Fundamentals of Content Transport
TV 1/Ethernet/IP/MPLS

Fred Huffman
Huffman Technical Services
Ethernet/IP/ Based Network
- Planning
- Design
- Test & Verification ITU-T Y.1564, Y.1731, IEEE 802.1ag, 802.3ah
18 Kolas Court, Middletown, NJ 07748
+1 732-787-5462 +1 973-356-7219 (Mobile)
Email: fred@huffmantechnicalservices.com

My Book: Practical IP and Telecom For Broadcast Engineering and Operations Kindle version

Fine Print:
This presentation is a combination of business, economic and technical information describing and defining current content transport methodology (Dark Fiber Based Digital TV 1 links “Local Loops”) and SONET/SDH/TDM/ATM based Long Haul links and use that information to craft equivalent functional facilities based on Ethernet/IP/MPLS likely to be required in the coming years. Of necessity, several examples of products and services are included. Use of these examples in this way, is not to be construed as a recommendation, endorsement or recommendation by SMPTE or Fred Huffman.
Caveat Emptor. Caveat Venditor.
IOT? Internet of Things

IP On Everything!
Content is constantly on the move. Across the entire landscape, Communications Links support **Content Transport** -Content *Creation*, Content *Distribution*, Content *Delivery*.
SDI (real time) in parallel with Ethernet based *non-real time* content transport
• CCCLs and real time streaming Ingest –play-out server in the cloud
• Network services bundled with data center processing and network services
• End-to-end application response time can never be better than best underlying communications link response time
• Advice: Be diligent & detailed
• Insist on evaluation of end-to-end configuration and performance separate from application evaluation per ITU-Y.1564 SAM (Service Activation Methodology)
High Bitrate Media Transport Facility (SMPTE 2022-6-2012)

- "...this standard defines a method for encapsulation of the payloads of a variety of existing serial digital video standards." (259, 292, 425,) **NOT UHD 4K**
- Covers single path transport, network (dirty) switching
- SMPTE 2022-7 Diverse path, clean switching
- Forward Error Correction (FEC) optional
- In dire need of EGs and RPs

### 6.1 Basic Network Requirements

In order for a system supporting this standard to function correctly, the bandwidth available in the network shall always meet or exceed that required by the IP Stream generated by the system.

Note: It is important to ensure that the network path is designed with adequate bandwidth and a low enough error rate such that end equipment can successfully decode the stream. An optional error correction scheme is defined in SMPTE ST 2022-5.
## High Bitrate Media Transport Processing

### SDI Program Content Into Ethernet IP Transport Structure

```plaintext
<table>
<thead>
<tr>
<th>Step</th>
<th>SDI 01010111110101001100111101010111110110100110...1</th>
</tr>
</thead>
<tbody>
<tr>
<td>Parse into 1376 Byte groups</td>
<td>1376 Bytes, 1376 Bytes, 1376 Bytes, 1376 Bytes, 1376 Bytes</td>
</tr>
<tr>
<td>Number &amp; Time Stamp</td>
<td>RTP (L5), 1376 Bytes</td>
</tr>
<tr>
<td>Attach UDP Header</td>
<td>UDP (L4), 1376 Bytes</td>
</tr>
<tr>
<td>Attach IP Header</td>
<td>IP (L3), 1376 Bytes</td>
</tr>
</tbody>
</table>
```

### Diagram

- **Layer 2 (Ethernet) Transport Stream**: Ethernet (L2) - 1376 Bytes
- **Layer 1 (SONET/SDH) Transport Stream**: PHY (L1) - 1376 Bytes
- **SDI/IP/Ethernet/Packet/SONET/SDH**:
  - SDI/IP/Packet/SONET/SDH
  - Packet over SONET (POS)

---

5/20/2015  
Fred Huffman
What MPLS Is, How It Functions

- **MPLS**: *Multi-Protocol Label Switching* a technique where by an IP Network equipped with MPLS enabled Routers, routes packets along a pre-determined path to their destination based on information in the label instead of source and destination addresses.
- Customer Edge device (CER) creates packets containing content with CoS marking & puts them in Ethernet frames
- Metro Ethernet service transparently transports packets to Label Edge Router (LER)
- LER establishes Forwarding Equivalence Class (FEC) labels and calculates a path (LSP) or Tunnel through an MPLS capable network.
- Label Edge Router (LER) forwards to next hop Label Switching Router (LSR) according to label information
- Last router in the path (LER) removes label and forwards clean packet to Customer equipment (CER) for decoding and use.
IP Production Facility Requirements

