Overview of Broadband Cable Access Technologies

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Outline

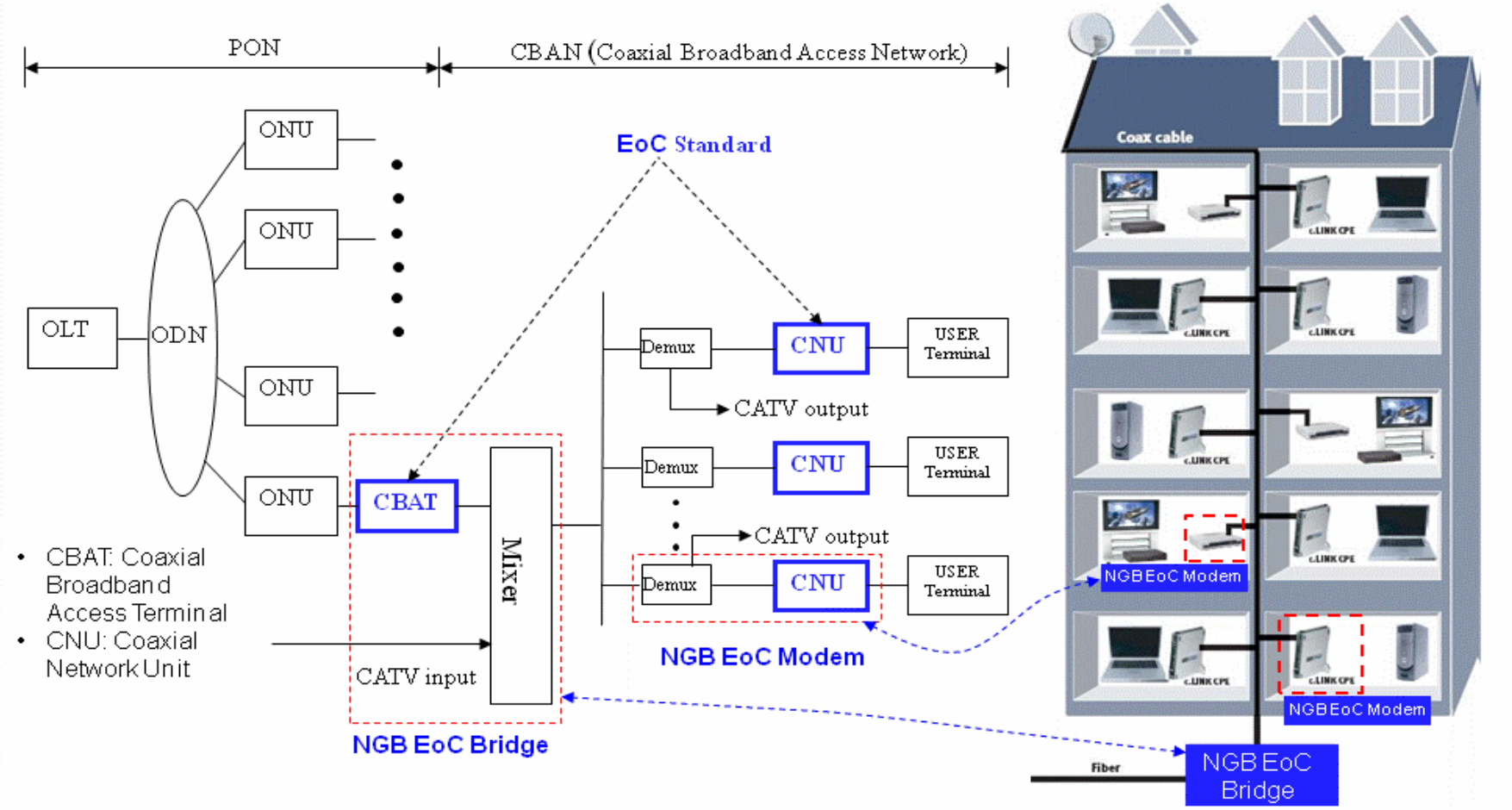
- **Introduction**
- **Technologies**
  - EPoC
  - MoCA
  - HINOC
- **ASTRI's Project Development: HINOC**
- **Summary**

Introduction

- **Broadband Cable Access Technologies**
  - Utilize the existing coax network for “last 100m” broadband access
  - Target data rate from hundreds Mbps to 1Gbps

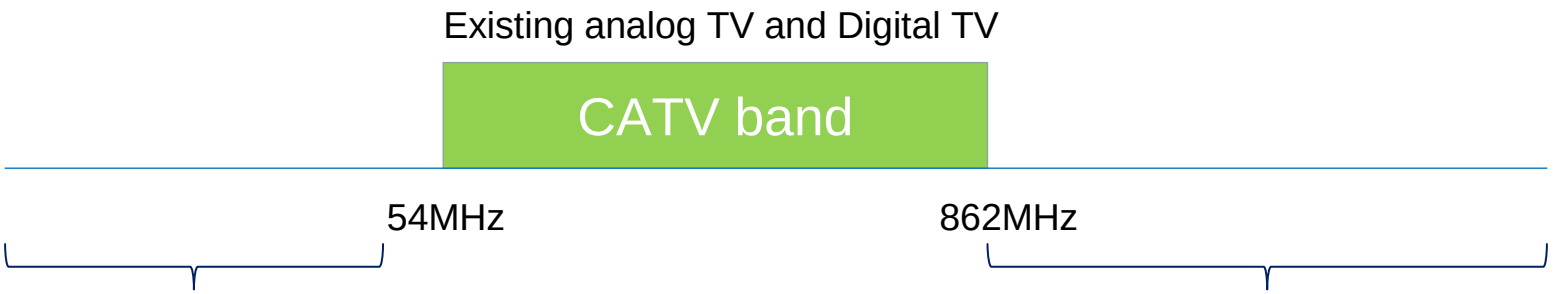
Cable Access Network Architecture

Example: Ethernet over Coax (EoC) Network



Coax Access Solutions Around the World

- EoC development focuses on the use of existing cable television (CATV) infrastructure for Internet access or broadband data transmission.



