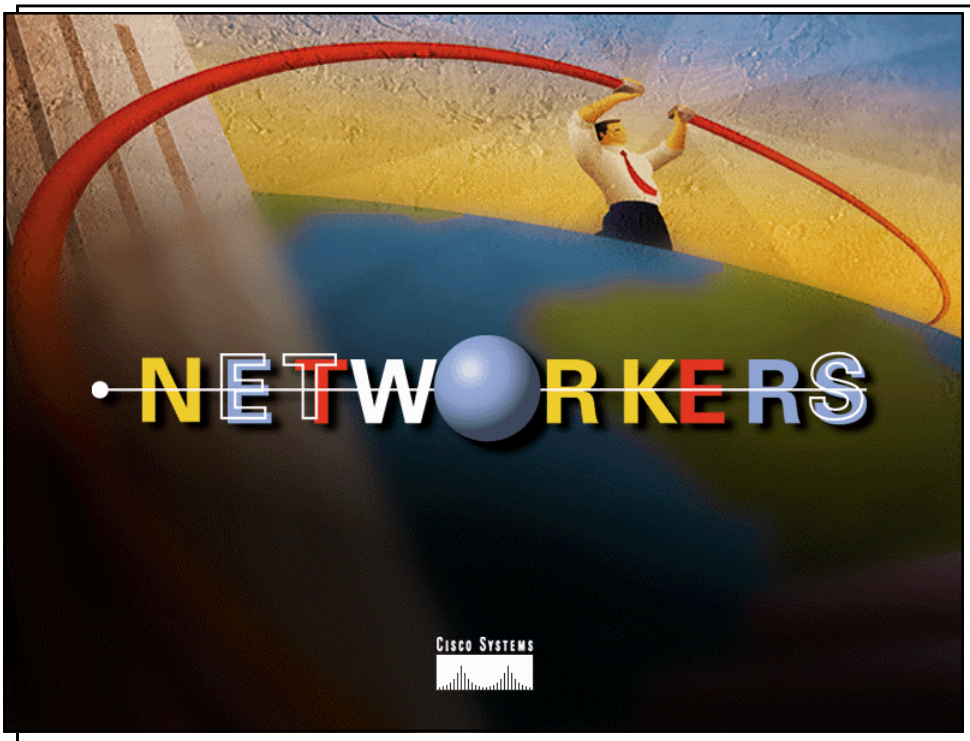

"Planning Is Paramount when Establishing a Viable IP Network over CATV to Meet:
Investor Expectation
Consumer Expectation
Market Dynamics"

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Abstract

- Concepts and criteria to establish an access network over HFC (Hybrid-Fiber-Coax) using a DOCSIS (Data Over Cable Service Interface Specification) platform is presented
- Hardware configurations compatible with the HFC plant and business case are prescribed to ensure a scalable access and backbone network supporting subscriber growth with minimal ongoing physical plant or IP network disruption

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"We need to figure out how to build it, how to deploy it, how to support it, how to maintain it"

Michael Armstrong
AT&T chairman

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Agenda

- Key Factors for Success
- Market Dynamics
- Standards
- "New World Vision"
- Cisco Cable Solution
- Investors
- Business Case Parameters
- Plant Infrastructure
- Hardware Selection
- Traffic Analysis
- Conclusion

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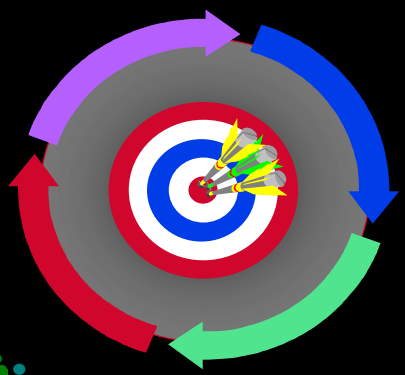
Factors for Success



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Market Dynamics

- Measurable demand for HS data
  - Enterprise (VPN)
  - Web browsing
  - Telecommute
  - SOHO
- Telephony (VoIP)
- Video
- Ad insert
- Gaming
- Future (undefined)
- Wireless

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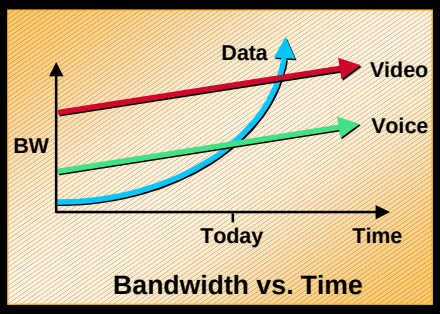
Market Dynamics

Data, a "Growth Opportunity"

- Acceptance and penetration of the Internet
- Data bandwidth/cost beating Moore's Law
- Open standards for DOCSIS and digital TV



Bandwidth vs. Time

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"Cox saw continued growth, both in our cable television business and in our deployment of new residential and commercial services"

