Audio Over IP

A Manufacturers View

Gregory Massey – Chief Technical Officer

Agenda

- Interoperability
- Network Design
- Expectations vs Reality
- Summary

Interoperability - Overview

Standards

AAC-ELD

AAC-LD

MP2 AAC-LC

4SB

MP4 AAC-LC

Enhanced apt-X

HE-AACv2

HE-AAC

PCM16

MP3

G.722

MPEG LII

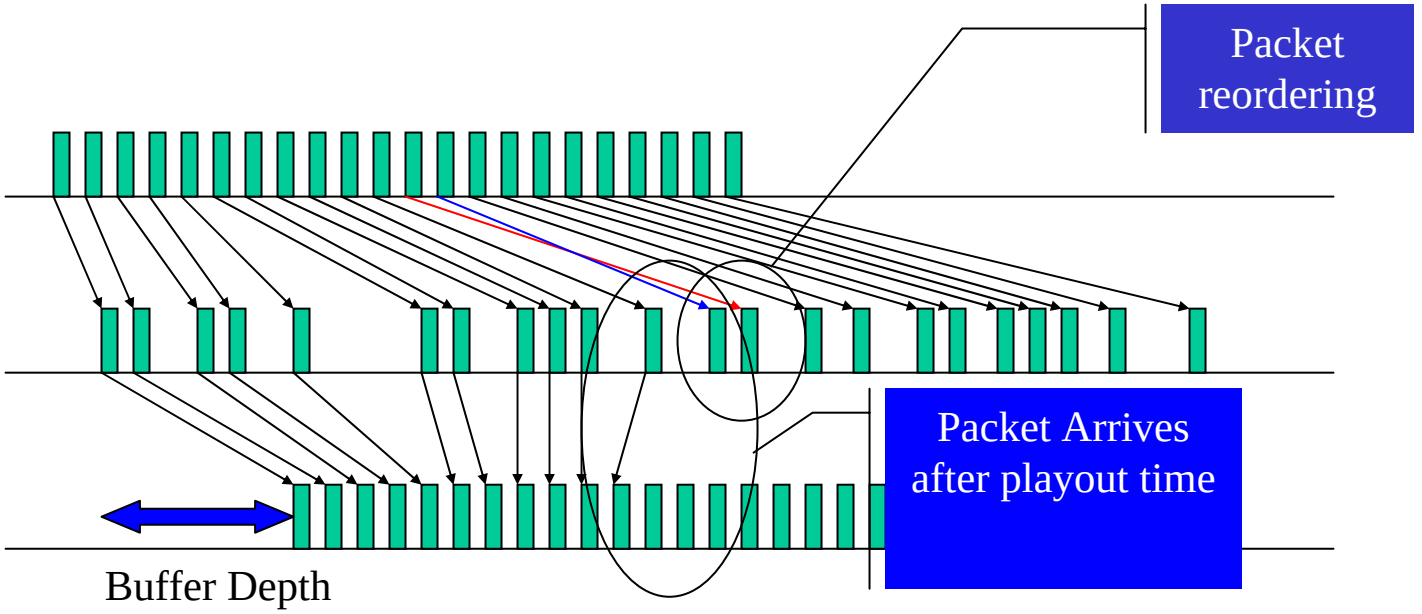
PCM24

MP2 LI

Ogg Vorbis

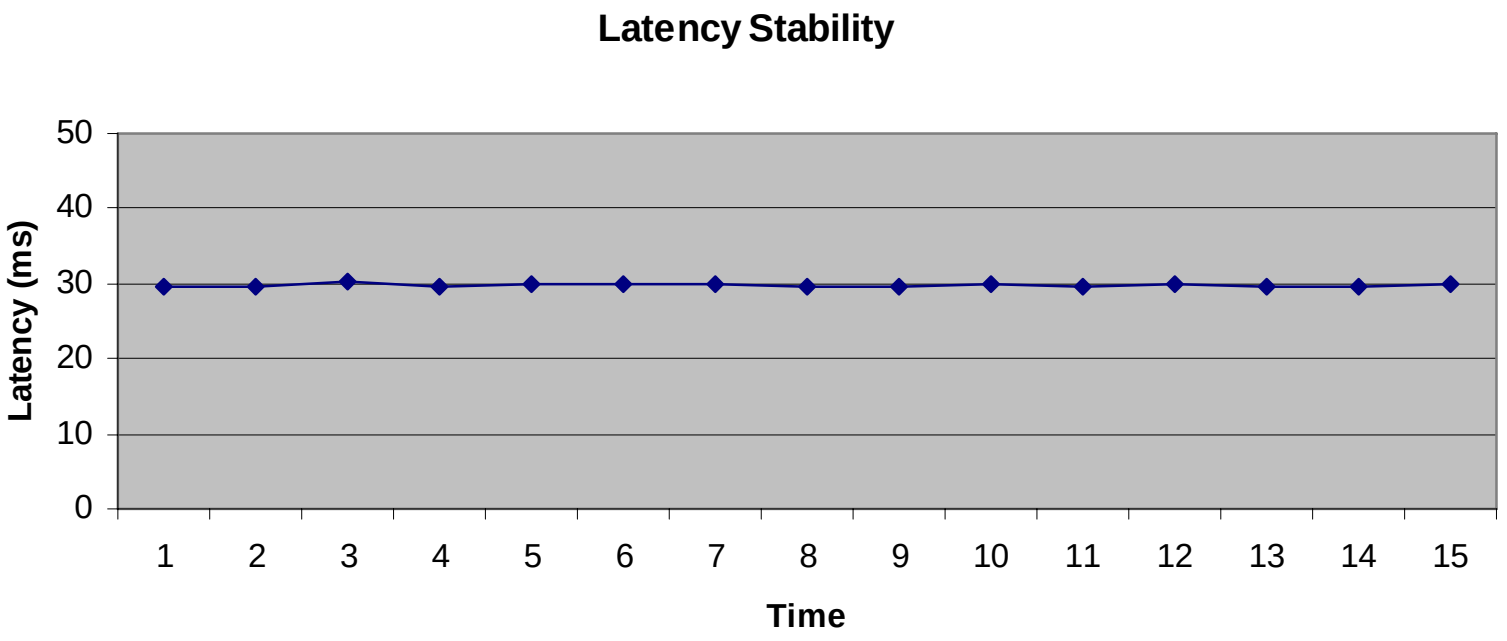
G.711

Latency & Jitter



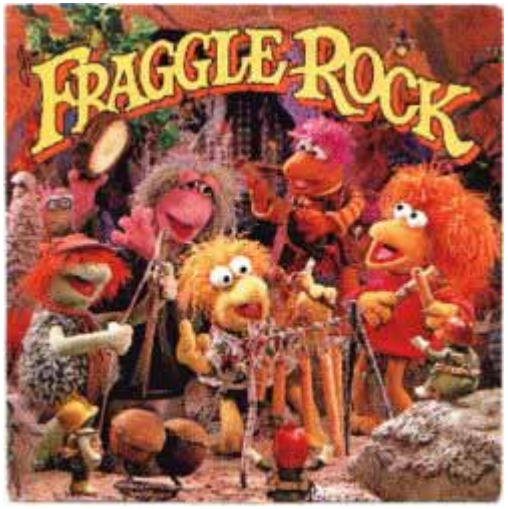
- Packet delay through system
- Rx Buffer depth(ms) vs Latency

Latency Stability



Denial of Service (DoS) attack

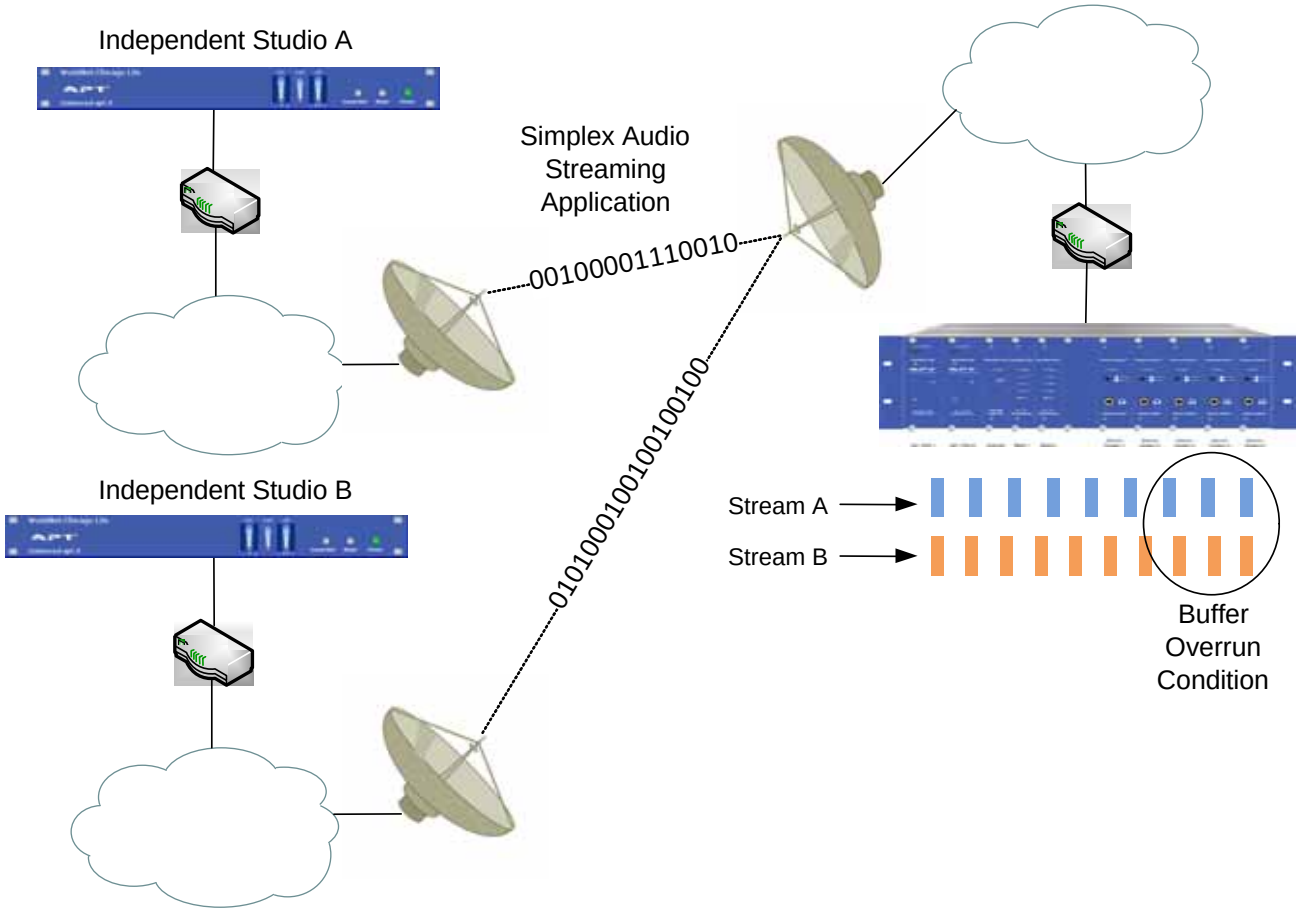
- Overloading network traffic
- Random/Sudden peaks in traffic
- Network preparation
- Firewall configuration



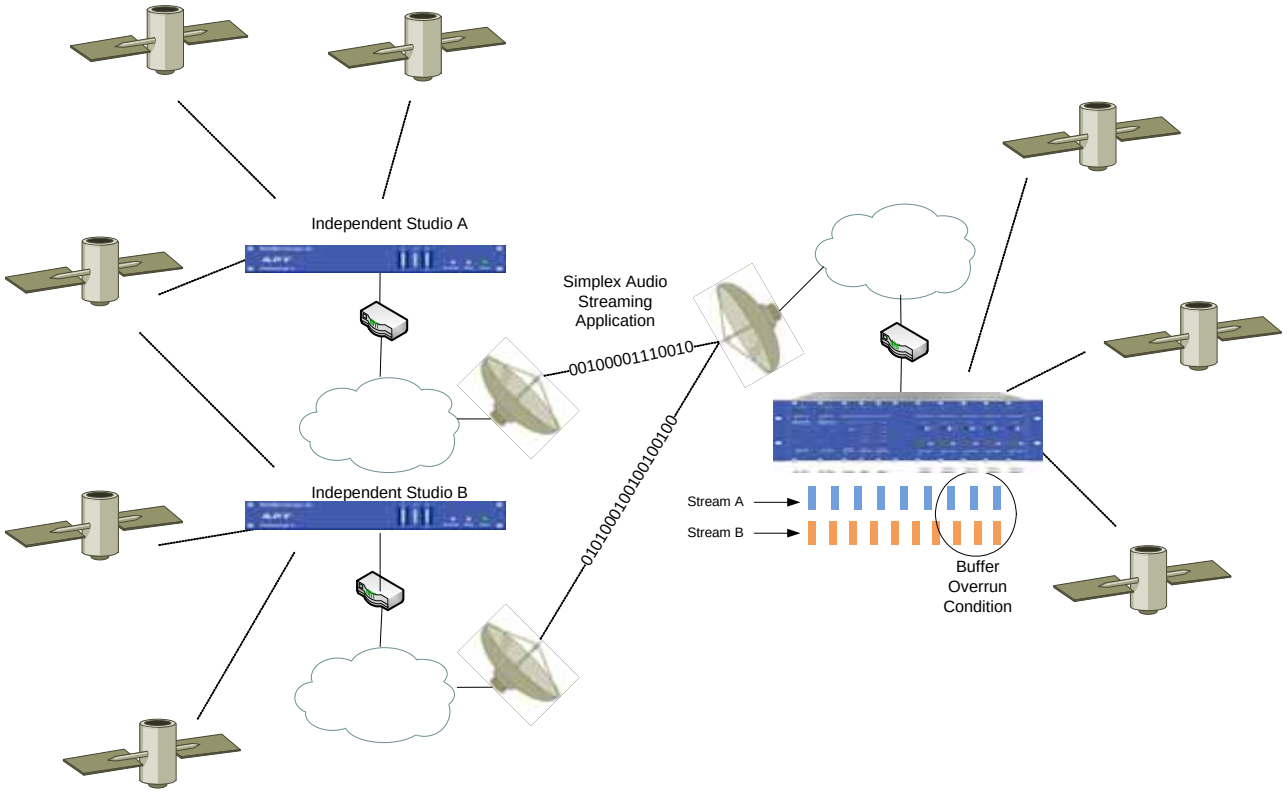
UDP floods

UDP floods include "Fraggle attacks". In a **fraggle attack** an attacker sends a large amount of UDP echo traffic to IP broadcast addresses, all of it having a fake source address. It is a simple rewrite of the smurf attack code.

