Flow-Based Monitoring, Troubleshooting and Security using nProbe

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Packets, Flows, Activities [1/3]

- For years monitoring tools focused on standards often fostered by vendors: NetFlow vs sFlow vs SNMP, Cisco vs Juniper…
- This has plagued the market by creating tools more vendor oriented, than result oriented.
- Fortunately recent advances in computing and in particular the big data movement, have pushed companies to overcome the market/vendor fragmentation and produce tools able to produce data on a standard format (often JSON) that could be consumed even by non-monitoring tools (e.g. Hadoop, ElasticSearch).

Packets, Flows, Activities [2/3]

- As data increases and people demand feature rich monitoring tools, it has become necessary to ‘compress’ monitoring data.
- Network packets are still important for providing evidence or troubleshooting problems (packets or it didn't happen!) but they are “too raw” and take too much storage space, so limiting them to specific situations is a good idea.
- Network flow analysis is a good way to “compress packets” into events: sFlow do it with sampling, NetFlow with stateful connection-based packet classification.

Packets, Flows, Activities [3/3]

- These days, saving flows on a big data system is a common practice but it still plagued by the visibility issue:
    - What flows are "more relevant" than others?
    - Can we use flows for more than just host/protocol/application traffic accounting ?
    - How can a network administrator look for a needle in a haystack when the monitoring platform is emitting tenth of thousand flows/second?
- We need yet another level of abstraction on top of flows able to identify activities on top of flows (e.g. these 20 HTTPS connections and 5 DNS queries mean that host X just open the landing page of newspaper corriere.it).

Flow Generation [1/2]

- Unfortunately there are still too many "NetFlow dialects" (e.g. Cisco ASA or Barracuda Networks flows) available that make interoperability not that simple
- sFlow is even simpler than NetFlow/IPFIX to implement and available in most switches deployed today (Cisco features a sFlow-like protocol named NetFlow Lite).
- With the baseline bytes/packets of traffic flow from these flow protocols, we can do a lot with good analytics. This including congestion, cost analysis, DDoS detection, security and forensics.

Flow Generation [2/2]

- Ideally, we want to gather rich measurement metrics, from everywhere possible.
- For the above goals 5-tuples (IPs, Ports, Protocol) and and bytes/packets are not enough as we expect at least:
  - Latency, Packet Drops, Retransmissions.
  - QoE (e.g. HTTP service time).
  - Application visibility (DPI, URLs, DNS responses).
- And with those metrics per flow, we can provide even more actionable insights into performance and security issues.

Do We Need Custom Probes in 2017? [1/2]

