Professional Media Transport over Packetized Networks

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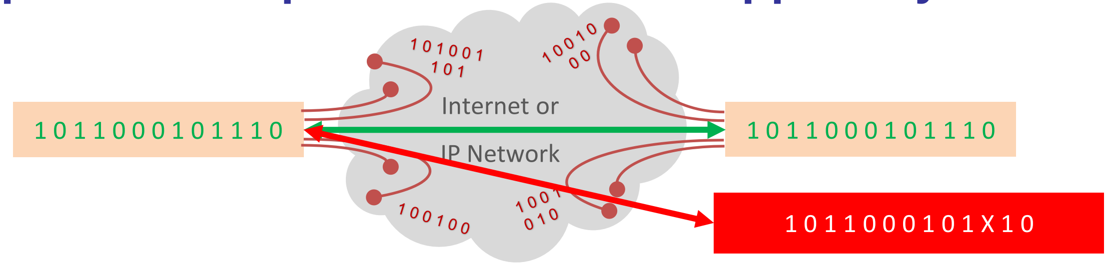
Executive Summary –1–

- **Universal Problem: Real Time Video Over Packet Networks**
  - **Video corrupted due to:**
    - **Packet Loss**
    - **Packet Duplication**
    - **Packet Corruption (bit errors)**
  - **Playout quality degraded by Jitter due to:**
    - **Packet Delay**
    - **Variations in Inter-Packet Spacing**
    - **Congestion**
    - **Latency**

Executive Summary –2–

Correcting the Problem with QOS / FEC / CDN / BEC / DPI

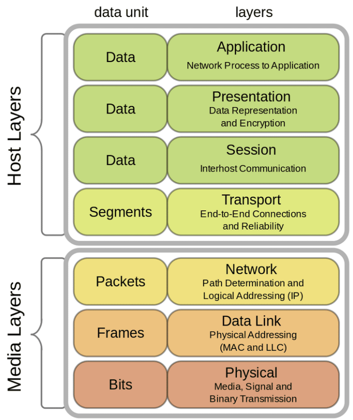
- No Single Method Covers All Bases
  - Quality of Service: Does not Correct for Jitter and Dropouts
  - Forward Error Correction: Adds Overhead, *can Cause* Congestion
  - Content Delivery Networks: Can be Expensive for Single Streams
  - Backward Error Correction: Does Not Address Jitter
  - Deep Packet Inspection: Relies on Upper Layer Variables



Executive Summary –3–

Our Solution: Layer 2 Network Protocol (Unique!)

- **Implemented in OS Network Layer at Both Sides**
  - **Backward Error Correction/Re-Request Mechanism**
  - **Timing Mechanism Recreates Inter-Packet Speed/Spacing**
- **Benefits**
  - **At Layer 2, Applications Use It Without Even Knowing It’s There**
  - **Re-Request Mechanism Corrects Without Adding to Congestion**
  - **Delivers Packets at Same Speed They Were Sent, Adding *Zero* Jitter**



IP Transport

1. Issues
2. FEC and ARQ
3. QOS and DPI

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IP Packet Transport: Issues (Well Known!)

- **Network Problems**
  - **Duplicated, out of sequence and long strings of missing packets**
- **Physical Problems**
  - **Within Own Physical Plant, or in Local Loop**
  - **Bit Errors and Individual Corrupted Packets**
- **Varying Network Paths or Congestion**
  - **Variations in Inter-Packet Spacing**
  - **Jitter on Received Packets**
- **Vendor Implementation Issues**
  - **Contents of Upper Layer Variables not Always Accurate**
  - **Incompatibilities in Vendors' Upper Layer Protocols**

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IP Transport: FEC and ARQ

- **Automatic Repeat Request: Been Around a Long Time**
  - **Telegraph 1850's**
  - **Radio – 1940's**
  - **Telex – 1950's**
  - **TCP – RFC 793 – September 1981**
  - **Overhead a Function of Error Rate**
- **Forward Error Correction**
  - **First Use Richard Hamming – 1950 (Hamming code)**
  - **Extensively Used in Satellite Transmission**
  - **Memory and Disk Drives**
  - **Relatively High Overhead**

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IP Transport: QOS and DPI

- **QOS - Media Access Control Layer (Ethernet)**
  - **Does Not Extend Across Disparate IP Networks (the Internet)**
- **DPI - Deep Packet Inspection**
  - **Requires Significant Processing Power and Delays Video Stream**
  - **Not Supported or Controllable Outside Your Network**

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Our Solution

US Patent # 9338259

Our Goals

- **Robust Re-Request Mechanism to Prevent Dropouts**
- **Control Inter-Packet Spacing to Prevent Jitter**
- **Support Both Unicast and Multicast**
- **Transparent to Server and Client Applications**
- **Cross-OS Support: Linux, Windows, Android, iOS**
- **Vendor Independence**

