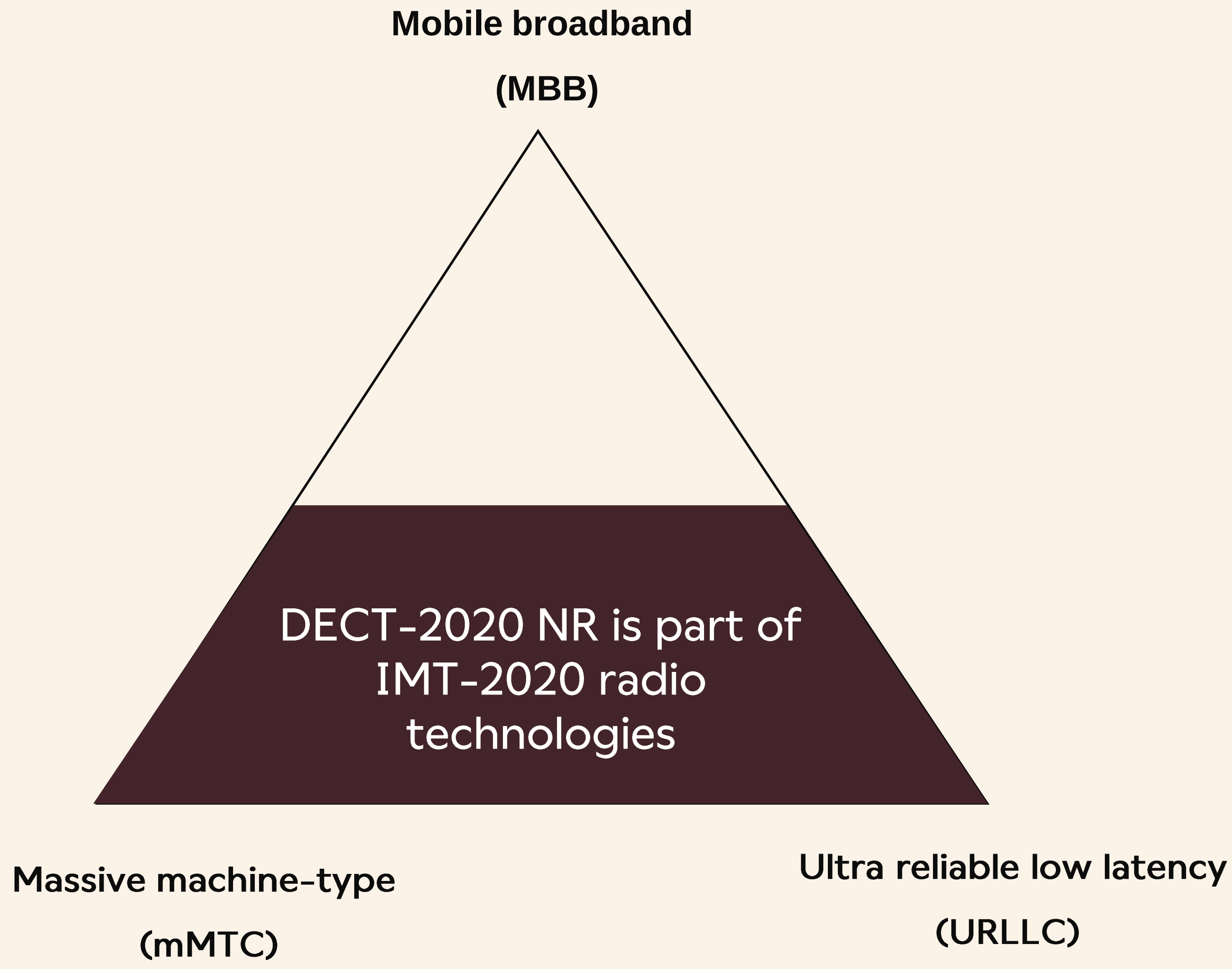
Channel capacity *C* is theoretical upper limit of information rate that can communicated through communication channel, with received signal power *S* in the presence on noise *N.*

$$C = B * \log_2\left(1 + \frac{S}{N}\right)$$

*B* = Bandwidth of the communication channel
S= Received signal power
N= Noise (also interference) power

# DECT-2020 Introduction

# DECT-2020 New Radio (NR) design objectives




— DECT-2020 NR design objective has been to create a wireless communication technology which can **be deployed by anyone, be operated by anybody and used anywhere**. Its operation must **be simple, autonomous** and able to co-exist with other local networks in the same area **sharing spectrum**. Technology is easy to introduce into new frequency bands.

— It should be **application agnostic** enabling rapid adoption of different use cases fostering digitalization. It should focus on **reliable low latency communication** and **massive scale machine communication** networks **exploiting mesh** communication.

| Why | what | how |
| --- | --- | --- |
| Scarcity of spectrum | Mesh System Architecture | • Cost based scalable routing<br>• High coverage, every node is an access point, low power hops<br>• No single point of failure |
| Low Power | MAC | • Local decision making of used spectrum and channels<br>• Neighbouring device discovery<br>• Over the air Synchronization of nodes |
| Scale and Density | PHY | • Packet Synchronization design<br>• PHY packet format design<br>• OFDM with channel coding and HARQ |
| Ultra Reliability | Spectrum | • Dedicated, free to operate 1.9 GHz frequency band<br>• 1.9 GHz is ideal trade-off between bandwidth and link budget<br>• Operations at licensed and license exempt bands possible. |

# Autonomy in multiple levels

- Radio access and device autonomy
  - DECT-2020 NR is designed to support **autonomous radio device (RD) operation**. Each RD can choose their role in the communication network, whether they are routing or not.
  - **RD does independent decisions on associations** with other RDs related to local radio conditions and mobility.
  - **RD autonomy takes care of the reliable radio communication and data routing** between RDs as well as between RDs and back-end system.
- System autonomy
  - DECT-2020 NR supports **flat radio architecture** enabling to connect to multiple types on back-end systems with varying deployment constrains (public or on premise cloud).
- Application autonomy
  - DECT-2020 NR is **agnostic to application** data and can support e.g. non-IP and IP based applications.

# DECT-2020 NR standards

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# Specification structure

- ETSI has published Release 1 DECT-2020 NR specifications:
  - TS103.636-1, DECT-2020 New Radio (NR); Part 1: Overview; Release #1
  - TS103.636-2, DECT-2020 New Radio (NR); Part 2: Radio reception and transmission requirements; Release #1
  - TS103.636-3, DECT-2020 New Radio (NR); Part 3: Physical layer; Release #1
  - TS103.636-4, DECT-2020 New Radio (NR); Part 4: MAC layer; Release #1
  - TS103.636-5, DECT-2020 New Radio (NR); Part 5: DLC and Convergence layers, Release #1
- Harmonized standard for DECT-2020 NR under development
- New work item approved on Application Profiles
  - Smart meter profile is the first one to be defined
  - Intension is to define how DECT-2020 NR is configured for supporting DLMS
  - Other use case profiles under development.
- ETSI press release can be found here.
- TC-DECT is working further to provide additions to this specification series in following releases.

# Part 1: DECT-2020 NR overview

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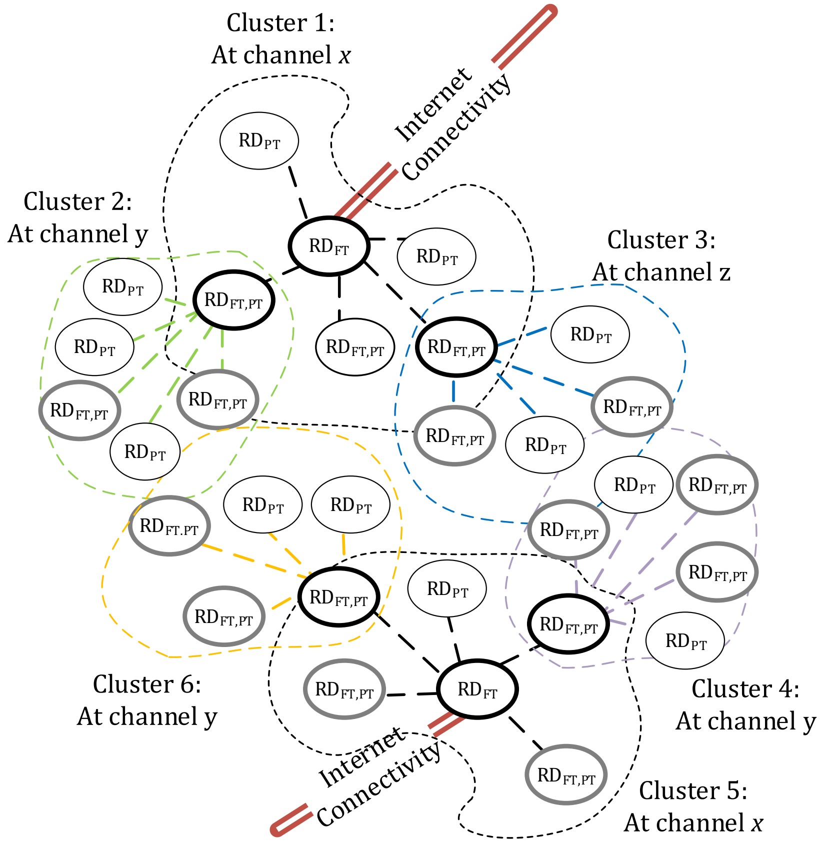
# Overview - System Architecture

- Supports multiple deployment scenarios
  - Mesh topology based on Radio Device (RD) to RD communication
  - Local area network (Star Topology)
  - Direct P2P and P2M connections
- State of art co-existence capabilities to support multiple networks in the same area sharing spectrum
  - Between other independent DECT-2020 networks
  - Between DECT-2020 networks and any other wireless systems
- Local synchronization between different DECT-2020 equipment.
- Symmetric uplink (TX) and downlink (RX) radio access supports cost effective equipment designs.
- Device centric, de-centralized decisions, enable autonomous operation fostering industry digitalization.



# Part 2: DECT-2020 NR Radio requirements

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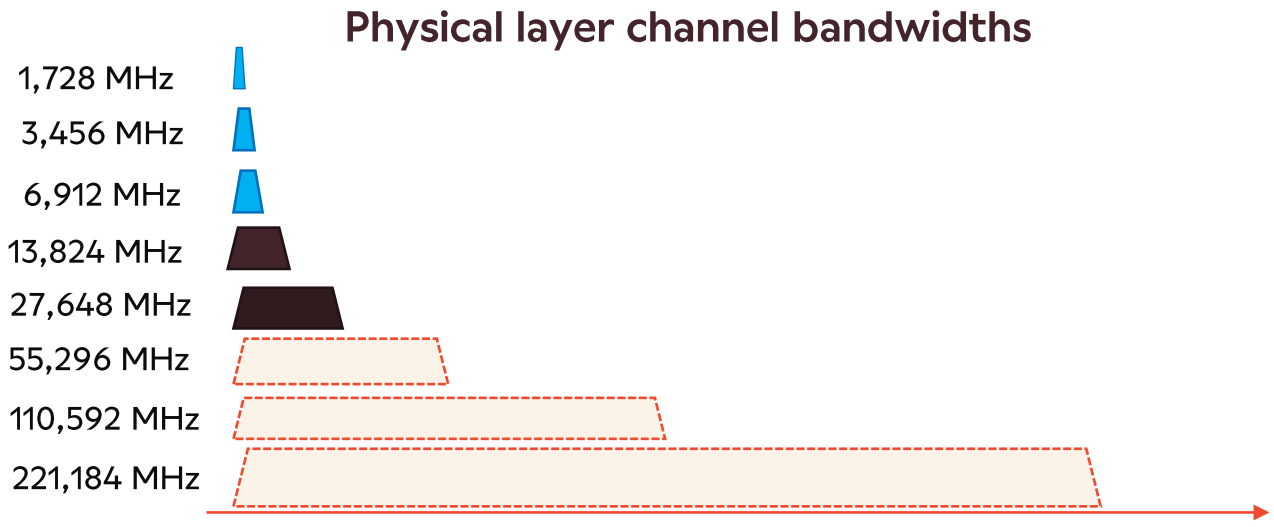
# Radio transmission requirements
# - Operating bands and channel bandwidths

— DECT-2020 technology has flexible spectrum support, 19 bands up to 6 GHz frequencies.

— Release 1 already supports variable operating channel bandwidth(s) up to 221 MHz offering in future latency and performance boost option.

— Release 1 supports 1,728, 3,456 and 6,912 MHz operating channel options.






**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 |

# Radio transmission requirements

- Receiver requirements
  - Sensitivity, adjacent channel and blocking requirements
  - Sensitivity scales from -99,7 dBm @1.728 MHz depending on operating channel bandwidth.
  - Receiver decoding requirements.
- Transmitter requirements
  - Four different power classes: 23 dBm, 21 dBm, 19 dBm and 10 dBm maximum TX power levels.
  - LBT -operation and no duty cycle limitations.
  - Minimum power down to -40 dBm.
  - Transmitter behaviour comparable to LTE-M UE requirements.
- Frequency channel numbering
  - Absolute channel numbering throughout all bands.
  - Uniform neighbour information across all bands.
- Measurements
  - Received signal and demodulated signal received power.
  - Received demodulated signal quality

**Table 6.2.1-3: Transmit Power**

| Bit field | TX Power [dBm] |
|---|---|
| 0000 | -40 |
| 0001 | -30 |
| 0010 | -20 |
| 0011 | -16 |
| 0100 | -12 |
| 0101 | -8 |
| 0110 | -4 |
| 0111 | 0 |
| 1000 | 4 |
| 1001 | 7 |
| 1010 | 10 |
| 1011 | 13 |
| 1100 | 16 |
| 1101 | 19 |
| 1110 | 21 |
| 1111 | 23 |

Single set of requirements enables same design to be used in any part of the system.

