SharkFest '18 US

sFlow: Theory and Practice of a Sampling Technology

and Its Analysis with Wireshark

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Outline

- What is sFlow? When is it useful and when it is not
- How does sFlow work? Agents, collectors, packets and sampling techniques
- Using Wireshark to master sFlow

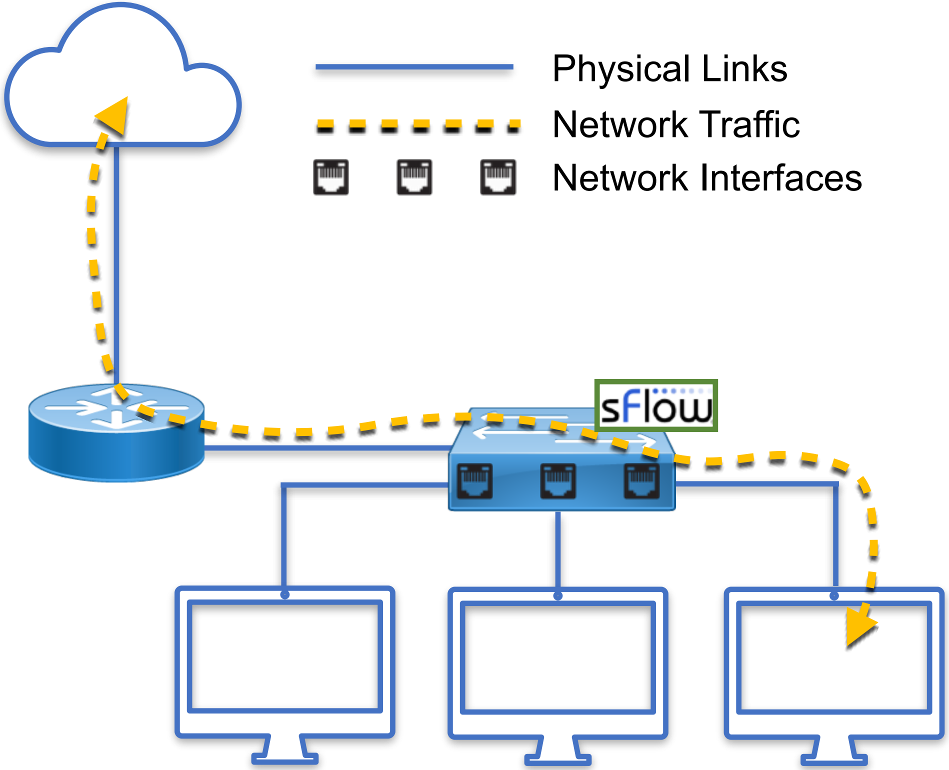
What is sFlow? [1/2]

- sFlow is a sampling technology designed to export
  - Network devices information (à la SNMP)
  - Packets traversing network devices (à la ERSPAN)

What is sFlow? [2/2]

- Network-wide visibility is obtained by means of configurable sampling
  - Counters samples
  - Flow samples
- Samples are periodically put in sFlow UDP datagrams and pushed over the network

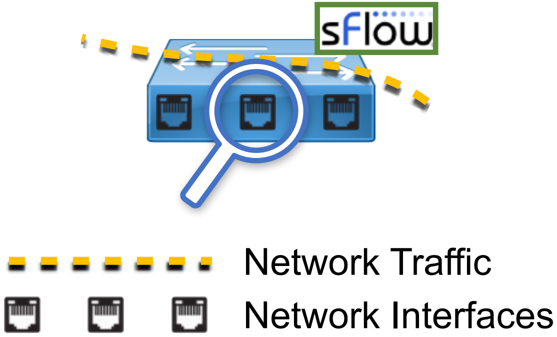
sFlow Visibility

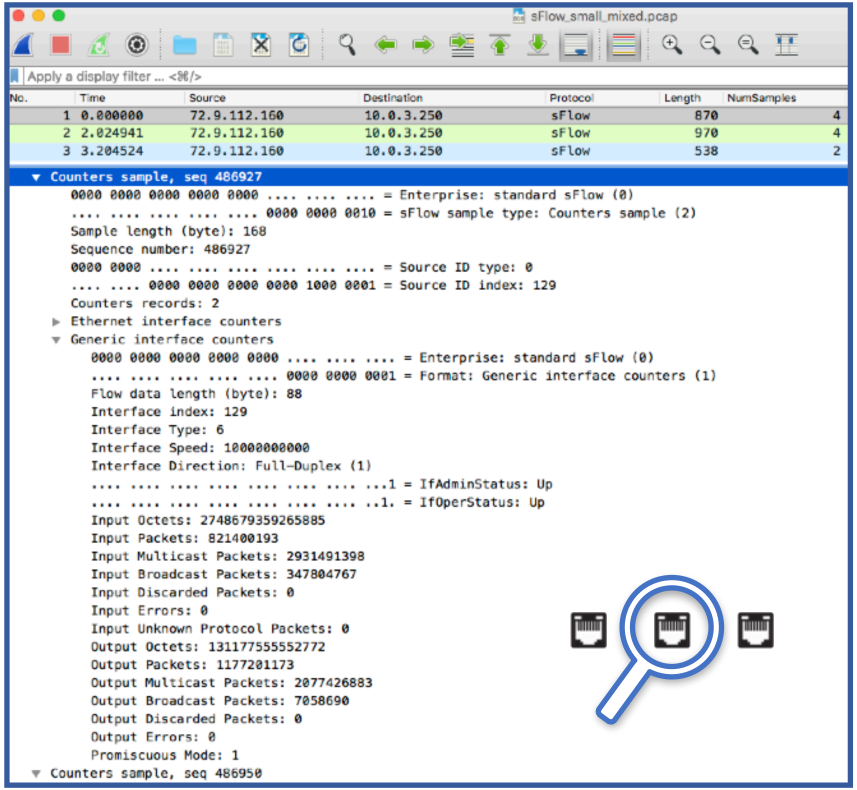


- Device visibility
  - Counter Samples
- Traffic visibility
  - Flow Samples

sFlow Counter Samples

- Interfaces status, speed, type
- Cumulative input and output bytes/packets, errors, ...



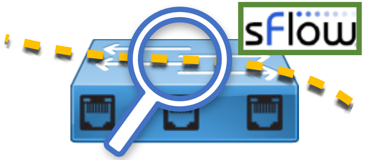


No.	Time	Source	Destination	Protocol	Length	NumSamples
1	0.000000	72.9.112.160	10.0.3.250	sFlow	870	4
2	2.024941	72.9.112.160	10.0.3.250	sFlow	970	4
3	3.204524	72.9.112.160	10.0.3.250	sFlow	538	2

```
▼ Counters sample, seq 486927
      0000 0000 0000 0000 0000 .... .... .... = Enterprise: standard sFlow (0)
      .... .... .... .... .... 0000 0000 0010 = sFlow sample type: Counters sample (2)
      Sample length (byte): 168
      Sequence number: 486927
      0000 0000 .... .... .... .... .... .... = Source ID type: 0
      .... .... 0000 0000 0000 0000 1000 0001 = Source ID index: 129
      Counters records: 2
    ▶ Ethernet interface counters
    ▼ Generic interface counters
        0000 0000 0000 0000 0000 .... .... .... = Enterprise: standard sFlow (0)
        .... .... .... .... .... 0000 0000 0001 = Format: Generic interface counters (1)
        Flow data length (byte): 88
        Interface index: 129
        Interface Type: 6
        Interface Speed: 10000000000
        Interface Direction: Full-Duplex (1)
        .... .... .... .... .... .... .... ...1 = IfAdminStatus: Up
        .... .... .... .... .... .... .... ..1. = IfOperStatus: Up
        Input Octets: 2748679359265885
        Input Packets: 821400193
        Input Multicast Packets: 2931491398
        Input Broadcast Packets: 347804767
        Input Discarded Packets: 0
        Input Errors: 0
        Input Unknown Protocol Packets: 0
        Output Octets: 1311775555552772
        Output Packets: 1177201173
        Output Multicast Packets: 2077426883
        Output Broadcast Packets: 7058690
        Output Discarded Packets: 0
        Output Errors: 0
        Promiscuous Mode: 1
▼ Counters sample, seq 486950
```

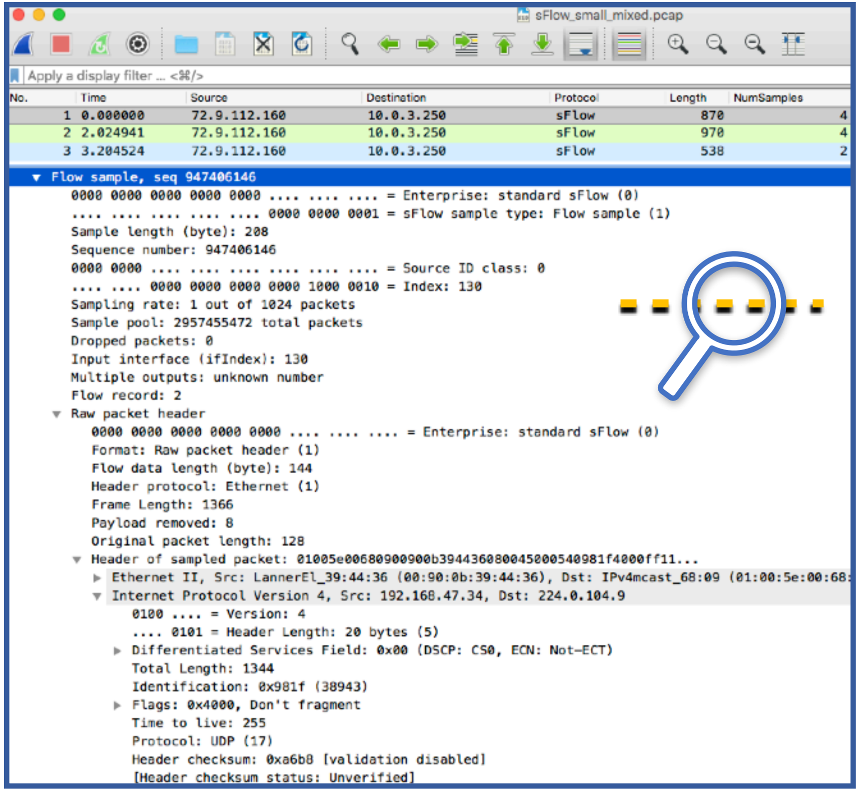
sFlow Flow Samples

- Random selection of a fraction of the packets observed



- - - - - - - Network Traffic

▨ ▨ ▨ Network Interfaces



```
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     1 0.000000   72.9.112.160    10.0.3.250     sFlow        870           4
     2 2.024941   72.9.112.160    10.0.3.250     sFlow        970           4
     3 3.204524   72.9.112.160    10.0.3.250     sFlow        538           2

▼ Flow sample, seq 947406146
      0000 0000 0000 0000 0000 .... .... .... = Enterprise: standard sFlow (0)
      .... .... .... .... .... 0000 0000 0001 = sFlow sample type: Flow sample (1)
      Sample length (byte): 208
      Sequence number: 947406146
      0000 0000 .... .... .... .... .... .... = Source ID class: 0
      .... .... 0000 0000 0000 0000 1000 0010 = Index: 130
      Sampling rate: 1 out of 1024 packets
      Sample pool: 2957455472 total packets
      Dropped packets: 0
      Input interface (ifIndex): 130
      Multiple outputs: unknown number
      Flow record: 2
    ▼ Raw packet header
        0000 0000 0000 0000 0000 .... .... .... = Enterprise: standard sFlow (0)
        Format: Raw packet header (1)
        Flow data length (byte): 144
        Header protocol: Ethernet (1)
        Frame Length: 1366
        Payload removed: 8
        Original packet length: 128
      ▼ Header of sampled packet: 01005e00680900900b394436080045000540981f4000ff11...
        ▶ Ethernet II, Src: LannerEl_39:44:36 (00:90:0b:39:44:36), Dst: IPv4mcast_68:09 (01:00:5e:00:68:
        ▼ Internet Protocol Version 4, Src: 192.168.47.34, Dst: 224.0.104.9
            0100 .... = Version: 4
            .... 0101 = Header Length: 20 bytes (5)
          ▶ Differentiated Services Field: 0x00 (DSCP: CS0, ECN: Not-ECT)
            Total Length: 1344
            Identification: 0x981f (38943)
          ▶ Flags: 0x4000, Don't fragment
            Time to live: 255
            Protocol: UDP (17)
            Header checksum: 0xa6b8 [validation disabled]
            [Header checksum status: Unverified]
```

When is sFlow Useful? [1/2]

- Network-wide estimations of top:
  - Layer-7 application protocols usage (e.g., HTTP, YouTube, Skype)
  - Sources
  - Destinations
  - Conversations
  - Ports
- Detect volumetric attacks

When is sFlow Useful? [2/2]

- Capacity planning
- Traffic engineering (eg., decide to establish a new peering, buy more bandwidth)
- Network topology adjustments (e.g., bring guys communicating the most onto the same link)
- Detect network issues (e.g, switches port status changes)
- Link congestion

When is sFlow NOT Useful? [1/2]

- Detect bottom-sources, -destinations, -ports, -Layer-7 application protocols, …
- Feed signature-based Intrusion Prevention/Intrusion Detection Systems (IDS/IPS)

