IEEE 802.16
Narrowband (NB) Evolution

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IEEE 802.16 NB Evolution

- **IEEE 802.16-2012 (OFDMA Variant)**
  - Supported channel bandwidth: 1.25 MHz, 5 MHz & 10 MHz
  - FFT: 128, 512, 1024
  - Permutation: PUSC
  - Continuous spectrum
- **IEEE802.16-2017**
  - Added channel bandwidth between 100 KHz and 1.25 MHz
  - 128 FFT
  - Permutation: AMC 1X6
  - Continuous spectrum
  - The waveform is adjusted to fit into the channel bandwidth by:
    - Symbol rate/subcarrier spacing reduction
    - Maintain a subset of the sub-channels (this is needed to avoid excessive reduction in subcarrier spacing)
  - PHY & MAC layer overhead reduction for NB:
    - Extend frame duration to reduce per frame overhead
    - More efficient MAC layer, e.g, DLSF bursts are not rectangular
    - Automatic PHS

IEEE 802.16t Amendment

- **IEEE802.16t Point to Multipoint (PtMP)**
  - Connection oriented air interface protocol
  - Scheduled MAC layer
  - An evolution of the IEEE802.16-2017 standard optimized for narrow channels

- **IEEE802.16t Direct Peer to Peer (DPP)**
  - A symmetrical and connectionless air interface protocol
  - CSMA/CA channel access
  - Employs the IEEE802.16t PtMP UL PHY layer in both UL and DL
  - Supports any to any communication

IEEE 802.16t Highlights – Characteristics Common to PtMP and DPP

- Supports channel bandwidth down to 5 kHz
- The available bandwidth span is divided into equal bandwidth subchannels
- Multiple adjacent or non-adjacent sub-channels are aggregated into sub-channel groups.
- Supports a wide range of Modulation and Coding Schemes with adaptive modulation:
  - Modulation schemes: QPSK, 16 QAM, 64QAM and 256 QAM.
  - Coding schemes: Convolutional Code (CC) and Convolutional Turbo Codes (CTC) rates ½, ¾, 5/6, 7/8.
- Supports over the air authentication and encryption

IEEE 802.16t Highlights – PtMP Characteristics

- Each sub-channel group is “self-sufficient”, i.e., all connectivity maintenance signals and messages, e.g., preamble, are transmitted in each subchannel group.
- The Base Station controls multiple sub-channel groups. As such, one base station replaces multiple base stations in the traditional architecture.
- Each Remote operates in a single subchannel group. It only receives and transmits over the subchannels within its sub-channel group. As such, multiple types of remotes with different bandwidth capabilities can share the same base station.
- Extensive Quality of Service (QOS) features including support of multiple QOS profiles per remote in each direction. A QOS profile is associated with a service flow characterized packet attributes, e.g., type of protocol. A QOS profile include parameters such as scheduler type, priority, minimum bit rate, maximum bitrate, maximum latency and more.

