NGBP Physical Layer Overview

September, 2014

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Agenda

- Meeting Objectives and PHY Development Process
- Frame Structure
- Channel Mapping
- System Configuration and Parameter Selection
- Provisioning and Payload Builder
- Service Multiplexing
- Signaling and Sync Detect

NGBP PHY System Overview

Meeting objectives and PHY development process

Objectives

- Discuss updates to the ONE Media NGBP PHY:
  - Vet the technical approach;
  - Discuss refinements/strategies to re-engage S32.
- Identify opportunities for collaboration moving forward
  - S32 sub-committee activities
  - Separate interaction
  - Cooperation with 3GPP

PHY Development Process

Market Requirement

NGBP PHY: Parameterized OFDM Waveform + Extensible Signaling Framework	Reliable mobile reception	Increased Throughput Efficiency	Fixed and mobile service delivery in the same channel resource
	Configurable sampling rate and subcarrier spacing	Wide range in available FFT sizes and CP durations	Mixed FFT mode time-multiplexing

ONE Media Response

PHY Development Process

Market Requirement

Frequency Agility	Bandwidth Scalability	Spectrum Sharing

ONE Media Response

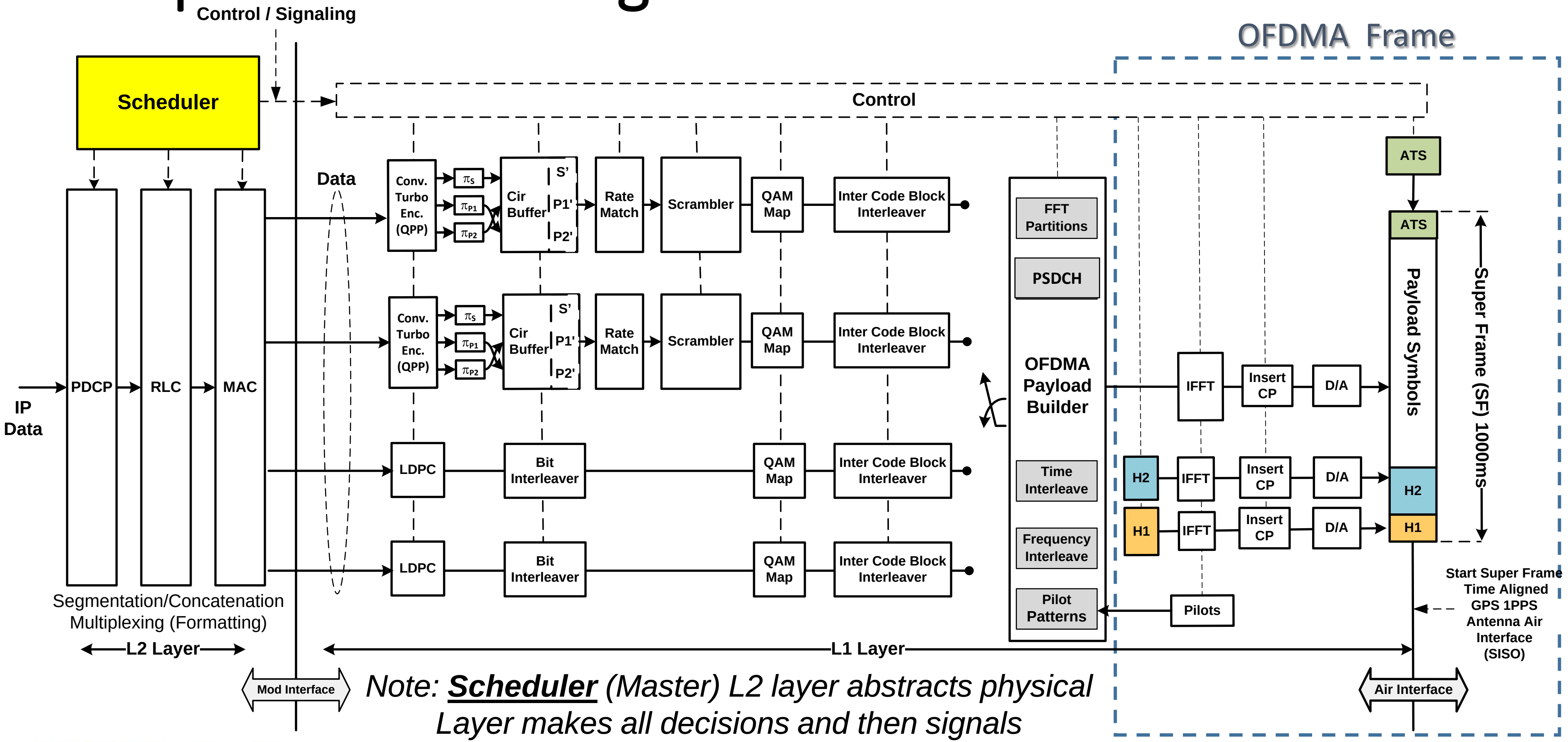
Unified approach to parameter selection and frame configuration	Configurable sampling rate independent of signal BW	Configurable frame duration aligned to GPS timing

