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Physical Layer Proposal for the 802.16 Air Interface Specification

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Purpose:

This presentation is intended to provide an overview of the submission IEEE 802.16pc-00/02, “Physical Layer Proposal for the 802.16 Air Interface Specification”

Physical Layer Proposal for the 802.16 Air Interface Specification

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Overview

- Philosophy behind the design
- Reference configuration
- Multiple access and duplexing techniques
- DS and US convergence sublayers
- Downstream PHY layer
- Upstream PHY layer
- Radio subsystem controls
- Evaluation table
- Limitations and benefits of proposal

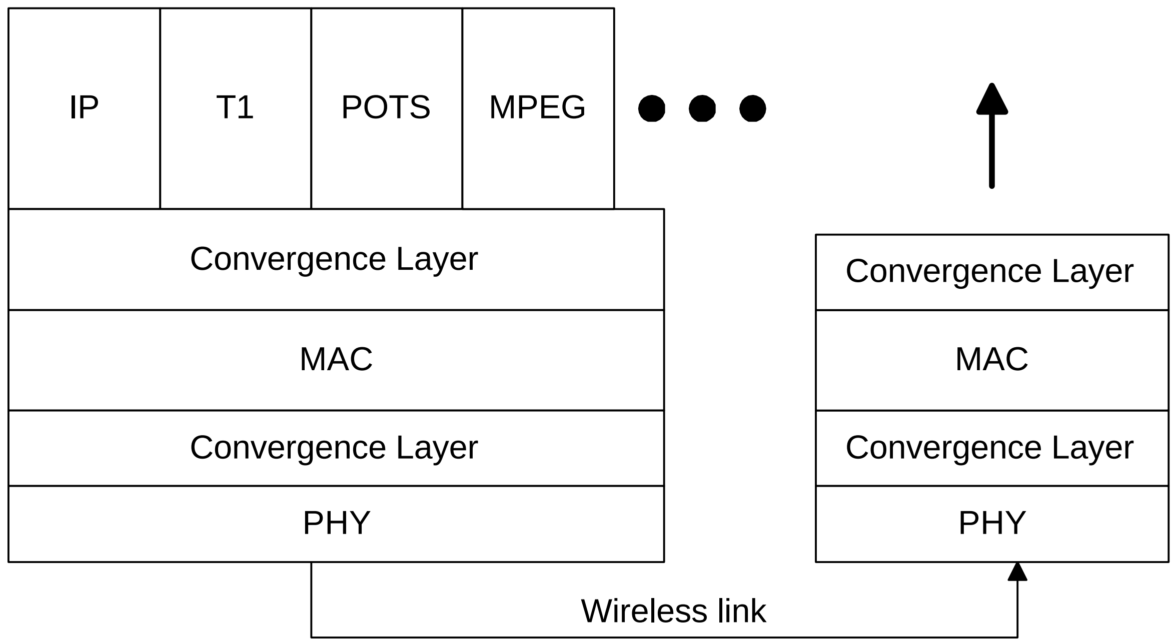
Philosophy behind the design

- Leverage the designs of other existing standards
  - –Relevant standards include: ETSI EN 300 421, ETSI EN 301 210, ETSI EN 301 199, ITU-T J.83, Data-Over-Cable Service Interface Specifications
  - –Allows for rapid deployment of standardized equipment
  - –Reduces cost by allowing chip vendors to design products to meet multiple standards
  - –Validates concept and robustness of design through operational equipment
  - –Fosters international support for this standard
- Define simple and robust mode of operation
  - –Reliability is very important for BWA to gain credibility in the public eye
  - –Additional "optional" modes defined for future migration to greater capacity, improved performance, bigger cells…

Philosophy behind the design (cont.)