Absolute frequency channel numbering provides straightforward multiband support, neighbor frequency information is explicit across all operating bands

Neighboring RD's signal measurements supports the device centric autonomous operation and mobility

# Absolute Channel Numbering

- The Nominal Centre Frequencies $f_n$ are given by equation:
- $f_n = f_{0,1} + n \times 0{,}864$ MHz,
  - $f_{0,1}$ = 450,144 MHz,
  - below 3 GHz for $n$ = 1…2951
- In MAC signaling value of the $n$ is signaled.
- Total of 11 channels (BW of 1.728 MHz) at DECT Core band on.
- 2.4 GHz IMS band:
  - 48 channels, 20 % more than with BLE
- US 900MHz ISM band
  - 14 channels; Channel number: 524, 526, 528 … 552.

## DECT band (Europe)

| **Nominal channel Bandwidth *B*** | **Absolute channel number range** | **Operation restricted to the following specific absolute channel numbers** | **Corresponding frequency (MHz)** |
|---|---|---|---|
| 1,728 MHz | 1657 to 1677 | 1657,<br>1659,<br>1661,<br>1663,<br>1665,<br>1667,<br>1669,<br>1671,<br>1673<br>1675, and<br>1677 (No legacy DECT) | 1881,792<br>1883,52<br>1885,248<br>1886,976<br>1888,704<br>1890,432<br>1892,16<br>1893,888<br>1895,616<br>1897,344<br>1899,072 |

## 2.4 GHz ISM band

| **Nominal channel Bandwidth *B*** | **Absolute channel number range** | **Operation can be on following channel numbers** | **Corresponding frequency (MHz)** |
|---|---|---|---|
| 1,728 MHz | 2258,<br>2260,<br>2262<br>….<br>2352 | Any | 2401,056<br>2402,784<br>2404,512<br>….<br>2482,272 |

# Measurement

- RRSI-1 measurement is a linear average of received power.
  - Any arbitrary signal.
  - Accuracy: ± 5,5 dB, or ± 3,5dB (depending on signal strength)
- RSSI-2 signal strength measurement is measured from detected and demodulated DECT-2020 NR packet.
  - Shall be mapped to the respective transmitter and network ID
  - Accuracy: ± 4 dB, ± 2 dB (depending on signal strength)
- The received signal to noise quality (SNR) is intended to measure radio device signal quality from detected and demodulated DECT-2020 packet.
  - shall be mapped to respective transmitter and network ID.
  - Accuracy: ± 3 dB

**Table 8.2.2-1: RSSI-1 power measurement requirement**

| Reported value | Reported value (dBm) | Measured Value (dBm) |
|---|---|---|
| 0xFF | -1 | -1,5 < x |
| 0xFE | -2 | -1,5 ≤ x < -2,5 |
| 0xFD | -3 | -2,5 ≤ x < -3,5 |
| … | … | … |
| 0x74 | -140 | x < -139,5 |
| 0x73 | Reserved | Reserved |
| 0x72 | Reserved | Reserved |
| … | …. | … |

**Table 8.3.3-1: RSSI-2 measurement report mapping**

| Reported value | Reported value (dBm) | Measured value (dBm) |
|---|---|---|
| 0xFF | -1 | -1,5 < x |
| 0xFE | -2 | -1,5 ≤ x < -2,5 |
| 0xFD | -3 | -2,5 ≤ x < -3,5 |
| … | … | … |
| 0x74 | -140 | x< -139,5 |
| 0x73 | Reserved | Reserved |
| 0x72 | Reserved | Reserved |
| … | … | … |

**Table 8.4.3-1: Demodulated signal to noise quality measurement report mapping**

| Reported value | Reported value (dB) | Measured value (dB) |
|---|---|---|
| 0x7F | 63,5 | 63,25 ≤ x |
| 0x7E | 63,0 | 62,75 ≤ x < 63,25 |
| 0x7D | 62,5 | 62,25 ≤ x < 62,75 |
| … | … | … |
| 0x01 | 0.5 | 0,25 ≤ x < 0,75 |
| 0x00 | 0 | -0,25 ≤ x < 0,25 |
| 0xFF | -0.5 | -0,75 ≤ x < -0,25 |
| … | … | … |
| 0xE0 | -16.0 | x < -15,75 |
| 0xDF | Reserved | Reserved |
| … | … | … |

# Part 3: DECT-2020 NR Physical layer

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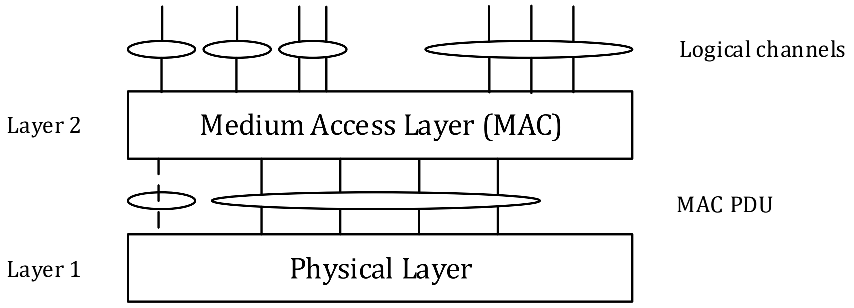
# Physical layer




Physical layer channels

- Physical layer control channel (PCC)
- Physical layer data channel (PDC)

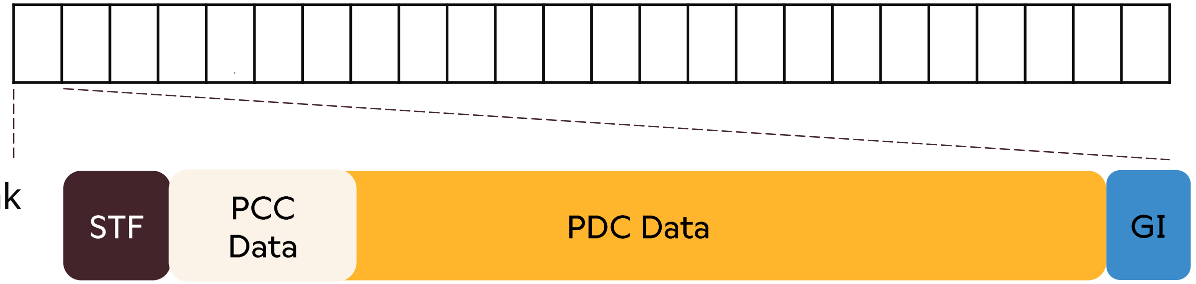
Rich physical layer functionality enables efficient shared spectrum use, reliable communication, low latency capability and scalable bitrates to match business requirements.
Rich feature set boosts future performance enhancements.

— Physical layer functionality
  - — Error detection on the physical channels (16- or 24-bit CRC)
  - — Channel coding and mapping onto physical channels
  - — Physical layer fast re-transmission scheme (Hybrid ARQ with soft-combining)
  - — Modulation and demodulation of physical channels
  - — Frequency and time synchronization
  - — Physical layer measurements
  - — Multi-antenna support (MIMO, TX diversity and beamforming)
  - — High frequency parts control

# Physical layer highlights

- 10 ms frame with 24 slots, each slot is 416,7 µs
  - Each slot is dived to sub-slots of 5 symbols.
  - Number of subslots per slot is 2, 4, 8 or 16 depending on numerology
- Symmetrical Cyclic Prefix OFDM signal both for uplink and downlink
  - Sub Carrier Spacing (SCS): 27 kHz, 54 kHz, 108 kHz or 216 kHz
  - Channel bandwidths from 1,728 MHz up to 221,184 MHz.
  - ~ Up to 4,6 us Cyclic Prefix (CP).
  - Numerology supports robust operation against multipath propagation
- Adaptive modulation and coding for each packet individually.
  - Physical Data Channel (PDC) modulation BPSK, QPSK, 16-, 256- and 1024 QAM and turbo coding rates ½, 2/3, ¾ and 5/6
  - Physical Control Channel (PCC) PCC is transmitted always with QPSK(1/2) coding.
- Hybrid ARQ supports 8 processes
- Multiantenna support 1, 2, 4 or 8 MIMO layers.

10 ms frame, 24 slots




416,7 µs  slot, 10 symbols

- Perfect fit for DECT core band:
  - 1.728 MHz and 10 channels on DECT core band 1880-1900 MHz.
  - Channel bandwidth and frame/slot timings supports legacy DECT systems coexistence.

# Physical layer packet structure is always the same

416,7 µs slot, 27 kHz SCS and 10 symbols

| STF | PCC Data | PDC Data | GI |
|---|---|---|---|

Synchronization is based on STF field transmission in each packet.

- Receiving RD synchronizes directly to each received packet.
- STF format optimized to minimize PAPR.

Demodulated Reference Symbols (DRS), Physical Control Channel (PCC)

- DRS are used for receiver channel estimation and equalization – repeated every 5 symbols.
- PCC has 2 types: sending beacons and support data transmissions.

Physical Data Channel (PDC).

- PDC can have a variable length and can be transmitted using variable MCS between different packets to adapt varying radio conditions.

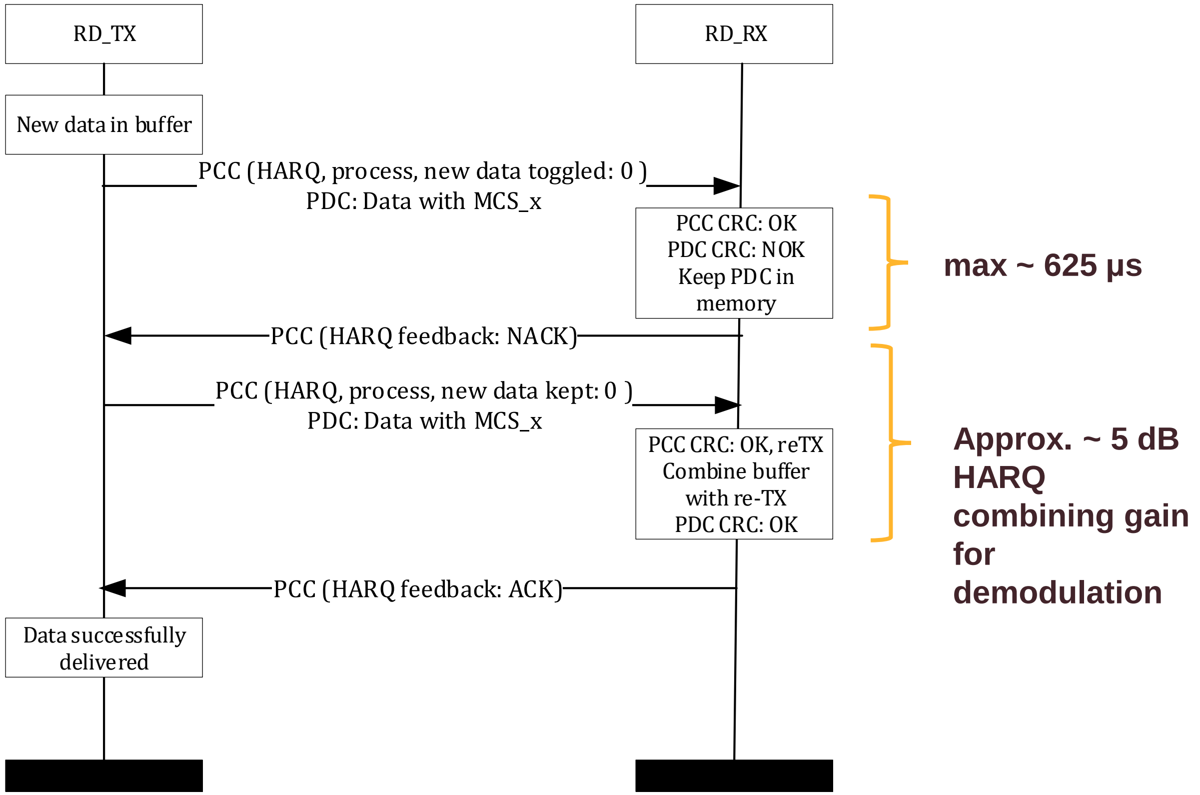
Guard Interval (GI)

- separates different transmission from each other and enables RX/TX switching time.

Symmetrical physical layer packet design
- Supports different topology scenarios
- Enables straightforward device to device communication scheme.
- Same radio chipset design can be used throughout the network.

