



Advanced Registry Operations Curriculum

NetFlow



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Contents

- Netflow
 - What it is and how it works
 - Uses and Applications
- Vendor Configurations/Implementation
 - Cisco
- NetFlow tools
 - Architectural issues
 - Software, tools etc

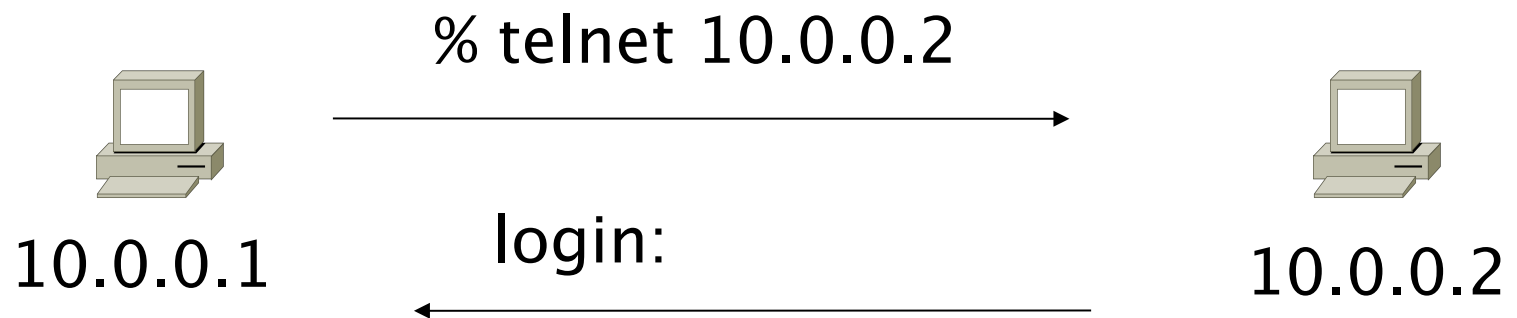
What are network flows ?

- Packets or frames that have a common attribute.
- Creation and expiration policy – what conditions start and stop a flow.
- Counters – packets,bytes,time.
- Routing information – AS, network mask, interfaces.

Network flows...

- Unidirectional or bidirectional.
- Bidirectional flows can contain other information such as round trip time, TCP behavior.
- Application flows look past the headers to classify packets by their contents.
- Aggregated flows – flows of flows.

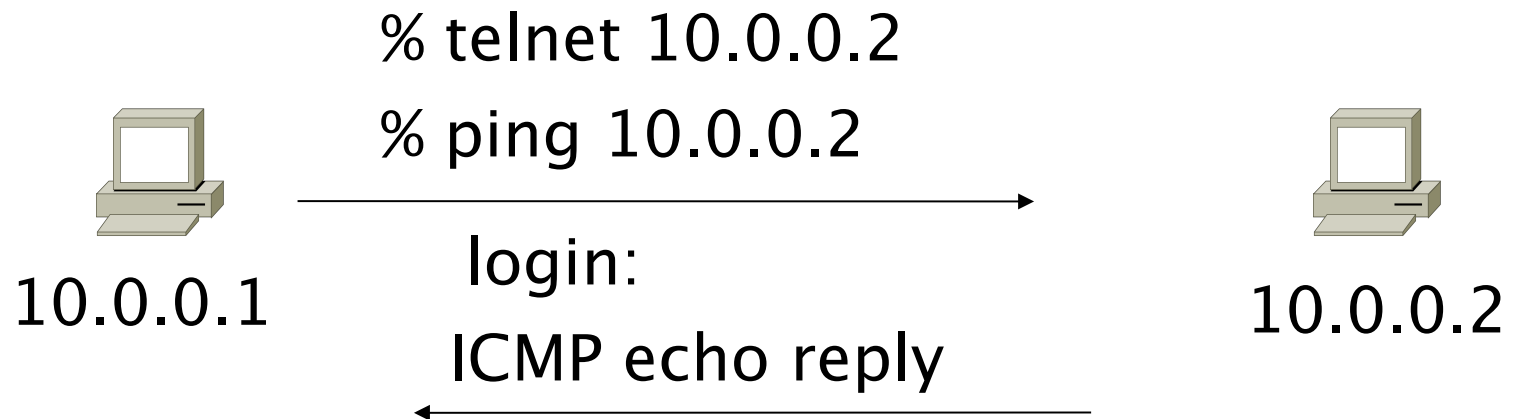
Unidirectional Flow with Source/Destination IP Key



Active Flows

Flow	Source IP	Destination IP
1	10.0.0.1	10.0.0.2
2	10.0.0.2	10.0.0.1

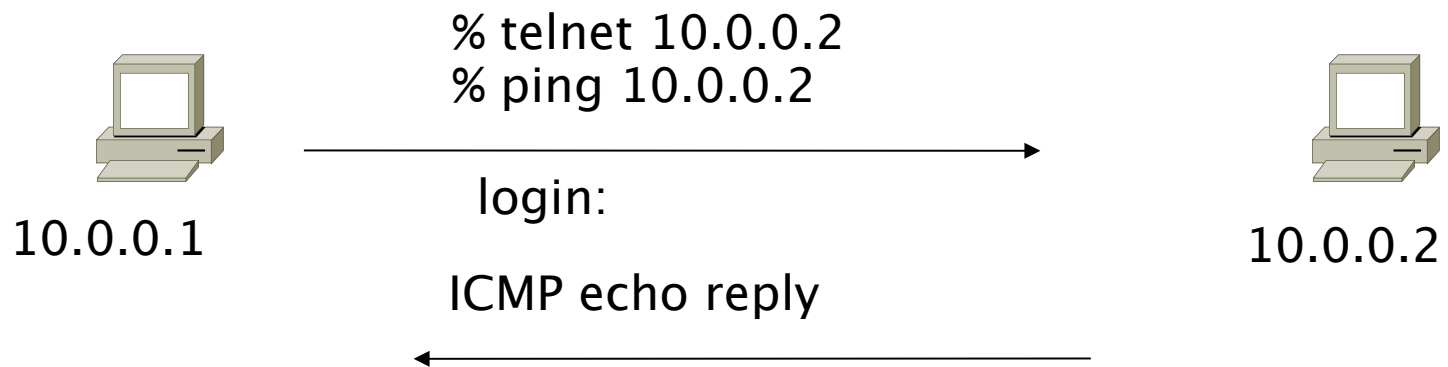
Unidirectional Flow with Source/Destination IP Key



Active Flows

Flow	Source IP	Destination IP
1	10.0.0.1	10.0.0.2
2	10.0.0.2	10.0.0.1

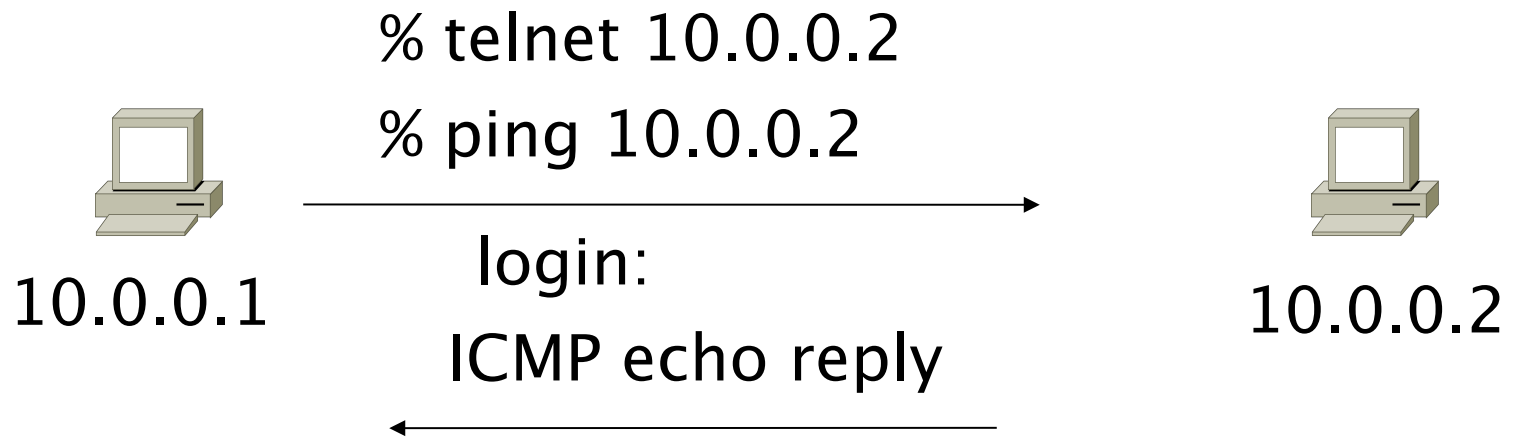
Unidirectional Flow with IP, Port, Protocol keys



