Improvement of L-DACS1 Design by Combining B-AMC with P34 and WiMAX Technologies

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Contents

- Introduction
- L-DACS1 main characteristics
- Improvements of the B-AMC design
- Adopted P34 and WiMAX concepts
- Rejected P34 and WiMAX concepts
- Conclusions

Introduction

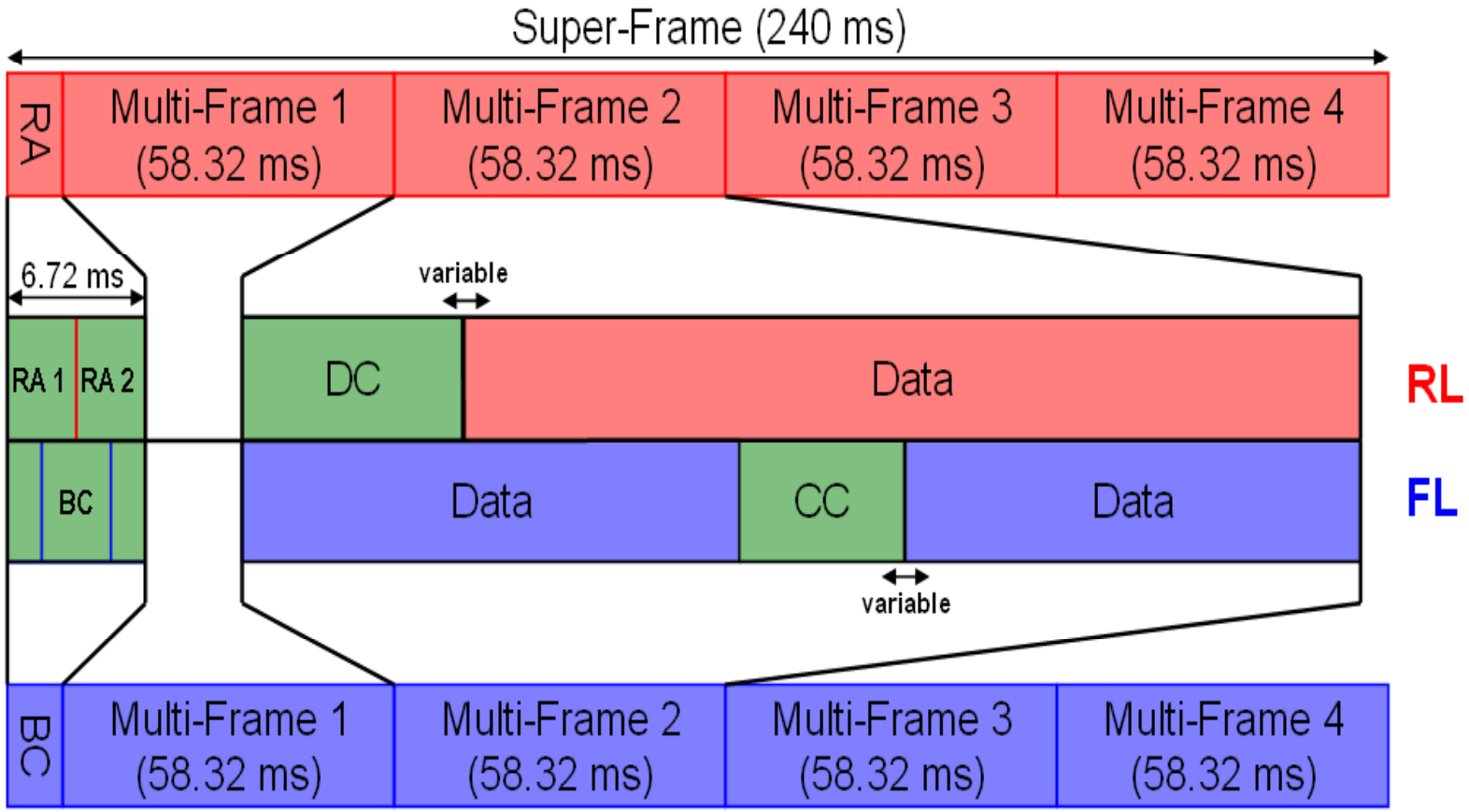
- ATM needs a new aeronautical communication system
- EUROCONTROL/FAA AP17 conclusions:
  - Terrestrial system shall preferably operate in L-band
  - Two technologies identified: L-DACS1 (OFDM/FDD) and L-DACS2 (CPFSK/TDD)
  - L-DACS1 solution shall comprise desirable features of B-AMC and similar OFDM-based technologies (P34, WiMAX)
- In 2008, EUROCONTROL launched two tasks aiming at specifying L-DACS1 and L-DACS2
  - System specifications and specifications for initial prototypes
- This talk is about the L-DACS1 specification task
  - Based on L-DACS1 Study deliverables that considered valuable contributions from FAA, NASA, MITRE and ITT

L-DACS1 Main Characteristics

- L-DACS1 A/G mode inherits B-AMC characteristics
  - Cellular point-to-multipoint full-duplex L-band system
    - Ground Station (GS) controls multiple Airborne Stations (AS)
    - Cell (GS) operational range up to 200 nm
    - Separate Forward Link (FL) and Reverse Link (RL) channels
    - Multiple simultaneous bi-directional A/G links
    - Continuous GS transmission, bursty AS transmissions
    - Resources for AS data allocated by the GS upon AS request
    - Resources for system data allocated permanently
  - Support for COCRv2 ATS and AOC A/G service requirements
    - Optional A/G digital voice and A/A data communications mode
  - Only A/G mode has been specified in detail in the course of this study!