NGBP PHY: Parameterized OFDM Waveform + Extensible Signaling Framework

NGBP PHY System Overview

Frame Structure and Channel Mapping

Simplified Block Diagram

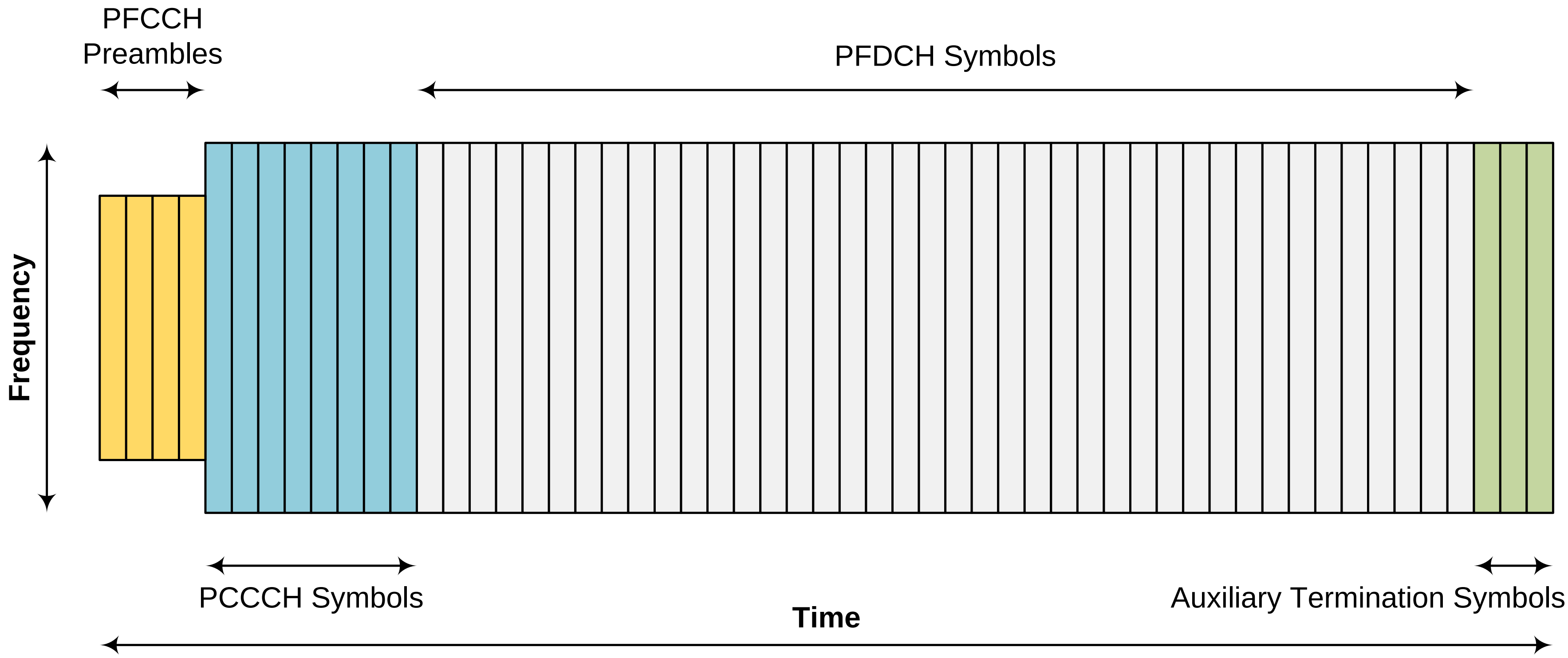


*Note: **Scheduler** (Master) L2 layer abstracts physical Layer makes all decisions and then signals L1 layer (Slave) to build each Frame*

Channel Definitions

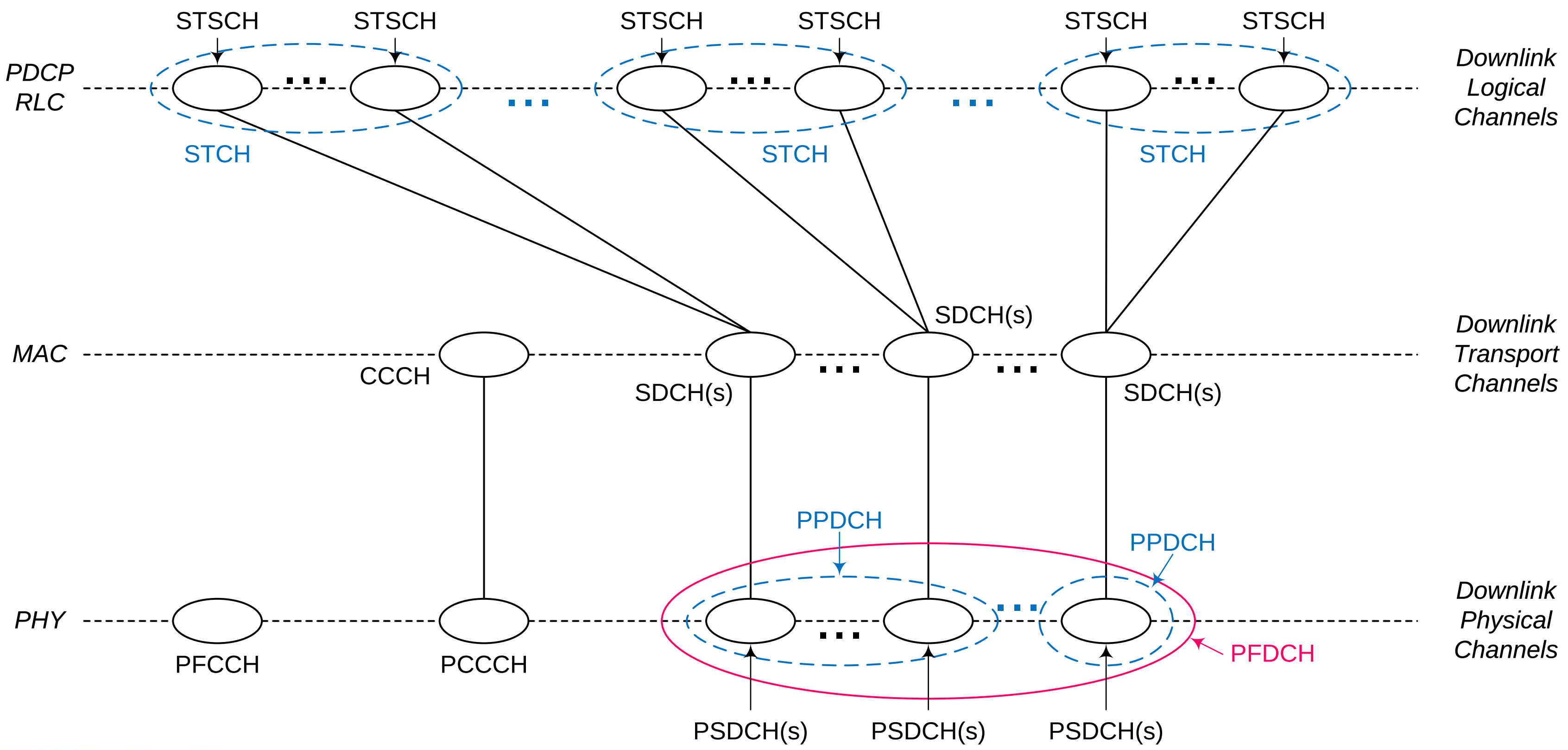
Level	Channel	Full Name
Logical	STCH	Service Traffic CHannel
	STSCH	Service Traffic SubCHannel
Transport	CCCH	Content Control CHannel
	SDCH	Service Data CHannel
Physical	PFCCH	Physical Format Control CHannel
	PCCCH	Physical Content Control CHannel
	PFDCH	Physical Frame Data CHannel
	PPDCH	Physical Partition Data CHannel
	PSDCH	Physical Service Data CHannel

ONE Media Frame Structure



Note: Not shown to Scale, Number of PFCCH, PCCCH, and ATS Symbols signaled in PFCCH