- Importance of flexibility
  - BWA systems will service many different applications
    - Internet access for business and residential,Video on demand, Trunked T1/E1, POTS, Virtual LANs
  - Various system requirements will exist
    - BER, Cell radius, Cost, Available BW, Carrier frequency
  - Allow service providers to optimize deployments for targeted markets
- Large BW = greater statistical multiplexing gain

Reference Configuration



Multiple Access and Duplexing Technique

- Multiple Access and Multiplexing
  - TDM Downstream (DS)
  - TDMA Upstream (US)
    - Bandwidth on Demand allocation of time slots
- Duplexing Technique
  - Basic mode of operation was designed for FDD
    - Many allocations world wide have already defined US and DS channels
    - Ortho-mode transducers can be used to reduce radio unit cost and allow operation in narrow channels
  - Optional mode of operation defined to support half-duplex FDD or TDD operation utilizing same components of basic FDD mode.

DS Transmission Convergence Sublayer

- Based on MPEG packet structure including a 4-byte header + a 1-byte pointer byte as needed
  - Allows for efficient multiplexing of MPEG video streaming with MAC payload
    - Added flexibility results in only ~2-3% reduction in Downstream Bandwidth
- Convergence sublayer segments the incoming data from the MAC into fixed 188 byte payloads to be Reed-Solomon encoded
- Convergence sublayer is independent of MAC layer packet structure

Format of MPEG packet

Header 4-bytes	P	183-184 byte Payload

Field	**Length (bits)**	**Description**
sync_byte	8	0x47 or 0xB8; MPEG Packet sync byte
transport_error_indicator	1	Indicates an error has occurred in the reception of the packet. This bit is reset to zero by the sender, and set to one whenever an error occurs in the transmission of the packet.
payload_unit_start_indicator (PUSI)	1	A value of one indicates the presence of a pointer_field as the first byte of the payload (fifth byte of the packet).
transport_priority (frame_start_indicator)	1	This bit is set to 1 to indicate the beginning of a downstream frame, when framing is used.
PID	13	802.16 well-known packet ID (TBD)
transport_scrambling_control	2	Reserved, set to '00'
adaptation_field_control	2	'01'; use of the adaptation_field is NOT ALLOWED on the 802.16 PID
continuity_counter	4	cyclic counter within this PID

Operation of the pointer byte

•The pointer_field contains the number of bytes in the packet that immediately follow the pointer_field that the subscriber station decoder must skip past before looking for the beginning of an 802.16 MAC frame.

•A pointer field MUST be present if it is possible to begin an 802.16 MAC frame in the packet, and MUST point to either:

– the beginning of the first MAC frame to start in the packet

– to any stuff_byte preceding the MAC frame

Header (PUSI=1)	P =M	Tail of MAC frame #1 (M bytes)	stuff_byte (0 or more)	Start of MAC Frame 2