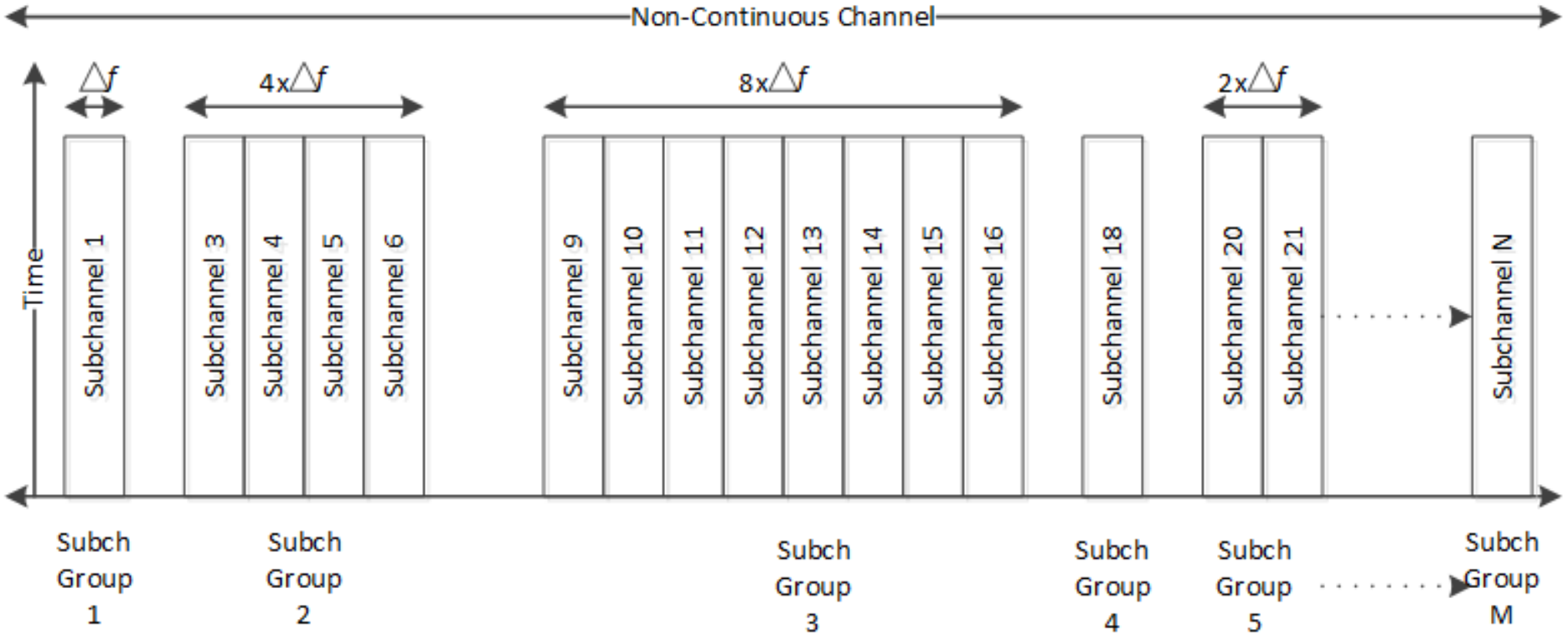
IEEE 802.16t PtMP Air Interface Protocol Characteristics

- **PHY Layer characteristics:**
  - OFDMA downlink, SC-FDMA uplink
  - Single subcarrier per subchannel
  - Subchannel bandwidth is configurable
  - Preamble, pilots and data are time multiplexed. Configurable rate of preamble and pilots depending on speed
  - Up to 512 subchannels. A configurable subchannel bitmap is used to determine which subchannels are active. Subchannel groups are also configurable.
  - Support an additional FEC code (256 QAM with CTC 7/8) and high repetition rate (up to 128 repetitions).
- **MAC Layer characteristics**
  - DL/UL MAP are replaced with allocation messages decoupled from the frame.
  - New scheduling modes are added: Bulk, SPS. Bulk scheduling employs a prediction algorithm to allocate bandwidth in advance to minimize latency.
  - The BS scheduler supports 2 modes of operation:
    - Primary mode: the main scheduler runs in the BS
    - Secondary mode: the main scheduler runs in a Base Station Controller.
- **Security Characteristics**
  - Security modifications as needed to meet the FIPS140-2 requirements