Clock Synchronisation



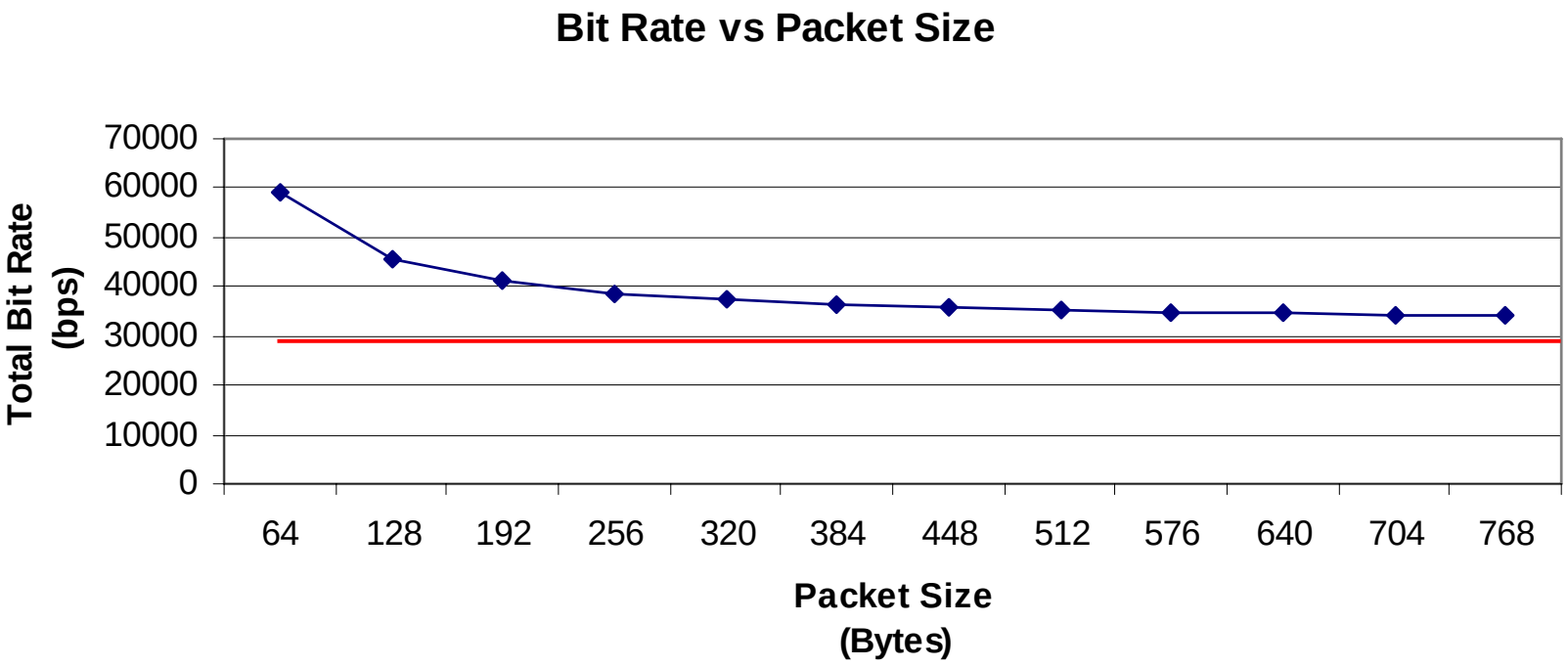
Clock Synchronisation - GPS



- Frequency Locked Network
- Overrun/underrun potential eliminated
- Buffering for NTP minimized