Active Flows

Flow	Source IP	Destination IP	prot	srcPort	dstPort
1	10.0.0.1	10.0.0.2	TCP	32000	23
2	10.0.0.2	10.0.0.1	TCP	23	32000
3	10.0.0.1	10.0.0.2	ICMP	0	0
4	10.0.0.2	10.0.0.1	ICMP	0	0

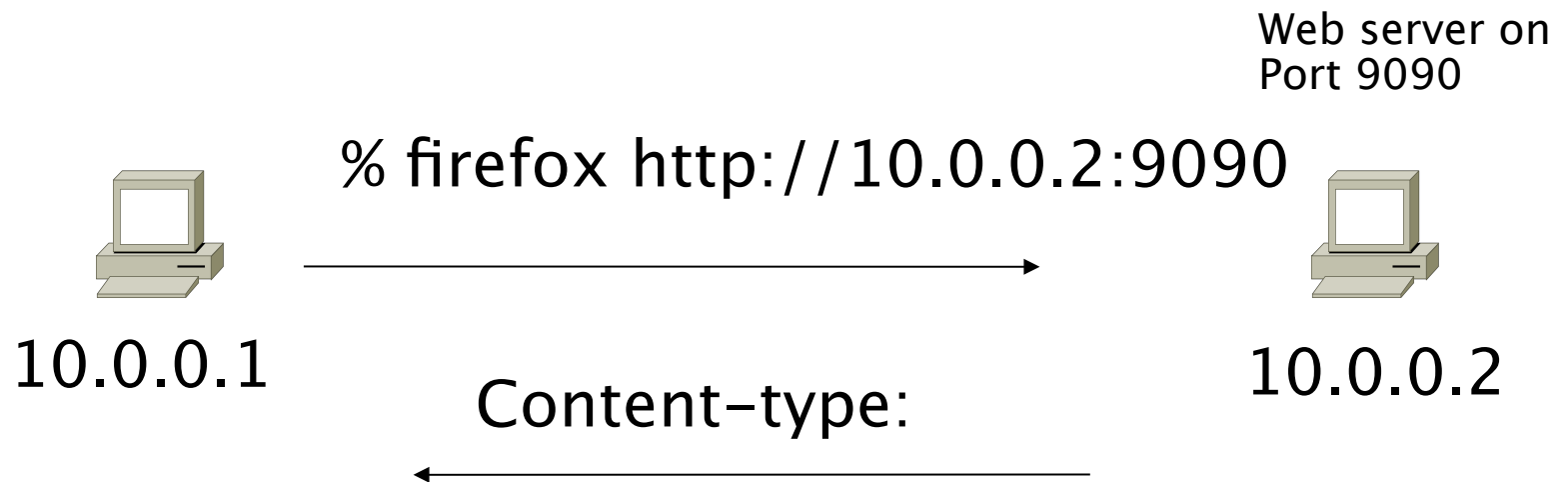
Bidirectional Flow with Source/Destination IP Key



Active Flows

Flow	Source IP	Destination IP	prot	srcPort	dstPort
1	10.0.0.1	10.0.0.2	TCP	32000	23
2	10.0.0.1	10.0.0.2	ICMP	0	0

Application flow



Active Flows

Flow	Source IP	Destination IP	Application
1	10.0.0.1	10.0.0.2	HTTP

Aggregated flow

Main Active flow table

Flow	Source IP	Destination IP	prot	srcPort	dstPort
1	10.0.0.1	10.0.0.2	TCP	32000	23
2	10.0.0.2	10.0.0.1	TCP	23	32000
3	10.0.0.1	10.0.0.2	ICMP	0	0
4	10.0.0.2	10.0.0.1	ICMP	0	0

Source/Destination IP Aggregate

Flow	Source IP	Destination IP
1	10.0.0.1	10.0.0.2
2	10.0.0.2	10.0.0.1

Working with flows

- Generating and Viewing Flows
- Exporting Flows from devices
 - Types of flows
 - Sampling rates
- Collecting it
 - Tools to collect flows: flow-tools, netflowd, pfflowd, ...
- Analyzing it
 - Use existing or write your own
 - nfSen, Netflow Dashboard, ...

Flow descriptors

- A **Key** with more elements will generate more flows.
- Greater number of flows leads to more post processing time to generate reports, more memory and CPU requirements for device generating flows.
- Depends on application.
 - Traffic engineering vs. intrusion detection.

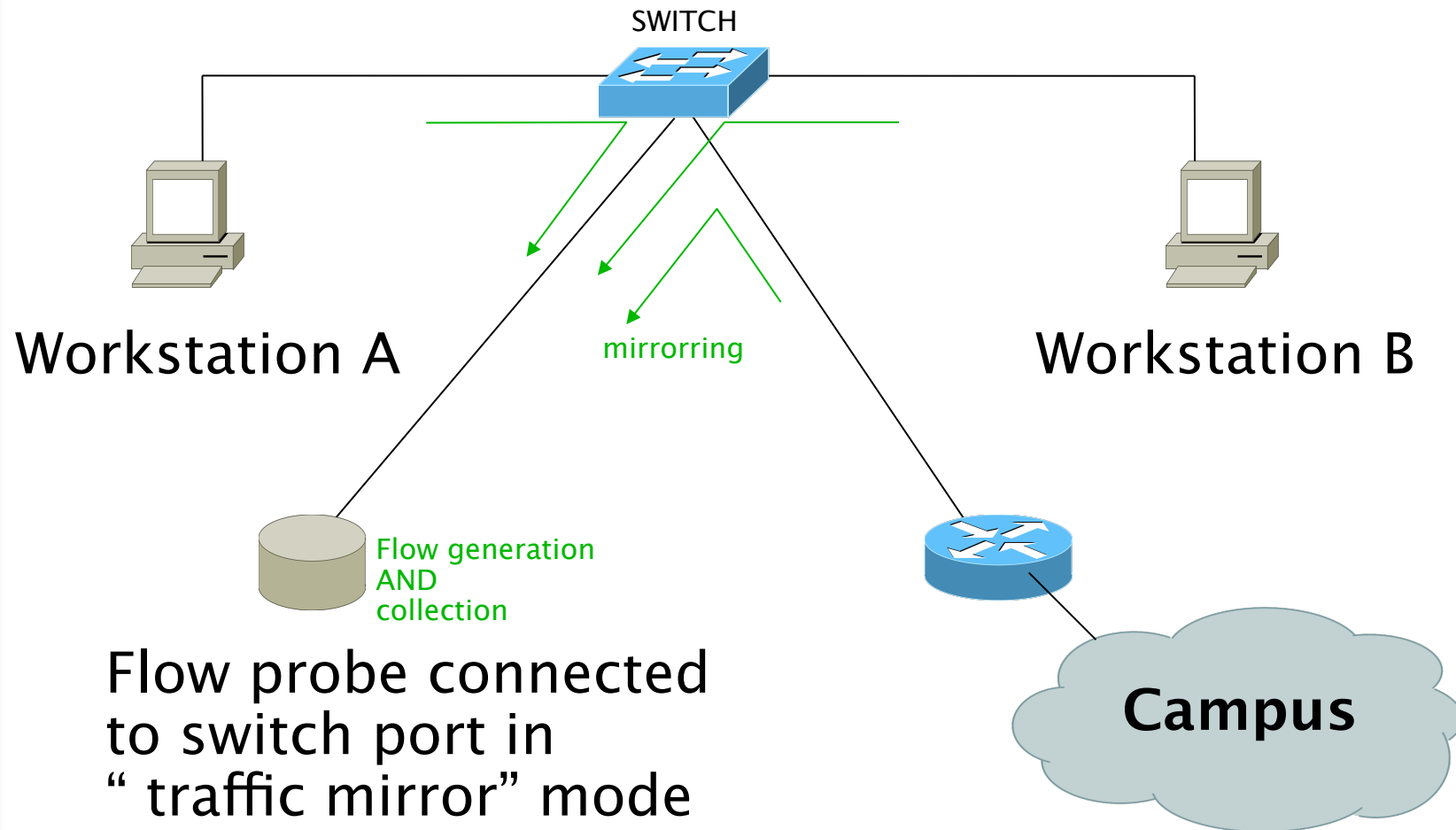
Flow Accounting

- Accounting information accumulated with flows.
- Packets, Bytes, Start Time, End Time.
- Network routing information – masks and autonomous system number.

