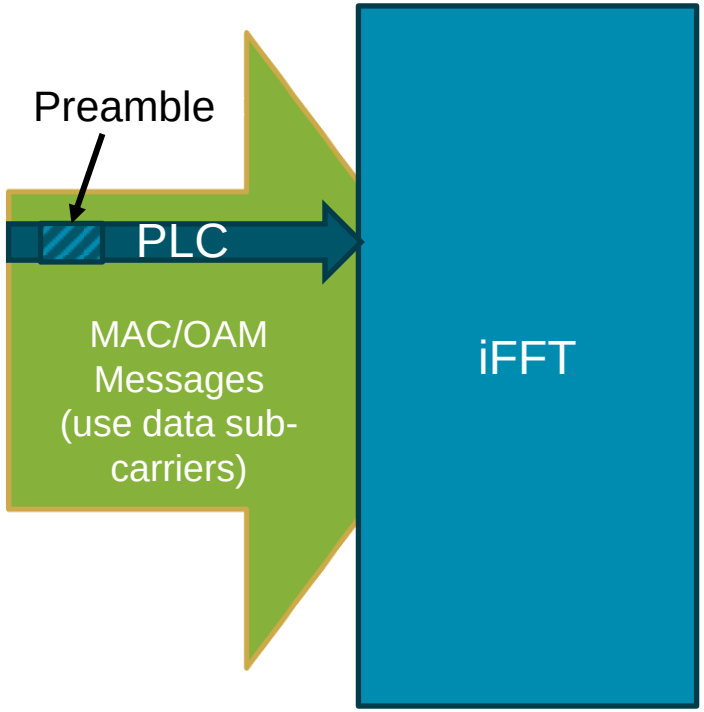
BROADCOM PROPOSAL FOR PHY SIGNALING

PRESENTED BY AVI KLIGER, BROADCOM

Four Types of PHY Signaling:

- **PHY Link Channel (PLC)**
  - Contains:
    - Information required for PHY link up, and details of OFDM channel and the baseline profile
    - Ranging information
    - Timestamps and synchronization information
    - Power management information (specifics TBD)
  - Uses dedicated sub-carriers
  - Center frequency is a DOCSIS downstream center frequencies (every 6MHz or 8 MHz)

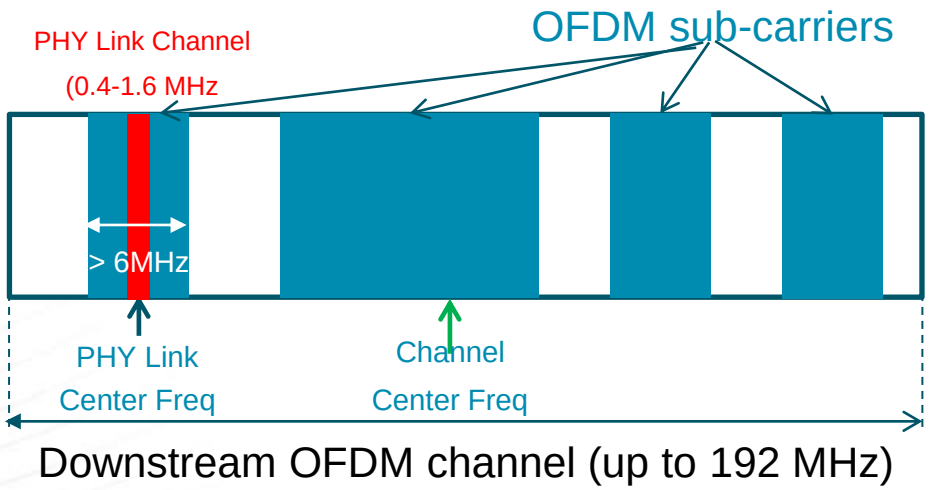
- **OFDM SYNC ("Preamble")**
  - Embedded in the PHY Link Channel
  - Used for initial OFDM channel detection and acquisition by a new node joining the network
- **MAC / OAM Messages**
  - Runs as part of the Data symbols
  - New OAM messages may be created, including profile information, upstream management, other OFDM-specific information, etc.