Channel Mapping



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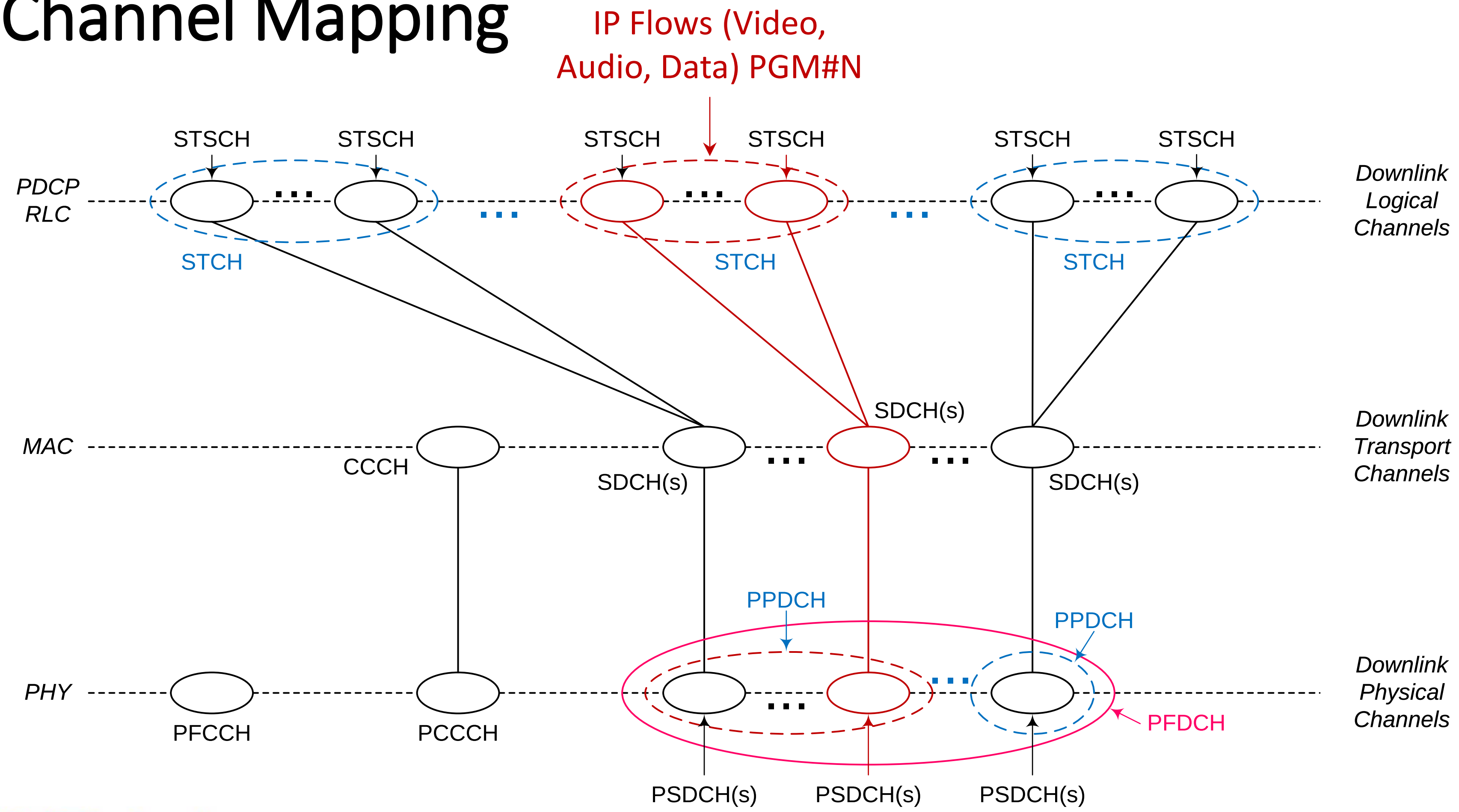
Channel Mapping



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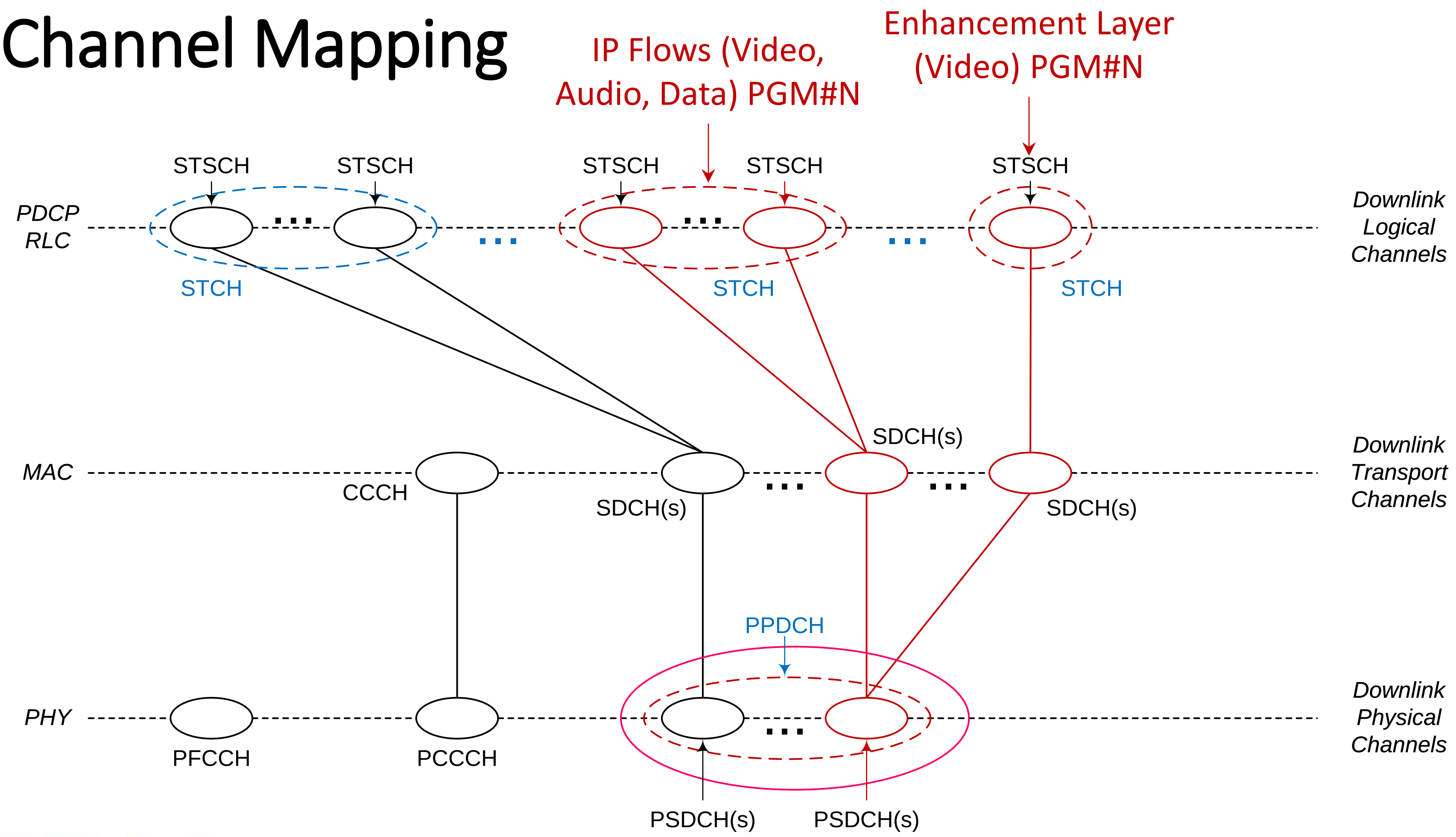
Channel Mapping