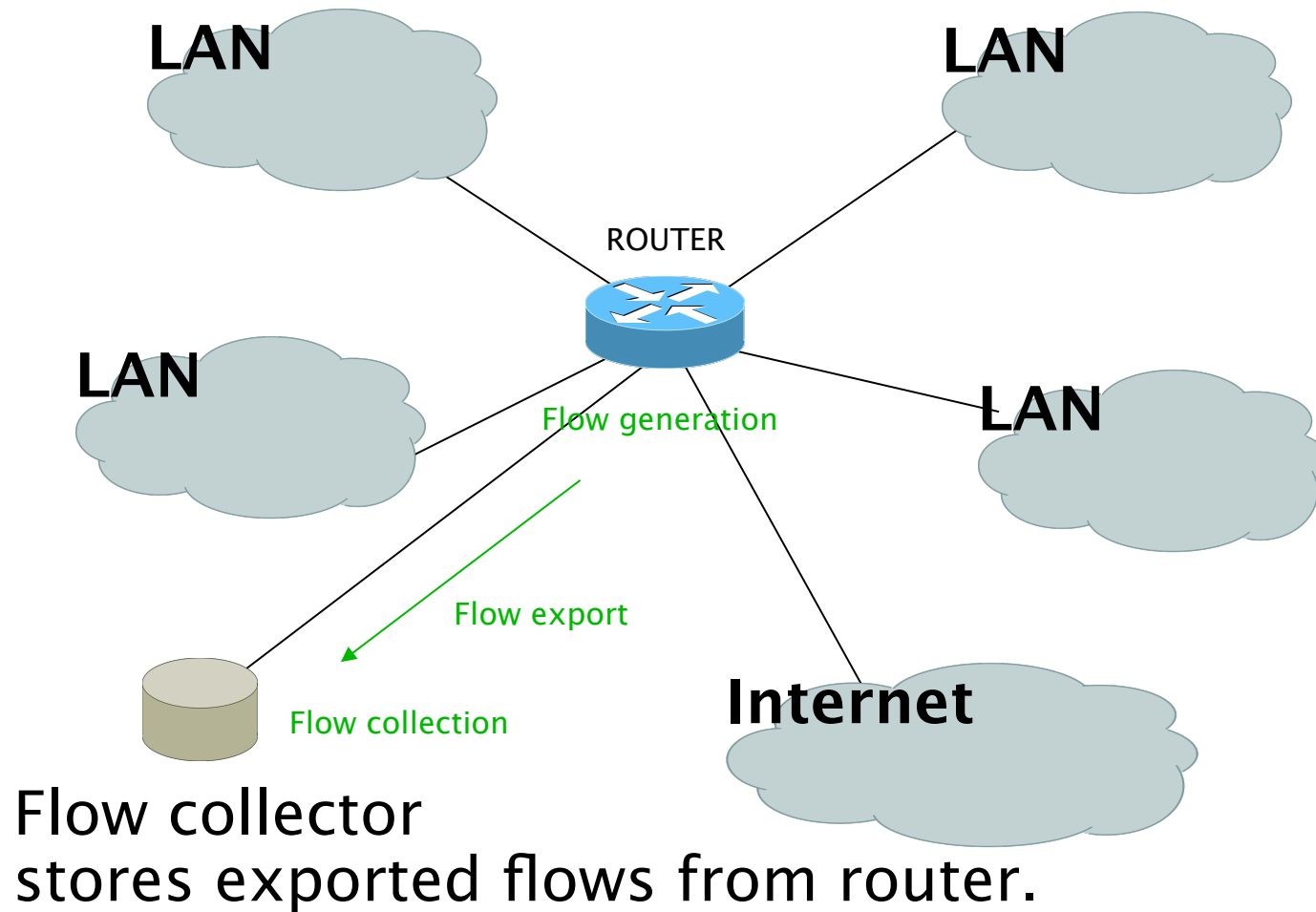
Flow generation / collection

- Passive monitor
 - A passive monitor (usually a UNIX host) receives all data and generates flows.
 - Resource intensive, newer investments needed
- Router or other existing network device.
 - Router or other existing devices like switch, generate flows.
 - Sampling is possible (don't account for every packet)
 - Nothing new needed

Passive monitor collection



Router/eqpt. based generation



Passive monitor

- Directly connected to a LAN segment via a switch port in “mirror” mode, optical splitter, or repeated segment.
- Generate flows for all local LAN traffic.
- Requires having an interface or monitor deployed on each switch/stack of the LAN/segment.
- Support for more detailed flows – bidirectional and application.

Router or on-eqpt. generation

- Router will generate flows for traffic that is directed to the router.
- Flows are not generated for local LAN traffic (we are only seeing routed traffic).
- Limited to “simple” flow criteria (packet headers), but newer equipment can go deeper (firewalls).
- Generally easier to deploy – no new equipment.

Vendor implementations

Cisco NetFlow

- NetFlow originated at Cisco
- Unidirectional flows
- Bidirectional flows (Cisco ASA platform)
- IPv4 unicast and multicast.
- Aggregated and unaggregated.
- Flows exported via UDP.
- Supported on ASA, IOS and CatOS platforms.
- Catalyst NetFlow is different from IOS

Cisco NetFlow Versions

- 4 Unaggregated types (1,5,6,7).
- 14 Aggregated types (8.x, 9).
- Each version has its own packet format.
- Version 1 does not have sequence numbers
 - no way to detect lost flows.
- The “version” defines what type of data is in the flow.
- Some versions specific to Catalyst platform.

NetFlow v1

- Key fields: Source/Destination IP, Source/Destination Port, IP Protocol, ToS, Input interface.
- Accounting: Packets, Octets, Start/End time, Output interface
- Other: Bitwise OR of TCP flags.

NetFlow v5

- Key fields: Source/Destination IP, Source/Destination Port, IP Protocol, ToS, Input interface.
- Accounting: Packets, Octets, Start/End time, Output interface.
- Other: Bitwise OR of TCP flags, Source/Destination AS and IP Mask.
- Packet format adds sequence numbers for detecting lost exports.
- Still very popular today

NetFlow v8

- Aggregated v5 flows.
- Not all flow types available on all equipments
- Much less data to post process, but loses fine granularity of v5 – no IP addresses.

NetFlow v5 fields

- AS
- Protocol/Port
- Source Prefix
- Destination Prefix
- Prefix
- Destination
- Source/Destination
- Full Flow

NetFlow v8 fields (cont.)

- ToS/AS
- ToS/Protocol/Port
- ToS/Source Prefix
- ToS/Destination Prefix
- Tos/Source/Destination Prefix
- ToS/Prefix/Port

NetFlow v9

- Record formats are defined using templates.
- Template descriptions are communicated from the router to the NetFlow Collection Engine.
- Flow records are sent from the router to the NetFlow Collection Engine with minimal template information so that the NetFlow Collection Engine can relate the records to the appropriate template.
- Version 9 is independent of the underlying transport (UDP, TCP, SCTP, and so on).

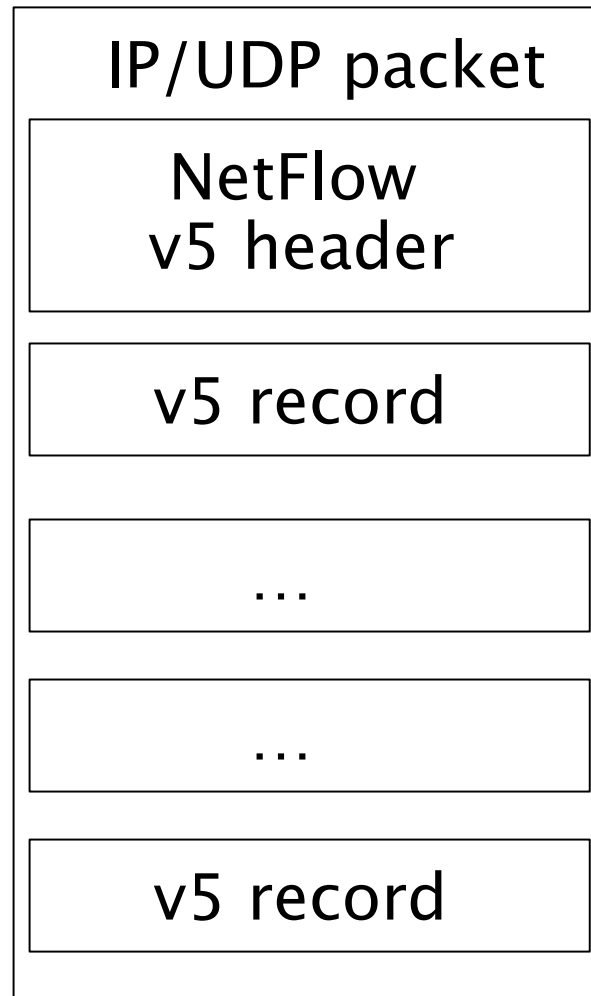
NetFlow v10 - IPFIX

- Also known as IPFIX (IETF standardization)
 - Enterprise specific support
 - Variable length fields

NetFlow Packet Format

- Common header among export versions.
- All but v1 have a sequence number.
- Version specific data field where N records of data type are exported.
- N is determined by the size of the flow definition. Packet size is kept under ~1480 bytes. No fragmentation on Ethernet.