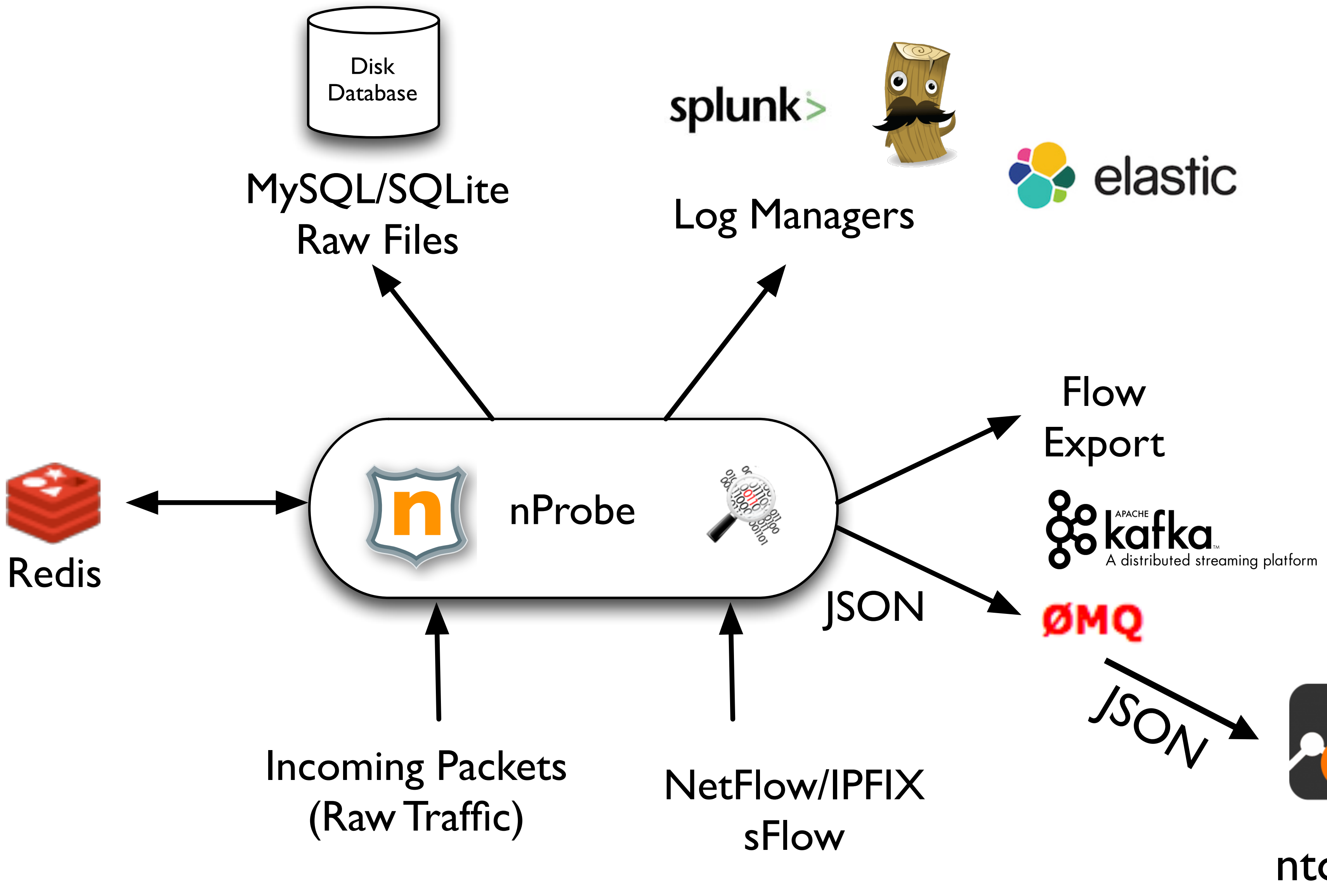
- Flow-based traffic analysis relies on network probes that are usually implemented in network devices such as routers and firewalls.
- Unfortunately being probe development driven by vendors, probes have not evolved much over the past 10 years, and where it happened, it as not been in a standard way.
- Most collectors complexity is due to the support of various IPFIX/NF dialects rather on using the collected data.

Do We Need Custom Probes in 2017? [2/2]

- More than 10 years ago, (at ntop) we realised that improvements in network monitoring were limited by the ability of network probes to generate rich monitoring data.
- In essence we cannot expect to move forward waiting the Cisco, Juniper… to embed in routers a next-generation probe.
- This was the motivation to create our own software probe, named nProbe.

nProbe [1/4]

- nProbe is a high-speed (multi 10G) traffic probe/ collector for Linux and Windows platforms.



Disk
Database

MySQL/SQLite
Raw Files

splunk>

elastic

Log Managers

Flow
Export

APACHE kafka
A distributed streaming platform

ØMQ

Redis

nProbe

JSON

JSON

Incoming Packets
(Raw Traffic)

NetFlow/IPFIX
sFlow

ntopng

nProbe [2/4]

- Originally designed as a drop-in replacement of a physical NetFlow probe, currently it can:
  - Convert flow format (sFlow-to-NetFlow/IPFIX) or version (e.g. v5 to v9).
  - High-speed packet-to-flow processing.
  - Leverage on in-memory-databases to maintain flow state coherency (e.g. SIP/RTP, Radius/Diameter or GTP traffic).
  - Ability to pre-compute data for realtime traffic aggregation.

nProbe [3/4]

- It has an open architecture extensible by means of plugins that include:
  - GTP (v0, v1, v2) plugins.
  - VoIP (SIP and RTP) plugins for analysing voice signalling (who's calling who/when) and voice quality (Jitter and pseudo-MOS/R-Factor).
  - HTTP(S), Email (SMTP, IMAP, POP3), Radius, Database (Oracle and MySQL), FTP, DHCP, and BGP.
  - JSON export (TCP, Kafka and ElasticSearch)

nProbe [4/4]

- nProbe supports flexible NetFlow, that allows data export format to be customised at runtime.
- nProbe allow users to define a template on the command line.
- In addition to the standard fields (IP, port…), nProbe can export many other fields such as packet stats (TTL and size distribution), network/application latency, geolocation, packets retransmitted/out-of-order, tunnel information, and DPI (Deep Packet Inspection).

nProbe vs YAF

- Ability to dissect application protocols (e.g. VoIP, Radius, HTTP) and export them in standard flow records (with ntop PEN).
- Network (latency, retransmission, OOO, TCP Window/ TTL stats…) and application metrics (response time).
- Application metadata (URL, BitTorrent Hash, SSL certification information, OperatingSystem).
- Flow user info (Radius/GTP/Diameter) in-probe flow correlation.
- Probe scriptability via Lua to extend flow information or to manipulate flow export policy.