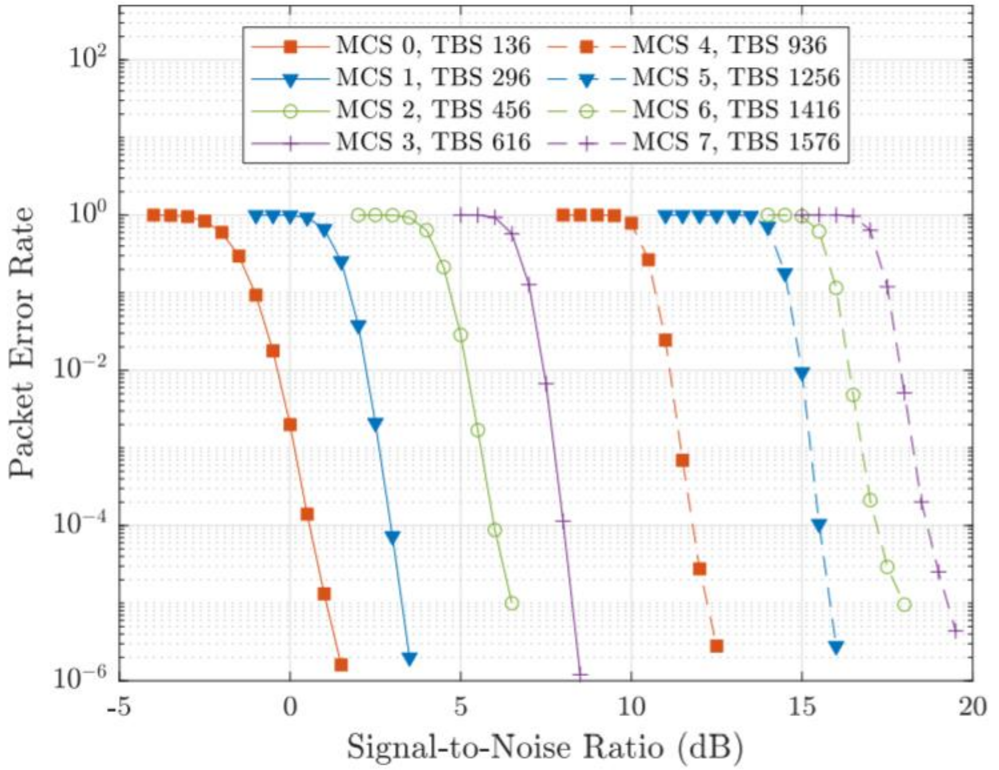
STF = Synchronization training field
DF = Data field
GI = Guard Interval
CP = Cyclic Prefix

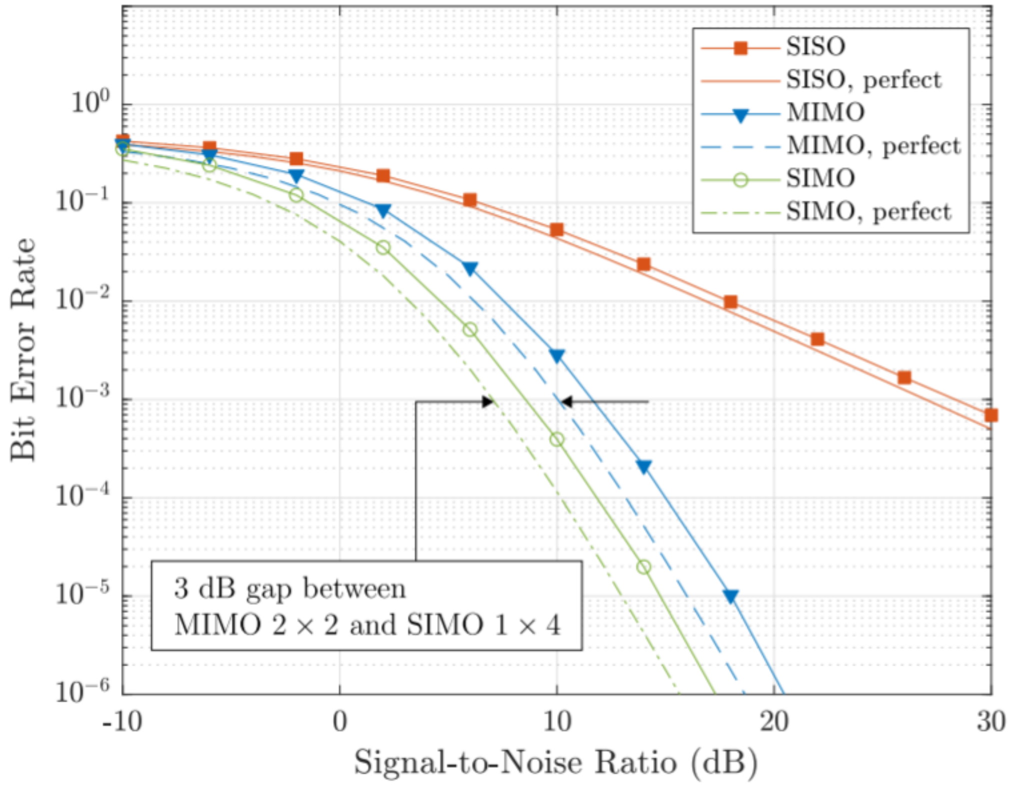
# Physical layer re-transmissions - HARQ procedure




Processing time for creating the feedback is two sub-slots for each numerology.

# Link performance

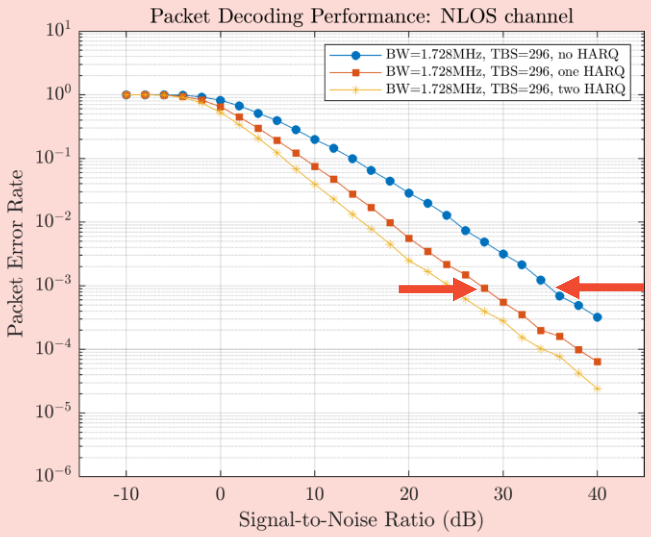


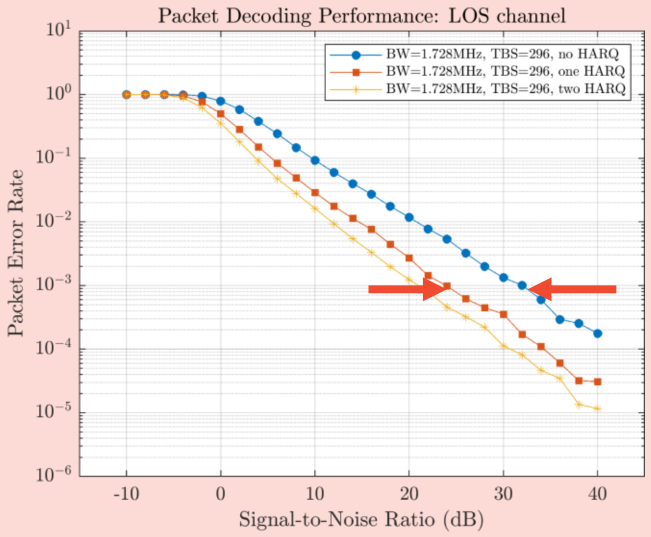




"Our experiments show that in all cases, receivers can be built that operate close to perfect channel knowledge. This confirms that for the models tested, DECT2020 NR is a well designed OFDM system"

Source: Maxim Penner, et al. [Link-Level Performance Evaluation of IMT-2020 Candidate Technology: DECT-2020 New Radio]

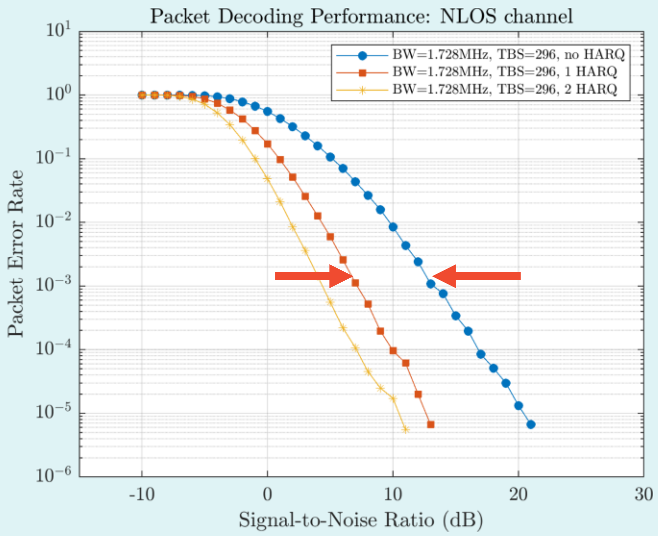
# Layer 1 hybrid ARQ performance examples

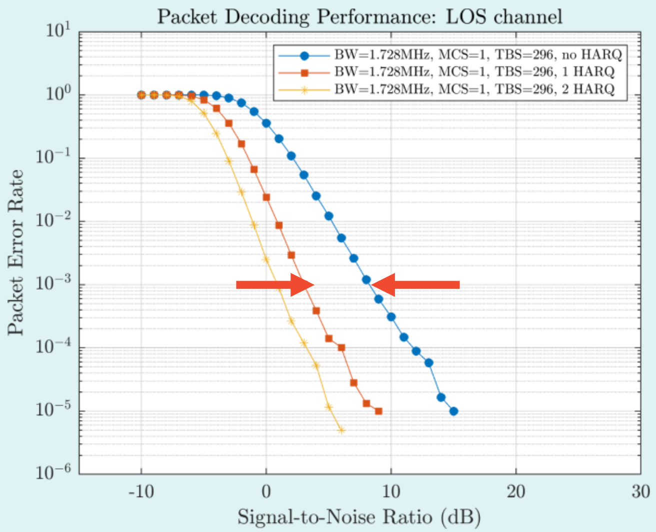



Device to device ( h=1,5 m ) channel model

1 RX – 1 TX HARQ performance in NLOS and LOS




FT (h=24 m) to device channel model

2 RX – 1 TX HARQ performance in NLOS and LOS

Source: ETSI MSGEVAL(21)003006

# Physical Data Channel (PDC) - Example quad slot bitrates

**MTC devices supports MCS-4 modulation index and Up to 8 HARQ processes and up to 2 HARQ processes per connection.**

**Single channel maximum throughput bits available to MAC layer in (Mbps) with single receiver with maximum turbo code block size of 2 048 bits, when packet duration is limited to 1664 μs (quad slot).**

| Physical layer numerology (μ,β) | BPSK, ½ Coding (MCS-0) | QPSK, ½ Coding (MCS-1) | QPSK, ¾ coding (MCS-2) | 16-QAM, ½ coding (MCS-3) | 16-QAM, ¾ coding (MCS-4) |
|---|---|---|---|---|---|
| 1,728 MHz @ SCS 27 kHz (1,1) | 0,552 | 1,118 | 1,646 | 2,222 | 3,360 |
| 3,456 MHz @ 27 kHz (1,2) | 1,157 | 2,299 | 3,475 | 4,613 | 6,965 |
| 3,456 MHz @ 54 KHz (2,1) | 1,176 | 2,338 | 3,514 | 4,690 | 7,080 |
| 6,912 MHz @ 108 kHz (4,1) | 2,414 | 4,843 | 7,296 | 9,725 | 14,621 |

# Part 4: DECT-2020 NR MAC layer

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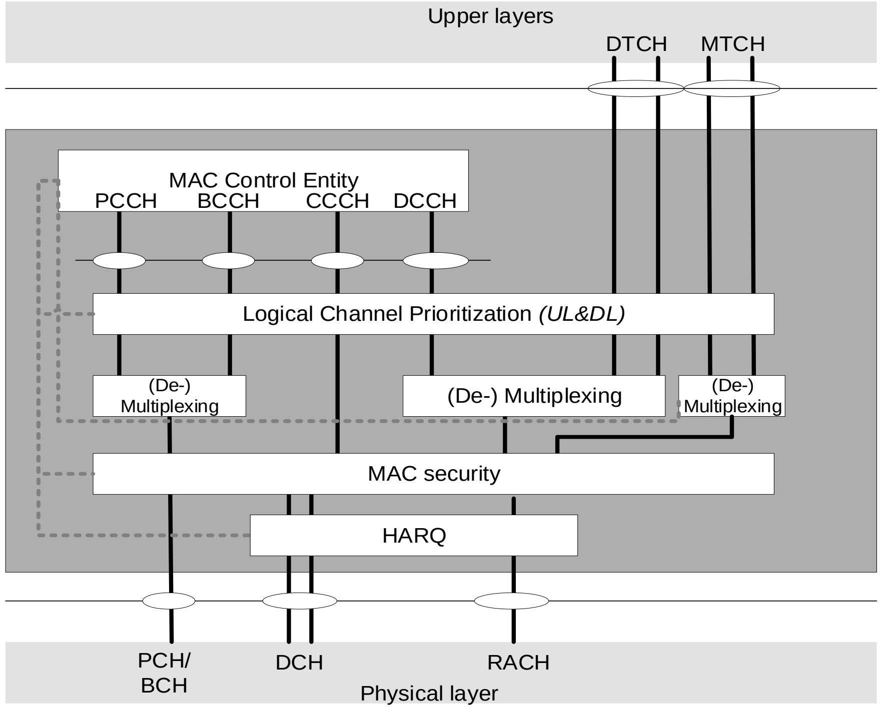
# MAC layer services and control functions