NGBP PHY System Overview

System Configuration and Parameter Selection

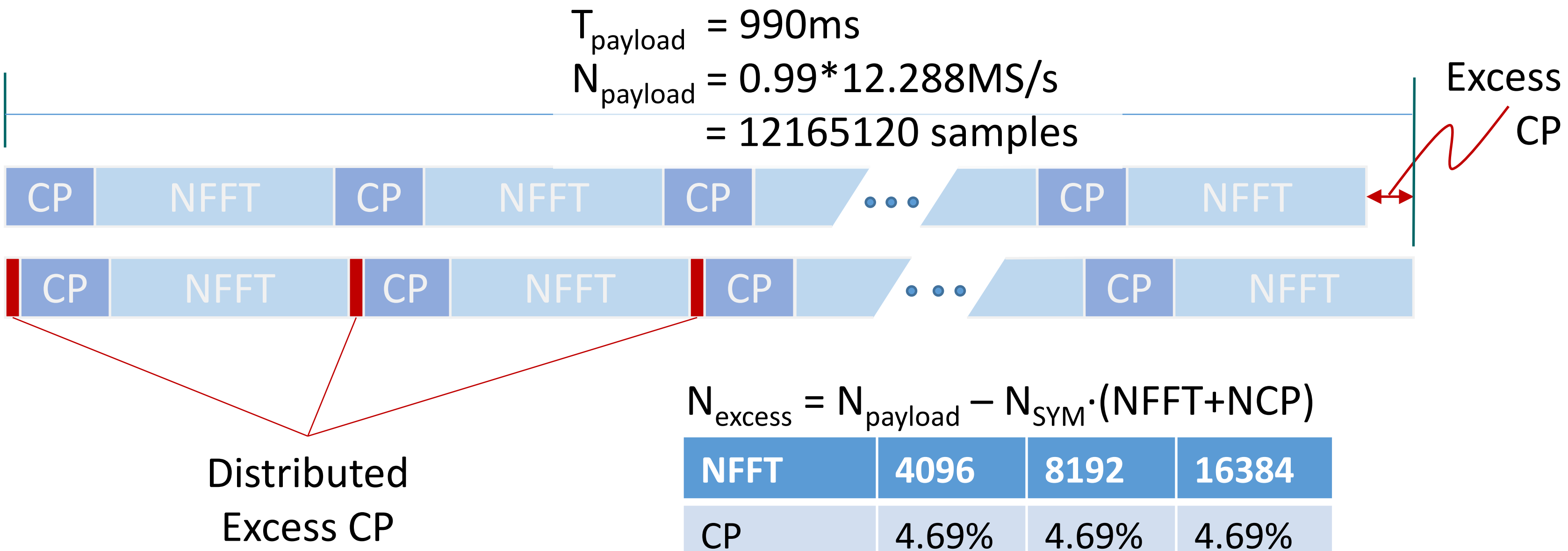
System Parameters

- **I/FFT:**
  - ***1K, 2K, 4K, 8K, 16K, 32K, 64K***
- **GI Duration:**
  - ***CP%*** relative T_{FFT}
  - *Fractional* GI via non-uniform CP distribution
- **Modulation** *(configurable per Service Data CHannel (PSDCH))***:**
  - Uniform ***QPSK, 16/64/256-QAM/…..?***
  - ??: non-uniform constellations for future extensibility?
  - ??: higher order modulation for future extensibility?
  - ??: hierarchical modulation for layered services?
- **Coding** *(configurable per Service Data CHannel (PSDCH))***:**
  - Convolutional Turbo Coding (CTC) with rate matching for ***mobile services***
  - Low Density Parity Check (LDPC) codes for ***fixed services***
  - ??: multiple decoder types for fixed reception?
- **Frame Structure**
  - Adjustable sampling rate (Fs), frame duration, signaling extent
  - Adjustable pilot density, pilot patterns, signal bandwidth (sub-bands)
  - Adjustable partitioning, service multiplexing, inter-code block interleaving

Waveform Generation (updated)

- Parameter selection:
  - Determine the minimum subcarrier spacing needed to support the intended user mobility
    - $v_D \Rightarrow \Delta f, F_S$
  - Determine the CP length to meet the intended range requirement
    - $R \Rightarrow T_{CP}$
  - Determine the excess CP needed to yield an integer number of symbols per frame duration
    - $T_{EXCESS} = T_{SF} - N_{SYM} \cdot (T_{FFT} + T_{CP})$
  - Distribute the excess CP evenly among the first N symbol periods.
  - Enumerate the list of available system parameters as in any fixed standard to minimize signaling overhead.
- Sampling frequency (F_s = 7.68 x N/10 MHz):
  - Provides bandwidth flexibility
  - Ensures consistent Doppler performance across signal bandwidths
  - Enables added flexibility w.r.t. range/mobility performance tradeoffs

Non-uniform CP Distribution



$$N_{excess} = N_{payload} - N_{SYM} \cdot (NFFT+NCP)$$

NFFT	4096	8192	16384
CP	4.69%	4.69%	4.69%
N_{CP}	193	385	769
#symbols	2836	1418	709
N_{excess}	1516	2934	3643

NGBP PHY System Overview

Service Multiplexing

Payload Builder

Partition

- A PPDCH (Physical Partition Data Channel) is a rectangular logical area (# Sub-Carriers, # Symbols)
- Need not span the total bandwidth or time (PFDCH) 1 or more (PPDCH) are permitted in Physical Frame Data Channel (PFDCH) total bandwidth and each Partition can support a FFT Size