DNS Traffic Monitoring

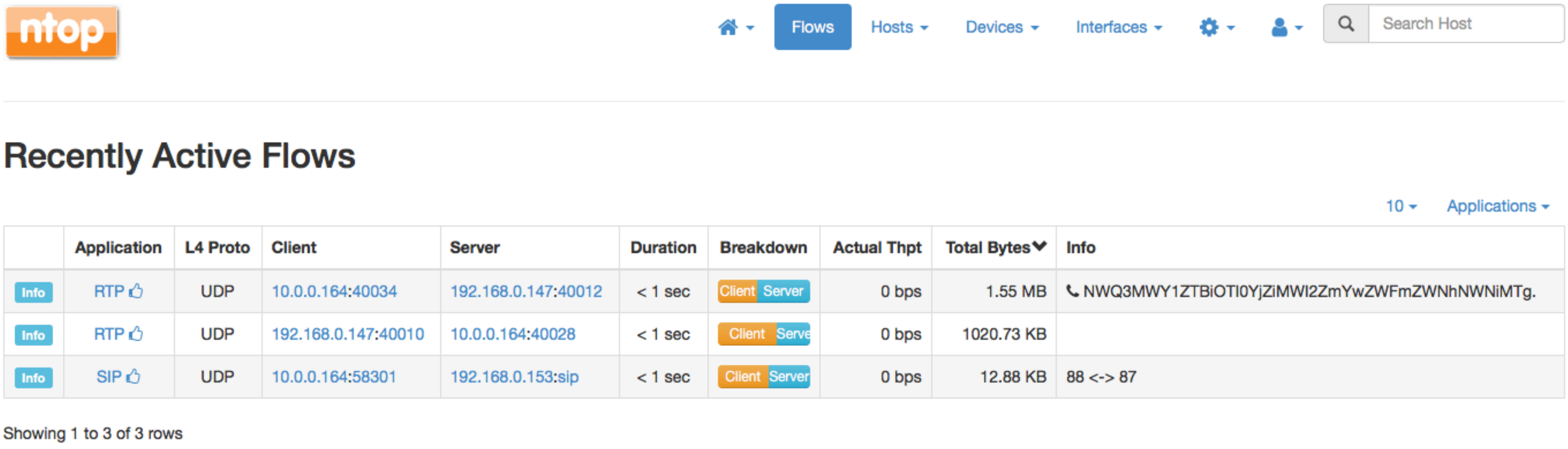
- Using nProbe it is possible to generate flow records containing DNS req/reply… and dump them to disk
- Malformed DNS packets can be saved in pcap format for later analysis and troubleshooting.

```
#
# When[epoch]   DNS_Client[ascii:32]    AS[uint]        ClientCountry[ascii:32] ClientCity[ascii:32]    DNS_Server[ascii:32]
Query[ascii:64] NumRetCode[uint]        RetCode[ascii:16]       NumAnswer[uint] NumQueryType[uint]      QueryType[ascii:8]
TransactionId[uint]     Answers[ascii:128]      AuthNSs[ascii:32]       Cli2SrvTTL[uint]        Srv2CliTTL[uint]
NumQueryPkts[uint]      NumReplyPkts[uint]      ServerResponseTime(ms)[float]   RecordTTL[uint]
#
1481220355      192.168.1.7     0                       8.8.8.8 bramp.github.io 0       NOERROR 2       1       A       36320
151.101.16.133/A;github.map.fastly.net/CNAME            0       255     1       1       65.628  12
1481220356      192.168.1.7     0                       8.8.8.8 edition.cnn.com 0       NOERROR 3       1       A       30012
151.101.60.73/A;www.edition.cnn.com/CNAME;turner.map.fastly.net/CNAME           255     255     2       1       1044.427
29
1481220357      192.168.1.7     0                       8.8.8.8 tpc.googlesyndication.com       0       NOERROR 2       1
A       41074   172.217.16.1/A;pagead-googlehosted.l.google.com/CNAME           0       255     1       1       46.898  299
1481220357      192.168.1.7     0                       8.8.8.8 pagead2.googlesyndication.com   0       NOERROR 2       1
A       21182   216.58.205.66/A;pagead46.l.doubleclick.net/CNAME                0       255     1       1       49.280  299
1481220357      192.168.1.7     0                       8.8.8.8 www.google.com  0       NOERROR 1       1       A       33128
216.58.205.196/A                0       255     1       1       47.855  292
1481220357      192.168.1.7     0                       8.8.8.8 aax.amazon-adsystem.com 0       NOERROR 3       1       A
44800   52.94.218.7/A;aax.amazon-adsystem.amazon.com/CNAME;aax-eu.amazon-adsystem.com/CNAME             0       255     1
1       81.974  29
```