- Operational practices should not be changed to accommodate new designs and technology
- Current operations must be parsed and defined to determine where work flows can be made more efficient under software manipulation and control
- Should be Standards Based
  - Existing /emerging SMPTE, applicable IEEE, IETF, ITU
- Adapt and adopt Standard Information Technology (IT)
  - Generic COTS Ethernet Switch & IP Router equipment
  - Metro Ethernet Virtual Services
  - Hypervisor based Data Center switching, processing and storage models
- Standards based multi-vendor facility that includes trial or lab resources for equipment and software test/evaluation
- Mindset: Never forget that production facility technical performance, e.g., picture quality, sound fidelity drives viewer experience
IP Live Production Facilities Migration Milestones

- Virtualized two-way links facilitating live production
- Availability of extended, interoperable SMPTE 2022 compatible, essence signal processing “clean switching” mixing, key, special effects *and*
- IT Compatible timing & synchronization products compliant with SMPTE 2059-2015
- Television friendly protocol analyzers and intelligent automated monitoring tools
  - ping and tracert won’t cut it.
- 10GigE Virtual interface on cameras, file servers, switching & mixing devices capable of carrying sync, control, tally, communications, IFB, audio pickup, program feed and any other required signals
- Passing of hybrid signal conversion boxes (SDI to IP, IP to SDI)
Content Transport Links

- Communications marketplace situation, circumstances, reality
  - How can I get my work done, protect my job and be successful?
- Legacy technology based TV 1 link models
  - Dark Fiber Transport
  - SONET/SDH/E3/DS3 (TDM) Transport
- Next Generation
  - Ethernet (L2) for local feeds and longer back-haul connections/links
  - How IP/MPLS transport fits in content transport technical operations
- Topics
  - Baseline Reference Models
  - Metro Ethernet Network Operators & Service Providers
  - Metro Ethernet interconnect – (External Network to Network Interface)
  - Along the way we will explore
    - Link architectures and touch on performance topics
    - Economics
Evolving Network Technology & Operations

• Carrier (Metro) Ethernet (Services) displacing ATM, TDM, Frame Relay
• Tariffs and regulations replaced by commercial Terms and Conditions with one-sided Service Level Agreement (SLA) provisions
• Carrier sales force and customer service functions headcount reduced in favor of inadequate, incomplete, incomprehensible website service, pricing information, chaos and confusion
• Increased level of third-party agents, resellers and wholesale Vendors in marketplace bizarre bazaar
• Automated order entry and service provisioning becoming more commonplace, ICBs falling out of favor, disappearing
Reference model for next gen IP ‘friendly’ content transport
- Service from Local Exchange Carrier (LEC) or other similar source
- Tx, Rx NIDs, Dark Fiber Transport
- NID Examples: Artel DLC 103 Series Evertz 7700 Series
- Dark Fiber from anywhere it is available, or install your own
- NID Example: Evertz 7890 Series Successor to 7700 modules; Nortel DV-45
- Unchannelized local loop Intra-LATA or Inter-LATA transport facility
- Note: Both Artel and Evertz offer bi-directional capability, Ethernet interface & transport in parallel with content transport
Next Generation Content Transport Alternatives

• Replace legacy TV 1 and ATM/TDM Access Facilities
• Metro Ethernet Network Services:
  – MEF 1.0 Local – Regional coverage roughly equivalent to Intra-LATA coverage -inside LATA boundaries
  – MEF 2.0 enables network interconnections – extends coverage across multiple network operators
• Or
• Media Network Services: End-to-End, Cradle-to-Grave, Soup-to-Nuts Media ‘solutions’ (Service Provider Design)
NID – Network Interface Device

• A multi-function piece of equipment (Device) that facilitates interface between television systems and communications networks

• Two types of devices:
  – Program content applications
  – Data or IT only applications

• Two architectural arrangements
  – Type A: Video/Audio signal handoff to carrier
  – Type B: Data / Ethernet RJ-45 or Optical (SFP) handoff (Premises based Carrier Equipment i.e., Ciena (LE-311V))