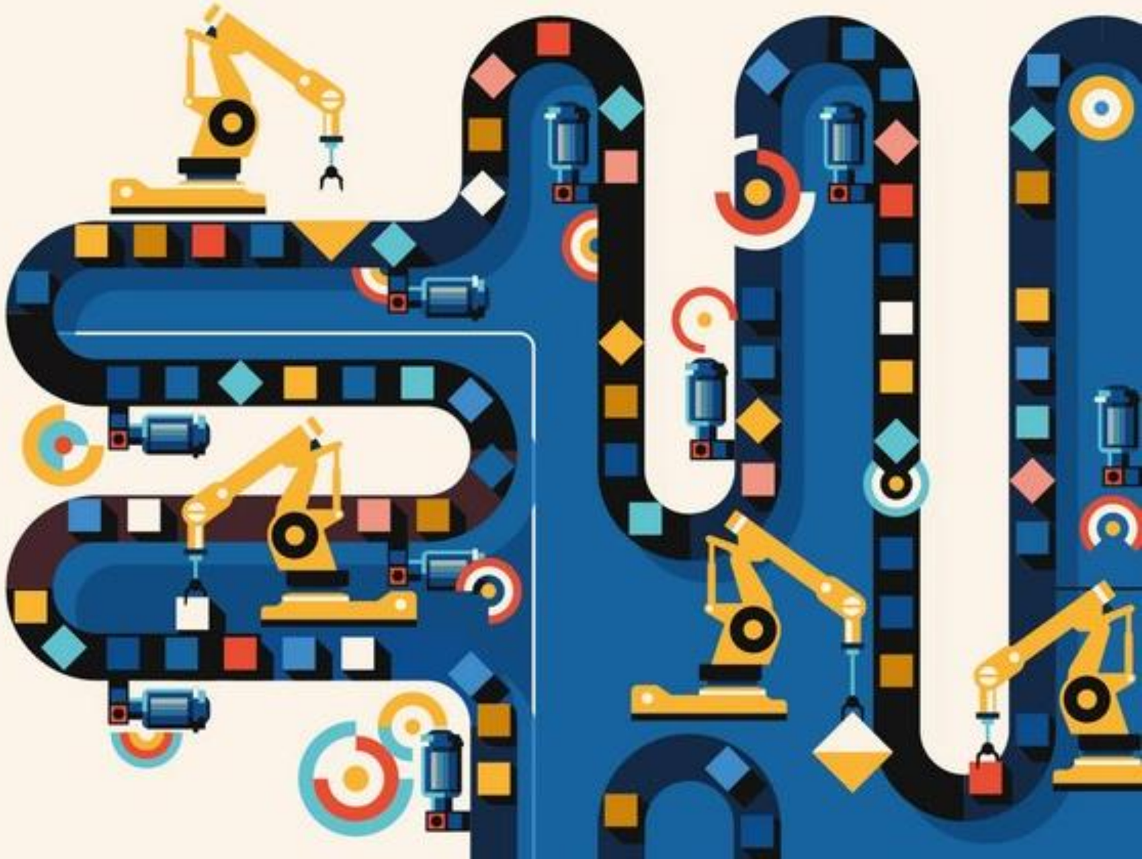

- RD in FT mode manages radio resources in cluster.
  - Such as beacon and broadcast/multicast, Unicast, Random Access and Paging control.
- Each RD manages
  - data multiplexing, mapping data to the physical transport channel, modulation and coding class,
  - HARQ re-transmission ctrl, MAC security and handovers.
- MAC layer functions:
  - Radio channel selection and channel access procedures.
  - MAC layer signalling.
  - Data mapping between logical channels and transport channels.
  - Error correction through HARQ.
  - MAC layer security.

# Network identification

- **Network identification has** 24 bits Long NW ID and 8 bits Short NW ID.
- **24-bit Long** NW ID is used by RD to associate correct NW (approx. 16,77 M globally unique networks).
- **8-bit Short** NW ID is used for identifying own network traffic from 256 overlapping NWs in a radio area.
- No need for **administration of network IDs.**
- Short NW ID optimized for **detecting overlapping networks and packet filtering.**

# High number of devices

- **Radio device identification has** 32 bits Long RD ID and 16 bits Short RD ID.
- **32-bit Long RD ID** supports more than **4B unique devices** in a single network.
  - Used for packet Routing
  - Special addresses are reserved for Broadcast and Backend.
  - Set of addresses can be assigned for multicast.
- 16-bit Short RD ID is used for local receiver and transmitter identification.
  - This supports more than 65k equipment within a radio communication range.
  - Optimized for HARQ operation and fast packet filtering.
- RD chooses randomly its own 16-bit Short RD ID
  - When it starts beacon transmission or association process to another device.



# Physical layer control field in PCC

- Physical layer supports two sizes
  - 40 bits for Beaconing
  - 80 bits for Data transmission
- MAC controls transmissions and sets the content of the header field.
  - Length of the transmission with 5 symbol granularity
  - Identities
  - TX power
  - Modulation coding and MiMO settings
  - HARQ and Feedback Info
    - Feedback info used to send HARQ ACK/NACK, Buffer status, CQI,<br>MIMO Precoding and channel Rank info

**Table 6.2.1-2: Physical Layer Control Field: Type 2, Header Format: 000**

| Control channel field | #bits | Explanation |
|---|---|---|
| Header Format | 3 | Defines the format of the control header Type 2.<br>Bits are set to 000. |
| Packet length type | 1 | Indicates whether transmission length is indicated in subslots or slots:<br>If set to 0, the length is given in subslots.<br>If set to 1 the length is given in slots. |
| Packet length | 4 | The length of packet transmission in subslot or slots. Packet length is signalled numerical value plus one subslot or slot. The length of the subslot is 5 OFDM symbols as defined in ETSI TS 103 636-3 [3]. |
| Short Network ID | 8 | Short network ID of the RD as defined in clause 4.2.3.1. |
| Transmitter Identity | 16 | Short RD ID of the RD as defined in clause 4.2.3.3. |
| Transmit Power | 4 | Defines the used TX power as defined in Table 6.2.1-3a. |
| DF MCS | 4 | Defines the MCS of the transmission as defined in ETSI TS 103 636-3 [3]. |
| Receiver Identity | 16 | Short RD ID of receiver RD, or broadcast ID as defined in clause 4.2.3.3. |
| Number of Spatial Streams | 2 | Number of spatial streams of the data field as defined in Table 6.2.1-4. |
| DF Redundancy Version | 2 | Defines the redundancy version number of the transmission as defined in clause 6.1.5.3 of ETSI TS 103 636-3 [3]. |
| DF New data Indication | 1 | Transmitter toggles this bit to control whether receiver combines this transmission with previous content of the HARQ process. |
| DF HARQ Process Number | 3 | HARQ process number of this transmission. |
| Feedback format | 4 | Defines the coding of the feedback info as defined in Table 6.2.2-1. |
| Feedback info | 12 | Feedback information in clause 6.2.2. |

# Spectrum and Co-existence

- Radio Device in **FT Mode controls** radio resources in the cluster:
  - Selects operating channel with the lowest interference.
  - Provides connection for RDs in PT mode.
  - Manages Random Access and Schedules of dedicated radio resources.
  - Can perform local synchronization with other FTs.
- Radio Device in **PT mode selects** which RD in FT mode to connect:
  - Network scanning and finding new neighbors optimized.
  - May maintain multiple connections.
- Radio device can **have both FT and PT modes simultaneously**
  - FT mode to control its own cluster.
  - PT mode to be a member in the next cluster.

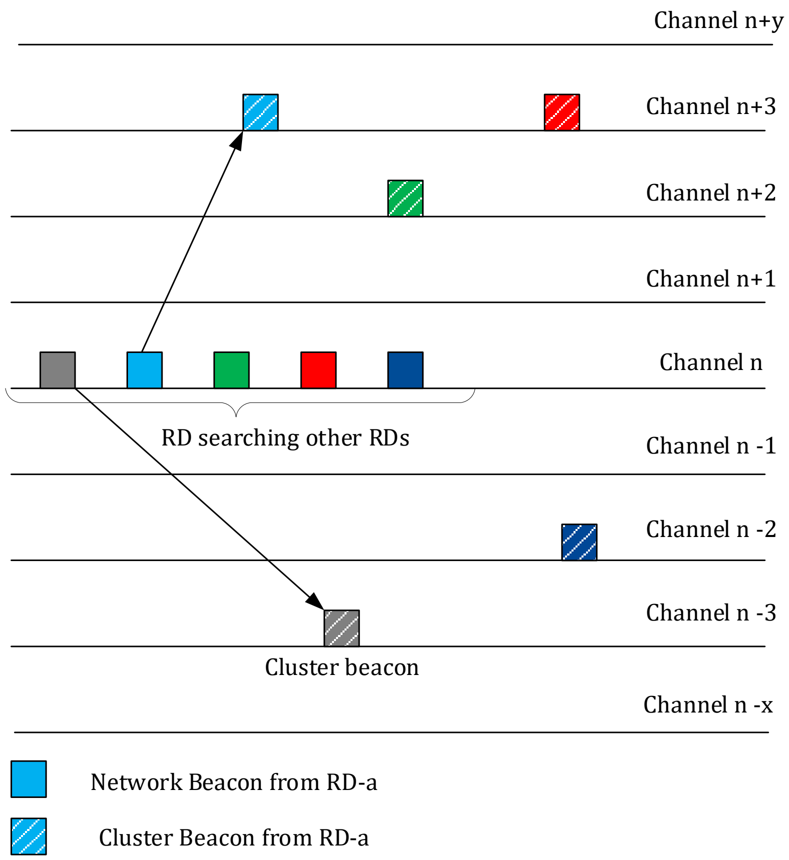



Figure: Optimized scanning strategy

# Unscheduled and Scheduled services

After association **RD** may operate with **scheduled recourses** with dedicated sub-slot(s) for transmissions. Such use cases could be such as audio services.

OR

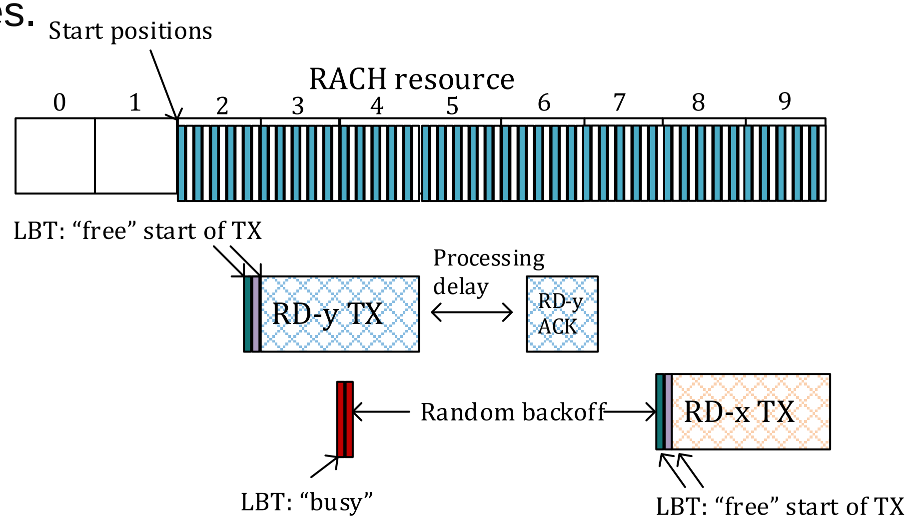
**RD** is operating with **unscheduled recourses** sending data with **Random Access process**. Use case could be such as sensor network.

Random-access control info:

- First and last subslot in a frame allocated for RACH, periodicity, how long allocation is valid, maximum allowed packet size per single RD and RACH response time window.