P=1 byte pointer field

Downstream framing

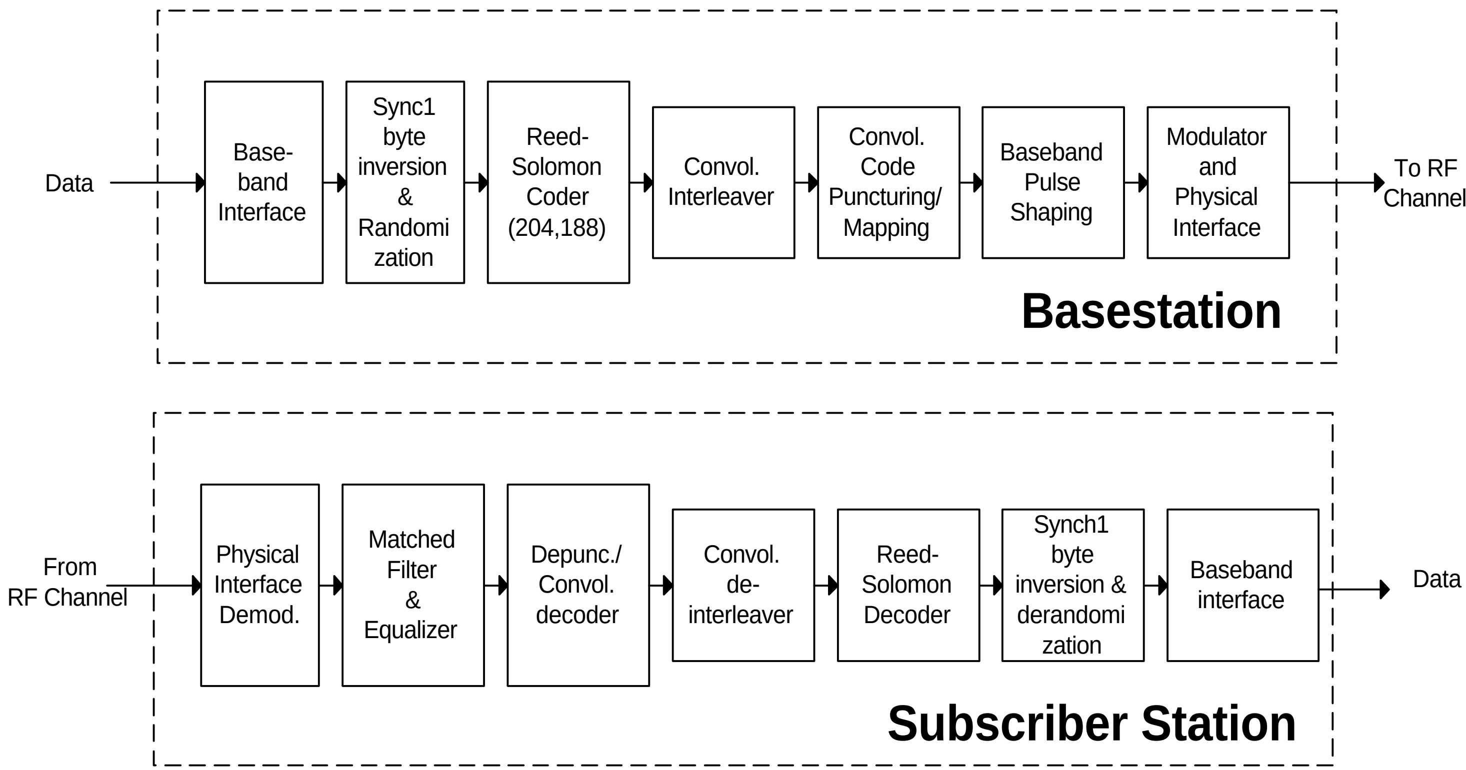
- •Downstream channel could be partitioned into a series of frames, where each frame contains an integer number of MPEG packets.
- •Variable length frame times can be supported by having programmable symbol rates using any of the DS coding options that will be discussed.
- •Frame_start_indicator in the header byte can be used to frame the DS packets.
- •This framing bit can be ignored if framing is not used.

US convergence sublayer and framing

- Directly transports MAC packets in the upstream channel
  - No convergence sublayer encapsulation used
- Upstream time slot and framing concept
  - Upstream channel is divided into a contiguous series of time slots which define the granularity of bursts
  - Time slot sizes and uses are to be defined by the MAC layer
  - A "virtual framing" structure can be accommodated
    - Used to simplify bandwidth allocations for guaranteed QoS applications
    - Variable length frame times can be supported through programmable symbol rates

Downstream Physical Layer

Mode A: Basic Mode of Operation



Downstream Physical Layer (cont.)

Summary of Mode A Downstream Physical Layer Parameters

Randomization	$1 + X^{14} + X^{15}$ Initialization: 100101010000000
Reed-Solomon Coding	(204,188) based on GF(256) with T=8 byte errors correction capability
Interleaving	Convolutional with depth I=12.
Convolutional coding	Selectable: rate ½, 2/3, ¾, 5/6, 7/8, or 1 (disabled)
Modulation	QPSK or 16-QAM (16-QAM supported only when convolutional coding is disabled)
Differential encoding	enabled/disabled (only enabled when convolutional coding is not employed)
Spectral shaping	α=0.15 or 0.35
Spectral inversion	inverted or non-inverted
Achievable symbol rates	1-45 Mbaud

Downstream Physical Layer (cont.)