• Ownership & Service Management
  – Do you want to own/manage, or delegate to trusted service provider?
  – Define service demarcation point or points as a starting place
Anatomy of a Carrier Class NID

- Interfaces media facility to content transport network
- Key functions include
  - Accommodate myriad line side and trunk side (carrier) interfaces
  - Interwork and interoperate with carrier networks and other NIDs across network
  - Centralized media network configuration, monitoring, control and management
- Real World Examples: (Data) Ciena Packet Optical (LE-311V) Cisco ME 3400
- Media Network: Net Insight Nimbra 600, 300, 200
NID Considerations

• Resolution of ownership & operations responsibilities requires video head and network head banging over tons of detailed subject matter
• Detailed system design and operational workflow requirements a must!
• Highly dependent on operations philosophy and technical preferences
• High level use case descriptions with Opex / Capex $$$ estimates:
  – Service provider ownership, management, configuration per specific service order request ($$)
  – User owned, or third party managed, configured, maintenance preference
• Comprehensive Service Agreement (SA) covering network service elements, demarcation points, service levels (SLAs), CoS/QoS, signal interface/handoff, pricing, billing, general terms and conditions of service (“boiler plate”)
• Who’s Capex $ and what’s your resulting Opex of each alternative?
Metro Ethernet Services Content Transport

SONET/SDH/TDM/E3/DS3/OC3/STM1 Content Transport Digital TV1 Access

End-To-End Content Transport Service

Telco Equipment & Facilities

Example: Comcast Business (or other) Ethernet Virtual Private Line

Single Network Operator Ethernet Based Content Transport Facility

Metro Ethernet Services User

Metro Ethernet Network (MEF 1.0)

Metro Ethernet Services User

NID Media NID MEF 1.0 Switch Module NID Service Provider NID User Network Interface (UNI)

Example: Comcast Business (or other) Ethernet Virtual Private Line

5/20/2015

Fred Huffman
Metro Ethernet Services Content Transport

- Metro Ethernet service per MEF 1.0 with appropriate CoS marking
- Migrate E3/DS3 To 100Mbit/s Ethernet Virtual Private Network / Virtual Private Line
- Both or all sites connected through the same network operator
- Excellent virtualization capability – voice, video, data, control depending on NID and underlying network capabilities
- GigE/10GigE supports multiple connections carrying compressed & uncompressed SDI/HD SDI content
- Requires NID and Ethernet network combination with well thought out configuration parameters providing end-to-end deterministic performance
Metro Ethernet Services Content Transport

- Metro Ethernet service per MEF 2.0 (ENNI –Network-to-Network)
- Extend reach across multiple Ethernet Operator Networks
- Excellent virtualization capability – voice, video, data, control depending on NID capabilities
- ITU-T Y.1731; IEEE 802.1ag, 802.3ah end-to-end monitoring, fault isolation
- Requires End-to-end NID AND Network configuration to achieve deterministic end-to-end Service Quality (QoS)
Best Efforts IP (Internet) Content Transport

• Basis for most content delivery today; seeing limited use in distribution applications
  – IPTV, OTT, Streaming Video, et.al.
  – Packet loss, delay variation require error correction and large buffers to compensate for network performance (or lack thereof)
  – Unlikely to support Pro Media content creation and higher bit-rate distribution
  – Fix: EVC/PL IP/MPLS with CoS marking & bandwidth configuration as appropriate to SDI /HDSDI basic requirements
• Promoted by Net Insight as Distribution capable See: VA 200 series Video Appliances
Next Generation (TV-2?) Content Transport

- **Components:**
  - Network Interface Device (NID) endpoints A&B
  - Metro Ethernet Service transport link
- **Metro Ethernet Services MEF 1.0, MEF 2.0**
- **Future Metro Ethernet Forum** [third network](http://example.com) or NaaS Seen as next version of architecture addressing SDN, NFV, enterprise & data center business & technical operations requirements
- **Players**
  - NID OEMs
  - Network Service Operators
  - Network Service Providers
  - Network Service price quoters, agents, master agents, resellers, wholesalers, solution purveyors, et.al

