Bandwidth drivers for 100 G Ethernet

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Outline

- Comcast Profile & Triple Play Offering
- Network Overview
- What is driving network bandwidth?
- Where will we see high bandwidth requirements?
- Why 100GE?
Comcast Profile

Largest U.S. Cable Company
> 40 Million homes passed
24 Million Basic Cable subs
12 Million Digital Cable subs
11 Million HSD subs
2 Million CDV subs

A Portfolio of Growing Cable Channels

![Comcast Logo]

![E Logo]

![Style Logo]

![G Logo]

![The Golf Channel Logo]

![Discovery Health Logo]

![Comcast SportsNet Logo]

![tvone Logo]
Services Currently Supported by Network Infrastructure

Current Spectrum Utilization

- Analog Video: 65%
- HD VOD: 1%
- SD VOD: 3%
- HD Digital Broadcast: 7%
- Digital Simulcast: 6%
- SD Digital Broadcast: 16%
- HSD & CDV (DOCSIS): 2%

Shift from Broadcast to Unicast services drives core network capacity!

Unicasting for personalized & interactive services

Broadcast services: Analog video, digital broadcast, digital simulcast
Narrowcast and Unicast services: DOCSIS, VOD, SDV
New Unicast / Interactive Services on Roadmap

**Video**
- VRN Guide
- Video Search Tools
- TV Recommendations
- Online TV Planner
- “Follow-me” On Demand
- E-Mail Reminders
- Click to Record

**High-Speed Internet**
- Comcast Dashboard
- PowerBoost Upstream

**Voice**
- Single Address Book
- Communications Hub
  - Voice, text, IM, video
- Personalized/ Celebrity Greetings
- CDV Quick Info
  - news, weather, sports, traffic
Growth in On-Demand Services

- 1.9Bn Views in 2006
- 95% of Programs at No Charge
- ~70% of Customers View ON DEMAND Monthly
- Customers View ON DEMAND 27X a Month on Average

3.5 Billion+ ON DEMAND Views Since 2004
Growth in On-Demand Services

A Superior Hi-Def Experience

- **A Growing High-Def Offering**
  - Up to 20 Linear HD Channels Today... and Growing

- **Leveraging ON DEMAND**
  - 100+ Hours of HD ON DEMAND
  - HD VOD Hours to Double in 2007 and Again in 2008

- **Blockbuster HD ON DEMAND**

  ![Blockbuster Movies](image)

  2 Million HD-VOD Views Since Launch
Network Infrastructure Segments: Backbone, Regional and Access

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<th>Regional Area Network</th>
<th>Access Network (HFC)</th>
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<td>Head End / RAN Network</td>
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<td>CMC</td>
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- **Network Infrastructure Segments:**
  - **Backbone:** National Backbone
  - **Regional Area:** Head End / RAN Network
  - **Access:** Fiber Node / Tap, Analog, MPEG, IP

- **Key Components:**
  - National Backbone
  - Head End / RAN Network
  - Fiber Node / Tap
  - CMC, NOC, NDC, LMC, RDC/APOP
  - Analog, MPEG, IP
  - Bi-Dir Amp
  - Home Network
The Converged Regional Area Networks (CRAN) supports the delivery of multiple services over a common IP infrastructure.

- **Benefits**
  - Reduces the cost of transporting all services by up to 40% (In Greenfield deployment)
  - Allows Comcast to offer a variety of end customer service levels
  - The network architecture more scalable and future-proof minimizing future capital expenditure
  - Enhances operational efficiency by unifying operations

- **Features**
  - Provides a common pipe for the delivery of all services
  - Bandwidth can be allocated dynamically across services to accommodate demand changes
  - Supports a range of quality of services levels
  - Allows servers to be consolidated at a regional level

- **Able to support very high bandwidths and low price points required for video delivery**

- **Able to support low latency, minimal jitter and high reliability required to deliver quality voice services**

- **Common IP Pipe**
  - Voice
  - Video
  - Data
The backbone interconnects regional networks to create a unified national network

Comcast National Backbone Network

- Over 19,000 route miles of national fiber
- Covers 95+% of Comcast Homes Passed
- All major peering points
- Transport capability of >2500+ Gbps in 2006
- 40Gbps IP links in 2006
- QoS based voice, video and data over IP

Features
- Links all the regional networks into a unified network
- Consolidates peering and interconnection with other operators
- Managed QoS service delivery end-to-end with no third-parties involved
- Supports centralized management functions

Benefits
- Very flexible and low cost linear and OnDemand video distribution
- Backbone transport payments to transit providers reduced
- Reduce overall operational costs and complexity by supporting centralization
- Increased revenue opportunities by providing high quality, national end-to-end services
- Opens up wholesale opportunities
VoD Adoption is Shaping New Network Needs

Architectural Drivers

- Rebuilds Push Fiber (FTTN)
- DOCSIS Enables Ethernet (ETTH)
- HSI Drives IP Foundation
- VoIP Drives Availability & dQoS
- VoD Sets Capacity & Economics
- TV & STB (DSG) Drive Huge Scale
- SIP/PCMM Shapes Future services
Example of VOD Server Connectivity

VOD streams for each Hub/OTN are distributed evenly between:

- Two downstream fibers (diverse paths) from HE to Hub/OTN
- Two routers at Hub/OTN or two distinct ports on the same router
Example of Edge Connectivity

VOD streams for each Hub/OTN are distributed evenly between:
- Two downstream fibers (diverse paths) from HE to Hub/OTN
- Two routers at Hub/OTN (when available) or two distinct ports on the same router
Example of VOD Implementation

1M subscribers, 1 HE, 6 Dhubs, 100,000 Total Video Streams
265 SD streams per 1 Gbps, 56 HD streams per 1 Gbps

90% SD ~ 18,000 SD/ Dhub ~ 68 GE/ Dhub
10% HD ~ 2,000 HD/Dhub ~ 36 GE/ Dhub

50% SD ~ 10,000 SD/ Dhub ~ 38 GE/ Dhub
50% HD ~ 10,000 HD/Dhub ~ 180 GE/ Dhub
Limitations imposed by parallel nx10Gbps links

- Multiple ways to utilize parallel nx10G links
  - L3 ECMP
  - L2 Link-bundling

- Distribution of traffic over parallel links done via flow-based hash mechanism in both cases
  - Per-packet/round-robin distribution CANNOT be used due to packet re-ordering which results in significant drop in “goodput”

- Effectiveness of flow-based Hash distribution determined by traffic characteristics
  - Flow diversity - large number of flows
  - Average bandwidth per flow - determines number of flows that can be supported on any given link

- Flow-based hash mechanism CANNOT guarantee equal distribution of load
  - With ideal traffic characteristics it is statistically possible to uniformly distribute load over all links
Effectiveness of load distribution depends on
- Hash algorithm
- Diversity of hash input (variability in SRC/DEST IP address)
- Number of flows/size of flows

Hash can result in un-equal load distribution
- Caused by Non-ideal traffic characteristics such as:
  - Small distribution of src/dest IP addresses
  - High per-flow bandwidth

Un-equal load distribution can results in under-utilization of available capacity
- May potentially cause artificial congestion and packet loss

10x10Gbps is not the same as 1x100Gbps from a real throughput perspective

How many parallel 10Gbps links do you need to match usable bandwidth on one 100Gbps link?
- Depends on traffic characteristics...
Key Points

- There is a market need for 100GE
- Must standardize 100GE, pre-standard implementations are less accepted in the market
- Non-standard 40/80GE solutions will only slow 100GE development and adoption
- Providing a standard, cost effective solution is the best way to make 100GE successful
Thank You!