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Basic Approach

- **Why a Layer 2 BEC/ARQ Solution?**
  - **OSI Network Model:**
    - **Level 1 is the Copper**
    - **Level 7 is where the Applications Run**
    - **In Theory, the Closer to the Copper, the Faster It Runs**
  - **"Bake it into the OS Approach"**
    - **OS Handles Network/UDP Packets at Level 2**
    - **Level 7 Apps Don't Know How Level 2 Works – They Just *Use* it**
    - ***Existing* Internet Media Server and Media Client Apps Can Use it**
    - **Media Format Irrelevant – All Packets Treated the Same**

Implementation Steps

- **Emulate a VPN: Solution Needs a Controlled Tunnel**
- **Filter and Tag Every Packet With Sequence and Timing Info**
- **Maintain a Buffer On The Transmitter of Sent Packets**
- **Maintain a Buffer on the Receiver of Received Packets**
- **Parse the Tags As They Arrive to Identify Missing Packets**
- **Send Negative Acknowledgements Where Necessary**
- **(Transmitter Resends as Requested)**
- **Strip Tags and Deliver All Packets With the Same Inter-Packet Timing as Originally Noted**

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Details of the Solution –1–

- **Emulate a VPN**
  - **Transmitter and Receiver Appear as Network Nodes With an IP Tunnel Between Them Having Separate, Private, IPv4 Addresses**
  - **Any Packets Sent To or Coming From Any Port at That IP Goes Through That Re-Request Mechanism**
  - **Allows Multicast Tunneling**
  - **Since This Happens at Layer 2, it Requires the OS to Run a Service or Daemon. The Solution Runs on Linux or Windows**
    - **Soon iOS and Android**
  - **Optional AES encryption, LZO Compression, user/pass Authentication, Redundant Paths or Split Paths**

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Details of the Solution –2–

- **Filtering and Tagging**
  - **The Solution Tags the Packets With Additional Information**
    - **Sequence Number**
    - **Time Elapsed Since Last Packet**
    - **An Additional Virtual Packet Size Calculation (We'll Explain Later)**
  - **Used For**
    - **Detection of Missing Packets**
    - **Detection of Out-of-Order Packets**
    - **Emit Packets at the Destination with Precise Duplication of the Inter-Packet Spacing with which they Arrived at the Transmitter**

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Details of the Solution –3–

- **Sender Buffer**
  - **If Receiver Asks For Resend of Sequence #123, Transmitter Retrieves it from the Buffer by Sequence Number and Resends**
  - **FIFO Buffer Maintained at a Configurable Size**
- **Receiver Buffer**
  - **FIFO Buffer Maintained at a Configurable Size**
  - **Real-World Experience: 4x Ping Time Between Sides Works Nicely**
    - **Examples: 50ms New York to/from Texas; 800ms Florida to/from New Zealand**

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Details of the Solution –4–

- **Receiver Parser**
  - **Reads the Tags in the Packets in the Buffer**
  - **Identifies Missing, Sends Negative Acknowledgement as Necessary so that the Transmitter Negative ACK Module Can Resend it**
  - **Reorders Out-of-Sequence Packets**

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Details of the Solution –5–

- Receiver Gate
  - Receives Complete Packets from the Parser, Releases Them to the Counter Removal Unit with the Exact Interval Spacing Between Packets as Recorded by the Transmitter
- Counter Removal Unit
  - Removes the Extra Tags the Solution had Placed in the Packet and Releases Them to the OS
    - Typically, the localhost Address, 127.0.0.1, at Whatever Port Was Configured for the Solution

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Conclusion

1. **Keep Error Correction and Timing Mechanism at Layer 2**
2. **Configure Media Source to Output and Client to Receive on an IPv4 Address and Port**
3. **Solution Delivers Packets Reliably with No Added Jitter**

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Customer Use Cases

Point-to-Point

Point-to-Multipoint

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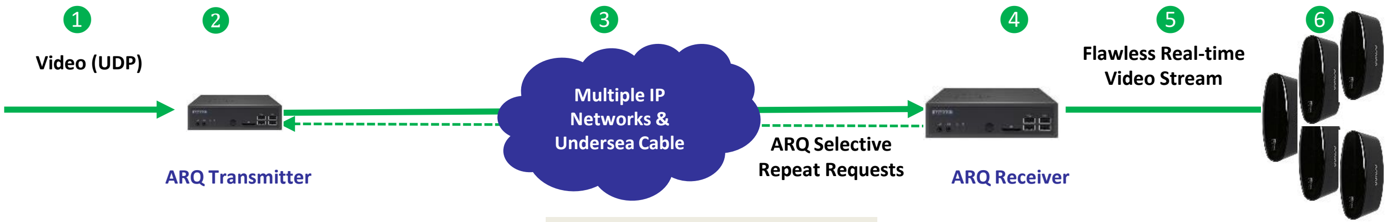
Long-haul Point-to-Point Transport