Jim Robbins,
President and CEO, Cox Communications

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Standards

- Benefits of standards
  - Multisystem connectivity
  - Product interoperability
  - User product choice possible
  - Reduced risk of system obsolescence
  - Competitive pricing environment
  - Promotes product advancements
  - Fosters new applications

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Standards

- DOCSIS (ITU J112)
  (Data Over Cable System Interface Specification)
  - IP (packet-based)
  - MPEG frame format
  - DOCSIS 1.0 (data)
  - DOCSIS 1.1 (VoIP)
- CableLabs 'Qualified' CMTS
  (Cable Modem Terminating System)
- CableLabs 'Certified' CPE

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Understand the Benefits of "Standards"-Based Products vs. Proprietary; Study the Products and their Capabilities

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New World Vision

An End-to-End IP-Based Solution

- IP ensures bandwidth efficiency
- IP offers reduced networking costs
- IP supports operational efficiency

All Services Converge to a Common Multimedia IP Platform

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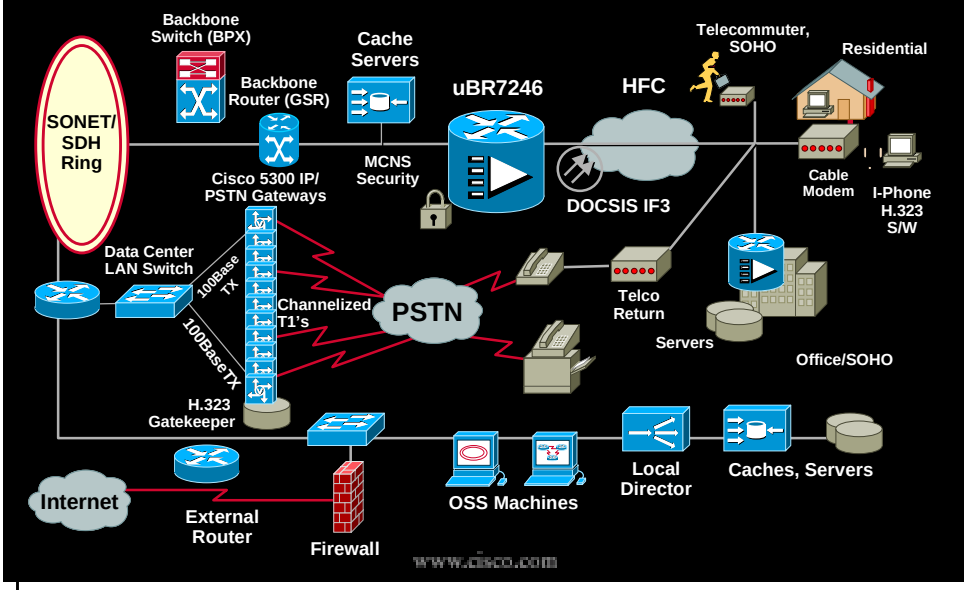
“New World Vision”



“…broadband data is very important, everybody acknowledges that time and technology are moving, applications will converge and devices will converge”

Michael Armstrong
AT&T chairman

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"The convergence of optical and internetworking technologies will let service providers such as Thrunet build high-speed multimedia networks that are considerably cheaper than traditional TDM telecom networks.

Migration to the new world of integrated voice, video and data networks based on packet architectures is inevitable, and rapid adoption is a matter of survival for companies and service providers, Thrunet has shown true vision by recognizing the advantages of this new infrastructure."

Dr. Hong Sung-Won
President of Cisco Systems Korea

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Recognize, Understand, and Adopt Technological and Networking Innovation to Avoid the Obsolescence of Capital and to Ensure Competitiveness

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Cisco Cable Solutions

Cisco DOCSIS Products

- Cisco uBR 7223/uBR7246 (Universal BroadBand router)
  - Cisco router integrated with:
  - CMTS (Cable Modem Terminating System)
  - BackBone port adapters
- Cisco uBR 904/uBR924 CM
- CableLabs ‘certified’ multi-vendor CPE

Cisco Cable Solutions

Cisco IP Access Platform

uBR904 SOHO CM
uBR924 SOHO CM e/w VoIP

uBR7246

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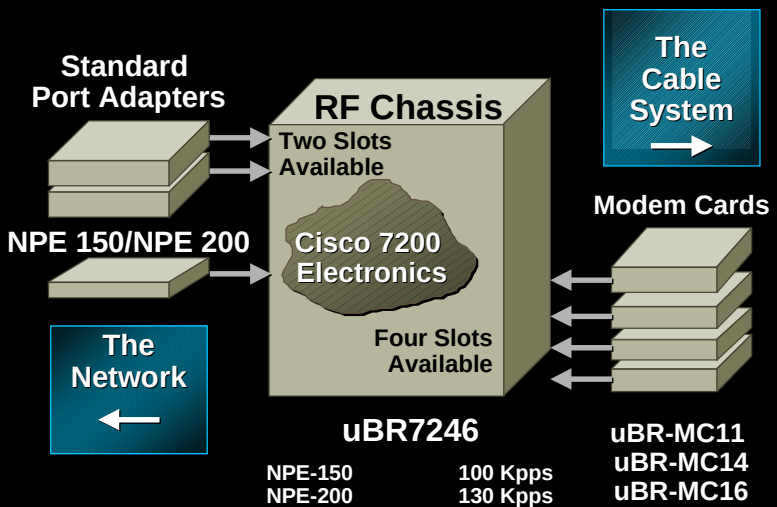
Cisco Cable Solutions