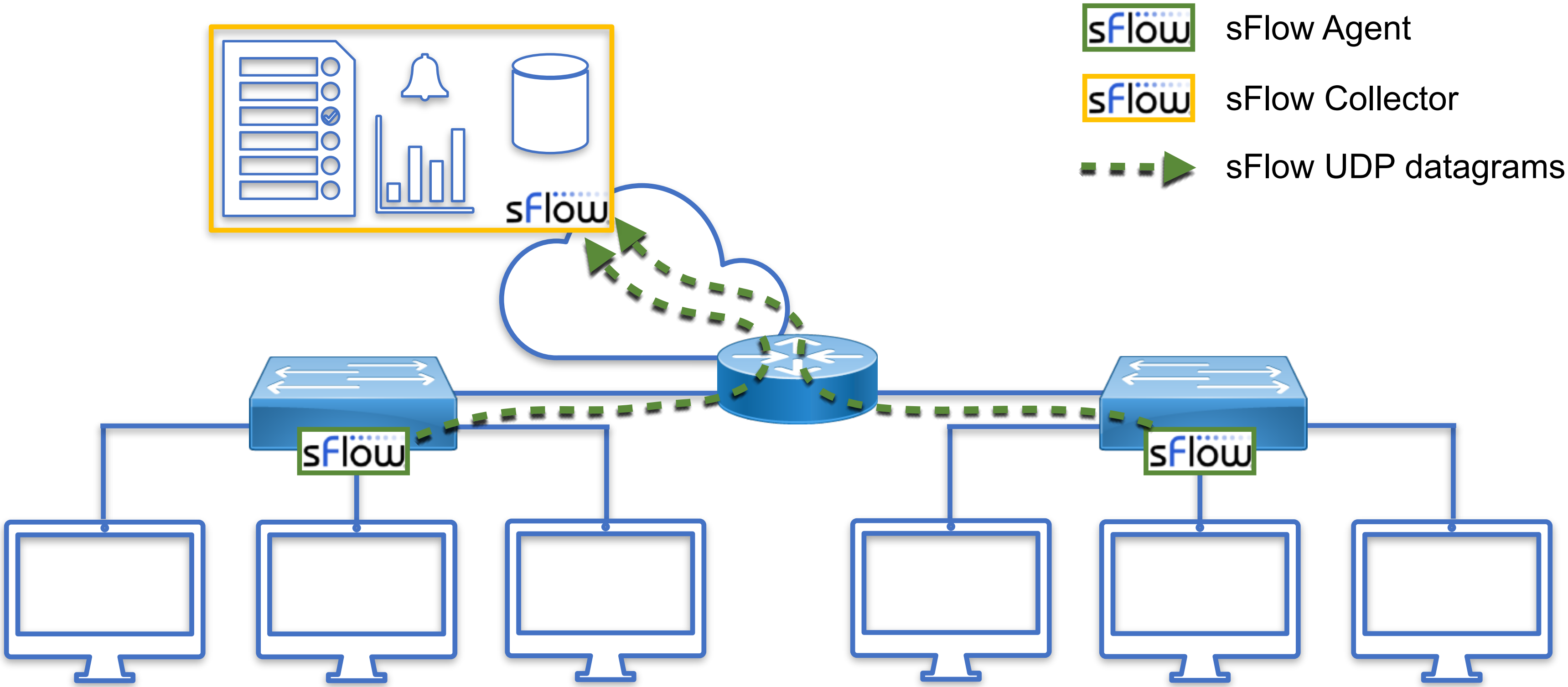
When is sFlow NOT Useful? [2/2]

- Stateful protocols analyses
  - No SEQ number analysis
- Sessions reconstruction
  - No TCP reassembly
- Detect Low-and-Slow network attacks
- Content-based network forensics
  - No extraction of files, images, documents

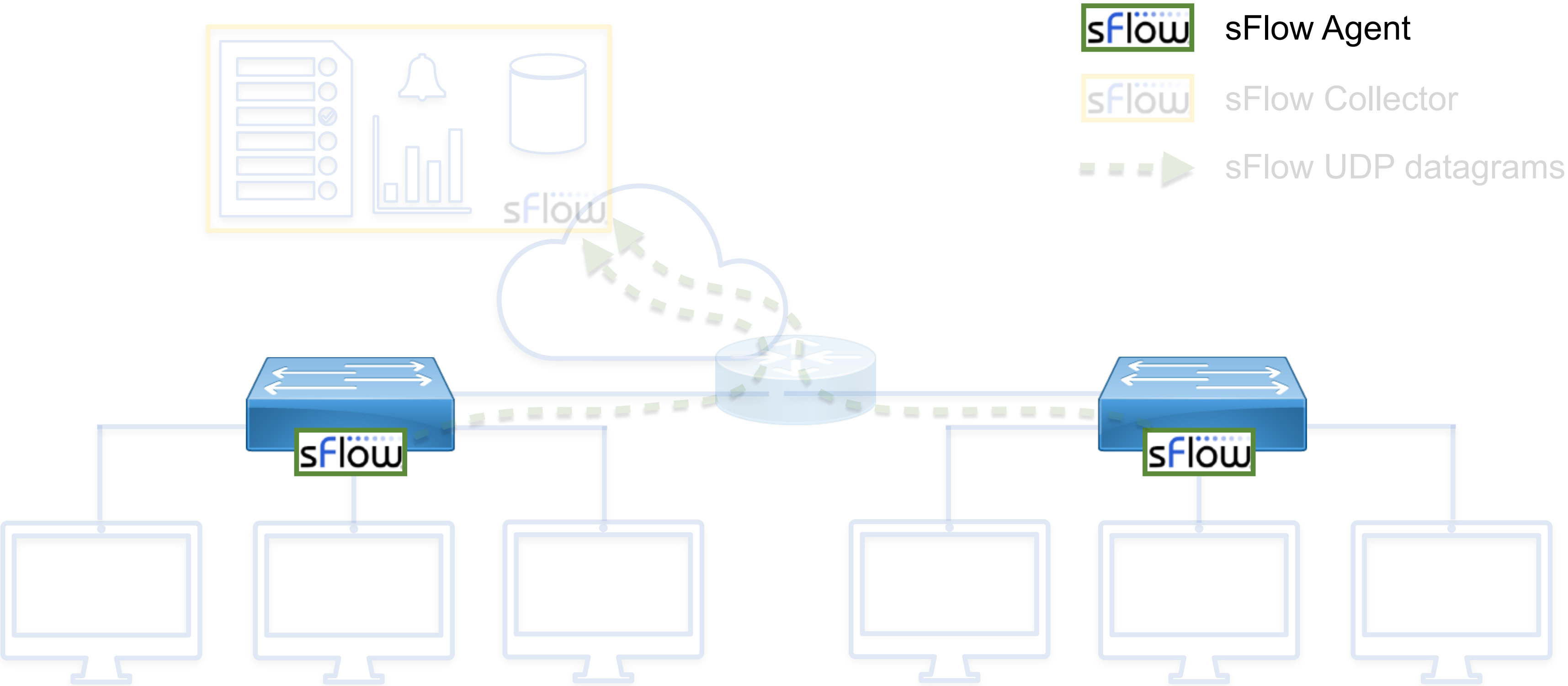
sFlow Monitoring Systems

- sFlow Agents
  - Embedded in switches
  - Marshal samples into UDP Datagrams to send them to one or more sFlow collectors
- sFlow Collectors
  - Receive UDP Datagrams from sFlow Agents
  - Process received data (e.g., to troubleshoot, create and store traffic time series, alert on unexpected traffic patterns)

sFlow Monitoring Systems



sFlow Monitoring Systems: Agents



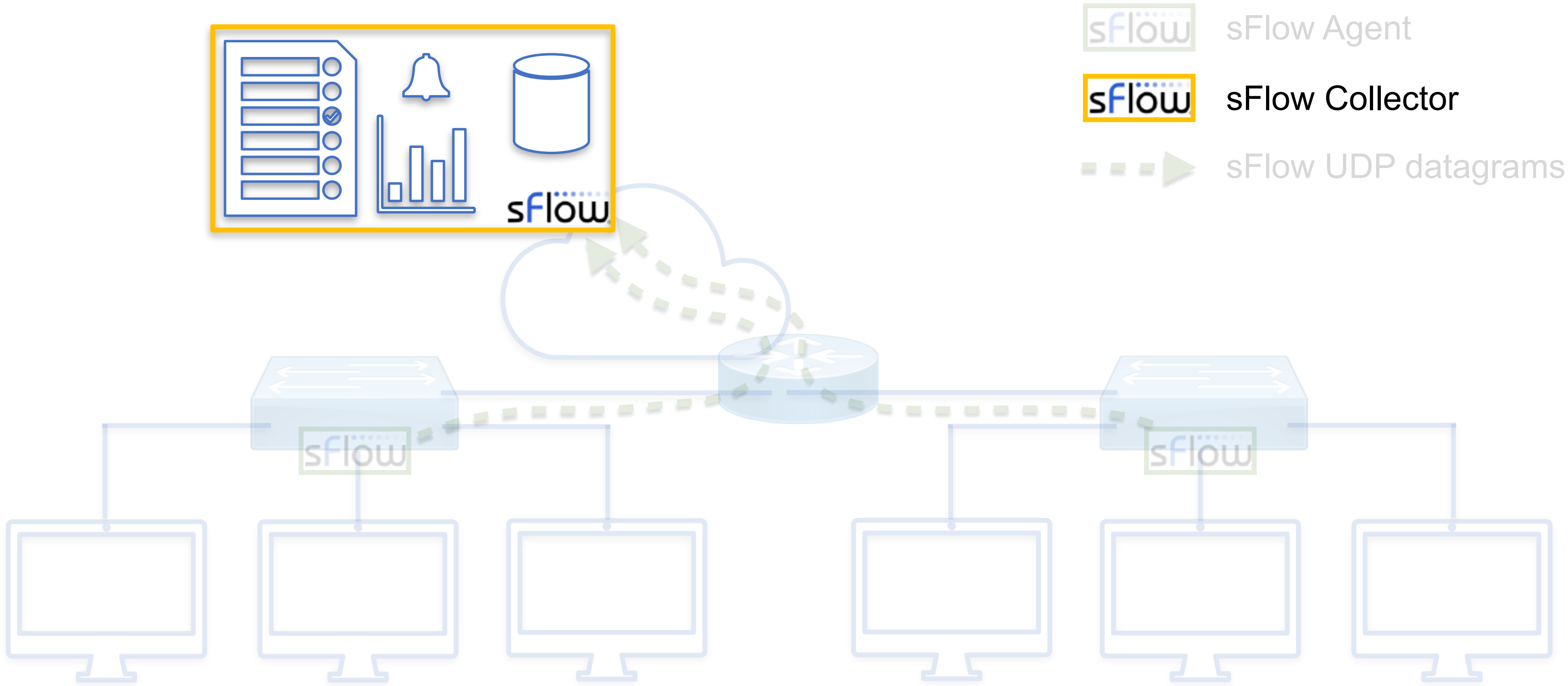
sFlow Embedded Agents

- Tens of manufacturers
  - A10, Aerohive, AlexaIA, ALUe, Allied Telesis, Arista, Aruba, Big Switch, Brocade, Cisco, Cumulus, DCN, Dell, D-Link, Edge-Core, Enterasys, Extreme, F5, Fortinet, HPE, Hitachi, Huawei, IBM, IP Infusion, Juniper, NEC, Netgear, OpenSwitch, Open vSwitch, Oracle, Pica8, Plexxi, Pluribus, Proxim, Quanta, Silicom, SMC, ZTE, and ZyXEL, etc.
- (Non-exhaustive) list maintained at https://sflow.org/products/network.php

sFlow Software Agents

- Host sFlow agent (https://github.com/sflow/host-sflow)
- OSes: AIX, FreeBSD, Linux, Solaris, and Windows
- Docker containers
- Hypervisors: Hyper-V, KVM/libvirt, Nutanix AHV and Xen hypervisors
- Supported switches, Arista EOS, Cumulus Linux, Dell OS10, OpenSwitch

sFlow Monitoring Systems: Collectors

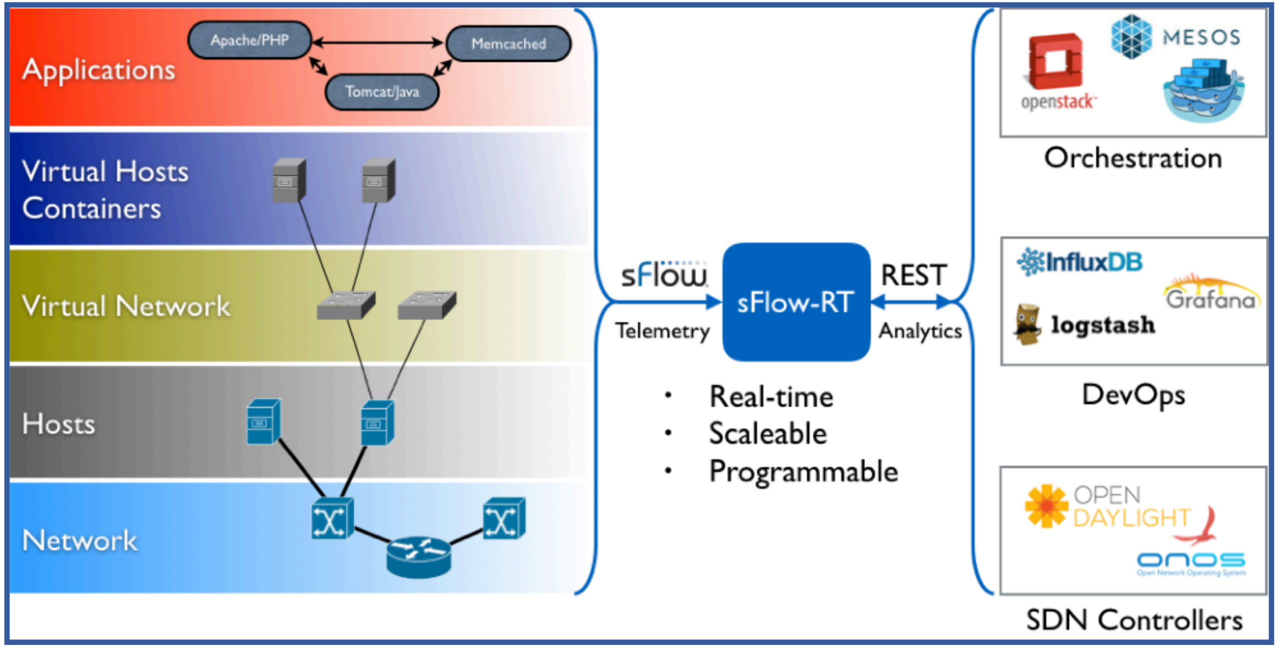


sFlow Collectors [1/4]

- sFlow Toolkit
  - Basic command line utilities (output to pcap, sFlow to NetFlow, txt)
- sFlowTrend/sFlowTrend-Pro
  - Graphical tool to generate live statistics network interfaces, top sources/destinations, top applications, …