Provision

- PPDCH is provisioned for the intended environment by adding appropriate Pilot Pattern, etc.
- # Sub-carriers (Bandwidth), Virtual to Logical Sub-band stripes resource mapping

Assign

- Assign data (STCH) to provisioned PHY resources provided (PPDCH)
- Deterministic insertion of (STCH) into (PFDCH) can occur from central location and the Edge

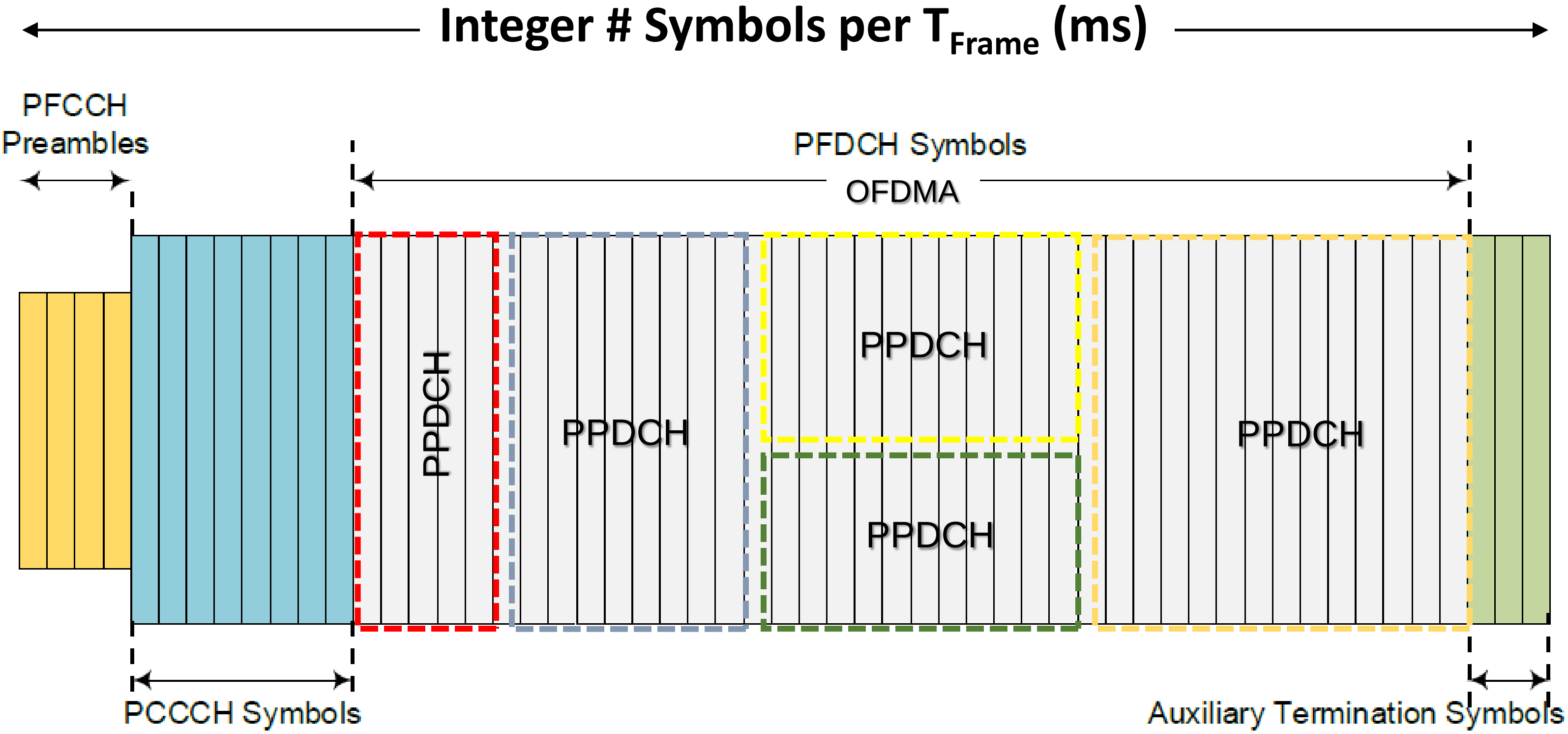
Service Multiplexing (1/2)

- Single Transport:
  - Each service type (fixed/mobile) confined to single band
  - Requires a separate channel, i.e. VHF, UHF per service type
  - Multiple SDCHs assigned per channel
- Split Band: FDM (w/ multiple SDCHs therein)
  - Distinct system configurations carried in separate sub-bands where the sub-bands together comprise a single channel
  - Each sub-band provisioned separately (BW, Δf, CP%)
  - Combined at respective IFFT outputs as time domain samples
    - Allows uneven split in signal BWs (predicated on fixed sampling rate)
    - Dynamically reconfigurable on Frame boundaries

Service Multiplexing (2/2)