NetFlow v5 packet format



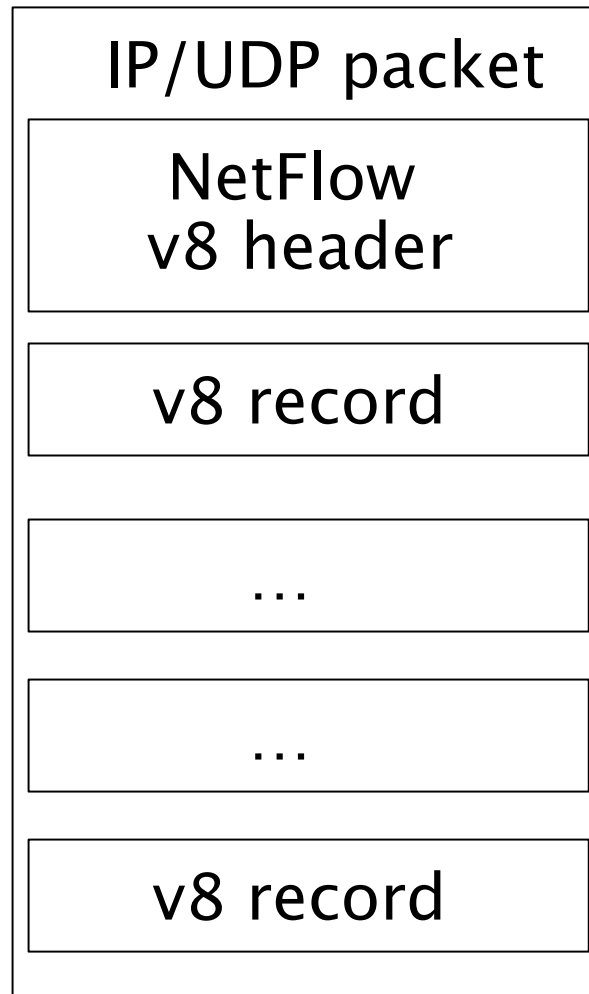
NetFlow v5 packet header (C)

```
struct ftpdu_v5 {  
    /* 24 byte header */  
    u_int16 version;          /* 5 */  
    u_int16 count;            /* The number of records in the PDU */  
    u_int32 sysUpTime;        /* Current time in millisecs since router booted */  
    u_int32 unix_secs;        /* Current seconds since 0000 UTC 1970 */  
    u_int32 unix_nsecs;       /* Residual nanoseconds since 0000 UTC 1970 */  
    u_int32 flow_sequence;    /* Seq counter of total flows seen */  
    u_int8  engine_type;      /* Type of flow switching engine (RP,VIP,etc.) */  
    u_int8  engine_id;        /* Slot number of the flow switching engine */  
    u_int16 reserved;  
};
```

NetFlow v5 packet format (C)

```
/* 48 byte payload */
struct ftrec_v5 {
    u_int32 srcaddr; /* Source IP Address */
    u_int32 dstaddr; /* Destination IP Address */
    u_int32 nexthop; /* Next hop router's IP Address */
    u_int16 input; /* Input interface index */
    u_int16 output; /* Output interface index */
    u_int32 dPkts; /* Packets sent in Duration */
    u_int32 dOctets; /* Octets sent in Duration. */
    u_int32 First; /* SysUptime at start of flow */
    u_int32 Last; /* and of last packet of flow */
    u_int16 srcport; /* TCP/UDP source port number or equivalent */
    u_int16 dstport; /* TCP/UDP destination port number or equiv */
    u_int8 pad;
    u_int8 tcp_flags; /* Cumulative OR of tcp flags */
    u_int8 prot; /* IP protocol, e.g., 6=TCP, 17=UDP, ... */
    u_int8 tos; /* IP Type-of-Service */
    u_int16 src_as; /* originating AS of source address */
    u_int16 dst_as; /* originating AS of destination address */
    u_int8 src_mask; /* source address prefix mask bits */
    u_int8 dst_mask; /* destination address prefix mask bits */
    u_int16 drops;
} records[FT_PDU_V5_MAXFLOWS];
};
```


NetFlow v8 Packet Example (AS Aggregation)



NetFlow v8 AS agg. Packet

```
struct ftpdu_v8_1 {
    /* 28 byte header */
    u_int16 version;          /* 8 */
    u_int16 count;            /* The number of records in the PDU */
    u_int32 sysUpTime;        /* Current time in millisecs since router booted */
    u_int32 unix_secs;        /* Current seconds since 0000 UTC 1970 */
    u_int32 unix_nsecs;       /* Residual nanoseconds since 0000 UTC 1970 */
    u_int32 flow_sequence;    /* Seq counter of total flows seen */
    u_int8 engine_type;       /* Type of flow switching engine (RP,VIP,etc.) */
    u_int8 engine_id;         /* Slot number of the flow switching engine */
    u_int8 aggregation;       /* Aggregation method being used */
    u_int8 agg_version;       /* Version of the aggregation export */
    u_int32 reserved;
    /* 28 byte payload */
    struct ftrec_v8_1 {
        u_int32 dFlows;       /* Number of flows */
        u_int32 dPkts;        /* Packets sent in duration */
        u_int32 dOctets;      /* Octets sent in duration */
        u_int32 First;        /* SysUpTime at start of flow */
        u_int32 Last;         /* and of last packet of flow */
        u_int16 src_as;       /* originating AS of source address */
        u_int16 dst_as;       /* originating AS of destination address */
        u_int16 input;        /* input interface index */
        u_int16 output;       /* output interface index */
    } records[FT_PDU_V8_1_MAXFLOWS];
};
```

Cisco IOS configuration

- Configured on each input interface.
- Define the version.
- Define the IP address of the collector (where to send the flows).
- Optionally enable aggregation tables.
- Optionally configure flow timeout and main (v5) flow table size.
- Optionally configure sample rate.

Cisco IOS configuration

```
interface FastEthernet0/0
  description Local network
  ip address 192.168.10x.1 255.255.255.0
  duplex auto
  speed auto
!
interface FastEthernet0/1
  description Connection to ISP
  ip address 192.168.86.10x 255.255.255.0
  ip flow egress
  ip flow ingress
  duplex auto
  speed auto

ip flow-export version 5
ip flow-export destination 192.168.10x.30 2002
ip flow top-talkers
  top 10
  sort-by bytes
```

Cisco IOS configuration

- IOS versions

```
interface FastEthernet0/0
  ip route-cache flow      ! Prior to IOS 12.4
  ip flow [ingress|egress] ! From IOS 12.4
```

Cisco IOS configuration

```
Flow export v5 is enabled for main cache
Exporting flows to 169.223.142.3 (2002)
Exporting using source IP address 169.223.142.1
Version 5 flow records
127480 flows exported in 6953 udp datagrams
0 flows failed due to lack of export packet
0 export packets were sent up to process level
0 export packets were dropped due to no fib
0 export packets were dropped due to adjacency issues
0 export packets were dropped due to fragmentation failures
0 export packets were dropped due to encapsulation fixup failures
```

Cisco IOS configuration

```
TLDx-RTR# show ip cache flow
```

```
IP packet size distribution (1765988 total packets):
```

1-32	64	96	128	160	192	224	256	288	320	352	384	416	448	480
.000	.538	.113	.049	.027	.006	.002	.006	.002	.001	.001	.001	.017	.002	.001
512	544	576	1024	1536	2048	2560	3072	3584	4096	4608				
.001	.001	.002	.018	.204	.000	.000	.000	.000	.000	.000				

```
IP Flow Switching Cache, 278544 bytes
```

```
105 active, 3991 inactive, 127794 added
```

```
2151823 age polls, 0 flow alloc failures
```

```
Active flows timeout in 30 minutes
```

```
Inactive flows timeout in 15 seconds
```

```
IP Sub Flow Cache, 21640 bytes
```

```
105 active, 919 inactive, 127726 added, 127726 added to flow
```

```
0 alloc failures, 0 force free
```

```
1 chunk, 8 chunks added
```

```
last clearing of statistics never
```

Protocol	Total	Flows	Packets	Bytes	Packets	Active (Sec)	Idle (Sec)
-----	Flows	/Sec	/Flow	/Pkt	/Sec	/Flow	/Flow
TCP-Telnet	62	0.0	60	50	0.0	15.7	14.3
TCP-FTP	1	0.0	3	60	0.0	8.9	15.2
TCP-WWW	54359	0.1	14	658	2.3	5.3	5.1
TCP-SMTP	20	0.0	103	47	0.0	6.3	13.5
...							