VoIP Traffic Monitoring [1/3]

- nProbe can monitor both SIP and RTP, and correlate signalling to traffic via the redis cache.
- It can:
  - Generate "legacy" CDR (Call Data Records) containing caller/called/duration… information on SIP traffic.
  - Dissect RTP traffic and generate call quality metrics including jitter, packet lost, max inter-arrival time, pseudo-MOS (Mean Opinion Score) and R-Factor.
- A low-end x86 PC with nProbe can monitor thousand of simultaneous VoIP calls.

VoIP Traffic Monitoring [2/3]



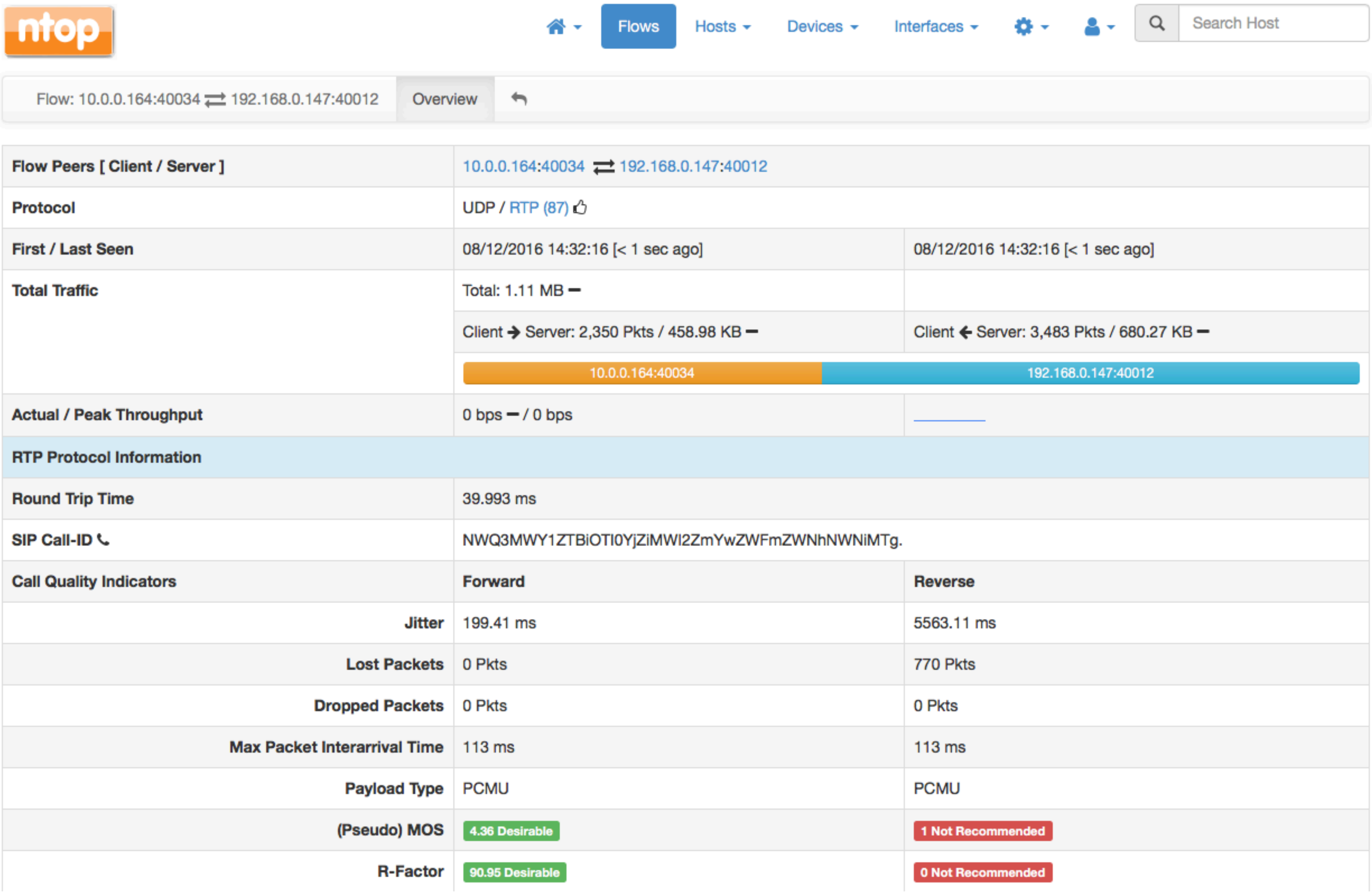
Recently Active Flows

