REAL-TIME PROFESSIONAL BROADCAST SIGNALS OVER IP NETWORKS

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Introduction

• Transport of high quality real-time contribution video over IP networks

• Goal is lower CAPEX and OPEX while maintaining quality and reliability and increasing flexibility

• Discuss the challenges, trade-off and technologies to achieve this goal
Transition from Coax to IP
Network Impairments

- Packet Loss
- Burst Loss
- Packet Out of Order
- Delay Variation – Jitter/Wander
- Signals impact other signals
- Performance varies over time
Design Factors

• Is your system point-to-point or it is multicast?
• Is there a back channel from the receiver to the transmitter?
• Are the network connections relatively static or do they change often?
• What level of control over the network do you have? Can you directly manage the network, or is it done with Service Level Agreements (SLAs)?
• What is the error rate of the network?
• What are bandwidth costs for the data and overhead that is required?
Challenges over IP Networks

- Encapsulating The Video Data
- Dealing With Packet Loss
- Getting Video Across The Network
- Protecting The Data
- To Compress Or Not To Compress
• Encapsulating The Video Data
• Dealing With Packet Loss
• Getting Video Across The Network
• Protecting The Data
• To Compress Or Not To Compress
Encapsulating The Video Data

• Challenges to solve
  – Break up video to get across network
  – Routing to get across network
  – Packet re-ordering
  – Detect packet corruption
  – Detect packet loss
Encapsulating The Video Data

- **Video Signal**: 188 to 1376 bytes
- **RTP Video Signal**: Session Layer (5)
- **UDP RTP Video Signal**: Transport layer (4)
- **IP UDP RTP Video Signal**: Layer 3
- **Ethernet IP UDP RTP Video Signal**: Layer 2
Encapsulating The Video Data

- SMPTE 2022 Family
- Real-Time-Protocol (RTP)
- User Datagram Protocol (UDP)
- IP
- Ethernet
SMPTE 2022 Family

SMPTE 2022-1 “Forward Error Correction for Real-Time Video/Audio Transport Over IP Networks”
SMPTE 2022-2 “Unidirectional Transport of Constant Bit Rate MPEG-2 Transport Streams on IP Networks”

SMPTE 2022-3 “Unidirectional transport of variable bit rate MPEG-2 Transport Streams on IP Networks”
SMPTE 2022-4 “Unidirectional Transport of Non-Piecewise Constant Variable Bit Rate MPEG-2 Streams on IP Networks”

SMPTE 2022-5 “Forward Error Correction for High Bit Rate Media Transport over IP Networks”
SMPTE 2022-6 “High Bit Rate Media Transport over IP Networks”
Break up video to get across network

• SMPTE 2022-2
  – For MPEG-2 Transport Stream (TS)
  – 188 bytes TS packets. Up to 7 TS packets
    • Up to 1316 bytes (for 7 TS)

• SMPTE 2022-6
  • For uncompressed
  • 1376 bytes
UDP

- 8 bytes of overhead
RTP

<table>
<thead>
<tr>
<th>Control Fields</th>
<th>Sequence Number</th>
</tr>
</thead>
<tbody>
<tr>
<td>Timestamp</td>
<td>SSRC identifier</td>
</tr>
<tr>
<td>Data</td>
<td></td>
</tr>
</tbody>
</table>

- 12 bytes of overhead
• 20 bytes of overhead
Ethernet

- 42 bytes of overhead
Encapsulating The Video Data

- **Video Signal**: 188 to 1376 bytes
  - Session Layer (5), Overhead 12 bytes or 0.9%
  - Transport layer (4) Overhead 8 bytes or 0.6%
  - Layer 3, Overhead 20 bytes or 1.5%
  - Layer 2, Overhead 42 bytes or 3.1%
• Encapsulating The Video Data
• **Dealing With Packet Loss**
• Getting Video Across The Network
• Protecting The Data
• To Compress Or Not To Compress
Sources of Packet Loss

- Congestion in the network
- Random Noise
- Cuts to links
- Equipment failure
Dealing With Packet Loss

• Detecting packet corruption
• Detecting packet loss
• Regenerating lost information
Detecting packet corruption/loss

- Ethernet and UDP have check field
- Corruptions -> Loss packet

- RTP has sequence number
Regenerating Lost Packets

- Do nothing
- Forward Error Correction (FEC)
- Retransmit missing packets
FEC

• SMPTE 2022-1 “Forward Error Correction for Real-Time Video/Audio Transport Over IP Networks”
  • For compressed TS

• SMPTE 2022-5 “Forward Error Correction for High Bit Rate Media Transport over IP Networks”
  • For uncompressed
FEC (SMPTE 2022-1)
Error Recover Process
## FEC Rates

<table>
<thead>
<tr>
<th>Rows</th>
<th>Columns</th>
<th>Overhead</th>
<th>Latency</th>
<th>Recovery</th>
<th>Matrix size</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Column only</td>
<td>Row and Column</td>
<td>3 Mbps (ms)</td>
<td>30 Mbps (ms)</td>
</tr>
<tr>
<td>10</td>
<td>5</td>
<td>10%</td>
<td>30%</td>
<td>175</td>
<td>18</td>
</tr>
<tr>
<td>5</td>
<td>10</td>
<td>20%</td>
<td>30%</td>
<td>175</td>
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<tr>
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<td>10%</td>
<td>20%</td>
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<td>25%</td>
<td>351</td>
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<td>8</td>
<td>13%</td>
<td>25%</td>
<td>225</td>
<td>22</td>
</tr>
<tr>
<td>5</td>
<td>8</td>
<td>20%</td>
<td>33%</td>
<td>140</td>
<td>14</td>
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<tr>
<td>6</td>
<td>4</td>
<td>17%</td>
<td>42%</td>
<td>84</td>
<td>8</td>
</tr>
<tr>
<td>4</td>
<td>6</td>
<td>25%</td>
<td>42%</td>
<td>84</td>
<td>8</td>
</tr>
</tbody>
</table>
FEC