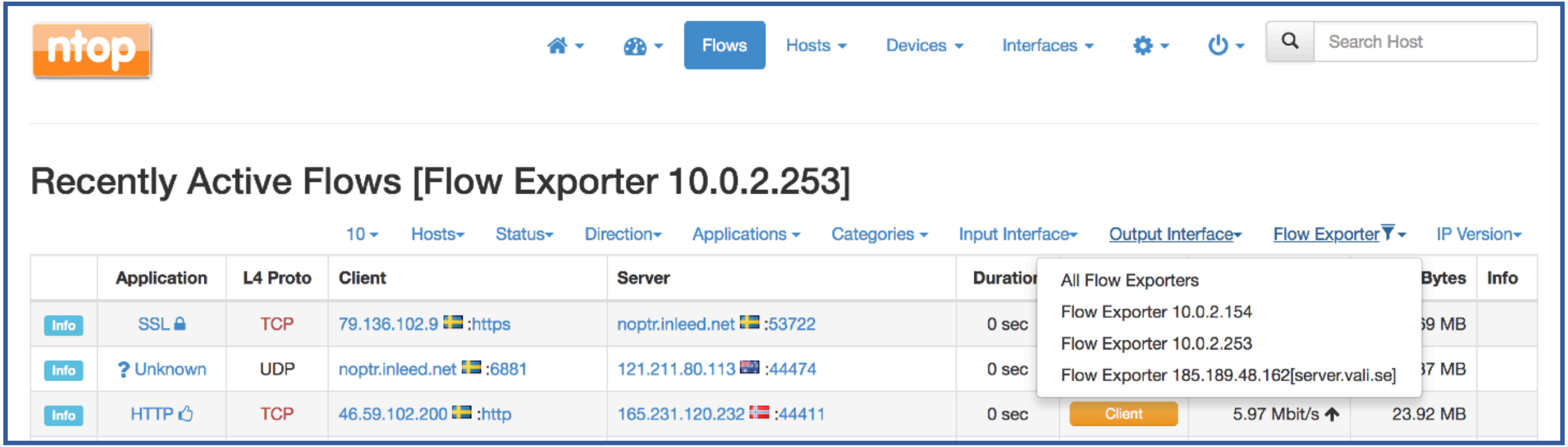
sFlow Collectors [2/4]

- sFlow-RT
  - Scriptable collector via REST/JavaScript
  - Retrieve metrics, set thresholds, receive notifications, …



sFlow Collectors [3/4]

- ntopng
  - Graphical tool to generate live and historical statistics on sources and destinations, network conversations (who talks to whom), and network interfaces
  - Facilitates the correlation of sources and destinations with the physical ports they are using



Recently Active Flows [Flow Exporter 10.0.2.253]

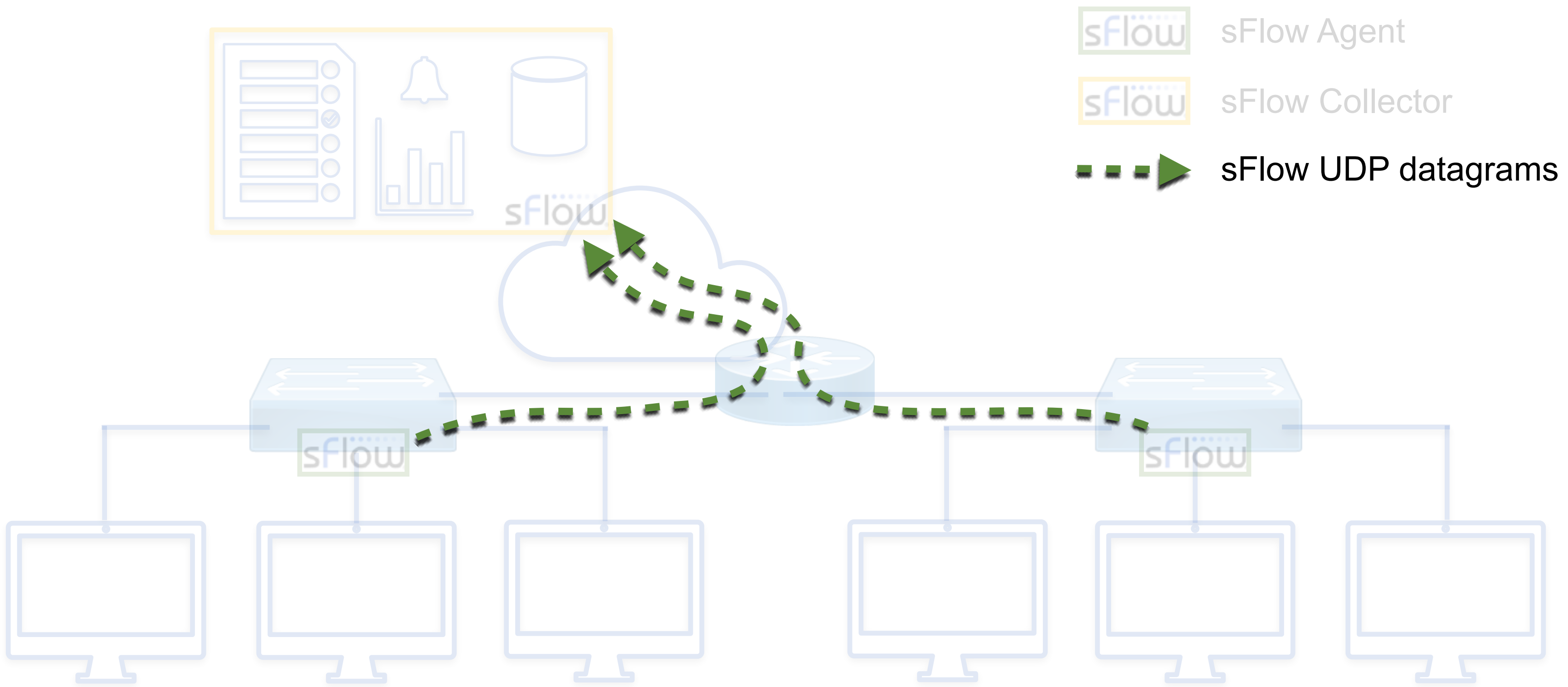
	Application	L4 Proto	Client	Server	Duratio			Bytes	Info
Info	SSL 🔒	TCP	79.136.102.9 :https	noptr.inleed.net :53722	0 sec			9 MB	
Info	? Unknown	UDP	noptr.inleed.net :6881	121.211.80.113 :44474	0 sec			7 MB	
Info	HTTP 👍	TCP	46.59.102.200 :http	165.231.120.232 :44411	0 sec	Client	5.97 Mbit/s ↑	23.92 MB	

All Flow Exporters
Flow Exporter 10.0.2.154
Flow Exporter 10.0.2.253
Flow Exporter 185.189.48.162[server.vali.se]

sFlow Collectors [4/4]

- Wireshark
  - Dissect sFlow traffic
  - Dissect packets in flow samples as if they were regular packets
  - Lua plugin to see aggregated information
- (Non-exhaustive) list available at https://sflow.org/products/collectors.php

sFlow Monitoring Systems: Transport



sFlow Transport

- sFlow works over UDP
    - Reduced memory and CPU wrt TCP
    - Robust in congested networks
        - Higher delays and lost packets increase but there is no need to buffer any data nor to wait for retransmissions
- sFlow packets are sequenced so the application can detect losses

sFlow⬆Push Architecture [1/2]

- sFlow UDP datagrams are periodically and unsolicitedly sent by each agent to one or more collectors
- Collectors don't need to discover new agents
- Reduced workload
    - Collectors don't have to generate reqs and match reqs/resps
    - Agents don't have to parse and process reqs

sFlow ⬆ Push Architecture [2/2]

- Increased security
  - Agents don't have to listen on open ports
  - Firewalls only have to allow mono-directional agent-to-collector communications
- Reduced latency
  - No need to establish connections

sFlow Sampling Processes

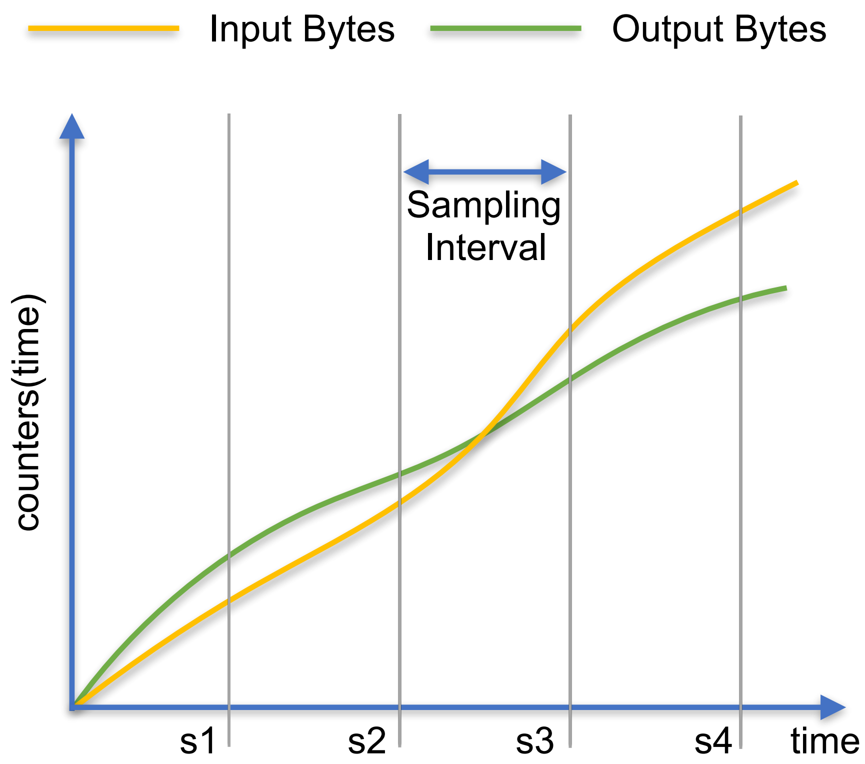
- Two different sampling processes in sFlow
- Counters Sampling
  - Produce Counter Samples

- Statistical Packets Sampling
  - Produce Flow Samples

sFlow Counters Sampling [1/3]

- Produce counter values for the Counter Samples
- Periodic sampling of network interfaces counters (e.g, input and output bytes and packets)
- sFlow agents are configured with a Sampling Interval
    - One sample every Sampling Interval

sFlow Counters Sampling [2/3]



- Δ = Sampling Interval
- sX = Xth counter sample
- s1 = counters(Δ)
- s2 = counters(2Δ)
- …
- sN = counters(NΔ)

sFlow Counters Sampling [3/3]

- Sampling Interval is intended to be the maximum time between two consecutive counter samples
- Counter samples may be taken opportunistically to "pad" other sFlow datagrams

sFlow Packets Sampling

- Produce packets for the Flow Samples
- Must ensure that any packet observed has an equal chance of being sampled
- Sampling rate is configurable

Sampling Accuracy

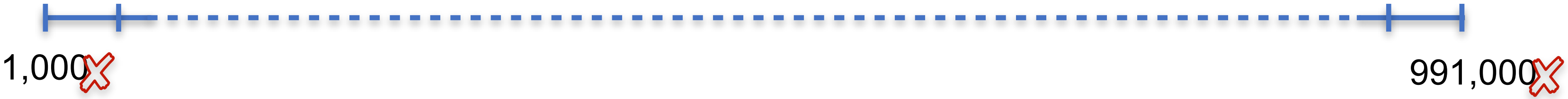
- Sampling, although unable to offer 100% exact results, are able to provide results with a statistically-quantifiable accuracy

An Example of Packets Sampling: HTTP

- 1,000,000 packets transit the network
- 10,000 packets are sampled at random (1%)
- 1,000 of the samples represent HTTP traffic

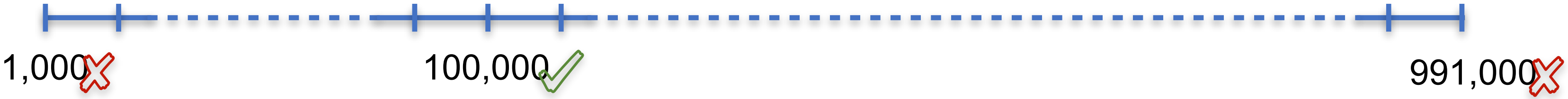
Estimating the Actual Number of HTTP Packets

- If 1,000 of the samples represent HTTP traffic, then how many of the original 1M packets were actually HTTP?
  - At least 1,000 (those that have been sampled)
  - At most 991,000 (990,000 unsampled + 1,000 HTTP samples)
  - ... but neither of these two values is at all likely...



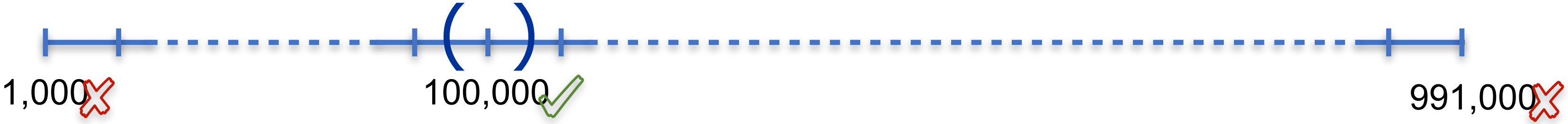
Best Estimate of the Actual Number of HTTP Packets

- It is most likely that the fraction of HTTP traffic is in the same ratio as its fraction of the samples
- 1,000 of the 10,000 samples, i.e., 10%
- This gives a value of 100,000 packets as the best estimate of the total number of HTTP packets



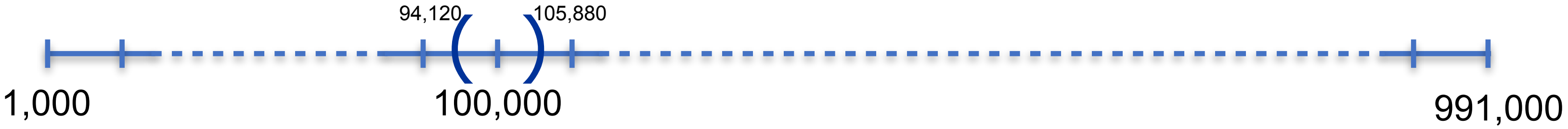
How Confident We can Be?