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Cisco Cable Solutions

Effective Data Rates

	200 KHz BW	400 KHz BW	800 KHz BW	1600 KHz BW	3200 KHz BW	6000 KHz BW
QPSK	300 kbs	600 kbs	1200 kbs	2300 kbs	4500 kbs	
16 QAM	600 kbs	1200 kbs	2300 kbs	4500 kbs	9000 kbs	
64 QAM						27 Mbs
256 QAM						38 Mbs

RF Bandwidth and Modulation choices as specified by DOCSIS

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Investors

Investors Role

- Assume risk
- Expect good return
- Implement only a sound business case

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Investors

Demonstrated Growth in Penetration

	Number of Modems	Number of Homes Passed with Two Way Plant	Percent Penetration
3/31/99	.46 M	15 M	3.07
12/31/98	.331 M	13.2 M	2.51
9/30/98	.210 M	10 M	2.10
6/30/98	.147 M	7.9 M	1.86
3/31/98	.090M	5.7 M	1.58
12/31/97	.050 M	4.5 M	1.11
9/30/97	.026 M	2.7 M	0.96

Investor Justification!

Source: @Home

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Investors

Recent CATV Consolidations

- AT&T purchase of TCI
- AT&T purchase of Media One
- Adelphia purchase of Century
- Cox purchase of TCA
- Cox purchase of Media General

High-Capacity HFC Cable Plant Is the Common Denominator to Support IP

"The promise is great: a system that could allow AT&T to provide competition against Baby Bells in local phone markets through cable connections—even while delivering which could allow viewers to select their interactive television, own angles or replays, and lightning-quick Internet access to household more accustomed to molasses-like speeds"

Seth Schiesel
New York Times May 7, 1999

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Business Case Parameters

Five Year Plan

- Plant growth at 0.75% per annum
- HS data service products

Residential	256 Kbs DS, 128 Kbs US
Business	1.5 Mbs DS, 512 Kbs US

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Business Case Parameters

Penetration Rates

Residential Customer:	3% Year 1
	30% CAGR
Business Customer : (Per Hub/Head-end)	TwoYear 2 Add one per year

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Is the Business Case Reasonable? Are Projections Valid?

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Infrastructure

- HFC
  - 750 MHz downstream
  - 5-42 MHz upstream
- Head end
  - 25 K homes passed
  - 25 nodes (average of 1 K home passed)
- Hub 1 and 4
  - 40 K homes passed
  - 60 nodes (average of .65 K home passed)
- Hub 2
  - 30 K homes passed
  - 60 nodes (average of .50 K home passed)
- Hub 3
  - 30 K homes passed
  - 20 nodes (average of 1.50 K home passed)

Infrastructure

Upstream CNR Characteristics

- Head-end
  - CNR 30 to 36, average 32
- Hub 1 and 4
  - CNR 30 to 40 average 33
- Hub 2
  - CNR 35to 41 average 36
- Hub 3
  - CNR 27 to 36 average 29

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Infrastructure

- Backhaul
  - Dark fiber available in ring configuration
- Available spectrum
  - No restrictions on downstream frequency
  - Upstream frequency limitations

Head-end	800 KHz maximum
Hub 1 and 4	1600 KHz maximum
Hub 2	400 KHz maximum
Hub 3	3200 KHz maximum