10 Applications

	Application	L4 Proto	Client	Server	Duration	Breakdown	Actual Thpt	Total Bytes	Info
Info	RTP	UDP	10.0.0.164:40034	192.168.0.147:40012	< 1 sec	Client Server	0 bps	1.55 MB	☎ NWQ3MWY1ZTBiOTI0YjZiMWI2ZmYwZWFmZWNhNWNiMTg.
Info	RTP	UDP	192.168.0.147:40010	10.0.0.164:40028	< 1 sec	Client Serve	0 bps	1020.73 KB	
Info	SIP	UDP	10.0.0.164:58301	192.168.0.153:sip	< 1 sec	Client Server	0 bps	12.88 KB	88 <-> 87

Showing 1 to 3 of 3 rows

VoIP Traffic Monitoring [3/3]



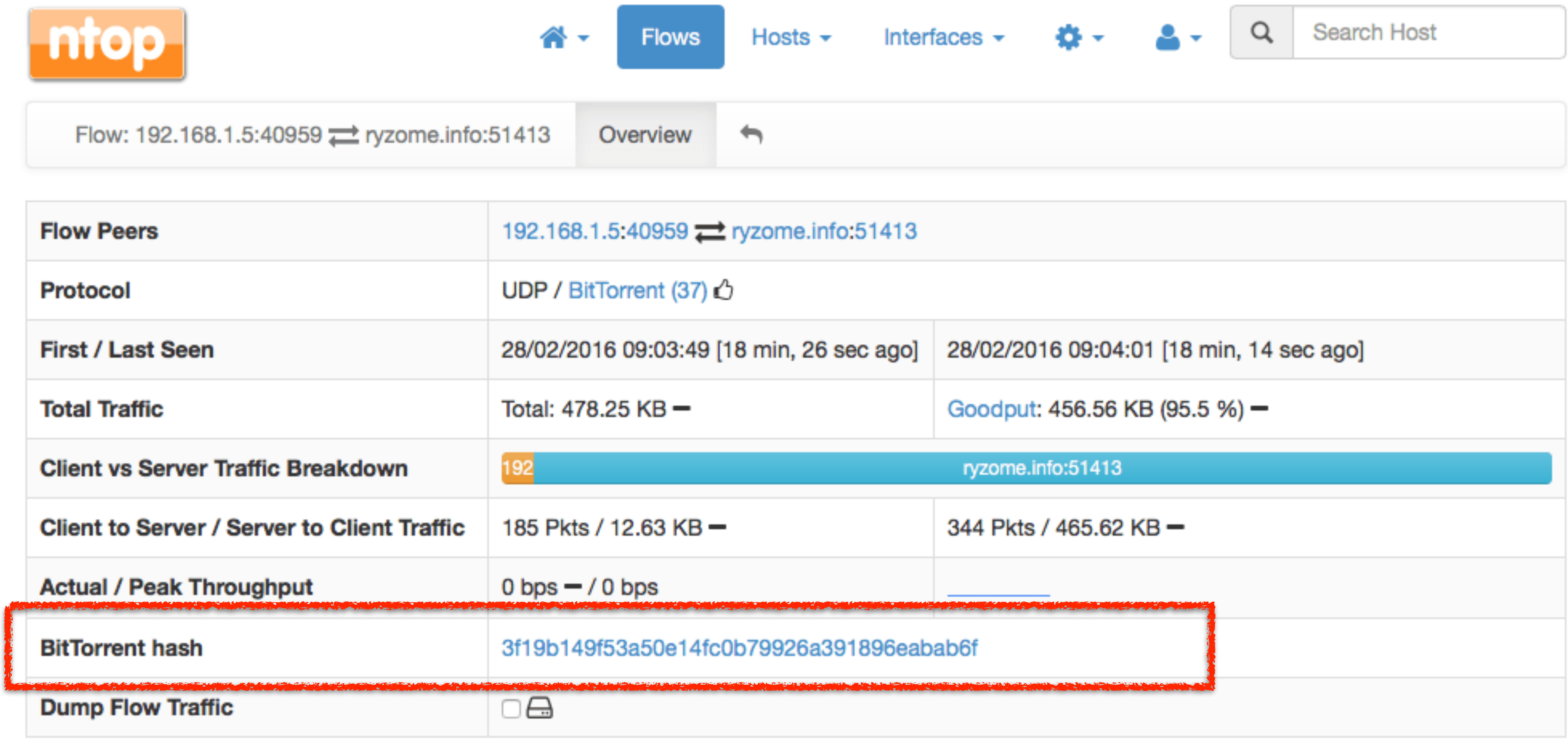
Flow: 10.0.0.164:40034 ⇄ 192.168.0.147:40012