Cisco IOS configuration

TCP-X	1991	0.0	32	40	0.1	0.5	14.3
TCP-other	8069	0.0	61	214	1.5	7.8	8.9
UDP-DNS	24371	0.0	1	69	0.0	0.1	15.4
UDP-NTP	7208	0.0	1	74	0.0	0.0	15.4
UDP-Frag	14	0.0	1	508	0.0	1.2	15.4
UDP-other	27261	0.0	11	105	0.9	0.4	15.4
ICMP	4457	0.0	17	83	0.2	16.9	15.4
IP-other	1	0.0	1	50	0.0	0.0	15.6
Total:	128017	0.3	13	373	5.3	3.5	10.6

SrcIf	SrcIPaddress	DstIf	DstIPaddress	Pr	SrcP	DstP	Pkts
Fa0/0	210.118.80.41	Fa0/1	192.168.142.112	11	0627	059A	1
Fa0/1	192.168.142.3	Fa0/0*	192.168.35.48	06	0050	C166	1
Fa0/0	192.168.35.175	Local	192.168.142.1	06	EFFD	0016	145
Fa0/0	192.168.35.175	Local	192.168.142.1	06	EEFC	0017	1
Fa0/0	192.168.35.175	Fa0/1	192.168.142.3	06	EE61	0016	79
Fa0/1	192.168.142.102	Fa0/0*	216.34.181.71	06	E058	0050	6
Fa0/1	192.168.142.70	Fa0/0*	66.220.146.18	06	CBD3	0050	6
Fa0/0	208.81.191.110	Fa0/1	192.168.142.70	06	0050	DABD	13

...

Cisco IOS configuration

```
ip flow-top-talkers
  top 10
  sort-by bytes
```

TLDx-RTR# `show ip flow top-talkers`

SrcIf	SrcIPaddress	DstIf	DstIPaddress	Pr	SrcP	DstP	Bytes
Fa0/1	192.168.142.39	Fa0/0*	192.168.35.139	06	0050	D804	33K
Fa0/0	192.168.32.102	Fa0/1	192.168.142.37	06	816E	0016	28K
Fa0/1	192.168.142.39	Fa0/0*	192.168.35.139	06	0050	D805	26K
Fa0/1	192.168.142.39	Fa0/0*	192.168.35.139	06	0050	D807	24K
Fa0/1	192.168.142.39	Fa0/0*	192.168.35.139	06	0050	D806	23K
Fa0/1	192.168.142.37	Fa0/0*	192.168.32.102	06	0016	816E	23K
Fa0/0	192.168.35.139	Fa0/1	192.168.142.39	06	D804	0050	6675
Fa0/1	192.168.142.70	Fa0/0*	208.81.191.110	06	ABE7	0050	4341
Fa0/0	192.168.35.175	Fa0/1	192.168.142.3	06	EE61	0016	3140
Fa0/1	192.168.142.3	Fa0/0*	192.168.35.175	06	0016	EE61	2528

10 of 10 top talkers shown. 122 flows processed.

IOS command summary

- Enable flow on each interface

```
ip route-cache flow
```

OR

```
ip flow ingress
```

```
ip flow egress
```

- View flows

- show ip cache flow

- show ip flow top-talkers

IOS command summary

- Export flows

```
ip flow-export version 5 [origin-as|peer-as]  
ip flow-export destination x.x.x.x <udp-port>
```

- Exporting aggregated flows

```
ip flow-aggregation cache as|prefix|dest|source|proto  
enabled  
export destination x.x.x.x <udp-port>
```

Flows and applications

Uses for flows

- Problem identification / solving
 - Traffic classification
 - DoS analysis
- Traffic Analysis
 - Inter-AS traffic analysis
 - Reporting on application proxies
- Accounting
 - Cross verification from other sources
 - Can cross-check with SNMP data

Traffic classification

- Based on Protocol, source and destination ports
 - Protocol identification (TCP, UDP, ICMP)
 - Can define well known ports
 - Can identify well known P2P ports:
 - Uses
 - Proxy measurement - http , ftp
 - Rate limiting P2P traffic
 - Produce usage reports on traffic distribution

Traceback: Flow-based*

- Trace attack by matching fingerprint/signature at each interface via passive monitoring:
 - Flow data (e.g., NetFlow, cflowd, sFlow, IPFIX)
 - Span Data
 - PSAMP (Packet Sampling, IETF PSAMP WG)
- Number of open source and commercial products evolving in market
- Non-intrusive, widely supported

Flow-based detection

- Monitor flows (i.e., Network and Transport Layer transactions) on the network and build baselines for what normal behavior looks like:
 - Per interface
 - Per prefix
 - Per Transport Layer protocol & ports
 - Build time-based buckets (e.g., 5 minutes, 30 minutes, 1 hour, 12 hours, day of week, day of month, day of year)

Detect anomalous events: here, a "Slammer" SQL worm attack

peakflow | DoS

Recent Anomalies: Anomaly 125772 : Detailed

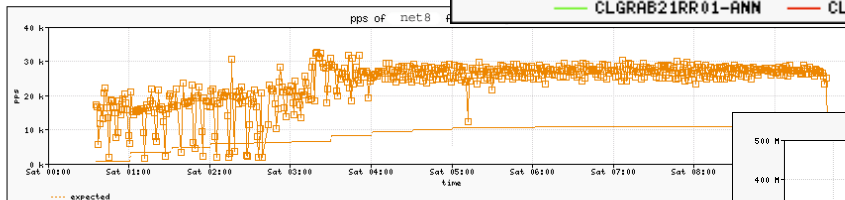
11:51:49 EST 27 Jan 2003

Statistics

Status Topology Ongoing Recent Dark IP Admin About

Anomaly 125772 Detailed Statistics

ID	Importance	Severity	Duration	Direction
125772	High	958.2% of 3.40 Kpps	09h 06m 47s	Outgoing



Affected Network Elements

Router net8 1.2.3.4

	Triggering	Expected	Difference	Maximum
Bitrate	71.69 Mbps	2.34 Mbps	69.35 Mbps	105.26 Mbps @ 03
Packet Rate	22.20 Kpps	712 pps	21.49 Kpps	32.58 Kpps @ 03

Summary | Source Addresses | Destination Addresses | Source Ports | Destination Ports | Protocols | Output Interfaces | Input Interfaces | Generate Filter

Summary of all Data Snapshots Collected:

	Bytes	Packets	Bytes/Pkt	bps
	308.01 GB	762,849,500	404 B	76.05 Mbps
				23.54

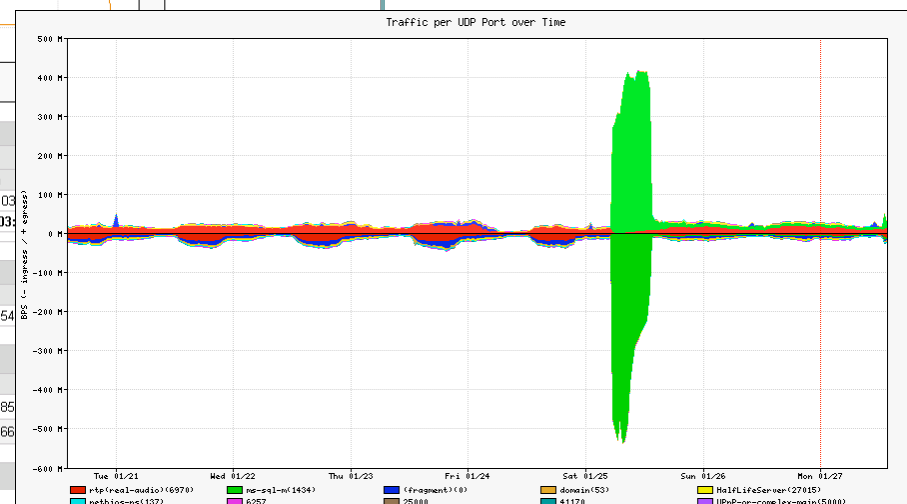
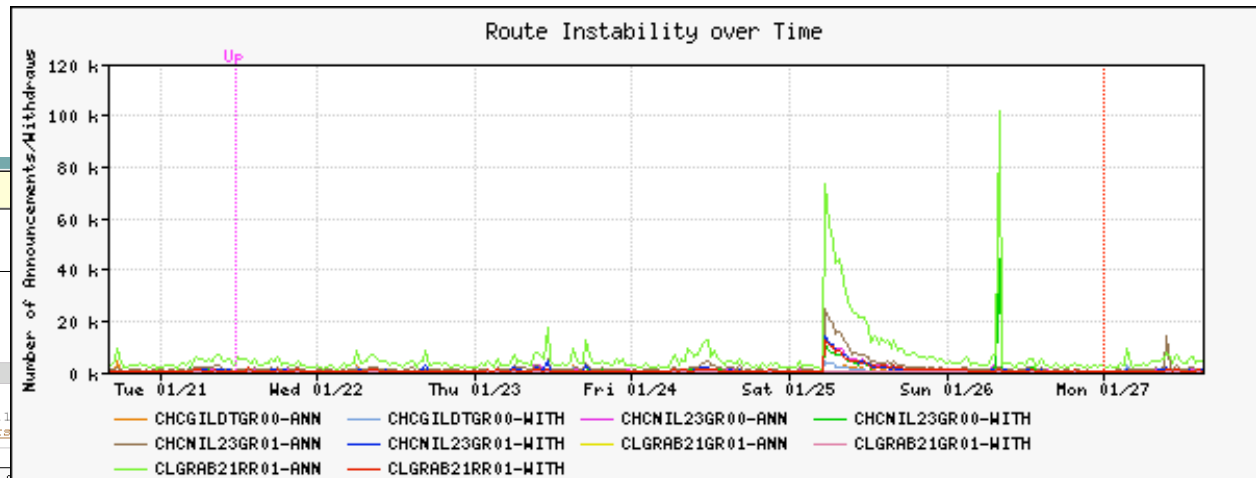
Summary | Source Addresses | Destination Addresses | Source Ports | Destination Ports | Protocols | Output Interfaces | Input Interfaces | Generate Filter

Source Addresses

Network / Mask	Bytes	Packets	Bytes/Pkt	bps
192.168.20.217/32	168.22 GB	416,436,800	404 B	41.54 Mbps
192.168.18.187/32	139.53 GB	345,372,800	404 B	34.45 Mbps

Summary | Source Addresses | Destination Addresses | Source Ports | Destination Ports | Protocols | Output Interfaces | Input Interfaces | Generate Filter

Destination Addresses



Flow-based detection (cont.)

- Once baselines are built anomalous activity can be detected
 - **Rate-based** (pps or bps) anomalies may be legitimate or malicious
 - Many **misuse** attacks can be immediately recognized, even **without** baselines (e.g., TCP SYN or RST floods)
 - **Signatures** can also be defined to identify “interesting” transactional data (e.g., proto udp and port 1434 and 404 octets(376 payload) == slammer!)
 - Temporal compound signatures can be defined to detect with higher precision

Flow-based tools – commercial and other

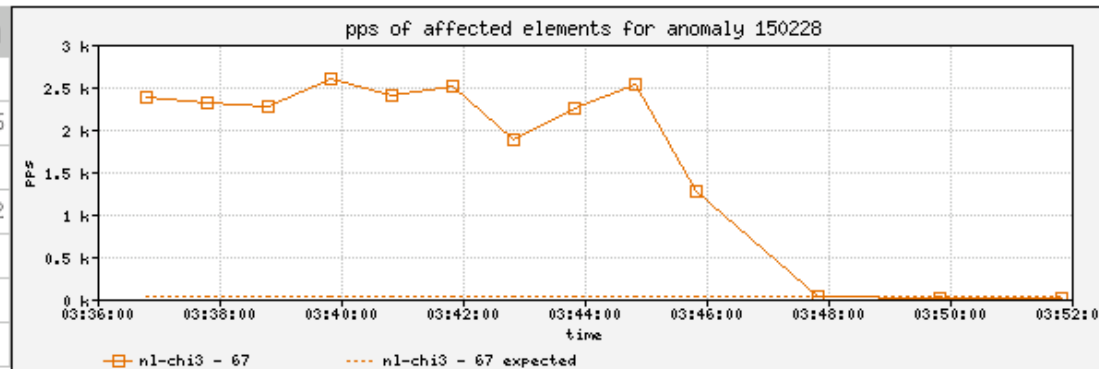
Anomaly 150228

Get Report: [PDF](#) [XML](#)

ID	Importance	Duration	Start Time	Direction	Type	Resource
150228	High 130.0% of 2 Kpps	17 mins	03:34, Aug 16	Incoming	Bandwidth (Profiled)	Microsoft 207.46.0.0/16 windowsupdate.com

Traffic Characterization

Sources	204.38.130.0/24
	204.38.130.192/26
	1024 - 1791
Destination	207.46.248.234/32
	80 (http)
Protocols	tcp (6)
TCP Flags	S (0x02)