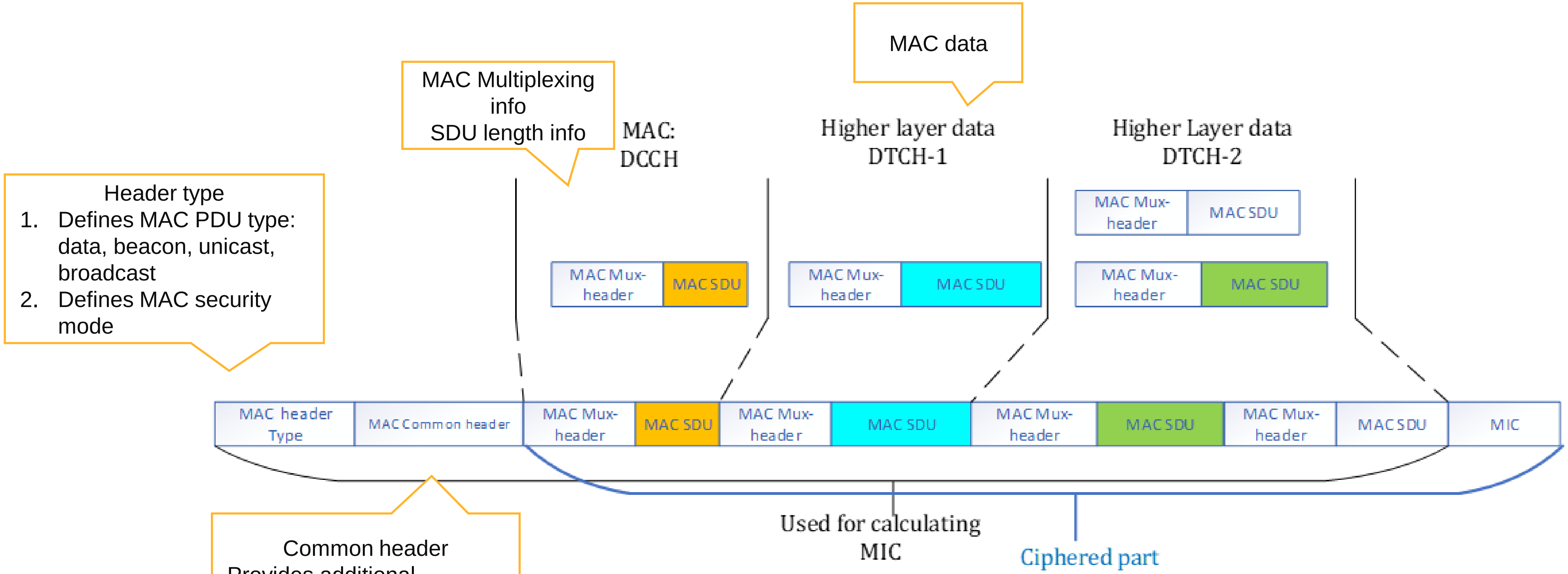
- To facilitate low latency operation the RACH start position granularity is the 2 symbols. The start times are randomized to avoid collisions.

- Fast (2 symbol) Listen Before Talk (LBT) measurements facilitates low latency operation.




RACH process is designed to support low latencies and high RD densities for unscheduled mMTC traffic.

# MAC data units and security




MAC layer ciphering is done for each communication hop independently with unique mask. Encryption and integrity process is repeated in each hop.

MAC layer security uses AES-128 counter mode for ciphering and OMAC-1 message integrity protection

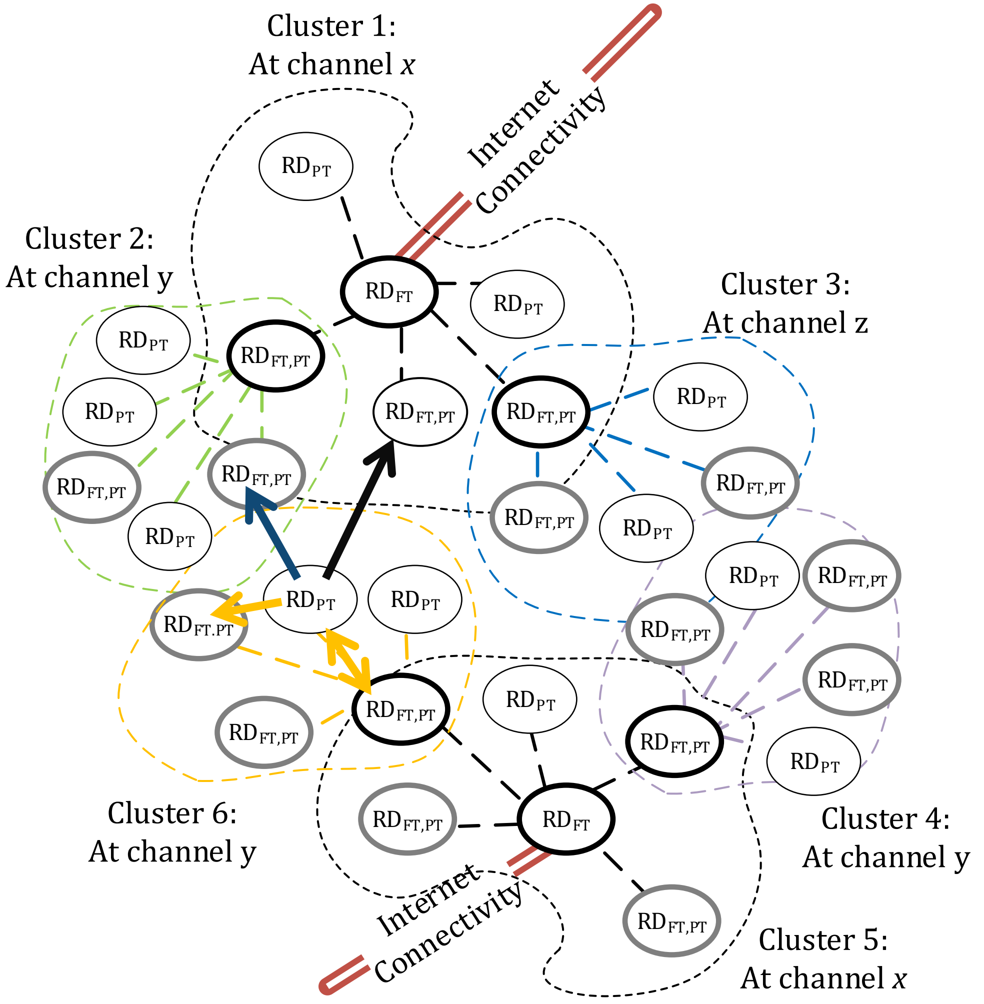
MAC PDU always follows this format for all transport channels (PCH/BCH, DCH or RACH).

# Mobility

RD may associate with multiple other RDs

- $RD_x$ makes the association decision based on $RD_{FT}$s' beacon signal info.
- Cluster beacons can be discovered Neighbouring IE share by other RDs reducing scanning times.
- The rate for associations is at $RD_x$'s control.
- Association is completed once the new $RD_{FT}$ has provided necessary connectivity recourses.

RD supports "make before break" mobility, the associating $RD_x$ makes an independent decision when to switch user plane data flow to a new $RD_{FT}$



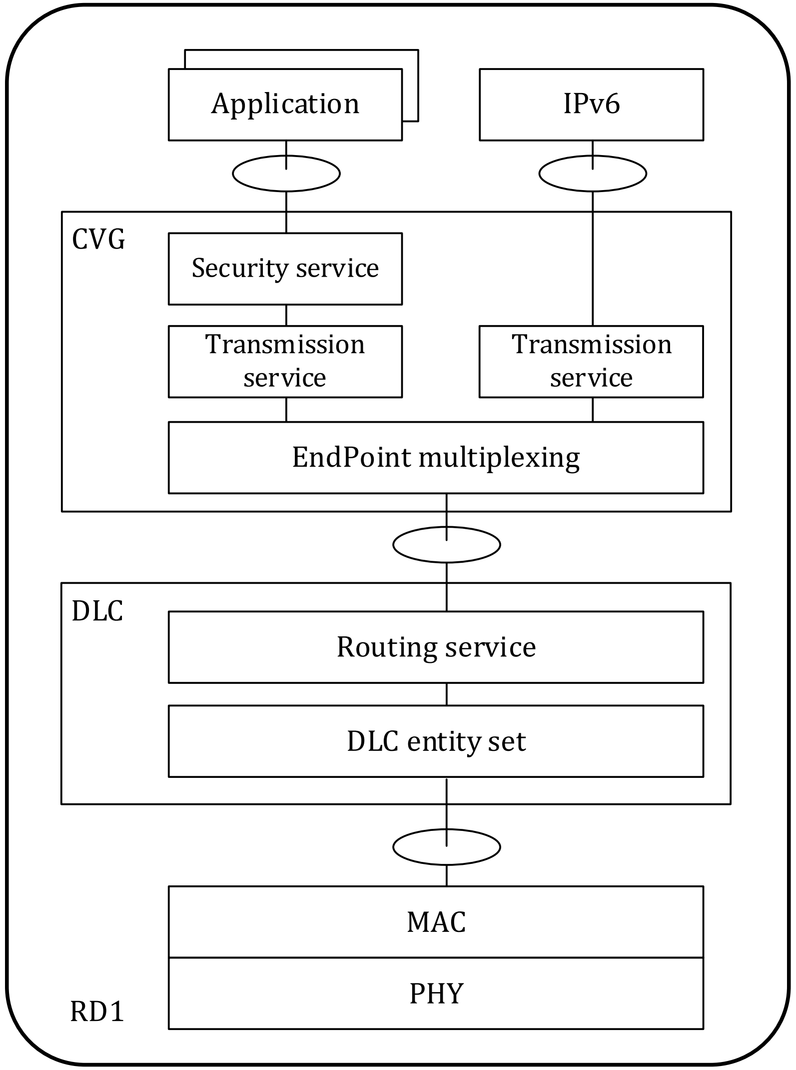
# MAC security

- MAC layer security uses
  - AES-128 counter mode for ciphering.
  - OMAC-1 (CMAC) message integrity protection.
- Both ciphering and integrity protection is done for each communication hop
  - Receiver can ensure that data is legitimate for routing.
  - Encryption and integrity process is repeated in each hop.
- Both ciphering and integrity protection can be used for Beaconing
  - Network can only be accessed with correct security keys.
  - RD connects only legitimate RD in FT mode.