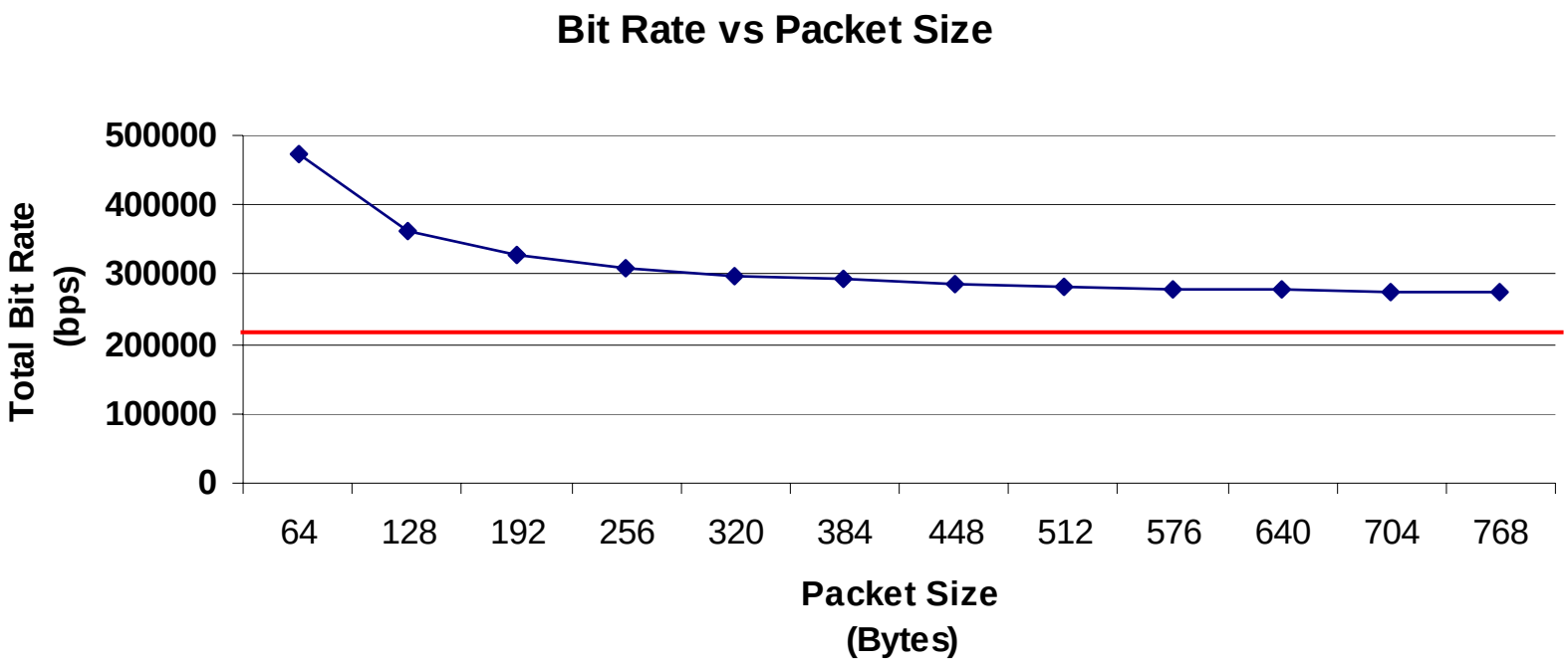
Bit Rate vs Packet Size

32kbps Audio content

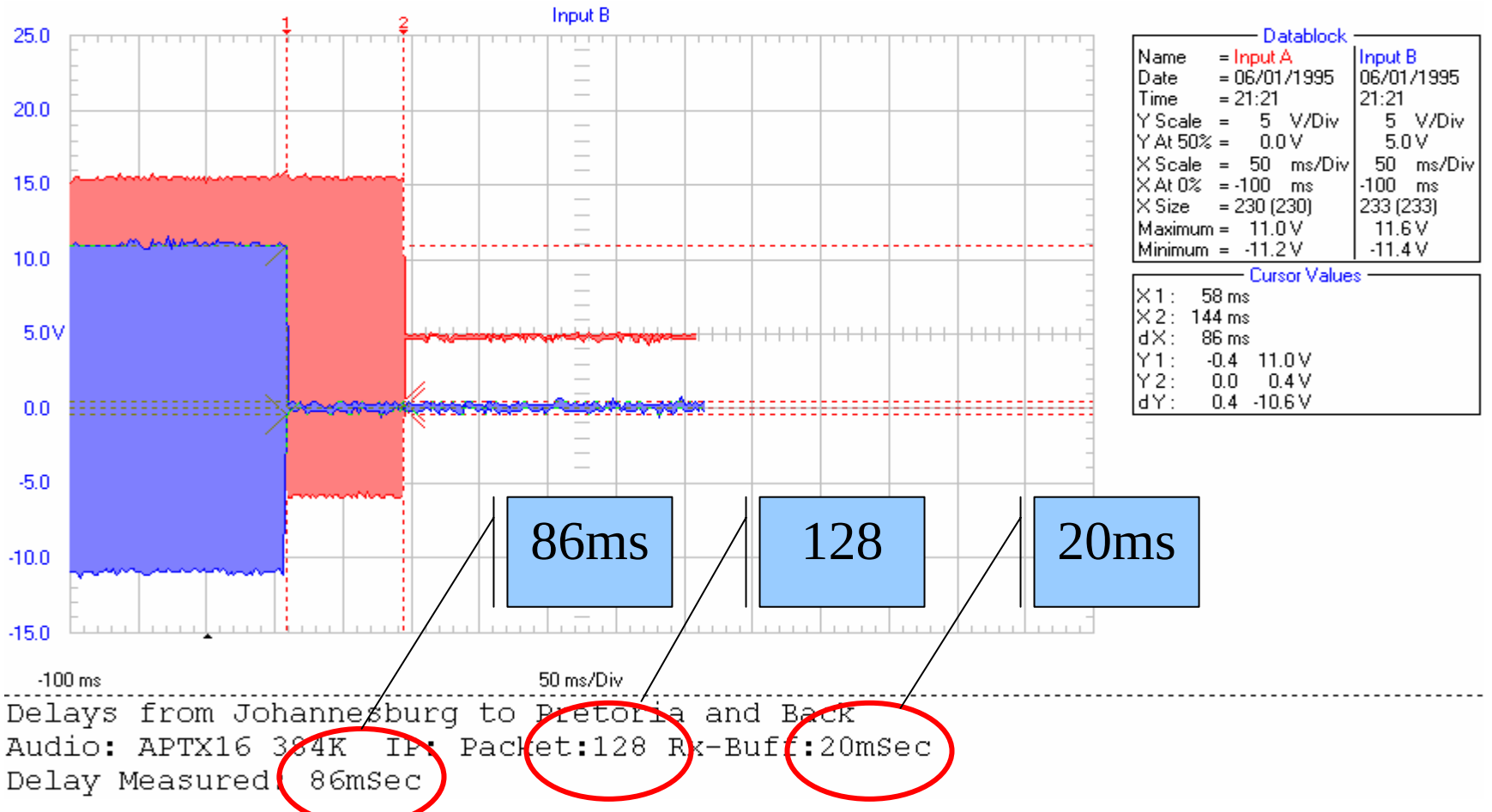


Bit Rate vs Packet Size

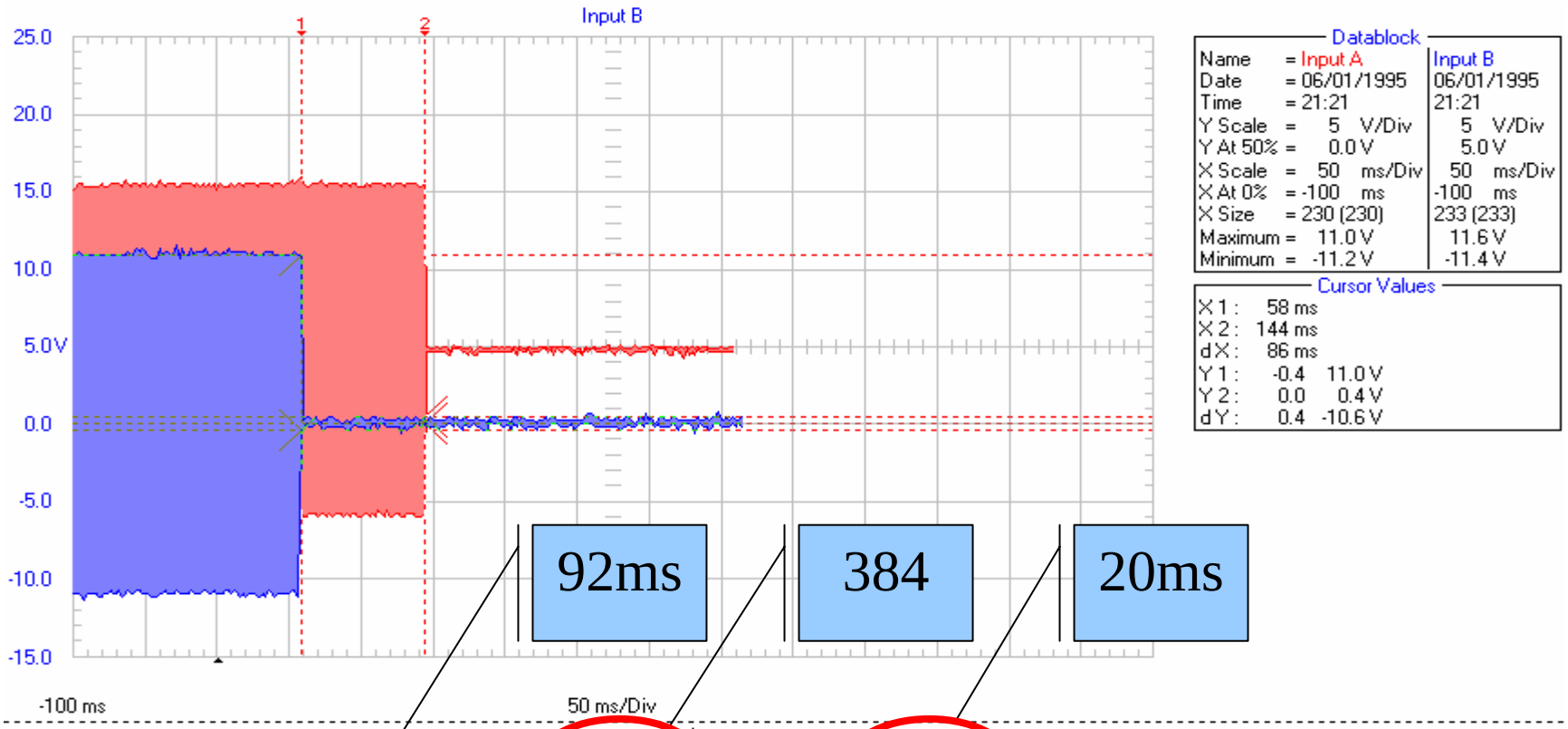
256kbps Audio content



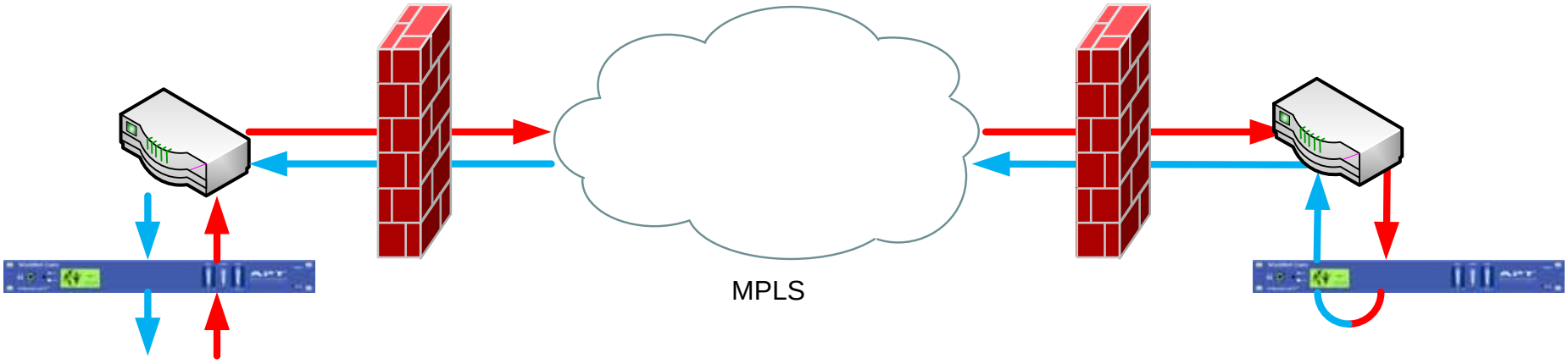
Network Delay



Network Delay



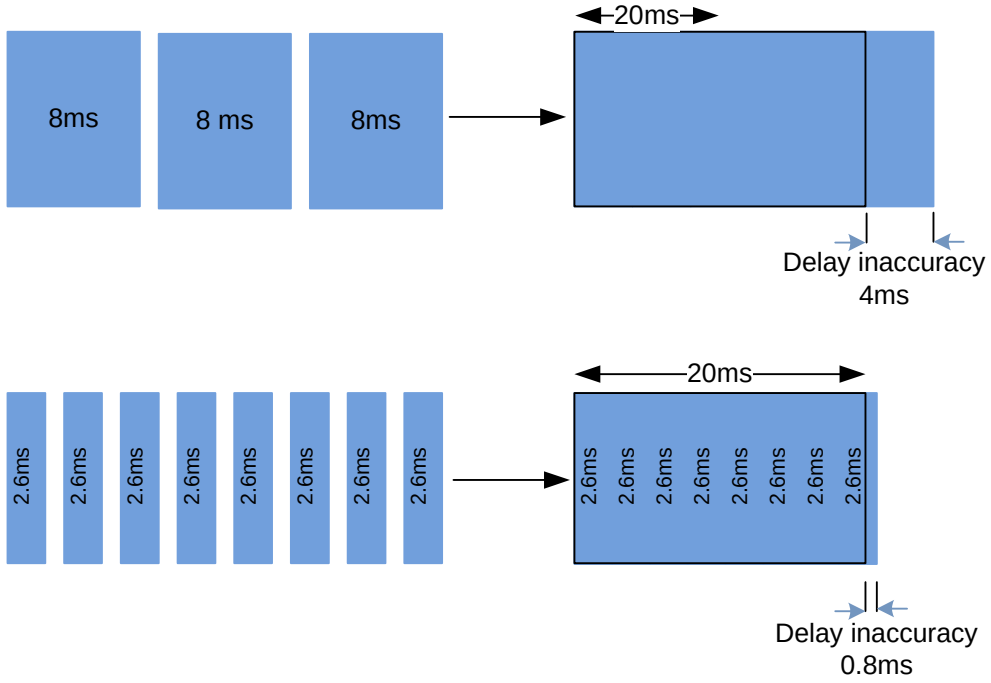
Network Delay



- Encode/Decode/Encode/Decode – Eapt-X 16/48 Stereo
- Two network delays
- 40 ms Buffering (2 x Rx)
- Calculation = 40 + 8 + N = 86 Therefore N = 38 ms (19ms)
- Calculation = 40 + 8 + N = 92 Therefore N = 44 ms (22ms)

Network Delay

- Delay inaccuracy
- Example
  - Difference 3.2ms
  - 6.4 ms return



Open Issues

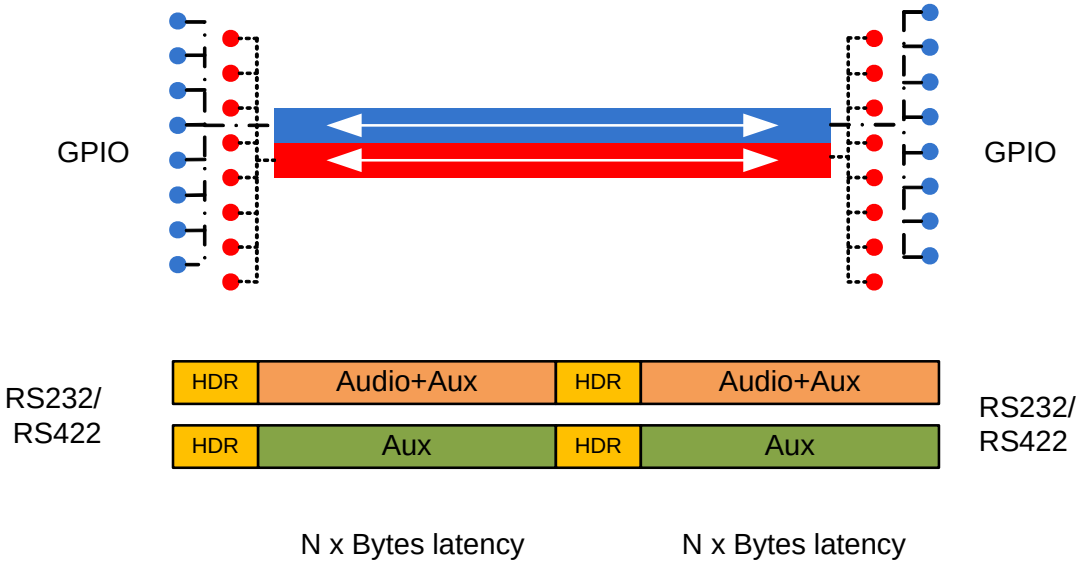
- Aux Data/Relay and contact Closure
- AES User Data
- FEC
- Security - SRTP
- STUN (Simple Traversal of UDP through NAT
- Keep alive packets

Security

- SRTP
  - Encrypts payload only
  - Based on Advanced Encryption Standard (**AES**) in counter mode (Mandatory) or F8 mode (Optional)
  - Block based algorithm
  - Simple XOR calculation

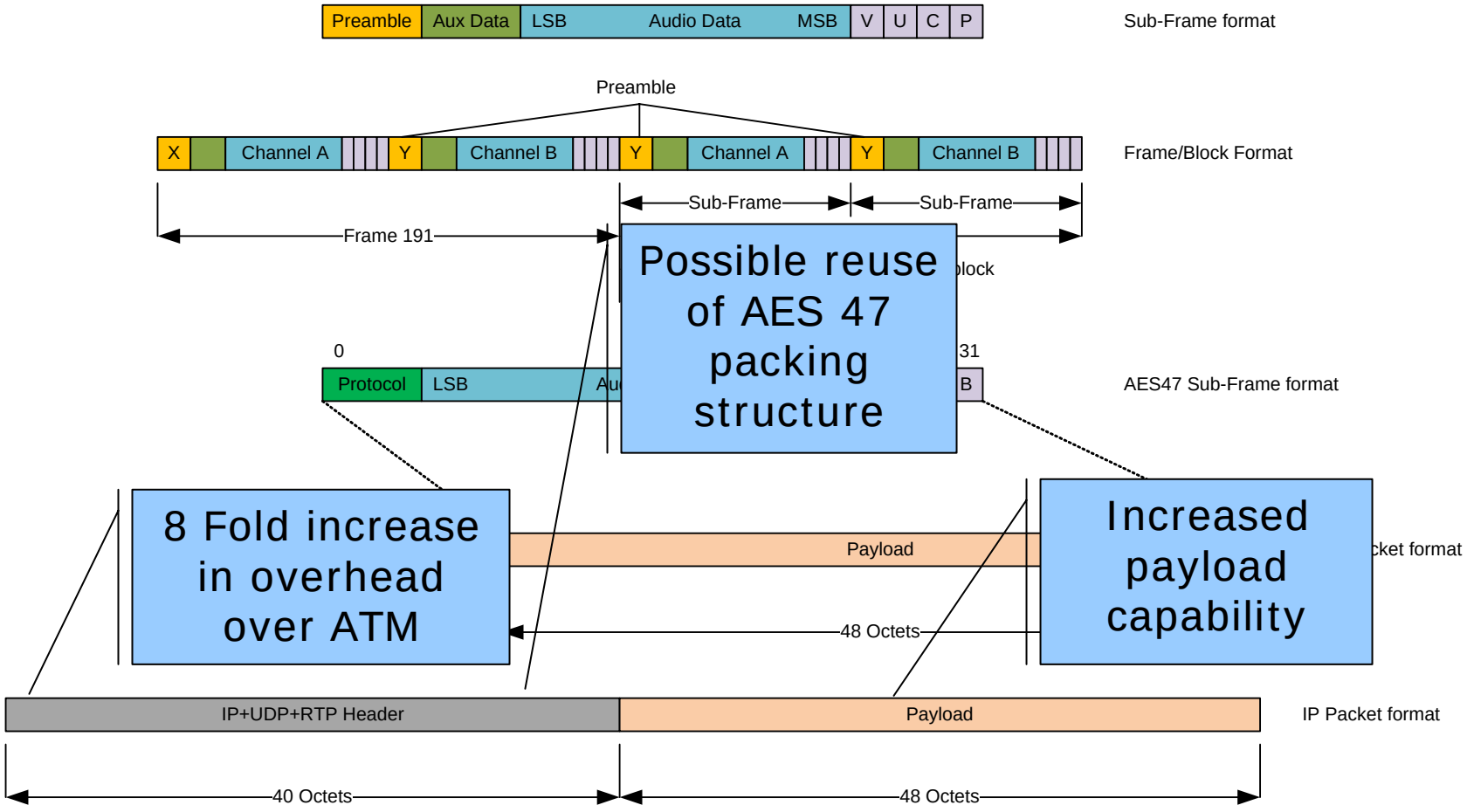
Aux Data and User Data

- Packetisation delay
- Latency
- Loss of synchronisation
- Independent vs inclusive packets

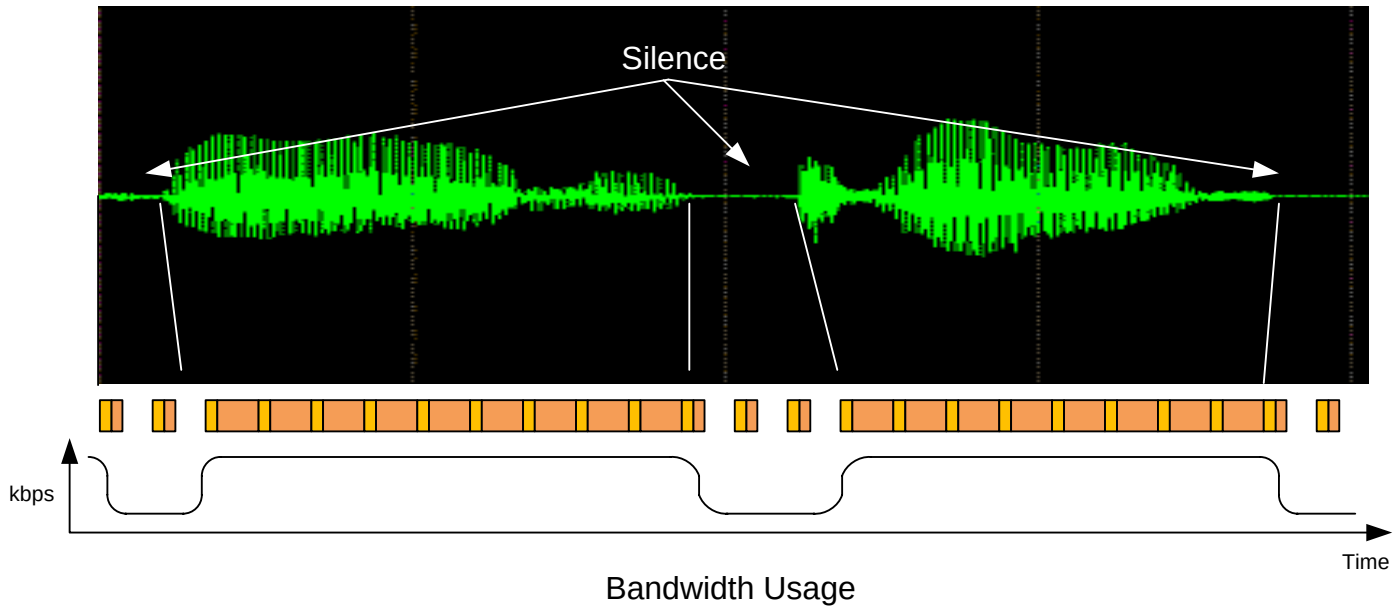


Example: 9600 Baud: 1 Symbol per ms N byte packet introduces N ms latency

AES User Data



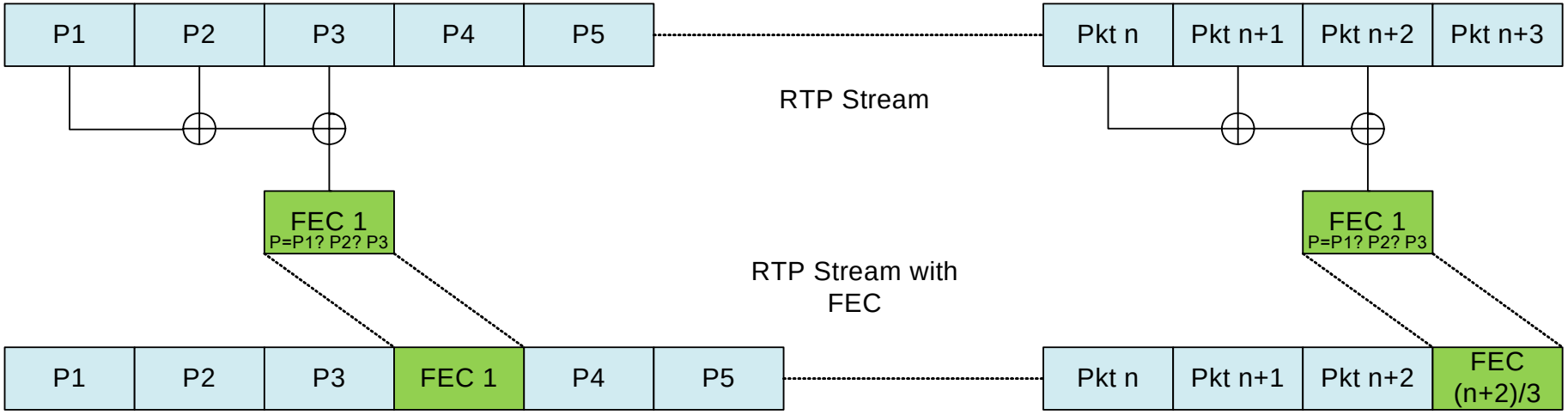
Keep Alive packets



Bandwidth Usage

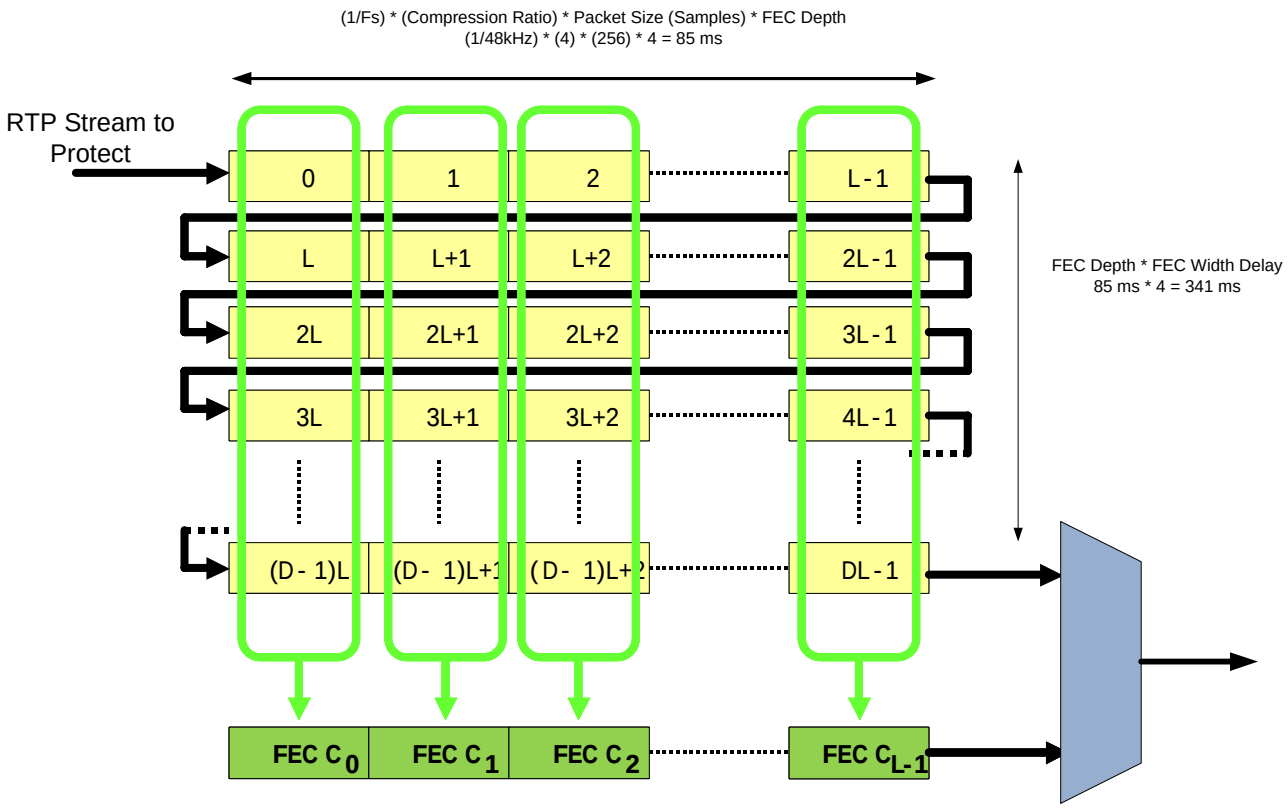
- Link will time out if no packets are transmitted
- Algorithm may lose lock without new data
- Keep alive is minimum data content to keep link alive