• Trade-offs
  – Overhead
  – Latency
  – Recovery ability
  – Design complexity -> Cost

• Advantages
  – Lossy network
  – Multi-cast
  – No reverse channel available
  – Deterministic overhead
Retransmit missing packets
Retransmit missing packets

• Advantages
  – Higher error recovery

• Disadvantages
  – Requires reverse channel
  – Point-to-point connections
  – Variable overhead
  – High latency
  – No standards – Proprietary solutions
• Encapsulating The Video Data
• Dealing With Packet Loss
• **Getting Video Across The Network**
• Protecting The Data
• To Compress Or Not To Compress
Getting Video Across The Network

• Challenges
  – QoS
    • Identify video packets as special
    • Rules for special processing/handling
  – Failure Recovery
    • Time to switch
Getting Video Across The Network

- Networks can be grouped into:
  - Smaller Local Area Networks (LAN) and Campus Area Networks (CAN)
  - Connected islands of LAN/CAN
  - The Internet cloud
LAN/CAN - VLAN

Using VLAN

LAN/CAN #1
VLAN

- IEEE 802.1q or Virtual LAN (VLAN)
- 4 bytes of overhead
VLAN

• Advantages
  – Direct control
  – QoS
  – Lower cost than layer 3 router

• Disadvantages
  – Scalability
  – New skills
LAN/CAN

- Over provisioning
- Spanning Tree Protocol (STP)
- Internet Group Management Protocol (IGMP)
- Redundancy
Connected LAN/CAN
Connected LAN/CAN

• SONET/SDH
  – (Synchronous Optical Networking)
  – (Synchronous Digital Hierarchy)
• MPLS
  – (Multiprotocol Label Switching)
• MPLS-TP
  – (MPLS Transport Profile)
• Carrier Ethernet
SONET/SDH

• Circuit switched TDM technology
• Rates
  – OC-3 (155 Mbps)
  – OC-12 (622 Mbps)
  – OC-48 (2.5 Gbps)
  – OC-192 (10 Gbps)
SONET/SDH

• How
  – GFP (Generic Frame Procedure)
    • ITU-T G.7041/Y.1303
  – POS (Packet Over SONET)
  – ATM
SONET/SDH

- Advantages
  - High reliability
  - High QoS
  - Readily available
  - 50mS protection switching

- Disadvantages
  - Fixed bandwidth
  - Flexibility
MPLS

- 4 bytes of label overhead
MPLS

• Advantages
  – Some QoS
  – Highly scalable
  – Protocol agnostic

• Disadvantages
  – QoS by SLA
  – Dynamic behavior
  – Higher costs
MPLS-TP

• Advantages
  – QoS
  – Protection switching
  – Lower cost than MPLS

• Disadvantages
  – QoS by SLA
  – Interoperability
Carrier Ethernet Services

• ‘Big’ Ethernet network

• Types
  – Point-to-Point service (E-line)
  – Multipoint-to-Multipoint (E-LAN)
  – Point-to-Multipoint (E-tree)
Carrier Ethernet

• Implemented with
  – Ethernet over SONET/SDH
  – Ethernet over MPLS
  – Ethernet over Carrier-Ethernet Transport (CET)

• Interface to user is Ethernet
Service Level Agreement (SLA)

- Packet Delay Variation
- Packet Loss Ratio
- Packet Reordering Ratio
- Packet Loss Period
- Failure Recovery
- Service Availability
The Internet cloud
• Encapsulating The Video Data
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Protecting The Data
Protecting The Data
Protecting The Data

- At source level
- At TS level
  - Basic Interoperable Scrambling System (BISS)
  - DVB Simulcrypt
- At network level
  - IPSec
• Encapsulating The Video Data
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• To Compress Or Not To Compress
To Compress Or Not To Compress
To Compress Or Not To Compress

• Quality vs. Bandwidth
  – Uncompressed, 3x SD in GigE
  – Uncompressed, 6x HD in 10 GigE
  – Mathematically lossless
  – Visually lossless
  – Visually lossy
To Compress Or Not To Compress

- Generation losses
- Latency
- Long GOP vs. I frame only
- HANC and VANC space
- Error concealment
## To Compress Or Not To Compress

### Typical HD bandwidths

<table>
<thead>
<tr>
<th>Bandwidth (Mbps)</th>
<th>Compress Technique</th>
</tr>
</thead>
<tbody>
<tr>
<td>1,500</td>
<td>Uncompressed</td>
</tr>
<tr>
<td>200</td>
<td>JPEG 2000 4:2:2 10 bit</td>
</tr>
<tr>
<td>50</td>
<td>MPEG-2 4:2:2 8 bit</td>
</tr>
<tr>
<td>25</td>
<td>H264 4:2:2 10 bit</td>
</tr>
</tbody>
</table>
Summary

- IP networks are becoming a cost-effective way to transport real time professional broadcast signals

- Challenges
  - Encapsulating The Video Data
  - Dealing With Packet Loss
  - Getting Video Across The Network
  - Protecting The Data
  - To Compress Or Not To Compress

- New skills
- Interoperability
Questions

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