IEEE 802.16t Highlights – DPP Characteristics

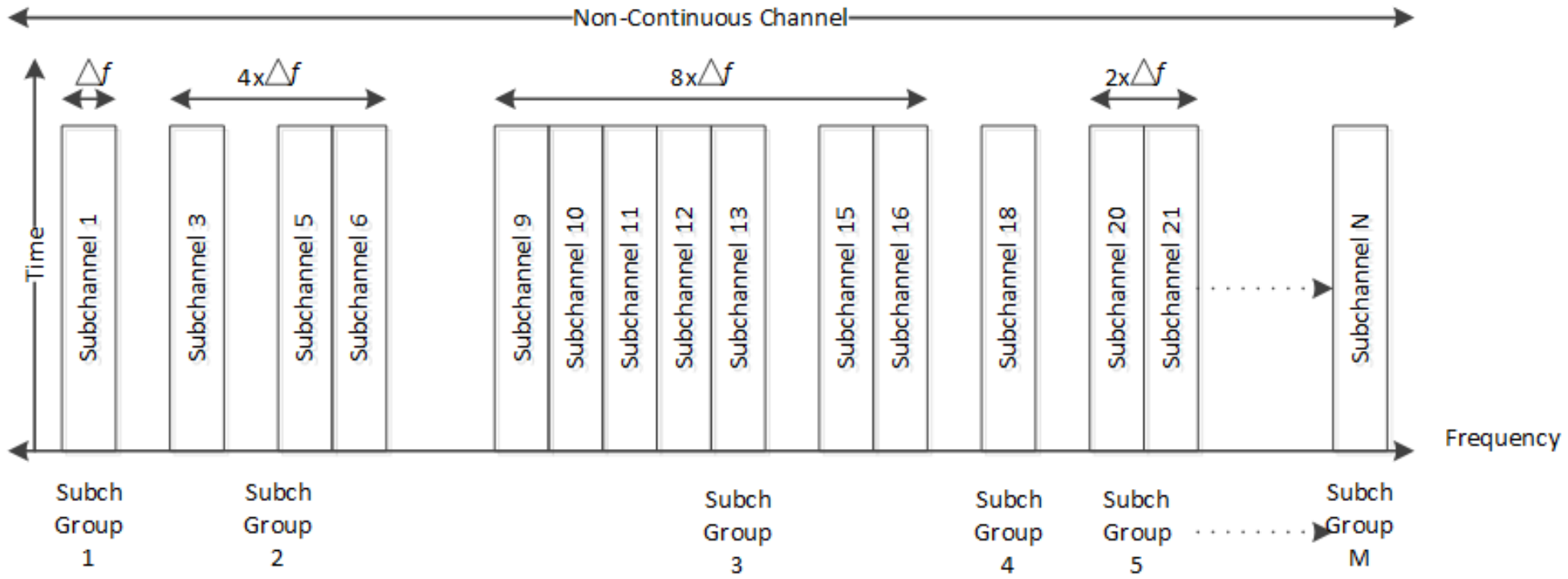
- A DPP terminal operates over a single subchannel group
- DPP supports repetition/combining with a configurable repetition/combing factor up to 128. Unlike simple repetitions (e.g., the 3 repetitions in the legacy front to back communication), all repetition instances are carefully synchronized and combined before demodulation. As a result, repetition/combining is equivalent to an increase in the transmit power or an improvement in the recover sensitivity by 10 log (repetition factor). Repetition/combining as applied on top of FEC to an extremely robust link.
- Supports DTLS 1.3 authentication.
- Supports Store & Forward Relay for range extension.

Non-Continuous Channel Partitioning



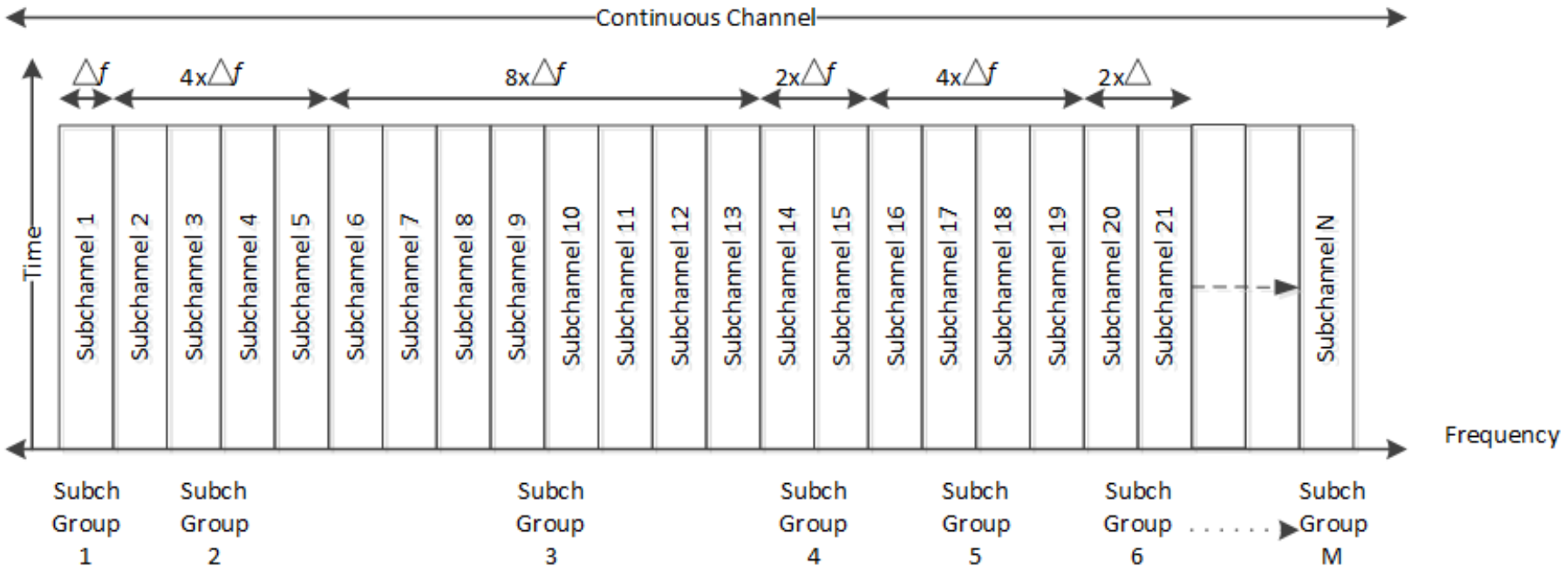
Note: The base station operates in all subchannel groups. Each remote operates in one of the subchannel groups.