- Of course it is very unlikely that there were exactly 100,000 HTTP packets
- A small range of values can be specified that are very likely, say 95% likely, to contain the actual value



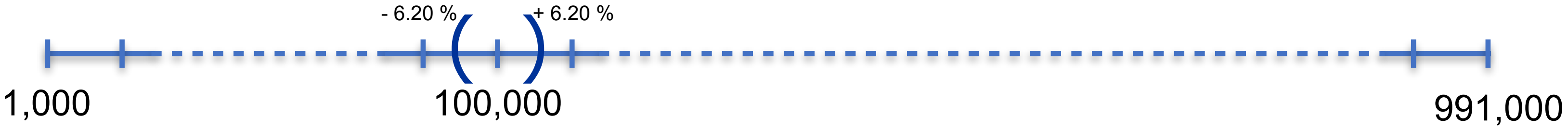
Calculating the Confidence

- Calculating the confidence boils down to estimating the variance of the best estimate (closed-form solution exists)
- We are 95% confident that the actual number of HTTP packets falls somewhere between 94,120 and 105,880

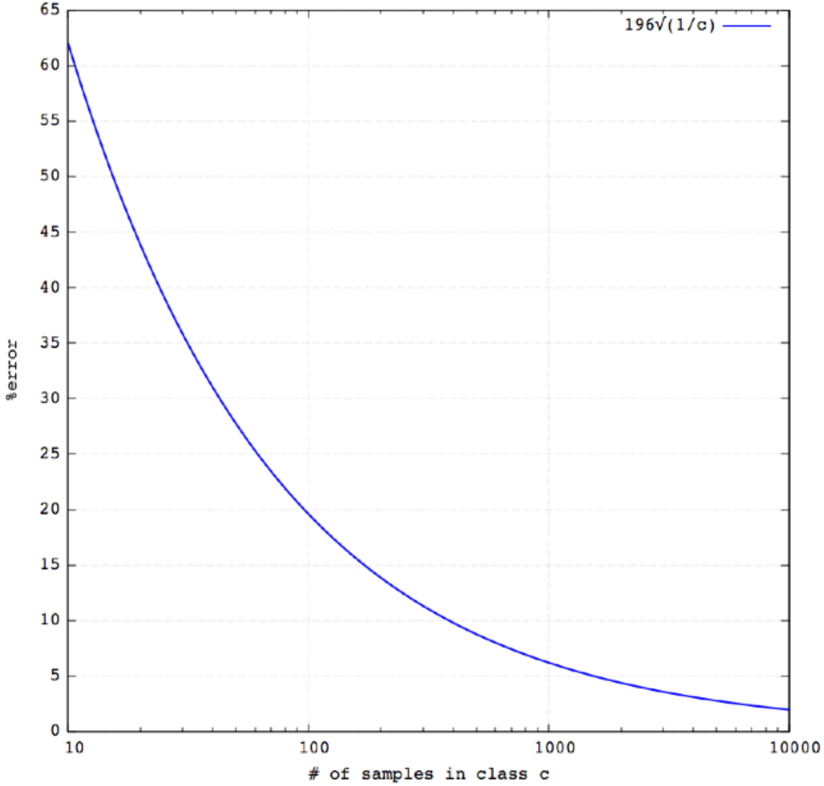


Confidence as a % [1/2]

- The confidence range calculated can also be expressed as a percentage of the best estimate
- One can say that the actual value is, with high probability, within a %error from the best estimate
- In other words the largest likely error is %error



Confidence as a % [2/2]



- Depends only on the number of samples c
- Independent from the total number of frames
- Same confidence:
  - 1,000 Pps sampling rate of 1%
  - 1,000,000 Pps sampling rate of 0,001%

sFlow vs Other Technologies

- Several other technologies have been developed over the years to provide network-wide visibility
  - Cisco NetFlow (v1, v5, v7, v8, v9)
  - IPFIX
  - SNMP (v1, v2c, v2c, v3)
  - RMON

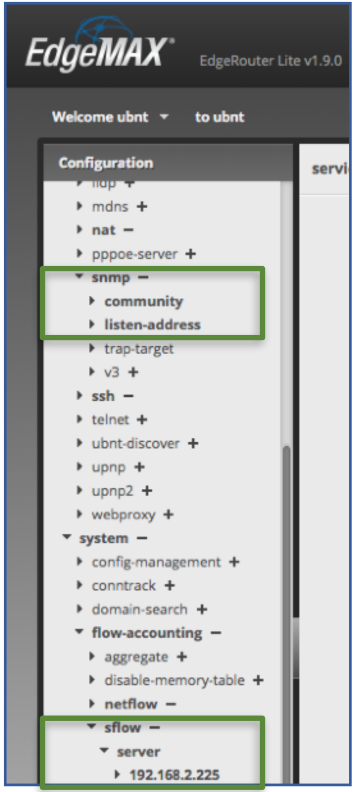
sFlow vs SNMP [1/2]

- SNMP provides what sFlow provides with counter samples but…
- … there is no concept of flow samples in SNMP
- With SNMP you can tell how much bandwidth is being used but…
- … you cannot tell who is using the bandwidth

sFlow vs SNMP [2/2]

	sFlow	SNMP
Transport	UDP	UDP
Architecture	⬆ PUSH	⬇ PULL
Device Visibility		
Traffic Visibility		

sFlow vs SNMP Traffic



EdgeMAX EdgeRouter Lite v1.9.0

Welcome ubnt to ubnt

Configuration

servi

```
  lldp +
  mdns +
  nat −
  pppoe-server +
  snmp −
    community
    listen-address
    trap-target
    v3 +
  ssh −
  telnet +
  ubnt-discover +
  upnp +
  upnp2 +
  webproxy +
system −
  config-management +
  conntrack +
  domain-search +
  flow-accounting −
    aggregate +
    disable-memory-table +
    netflow −
    sflow −
      server
        192.168.2.225
```

- Ubiquiti EdgeRouter Lite
- Configured with
  - sFlow
  - SNMP
- Assess the traffic required to have counters for one interface

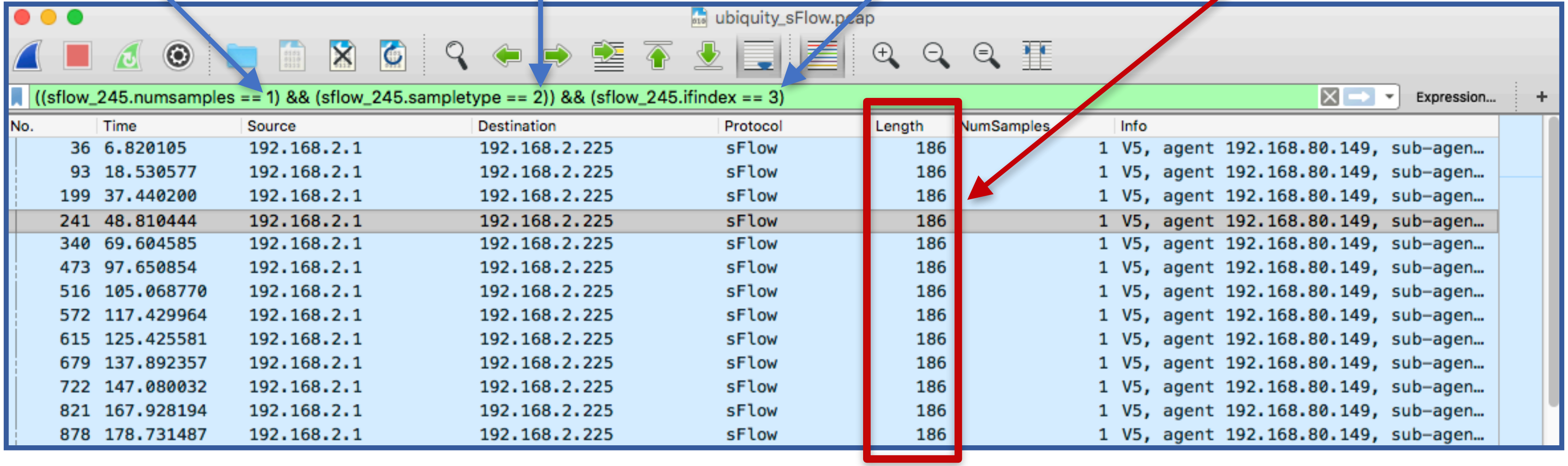
sFlow vs SNMP: sFlow Traffic

One sample per packet

Counter samples

Only for interface with id 3

186-Byte packets



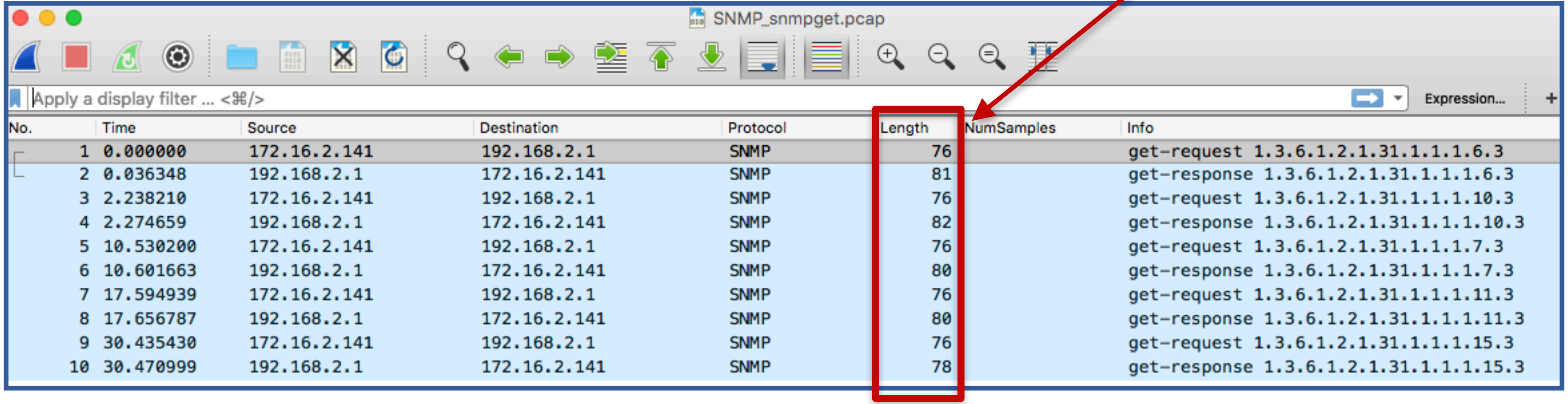
((sflow_245.numsamples == 1) && (sflow_245.sampletype == 2)) && (sflow_245.ifindex == 3)

No.	Time	Source	Destination	Protocol	Length	NumSamples	Info
36	6.820105	192.168.2.1	192.168.2.225	sFlow	186	1	V5, agent 192.168.80.149, sub-agen…
93	18.530577	192.168.2.1	192.168.2.225	sFlow	186	1	V5, agent 192.168.80.149, sub-agen…
199	37.440200	192.168.2.1	192.168.2.225	sFlow	186	1	V5, agent 192.168.80.149, sub-agen…
241	48.810444	192.168.2.1	192.168.2.225	sFlow	186	1	V5, agent 192.168.80.149, sub-agen…
340	69.604585	192.168.2.1	192.168.2.225	sFlow	186	1	V5, agent 192.168.80.149, sub-agen…
473	97.650854	192.168.2.1	192.168.2.225	sFlow	186	1	V5, agent 192.168.80.149, sub-agen…
516	105.068770	192.168.2.1	192.168.2.225	sFlow	186	1	V5, agent 192.168.80.149, sub-agen…
572	117.429964	192.168.2.1	192.168.2.225	sFlow	186	1	V5, agent 192.168.80.149, sub-agen…
615	125.425581	192.168.2.1	192.168.2.225	sFlow	186	1	V5, agent 192.168.80.149, sub-agen…
679	137.892357	192.168.2.1	192.168.2.225	sFlow	186	1	V5, agent 192.168.80.149, sub-agen…
722	147.080032	192.168.2.1	192.168.2.225	sFlow	186	1	V5, agent 192.168.80.149, sub-agen…
821	167.928194	192.168.2.1	192.168.2.225	sFlow	186	1	V5, agent 192.168.80.149, sub-agen…
878	178.731487	192.168.2.1	192.168.2.225	sFlow	186	1	V5, agent 192.168.80.149, sub-agen…

sFlow vs SNMP: SNMP Traffic

```
$ snmpget -v2c -cntop 192.168.2.1 ifHCInOctets.3
IF-MIB::ifHCInOctets.3 = Counter64: 57111598398
$ snmpget -v2c -cntop 192.168.2.1 ifHCOutOctets.3
IF-MIB::ifHCOutOctets.3 = Counter64: 1310307062699
$ snmpget -v2c -cntop 192.168.2.1 ifHCInUcastPkts.3
IF-MIB::ifHCInUcastPkts.3 = Counter64: 510083567
$ snmpget -v2c -cntop 192.168.2.1 ifHCOutUcastPkts.3
IF-MIB::ifHCOutUcastPkts.3 = Counter64: 921959741
$ snmpget -v2c -cntop 192.168.2.1 ifHighSpeed.3
IF-MIB::ifHighSpeed.3 = Gauge32: 1000
```