Low Band

- **HomePNA**
  - HPNA1.0—HPNA2.0—HPNA3.0 (ITU-T G.9954)—ITU-T G.9960—ITU-T G.hn (main include high band)
- **HomePlugAV (2-28MHZ)**
  - HomePlug1.1—HomePlugAV2
- **HomePlug BPL**
  - IEEE P1901
- **DOCSIS-EoC**
- **EPCN**

High Band

- **WiFi over Cable**
- **MoCA**
  - 1.0, 1.1, 2.0
- **HINOC**
  - Mainland specification
  - Under development
- **EPOC**
  - IEEE specification
  - Under development

Low Band vs. High Band

Low Band

- **Pros**
  - Longer distance
- **Cons**
  - Limited bandwidth resource
  - Larger noise & interference

High Band

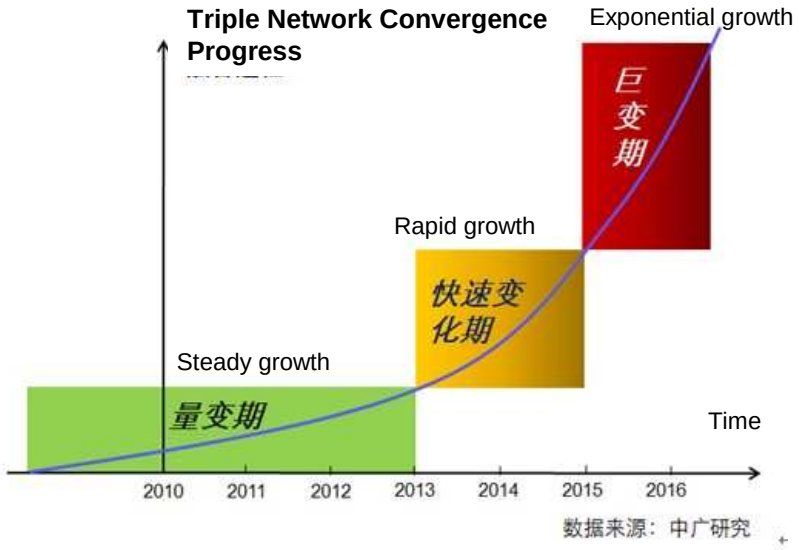
- **Pros**
  - Wide bandwidth resource
  - Less interference
- **Cons**
  - Larger attenuation

Some Coax Access Solutions

Standard	HINOC 1.0	HINOC 2.0	MoCA 1.0/1.1	MoCA 2.0	HomePlug AV
Single Channel bandwidth	16MHz	48MHz	50MHz	100MHz	25MHz
Spectrum	750~1005MHz	750~1005MHz	800~1500MHz	800~1500MHz	1.8~30MHz
Modulation	OFDM	Windowed OFDM	OFDM	OFDM	OFDM
FFT Size	256	TBD	256	512	3072
Available subcarriers	210	TBD	224	480	917
Constellation scheme	QPSK- 1024QAM	QPSK- 4096QAM	BPSK- 256QAM	BPSK- 1024QAM	BPSK- 1024QAM
FEC	BCH	BCH/RS/LDPC (TBD)	Reed-Solomon	QC-LDPC	Turbo code
Max number of nodes	32	32	31	63	253
Duplex/Multiple Access	TDD/TDMA	TDD/TDMA/OFDMA (TBD)	TDD/TDMA	TDD/TDMA	CSMA/CA
PHY data rate	114Mbps	>1Gbps	270Mbps	700Mbps	200Mbps
MAC data rate	5.98bits/Hz/s	TBD	2.80bits/Hz/s	4.0bits/Hz/s	3.41bits/Hz/s
Status	Published	Under draft	Published	Published	Published

Cable Access Market Trend

- **Market needs**
  - Triple-play market in Mainland will enter rapid growing period in 2013
  - Multiple EoC standards will coexistence and evolve, examples include MoCA, HINOC, and EPoC
  - One critical target of National Broadband Network Development for the Twelfth Five-Year-Plan: 100Mbps home-access capability



- **The NGB access group focuses on four areas**
  - HomePlugAV optimization, led by Oriental Cable Network (东方有线)
  - C-DOCSIS standardization, led by Shenzhen Topway (天威)
  - HINOC standard, led by Peking University
  - PON and xPON related research, testing etc.