# Part 5: DECT-2020 NR DLC and Convergence layers

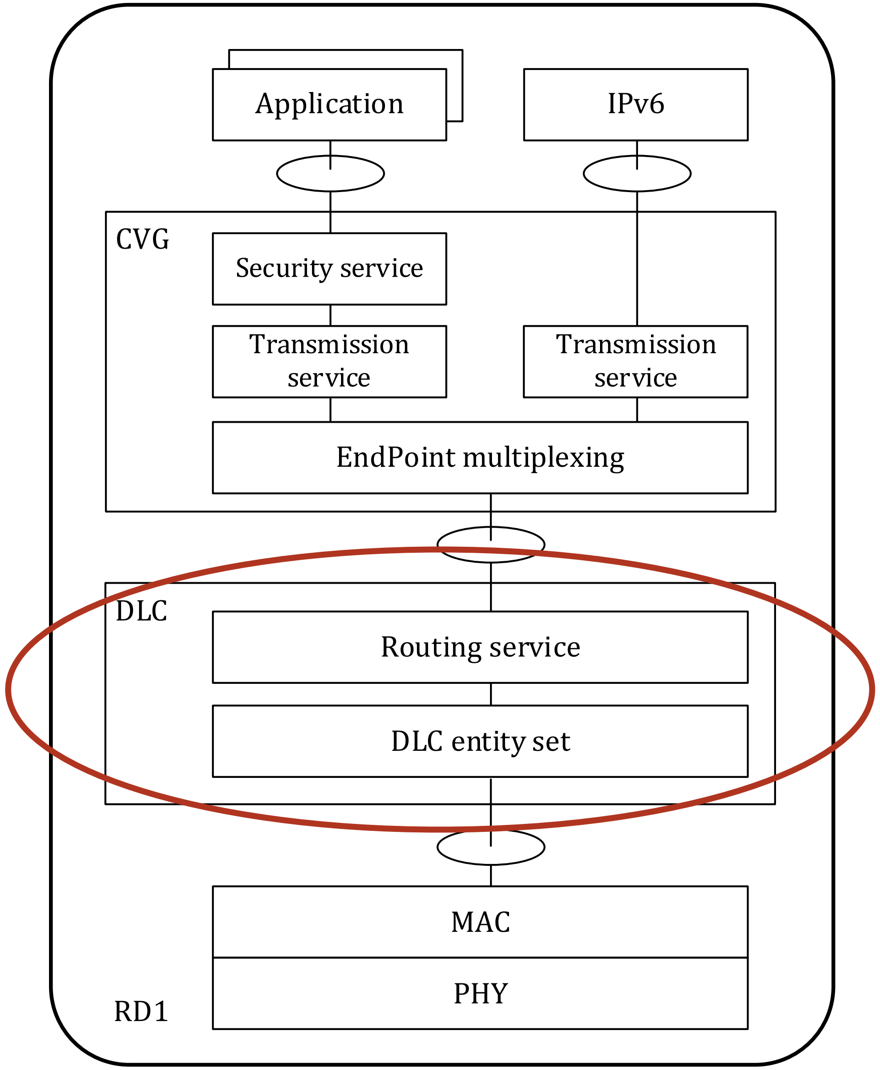
06

# DLC and Convergence (CVG) layers architecture



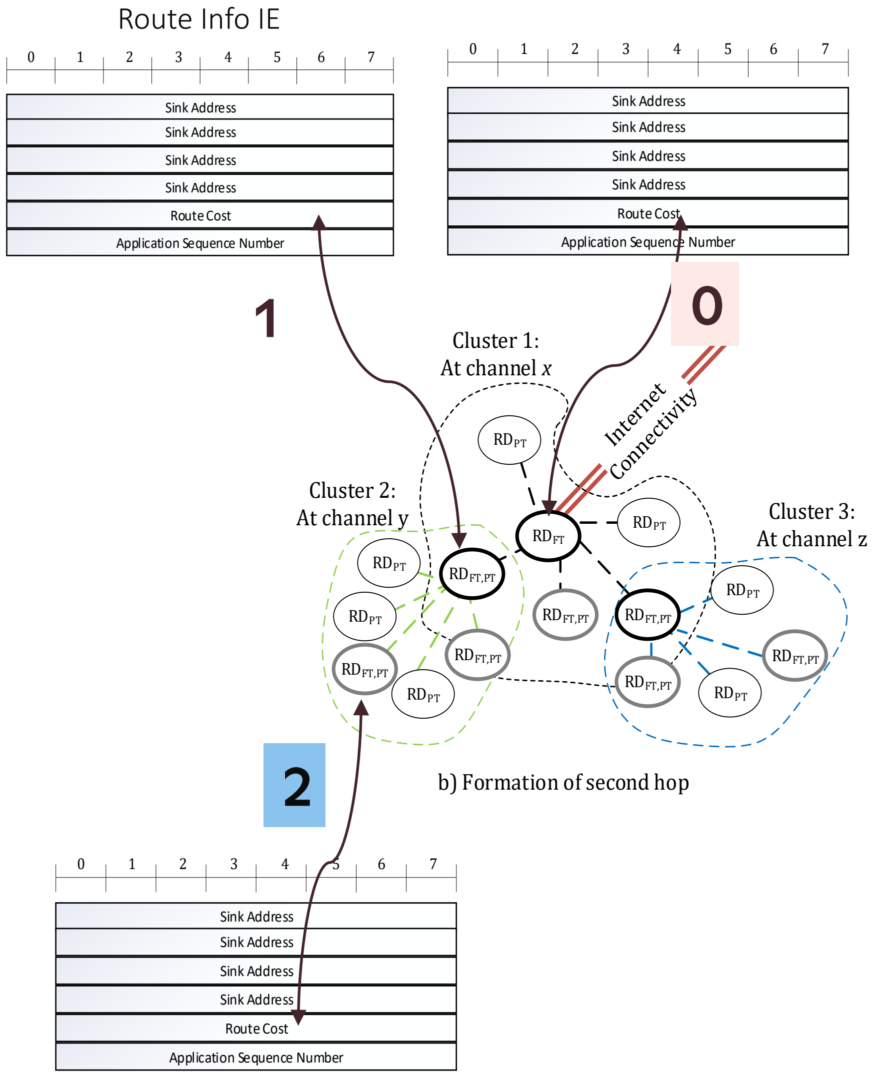

- DLC and CVG layers contain a set of selectable services.
  - Higher layer protocol (e.g. IPv6) or application data packets are processes in the selected services when passing the stack.
- DLC operates over a radio link
- CVG operates “end-to-end”, over the full chain of radio hops the application data travels

# DLC layer services




- DLC entity set is created with each associated neighbouring (one-hop) RD.
- Three transmission modes:
  - Transparent mode
    - No DLC level services in use
  - Segmentation mode
    - Link level segmentation and reassembly service in use.
  - ARQ mode
    - Retransmissions service, using the HARQ processes of PHY.
- Routing services
  - Uplink routing based on the (MAC) cost value
  - Downlink routing based on selective flooding
  - Packet routing between RDs based on hop-limited flooding

# Routing




DECT-2020 may use same routing for all topologies

RD roles:

a) $RD_{FT}$ provides access to outside world

b) $RD_{PT}$ communicates to $RD_{FT}$

c) Operate both in $RD_{FT,PT}$ modes and route data.

— Route cost to $RD_{FT}$ must increase at least by 1 in every hop. Implementations may consider multiple aspects for route cost calculations such as load or battery status of RDFT

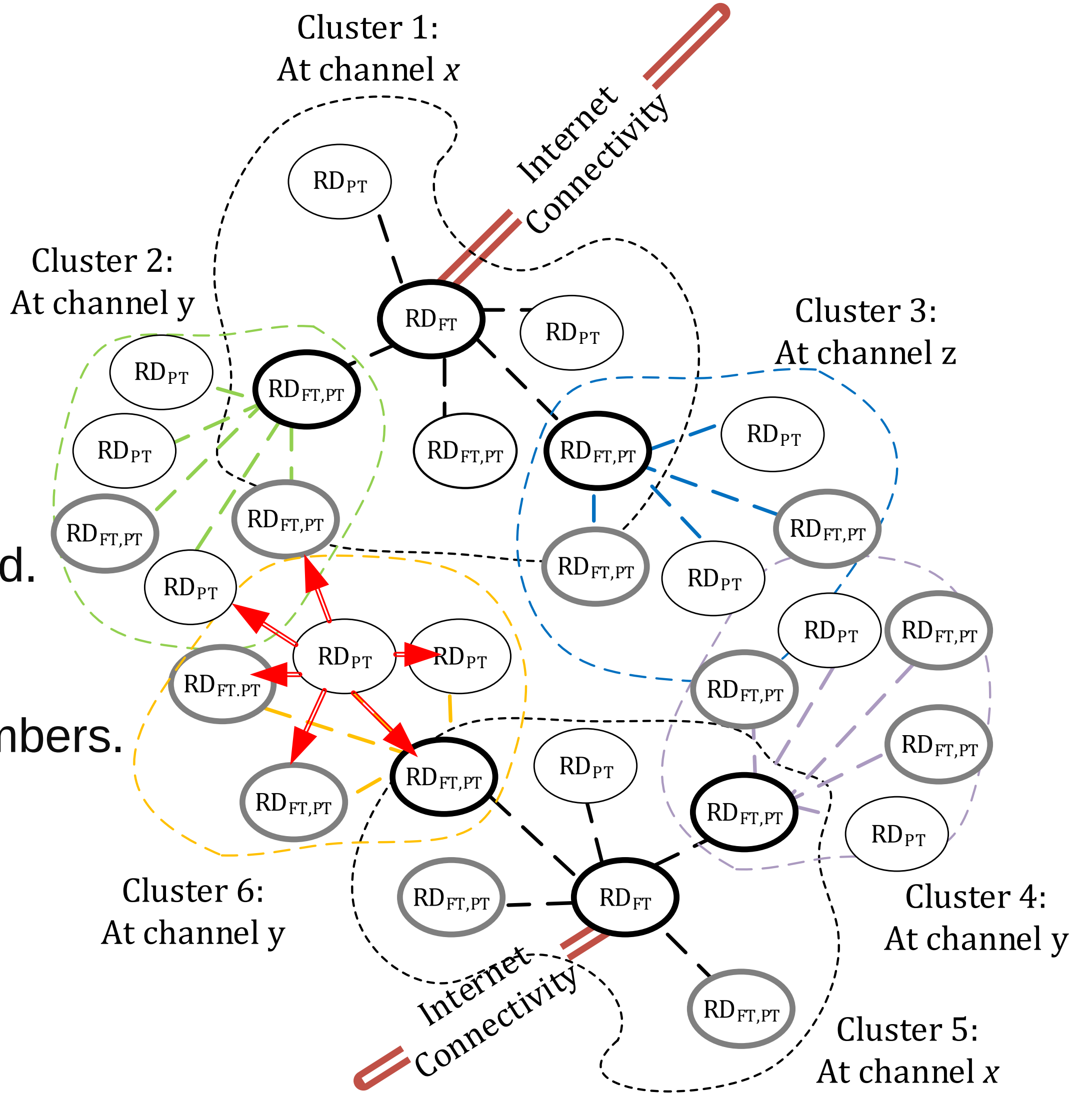
Routing uses Long RD addresses as source and destination address and supports:

— Uplink optimization for mMTC and clustered three topology.

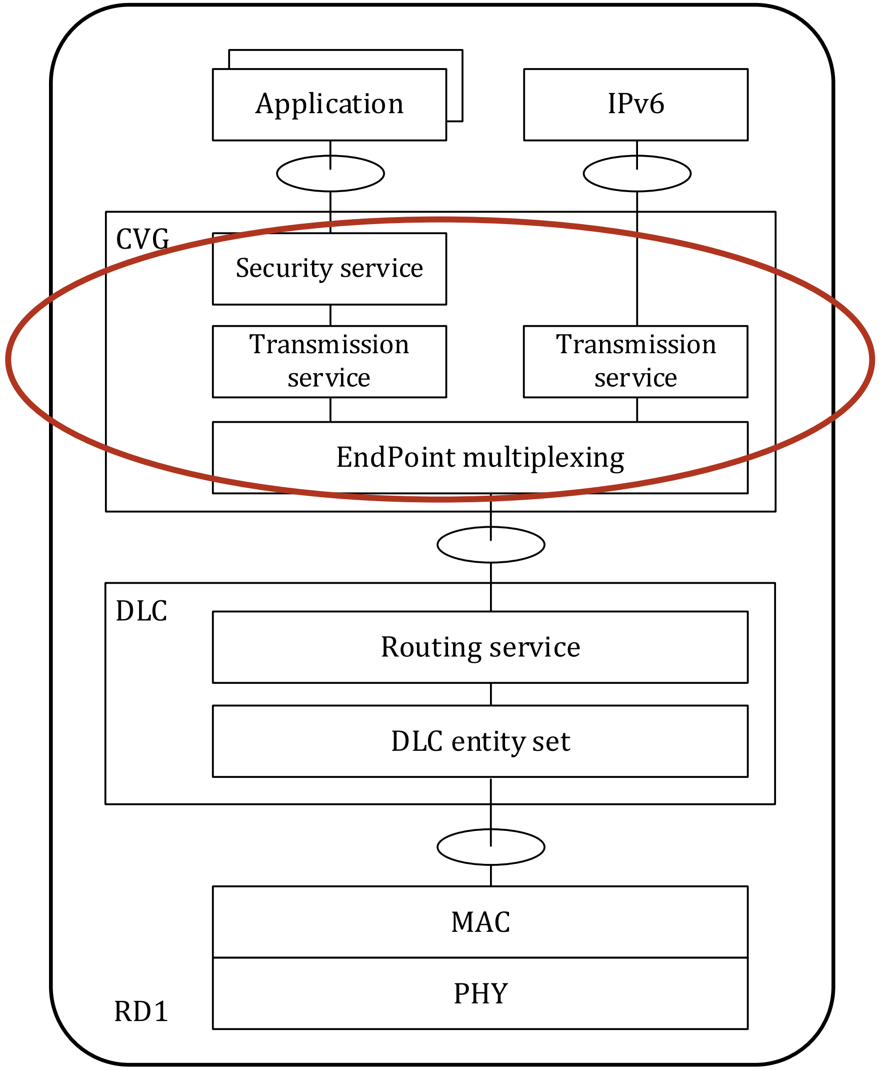
— Downlink and RD to RD routing based selective flooding in clustered three with capabilities to limit number of hops.

# Routing

- Uplink, Downlink and RD2RD supported.
- No routing tables assumed.
  - No network limitation size restrictions.
  - No maintenance signaling
- Uplink based on clustered tree topology
  - RD sends uplink data packet to next hop toward backend.
- Downlink based on restricted flooding
  - RD_FT role send data to all RD_FTs that may have members.
  - Distribution tree is pruned when ever possible.
- RD2RD designed for local communication
  - Flooding with limited number of hops
  - Can be one to one or one to multicast group.

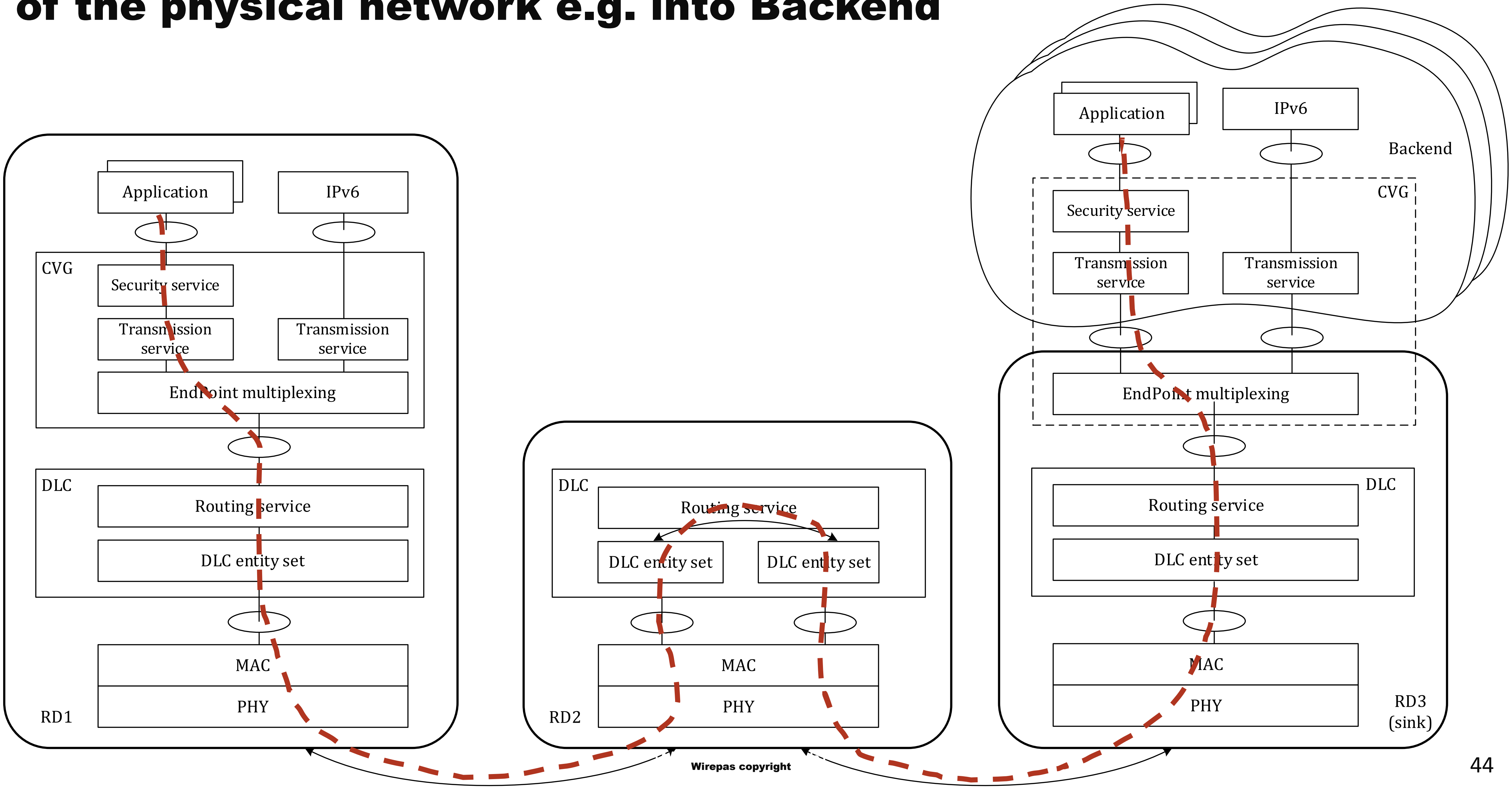


# CVG layer services




- EndPoint (EP) Multiplexing service
  - EP address is used to identify the higher layer framework of the packets. EP allows gateways to forward the packets to proper outside destination, e.g. to backend handling the framework.
  - EP multiplexing allows to choose different transmission and security service (including different keys) per EP / App framework.
  - Optional to use like all CVG services.
- Transmission services
  - Segmentation & reassembly
    - Up to 65 kB packet length support by the spec
  - Retransmissions (ARQ), single or block feedback
- Security service
  - AES-128 based encryption and integrity protection for the application data