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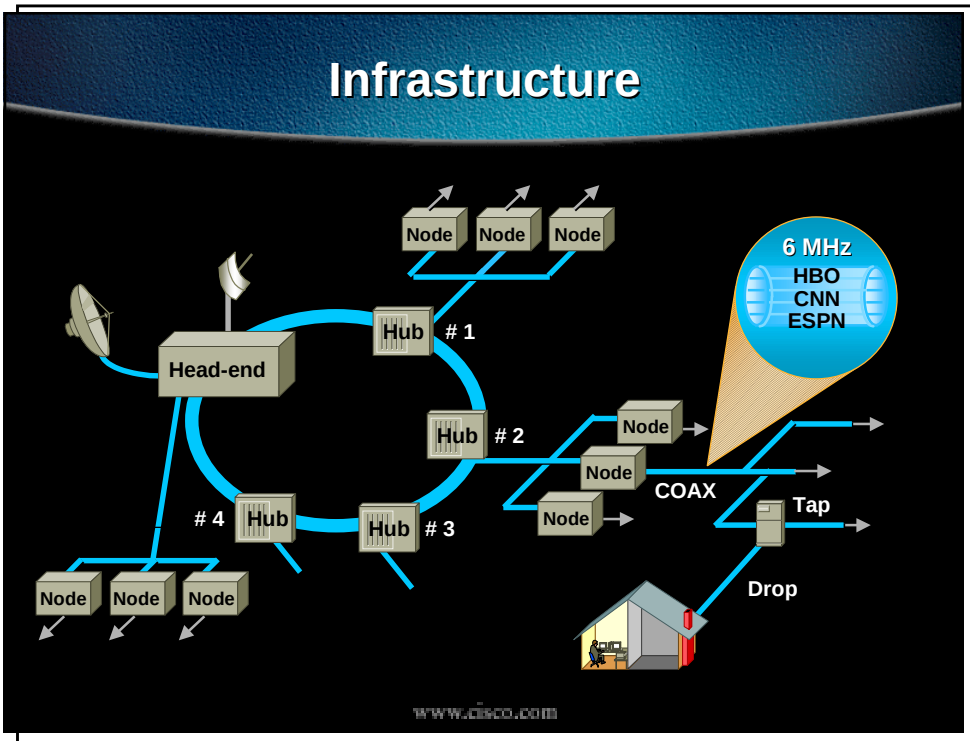
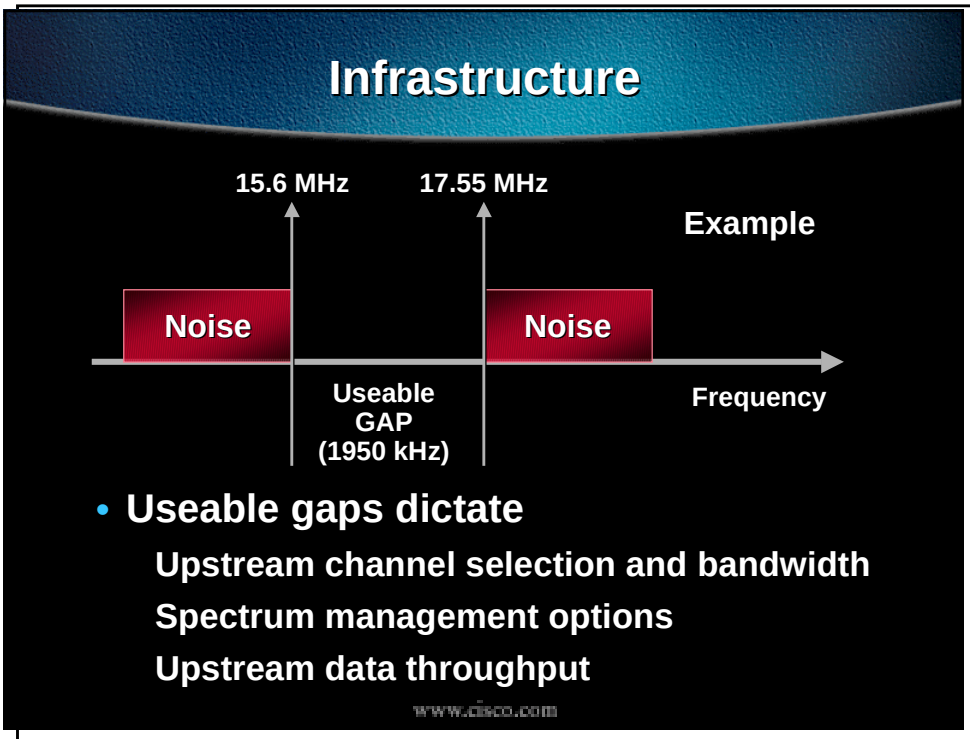