_Fred Huffman_
Structured IP/MPLS/VPN/VPL Content Transport

- **Deterministic Ethernet** – LAN, Metro Ethernet/IP/MPLS WAN virtual private line service (EVPL)
  - Supports VLAN based CoS for separate virtual transport facilities; requirements for dedicated private line content transport, monitor & control traffic
- **MPLS based packet labeling, CoS treatment and routing** create Virtual Private Line transport facilities for (required) QoS transport of disparate signals – voice-data-video-monitoring-control
• Local Network VLAN or NID (CER) creates packets containing content with CoS marking & puts them in Ethernet frames for transmission along an MPLS path or ‘tunnel’ in a Layer 3 network
• Metro Ethernet transports packets to Label Edge Router (LER)
• MPLS provides capability for dedicated service through a shared IP Network
• Metro Ethernet Service aggregation points can also be used as an interconnection point between two Ethernet switches in the same or separate networks (ENNI)
Virtual Private Line - Alarm Bell

• Virtual = Not Real
• Reference Models:
  – SDI over Coax – multiple device output to device input chain
  – TDM E3/DS3 (device Tx to device Rx) fixed bandwidth
• Ethernet / IP virtualization involves time slot multiplexing
• Class of Service (CoS) markings establish traffic reception, stack processing and transmission priority
• VLAN Segmentation (Local and Carrier) Separates & isolates disparate traffic
• Network Operators use traffic policing and strict monitoring to manage and maintain network performance
  – See MEF paper: Understanding Carrier Ethernet Throughput
• End-to-End payload integrity & performance must be equivalent to Legacy SDI / HD SDI Over TDM Operation
NID Related Service & Billing Arrangements

- NID must be CER (MPLS) capable with variety of access side and trunk side interfaces
- How much bandwidth is required Vs NID Capabilities
- Service provider or Enterprise Owned
- Self service or managed services
- Managed by service manager/orchestrator or pairs of hands? – Manual or automated?
- More and more, media production operations (especially News) requires a combination of nailed up and dynamic or dial tone type connections – set up on short notice, tear down on completion, pay for each use
Planning Tools & Resources

• NID data sheets and Carrier Technical Service Description documents
• Watch for, & be wary of ‘solutions’ purveyors – product or service
• Standards reference – SMPTE, IETF, IEEE, ITU
• Network coverage
  – service provider network map
  – lit building list
• Commercial pricing
  – Network Interface Device (NID) commercial products
  – Network service elements – access & transport services
High Level Project Plan

• Typical project plan (aka: desktop estimate or ROME – rough order magnitude estimate) includes:
  – Summary outlining what, where, when, who
  – Impact statement saying if approved, the result will be (strategic, tactical – improve competitive position, address another market, reduce operating expense, improve service level, viewer experience)

• Capital budget
• Operating Expense statement (P&L Impact)
• Preliminary operations plan
• Final project approval may require walking-the-site or sites effort to validate and update ROME / DT estimate
Sourcing and Qualifying Metro Ethernet Service

- **Definitive Generic Specifications & Service Descriptions:**
  - Metro Ethernet Forum
  - Definitions
  - MEF 33 - Ethernet Access Services
  - MEF 10.3 - CE Service Attributes
  - MEF 23.1 - Class of Service
  - MEF 26.1 - ENNI
  - MEF 45 - Multi-CEN L2CP
  - Certified Products/Services
  - Become a Certified Professional

- **Two Types of business entities (Caveat Emptor):**
  - Facilities based organization – owns transmission equipment, fiber & rights of way e.g. Network Operator
  - Network Service Provider Buys services from Operators and engages in business operations – planning, design, implementation, Marketing – service planning, advertising, promotion, Sales – finding customers, taking orders, convincing prospects to buy
Service & Facility Cost/Pricing guidelines

• Start with detailed analysis of existing service and facilities.
• Recommend detailed audit by knowledgeable experienced telecom/data services auditor
• Find or figure out your cost per bit for bandwidth. This becomes a benchmark for evaluation of alternatives
• Build a spreadsheet model based on your current network as determined by an audit of existing circuit, facility and (equipment) costs based on internal accounting (depreciation) records
Representative Pricing ME Services

- Method: Using models outlined, requested budgetary pricing from 3 carriers, from several metro locations (US Capitol, Verizon Center) and two distant locations (VA State Capitol and Philadelphia Democratic Convention site) to point B, (CBS News) for 100Mbit/s, GigE and 10GigE speed/BW
- Pricing appears to be fixed, distance insensitive for specific line rates mentioned