PHY Link Channel (PLC) and Preamble

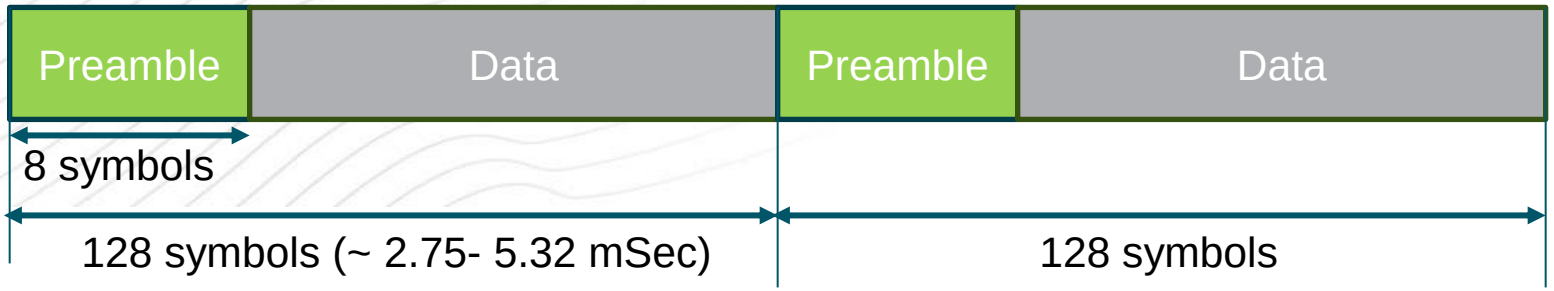
PHY Link Channel Details

- **QAM16 constellation**
  - ~12 dB more robustness to AWGN than QAM256 to protect against bad SNR
- **Center frequency is located at one of today's DOCSIS center frequencies (as determined by EIA or other channel plan in use by operator)**
- **Uses dedicated subcarriers**
  - 8, 16, or 32 subcarriers for 20 uSec symbol; 16, 32, or 64 for 40 usec symbol
  - Actual number of subcarriers provided in the PLC data
- **Specifics of messages to be sent are controlled by higher layer**
  - e.g., higher layer determines how often profile information must be sent, when to insert various sorts of power management or debug messages, etc.
  - New node management
  - Initial Ranging



PREAMBLE – "OFDM SYNC" FOR INITIAL ACQUISITION

- **Preamble is sent only on the subcarriers dedicated to the PLC**
- **Consists of a PN sequence in frequency domain**
- **8 symbol preamble duration gives excellent detection at bad SNR**
  - Better than 99.9% detection at SNR as low as 10 dB
  - Enables good detection performance with notches or narrowband noise
- **Preamble is repeated every 128 OFDM symbols**
  - This gives a preamble interval of ~2.75-5.32 mSec for 20u/40u symbols with CP=1.5uS
  - Could use a different number of symbols, but fixed in the spec
    - Tradeoff Preamble latency with PLC throughput overhead
  - Could be aligned with rotating pilot cycle
    - so that pilots do not interrupt preamble
    - Easy Pilots synchronization



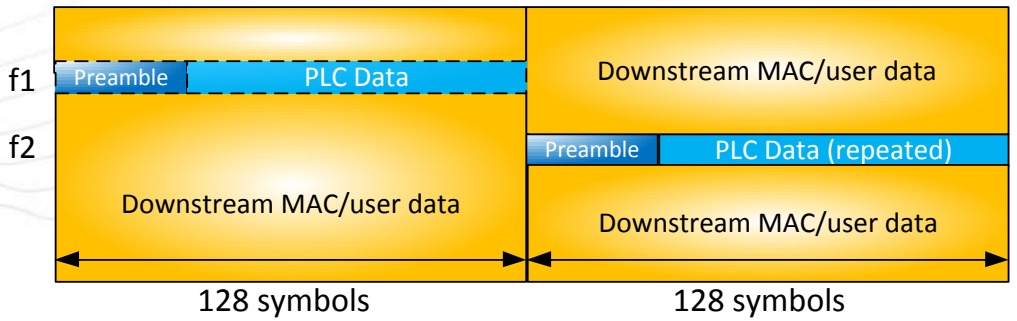
Initial Acquisition Sequence

- **Scan designated channel plan (6 MHz or 8 MHz) looking for PLC preamble**
  - The sequence below is an example and is implementation dependent
  1. Find FFT size and CP size using correlation
  2. Find FFT boundaries
  3. Find frequency offset
  4. Find Preamble
  5. Estimate channel using Preamble