Optional Modes

- Optional modes need not be implemented to be standards compliant
- When an "optional" mode or mechanism is implemented, it shall comply with the specification as given in the present document
- This approach to standardization allows for the following:
  - Rapid time to market using existing and mature technologies identified by the basic mode of operation
  - Defines a migration path for:
    - Advanced coding and modulation techniques
    - Added flexibility to support different services and/or deployment scenarios
    - Higher capacity links for future upgrades
    - Reduced equipment costs for sensitive markets

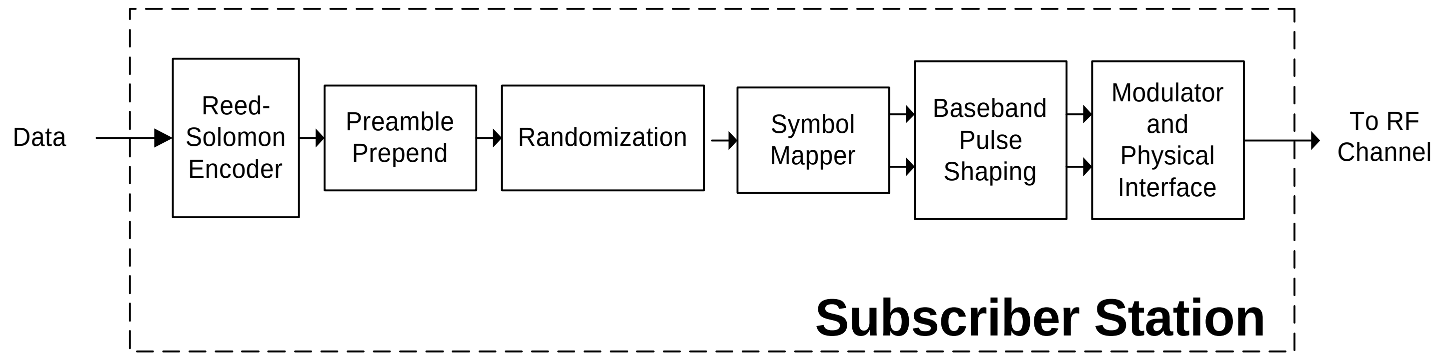
Downstream Physical Layer (cont.)

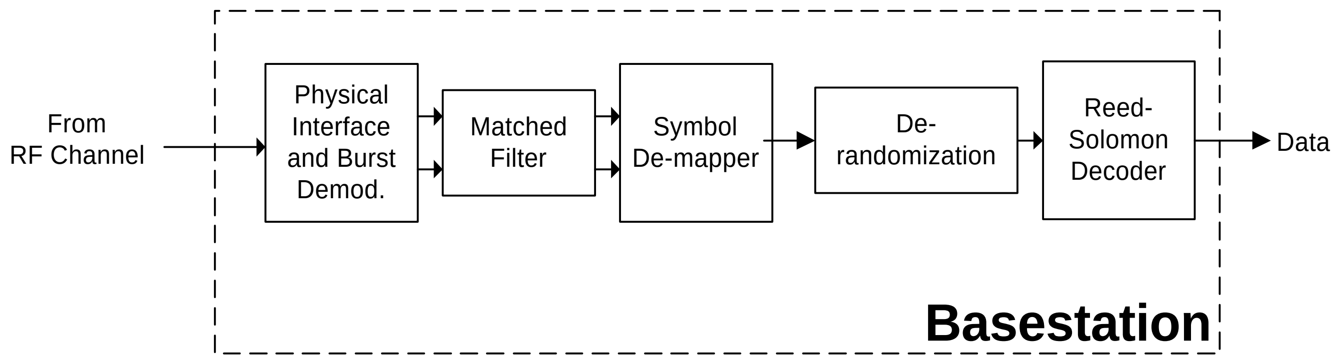
Summary of Downstream Physical Layer Optional Modes