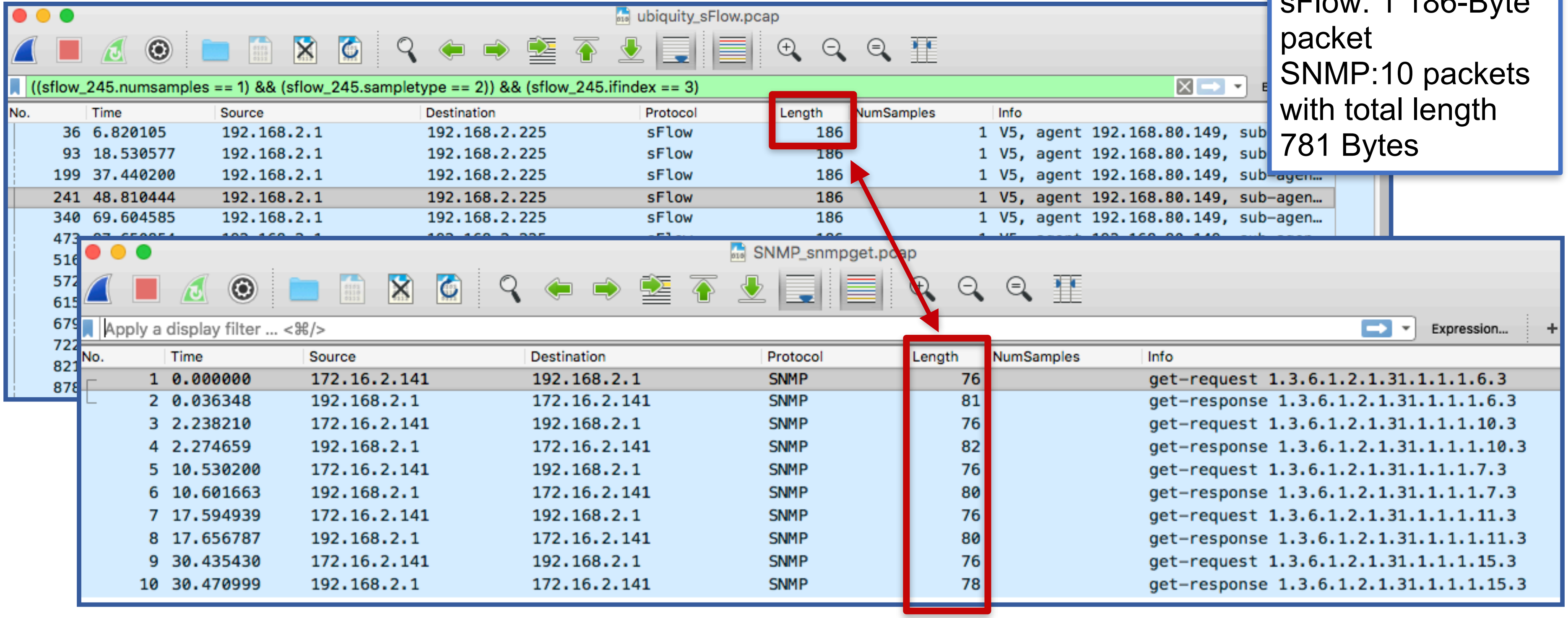
781 Bytes



No.	Time	Source	Destination	Protocol	Length	NumSamples	Info
1	0.000000	172.16.2.141	192.168.2.1	SNMP	76		get-request 1.3.6.1.2.1.31.1.1.1.6.3
2	0.036348	192.168.2.1	172.16.2.141	SNMP	81		get-response 1.3.6.1.2.1.31.1.1.1.6.3
3	2.238210	172.16.2.141	192.168.2.1	SNMP	76		get-request 1.3.6.1.2.1.31.1.1.1.10.3
4	2.274659	192.168.2.1	172.16.2.141	SNMP	82		get-response 1.3.6.1.2.1.31.1.1.1.10.3
5	10.530200	172.16.2.141	192.168.2.1	SNMP	76		get-request 1.3.6.1.2.1.31.1.1.1.7.3
6	10.601663	192.168.2.1	172.16.2.141	SNMP	80		get-response 1.3.6.1.2.1.31.1.1.1.7.3
7	17.594939	172.16.2.141	192.168.2.1	SNMP	76		get-request 1.3.6.1.2.1.31.1.1.1.11.3
8	17.656787	192.168.2.1	172.16.2.141	SNMP	80		get-response 1.3.6.1.2.1.31.1.1.1.11.3
9	30.435430	172.16.2.141	192.168.2.1	SNMP	76		get-request 1.3.6.1.2.1.31.1.1.1.15.3
10	30.470999	192.168.2.1	172.16.2.141	SNMP	78		get-response 1.3.6.1.2.1.31.1.1.1.15.3

sFlow vs SNMP: sFlow Traffic

sFlow: 1 186-Byte packet
SNMP:10 packets with total length 781 Bytes



ubiquity_sFlow.pcap

```
((sflow_245.numsamples == 1) && (sflow_245.sampletype == 2)) && (sflow_245.ifindex == 3)
```

No.	Time	Source	Destination	Protocol	Length	NumSamples	Info
36	6.820105	192.168.2.1	192.168.2.225	sFlow	186	1	V5, agent 192.168.80.149, sub
93	18.530577	192.168.2.1	192.168.2.225	sFlow	186	1	V5, agent 192.168.80.149, sub
199	37.440200	192.168.2.1	192.168.2.225	sFlow	186	1	V5, agent 192.168.80.149, sub-agen…
241	48.810444	192.168.2.1	192.168.2.225	sFlow	186	1	V5, agent 192.168.80.149, sub-agen…
340	69.604585	192.168.2.1	192.168.2.225	sFlow	186	1	V5, agent 192.168.80.149, sub-agen…
473							
516							
572							
615							
679							
722							
821							
878							

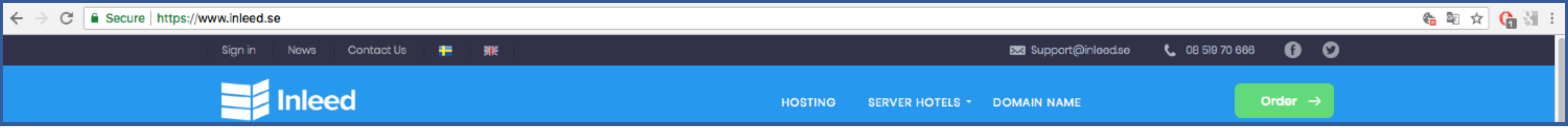
SNMP_snmpget.pcap

No.	Time	Source	Destination	Protocol	Length	NumSamples	Info
1	0.000000	172.16.2.141	192.168.2.1	SNMP	76		get-request 1.3.6.1.2.1.31.1.1.1.6.3
2	0.036348	192.168.2.1	172.16.2.141	SNMP	81		get-response 1.3.6.1.2.1.31.1.1.1.6.3
3	2.238210	172.16.2.141	192.168.2.1	SNMP	76		get-request 1.3.6.1.2.1.31.1.1.1.10.3
4	2.274659	192.168.2.1	172.16.2.141	SNMP	82		get-response 1.3.6.1.2.1.31.1.1.1.10.3
5	10.530200	172.16.2.141	192.168.2.1	SNMP	76		get-request 1.3.6.1.2.1.31.1.1.1.7.3
6	10.601663	192.168.2.1	172.16.2.141	SNMP	80		get-response 1.3.6.1.2.1.31.1.1.1.7.3
7	17.594939	172.16.2.141	192.168.2.1	SNMP	76		get-request 1.3.6.1.2.1.31.1.1.1.11.3
8	17.656787	192.168.2.1	172.16.2.141	SNMP	80		get-response 1.3.6.1.2.1.31.1.1.1.11.3
9	30.435430	172.16.2.141	192.168.2.1	SNMP	76		get-request 1.3.6.1.2.1.31.1.1.1.15.3
10	30.470999	192.168.2.1	172.16.2.141	SNMP	78		get-response 1.3.6.1.2.1.31.1.1.1.15.3

sFlow, Wireshark and ntop

- Wireshark can be used with sFlow traffic to
  - Dissect sFlow packets
  - Dissect packets in sFlow flow samples
- Using the a Lua plugin by ntop Wireshark can be used also as an sFlow collector

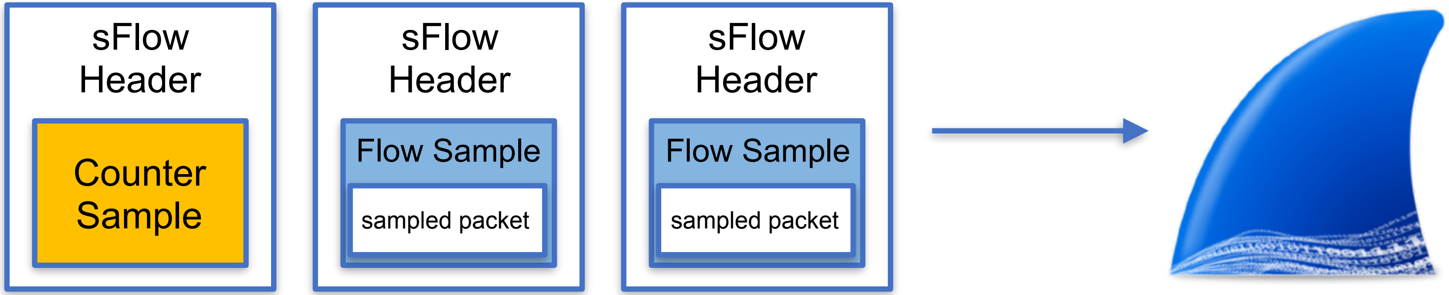
DEMOs



- Live sFlow traffic courtesy of our friend Jens Olsson at hosting provider Inleed
- Three switches generating sFlow that we will get via SSH

DEMO #1: Wireshark + sFlow Traffic [1/2]

- A closer look at sFlow traffic with Wireshark



sFlow Header

Counter Sample

sFlow Header

Flow Sample

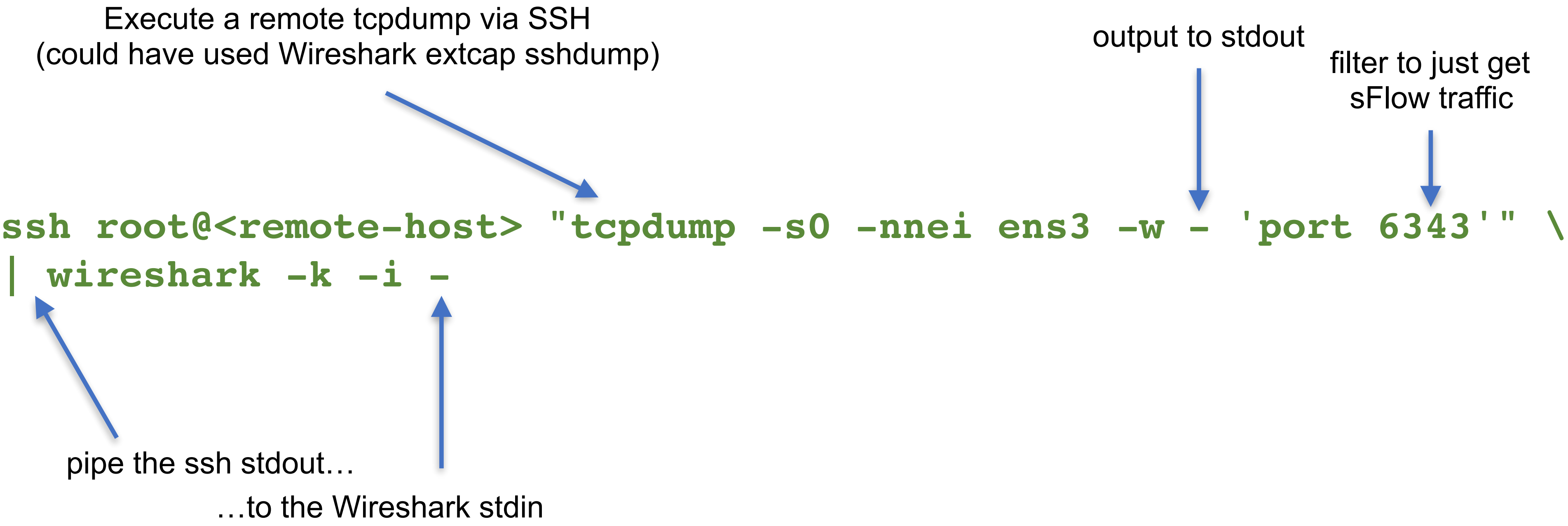
sampled packet

sFlow Header

Flow Sample

sampled packet

DEMO #1:
Wireshark + sFlow Traffic [2/2]



Execute a remote tcpdump via SSH
(could have used Wireshark extcap sshdump)

output to stdout

filter to just get
sFlow traffic

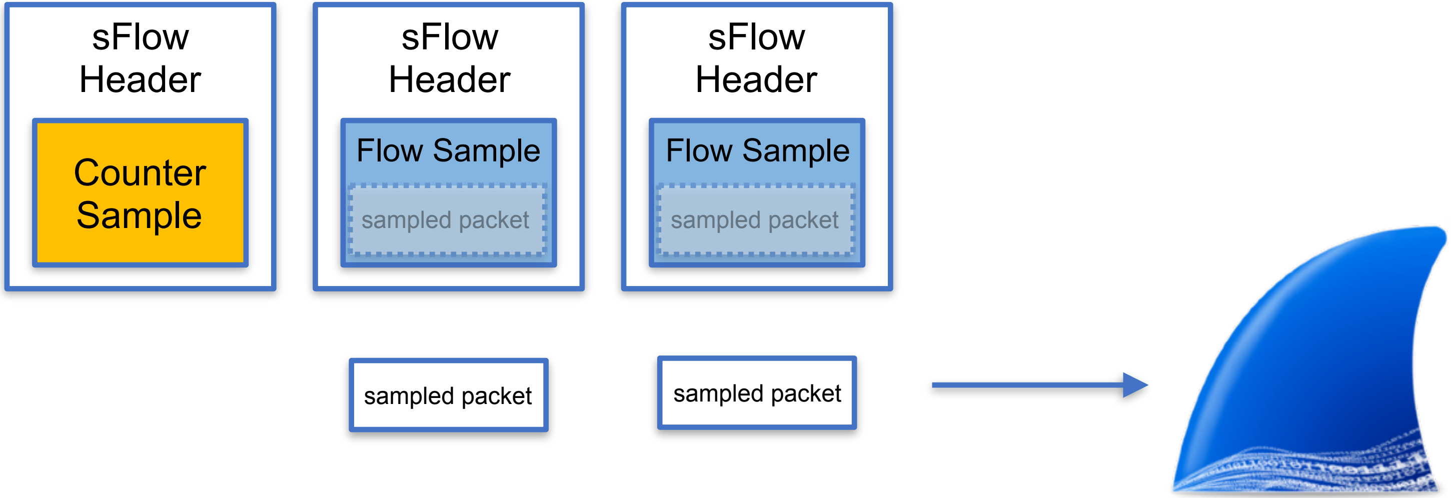
```
ssh root@<remote-host> "tcpdump -s0 -nnei ens3 -w - 'port 6343'" \
| wireshark -k -i -
```