Forward Error Correction

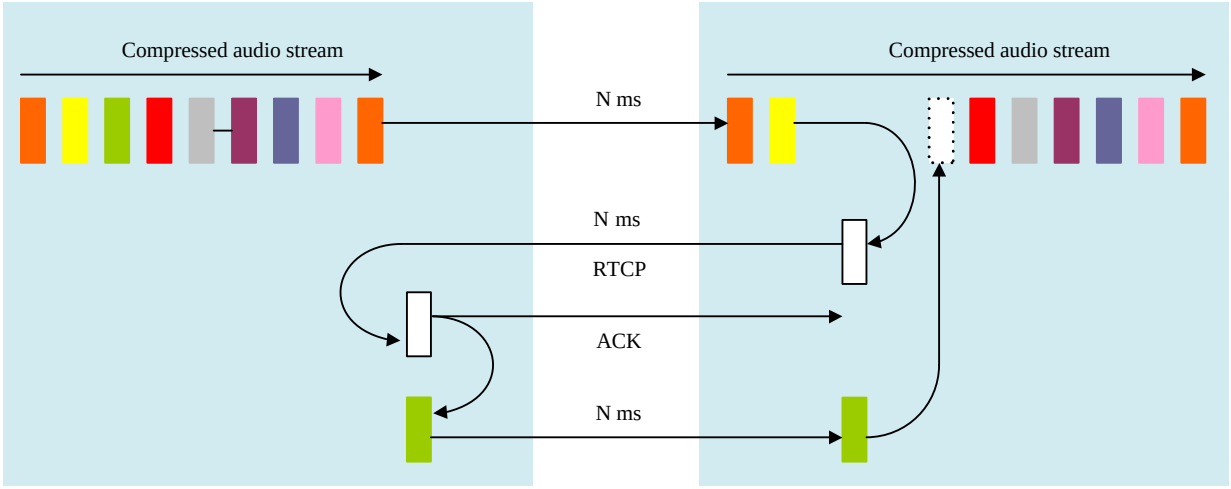


- Based on simple XOR
- Single packet Latency overhead
- Protects from single packet loss

FEC 2-Dimensional

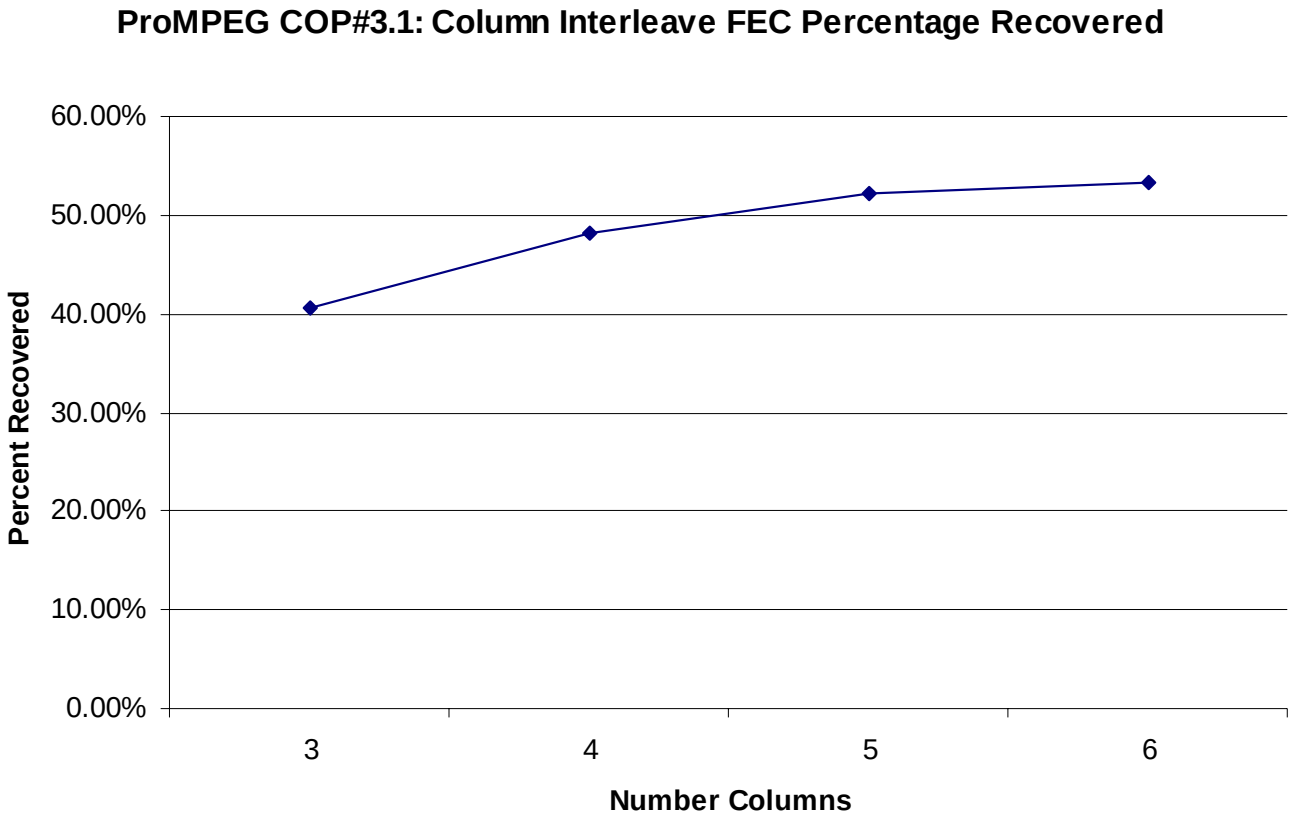


Retransmission



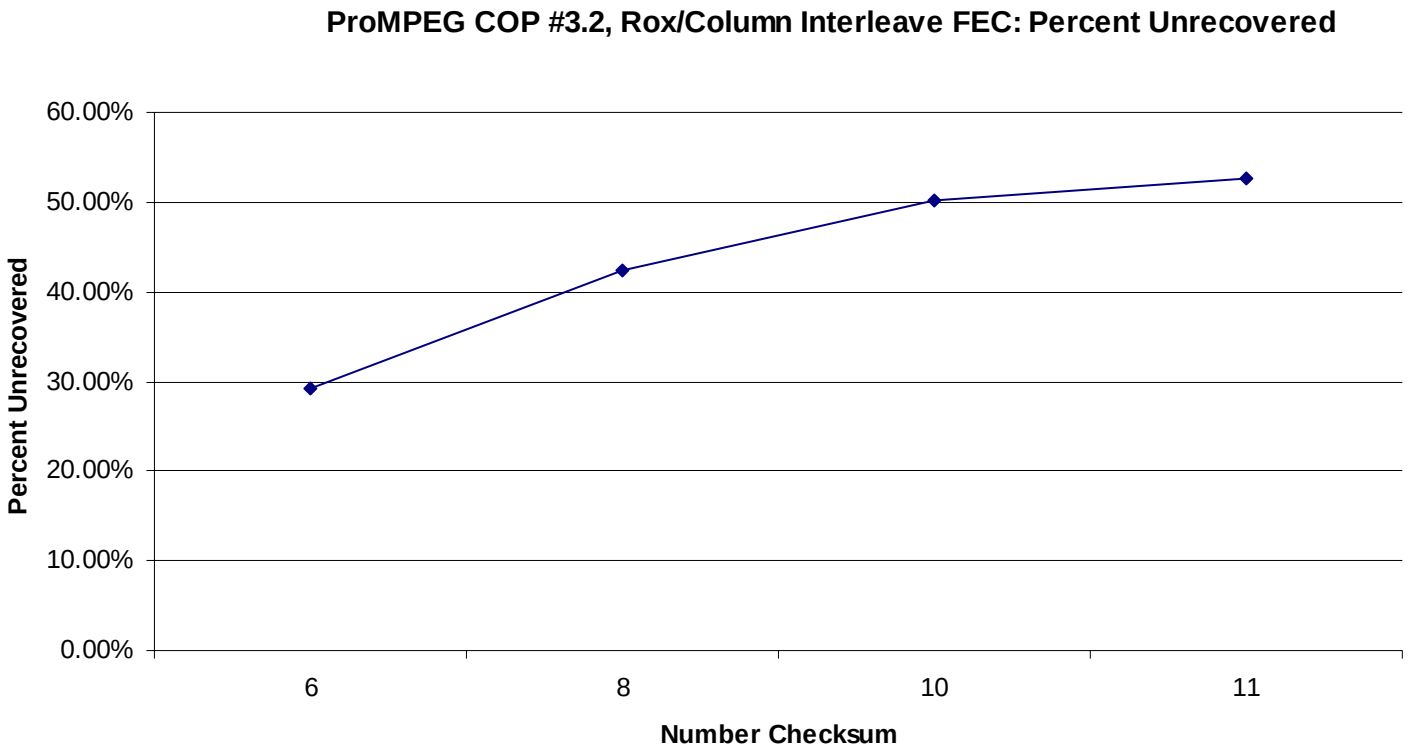
- Network Delay is additive
- Rx Buffer required is substantial to mask delay
- Increases network traffic – Possibly compounds packet loss
- No guarantee of audio drop out

FEC Performance



Source: QVidium

FEC Performance

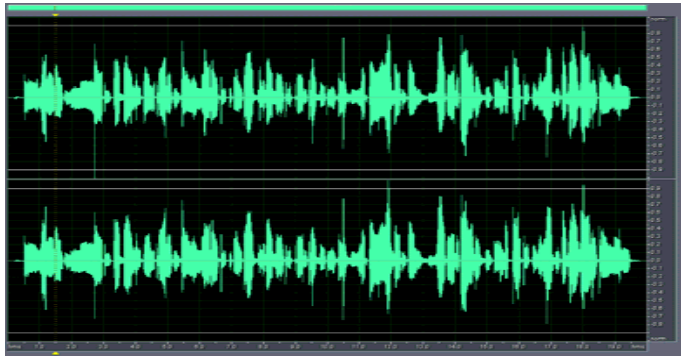


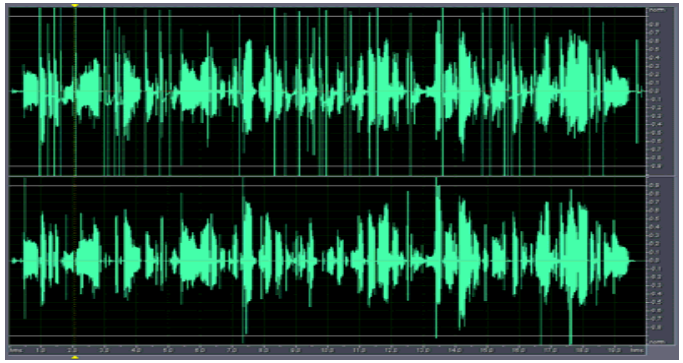
(Equal to the sum of column and rows)

Source: QVidium

Packet Loss - Examples

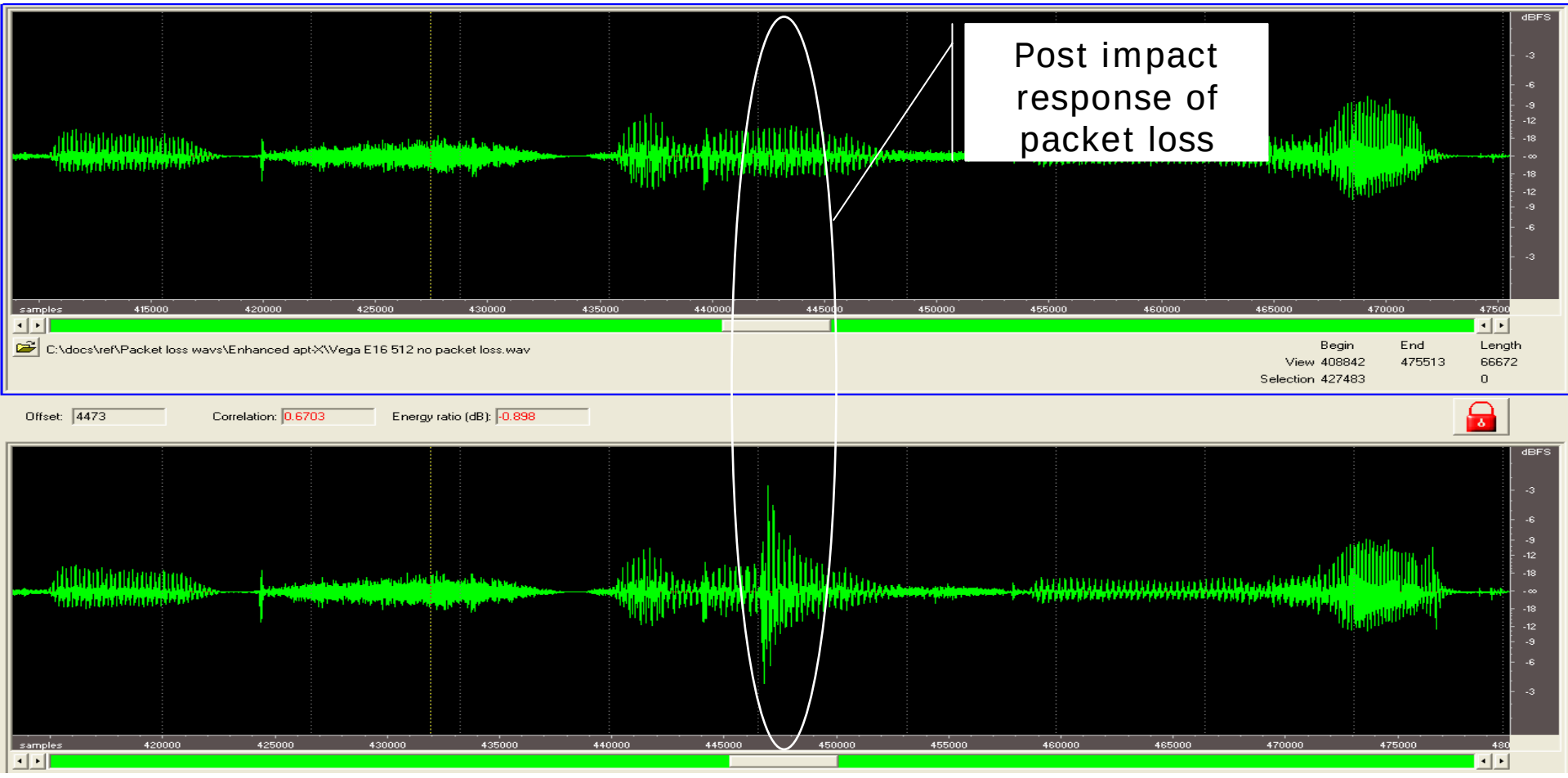
- 512 byte packet
  - No Packet Loss
  - 2% Packet Loss
  - 5% Packet Loss
- 128 byte packet
  - No Packet Loss
  - 2% Packet Loss
  - 5% Packet Loss