Major Broadband Cable Technologies

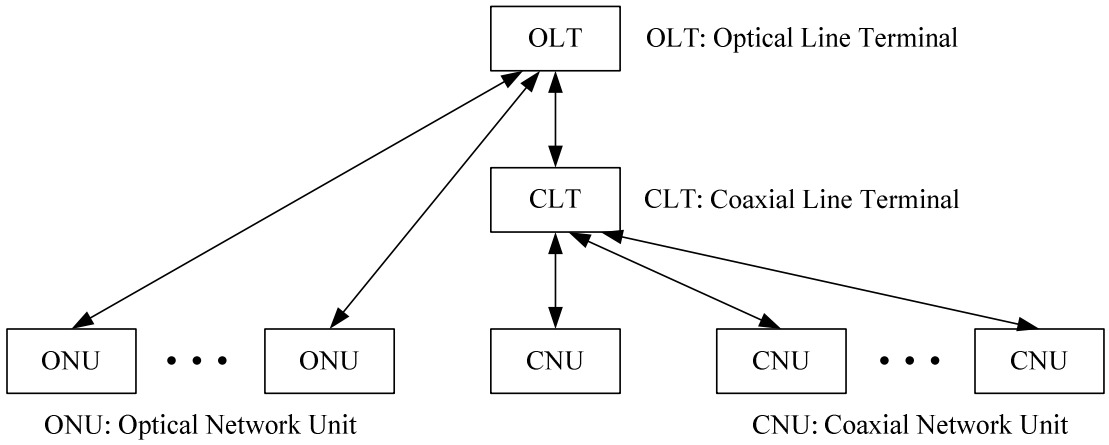
- **EPoC – EPON Protocol over Coax**
  - ✓ IEEE 802.3 EPoC Study Group set up on November of 2011
  - ✓ Still in very early stage with 4 meetings held on Jan, March, May and September of 2012 respectively
  - ✓ EPoC standard planed to be published in 2015
- **MoCA - Multimedia over Coax Alliance**
  - ✓ MoCA 1.0/1.1/2.0 finalized
- **HINOC- High performance Network Over Coax**
  - ✓ HINOC 1.0 released by SARFT, China
  - ✓ HINOC 2.0 standardization is on-going

Broadband: 100Mbps → 1G →10G;
Frequency Band: UHF

EPoC

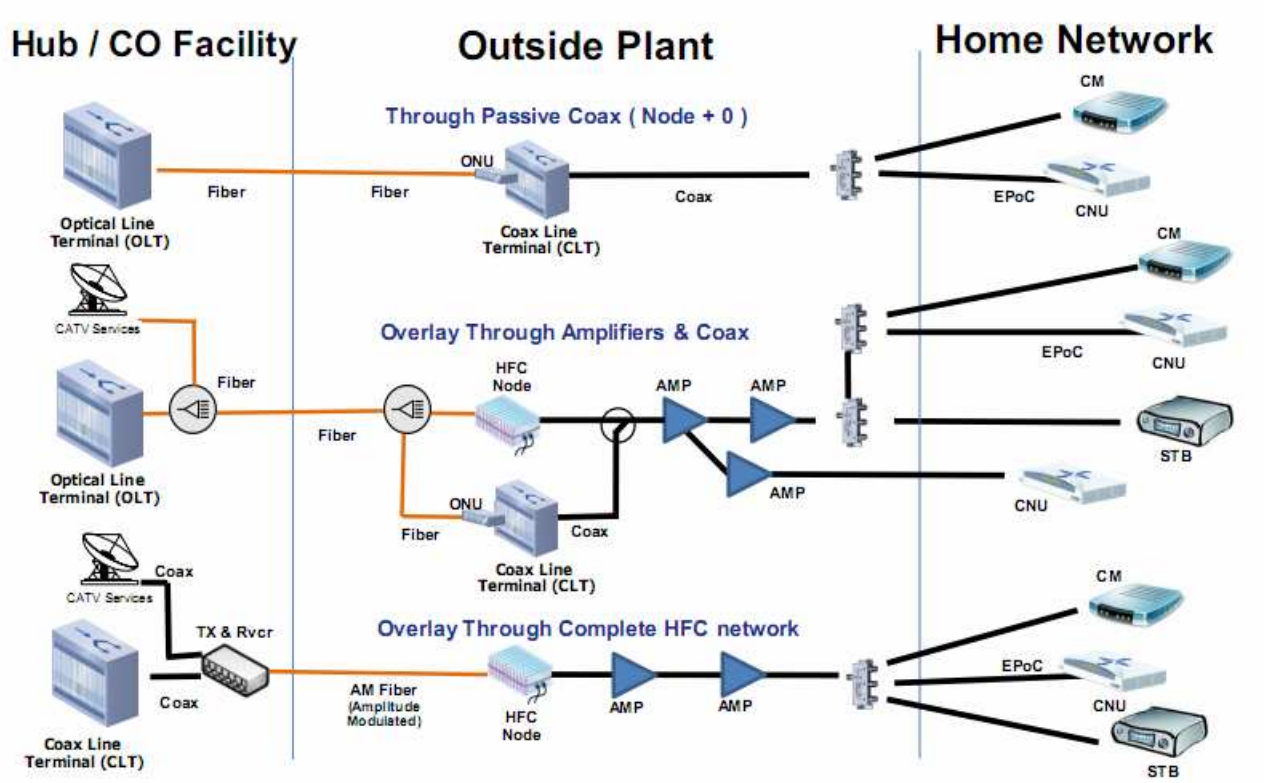
Introduction

- **EPoC**
  - ✓ Advanced new PHY under definition with 1G-EPON and 10G-EPON MAC over coax cable for end-to-end management, control, schedule and QoS
  - ✓ OLT unchanged or with minimal augmentation to MPCP/OAM if needed
  - ✓ CLT basically retains EPON MAC (especially MPCP) and OAM
  - ✓ Mixed network of ONUs and CNUs under control of one OLT