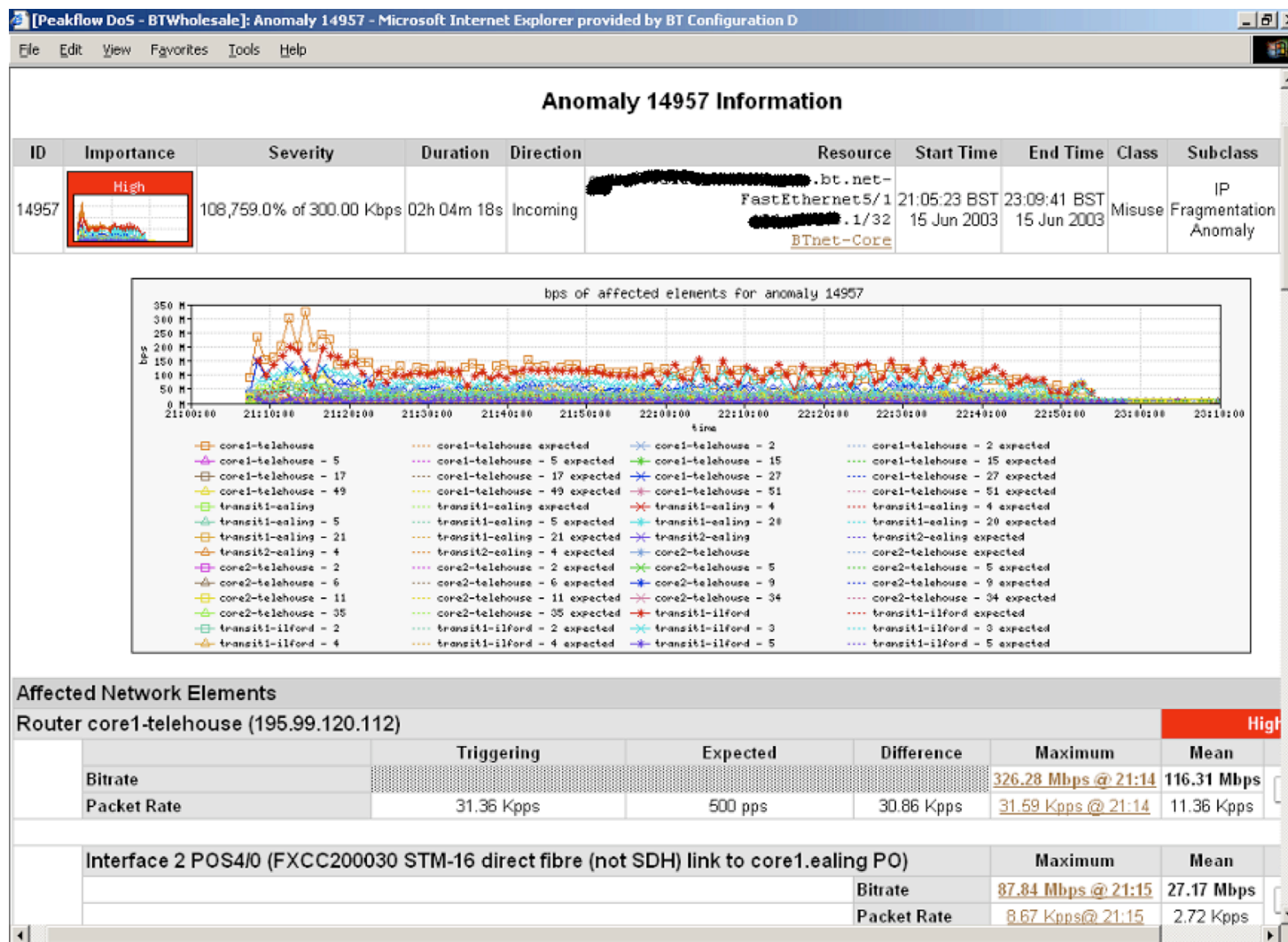


Affected Network Elements

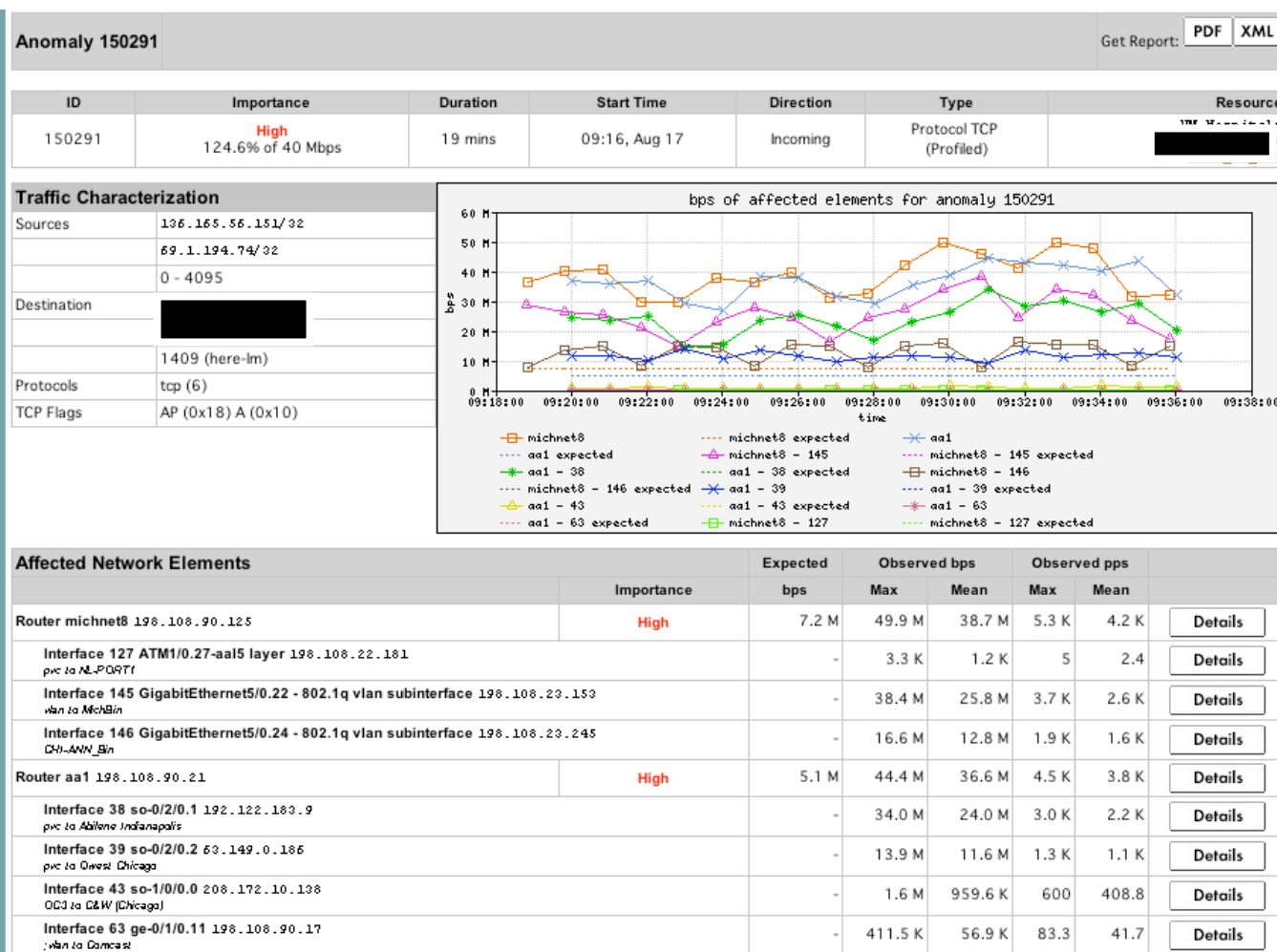
	Importance	Expected pps	Observed bps		Observed pps		
			Max	Mean	Max	Mean	
Router nl-chi3 198.110.131.125	High						
Interface 67 at-1/1/0.14 <i>pvc to WMU</i>		26	832 K	563.1 K	2.6 K	1.7 K	Details

Anomaly Comments

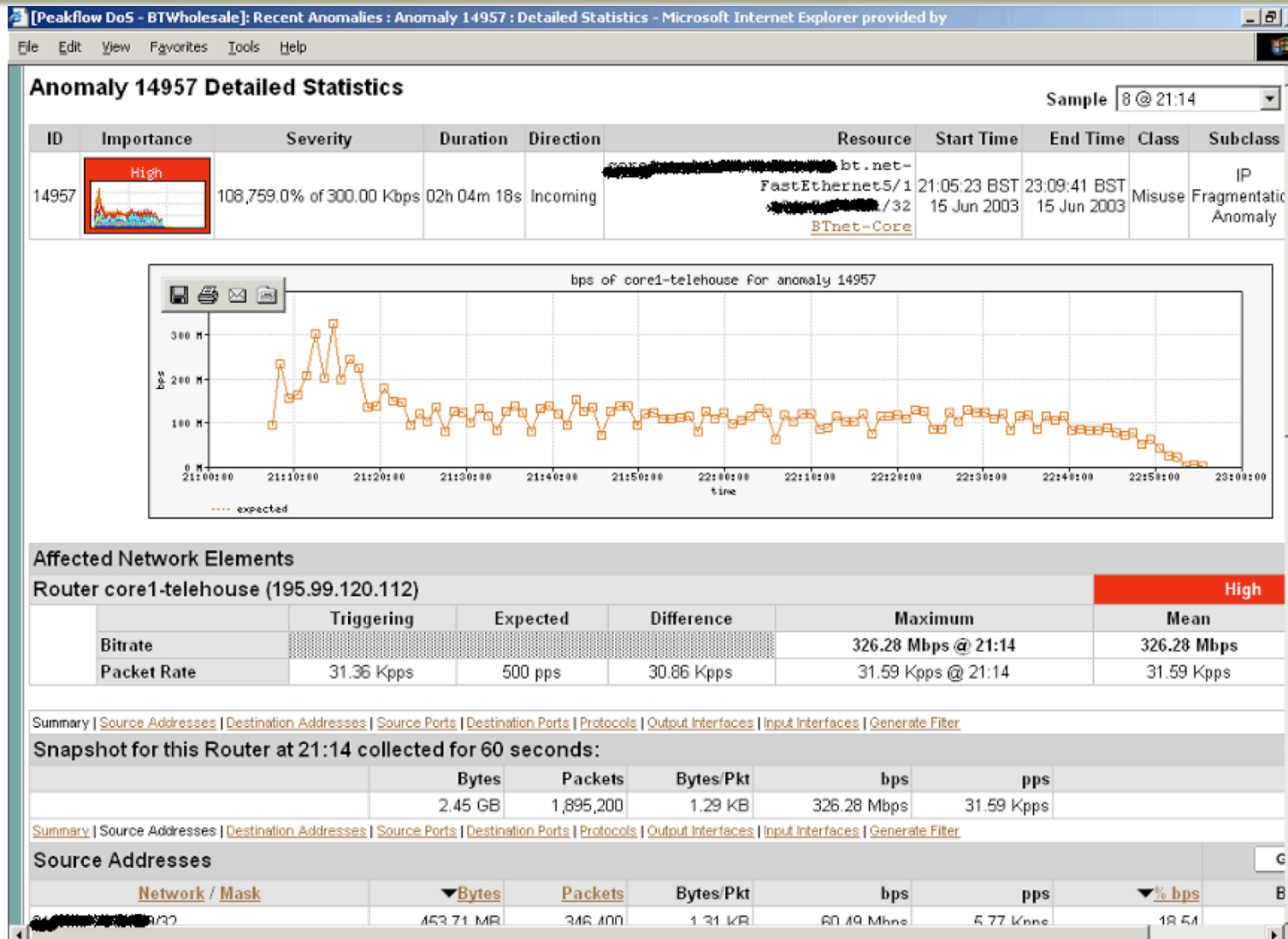
Commercial tools – large scale DoS attack