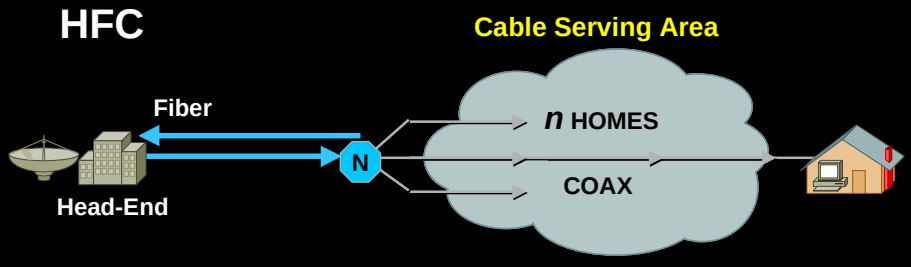
Infrastructure

Useable Spectrum Gaps

From (KHz)	To (KHz)	GAP (KHz)	200 (KHz)	400 (KHz)	800 (KHz)	1600 (KHz)	3200 (KHz)
5000	5950	950	4	2	1	0	0
6200	7000	800	4	2	1	0	0
7300	9500	2200	11	5	2	1	0
9900	10100	200	1	0	0	0	0
10150	11650	1500	7	3	1	0	0
12050	13600	1550	7	3	1	0	0
13800	14000	200	1	0	0	0	0
14350	15100	750	3	1	0	0	0
15600	17550	1950	9	4	2	1	0
17900	18068	168	0	0	0	0	0
18168	21000	2832	14	7	3	1	0
21850	24980	3040	15	7	3	1	0
24990	25670	680	3	1	0	0	0
26100	26960	860	4	2	1	0	0
27410	28000	590	2	0	0	0	0
29700	40000	10300	51	25	12	6	3

Infrastructure

HFC



Typically Fewer than Five Amplifiers in Cascade

- Multiple upstreams may be combined
- The video signal is transmitted over fiber to the node, where it is converted to an electrical signal and forwarded to the subscriber over existing coaxial cable
- Provision is made to support return traffic for advanced services

Is the Business Case Reasonable? Are Projections Valid?

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Is Your Current or Planned HFC Topology Compatible with Supporting New Services? It Might Not Be too Late!

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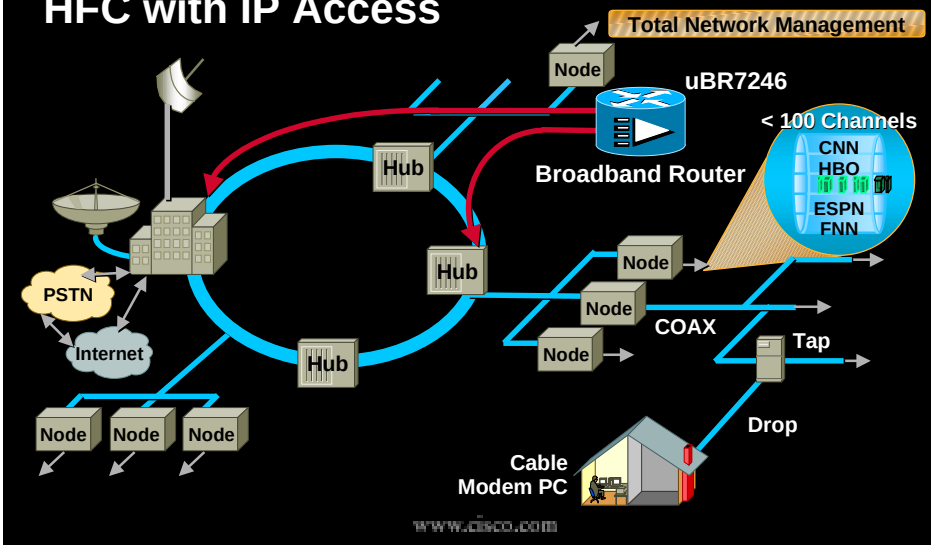
Hardware Selection

- Cisco universal broadband router
  - uBR7246
  - Redundant AC power supply
  - NPE-200 network processing engine (130 Kpps)
  - I/O controller e/w FE
  - uBR-MC16C CMTS RF module
  - POS (Packet Over SONET)—OC-3 SM

Infrastructure

HFC with IP Access



Hardware Selection

What about Network Management?

- Network management is imperative
  - Facilitates fault location
  - Supports preventive maintenance
  - Enhances customer support
  - Monitors traffic and market trends

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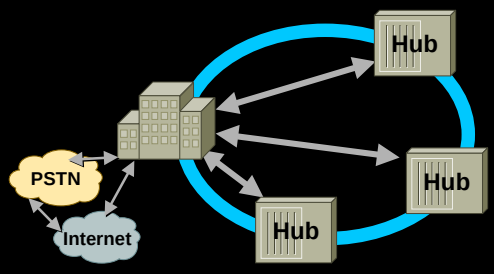
Hardware Selection

- Identify hardware components to meet the specific requirements of individual supporting locations
  - Port adapters to support the backbone
  - CMTS RF line modules to support access
  - Choice of power option
  - Router processing speed
  - Auxiliary outputs, etc.