Flow Peers [Client / Server]	10.0.0.164:40034 ⇄ 192.168.0.147:40012	
Protocol	UDP / RTP (87) 👍	
First / Last Seen	08/12/2016 14:32:16 [< 1 sec ago]	08/12/2016 14:32:16 [< 1 sec ago]
Total Traffic	Total: 1.11 MB —	
	Client → Server: 2,350 Pkts / 458.98 KB —	Client ← Server: 3,483 Pkts / 680.27 KB —
	10.0.0.164:40034	192.168.0.147:40012
Actual / Peak Throughput	0 bps — / 0 bps	
RTP Protocol Information		
Round Trip Time	39.993 ms	
SIP Call-ID ☎	NWQ3MWY1ZTBiOTI0YjZiMWI2ZmYwZWFmZWNhNWNiMTg.	
Call Quality Indicators	**Forward**	**Reverse**
Jitter	199.41 ms	5563.11 ms
Lost Packets	0 Pkts	770 Pkts
Dropped Packets	0 Pkts	0 Pkts
Max Packet Interarrival Time	113 ms	113 ms
Payload Type	PCMU	PCMU
(Pseudo) MOS	4.36 Desirable	1 Not Recommended
R-Factor	90.95 Desirable	0 Not Recommended

BitTorrent Traffic Monitoring [1/3]

- BitTorrent traffic is encrypted and so its content cannot be inspected. However sometimes it is necessary to track what users are downloading to check if the what they are doing is legitimate.
- Fortunately BitTorrent traffic tracks resources by means of a hashId that it can be dissected by nProbe.
- Using a search engine it is possible to bind a hashId to a downloaded resource and thus decide if the downloaded files are legitimate.

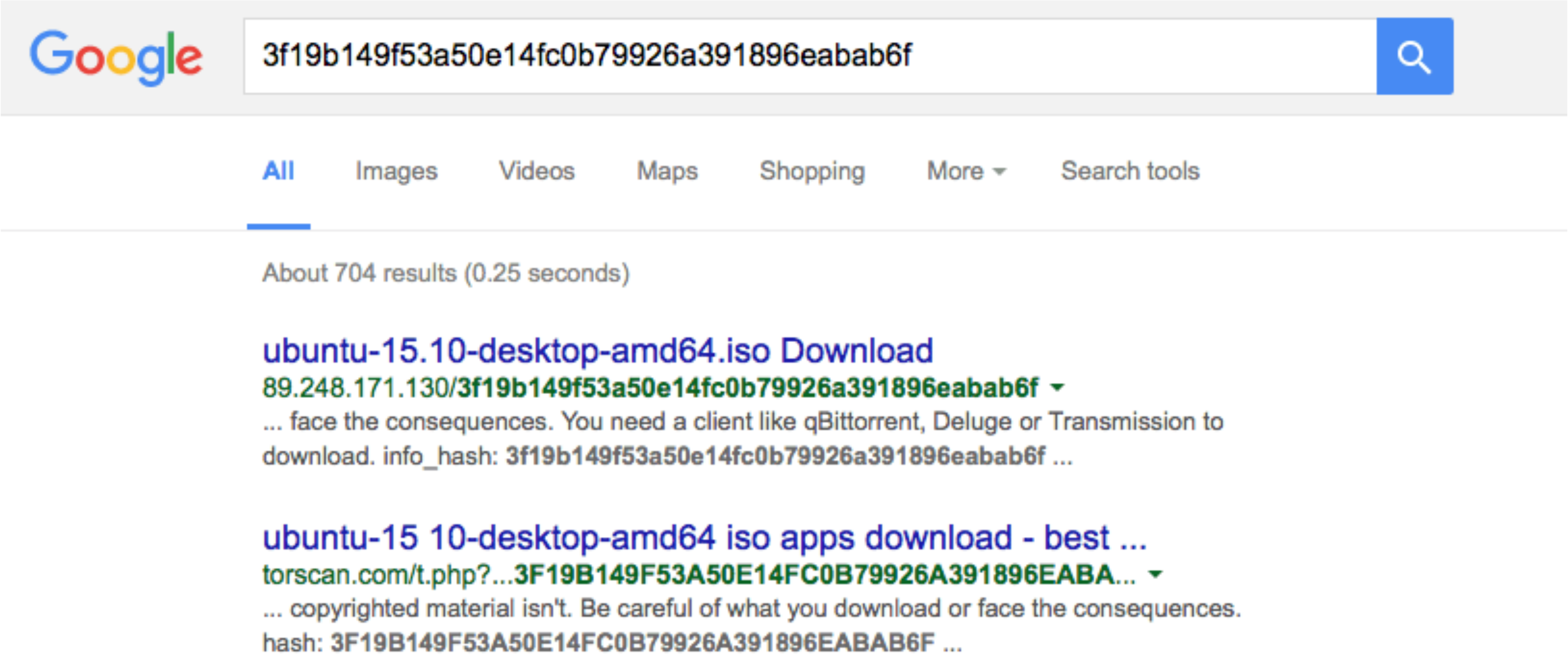
BitTorrent Traffic Monitoring [2/3]