pipe the ssh stdout…

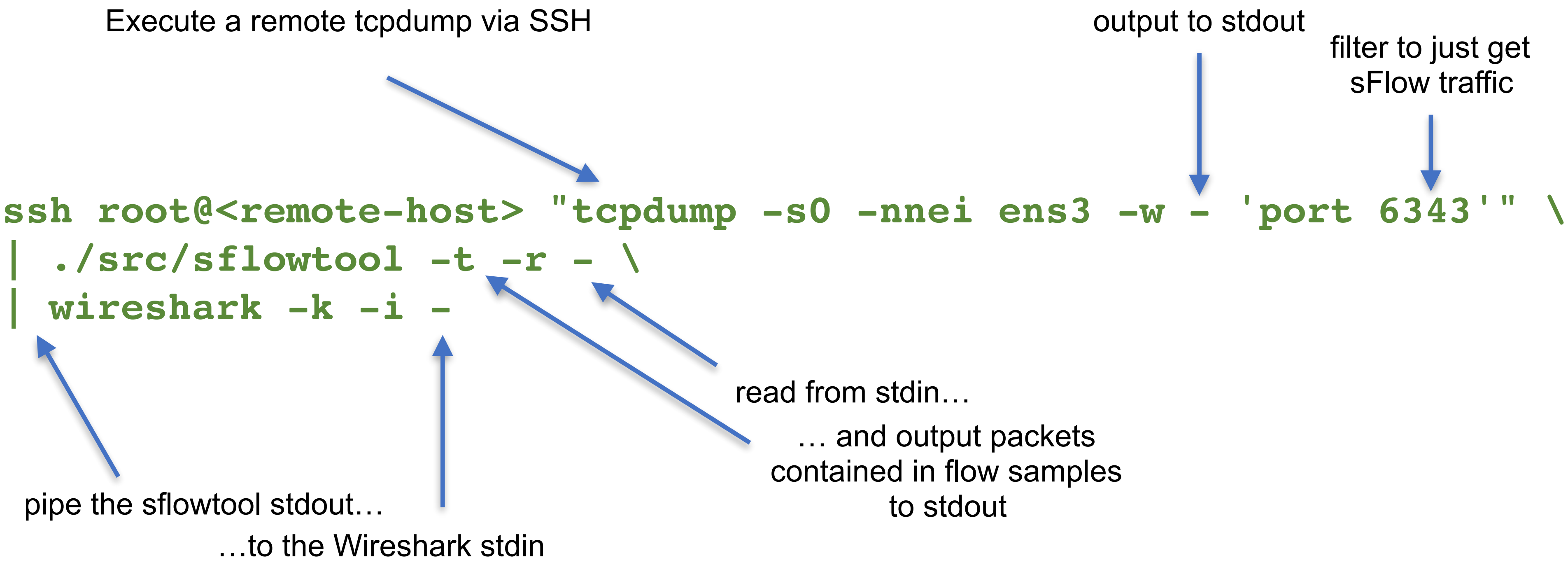
…to the Wireshark stdin

DEMO #2:
Wireshark + sFlow Sampled Packets [1/2]

- sflowtool required to extract packets
  https://github.com/sflow/sflowtool.git



DEMO #2: Wireshark + sFlow Sampled Packets [2/2]



```
ssh root@<remote-host> "tcpdump -s0 -nnei ens3 -w - 'port 6343'" \
| ./src/sflowtool -t -r - \
| wireshark -k -i -
```

Execute a remote tcpdump via SSH

output to stdout

filter to just get sFlow traffic

read from stdin…

… and output packets contained in flow samples to stdout

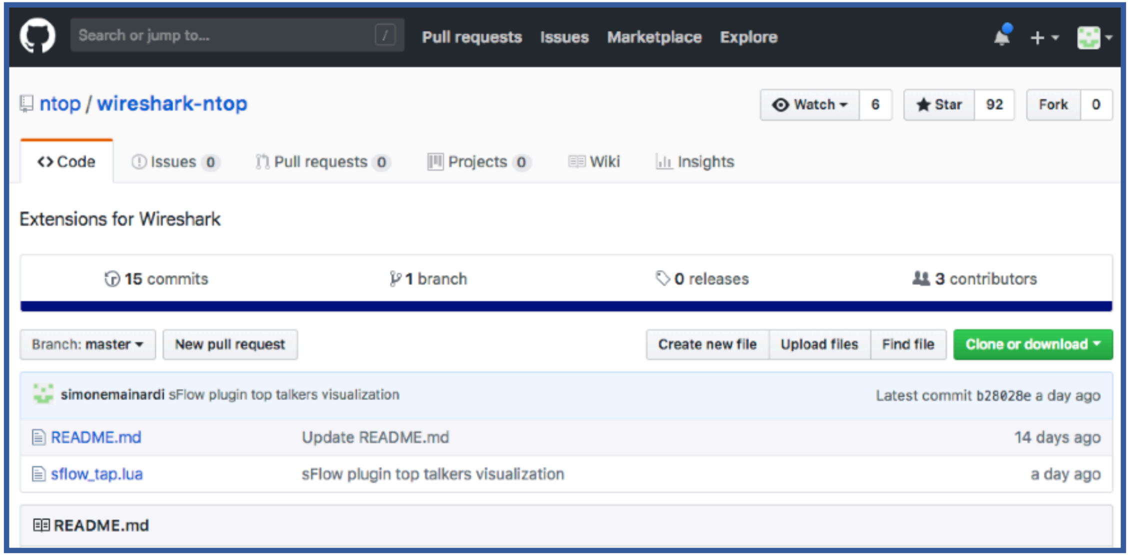
pipe the sflowtool stdout…

…to the Wireshark stdin

DEMO #3: Wireshark as an sFlow Collector [1/2]

Fork me on GitHub

- Lua plugin sflow_tap.lua is available at https://github.com/ntop/wireshark-ntop



Extensions for Wireshark

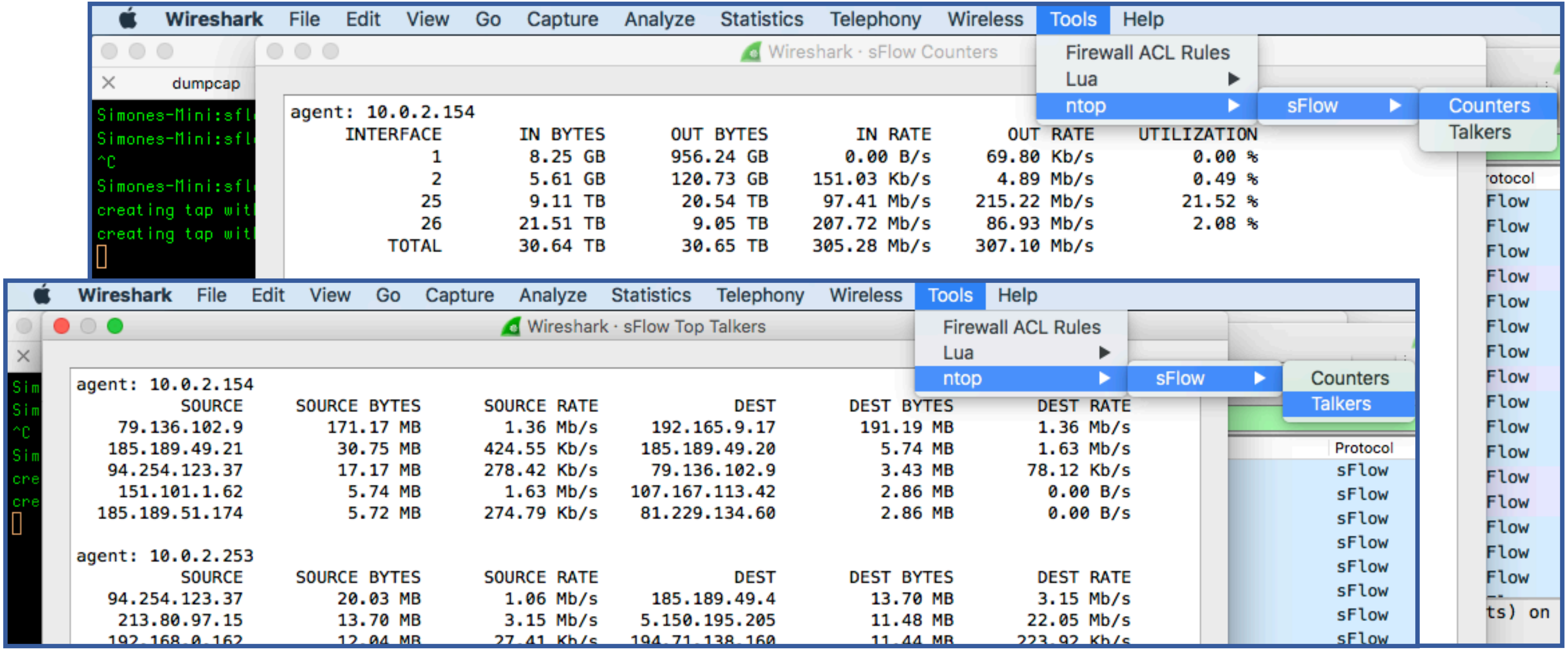
15 commits · 1 branch · 0 releases · 3 contributors

simonemainardi sFlow plugin top talkers visualization — Latest commit b28028e a day ago

README.md	Update README.md	14 days ago
sflow_tap.lua	sFlow plugin top talkers visualization	a day ago