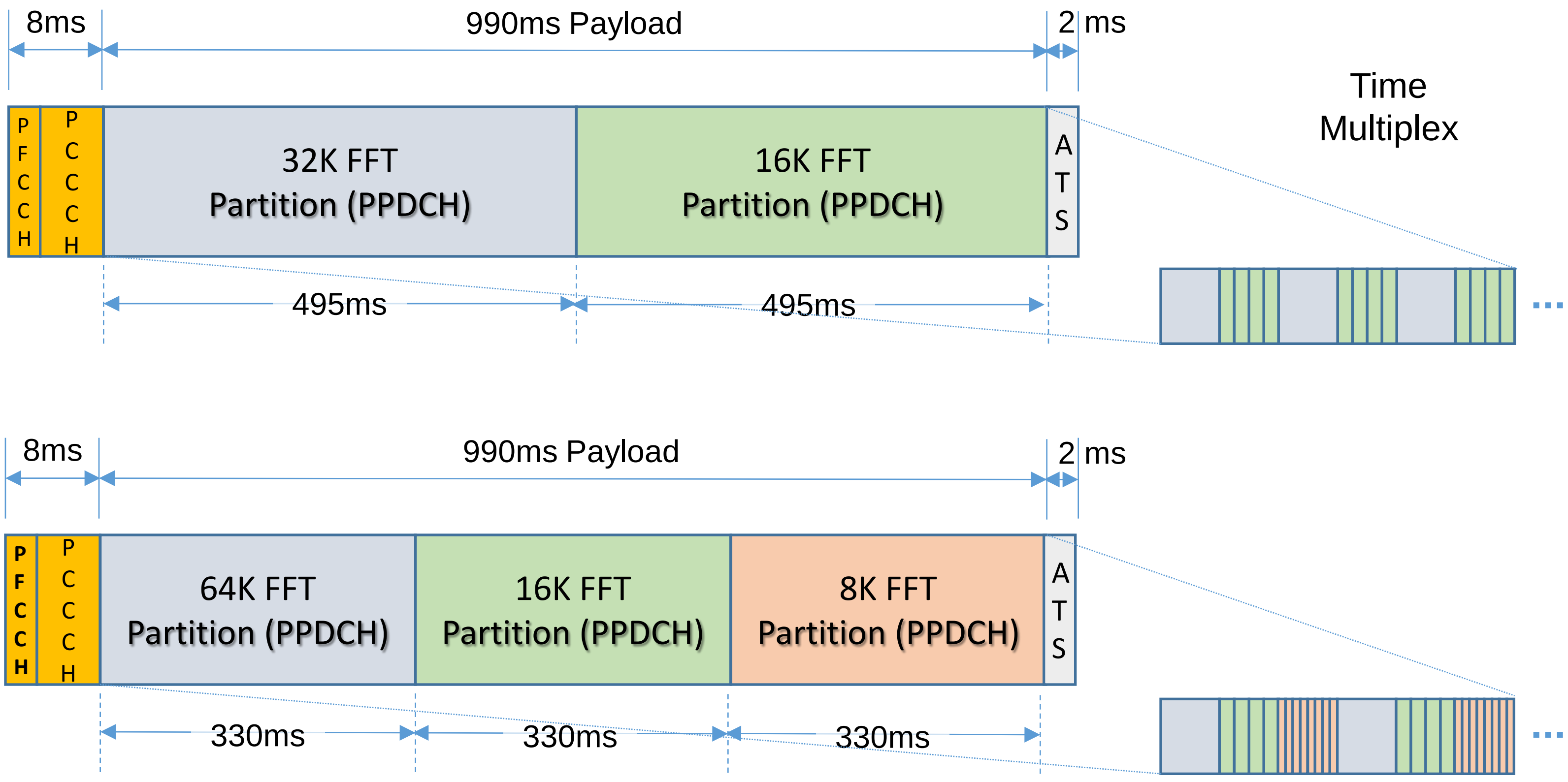
- Mixed FFT Mode: TDM (w/ multiple SDCHs therein)
  - Distinct system configurations multiplexed in time on OFDM symbol boundaries
  - Each time multiplex provisioned separately (Δf, CP%)
  - OFDM symbols interlaced in time to maximize time diversity
    - Statistical multiplexing of presumably separate symbol durations (again at a fixed sampling rate)
    - Dynamically reconfigurable on Frame boundaries

Frame Partitioning (T/F)



Note: Not to Scale, Each PPDCH (Physical Partition Data Channel) can support different FFT

Example: Mixed FFT Mode (TDM)



Note: Network Timing Super Frame Starts (1PPS) each STCH mapped (deterministically) Time/Freq Grid and Signaled

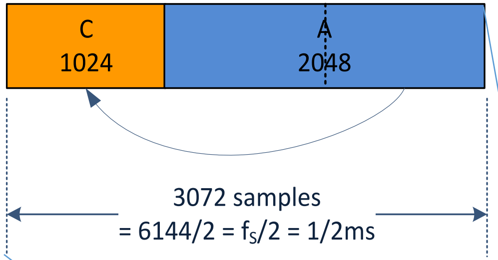
NGBP PHY System Overview

Preamble and Sync Detection

Signaling Structure

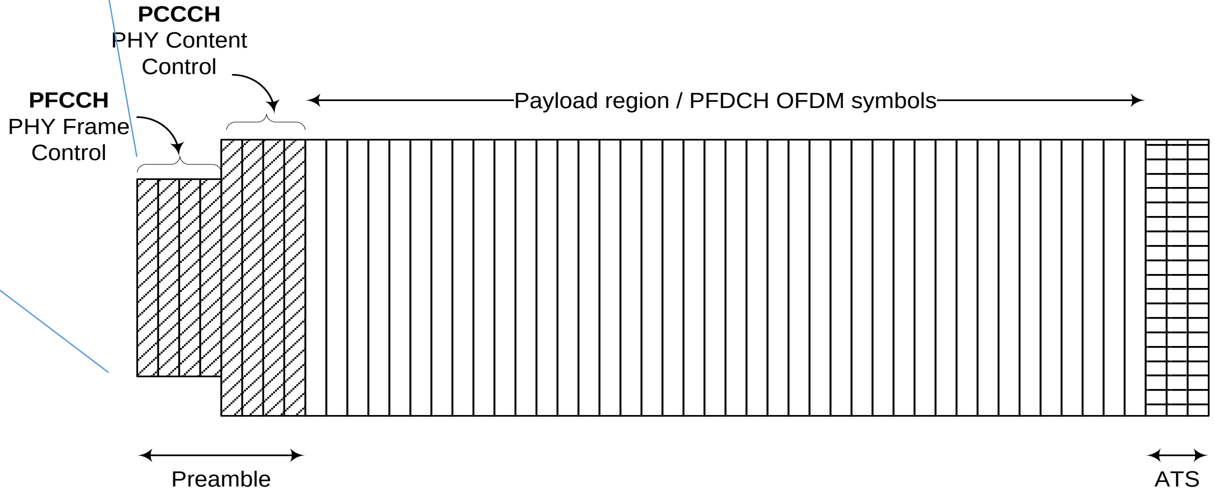
- ***PHY Frame Control CHannel (PFCCH):***
  - Provides initial synchronization and establishes the frame operating mode;
  - Enables channel estimation and initial carrier frequency offset (CFO) estimation;
  - Determines the frame configuration including the length of the preamble, the signal bandwidth and sampling rate, modulation and coding applied to PCCCH, and the presence of ATS.
- ***PHY Content Control CHannel (PCCCH):***
  - Describes the contents of the payload region including the number of partitions and the signal dimensions (i.e. FFT size and CP duration) applied in each partition;
  - Signals the mapping of data streams to each partition including the modulation, coding scheme, and interleaver depth.