<table>
<thead>
<tr>
<th>Link B/W Mbit/s</th>
<th>Point A</th>
<th>Point B</th>
<th>MRC</th>
<th>Cost/MBit</th>
<th>Install Interval</th>
<th>2nd Vendo</th>
<th>Cost/MBit</th>
</tr>
</thead>
<tbody>
<tr>
<td>100</td>
<td>US Capitol</td>
<td>2020 M St. (CBS)</td>
<td>$1,300.00</td>
<td>$13.00</td>
<td>90 to 120 days</td>
<td>$2,500</td>
<td>25</td>
</tr>
<tr>
<td>100</td>
<td>VA State Capitol</td>
<td>2020 M St. (CBS)</td>
<td>$1,300.00</td>
<td>$13.00</td>
<td>90 to 120 days</td>
<td>$2,500</td>
<td>25</td>
</tr>
<tr>
<td>100</td>
<td>Capitol (Verizon) Center</td>
<td>2020 M St. (CBS)</td>
<td>$1,030.00</td>
<td>$10.30</td>
<td>90 to 120 days</td>
<td>$2,500</td>
<td>25</td>
</tr>
<tr>
<td>100</td>
<td>Democratic Convention Site, Philadelphia, PA</td>
<td>2020 M St. (CBS)</td>
<td>$1,530.00</td>
<td>$15.30</td>
<td>90 to 120 days</td>
<td>$2,500</td>
<td>25</td>
</tr>
<tr>
<td>1000</td>
<td>US Capitol</td>
<td>2020 M St. (CBS)</td>
<td>$2,400.00</td>
<td>$2.40</td>
<td>90 to 120 days</td>
<td>$2,500</td>
<td>25</td>
</tr>
<tr>
<td>1000</td>
<td>VA State Capitol</td>
<td>2020 M St. (CBS)</td>
<td>$2,600.00</td>
<td>$2.60</td>
<td>90 to 120 days</td>
<td>$2,500</td>
<td>25</td>
</tr>
<tr>
<td>1000</td>
<td>Capitol (Verizon) Center</td>
<td>2020 M St. (CBS)</td>
<td>$2,400.00</td>
<td>$2.40</td>
<td>90 to 120 days</td>
<td>$2,500</td>
<td>25</td>
</tr>
<tr>
<td>1000</td>
<td>Democratic Convention Site, Philadelphia, PA</td>
<td>2020 M St. (CBS)</td>
<td>$2,650.00</td>
<td>$2.65</td>
<td>90 to 120 days</td>
<td>$2,500</td>
<td>25</td>
</tr>
<tr>
<td>10000</td>
<td>VA State Capitol</td>
<td>2020 M St. (CBS)</td>
<td>$17,000.00</td>
<td>$1.70</td>
<td>90 to 120 days</td>
<td>$2,500</td>
<td>25</td>
</tr>
</tbody>
</table>
Layer 2/3 Carrier Service Provider Examples

• Network Operator (Carrier) examples:
  – Comcast Business SVCs Ethernet Private Line
  – Lumos Networks Ethernet Services
  – Lightower Network LAN Extension & Private Line
  – Verizon (Generic) Business Services
  – Zayo Communications

• Network Service Provider examples:
  – MRV Communications Carrier Ethernet 2.0
  – Shop For Ethernet.Com
  – SOLVEFORCE Metro DC –Washington, County, MD

• Media Network End-to-End Solution Providers
  – Level 3 Vyvx Solutions
  – The Switch Washington, DC Ports & Circuits
  – Zayo Communications
  – Verizon (Generic) Business Services
Summary, Conclusions, & Recommendations

• Metro Ethernet Services appear to be a cost-effective technical replacement for aging legacy TDM and Dark Fiber transport in local and long haul links required by IP-based content creation

• MPLS Transport may or may not be desired or necessary to get end-to-end underlying network Quality of Service (QoS)

• Requires strong design practices and procurement actions – due diligence to ensure successful transition