Hardware Selection

Establishing the Backbone



Customer Traffic from *n* Hubs
Brought to Head-End for Processing

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Traffic Analysis

- Analysis assumptions
  - Residential activity tactor of 25%
  - Business activity factor of 25%
  - Data peak factor 8

Traffic Analysis

- Determining aggregated CNR when combining nodes

Example:

- Determine aggregated CNR for upstream signals having CNR of 37 dB, 34.5 dB, and 30 dB
- See nomograph

Total CNR = 28 dB

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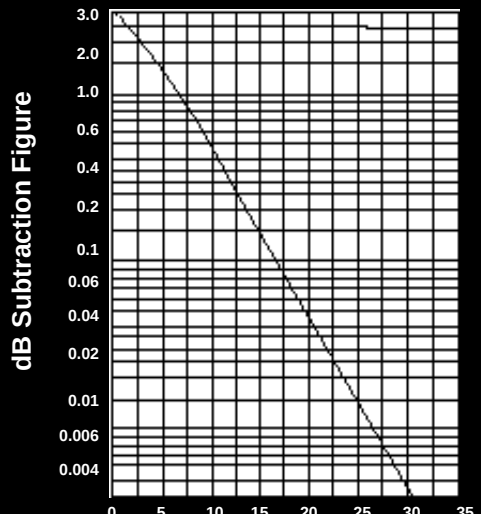
Traffic Analysis



10 LOG Nomograph for Combining Two CNR

NOTE:
This Information Is Beneficial when Determining the Aggregated CNR of Multiple Upstream Signals

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Traffic Analysis

Head-End Customer—Traffic Profile

	Year 1	Year 2	Year 3	Year 4	Year 5
Homes Passed	25000	25188	25376	25666	25758
Residential Customer	750	982	1286	1685	2207
Business Customer		2	3	4	5
Total Traffic	DS 48 M US 24 M	DS 64 M US 32 M	DS 84 M US 42 M	DS 110 M US 55 M	DS 144 M US 72 M

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Traffic Analysis

Head-End Hardware Selection—Validation

- Combine 3 nodes of 1 K homes, (average CNR of 32 dB)

  Resultant CNR approximately 27 dB OK

- Quantity of uBR-MC16 CMTS modules needed?

  25 nodes/3 nodes per receiver = 9 receivers

  To support 9 receivers, 2 uBR-MC16C required

- Quantity of uBR7246 needed?
  1 uBR7246 required

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Traffic Analysis

Head-End Hardware Selection—Validation

- Validate configuration against traffic needs

800 KHz US bandwidth available

Downstream	54 Mbs available
	18.1 Mbs required
Upstream	14.4 Mbs available (12 receivers)
	10.8 Mbs activated (9 receivers)
	9 Mbs required
Subscriber load	2207 residential
	5 business

Traffic Analysis

Head-End Hardware Selection—Validation

- Head-end hardware configured will support:
  - 5 year plan without configuration change using
    - 64 QAM downstream
    - QPSK upstream
    - 800 KHz upstream RF bandwidth
    - Spare receivers can be activated for capacity
- Modulation selection and increased RF bandwidth will support greater load, without consideration of incremental hardware

Traffic Analysis

Hub 1 and 4 Customer—Traffic Profile

	Year 1	Year 2	Year 3	Year 4	Year 5
Homes Passed	40000	40300	40602	40906	41213
Residential Customer	1200	1571	2056	2696	3531
Business Customer		2	3	4	5
Total Traffic	DS 77 M US 38.5 M	DS 102 M US 51 M	DS 134 M US 67 M	DS 176 M US 88 M	DS 230 M US 115 M

Traffic Analysis

Hub 1 and 4 Hardware Selection—Validation

- Combine 4 nodes of .65 K homes, (average CNR of 33 dB)
  - Resultant CNR approximately 27 dB OK
- Quantity of uBR-MC16 CMTS modules needed?
  - 60 nodes/4 nodes per receiver = 15 receivers
  - To support 9 receivers, 3 uBR-MC16C required
- Quantity of uBR7246 needed?
  1 uBR7246 required

Traffic Analysis

Hub 1 and 4 Hardware Selection—Validation

- Validate configuration against traffic needs

1600 KHz US bandwidth available

Downstream	81 Mbs available
	28.1 Mbs required (year 5)
Upstream	41.4 Mbs available (18 receivers)
	34.5 Mbs activated (15 receivers)
	14.3 Mbs required
Subscriber load	3531 residential
	5 business

Traffic Analysis

Hub 1 and 4 Hardware Selection—Validation

- Head-end hardware configured will support:
  - 5 year plan without configuration change using
    - 64 QAM downstream
    - QPSK upstream
    - 1600 KHz upstream RF bandwidth
    - Spare receivers can be activated for capacity

Modulation Selection and Increased RF Bandwidth Will Support Greater Load, without Consideration of Incremental Hardware

Traffic Analysis

Hub 2 Customer—Traffic Profile

	Year 1	Year 2	Year 3	Year 4	Year 5
Homes Passed	30000	30225	30452	30680	30910
Residential Customer	900	1178	1544	2022	2648
Business Customer		2	3	4	5
Total Traffic	DS 58 M US 29 M	DS 77 M US 38.5 M	DS 102 M US 51 M	DS 132 M US 66 M	DS 173 M US 86.5 M

