Audio Over IP

A Manufacturer's View

Gregory Massey – Chief Technical Officer

Agenda

- Interoperability
- Network Design
- Expectations vs Reality
- Summary

Interoperability - Overview

Standards

AAC-ELD

MP2 AAC-LC

AAC-LD

4SB

MP4 AAC-LC

Enhanced apt-X

HE-AAC

HE-AACv2

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

Delays from Johannesburg to Pretoria and Back
Audio: APTX16 384K IP: Packet:128 Rx-Buff:20mSec
Delay Measured: 86mSec

Network Delay

Delays from Johannesburg to Pretoria and Back
Audio: APTX16 384K IP: Packet:384 Rx-Buff:20mSec
Delay Measured: 92mSec

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

- 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 N

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

Port Restricted C

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

Restricted Co

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

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	Loss & Duplication Law	Delay & Jitter Law
(Not Applicable)	packet loss	(No Delay, No Jitter)
	Percentage Loss 2% Edit	(No Delay and no Jitter) Edit
# Incoming Packets 0	# Lost or Duplicated Packets 0 [0 %]	# 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	Loss & Duplication Law	Delay & Jitter Law
(Not Applicable)	(No Loss, No Duplication)	(No Delay, No Jitter)
	(No Loss, No Duplication) Edit	(No Delay and no Jitter) Edit
# Incoming Packets 0	# Lost or Duplicated Packets 0 [0 %]	# 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 | Reset Counters | Parameters

Show Context | Reset Trace

```
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 1 megabyte(s)

☐ Next file every 1 minute(s)

☑ Ring buffer with 2 files

☐ Stop capture after 1 file(s)

Stop Capture ...

☐ ... after 1 packet(s)

☐ ... after 1 megabyte(s)

☐ ... after 1 minute(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

Help Start Cancel

Apply

d type=Qualcomm Code Exci
d type=Qualcomm Code Exci
d type=Qualcomm Code Exci
d type=Qualcomm Code Exci
d type=Qualcomm Code Exci
d type=Qualcomm Code Exci
d type=Qualcomm Code Exci
d type=Qualcomm Code Exci
d type=Qualcomm Code Exci
d type=Qualcomm Code Exci
d type=Qualcomm Code Exci
d type=Qualcomm Code Exci
s 192.168.100.126? Tell
d type=Qualcomm Code Exci
d type=Qualcomm Code Exci
d type=Qualcomm Code Exci
d type=Qualcomm Code Exci
d type=Qualcomm Code Exci
d type=Qualcomm Code Exci
d type=Qualcomm Code Exci

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
Payload type: Qualcomm Code Excited Linear Predictive coding (13)
```

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
22	0.279943	192.168.100.120	192.168.100.123	RTP	Payload type=Qualcomm Code Excited Linear Predictive coding, SSRC=437714027, Seq=45605, 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