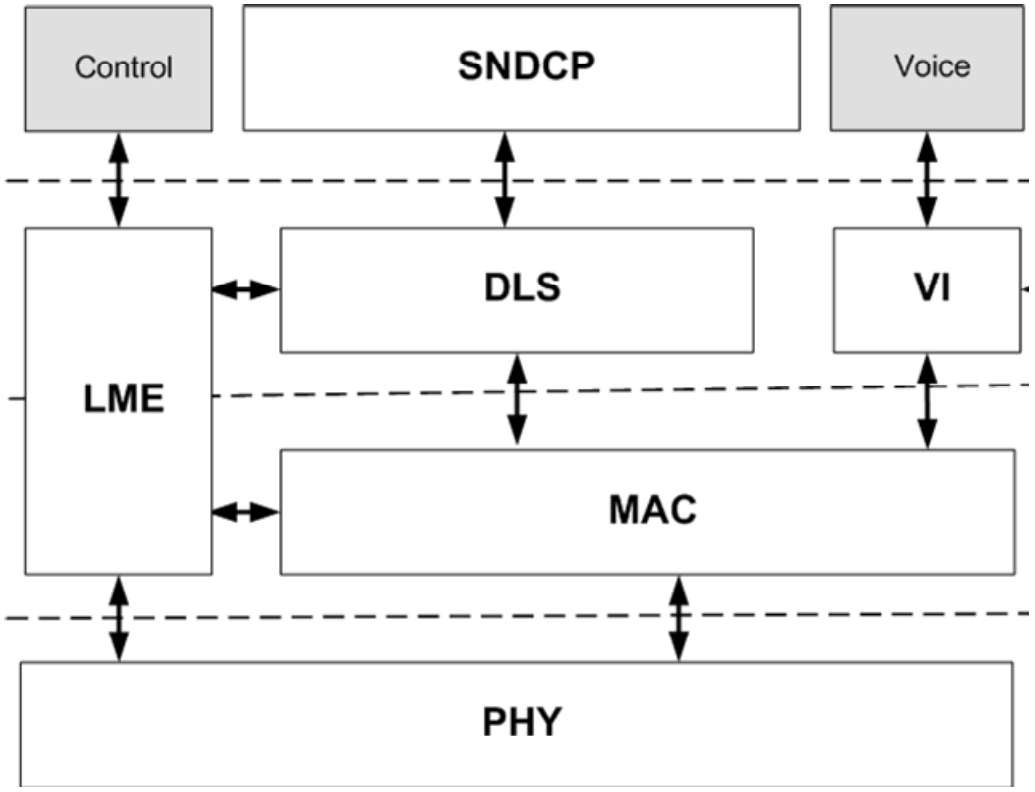
L-DACS1 Main Characteristics (2)

- OFDM physical layer organised via framing structure



L-DACS1 Main Characteristics (3)

- L-DACS1-specific protocol suite
  - Allows L-DACS1 to become a sub-network of ATN/IPS



Improvements of the B-AMC Design

- L-DACS1 specification task was considered as opportunity for improving B-AMC design!
  - QoS handling on LLC avoids second segmentation level
  - Only one acknowledged transport service adopted for all AS data classes
  - Improved Automatic Repeat Request (ARQ) protocol - LLC packets are now fully transmitted
  - MAC timing available to DLS – simpler timing management
  - Two modes of Adaptive Coding and Modulation (ACM)
    - Cell- specific: common coding and modulation applies to all ASs
    - User-specific: individual coding and modulation settings are separately applied to different users
  - B-AMC waveform retained, but further optimized (e.g. carrier spacing, bandwidth, …)

Adopted P34 and WiMAX Concepts

- AGC preambles for RA frames and DC segments (P34)
  - GS receiver uses AGC preambles to adapt to RA frames without a-priori knowledge about their received power level
  - GS adjusts the transmitting power for Data segments of a particular AS by forcing this AS to send the AGC preamble of the DC segment, measuring the received power and issuing “in-the-loop” corrections
- Peak-to-Average Power Ratio (PAPR) reduction via adjusting phases of pilot tones (P34)
  - Special PAPR-reduction symbols for RL OFDM symbols that do not contain pilots
  - “Low-PAPR” AGC preambles and synchronization symbols”
    - General PAPR reduction method has not been specified during that L-DACS1 study, but should comprise above methods!