PFCCH Signal Design



PFCCH:

- Symbol structure: N_{FFT} = 2048, N_{CP} = 1024, f_S = 6.144MS/s
  - T_{SYM} = 500µs, T_{GI} = 167µs, Δf = 3kHz
- ZC symbol contents modulated by PN sequence
  - Improves autocorrelation response
  - PN sequence reset at the start of each frame
  - Mitigates inadvertent correlation to preamble symbol other than the initial sync symbol

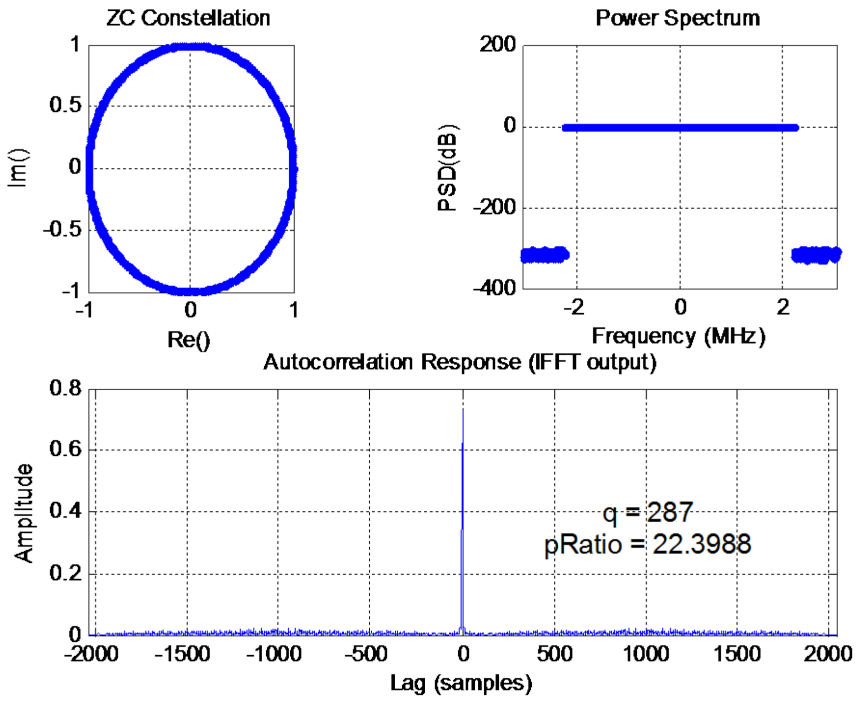


Design Objectives

- Universal signal discovery independent of channel bandwidth;
- Reliable detection in the presence of a variety of channel impairments, e.g. time dispersion and multipath fading, Doppler shift, carrier frequency offset;
- Multiple service contexts accessible based on mode detection during signal discovery enabling broad flexibility in system configuration;
- Extensibility to accommodate ongoing evolution in service capability based on hierarchical signaling structure;
- Reusable bit-fields interpreted based on the detected service mode/type enabling bit-efficient signaling despite the level of extensibility afforded.

PHY Preamble

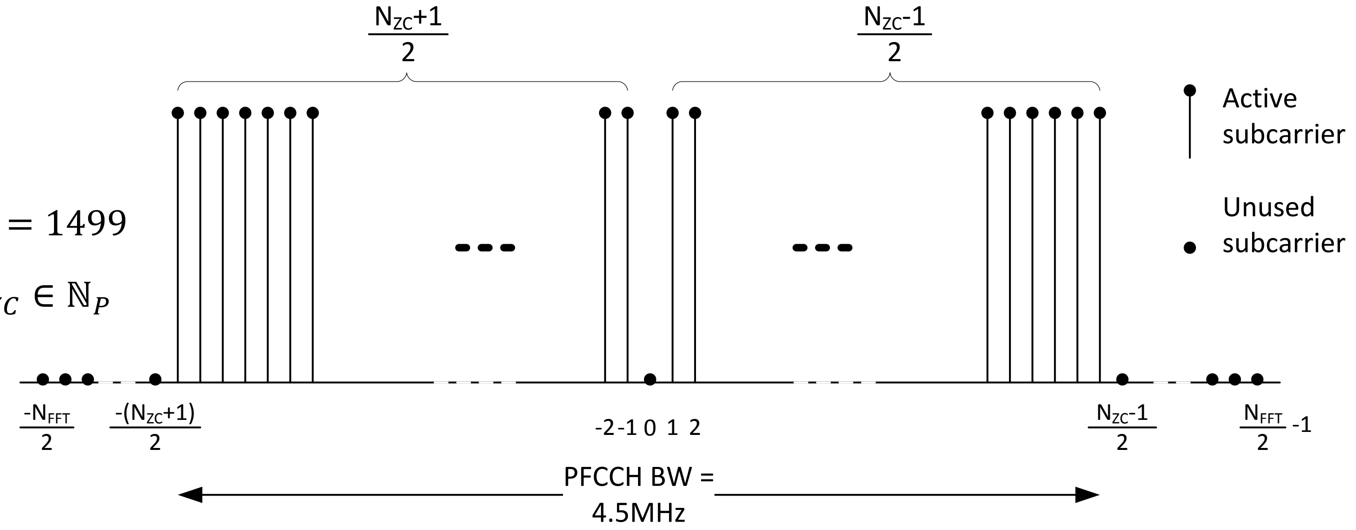
- **PFCCH**:
  - Sync detect/service discovery based on cross-correlation with a known preamble sequence;
  - Parameter selection conveyed post initial synchronization through cyclic shifts of the detected preamble sequence;
  - Hierarchical signaling protocol enabling reusable bit-fields, the interpretation of which is based on the detected service type.
- **PCCCH**:
  - Frame payload content description: # of partitions, FFT sizes and CP durations;
  - SDCH mapping: modulation, coding and interleaver depth.



PFCCH Subcarrier Mapping

$$N_{SC} = \left\lfloor \frac{B_{SIG}}{\Delta f} \right\rfloor - 1(null) = 1499$$

$$N_{ZC} = max[1: N_{SC}], N_{ZC} \in \mathbb{N}_P$$



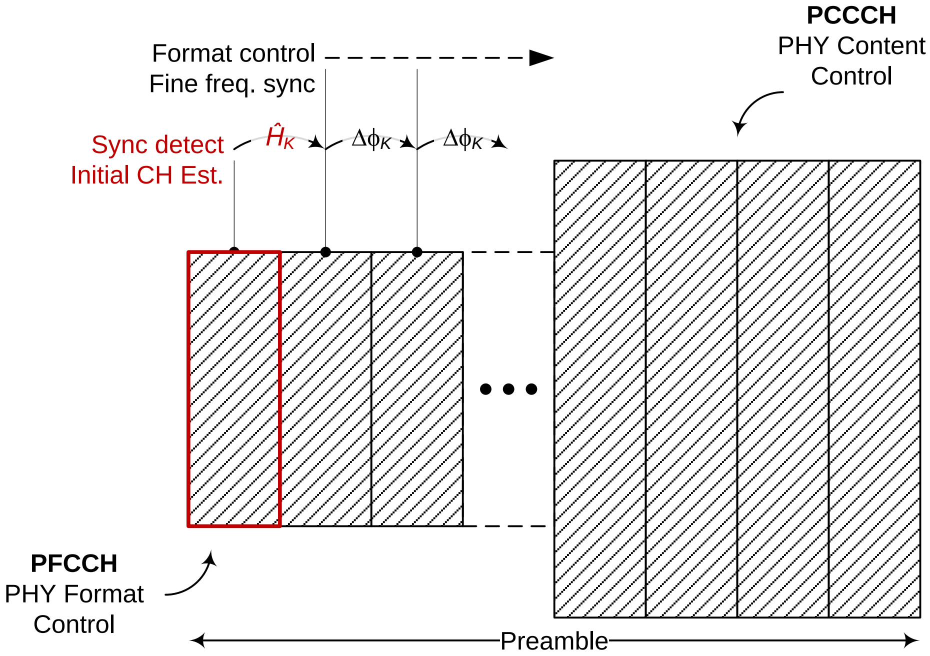
The complex preamble sequence is mapped to the IFFT input on either side of the DC subcarrier;
Given an odd length sequence, one additional subcarrier is mapped to the negative frequencies such that an equal number of subcarriers are mapped to negative and positive frequencies where positive frequencies include DC.