README.md

DEMO #3:
Wireshark as an sFlow Collector [2/2]



```
Simones-Mini:sfl
Simones-Mini:sfl
^C
Simones-Mini:sfl
creating tap wit
creating tap wit
```

```
agent: 10.0.2.154
     INTERFACE         IN BYTES      OUT BYTES        IN RATE       OUT RATE   UTILIZATION
             1          8.25 GB      956.24 GB       0.00 B/s     69.80 Kb/s        0.00 %
             2          5.61 GB      120.73 GB    151.03 Kb/s      4.89 Mb/s        0.49 %
            25          9.11 TB       20.54 TB     97.41 Mb/s    215.22 Mb/s       21.52 %
            26         21.51 TB        9.05 TB    207.72 Mb/s     86.93 Mb/s        2.08 %
         TOTAL         30.64 TB       30.65 TB    305.28 Mb/s    307.10 Mb/s
```

```
agent: 10.0.2.154
           SOURCE    SOURCE BYTES     SOURCE RATE             DEST    DEST BYTES     DEST RATE
    79.136.102.9       171.17 MB       1.36 Mb/s     192.165.9.17     191.19 MB     1.36 Mb/s
   185.189.49.21        30.75 MB     424.55 Kb/s    185.189.49.20       5.74 MB     1.63 Mb/s
   94.254.123.37        17.17 MB     278.42 Kb/s     79.136.102.9       3.43 MB    78.12 Kb/s
    151.101.1.62         5.74 MB       1.63 Mb/s   107.167.113.42       2.86 MB      0.00 B/s
  185.189.51.174         5.72 MB     274.79 Kb/s    81.229.134.60       2.86 MB      0.00 B/s

agent: 10.0.2.253
           SOURCE    SOURCE BYTES     SOURCE RATE             DEST    DEST BYTES     DEST RATE
   94.254.123.37        20.03 MB       1.06 Mb/s     185.189.49.4      13.70 MB     3.15 Mb/s
    213.80.97.15        13.70 MB       3.15 Mb/s    5.150.195.205      11.48 MB    22.05 Mb/s
   192.168.0.162        12.04 MB      27.41 Kb/s   194.71.138.160      11.44 MB   223.92 Kb/s
```

```
Sim
Sim
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```

Take-Home

- sFlow is a pretty lightweight technology to have an overall view of your network devices and the traffic they are handling
  - Is this device overloaded? Who's consuming all this bandwidth?
- Wireshark is suitable not only to dissect and inspect sFlow packets but also to provide devices interfaces status and top talkers information!
  - sflow_tap.lua plugin available at: https://github.com/ntop/wireshark-ntop
- Contact me: mainardi@ntop.org / @simonemainardi

Appendix

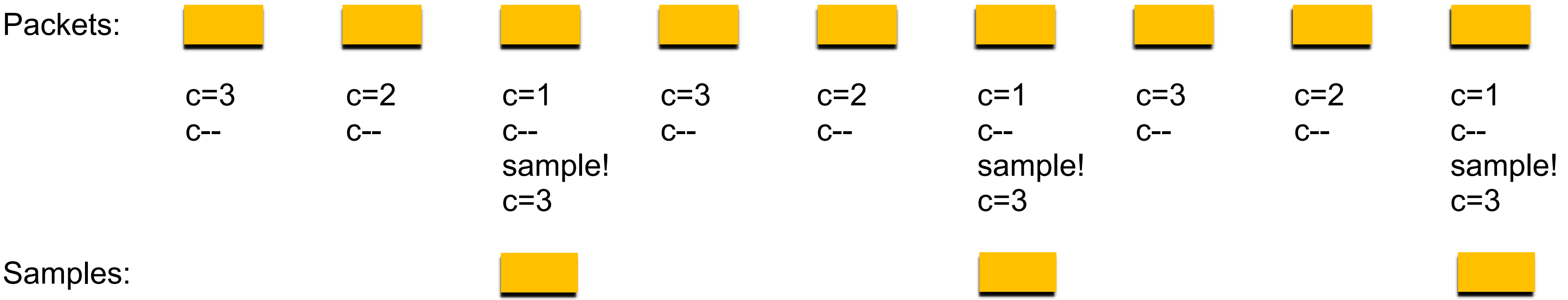
- Effects of lost sFlow packets
- Packet Sampling:
  - Strategies
  - Formulas
  - Statistical Background
- Demonstration screenshots

Effects of Lost sFlow Packets

- Lost counter samples
  - Values are cumulative, new (updated) values will be sent in the next sample
  - Almost impossible to miss the detection of a counter wrap (64-bit counters)
- Lost flow samples
  - Changes in the actual sampling rate

Packets Sampling Strategies [1/2]

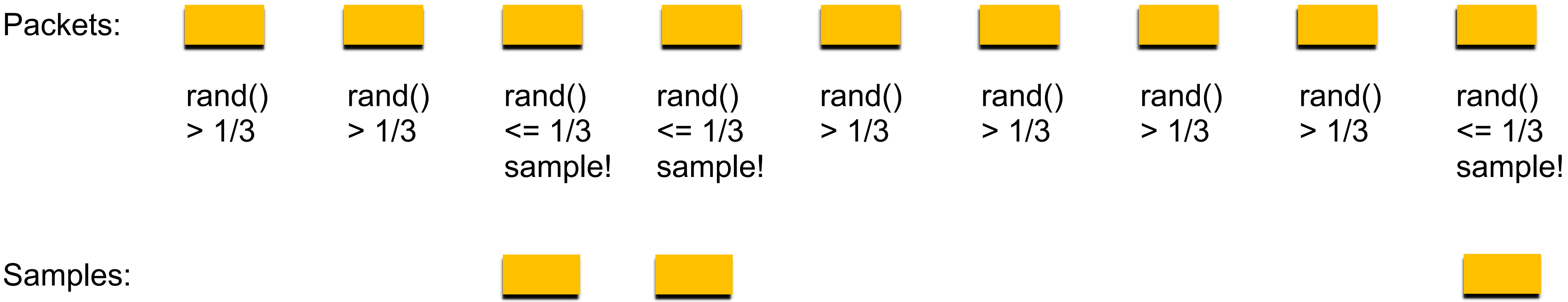
- One packet in N is sampled
  - Initialize a counter to N
  - Decrement the counter with each packet
  - Sample the packet when the counter reaches 0
- Example with N=3



Packets:	🟨	🟨	🟨	🟨	🟨	🟨	🟨	🟨	🟨
	c=3 c--	c=2 c--	c=1 c-- sample! c=3	c=3 c--	c=2 c--	c=1 c-- sample! c=3	c=3 c--	c=2 c--	c=1 c-- sample! c=3
Samples:			🟨			🟨			🟨

sFlow Packets Sampling [2/2]

- One packet in N (on average) is sampled
    - Draw a random number 0 <= r <= 1
    - Sample if r <= 1/N
- Synchronization with periodic traffic patterns is prevented with randomness
- Example with N=3, rand() = random [0,1] number generator



Packets:

rand() > 1/3

rand() > 1/3

rand() <= 1/3 sample!

rand() <= 1/3 sample!

rand() > 1/3

rand() > 1/3

rand() > 1/3

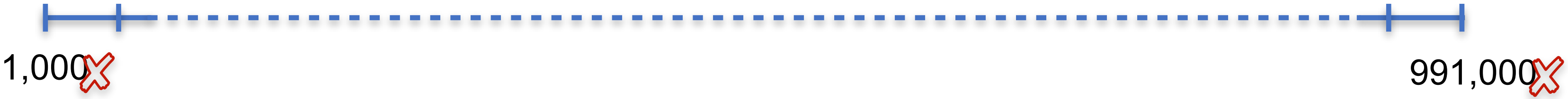
rand() > 1/3

rand() <= 1/3 sample!

Samples:

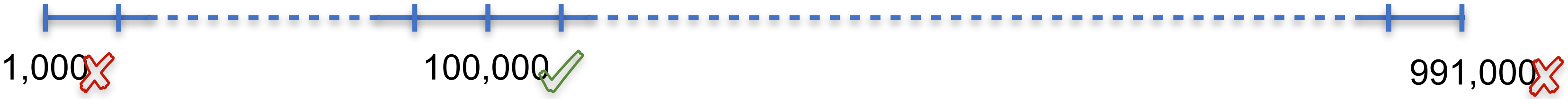
Estimating the Actual Number of HTTP Packets

- If 1,000 of the samples represent HTTP traffic, then how many of the original 1M packets were actually HTTP?
  - At least 1,000 (those that have been sampled)
  - At most 991,000 (990,000 unsampled + 1,000 HTTP samples)
  - ... but neither of these two values is at all likely...



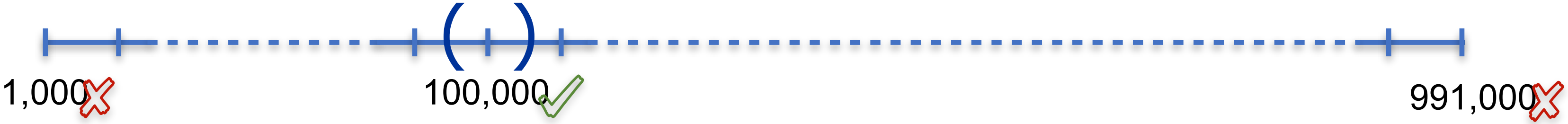
Best Estimate of the Actual Number of HTTP Packets

- It is most likely that the fraction of HTTP traffic is in the same ratio as its fraction of the samples
- 1,000 of the 10,000 samples, i.e., 10%
- This gives a value of 100,000 packets as the best estimate of the total number of HTTP packets



How Confident We can Be?

- Of course it is very unlikely that there were exactly 100,000 HTTP packets
- A small range of values can be specified that are very likely, say 95% likely, to contain the actual value



Calculating the Confidence [1/3]

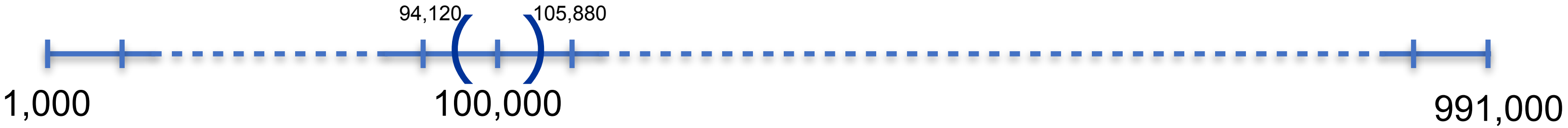
- Calculating the confidence boils down to estimating the variance of the best estimate

Calculating the Confidence [2/3]

- $N = 1{,}000{,}000$ packets transited
- $n = 10{,}000$ packets sampled
- $c = 1{,}000$ HTTP samples
- $N_c = 100{,}000$ = best estimate $= c / n * N$
- The variance of the best estimate N_c is
  $\sigma^2 = N^2 * c * (1 - c / n) * 1 / (n * (n - 1)))$
  $= 9{,}000{,}000$

Calculating the Confidence [3/3]

- The 95% confidence is within 1.96 standard deviations from the best estimate $[N_c - 1.96\sigma; N_c + 1.96\sigma]$
- In the HTTP example
  - $\sigma^2 = 9{,}000{,}000$
  - $\sigma = 3{,}000$
  - [100,000 - 1.96 * 3000, 100,00 + 1.96 * 3000] = [94,120; 105,880]
- We are 95% confident that the actual number of HTTP packets falls somewhere between 94,120 and 105,880

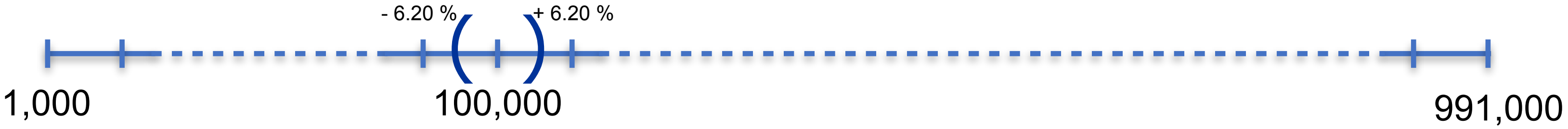


Confidence as a % [1/3]

- The confidence range calculated can also be expressed as a percentage of the best estimate
- One can say that the actual value is, with high probability, within a %error from the best estimate
- In other words the largest likely error is %error

Confidence as a % [2/3]

- The estimate of the percentage error %error
  %error = √(1 / c)
- In the HTTP example
  - %error = 196 * √(1 / c)
    = 196 * √(1 / 1,000)
    = 6.20 %
- The largest likely error is 6.20 %
- Note: %error formula given is an approximation and only works well when n >> c

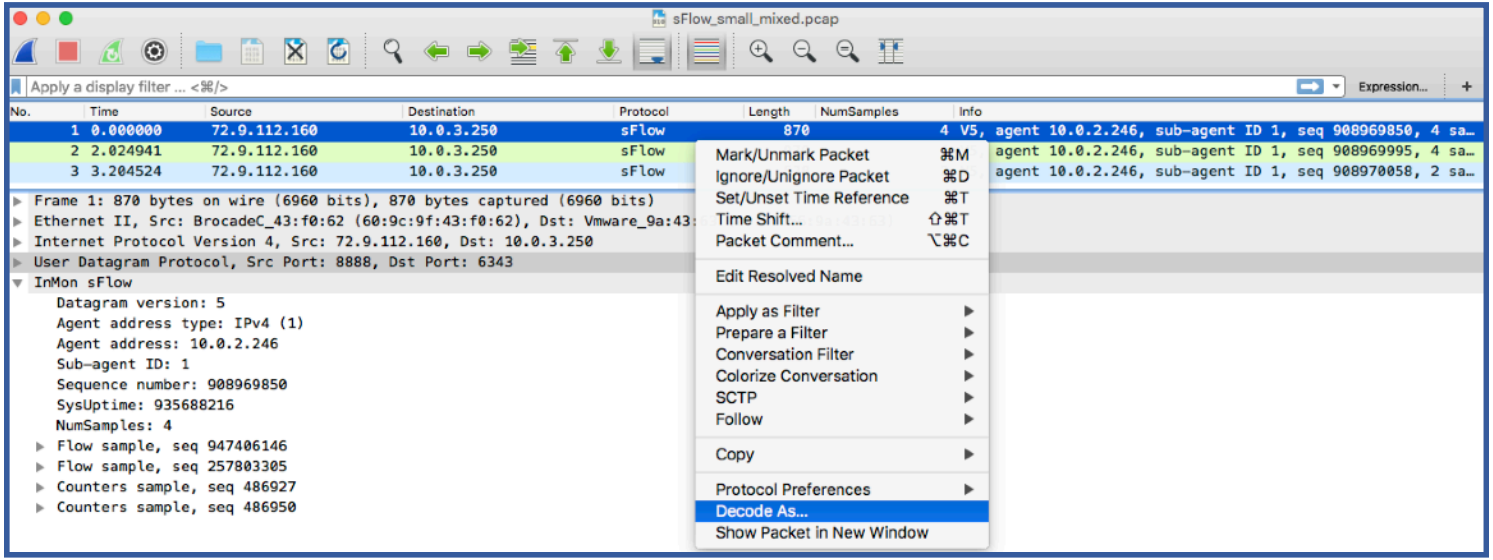


Statistical Background

- Assumption is that packet sampling can be modeled by the binomial distribution
- Prove that measured statistics can be used to accurately estimate the parameters of the actual theoretical binomial distribution
- Use the central limit theorem to compute the confidence intervals of a normal curve

DEMO: Wireshark + sFlow Traffic

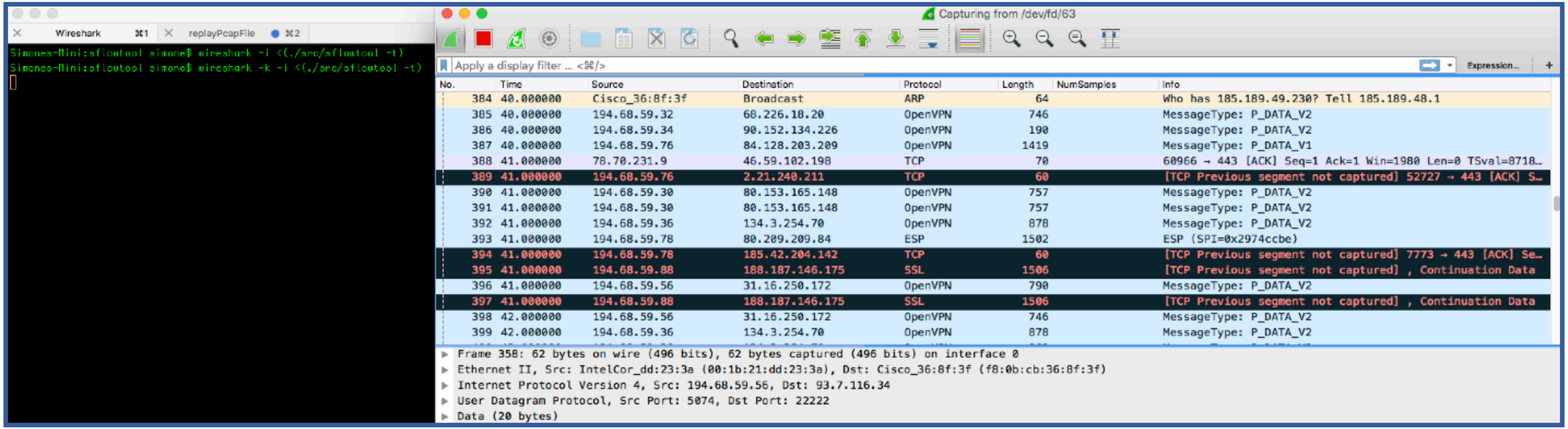
- Simply feed Wireshark with sFlow traffic (pcap, extcap, live interfaces)



```
No.    Time       Source         Destination    Protocol  Length  NumSamples  Info
     1 0.000000   72.9.112.160   10.0.3.250     sFlow        870           4  V5, agent 10.0.2.246, sub-agent ID 1, seq 908969850, 4 sa…
     2 2.024941   72.9.112.160   10.0.3.250     sFlow                            agent 10.0.2.246, sub-agent ID 1, seq 908969995, 4 sa…
     3 3.204524   72.9.112.160   10.0.3.250     sFlow                            agent 10.0.2.246, sub-agent ID 1, seq 908970058, 2 sa…
```