Mode B: Enhanced flexibility mode	Defines the support of a variable length interleaver, a programmable roll-off factor, 64-QAM modulation with differential encoding, or $\pi/4$-DQPSK modulation.
Mode C: Advanced coding and modulation mode using Binary Product Codes	Replaces convolutional interleaver, Reed-Solomon encoder, and inner convolutional code with a Binary Product Code. Supports 4, 16, and optionally 64QAM Gray coded constellations.
Mode D: Advanced coding and modulation mode using "pragmatic" trellis codes	Use same inner convolutional code as basic physical layer with 8-PSK and 16-QAM constellations and different input to inner code and mapping of bits to symbols.
Mode E: Advanced duplexing mode supporting Half-Duplex FDD and/or TDD	Bypasses interleaving and inner convolutional coding, and modifies convergence layer to support a preamble for burst detection.

Upstream Physical Layer

Mode A: Basic Mode of Operation





Upstream Physical Layer (cont.)

Summary of Mode A Upstream Physical Layer Parameters

Reed-Solomon Coding	Based on GF(256) Codeword lengths: 18-255 bytes T=0-10
Randomization	$x^{15}+x^{14}+1$ Initialization seed: 15-bit programmable
Preamble	Programmable length: 0-1024 bits Programmable value
Modulation	QPSK or 16-QAM
Differential encoding	Selectable on/off
Spectral shaping	α=0.25
Achievable symbol rates	up to 40 Mbaud
Frame time (when enabled)	Programmable in steps of 125 usec

Upstream Physical Layer (cont.)

Summary of Upstream Physical Layer Optional Modes

Mode B: Enhanced Flexibility Mode	Adds support of a variable roll-off factor for spectral shaping with α=0.15-0.35 and π/4-DQPSK.
Mode C: Advanced coding and modulation mode using Binary Product Codes	Replaces Reed-Solomon encoder with a Binary Product Code.

Upstream Physical Layer (cont.)

Upstream channel descriptors

Parameter description	**Parameter needed from MAC**	**Meaning**
Mini-slot size	8-255 (M)	Number of bytes per mini-slot, which is the smallest unit of time slot size
Framing mode	0 or 1	enabled/disabled
Frame time	0-255 (N)	Frame time is Nx125 usec N=0 indicates framing is disabled
Mini-slots per frame	0-65,535 (P)	Number of mini-slots per frame
Symbols per mini-slot	0-1024 (Q)	Integer number of symbols per mini-slot period (independent of modulation used for transmission)
Upstream symbol rate (when framing is enabled)	--	Rs=PxQ/(Nx125 usec)
Upstream symbol rate (when framing is disabled)	--	Rs=PxQ/(125 usec)
Roll-off factor*	Ro	Ro=15-35 (for α=0.15-0.35)
Spectrum inversion	0= inverted, 1=non-inverted	
Scrambler tap coefficients	16 bits	Each tap is either on (1) or off (0)
Upstream center frequency	0-60 GHz	in KHz

* = used in optional mode only

Upstream Physical Layer (cont.)

Burst Profiles

Parameter description	Parameter needed from MAC
Modulation	2=QPSK, 4=16-QAM
Preamble length	0-1023 bits
Preamble pattern	0-1023 bits
RS information bytes	16-255 bytes
Error correction of codeword	0-10 bytes
Last codeword length	1=fixed; 2=shortened (**optional**)
Guard time	0-255 symbols
Scrambler seed	15 bits
Differential encoding	on/off
Maximum burst size	0-255 mini-slots
Scrambler	on/off