Traffic Analysis

Hub 2 Hardware Selection—Validation

- Combine 6 nodes of .5 K homes, (average CNR of 36 dB)
  - Resultant CNR approximately 28 dB OK
- Quantity of uBR-MC16 CMTS modules needed?
  - 60 nodes/6 nodes per receiver = 10 receivers
  - To support 9 receivers, 2 uBR-MC16C required
- Quantity of uBR7246 needed?
  1 uBR7246 required

Traffic Analysis

Hub 2 Hardware Selection—Validation

- Validate configuration against traffic needs

400 KHz US bandwidth available

Downstream	54 Mbs available
	21.7 Mbs required (year 5)
Upstream	7.2 Mbs available (12 receivers)
	6.0 Mbs activated (10 receivers)
	10.8 Mbs required
Subscriber load	2648 residential
	5 business

Traffic Analysis

Hub 2 Hardware Selection—Validation

- Hub 2 hardware configured will support:
  - 2 year of year plan without configuration change using
    - 64 QAM downstream
    - QPSK upstream
    - 400 KHz upstream RF bandwidth

Operator Can Build as Configured, and Overbuild for Year 3 of Business Plan, or Build now for Complete 5 Year Plan

Traffic Analysis

Hub 2 Hardware Selection—Validation

- Combine 4 nodes of .5 K homes, (average CNR of 36 dB)
  - Resultant CNR approximately 30 dB OK
- Quantity of uBR-MC16 CMTS modules needed?
  - 60 nodes/4 nodes per receiver = 15 receivers
  - To support 15 receivers, 3 uBR-MC16C required
- Quantity of uBR7246 needed?
  1 uBR7246 required

Traffic Analysis

Hub 2 Hardware Selection—Validation

- Validate configuration against traffic needs

400 KHz US bandwidth available

Downstream	81Mbs available
	21.7 Mbs required (year 5)
Upstream	10.8 Mbs available (18 receivers)
	9.0 Mbs activated (15 receivers)
	10.8 Mbs required
Subscriber load	2648 residential
	5 business

Traffic Analysis

Hub 2 Hardware Selection—Validation

- Hub 2 hardware configured will support:
  - 4 year of year plan without configuration change using
    - 64 QAM downstream
    - QPSK upstream
    - 400 KHz Upstream RF bandwidth

Operator Can Build as Configured, and Overbuild for Year 5 of Business Plan, or Build now for Complete 5 Year Plan

Traffic Analysis

Hub 2 Hardware Selection—Validation

- Combine 3 nodes of .5 K homes, (average CNR of 36 dB)
  - Resultant CNR approximately 31 dB OK
- Quantity of uBR-MC16 CMTS modules needed?
  - 60 nodes/3 nodes per receiver = 20 receivers
  - To support 15 receivers, 4 uBR-MC16C required
- Quantity of uBR7246 needed? 1 uBR7246 required

Traffic Analysis

Hub 2 Hardware Selection—Validation

- Validate configuration against traffic needs

400 KHz US bandwidth available

Downstream	108 Mbs available
	21.7 Mbs required (year 5)
Upstream	14.4 Mbs available (24 receivers)
	12.0 Mbs activated (20 receivers)
	10.8 Mbs required
Subscriber load	2648 residential
	5 business

Traffic Analysis

Hub 2 Hardware Selection—Validation

- Head-end hardware configured will support:
  - 5 year of year plan without configuration change using
    - 64 QAM downstream
    - QPSK upstream
    - 400 KHz upstream RF bandwidth

Modulation Selection and Increased RF Bandwidth Will Support Greater Load, without Consideration of Incremental Hardware

Traffic Analysis

Hub 3 Customer—Traffic Profile

	Year 1	Year 2	Year 3	Year 4	Year 5
Homes Passed	30000	30225	30452	30680	30910
Residential Customer	900	1178	1544	2022	2648
Business Customer		2	3	4	5
Total Traffic	DS 58 M US 29 M	DS 77 M US 38.5 M	DS 102 M US 51 M	DS 132 M US 66 M	DS 173 M US 86.5 M

Traffic Analysis

Hub 3 Hardware Selection—Validation

- Combine 2 nodes of 1.5 K homes, (average CNR of 29 dB)
  - Resultant CNR approximately 26 dB OK
- Quantity of uBR-MC16 CMTS modules needed?
  - 20 nodes/2 nodes per receiver = 10 receivers
  - To support 15 receivers, 2 uBR-MC16C required
- Quantity of uBR7246 needed?
  1 uBR7246 required

Traffic Analysis

Hub 3 Hardware Selection—Validation

- Validate configuration against traffic needs

3200 KHz US bandwidth available

Downstream	54 Mbs available
	21.7 Mbs required (year 5)
Upstream	54 Mbs available (12 receivers)
	45.0 Mbs activated (10 receivers)
	10.8 Mbs required
Subscriber load	2648 residential
	5 business