EPoC Deployment Options

- **EPoC**
  - ✓ **Node+0 (passive) / Node+N (N<5) / Traditional HFC**

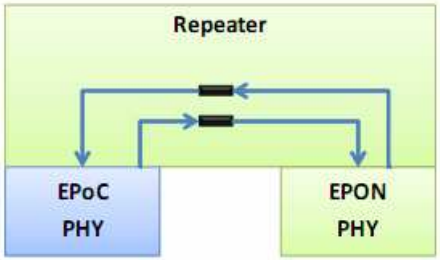


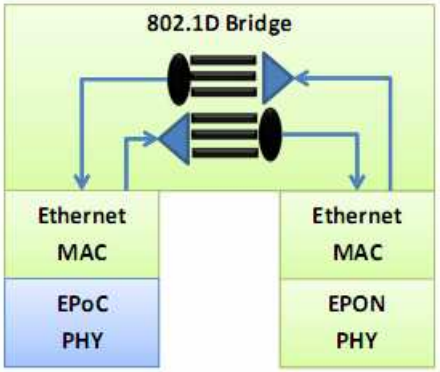
Technical Features of EPoC

- **Support symmetric and asymmetric data rate, spectrum assignment, and independent configuration for uplink/downlink transmission**
  - 1st step: uplink 1Gbps (~120MHz BW), downlink 1Gbps (~120MHz BW)
  - 2nd step: uplink 1Gbps (~120MHz BW), downlink 10Gbps (~1GHz BW)
  - 3rd step: uplink 10Gbps (~1GHz BW), downlink 10Gbps (~1GHz BW)
- **Support BER better or equivalent to 1e-10 at MAC service interface at the uplink/downlink receivers**
- **Spectrum allocation flexible enough not to hinder future bandwidth plans**
- **OLT should transparently manage ONU and CNU using same EPON protocols**

Discussion Focus of EPoC

- **FDD vs TDD**
- **"Single modulation order" vs "multiple modulation order"**
  - ✓ Single modulation order: a single common bit loading per subcarrier mapping - to minimize latency, complexity & overhead
  - ✓ Multiple modulation order: a bit loading per subcarrier mapping that is specific to each **CNU**
- **Is CLT a repeater or bridge?**
  - ✓ Repeater: fixed delay from between coax and fiber; single small queue; lower cost & power; no SLA provisioning; single layer of scheduling; ONU MAC could be placed along side for managed repeater
  - ✓ Bridge: double scheduler (one for coax, one for fiber); queuing, switching, and classification; full utilization of coax and fiber; requires SLA provisioning and classification