Flow: 192.168.1.5:40959 ⇄ ryzome.info:51413

Flow Peers	192.168.1.5:40959 ⇄ ryzome.info:51413	
Protocol	UDP / BitTorrent (37) 👍	
First / Last Seen	28/02/2016 09:03:49 [18 min, 26 sec ago]	28/02/2016 09:04:01 [18 min, 14 sec ago]
Total Traffic	Total: 478.25 KB —	Goodput: 456.56 KB (95.5 %) —
Client vs Server Traffic Breakdown	192 ryzome.info:51413	
Client to Server / Server to Client Traffic	185 Pkts / 12.63 KB —	344 Pkts / 465.62 KB —
Actual / Peak Throughput	0 bps — / 0 bps	
BitTorrent hash	3f19b149f53a50e14fc0b79926a391896eabab6f	
Dump Flow Traffic	☐	

BitTorrent Traffic Monitoring [3/3]



About 704 results (0.25 seconds)

ubuntu-15.10-desktop-amd64.iso Download
89.248.171.130/3f19b149f53a50e14fc0b79926a391896eabab6f
... face the consequences. You need a client like qBittorrent, Deluge or Transmission to download. info_hash: 3f19b149f53a50e14fc0b79926a391896eabab6f ...

ubuntu-15 10-desktop-amd64 iso apps download - best ...
torscan.com/t.php?...3F19B149F53A50E14FC0B79926A391896EABA...
... copyrighted material isn't. Be careful of what you download or face the consequences. hash: 3F19B149F53A50E14FC0B79926A391896EABAB6F ...

HTTP Traffic Analysis [1/2]

- The HTTP plugin is used by many users to both analyse user traffic and detect malware. For this reason it produces a rich set of metrics and metadata to make detection possible.
- As flow-based probes usually emit flows after some timeouts are past (e.g. flow duration), in order to promptly trigger detection, nProbe plugins can emit events immediately (e.g. as soon as the HTTP headers have been observed).

HTTP Traffic Analysis [2/2]