Sync Detect and CE

Sync Detection: based on correlation to one of many prescribed roots of the ZC sequence (zero cyclic shift).

Mode Selection: the detected root sequence determines the service type/ mode carried in the frame, e.g.: Standalone Transmission, Broadcast Management Exchange (BMX) Controlled, BMX Beacon, …, Private Use, …

Channel Estimation: cross correlation of the identified sync detect symbol is available for channel estimation. The channel estimate is used in compensating for time dispersion and other channel effects prior to decoding the remaining PCCCH symbols.



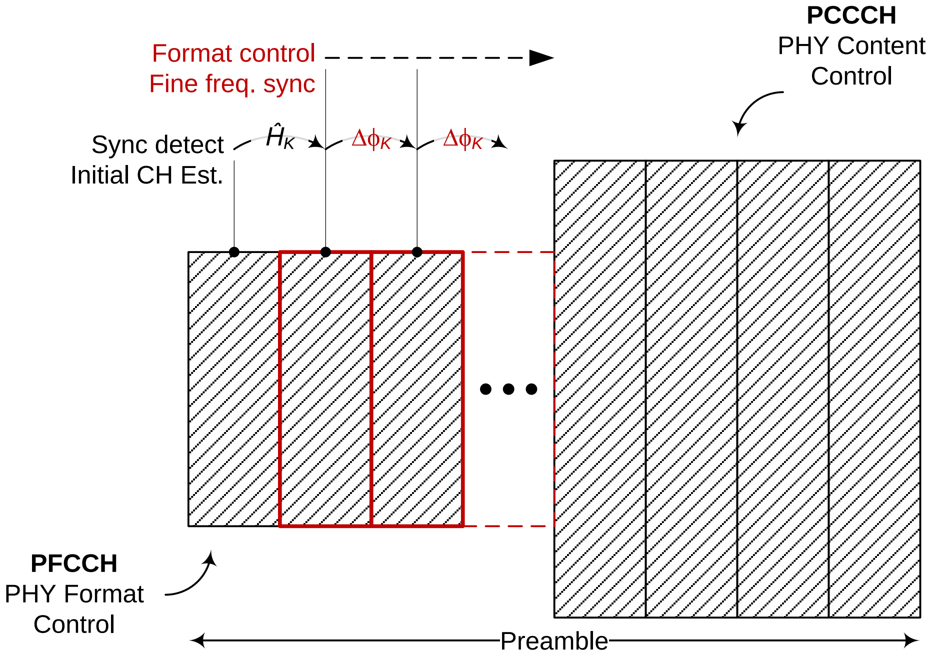
Frame Format Control

Cyclic shifts of the detected root sequence are applied in symbols following initial sync detection, i.e. secondary symbol periods, to convey the frame configuration.

Context Mapping: the observed (estimated) cyclic shift is mapped to an assigned bit-field, the meaning of which is specific to a current symbol period (i.e. proximity to the sync detect symbol) interpreted relative to the context set by the detected service mode.

Frame Format Parameters: frame count, frame duration, signal bandwidth employed in PCCCH and the frame payload, the PCCCH FFT size and CP length, the PCCCH modulation and code rate.

Fine Symbol Sync: delayed correlation (CP) is available per secondary symbol to refine frequency offset estimates, compensation for which is applied in the next symbol period.

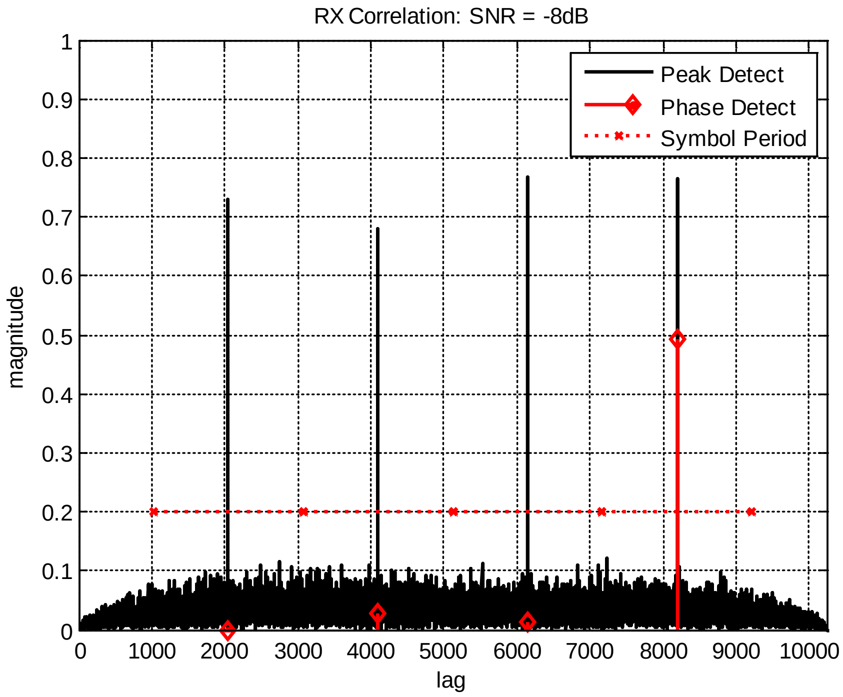


Field Termination

The sequence transmitted in the final symbol period is inverted (i.e. rotated 180°) signaling the end of PFCCH.

The final PFCCH symbol includes a cyclic shift as needed to convey additional parameter selection.

Provides an efficient means to indicate the start of PCCCH in the next symbol period while permitting the length of PFCCH to be extended to increase signaling capacity as needed as the system specification evolves.



Thank you!