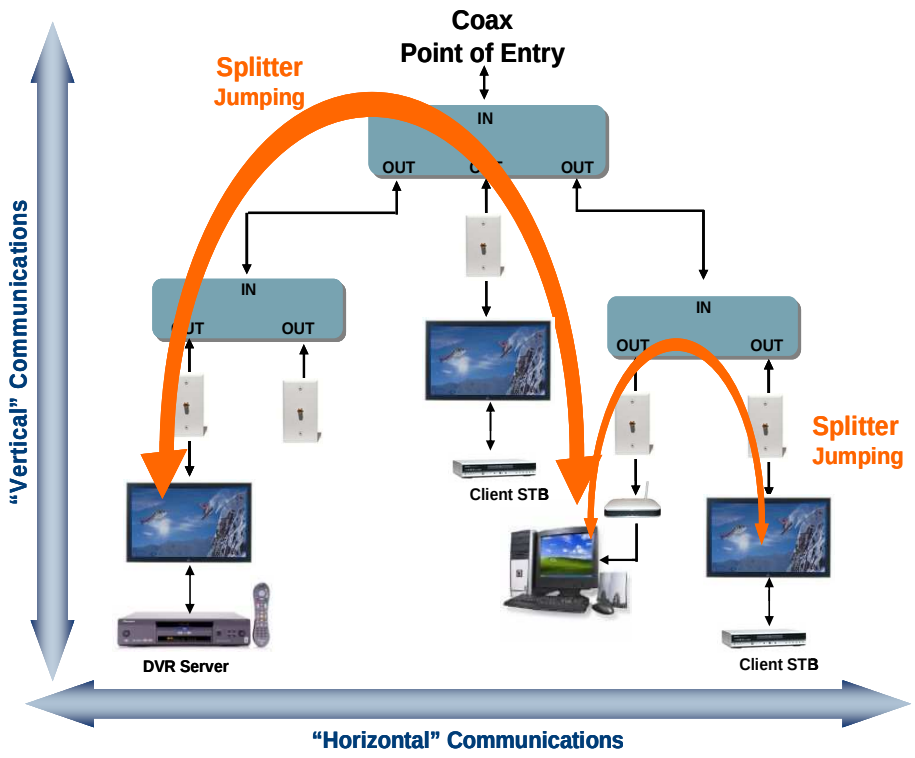




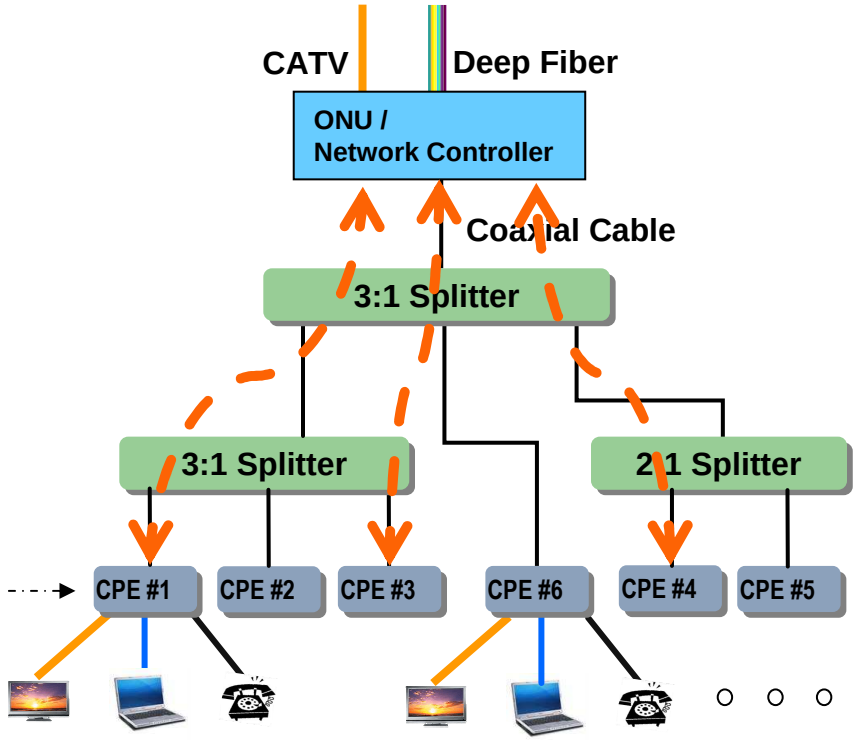
MoCA

System Architecture

MoCA Mesh Network (for Home)



c.LINK Star Network (for Access)



In-home network is a mesh network, and any two nodes can communication with each other. Access network is a star-tree network, and the slave node can only communicate with network controller.

MoCA PHY Features

- **Bandwidth/ constellation size**
  - ✓ MoCA 1.x: 50MHz / up to 256QAM
  - ✓ MoCA 2.0: 100MHz / up to 1024QAM
- **Forward error correction (FEC)**
  - MoCA 1.x: RS
  - MoCA 2.0: LDPC
- **Channel bonding in MoCA 2.0**
- **ACMT modulation - Adaptive Constellation Multi-Tone**
  - ✓ Pre-equalize modulation to frequency response of each path using bit-loading OFDM
  - ✓ Channel probing mechanism allowing performance optimization per connection
- **Fully coordinated and synchronized network**
  - ✓ Carrier frequency, sampling clock and channel time clock of each node are synchronized to that of network controller.

MoCA MAC Features

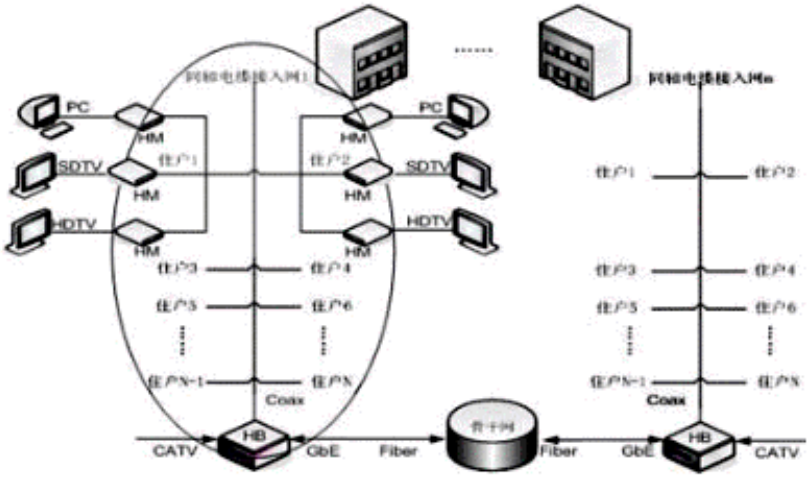
- **Channel access: TDMA/TDD**
- **Fully scheduled MAC – no collisions**
  - ✓ Channel access fully controlled by network controller
  - ✓ Transmission slots assigned by request-grant mechanism
- **QoS support**
  - ✓ Parameterized QoS – bandwidth reservation per flow
  - ✓ Prioritized QoS – network wide
- **Packet aggregation for high efficiency**
- **Link layer privacy**

HINOC

HINOC Network Architecture

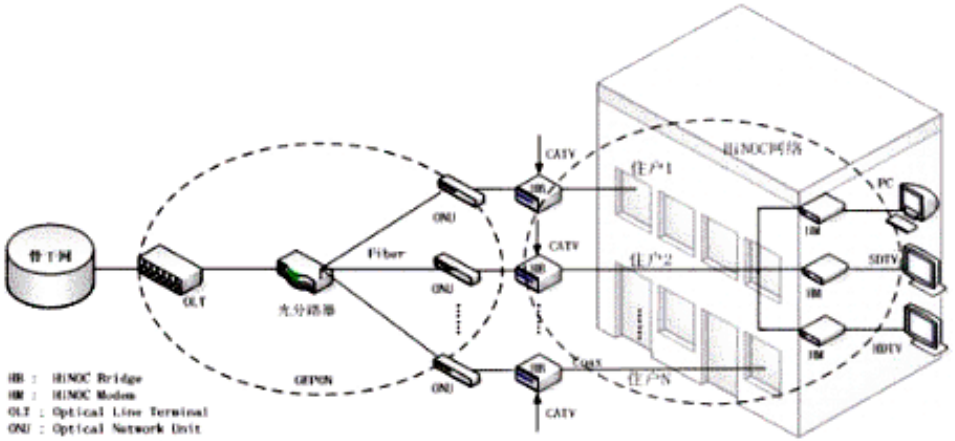
FTTB + HINOC in Building

- HiNOC系统FTTB＋楼内分配网络的组网方案



FTTH + HINOC in Home

- HiNOC系统FTTH＋户内分配网络的组网方案



HINOC and Standardization Activities

- HINOC is industry standard for next generation broadband access in China
- 256MHz bandwidth available
- Supported by “863” High-Tech Programs in China
- Target for broadband access with high MAC efficiency
- HINOC 2.0 standardization is on-going targeting >1Gbps PHY data rate