# Architecture allows taking CVG services out of the physical network e.g. into Backend



# DECT-2020 Performance

07

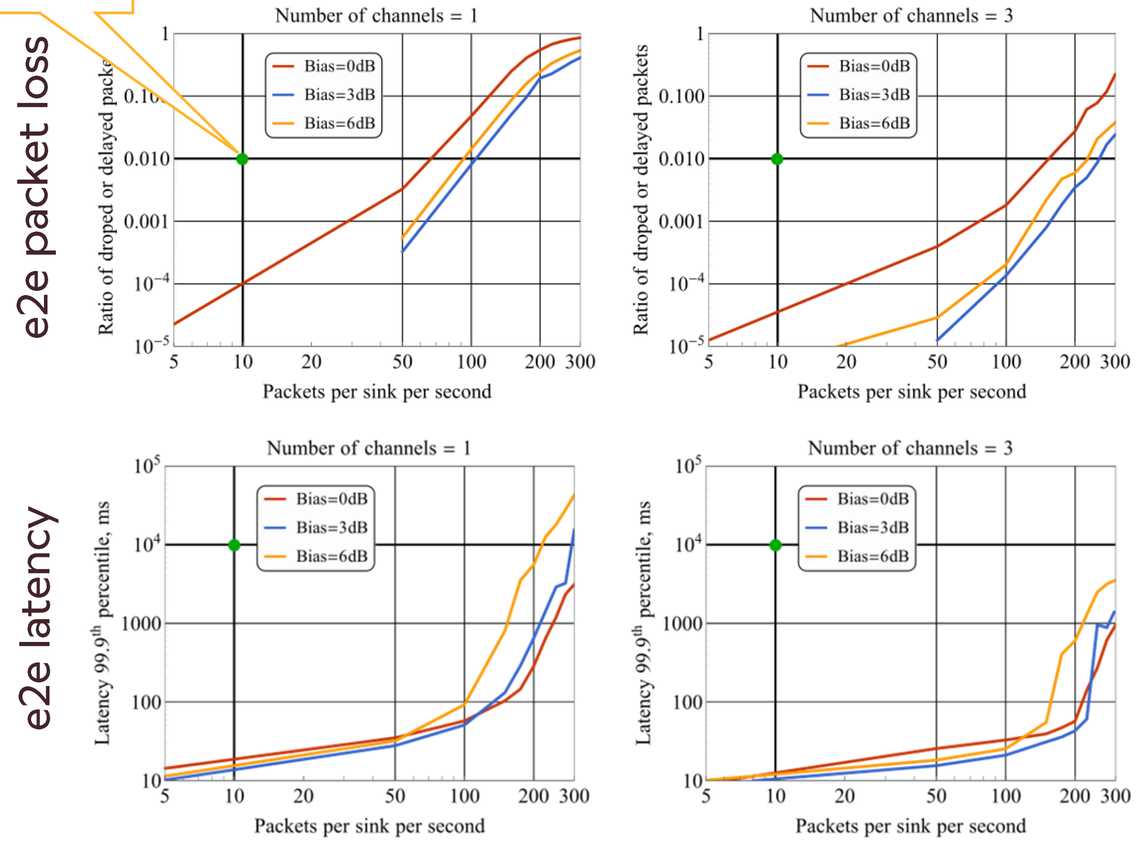
# DECT-2020 NR Performance evaluation

- ETSI MSG Eval performed full evaluation analysis of DECT-2020 NR for ITU. The final evaluation report is in ETSI TR 103 810
  - Research report from VTT on mMTC system simulation results.
  - Research report from Leibniz Universität Hannover on DECT-2020 NR link performance.

- WWRF DECT 2020 NR evaluation report includes a full analysis of technology
- In following slides, some go through these results.

# DECT-2020 performance in IMT-2020 mMTC scenario

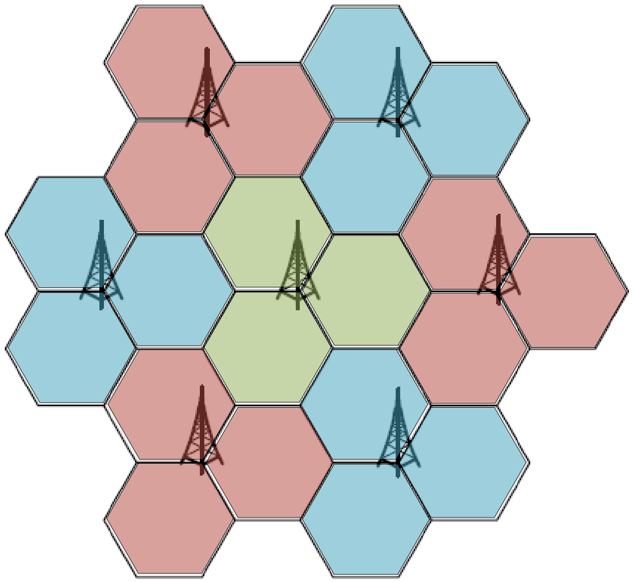
Green mark = ITU mMTC requirement




Source: DECT(20)000191

| | 1 channel | 3 channels |
|---|---|---|
| Bias = 0dB (Red) | 67 pps or<br>1 message / 17.8 minutes/device | 154 pps or<br>1 message / 7.8 minutes/device |
| Bias = 3dB (Blue) | 105 pps or<br>1 message / 11.4 minutes/device | 255 pps or<br>1 message / 4.7 minutes/device |
| Bias = 6dB (Yellow) | 93 pps or<br>1 message / 12.8 minutes/device | 226 pps or<br>1 message / 5.3 minutes/device |

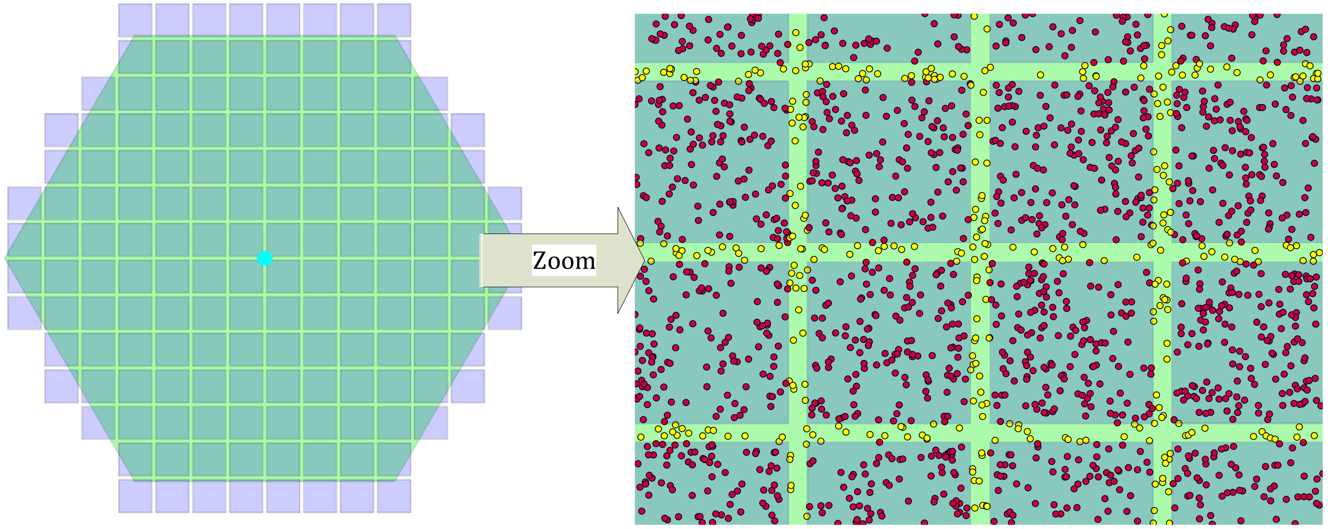
# mMTC System simulations – ISD 1723m



Simulated cell sector using 6 or 9 channels of 1.728MHz, (10.5 MHz or 15.5 MHz)

Other cell sector using different 6 or 9 channels of 1.728MHz, (10.5 MHz or 15.5 MHz)

Other cell sector using different 6 or 9 channels of 1.728MHz, (10.5 MHz or 15.5 MHz)




- Grid of BTS/gateways with ISD of 1723m.
- Building (dark green) and streets (light green)
- 80% of device indoors with red dots – Outdoor devices 20% with yellow dots.

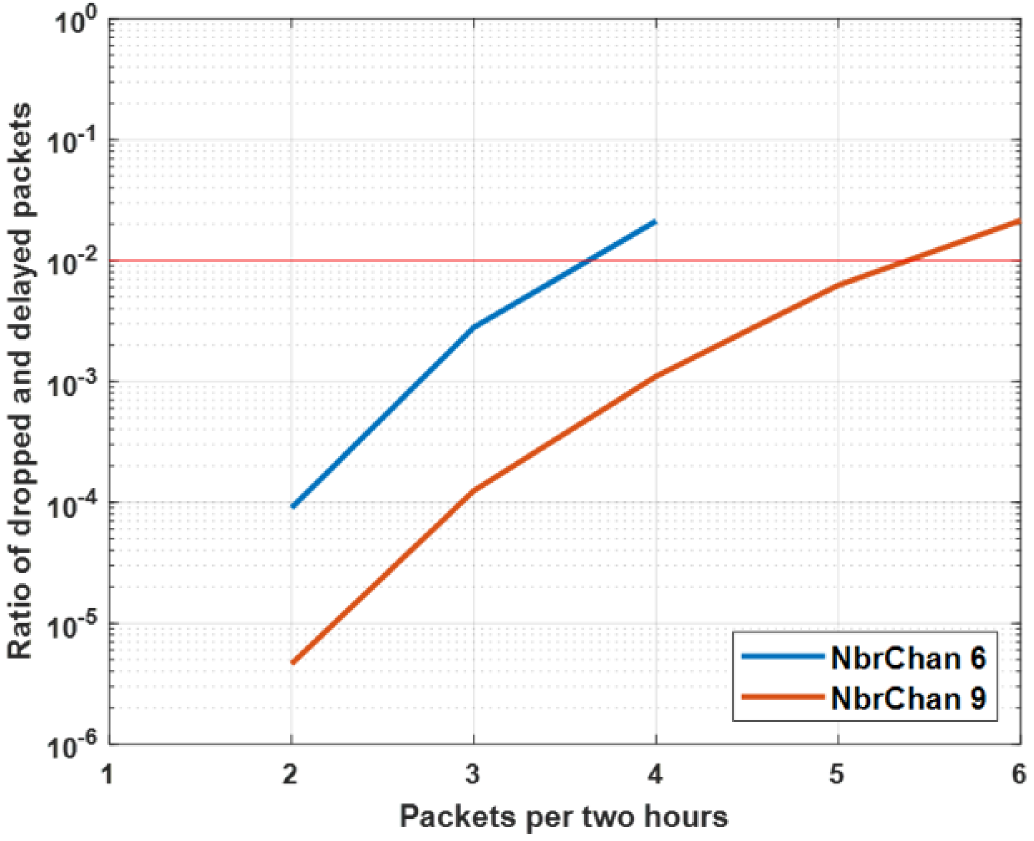
Source: ETSI MSG(21)0004_ ETSI Evaluation group Final evaluation report.