Radio Sub-system Control

- Synchronization
  - –MAC to control ranging alignment through periodic polling
  - –Downstream demodulator should have the capability to provide a reference clock that is phase locked to the downstream symbol rate
  - –Framing can be controlled by the MAC and convergence layer
- Frequency
  - –MAC to control ranging alignment through periodic polling
  - –US and DS RF frequencies should reference each other to allow for low cost CPE equipment
- Power
  - –MAC to control ranging alignment through periodic polling
  - –US power level should reference DS received power level to correct for correlated fades (possibly due to rain or other shadowing)
  - –Should support at least 5 dB/sec fades with depths of at least 20 dB
  - –Should be able to account for static attenuation due to distance loss for up to 20 dB distance variation

Physical Layer Transmitter Characteristics

- Some characteristics are listed in the paper
- These can be defined and discussed at a later date

Evaluation Table

- Meets system requirements
- Spectrum efficiency

Downstream:
assuming α=0.25 and
a payload of 183 bytes.

Modulation	Inner Code Rate	bps/Hz
QPSK	0.5	0.71765
	0.666666667	0.95686
	0.75	1.07647
	0.833333333	1.19608
	0.875	1.25588
	1	1.43529
HPC (rate=0.714)*	1	1.1424
8-PSK*	0.666666667	1.43529
*	0.833333333	1.79412
*	0.888888889	1.91373
16-QAM	1	2.87059
*	0.75	2.15294
*	0.875	2.51176
HPC (rate=0.714)*	1	2.2848
64-QAM*	1	4.30588
HPC (rate=0.714)*	1	3.4272

* = "optional" mode

Upstream: As an example: 4 byte preamble, 1 byte guard time, roll-off of 0.25, and QPSK modulation.

bps/Hz=1.247 (RS(63,53) code with differential encoding)

Evaluation Table (cont.)

- Simplicity of implementation
  - leverages existing standards
- CPE cost optimization
  - leverages existing standards
- Spectrum resource flexibility
  - proposal contains several flexible parameters including:
    - symbol rates, roll-off factors, modulation, coding
- System diversity flexibility
  - convergence layer is MAC independent
- Protocol interfacing complexity
  - convergence layer is MAC independent
- Implications on other network interfaces
  - convergence layer is MAC independent

Evaluation Table (cont.)

- Reference system gain
  - Assumptions: BER=10^(-10), 40 MHz DS channel, 10 MHz US channel, DS and US assumes a 0 dBW transmitter, 0 dB NF LNA, noise floor = -174 dBm + 10log(BW). See Annex B for complete results.

Modulation	**Inner Code**	**Eb/No (dB)**	**C/N (dB)**	**Backoff (dB)**	**RSG (dB)**
Downstream					
QPSK	5/6	6	7.85	4	116.13
Upstream	**Code rate**	**Eb/No (dB)**	**C/N (dB)**	**Backoff (dB)**	**RSG (dB)**
QPSK (differential encoding)	53/63	11	13.25	4	116.75

Note that the above numbers include an implementation loss of 0.8 dB in the downstream and 2 dB in the upstream.

Evaluation Table (cont.)

- Robustness to interference
  - Basic mode of operation uses QPSK modulation with flexible code rates to accommodate different channel conditions
- Robustness to channel impairments
  - Basic mode of operation uses QPSK modulation with flexible code rates to accommodate different channel conditions

Limitations of Proposal

- Added flexibility may require provisioning during installation or negotiation with MAC layer
  - Accurate pointing of antennas at installation could be critical, so local configuration of the subscriber station may be acceptable
  - Use of "smart card" type techniques could allow for user provisioned subscriber stations
  - Automatic receiver detection algorithms

Benefits of Proposal

- Flexible, reliable, low cost mode of operation that enables rapid time to market for this standard
- Optional modes defined which support enhanced coding and modulation, system optimization based on specific service requirements, higher capacity links, and cheaper deployment costs
- Proven reliability in deployed systems for satellite channels, cable channels, as well as BWA channels in 10-60 GHz
- Leverages existing international standards for world-wide acceptance