HINOC PHY Features

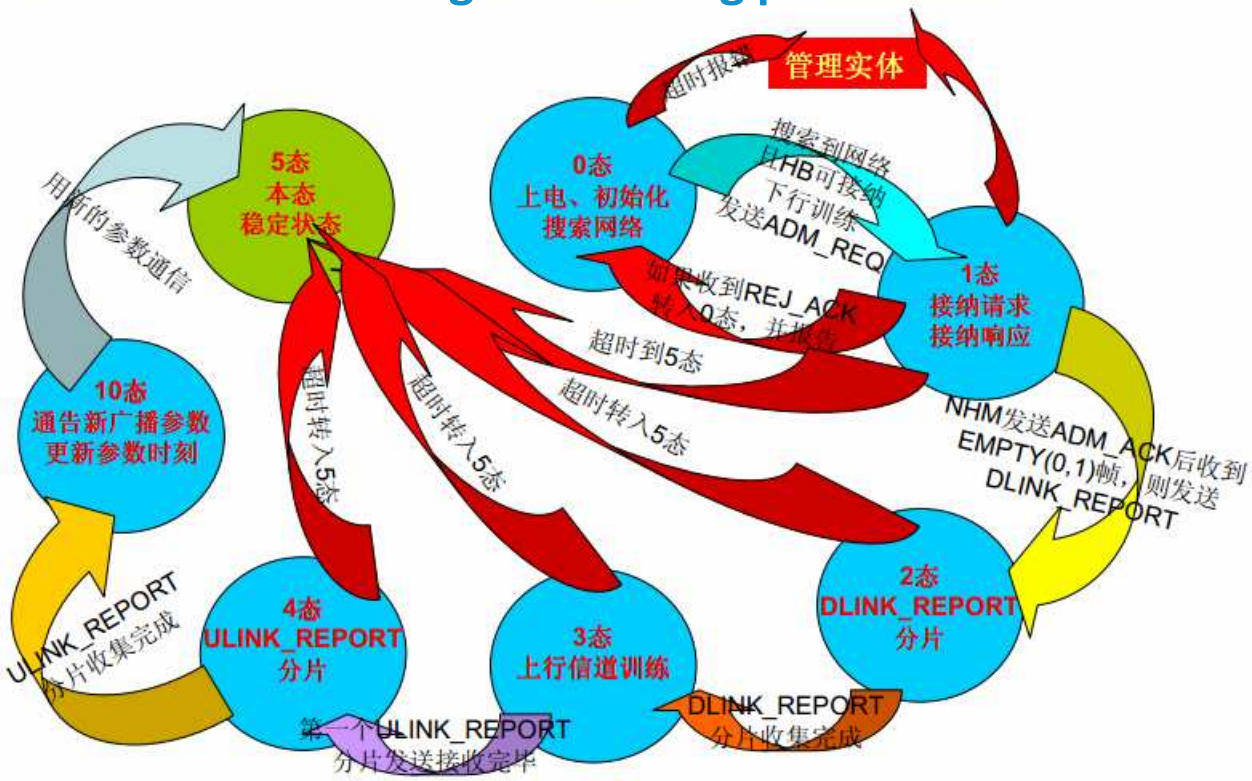
- Bandwidth: 16MHz (HINOC 1.0) or 48MHz (HINOC 2.0)
- Adjacent channel usable
- Constellation size: up to 1024QAM (HINOC 1.0) or 4096QAM (HINOC 2.0)
- Forward error correction: BCH (HINOC 1.0) or LDPC (HINOC 2.0)
- Distributed channel estimation based on periodic Pd/Pu frames
- Shorter preamble for estimating sampling timing offset of each packet instead of fully estimating channel gain of all sub-carriers
- Adaptive modulation on each sub-carrier optimized by periodic link maintenance mechanism
- Fully synchronized network

HINOC 1.0 MAC Features

- Channel access: TDMA/TDD
- Fully scheduled MAC – no collisions
  - ✓ Channel access fully controlled by headend
  - ✓ Transmission slots assigned by request-grant mechanism
- Support QoS, flow classification, and dynamic bandwidth allocation (DBA)
- High MAC layer bandwidth efficiency >5bit/s/Hz
- Link layer privacy