• Engage with OEMs Network Operators and Service Providers

• “Trust, but (validate and) verify”
SMPTE Education & Professional Development

- **SMPTE Education: Essentials of IP Media Transport for Broadcasters**
- **Learn** a solid grasp on facility workflow domains for networked file-based and streaming media transport
- **Compare** and contrast serial digital interface (SDI) and IP-based workflow models
- **Discuss** the components and protocols used in an IP-based video production workflow
- **Explain** how to choose and configure video and audio codecs across business applications
- **Select** appropriate image and audio synchronization methods during mixing and switching
- **Course Started** April 6 and runs for **6 weeks**.
- Upcoming session starts, July 13, October 5, November 23
Acknowledgements

- Philip Dubs  Artel
- Chuck Diehl  Evertz
- Love Thyresson  Net Insight
- Martin Karlsson  Net Insight
- Mike Peyton  CBS News
- Nick DelRegno  MCI Labs
- Robert Kaplan  Lightower Communications
- Virginia O’Mera  Zayo Communications
- Sean Wilson  Lightower Communications
- Wes Simpson  Telecom Product Consulting
- Rick Singer  SMPTE DC BBTB Program Genius
- Sterling Watts  Comcast
Thanks for your time and attention!

Q&A
Backup & Reference Material
High Level Reference Material

- SMPTE Motion Imaging Journal, March, 2015 VIDEO OVER IP:
  - Intro Thomas Edwards
  - Broadcast Timing, Genlock and Time Code in the Multiformat Age
  - Can COTS Ethernet Switches Handle Uncompressed Video?
  - A Practical Approach to IP Live Production
  - The Control of Media within an Internet of Things Using SMPTE ST2071
  - Taking Remote Production to the Next Level—CBC's Coverage of the 2014 Sochi Olympic Games

- Broadcasting and Cable Webinar:
  - The Media Industry Transition to IP: Defining the Business Case
  - Cisco Whitepaper: IP/MPLS Networks: Optimize Video Transport for Broadcasters
  - Net Insight Paper: Solving the QoS bottleneck in Video and Triple Play Networks
  - Metro Ethernet Forum Specifications and Technical Publications:
    - Metro Ethernet Services Technical Overview
    - CE 2.0 Overview
    - Definitions
    - MEF 10.3 - CE Service Attributes
    - MEF 33 - Ethernet Access Services
    - MEF 23.1 - Class of Service
    - MEF 26.1 - ENNI
    - MEF 45 - Multi-CEN L2CP

16/05/2015
Fred Huffman
Useful Non-SMPTE Standards

- IEEE Get Program
- IEEE 802™-2014 - IEEE Standard for Local and Metropolitan Area Networks: Overview and Architecture has been recently published and is available for purchase in our store. This standard will be available in the GET program January 2015 at which time you can download at no charge.
- 802.3 Ethernet
  - IEEE 802.3™-2012 – Section One
  - IEEE 802.3™-2012 – Section Two
  - IEEE 802.3™-2012 – Section Three
  - IEEE 802.3™-2012 – Section Four
  - IEEE 802.3™-2012 – Section Five
  - IEEE 802.3™-2012 – Section Six
- IEEE 1588V2 Precision Time Protocol (PTP)
- IETF RFC Ethernet Search
- IETF RFC Video Search
- ITU-T Y.1564 Ethernet Service Activation Test Methodology
- ITU-T Y.1731/IEEE 802.1ag/ah Connectivity Fault Management
Standardized Test & Verification

• **Out-Of-Service:** system and software due diligence & certification
  • Ethernet/IP Commissioning and Service Activation
    • ITU-T Y.1564 (L2 and L3), RFC 2544 (L3 only)
      • Analyzer –Traffic Generators: Adva Optical, Ixia, Spirent
  • In-service: Live technical operations
  • Connection, end-to-end connectivity (continuity) monitoring and alarms
    • ITU-T Y.1731; IEEE 802.1ag, 802.3ah
• Software based Protocol Analyzers
  • Microsoft Network Monitor Message Analyzer Free Download
  • Wireshark Free Download
  • Savvius Omnipeek $1,100
  • Solar Winds Netflow traffic analyzer $1,875
Monitoring, Test & Trouble Resolution Reality

- **Traditional Practice:**
  - Patch a questionable signal into a WFM/Display and see if the picture is impaired, measure the impairment, call the phone company and make a lot of noise

- **Get Ready for:**
  - Standardized, automated, intelligent network performance measurement; fault identification
  - Ping and Tracert won’t cut it in Media production technical operations