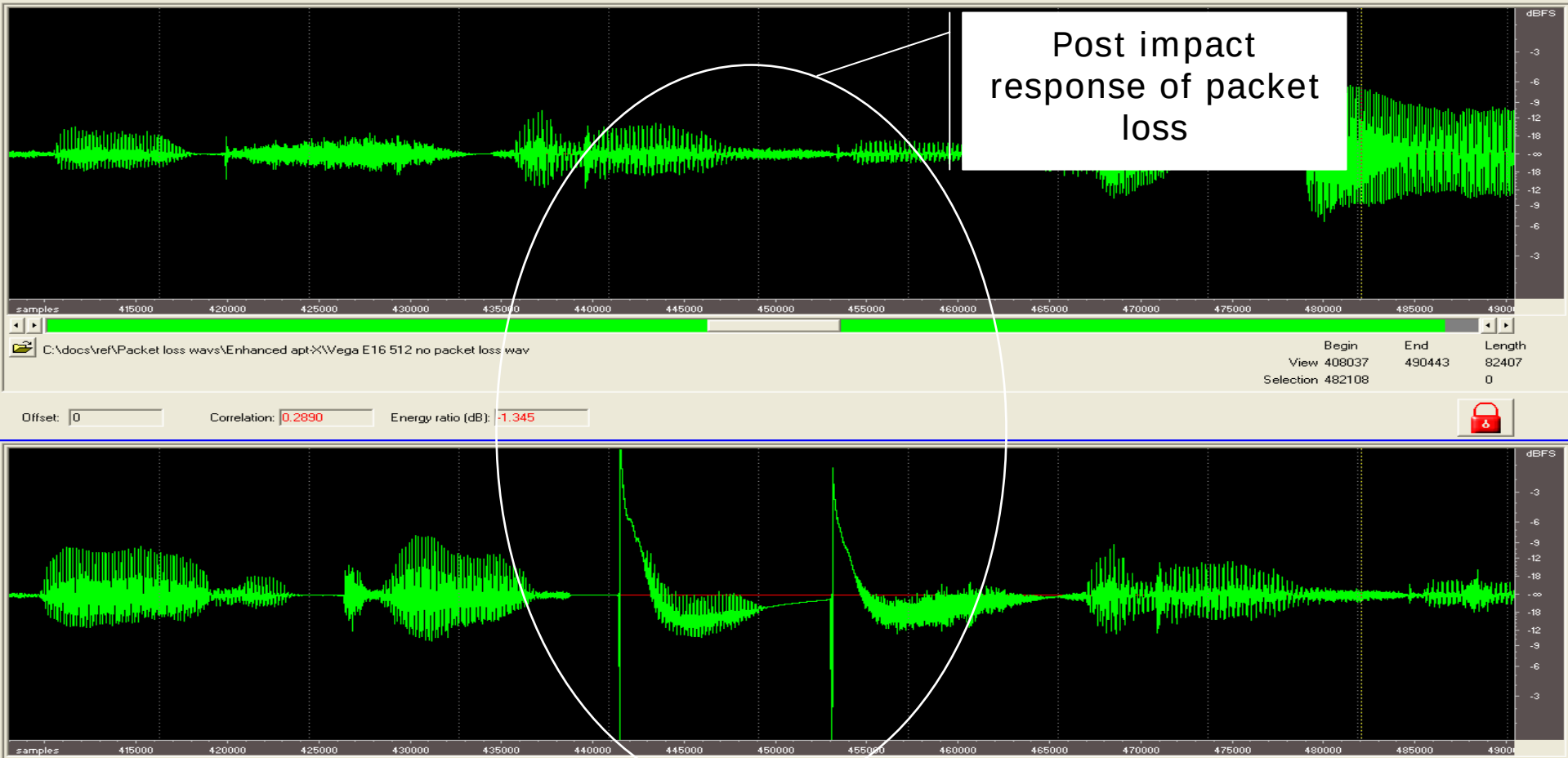



norm
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
-0.1
-0.2
-0.3
-0.4
-0.5
-0.6
-0.7
-0.8
-0.9
hms
1.0
2.0
3.0
4.0
5.0
6.0
7.0
8.0
9.0
10.0
11.0
12.0
13.0
14.0
15.0
16.0
17.0
18.0
19.0

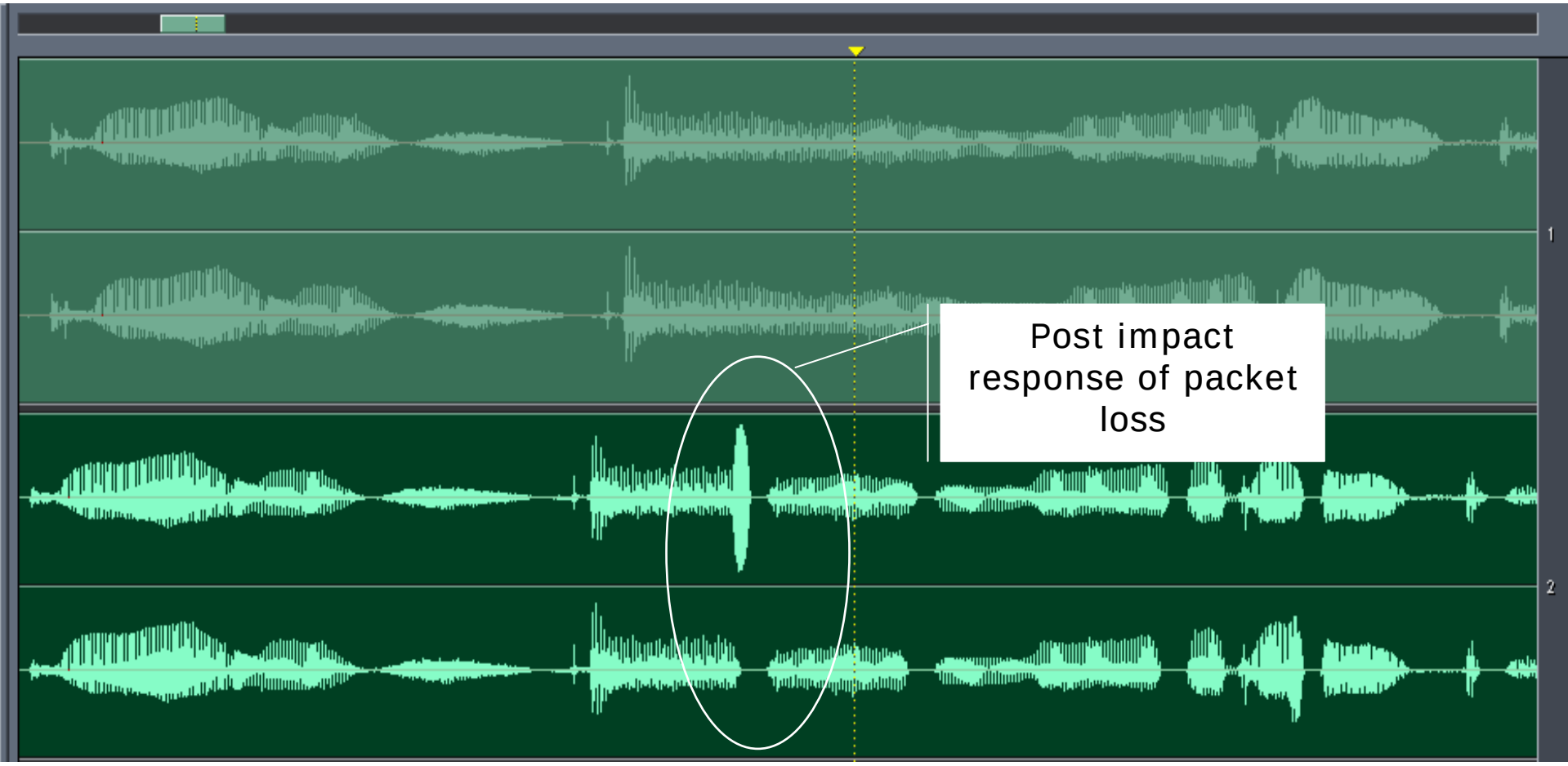
Packet Loss Effects



Packet Loss Effects

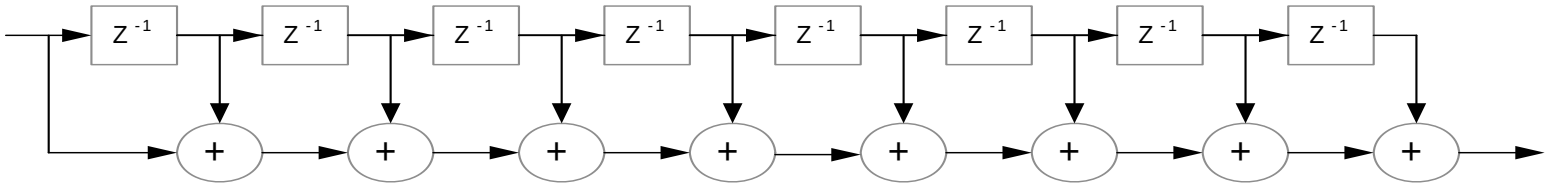


Packet Loss Effects



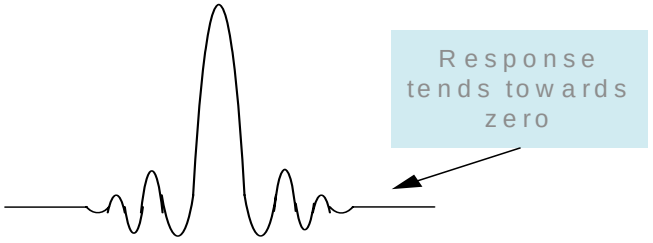
Response to transients

N Sample Priming Delay



N x TAP Finite Impulse Response Filter
Coefficients Ignored

CHARACTERISTICS
No Feedback from previous output
Simple Design
Stable topology

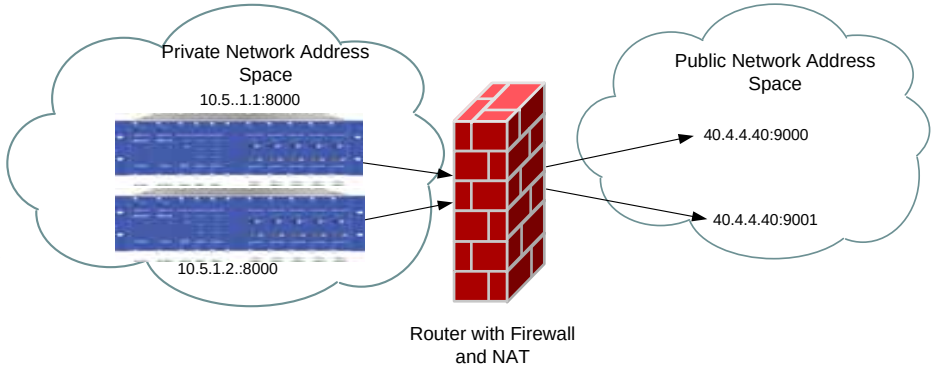


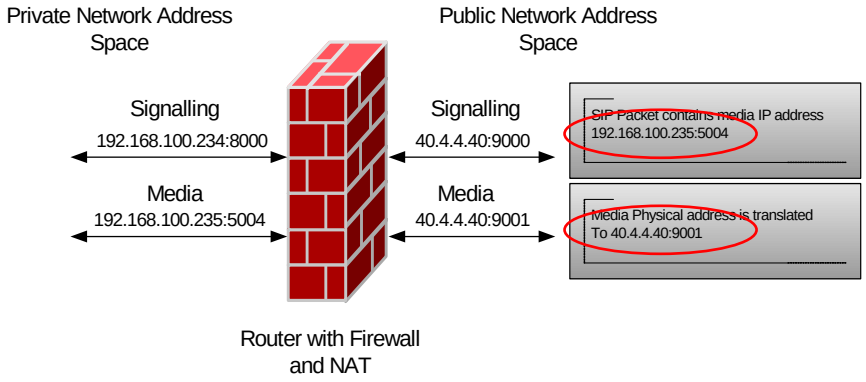
Impulse Response

- Packet loss similar in response to step input
- Priming delay – N Taps/N Samples

NAT Traversal

- Necessary in IPv4 to increase IP address limitations
- Separates private and public IP addresses
- Media and SIP addresses are conflicting after NAT
- Call return is to wrong physical IP address



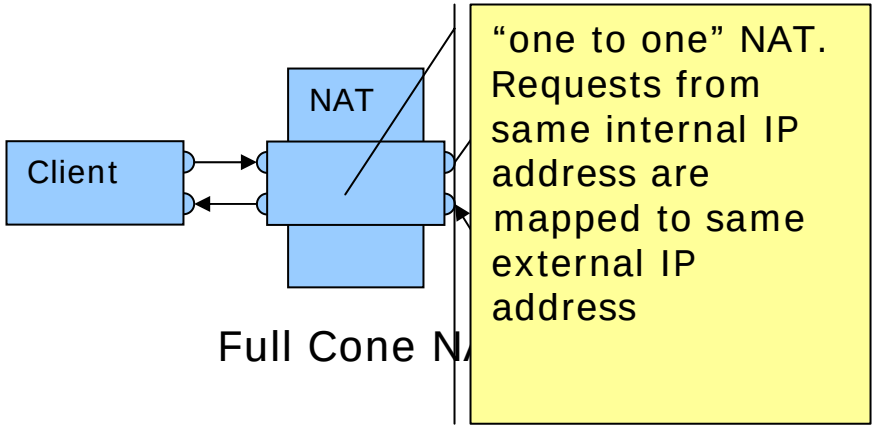


NAT Traversal - Solutions

- Universal Plug and Play (UPnP)
- Simple Traversal of UDP through NAT (STUN)
- Application Layer Gateway (ALG)
- Manual Config
- Tunnel Techniques

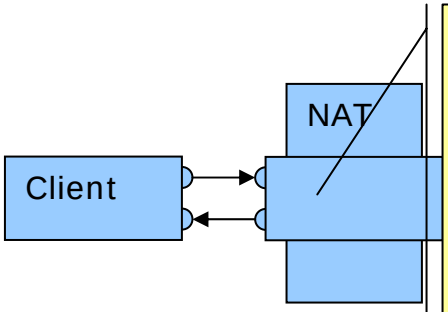
- Security
- Efficiency
- Complexity

NAT Topologies



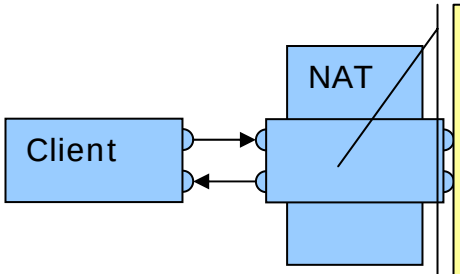
Full Cone NA

"one to one" NAT. Requests from same internal IP address are mapped to same external IP address



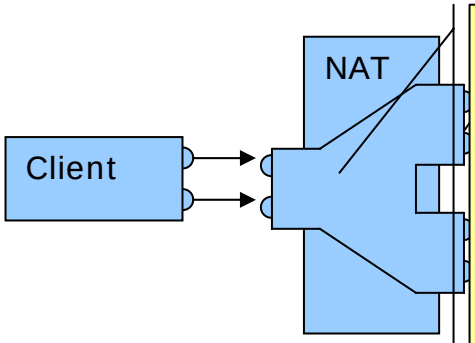
Port Restricted Co

Same as symmetric/full cone but with restriction on port numbers



Restricted Cor

Same IP mapping as full cone. External host can only send to internal host if internal host has previously sent.