Adopted P34 and WiMAX Concepts (2)

- Tiles for RL DC and Data segments (WiMAX)
  - Tile: two-dimensional time-frequency constellation of OFDM symbols allocated to the single user
  - L-DACS1 RL tile: 25 OFDM carriers x 6 OFDM symbols in time
    - One OFDM symbol can be used by at most two tiles (two users)
    - With B-AMC, up to 48 users could share an OFDM symbol → increased probability of Multiple Access Interference (MAI)
  - Tile contains pilot symbols and PAPR-reduction symbols
  - Two tiles are separated by the DC OFDM carrier that is not transmitted (P34 uses “gaps” between groups of RL OFDM carriers sent by different users)
- WiMAX concepts re-used for specifying “radio aspects”
  - Transmitter spectral flatness, constellation error, AS dynamic range, power adjustment step…

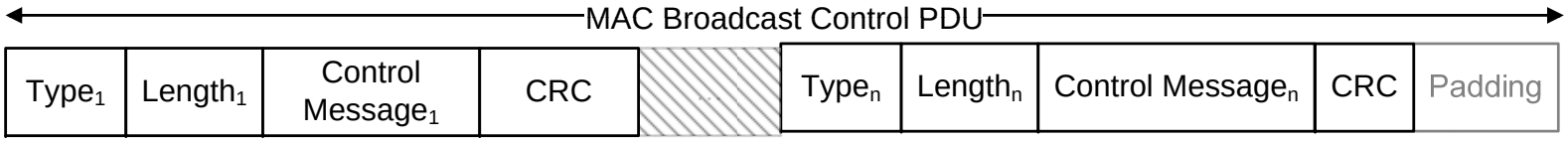
Adopted P34 and WiMAX Concepts (3)

- L-DACS1 pilot sequences re-use WiMAX generator polynomial
- L-DACS1 synchronization symbols use adapted WiMAX “long preamble”
- Concatenated channel coding and interleaving aligned with WiMAX

  - L-DACS1 uses concatenated coding scheme (similar to B-AMC and WiMAX)
    - Outer Reed-Solomon (RS) code, inner convolutional code (CC)
  - WiMAX generator polynomial re-used for L-DACS1 CC coder

Adopted P34 and WiMAX Concepts (4)

- L-DACS1 MAC state transition diagram is based on P34 MAC sub-layer states
- P34 broadcast channel concepts re-used for L-DACS1 broadcast channel



  - Protocol Data Unit (PDU) structure, message structure…
  - Random access method during handover between cells
- L-DACS1 acknowledged and unacknowledged data transport services are based on P34 procedures, primitives and parameters

Adopted P34 and WiMAX Concepts (5)

- L-DACS1 uses FL MAP concept similar to WiMAX
  - For announcing cell-specific coding and modulation information and other common data to the controlled ASs
- RL MAP and ACM RL MAP structures are also similar to WiMAX
- L-DACS1 interface to the network layer (SNDCP) is similar to P34 SNDCP.

Not Adopted P34 and WiMAX Concepts

- P34 SAM waveform
  - SAM is based on non-orthogonal FDM
  - SAM does not use cyclic prefix to combat multipath effects
  - Impossible to use IFFT, carrier spacing lower than for B-AMC
  - B-AMC waveform retained, with further optimizations
- P34 coding scheme
  - B-AMC coding scheme retained
  - Better compatible with L-band interference situation
- WiMAX framing and initial ranging procedure
  - This procedure works well within several nm, but is not compatible with target L-DACS1 ranges of up to 200 nm
  - B-AMC framing allows for RA access on RL without overlapping with non-RA frames

Not Adopted P34 and WiMAX Concepts (2)

- WiMAX tile structure and pilot pattern
  - Not compatible with L-band mobile channel
  - Finally selected L-DACS tiles and pilot patterns are different from that used for the B-AMC system
- WiMAX FFT size and guard ratio
  - WiMAX minimum FFT size of 128 not compatible with the L-DACS1 occupied bandwidth of 500 kHz (and inlay deployment)
  - L-DACS1-specific guard ratio (11/64) is not defined for WiMAX
- WiMAX does not offer windowing
  - Required for L-DACS1 as interference mitigation mechanism
- WiMAX carrier spacing and symbol duration
  - Not compatible with L-DACS1 framing (would prevent using AMBE-ATC-10 VDL mode 3 vocoder)

Conclusions

- Multiple P34 and WiMAX concepts and solutions could be re-used within the L-DACS1 system design
  - Yielding valuable improvements with respect to the baseline B-AMC design
- Some P34 and WiMAX concepts could not be adopted
  - Due to internal constraints of the target L-DACS1 system
- L-DACS1 specification task was significantly facilitated by informal contributions of USA parties
  - Two working meeting with FAA, NASA, MITRE and ITT
  - Regular teleconferences
  - Informal mail exchanges
- This supporting work is highly appreciated by the L-DACS1 team.