- The plugin supports both HTTP 1.0 and 1.1 (multi-requests per TCP connection).

```
#
# Client[ascii:32]      Server[ascii:32]        Protocol[ascii:8]       Method[ascii:8] URL[ascii:255]  HTTPReturnCode[uint]
Location[ascii:255]     Referer[ascii:255]      UserAgent[ascii:255]    ContentType[ascii:96]   Bytes[uint]     BeginTime[epoch]
EndTimeWithPayload[epoch]       FlowHash[ascii:16]      Cookie[ascii:255]       Terminator[ascii:4]     ApplLatency(ms)[uint]
ClientLatency(ms)[uint] ServerLatency(ms)[uint] ApplicationId[uint]     Application[ascii:32]   BalancerHost[ascii:32]
ServerIP[ascii:32]      RehttpPkts[uint]        Client2Server_TEID[ascii:8]     Server2Client_TEID[ascii:8]     FlowUserName (User
or IMSI/LAC/CCI/CSAC/NSAPI)[ascii:32]        AdditionalInfo[ascii:32]        Pkts_Cli2Srv[uint]      Pkts_Svr2Cli[uint]
Bytes_Cli2Srv[uint]     Bytes_Svr2Cli[uint]     OOO_Cli2Srv[uint]       OOO_Svr2Cli[uint]
       Retr_Cli2Srv[uint]      Retr_Svr2Cli[uint]      Duration_Cli2Srv(ms)[uint]      Duration_Svr2Cli(ms)[uint]
FlowID[uint]    X-Forwarded-For[ascii:255]      Via[ascii:255]  POSTParams[ascii:256]
#
217.31.54.202   www.ntop.org    http    GET     /blog/?feed=rss2        301     www.ntop.org/blog/feed  www.ntop.org/blog/?
feed=rss2    SimplePie/1.4-dev (Feed Parser; http://simplepie.org; Allow like Gecko) Build/20130924065456    text/html       1387
1481268507      1481268507
      1553062676              U       1.712   0.004   0.380   7       HTTP            131.114.21.22   0       00000000
00000000                        5       5       700     687     0       0       0       0       2.539   1.782   1
217.31.54.202   www.ntop.org    http    GET     /blog/feed/     200             www.ntop.org/blog/?feed=rss2    SimplePie/1.4-dev
(Feed Parser; http://simplepie.org; Allow like Gecko) Build/20130924065456    text/xml        19480   1481268507      1481268507
1553062704
        U       0.089   0.001   0.002   7       HTTP            131.114.21.22   0       00000000        00000000
16      7       1267    18213   0       0       0       0       0.451   0.447   4
192.41.231.101  version.ntop.org        http    GET     /version.xml    200                     ntop/5.0.2 host/
x86_64-2.6.32-279.5.2.el6.x86_64-linux-gnu distro/centos release/6.3 kernrlse/2.6.32-279.14.1.el6.x86_64 GCC/4.4.6 config() run(u;
W; a; F; d) gdbm/1.8.0 openssl/1.0.0-fips zlib/1.2.3 access/https interfaces(eth1)   application/xml 2803    1481268507
1481268507      1134337097              U       0.019   0.011   0.012   7       HTTP            131.114.21.22   0       00000000
00000000                        7       6       645     2158    0
       0       0       0       0.168   0.141   5
```

MySQL/Oracle Latency Analysis

- Same as for HTTP, DNS, DHCP, FTP… nProbe is also able to analyse applications protocols (when not used with encryption) and extract relevant metadata that is used to troubleshoot both network and coding issues.

```
#
# Client[ascii:32]      Server[ascii:32]        User[ascii:32]  Query[ascii:256]        ResponseCode[uint]
ResponseMsg[ascii:32]   Bytes[uint]     BeginTime       epoch[EndTime]  epoch[QueryDuration(sec)[uint]]
ClientLatency(ms)[uint] ServerLatency(ms)[uint]
#
10.96.4.141     10.96.4.28      root    SELECT msisdn FROM big_white_list WHERE authid = 459    1403    no
data found      6536    1481314177      1481314177      0.000   0.002   0.067
10.96.4.141     10.96.4.28      root    SELECT msisdn FROM big_white_list WHERE authid = 159    1403    no
data found      6527    1481314177      1481314177      0.001   0.000   0.002
10.96.4.141     10.96.4.28      root    SELECT msisdn FROM big_white_list WHERE authid = 759    1403    no
data found      6527    1481314177      1481314177      0.001   0.001   0.001
10.96.4.141     10.96.4.28      root    SELECT msisdn FROM big_white_list WHERE authid = 559    1403    no
data found      6527    1481314177      1481314177      0.001   0.000   0.001
```

Lua Scripting [1/2]

- During flow export, it is possible to instrument nProbe to execute some actions using Lua scripts.
- nProbe embeds a LuaJIT interpreter that executes a function when a flow is exported.
- Network administrators can use scripts to
  - Execute actions when specific flow values are observed (e.g. when a malware URL is reported).
  - Selectively prevent flow export (e.g. unidirectional flows)

Lua Scripting [2/2]

```
function checkFlow(label, flow, rule)
    for i = 1,#rule do
        local id = rule[i].id
        local filter = rule[i].filter

        local rsp = true -- be optimistic

      if(debug == true) then io.write("Checking rule "..id.."\n") end

      for j = 1,#filter do
       ….
     end


      if(debug == true) then io.write("Result for rule "..id.."="..tostring(rsp).."\n") end

      if(rsp == true) then
         execMatchCommand(label, flow, id, r)
      end
   end
end
```

Final Remarks

nProbe is a modern network probe:

- Flow generation and collection, 10 Gbit capable.
- Able to produce "rich" monitoring metrics (augmented flows).
- Extensible by means of plugins (SDK available).
- Scriptable using Lua.
- Available for Linux, Windows and embedded systems.
- BigData friendly (JSON export, Syslog, Kafka, ELK).
- Free for no-profit, research, and education.