Symmetric

Same source, different destination then a different mapping is used.

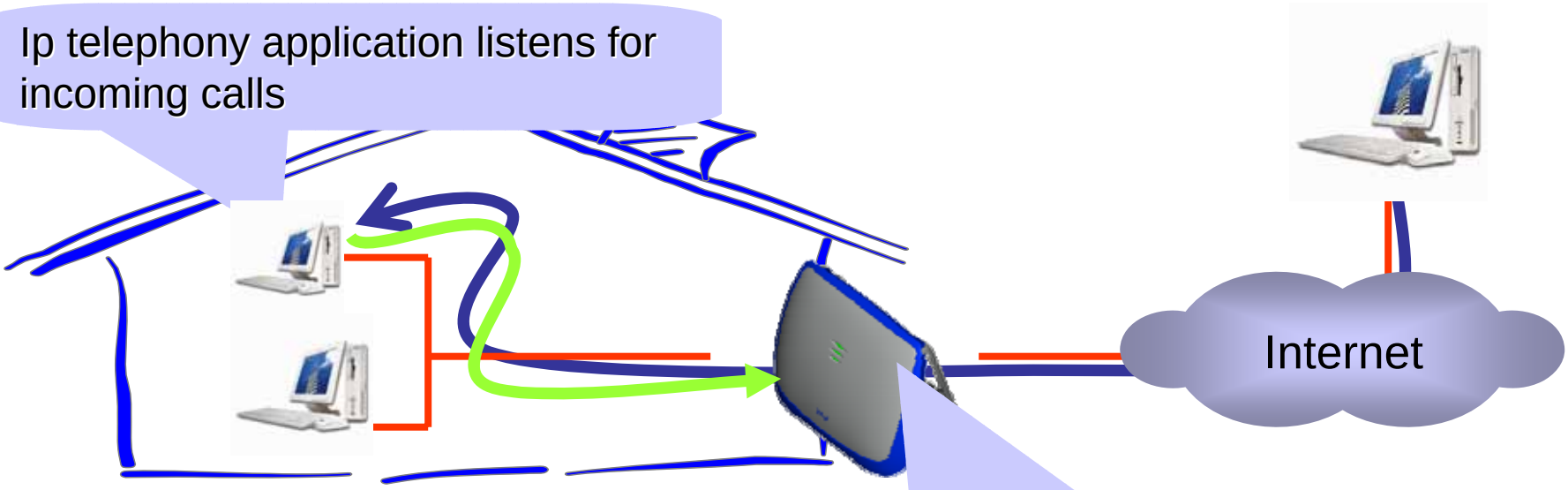
Universal Plug and Play (UPnP)

- Targeted at home office
- Both NAT and VoIP clients must be UPnP enabled
- Relies on NAT opening holes.
- Holes under dynamic control of uPnP client

UPnP™

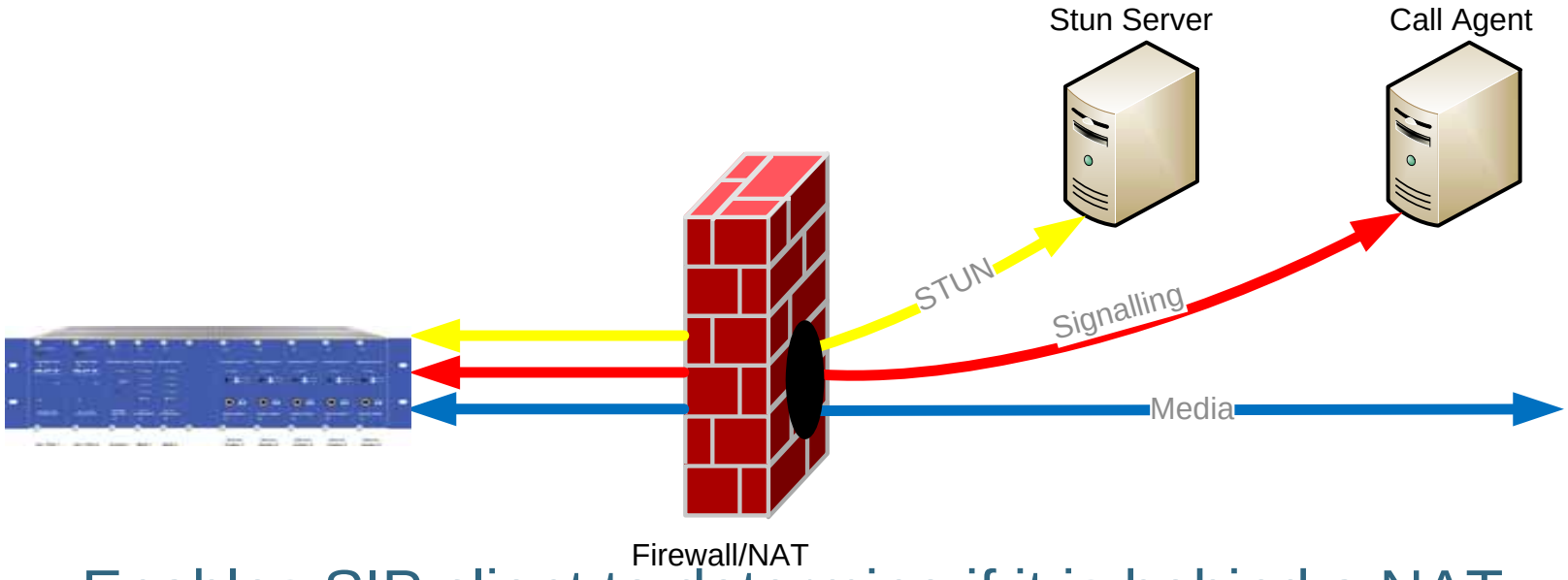
www.upnp.org

Universal Plug and Play (UPnP)



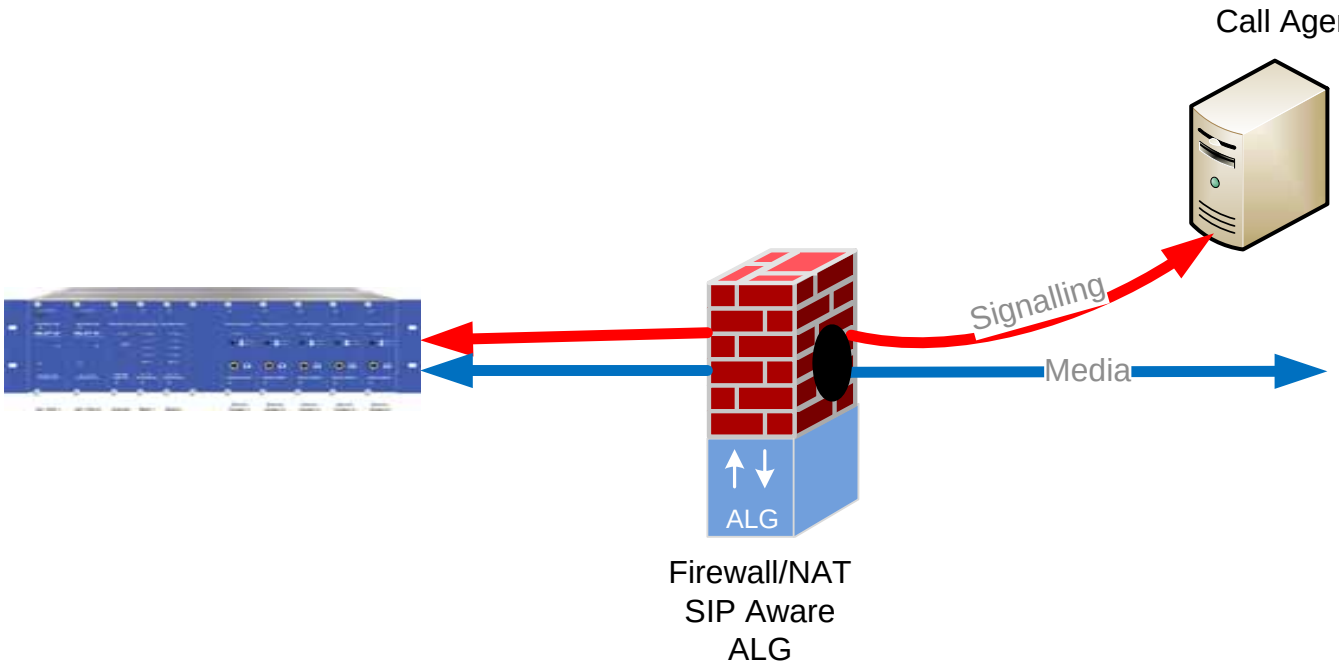
Source: uPnP Forum

STUN



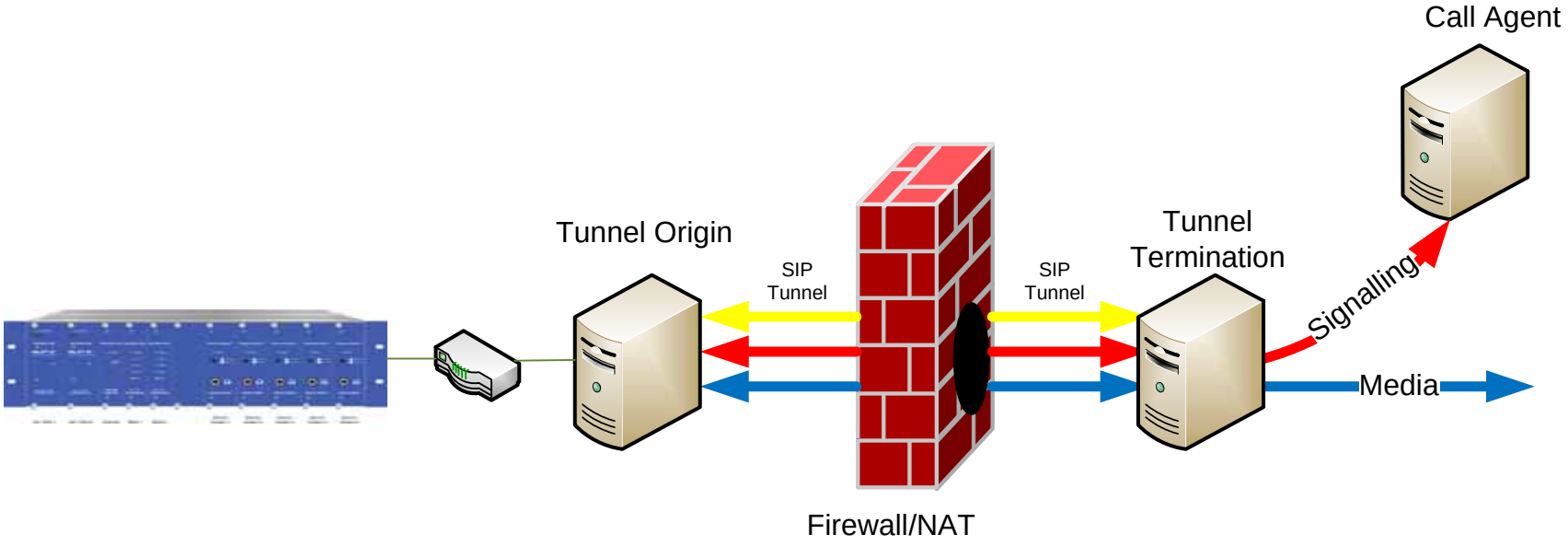
- Enables SIP client to determine if it is behind a NAT
- STUN Server resides in public address space
- Won't work with symmetric NAT
- Susceptible to port scan attacks

ALG



- Understands signalling messages
- Modifies signalling addresses/ports

Tunnel Techniques



- Tunnel servers in both public and private domains
- Carries all SIP traffic/reconfigured firewall
- External server modifies signalling