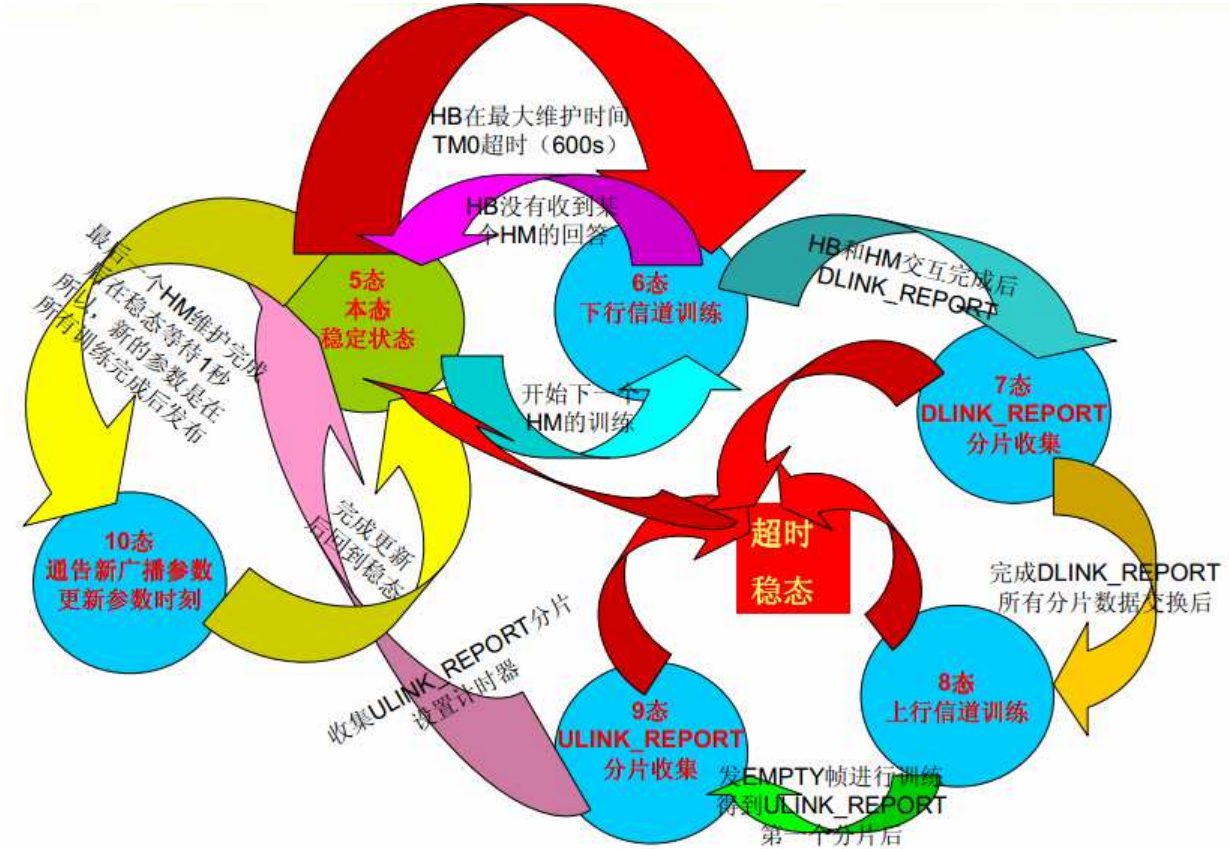
HINOC 1.0 MAC – Node Admission

- State 0： Network searching (Searching downlink training frames)
- State 1： Exchange registration and grant information
- State 2： Exchange downlink training report
- State 3： Send uplink training frames
- State 4： Exchange uplink training report
- State 10: Broadcast new parameters
- State 5： Communicate using the training parameters