Partitioning of a Non-Continuous Channel with a Non-Adjacent Sub-Channel Group



Note: The base station operates in all subchannel groups. Each remote operates in one of the subchannel groups.

Partitioning of a Continuous Channel



IEEE802.16t Base Station Controller (BSC)

- The BSC manages the ieee802.16t PtMP Air Interface Resources (AIRs) available in the band, e.g., in the AAR 900 MHz band, two 10 x 12.5 KHz sub-bands.
- The ieee802.16t AIRs are two-dimensional (frequency and time) entities referred to as “slots”. A slot is one symbol over one subchannel.
- The BSC communicates with BSs within a “control area”. It runs the primary scheduler for all BSs within its control area. It receives AIR allocation requests from the BSs and allocates AIRs to the BSs within its control area.
- The BSC runs a BS interference matrix to allow frequency re-use when the level of self interference between the respective sectors is acceptable. Unlike in traditional frequency planning, rigid partitioning of the available spectrum, i.e., limit of access of each BS to just a portion of the spectrum, is not needed.
- The BSC allocates AIRs for both DL and UL communication in each of the sectors within its control area. As such, the BSs sends to the BSC AIR requests for both DL and UL (unlike the iee802.16t BS scheduler which only receives bandwidth requests for UL communication).
- When a BSC is present, the BSs run a secondary scheduler which can re-purpose the AIRs allocated by the BSC. The BSs run the primary scheduler in the absence of a BSC.

IEEE802.16t Advantages

- An open wireless communication standard optimized for the Railroad bands and the Railroad applications.
- Reduction in Peak to Average Power Ratio to improve link budget. This is accomplished by moving to a single subcarrier per subchannel.
- Increase the number of supported sub-channels (up to 512) with non-adjacent active sub-channels aggregation. The large number of subchannels is needed to support the RR 160 MHz band.
- Operation in narrower channels down to 5 kHz.
- More efficient PHY and MAC layer and new scheduling modes to improve frequency utilization and reduce latency in narrow channels.
- Support of high repetition rate (up to 128) resulting in extremely robust communication for low throughput applications
- The MAC layer supports a secondary mode of operation when the primary scheduling is dictated by a Base Station Controller.
- Support of Direct Peer to Peer (DPP) with the same PHY layer as the Point to Multipoint (PtMP) protocol but with a CSMA/CA MAC layer.

IEEE 802.16t – Timeline

- System Requirements Document (SRD) approved: April 2021
- System Design Document (SDD) approved: January 2022
- Task group approval of the amendment specifications: September 2024
- Successful SA ballot completion: March 2025
- Expected forward to RevCom: March 2025

Note: IEEE 802.16t was already accepted by the Association of American Railroads (AAR) as the communication standard for the 900 MHz A-Block and is being considered for other railroad bands as well, e.g., the 160 MHz band.