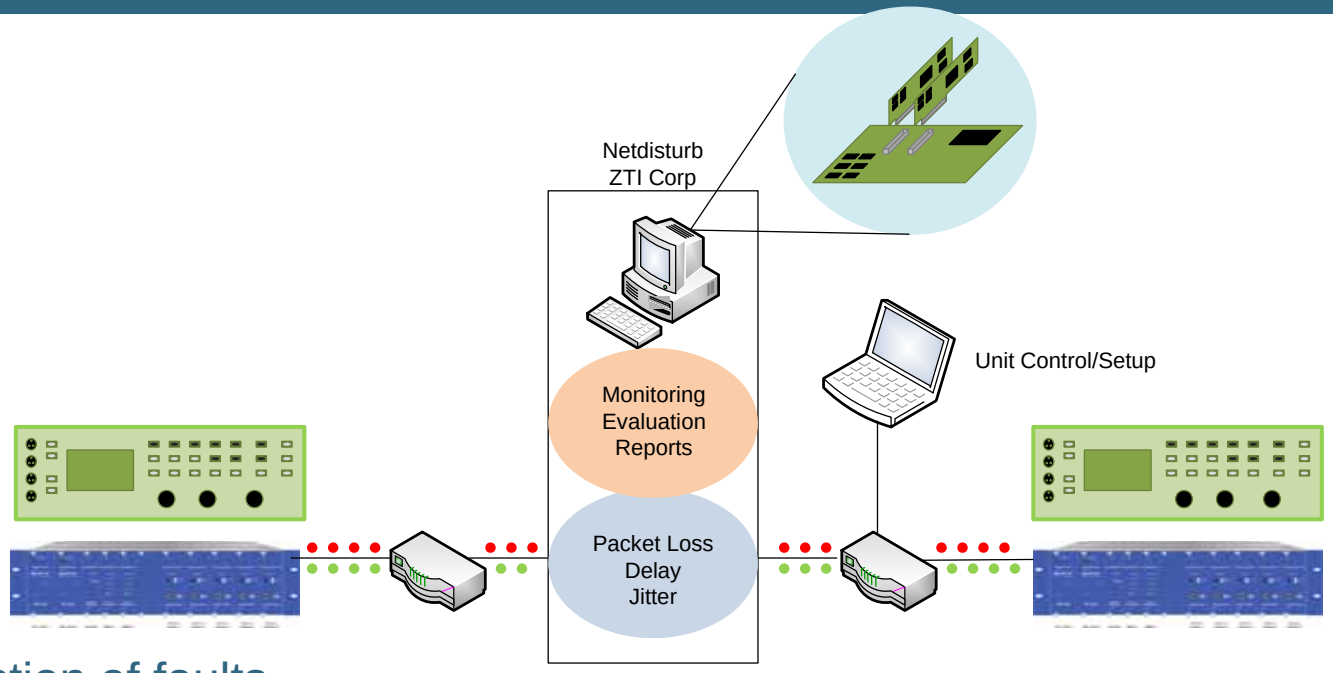
IP Addressing

Class	Address or Range	Status
A	0.0.0.0 1.0.0.0 to 126.0.0.0 127.0.0.0	Reserved Available Reserved
B	128.0.0.0 to 191.254.0.0 191.255.0.0	Available Reserved
C	192.0.0.0 192.0.1.0 to 223.255.254 223.255.255.0	Reserved Available Reserved
D	224.0.0.0 to 239.255.255.255	Multicast group Addresses
E	240.0.0.0 to 255.255.255.254 255.255.255.255	Reserved Broadcast

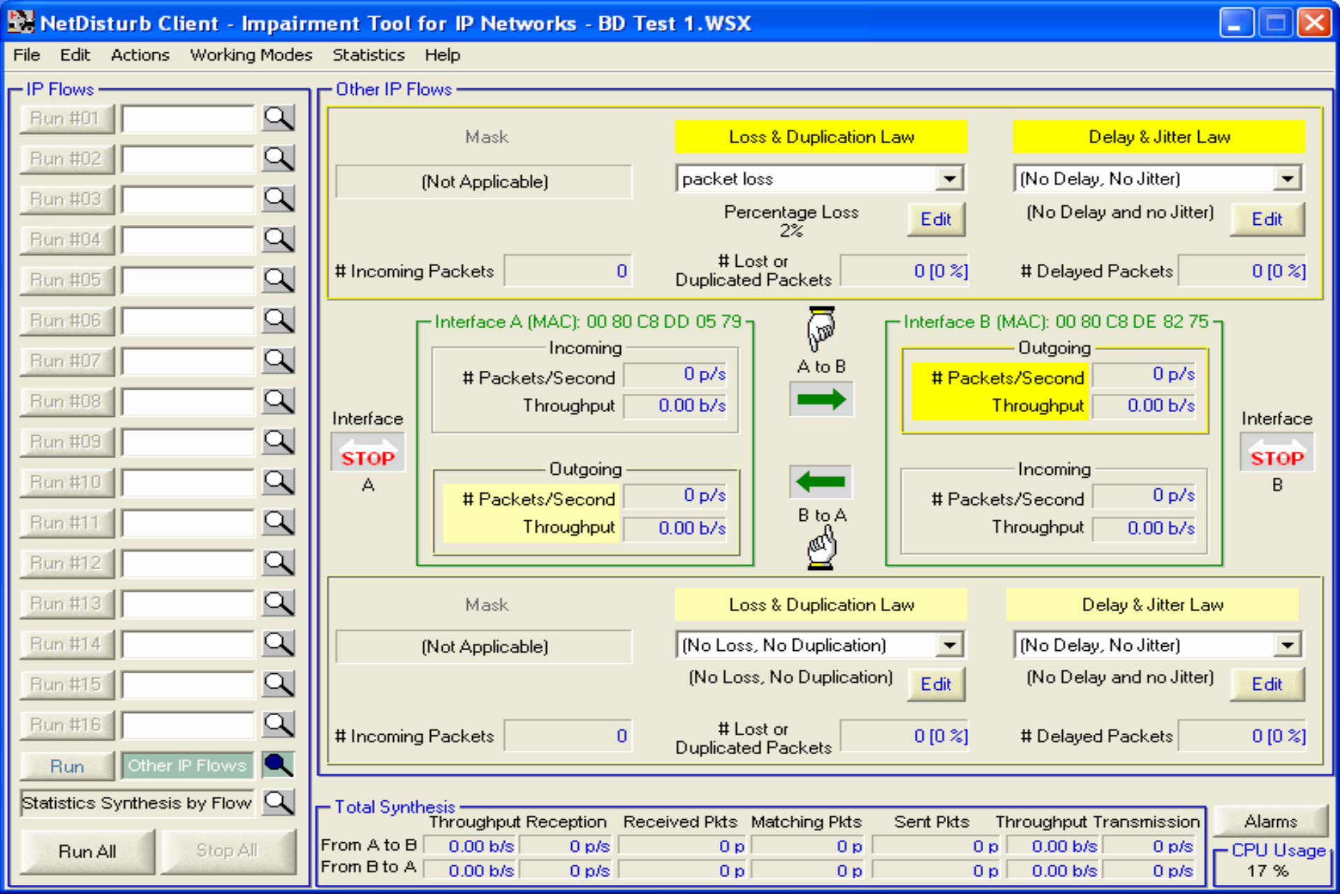
Testing/Evaluation

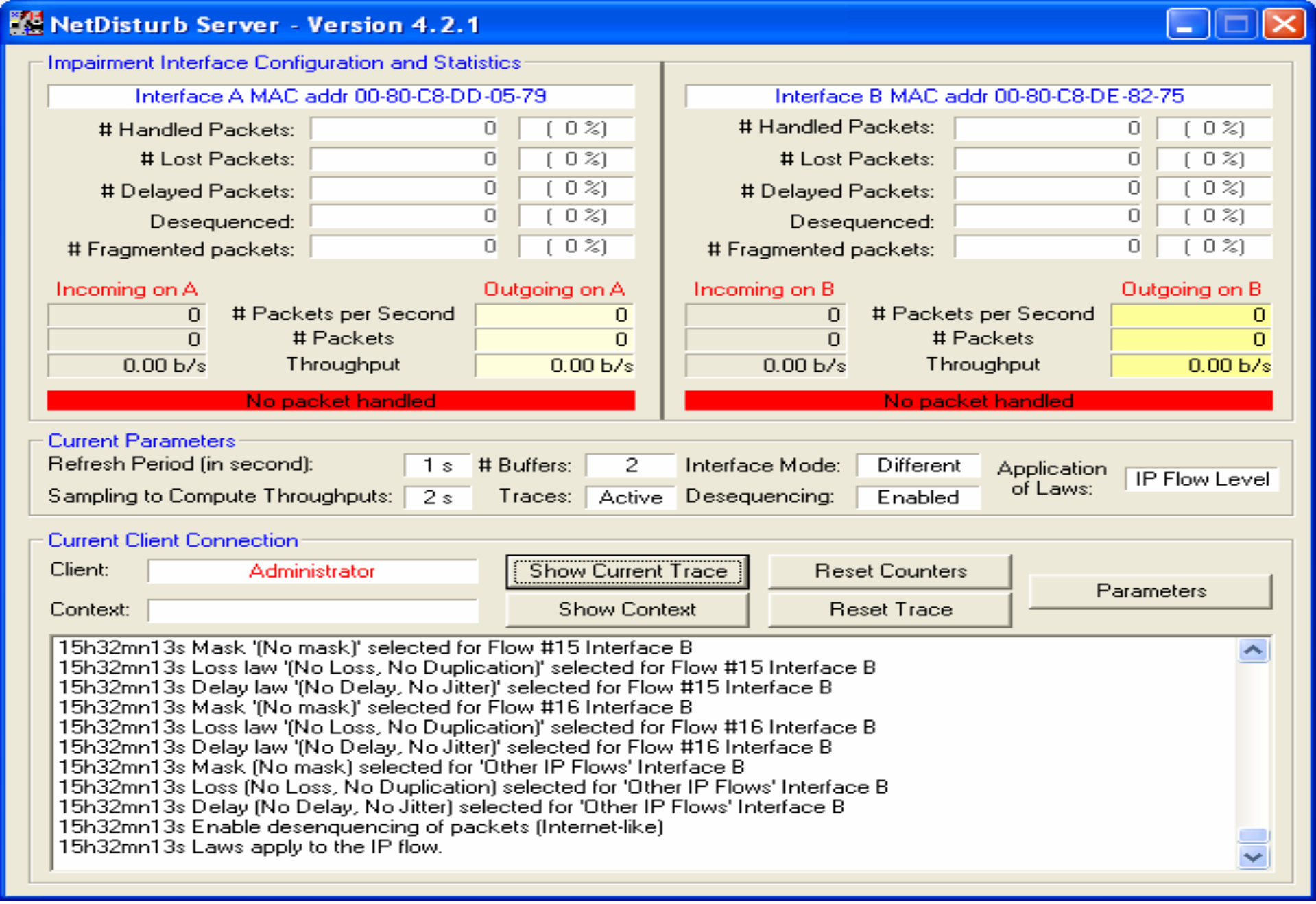
- IP Network Performance
  - Netdisturb (Omnicor) – Impairment emulator for IP networks
  - http://www.omnicor.com/netest.htm
- Monitoring and Debugging
  - Ethereal – Network protocol analyser
  - http://www.omnicor.com/netest.htm
- Audio Performance
  - Prism DScope