```
▶ Frame 1: 870 bytes on wire (6960 bits), 870 bytes captured (6960 bits)
▶ Ethernet II, Src: BrocadeC_43:f0:62 (60:9c:9f:43:f0:62), Dst: Vmware_9a:43:
▶ Internet Protocol Version 4, Src: 72.9.112.160, Dst: 10.0.3.250
▶ User Datagram Protocol, Src Port: 8888, Dst Port: 6343
▼ InMon sFlow
    Datagram version: 5
    Agent address type: IPv4 (1)
    Agent address: 10.0.2.246
    Sub-agent ID: 1
    Sequence number: 908969850
    SysUptime: 935688216
    NumSamples: 4
  ▶ Flow sample, seq 947406146
  ▶ Flow sample, seq 257803305
  ▶ Counters sample, seq 486927
  ▶ Counters sample, seq 486950
```

DEMO: Wireshark + sFlow Flow Samples

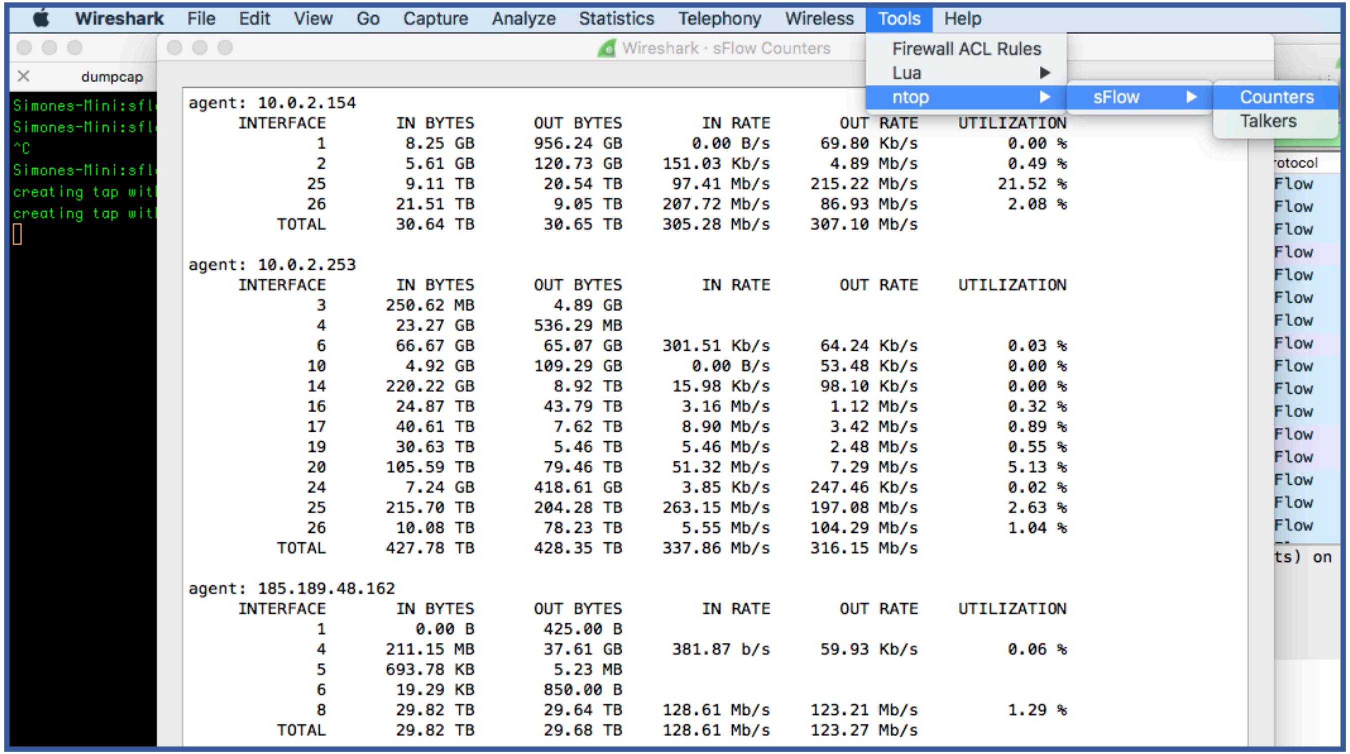


```
Simones-Mini:sflowtool simone$ wireshark -i <(./src/sflowtool -t)
Simones-Mini:sflowtool simone$ wireshark -k -i <(./src/sflowtool -t)
```

No.	Time	Source	Destination	Protocol	Length	NumSamples	Info
384	40.000000	Cisco_36:8f:3f	Broadcast	ARP	64		Who has 185.189.49.230? Tell 185.189.48.1
385	40.000000	194.68.59.32	68.226.18.20	OpenVPN	746		MessageType: P_DATA_V2
386	40.000000	194.68.59.34	90.152.134.226	OpenVPN	190		MessageType: P_DATA_V2
387	40.000000	194.68.59.76	84.128.203.209	OpenVPN	1419		MessageType: P_DATA_V1
388	41.000000	78.70.231.9	46.59.102.198	TCP	70		60966 → 443 [ACK] Seq=1 Ack=1 Win=1980 Len=0 TSval=8718…
389	41.000000	194.68.59.76	2.21.240.211	TCP	60		[TCP Previous segment not captured] 52727 → 443 [ACK] S…
390	41.000000	194.68.59.30	80.153.165.148	OpenVPN	757		MessageType: P_DATA_V2
391	41.000000	194.68.59.30	80.153.165.148	OpenVPN	757		MessageType: P_DATA_V2
392	41.000000	194.68.59.36	134.3.254.70	OpenVPN	878		MessageType: P_DATA_V2
393	41.000000	194.68.59.78	80.209.209.84	ESP	1502		ESP (SPI=0x2974ccbe)
394	41.000000	194.68.59.78	185.42.204.142	TCP	60		[TCP Previous segment not captured] 7773 → 443 [ACK] Se…
395	41.000000	194.68.59.88	188.187.146.175	SSL	1506		[TCP Previous segment not captured] , Continuation Data
396	41.000000	194.68.59.56	31.16.250.172	OpenVPN	790		MessageType: P_DATA_V2
397	41.000000	194.68.59.88	188.187.146.175	SSL	1506		[TCP Previous segment not captured] , Continuation Data
398	42.000000	194.68.59.56	31.16.250.172	OpenVPN	746		MessageType: P_DATA_V2
399	42.000000	194.68.59.36	134.3.254.70	OpenVPN	878		MessageType: P_DATA_V2

```
▶ Frame 358: 62 bytes on wire (496 bits), 62 bytes captured (496 bits) on interface 0
▶ Ethernet II, Src: IntelCor_dd:23:3a (00:1b:21:dd:23:3a), Dst: Cisco_36:8f:3f (f8:0b:cb:36:8f:3f)
▶ Internet Protocol Version 4, Src: 194.68.59.56, Dst: 93.7.116.34
▶ User Datagram Protocol, Src Port: 5074, Dst Port: 22222
▶ Data (20 bytes)
```

DEMO:
Wireshark as an sFlow Collector [1/2]



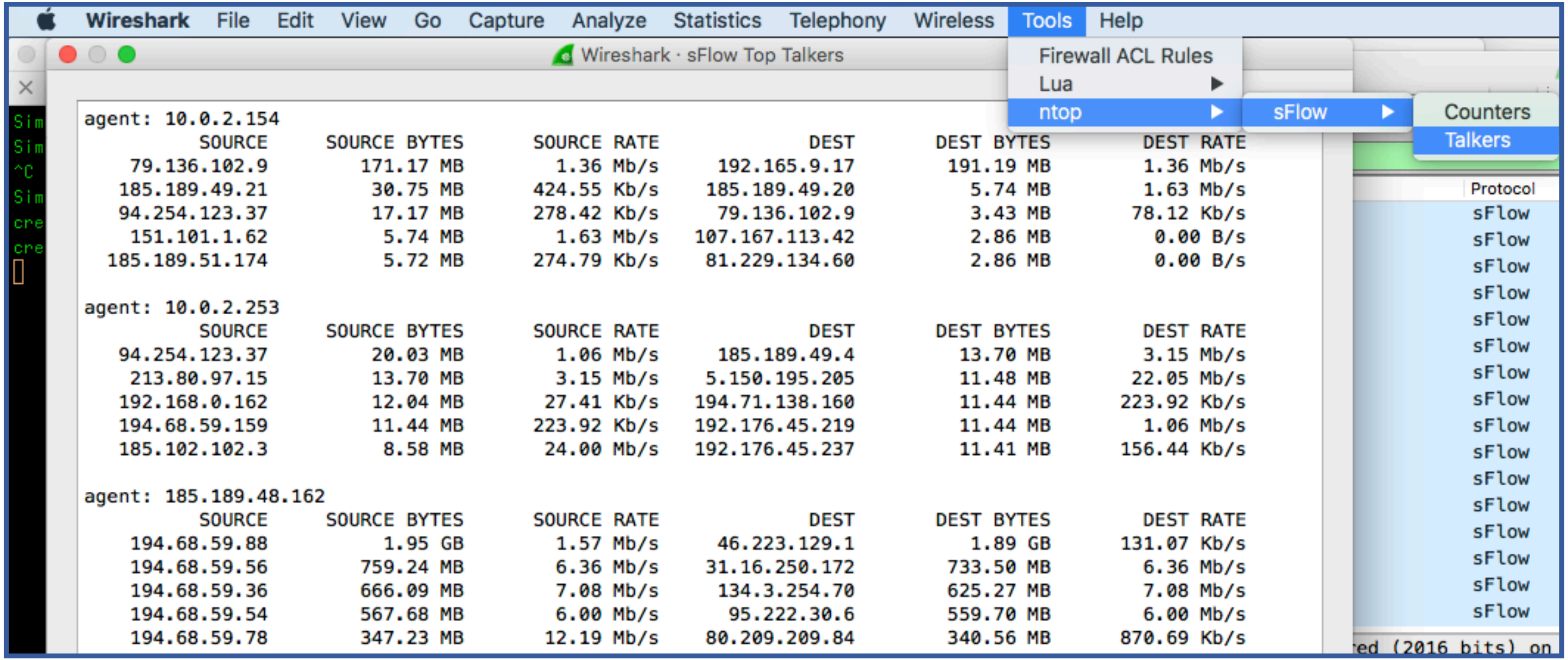
```
Simones-Mini:sfl
Simones-Mini:sfl
^C
Simones-Mini:sfl
creating tap wit
creating tap wit
```

```
agent: 10.0.2.154
     INTERFACE        IN BYTES       OUT BYTES         IN RATE        OUT RATE   UTILIZATION
             1         8.25 GB       956.24 GB        0.00 B/s      69.80 Kb/s        0.00 %
             2         5.61 GB       120.73 GB     151.03 Kb/s       4.89 Mb/s        0.49 %
            25         9.11 TB        20.54 TB      97.41 Mb/s     215.22 Mb/s       21.52 %
            26        21.51 TB         9.05 TB     207.72 Mb/s      86.93 Mb/s        2.08 %
         TOTAL        30.64 TB        30.65 TB     305.28 Mb/s     307.10 Mb/s

agent: 10.0.2.253
     INTERFACE        IN BYTES       OUT BYTES         IN RATE        OUT RATE   UTILIZATION
             3       250.62 MB         4.89 GB
             4        23.27 GB       536.29 MB
             6        66.67 GB        65.07 GB     301.51 Kb/s      64.24 Kb/s        0.03 %
            10         4.92 GB       109.29 GB        0.00 B/s      53.48 Kb/s        0.00 %
            14       220.22 GB         8.92 TB      15.98 Kb/s      98.10 Kb/s        0.00 %
            16        24.87 TB        43.79 TB       3.16 Mb/s       1.12 Mb/s        0.32 %
            17        40.61 TB         7.62 TB       8.90 Mb/s       3.42 Mb/s        0.89 %
            19        30.63 TB         5.46 TB       5.46 Mb/s       2.48 Mb/s        0.55 %
            20       105.59 TB        79.46 TB      51.32 Mb/s       7.29 Mb/s        5.13 %
            24         7.24 GB       418.61 GB       3.85 Kb/s     247.46 Kb/s        0.02 %
            25       215.70 TB       204.28 TB     263.15 Mb/s     197.08 Mb/s        2.63 %
            26        10.08 TB        78.23 TB       5.55 Mb/s     104.29 Mb/s        1.04 %
         TOTAL       427.78 TB       428.35 TB     337.86 Mb/s     316.15 Mb/s

agent: 185.189.48.162
     INTERFACE        IN BYTES       OUT BYTES         IN RATE        OUT RATE   UTILIZATION
             1          0.00 B        425.00 B
             4       211.15 MB        37.61 GB      381.87 b/s      59.93 Kb/s        0.06 %
             5       693.78 KB         5.23 MB
             6        19.29 KB        850.00 B
             8        29.82 TB        29.64 TB     128.61 Mb/s     123.21 Mb/s        1.29 %
         TOTAL        29.82 TB        29.68 TB     128.61 Mb/s     123.27 Mb/s
```

DEMO:
Wireshark as an sFlow Collector [2/2]



```
agent: 10.0.2.154
            SOURCE     SOURCE BYTES      SOURCE RATE            DEST      DEST BYTES      DEST RATE
       79.136.102.9       171.17 MB       1.36 Mb/s     192.165.9.17       191.19 MB      1.36 Mb/s
      185.189.49.21        30.75 MB     424.55 Kb/s    185.189.49.20         5.74 MB      1.63 Mb/s
      94.254.123.37        17.17 MB     278.42 Kb/s     79.136.102.9         3.43 MB     78.12 Kb/s
       151.101.1.62         5.74 MB       1.63 Mb/s   107.167.113.42         2.86 MB       0.00 B/s
     185.189.51.174         5.72 MB     274.79 Kb/s    81.229.134.60         2.86 MB       0.00 B/s

agent: 10.0.2.253
            SOURCE     SOURCE BYTES      SOURCE RATE            DEST      DEST BYTES      DEST RATE
      94.254.123.37        20.03 MB       1.06 Mb/s     185.189.49.4        13.70 MB      3.15 Mb/s
       213.80.97.15        13.70 MB       3.15 Mb/s    5.150.195.205        11.48 MB     22.05 Mb/s
      192.168.0.162        12.04 MB      27.41 Kb/s   194.71.138.160        11.44 MB    223.92 Kb/s
      194.68.59.159        11.44 MB     223.92 Kb/s   192.176.45.219        11.44 MB      1.06 Mb/s
      185.102.102.3         8.58 MB      24.00 Mb/s   192.176.45.237        11.41 MB    156.44 Kb/s

agent: 185.189.48.162
            SOURCE     SOURCE BYTES      SOURCE RATE            DEST      DEST BYTES      DEST RATE
       194.68.59.88         1.95 GB       1.57 Mb/s     46.223.129.1         1.89 GB    131.07 Kb/s
       194.68.59.56       759.24 MB       6.36 Mb/s    31.16.250.172       733.50 MB      6.36 Mb/s
       194.68.59.36       666.09 MB       7.08 Mb/s     134.3.254.70       625.27 MB      7.08 Mb/s
       194.68.59.54       567.68 MB       6.00 Mb/s      95.222.30.6       559.70 MB      6.00 Mb/s
       194.68.59.78       347.23 MB      12.19 Mb/s    80.209.209.84       340.56 MB    870.69 Kb/s
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