Traffic Analysis

Hub 3 Hardware Selection—Validation

- Hub 3 hardware configured will support:
  - 4 year of year plan without configuration change using
    - 64 QAM downstream
    - QPSK upstream
    - 3200 KHz upstream RF bandwidth

The Number of Subscribers has Exceeded the Recommended 1K to 1.2 K per CMTS Module

Traffic Analysis

Hub 3 Hardware Selection—Validation

- Operator may experience processing delay caused by excessive subscriber load on individual CMTS modules
- Recommended limit is from 1000 to 1200 subscribers

Traffic Analysis

System Customer—Traffic Profile

	Year 1	Year 2	Year 3	Year 4	Year 5
Homes Passed	165000	166238	167484	168740	170006
Residential Customer	4950	6483	8491	11121	14566
Business Customer		10	15	20	25
Total Traffic	DS 316 M US 158 M	DS 422 M US 211 M	DS 555 M US 276 M	DS 727 M US 362 M	DS 951 M US 473 M

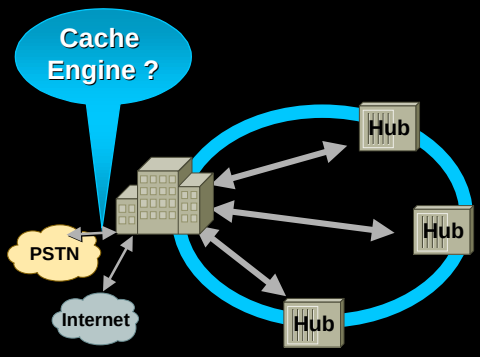
Traffic Analysis

Backhaul Capacity Requirements

	Year 1	Year 2	Year 3	Year 4	Year 5
Head End	DS 6 M US 3 M	DS 8 M US 4 M	DS 10.6 M US 5.3 M	DS 13.9 M US 6.9 M	DS 18.1 M US 9 M
Hub 1 and 4	DS 9.6M US 4.8 M	DS 12.8 M US 6.4 M	DS 16.8 M US 8.3 M	DS 22 M US 11 M	DS 28.1M US 14.3 M
Hub 2 and 3	DS 7.2 M US 3.6 M	DS 9.6 M US 4.8 M	DS 12.6 M US 6.3 M	DS 16.6 M US 8.3 M	DS 21.7 M US 10.8 M
Total Traffic	DS 39.6 M US 19.8 M	DS 52.8 M US 26.3 M	DS 69.3 M US 39.4 M	DS 90.8 M US 45.1 M	DS 118.9 M US 59 M

Traffic Analysis

Establishing the Backbone



All Hubs Provisioned with POS- OC-3 SM Port Adapters

Customer Traffic from *n* Hubs Brought to Head-end for Processing

Traffic Analysis

Analysis Summary

- Hardware selection based upon:
  - Data rate commitments
  - Upstream CNR
  - Available upstream RF bandwidth
  - Number of subscribers per CMTS
  - Packet size
  - Router throughput

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Numerous Variables Impact a HS Data Network Design; from Marketing to Cost, to Equipment Selection

"Planning Is Paramount when Establishing a Viable IP Network over CATV to Meet:
Investor Expectation
Consumer Expectation
Market Dynamics"

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Agenda

- Key Factors for Success
- Market Dynamics
- Standards
- “New World Vision”
- Cisco Cable Solution
- Investors
- Business Case Parameters
- Plant Infrastructure
- Hardware Selection
- Traffic Analysis
- Conclusion

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Conclusion

“The Proper Design of a Scalable IP Access Infrastructure Over Cable Television Plant Requires Considerable Planning to Achieve Success, Numerous Variables Must Be Considered”

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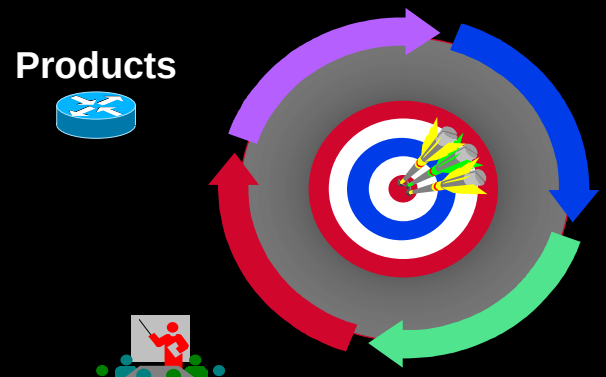
Conclusion

Defining the Solution



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Conclusion

- Hardware limitations include:
  - Receiver CNR limits
  - Number of recommended subscribers per CMTS
  - Router switching speed
- Business case limitations include:
  - Downstream data rate commitments
  - upstream data rate commitments

Planning Will Lead to Success!

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- Is your CATV plant being upgraded to HFC ?
- Are upgrades compatible with current standards?
- Are you familiar with DOCSIS standards and products?
- Are you familiar with the IP “new world” vision?
- Does your company have a business case supporting advanced services?

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