1. IPTV operator, INTERNETNC, in New Caledonia (South Pacific) sources content from Paris, France
2. Content originates as H.264/AVC, then transcoded to H.265/HEVC in Paris
3. Long-haul multi-network content transport (14,000 miles!) protected by ARQ
4. Content received flawlessly at the IPTV operator NOC in Noumena, New Caledonia
5. Content is transcoded back to H.264/AVC and streamed to the viewers
6. Viewers enjoy flawless video service via their IP-STBs

INTERNETNC



Paris, France ← 22,000 km = 14,000 miles → New Caledonia

Noumea NOC

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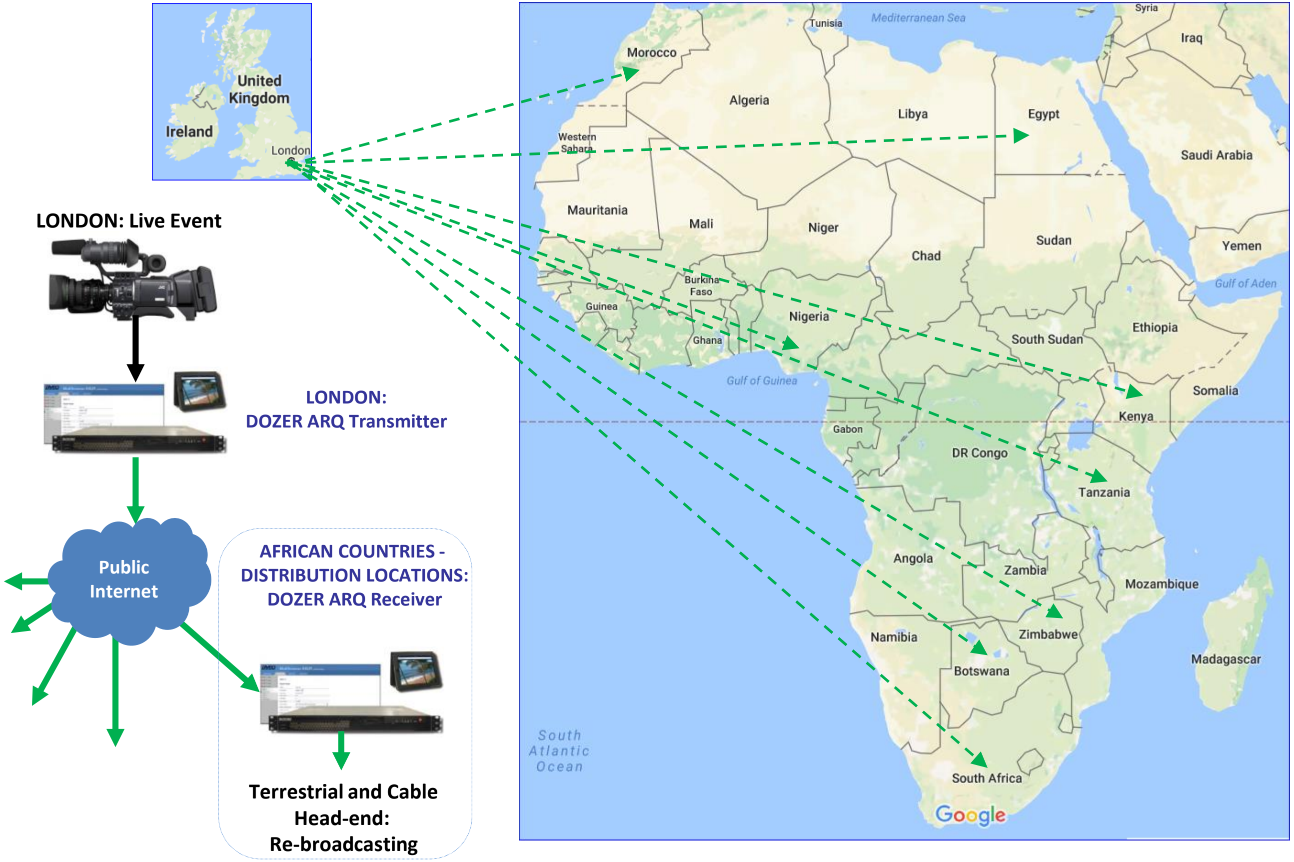
Long Haul Multicast London to Africa



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Thank You!
Questions?

Booth #11: Come see ARQ Layer 2

Real-time Error Correction in Action!