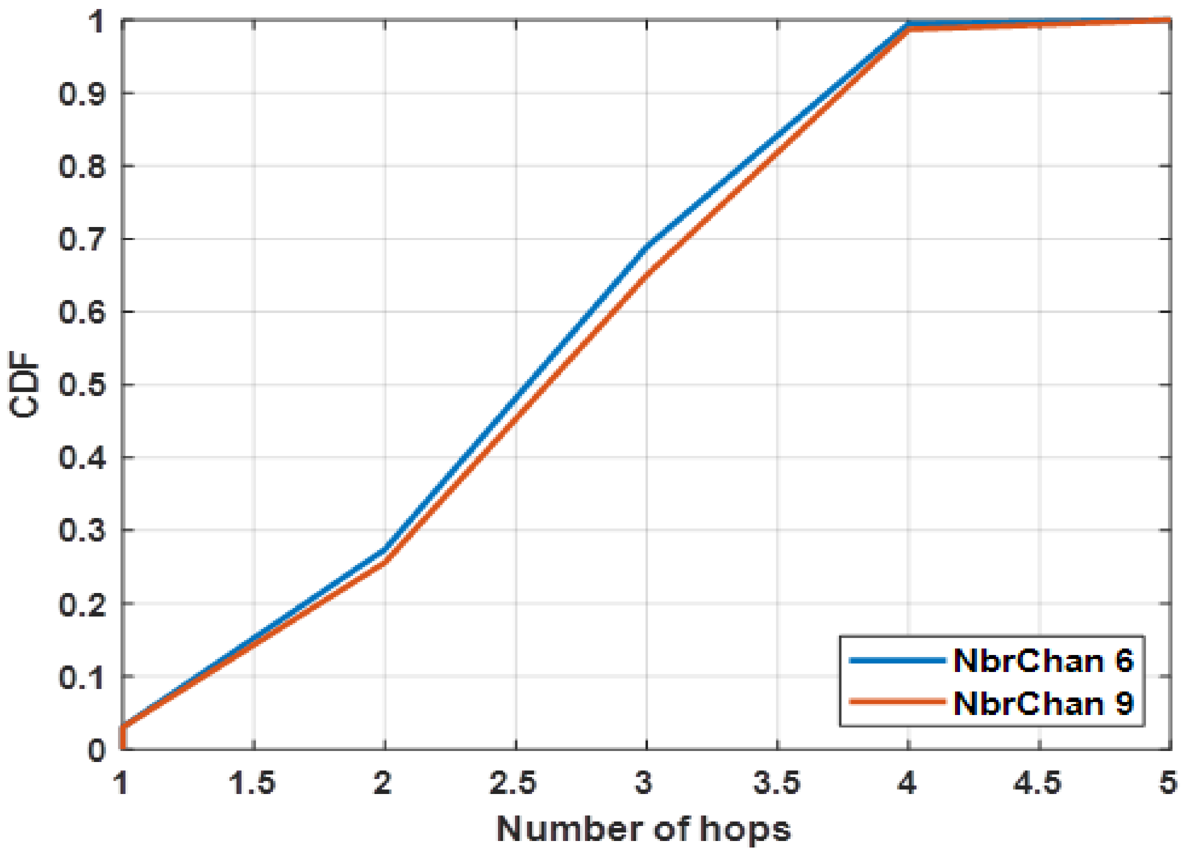
# mMTC System simulations results – ISD 1723m

| Scenario | Packet arrival time | Packet outage rate (Note) | Packet outage rate below 1% |
|---|---|---|---|
| a) 6 channels: 10.37 MHz | 1 message/2 hours/device | 0% | YES |
| | 2 messages/2 hours/device | 0.009% | YES |
| | 3 messages/2 hours/device | 0.28% | YES |
| b) 9 channels: 15.5 MHz | 1 message/2 hours/device | 0% | YES |
| | 2 messages/2 hours/device | 0.0005% | YES |
| | 3 messages/2 hours/device | 0.012% | YES |
| | 4 messages/2 hours/device | 0.11% | YES |
| | 5 messages/1 hours/device | 0.63% | YES |
| Note: Packet outage rate takes into account both packets lost during transmission and packets delayed more than 10 seconds. | | | |

Source: ETSI MSG(21)0004_ ETSI Evaluation group Final evaluation report.

# mMTC System simulations results – ISD 1723m




Source: ETSI MSG(21)0004_ ETSI Evaluation group Final evaluation report.

# mMTC System simulations results – ISD 500m

| Network configuration | | | | POR | Packet rate |
|---|---|---|---|---|---|
| $N_{FT}$ | $N_S$ | $N_{RD}$ | $N_{RD}/km^2$ | $\varepsilon$ = 0.5 % | |
| 1 | 3 | 216507 | 1 000 000 | 0.32% | the required packet rate |
| 1 | 3 | 216507 | 1 000 000 | 0.42% | 2x packet rate |
| 1 | 3 | 216507 | 1 000 000 | 0.58% | 4x packet rate |
| 1 | 3 | 216507 | 1 000 000 | 0.75% | 6x packet rate |
| 1 | 3 | 216507 | 1 000 000 | 0.88% | 7x packet rate |
| 1 | 3 | 216507 | 1 000 000 | 1.02% | 8x packet rate |

| Network configuration | | | | POR | Tx power and random access length |
|---|---|---|---|---|---|
| $N_{FT}$ | $N_S$ | $N_{RD}$ | $N_{RD}/km^2$ | $\varepsilon$ = 1.0 % | |
| 1 | 3 | 216 507 | 1 000 000 | 0.50% | tx power = 10 dBm, 24 slots |
| 1 | 3 | 216 507 | 1 000 000 | 0.51% | tx power = 10 dBm, 48 slots |
| 1 | 3 | 216 507 | 1 000 000 | 0.39% | tx power = 10 dBm, 96 slots |
| 1 | 3 | 216 507 | 1 000 000 | 0.87% | tx power = 10 dBm, 192 slots |

- Simulation results according ITU-R scenario: 80% of device indoors.
- System capacity up to 7 times the ITU-R requirement, with 86% of allowed spectrum.
- Operation also with lower TX power (10dBm) was demonstrated to work.

Source: VTT: Enabling Massive Machine Type Communications with DECT-2020 Standard

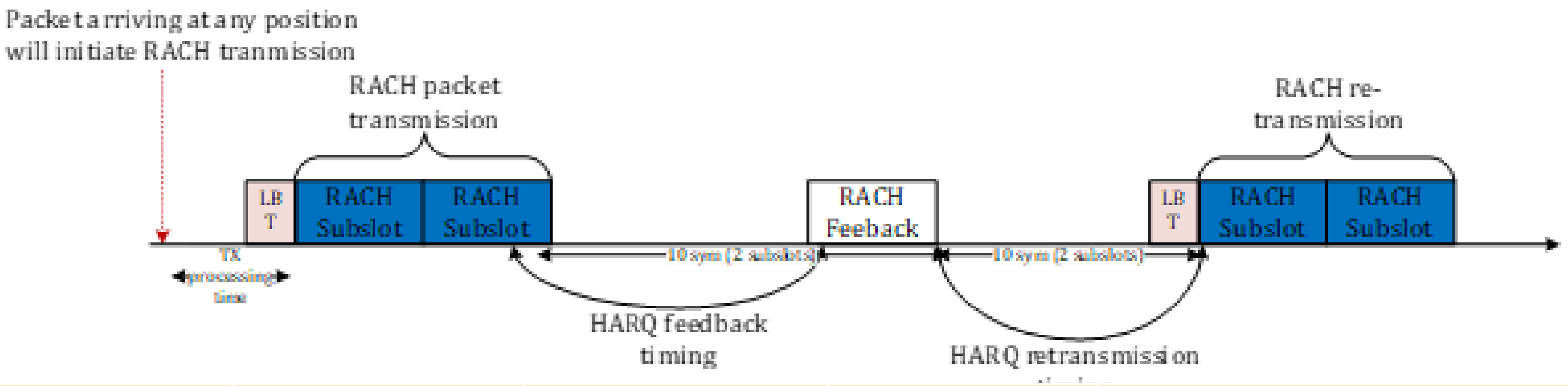
# mMTC System simulations results – ISD 500m

| Network configuration | | | | POR | Notes |
|---|---|---|---|---|---|
| $N_{FT}$ | $N_S$ | $N_{RD}$ | $N_{RD}/km^2$ | $\varepsilon$ = 0.5 % | |
| 1 | 3 | 216507 | 1 000 000 | 0.28% | the required node density |
| 1 | 3 | 433014 | 2 000 000 | 0.37% | 2x node density |
| 1 | 3 | 649521 | 3 000 000 | 0.34% | 3x node density |
| 1 | 3 | 866028 | 4 000 000 | 0.34% | 4x node density |
| 1 | 3 | 108254 | 500 000 | 0.21% | 0.5x node density |
| 1 | 3 | 54127 | 250 000 | 0.11% | 0.25x node density |
| 1 | 3 | 100 | 462 | 0.09% | ε = 100%, 10x simulation time, 100 iterations |
| 1 | 3 | 50 | 231 | 0.06% | ε = 100%, 10x simulation time, 100 iterations |
| 1 | 3 | 25 | 115 | 0.07% | ε = 100%, 10x simulation time, 100 iterations |
| 1 | 3 | 10 | 46 | Some unassociated nodes in some cases | ε = 100%, 10x simulation time, 100 iterations |

- Low density of devices is also possible
- Highlighted point – 115 devices per km² refers to are of one device in every 8600 m².
  - This is more than area of football field.
  - (But not open space)

Source: VTT: [Enabling Massive Machine Type Communications with DECT-2020 Standard]

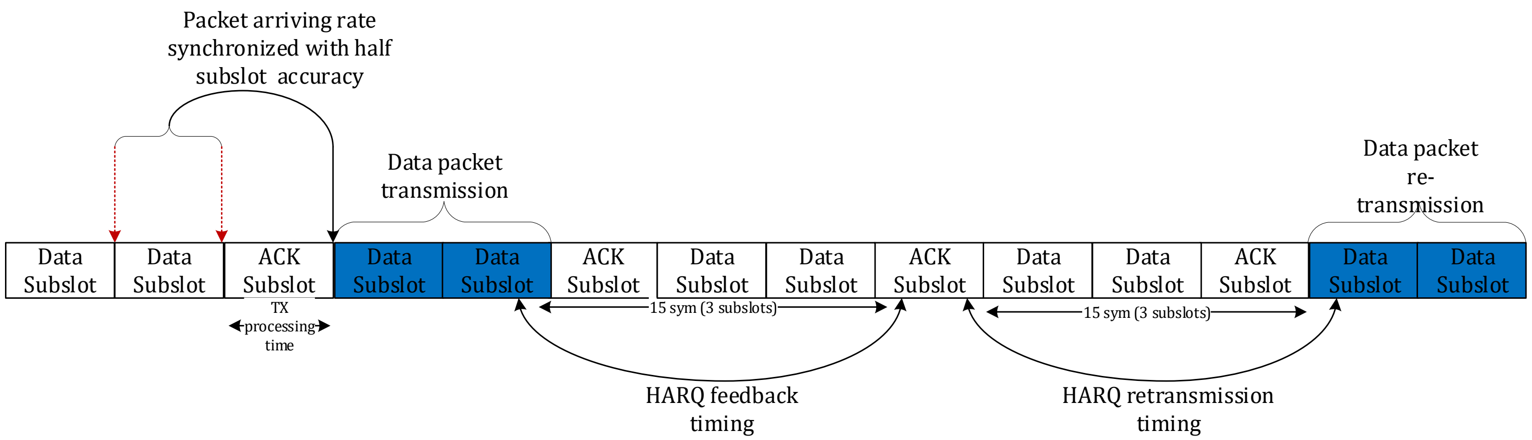
# Latency performance for mMTC, for single link




| PHY layer numerology | TX duration | Subslot duration | Transport block size | Frameless Transmission mode ( RACH ) | Latency per hop |
|---|---|---|---|---|---|
| 1,728 MHz @ 27 kHz | 416,667 µs | 208,333 µs | 296 bits | No HARQ transmission | 0,9 ms |
| | | | | With HARQ | 2,44 ms |
| 3,456 MHz @ 54 kHz | 208,333 µs | 104,166 µs | 368 bits | No HARQ transmission | 0,45 ms |
| | | | | With HARQ | 1,22 ms |

Source: ETSI MSG(21)0004_ ETSI Evaluation group Final evaluation report.

# Latency performance for mainly for URLLC




| PHY layer numerology | TX duration | Subslot duration | Transport block size | Frameless Transmission mode ( RACH ) | Latency per hop |
|---|---|---|---|---|---|
| 6.912 MHz @ 54 kHz | 208.333 μs | 104.166 μs | 288 bits | No HARQ transmission | 0,48 ms |
| | | | | With HARQ | 1,42 ms |
| 13,824 MHz @ 108 kHz | 104.166 μs | 52.083 μs | 288 bits | No HARQ transmission | 0,24 ms |
| | | | | With HARQ | 0.71 ms |

Source: ETSI MSG(21)0004_ ETSI Evaluation group Final evaluation report.

# Summary of DECT-2020 NR standards

- DECT-2020 NR standards benefits state of art radio design:
- Modern CP-OFDM radio access supporting robust performance and low latency on each communication link.
- Higher layers are designed to support efficient spectrum use by having an advanced coexistence capability thanks to optimized physical and MAC layer design.
- NW and device identity concept support very large and dense networks.
- Autonomous device operation and cost-based routing between devices supports future device based mMTC deployments.
- The performance results are enabling new use cases for the industry with local networks.

# Thank you

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