  All should be accomplished in a single Preamble period on the average
- **Begin receiving PLC**
  - First symbol after Preamble include size of PLC and FFT size information
- **Decode PLC to find messages describing OFDM channel parameters (center frequency, available sub-carriers, FEC/Interleaving pointers, profile …)**
- **Start Admission process and Ranging**
- **Begin receiving Data**

PLC Robustness Against Burst Events and Ingress

- **FEC: ~4Kbit LDPC code with ~83% code rate**
  - This is an example.
  - Trade code performance (code rate) with latency to determine FEC
- **Burst events: No Interleaver needed!**
  - Since the channel is narrow, a 4Kbit FEC codeword is spread over up to 128 symbols
  - A burst event will only affect one to two OFDM symbols
  - FEC can readily be designed to correct for this
- **Ingress, narrowband notches, etc.:**
  - Ingress is often predictable; locate channel where ingressors are not expected
    - CLT is capable of moving the PLC channel if required
  - For narrowband notches (possibly seen by certain modems due to local micro-reflections), QAM 16 constellation gives an additional 12 dB or more robustness (compared to QAM 256 or higher)
- If this is not adequate, PLC can be duplicated at two different frequencies
- Or, the channel could alternate between two different frequencies, with the same information being sent on both



PLC Data Rate And Example Message Sizes

- **With 8 subcarriers (20 usec symbol) and an 83.3% code rate, there are 400 information Bytes between preambles**
- **PLC data rates range from 1.2 Mbps to 4.8 Mbps (see table)**
  - Duplicating data on alternating frequencies (see previous slides) would result in a “half rate” option of 600 kbps
- **A single profile descriptor message (describes 128 sub-groups, 16 such messages to cover a complete profile) of 52 bytes would take ~0.35 msec to send using the lowest-rate option**
  - ... or ~5.6 msec for a full profile description
    - … or ~1.3 msec using the highest-rate option

PLC Data Rate, Mbps (83.3% FEC, 2.5 uSec CP)

Symbol size (uSec)	Number of subcarriers			
	8	16	32	64
20	1.2	2.4	4.7	
40		1.3	2.5	5.0

profile descriptor message	
Number of subgroups per message	128
Header (bits)	8
CRC (bits)	16
FEC (bits)	4
Bit loading (bits)	384
Subgroups Identifier (bits)	4
Total (Byte)	52

Preamble Detection Performance And Scanning Times

- **Scanning time is implementation dependent**
  - Could tune to a single or multi frequencies simultaneously
  - A single cycle to discover FFT size and CP size and Preamble detecting should take one Preamble period on the average
- **Preamble detection performance**
  - Preamble is a repetition of a PN sequence in the frequency domain
  - Detection probability vs. SNR with different numbers of symbols and sub-carriers were simulated
  - Results depicted in table below

Number of symbols with 99.9% Preambles detection

Num of sub carriers	Numer of symbols		
	10	15	25
32	6	4	4
16	4	4	4
8	8	6	4

POWER MANAGEMENT

"Light Sleep Mode"

- **CNU can request to enter "light sleep" mode**
- **It is up to the CLT to move a CNU into "light sleep" mode**
  - Either per request from CNU or initiated by CLT
- **Data to the sleeping nodes is sent over the baseline profile**
  - Unicast and broadcast user data packets
  - Unicast OAMs
  - Running on the data subcarriers of the OFDM channel
- **The PLC is used to carry power management messages (specifics TBD) indicating that a Data is coming over the data channel**
  - This will need to be sent some amount of time (TBD) in advance
  - Example: wake-up message x*10 msec in advance for Data recurring every 200 msec
- **Power management messages on the PLC may be transmitted periodically or intermittently to allow the CNU to sleep between messages**


Thank You!