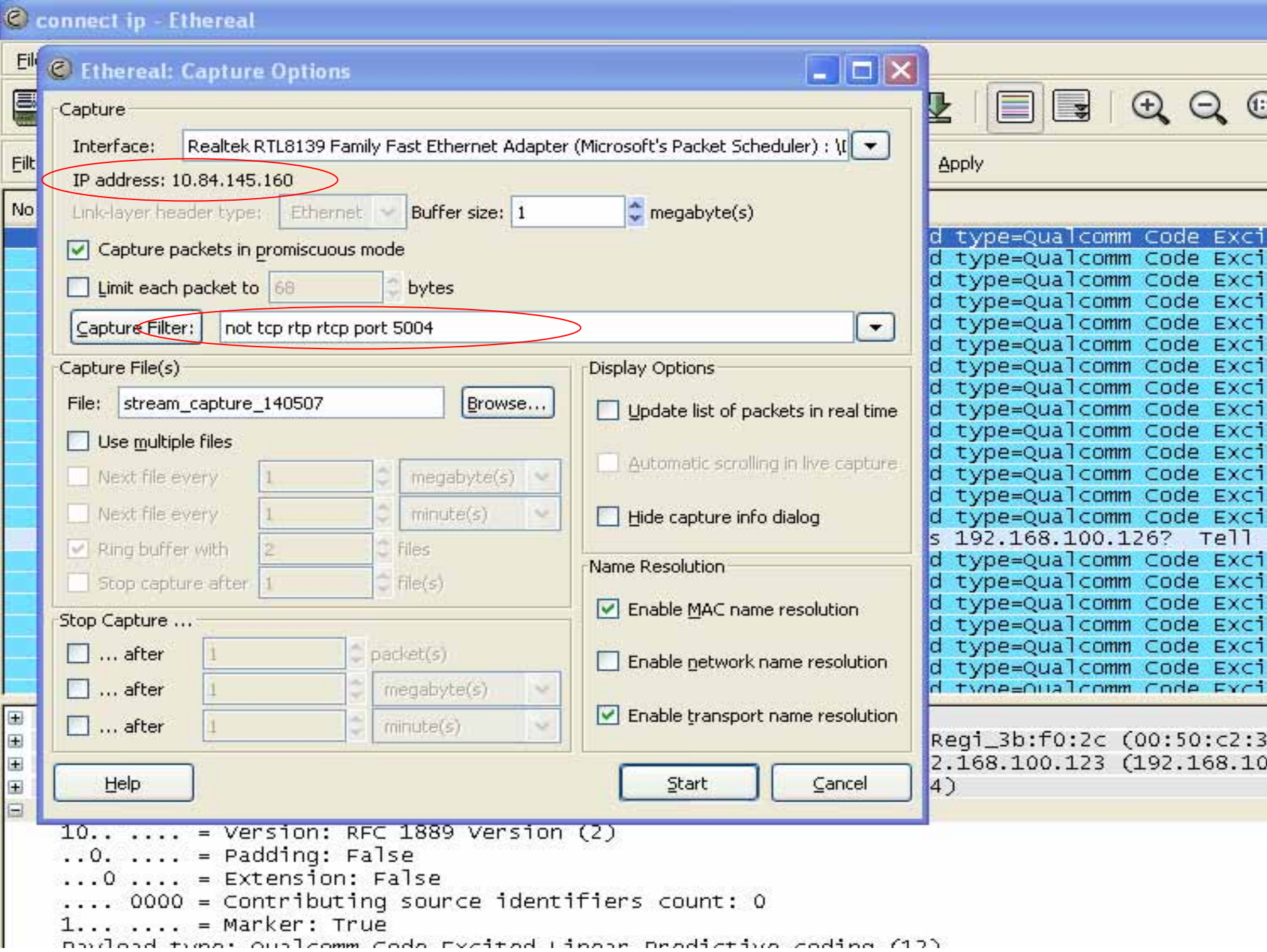
Test Network - Performance

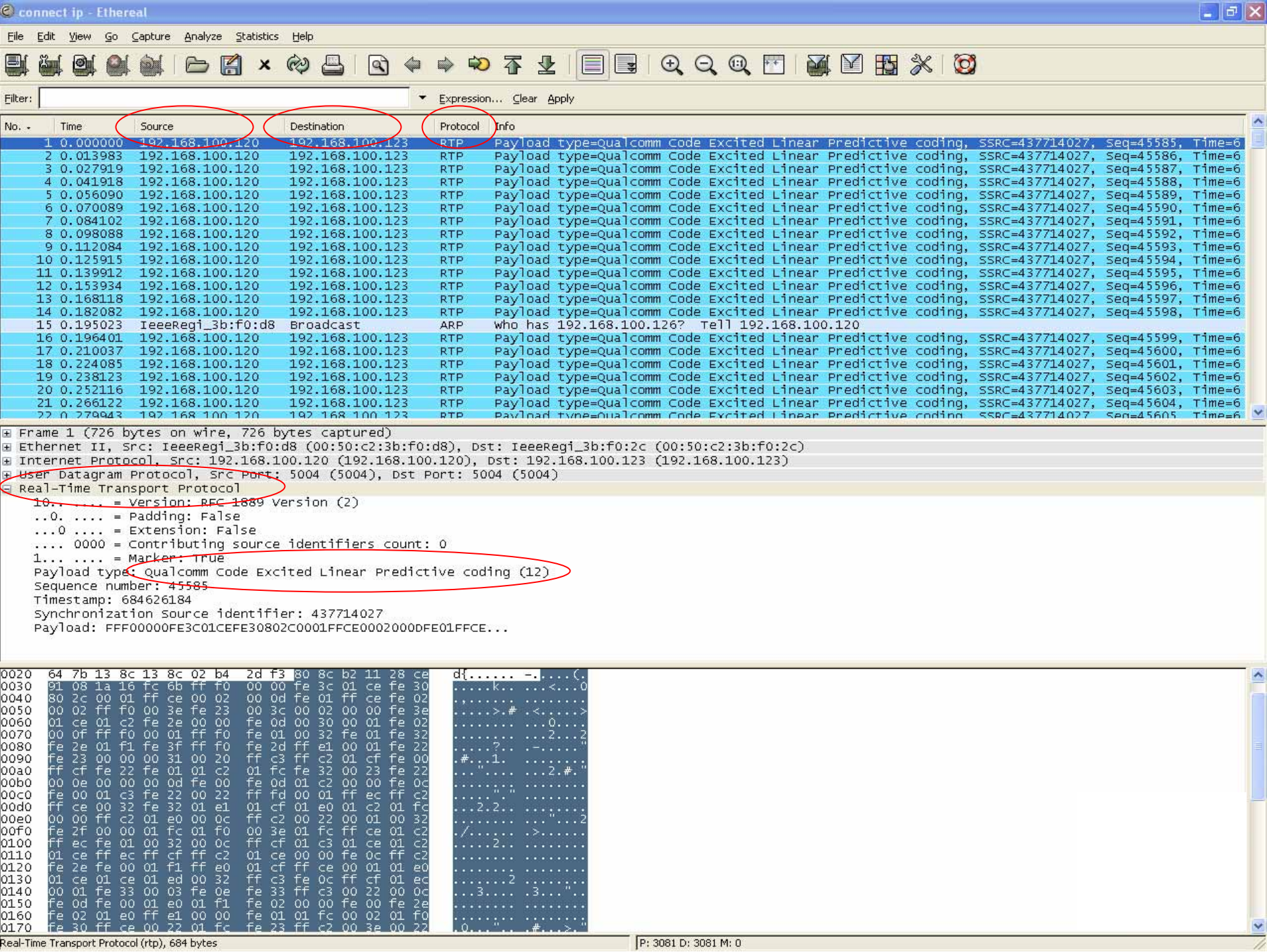


- Injection of faults
- Monitoring of faults – Reporting of faults/statistics to user
- Failure detection – Automatic evaluation of network performance
- Protocol evaluation – Packet re-ordering/Jitter buffer performance – Network delay handling


NetDisturb Client - Impairment Tool for IP Networks - BD Test 1.WSX
File Edit Actions Working Modes Statistics Help
IP Flows
Run #01
Run #02
Run #03
Run #04
Run #05
Run #06
Run #07
Run #08
Run #09
Run #10
Run #11
Run #12
Run #13
Run #14
Run #15
Run #16
Run
Other IP Flows
Statistics Synthesis by Flow
Run All
Stop All
Other IP Flows
Mask
(Not Applicable)
Loss & Duplication Law
packet loss
Percentage Loss
2%
Edit
Incoming Packets
0
Lost or Duplicated Packets
0 [0 %]
Delay & Jitter Law
(No Delay, No Jitter)
(No Delay and no Jitter)
Edit
Delayed Packets
0 [0 %]
Interface A (MAC): 00 80 C8 DD 05 79
Incoming
Packets/Second
0 p/s
Throughput
0.00 b/s
Outgoing
Packets/Second
0 p/s
Throughput
0.00 b/s
Interface
STOP
A
A to B
B to A
Interface B (MAC): 00 80 C8 DE 82 75
Outgoing
Packets/Second
0 p/s
Throughput
0.00 b/s
Incoming
Packets/Second
0 p/s
Throughput
0.00 b/s
Interface
STOP
B
Mask
(Not Applicable)
Loss & Duplication Law
(No Loss, No Duplication)
(No Loss, No Duplication)
Edit
Incoming Packets
0
Lost or Duplicated Packets
0 [0 %]
Delay & Jitter Law
(No Delay, No Jitter)
(No Delay and no Jitter)
Edit
Delayed Packets
0 [0 %]
Total Synthesis
Throughput Reception
Received Pkts
Matching Pkts
Sent Pkts
Throughput Transmission
From A to B
0.00 b/s
0 p/s
0 p
0 p
0 p
0.00 b/s
0 p/s
From B to A
0.00 b/s
0 p/s
0 p
0 p
0 p
0.00 b/s
0 p/s
Alarms
CPU Usage
17 %


NetDisturb Server - Version 4.2.1
Impairment Interface Configuration and Statistics
Interface A MAC addr 00-80-C8-DD-05-79
Handled Packets: 0 (0 %)
Lost Packets: 0 (0 %)
Delayed Packets: 0 (0 %)
Desequenced: 0 (0 %)
Fragmented packets: 0 (0 %)
Incoming on A
Outgoing on A
0
Packets per Second
0
0
Packets
0
0.00 b/s
Throughput
0.00 b/s
No packet handled
Interface B MAC addr 00-80-C8-DE-82-75
Handled Packets: 0 (0 %)
Lost Packets: 0 (0 %)
Delayed Packets: 0 (0 %)
Desequenced: 0 (0 %)
Fragmented packets: 0 (0 %)
Incoming on B
Outgoing on B
0
Packets per Second
0
0
Packets
0
0.00 b/s
Throughput
0.00 b/s
No packet handled
Current Parameters
Refresh Period (in second): 1 s
Buffers: 2
Interface Mode: Different
Application of Laws: IP Flow Level
Sampling to Compute Throughputs: 2 s
Traces: Active
Desequencing: Enabled
Current Client Connection
Client: Administrator
Context:
Show Current Trace
Show Context
Reset Counters
Reset Trace
Parameters
15h32mn13s Mask '(No mask)' selected for Flow #15 Interface B
15h32mn13s Loss law '(No Loss, No Duplication)' selected for Flow #15 Interface B
15h32mn13s Delay law '(No Delay, No Jitter)' selected for Flow #15 Interface B
15h32mn13s Mask '(No mask)' selected for Flow #16 Interface B
15h32mn13s Loss law '(No Loss, No Duplication)' selected for Flow #16 Interface B
15h32mn13s Delay law '(No Delay, No Jitter)' selected for Flow #16 Interface B
15h32mn13s Mask (No mask) selected for 'Other IP Flows' Interface B
15h32mn13s Loss (No Loss, No Duplication) selected for 'Other IP Flows' Interface B
15h32mn13s Delay (No Delay, No Jitter) selected for 'Other IP Flows' Interface B
15h32mn13s Enable desenquencing of packets (Internet-like)
15h32mn13s Laws apply to the IP flow.


connect ip - Ethereal
Ethereal: Capture Options
Capture
Interface:
Realtek RTL8139 Family Fast Ethernet Adapter (Microsoft's Packet Scheduler) : \[
IP address: 10.84.145.160
Link-layer header type:
Ethernet
Buffer size:
1
megabyte(s)
Capture packets in promiscuous mode
Limit each packet to
68
bytes
Capture Filter:
not tcp rtp rtcp port 5004
Capture File(s)
File:
stream_capture_140507
Browse...
Use multiple files
Next file every
megabyte(s)
Next file every
minute(s)
Ring buffer with
files
Stop capture after
file(s)
Display Options
Update list of packets in real time
Automatic scrolling in live capture
Hide capture info dialog
Name Resolution
Enable MAC name resolution
Enable network name resolution
Enable transport name resolution
Stop Capture ...
... after
packet(s)
... after
megabyte(s)
... after
minute(s)
Help
Start
Cancel
Apply
d type=Qualcomm Code Exci
s 192.168.100.126? Tell
Regi_3b:f0:2c (00:50:c2:3
2.168.100.123 (192.168.10
4)
10.. .... = Version: RFC 1889 Version (2)
..0. .... = Padding: False
...0 .... = Extension: False
.... 0000 = Contributing source identifiers count: 0
1... .... = Marker: True


connect ip - Ethereal
File Edit View Go Capture Analyze Statistics Help
Filter: Expression... Clear Apply
No. Time Source Destination Protocol Info
1 0.000000 192.168.100.120 192.168.100.123 RTP Payload type=Qualcomm Code Excited Linear Predictive coding, SSRC=437714027, Seq=45585, Time=6
2 0.013983 192.168.100.120 192.168.100.123 RTP Payload type=Qualcomm Code Excited Linear Predictive coding, SSRC=437714027, Seq=45586, Time=6
3 0.027919 192.168.100.120 192.168.100.123 RTP Payload type=Qualcomm Code Excited Linear Predictive coding, SSRC=437714027, Seq=45587, Time=6
4 0.041918 192.168.100.120 192.168.100.123 RTP Payload type=Qualcomm Code Excited Linear Predictive coding, SSRC=437714027, Seq=45588, Time=6
5 0.056090 192.168.100.120 192.168.100.123 RTP Payload type=Qualcomm Code Excited Linear Predictive coding, SSRC=437714027, Seq=45589, Time=6
6 0.070089 192.168.100.120 192.168.100.123 RTP Payload type=Qualcomm Code Excited Linear Predictive coding, SSRC=437714027, Seq=45590, Time=6
7 0.084102 192.168.100.120 192.168.100.123 RTP Payload type=Qualcomm Code Excited Linear Predictive coding, SSRC=437714027, Seq=45591, Time=6
8 0.098088 192.168.100.120 192.168.100.123 RTP Payload type=Qualcomm Code Excited Linear Predictive coding, SSRC=437714027, Seq=45592, Time=6
9 0.112084 192.168.100.120 192.168.100.123 RTP Payload type=Qualcomm Code Excited Linear Predictive coding, SSRC=437714027, Seq=45593, Time=6
10 0.125915 192.168.100.120 192.168.100.123 RTP Payload type=Qualcomm Code Excited Linear Predictive coding, SSRC=437714027, Seq=45594, Time=6
11 0.139912 192.168.100.120 192.168.100.123 RTP Payload type=Qualcomm Code Excited Linear Predictive coding, SSRC=437714027, Seq=45595, Time=6
12 0.153934 192.168.100.120 192.168.100.123 RTP Payload type=Qualcomm Code Excited Linear Predictive coding, SSRC=437714027, Seq=45596, Time=6
13 0.168118 192.168.100.120 192.168.100.123 RTP Payload type=Qualcomm Code Excited Linear Predictive coding, SSRC=437714027, Seq=45597, Time=6
14 0.182082 192.168.100.120 192.168.100.123 RTP Payload type=Qualcomm Code Excited Linear Predictive coding, SSRC=437714027, Seq=45598, Time=6
15 0.195023 IeeeRegi_3b:f0:d8 Broadcast ARP who has 192.168.100.126? Tell 192.168.100.120
16 0.196401 192.168.100.120 192.168.100.123 RTP Payload type=Qualcomm Code Excited Linear Predictive coding, SSRC=437714027, Seq=45599, Time=6
17 0.210037 192.168.100.120 192.168.100.123 RTP Payload type=Qualcomm Code Excited Linear Predictive coding, SSRC=437714027, Seq=45600, Time=6
18 0.224085 192.168.100.120 192.168.100.123 RTP Payload type=Qualcomm Code Excited Linear Predictive coding, SSRC=437714027, Seq=45601, Time=6
19 0.238123 192.168.100.120 192.168.100.123 RTP Payload type=Qualcomm Code Excited Linear Predictive coding, SSRC=437714027, Seq=45602, Time=6
20 0.252116 192.168.100.120 192.168.100.123 RTP Payload type=Qualcomm Code Excited Linear Predictive coding, SSRC=437714027, Seq=45603, Time=6
21 0.266122 192.168.100.120 192.168.100.123 RTP Payload type=Qualcomm Code Excited Linear Predictive coding, SSRC=437714027, Seq=45604, Time=6
Frame 1 (726 bytes on wire, 726 bytes captured)
Ethernet II, Src: IeeeRegi_3b:f0:d8 (00:50:c2:3b:f0:d8), Dst: IeeeRegi_3b:f0:2c (00:50:c2:3b:f0:2c)
Internet Protocol, Src: 192.168.100.120 (192.168.100.120), Dst: 192.168.100.123 (192.168.100.123)
User Datagram Protocol, Src Port: 5004 (5004), Dst Port: 5004 (5004)
Real-Time Transport Protocol
10.. .... = Version: RFC 1889 Version (2)
..0. .... = Padding: False
...0 .... = Extension: False
.... 0000 = Contributing source identifiers count: 0
1... .... = Marker: True
Payload type: Qualcomm Code Excited Linear Predictive coding (12)
Sequence number: 45585
Timestamp: 684626184
Synchronization Source identifier: 437714027
Payload: FFF00000FE3C01CEFE30802C0001FFCE0002000DFE01FFCE...
0020 64 7b 13 8c 13 8c 02 b4 2d f3 80 8c b2 11 28 ce d{...... -.....(.
0030 91 08 1a 16 fc 6b ff f0 00 00 fe 3c 01 ce fe 30 .....k.. ...<...0
0040 80 2c 00 01 ff ce 00 02 00 0d fe 01 ff ce fe 02 .,...... ....
0050 00 02 ff f0 00 3e fe 23 00 3c 00 02 00 00 fe 3e .....>.# .<.....>
0060 01 ce 01 c2 fe 2e 00 00 fe 0d 00 30 00 01 fe 02 ....0....
0070 00 0f ff f0 00 01 ff f0 fe 01 00 32 fe 01 fe 32 ....2...2
0080 fe 2e 01 f1 fe 3f ff f0 fe 2d ff e1 00 01 fe 22 .....?.. .-.....
0090 fe 23 00 00 00 31 00 20 ff c3 ff c2 01 cf fe 00 .#...1. ....
00a0 ff cf fe 22 fe 01 01 c2 01 fc fe 32 00 23 fe 22 ..."..... ...2.#."
00b0 00 0e 00 00 00 0d fe 00 fe 0d 01 c2 00 00 fe 0c ....
00c0 fe 00 01 c3 fe 22 00 22 ff fd 00 01 ff ec ff c2 ....
00d0 ff ce 00 32 fe 32 01 e1 01 cf 01 e0 01 c2 01 fc ...2.2.. ....
00e0 00 00 ff c2 01 e0 00 0c ff c2 00 22 00 01 00 32 ...."...2
00f0 fe 2f 00 00 01 fc 01 f0 00 3e 01 fc ff ce 01 c2 ./...... .>......
0100 ff ec fe 01 00 32 00 0c ff cf 01 c3 01 ce 01 c2 .....2.. ....
0110 01 ce ff ec ff cf ff c2 01 ce 00 00 fe 0c ff c2 ....
0120 fe 2e fe 00 01 f1 ff e0 01 cf ff ce 00 01 01 e0 ....
0130 01 ce 01 ce 01 ed 00 32 ff c3 fe 0c ff cf 01 ec ....2 ....
0140 00 01 fe 33 00 03 fe 0e fe 33 ff c3 00 22 00 0c ...3.... .3..."..
0150 fe 0d fe 00 01 e0 01 f1 fe 02 00 00 fe 00 fe 2e ....
0160 fe 02 01 e0 ff e1 00 00 fe 01 01 fc 00 02 01 f0 ....
0170 fe 30 ff ce 00 22 01 fc fe 23 ff c2 00 3e 00 22 .0..."... .#...>."
Real-Time Transport Protocol (rtp), 684 bytes
P: 3081 D: 3081 M: 0

Thank you for listening