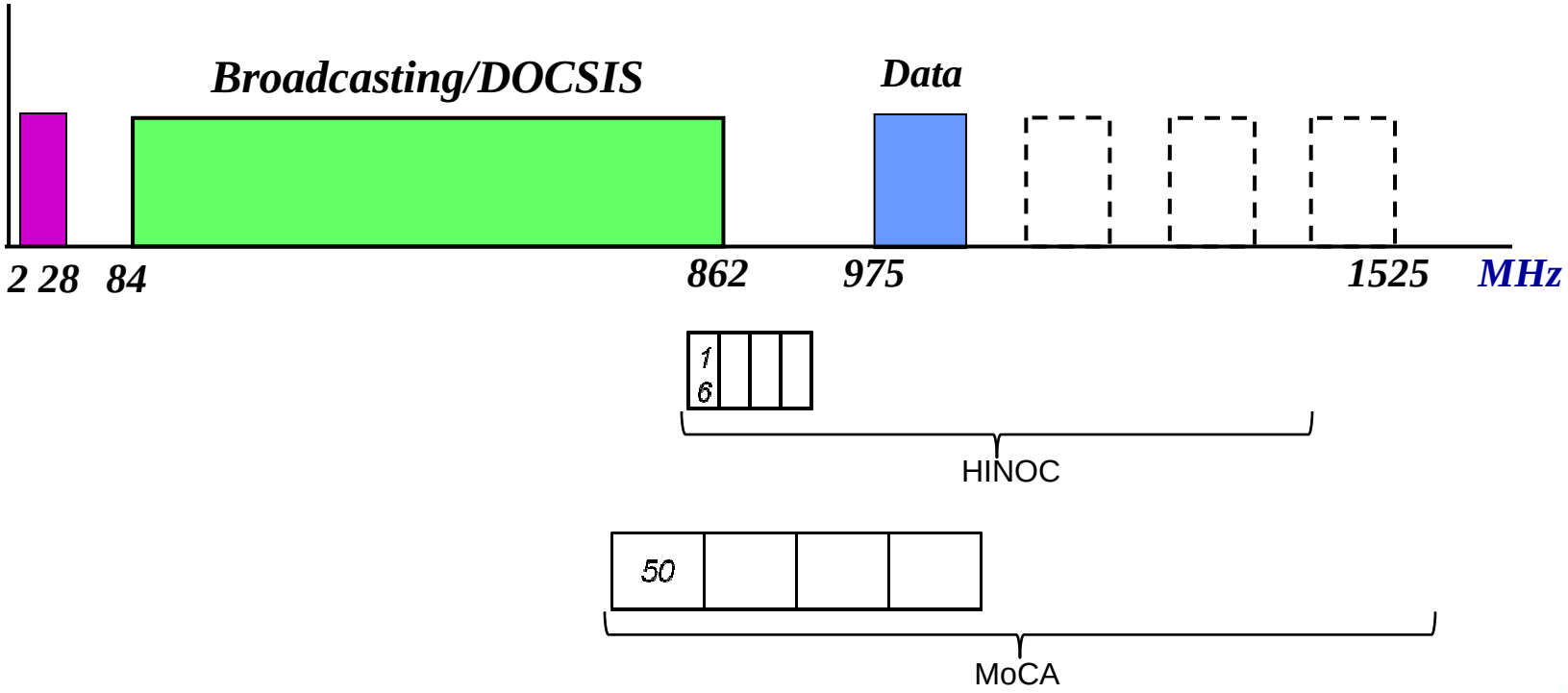
HINOC 1.0 MAC – Link Maintenance

- State 6： Downlink maintenance
- State 7： Exchange downlink training results
- State 8： Uplink maintenance
- State 9： Exchange uplink training result
- State 10: Broadcast new parameters
- State 5： Communicate using the new training parameters



Spectrum Allocation

	MoCA	HINOC	EPoC
Spectrum	475-1675MHz	750-1006MHz	TBD
Bandwidth	MoCA 1.x: 50MHz MoCA 2.0: 100MHz	HINOC 1.0: 16MHz HINOC 2.0: 48MHz (TBD)	120MHz (1G throughput) 1GHz (10G throughput)



ASTRI’s R&D on Broadband Cable Access

Team Summary

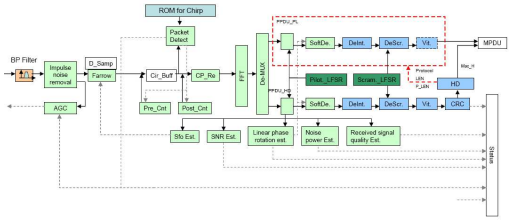
- Gained experience from local and overseas with PhD or Master degree
- Completed a few baseband projects for wired & wireless communication systems
- Established design environment and design flow to execute baseband and RF transceiver development

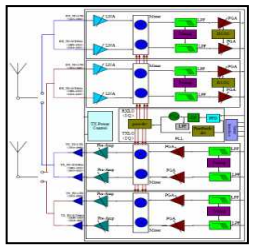
Capability and Expertise

- **Solid background on communication signal processing, rich experience on system/chip implementation**
  - Digital terrestrial TV, mobile TV and PLC baseband projects
  - System design, channel and noise modeling

- **Sophisticated hardware platform and embedded software development environment**

- **Analog and Digital IP portfolio**
  - RF, analog and mixed signal IP
  - PHY, MAC





Project Scope – HINOC Baseband

- Investigation of core technologies for existing broadband cable standards
- Development of HINOC baseband algorithms
- Establishment of HINOC simulation methodology and platform
- Co-design of hardware and software for improved throughput
- Test chip in advanced CMOS technology
- Participation in HINOC 2.0 standardization

Features

- HINOC 1.0 fully-compliant
- Extend to support scalable 16/24/32/48 MHz bandwidth
- Physical layer data rate up to 446 Mbps per channel
- MAC data rate up to 328Mbps for a single channel and up to 1.5Gbps for bounded channels
- Adaptive QAM modulation including QPSK, 8, 16, 32, 64, 128, 256, 512, 1024, 2048, 4096QAM
- RF impairment compensation technology for high performance transmission
- Flexible coding scheme, channel estimation scheme and CP selection

System Parameters

Channel bandwidth	16 MHz	24MHz	32MHz	48MHz
FFT size	256 points	384 points	512 points	768 points
Available bandwidth	13.125MHz	19.625MHz	26.25MHz	39.375MHz
Available subcarriers	210	314	420	630
Subcarrier bandwidth	62.5KHz			
OFDM body	256 points (16 us)	384points (16 us)	512 points (16 us)	768 points (16 us)
OFDM CP	16, 32 or 64 points (1, 2 or 4us)	24, 48 or 96 points (1,2 or 4us)	32, 64 or 128 points (1,2 or 4us)	48, 96 or 192 points (1,2 or 4us)
OFDM Symbol	272, 288 or 320 points (17, 18 or 20us)	408/432/480 (17, 18 or 20us)	544, 576 or 640 points (17, 18 or 20us)	816/864/960 points (17, 18 or 20us)
Constellation scheme	DQPSK, QPSK, 8, 16, 32, 64, 128, 256, 512, 1024,2048,4096QAM			
Coding scheme	(508,472)-BCH, (504,432)-BCH, (392,248)-BCH			
PHY data rate	148Mbps	223Mbps	296Mbps	446Mbps
MAC data rate	109Mbps	164 Mbps	218Mbps	328Mbps
CE symbol number	0, 1, or 2			

Deliverables

- Baseband algorithms
- Baseband simulation platform
- Baseband test chip
- Demo board and reference design

Summary

- Broadband cable access technologies utilizes the existing coaxial network with data rate 1Gbps.
- Cable will gain 25% of broadband market share by 2017.
- Triple-play market in Mainland will enter rapid growing period in 2013.
- Three key broadband cable technologies are EPoC, MoCA, and HINOC.
- ASTRI will focus on HINOC baseband technologies including: algorithms, simulation platform, test chip, demo board and reference design

End of Presentation

Thank you. Questions are welcome.

Our corporate website: www.astri.org