Traceback (commercial)



Traceback (commercial) – more data



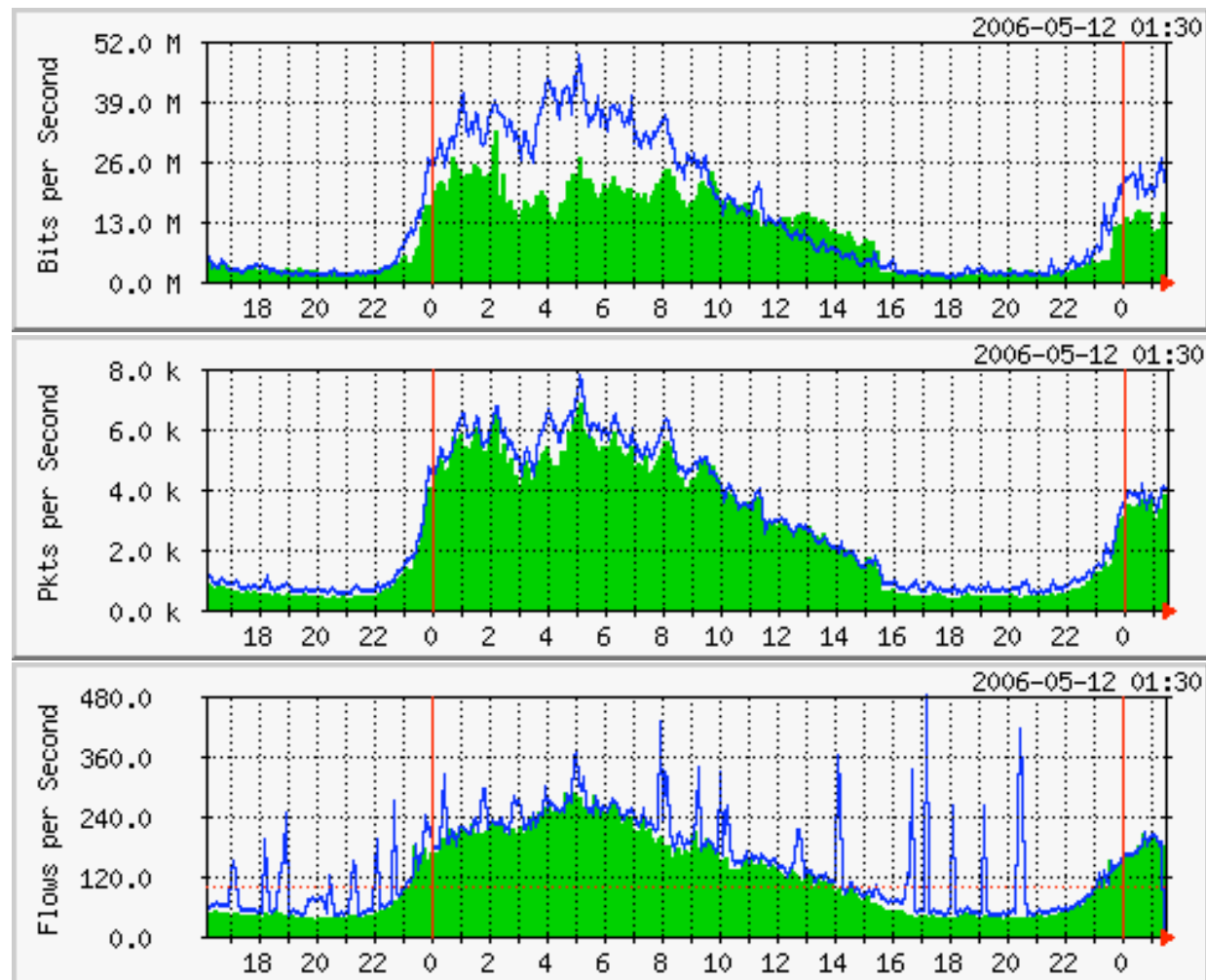
Traffic analysis

- Can see traffic based on source and destination AS
 - Source and destination AS derived through the routing table on the router
 - Introduces the need to run full mesh BGP at IXPs as well as transit and peering
 - Source and destination prefix based flows can be collected and plotted against external prefix to ASN data

Accounting

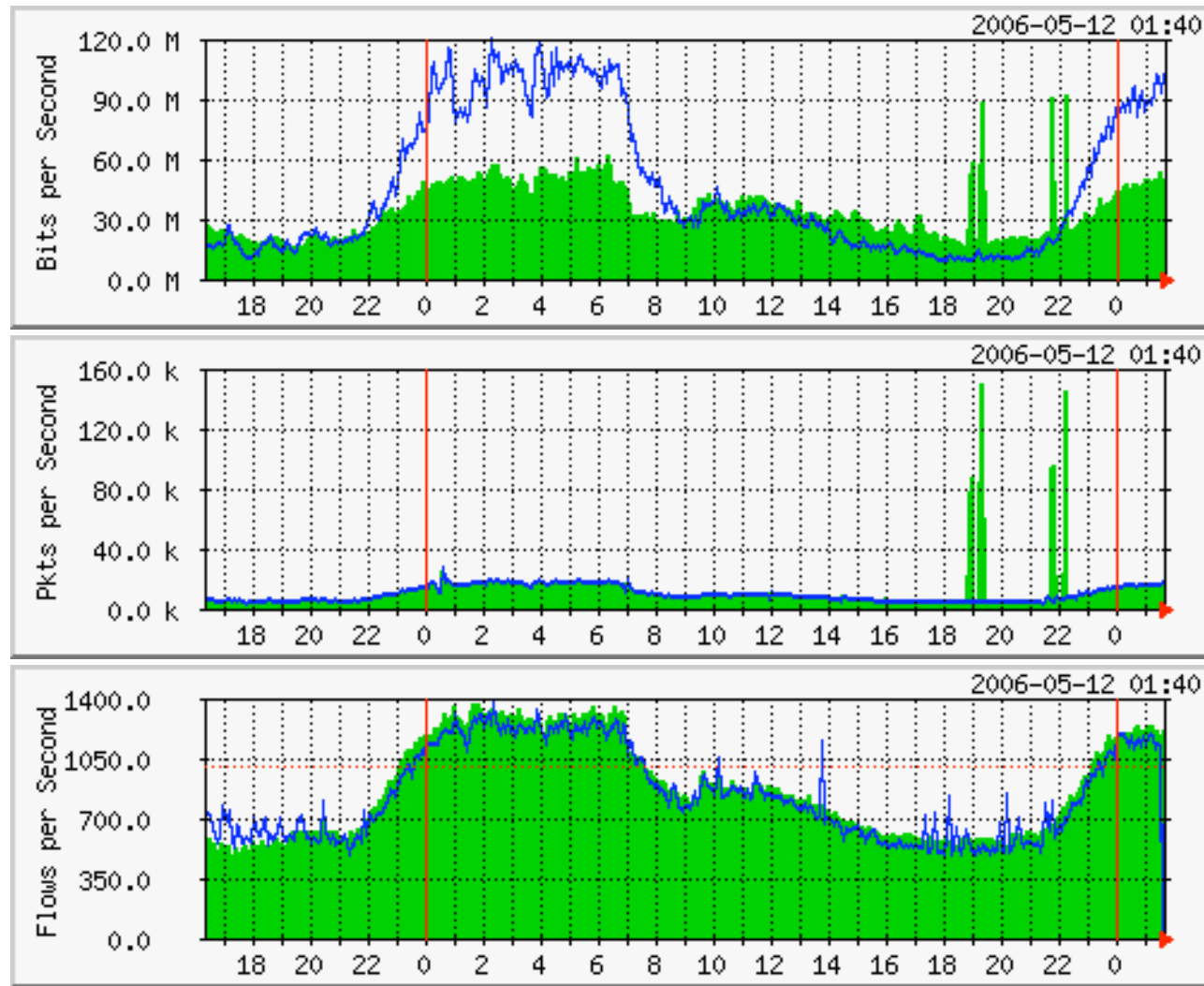
- Flow based accounting can be a good supplement to SNMP based accounting.

SNMP and flows



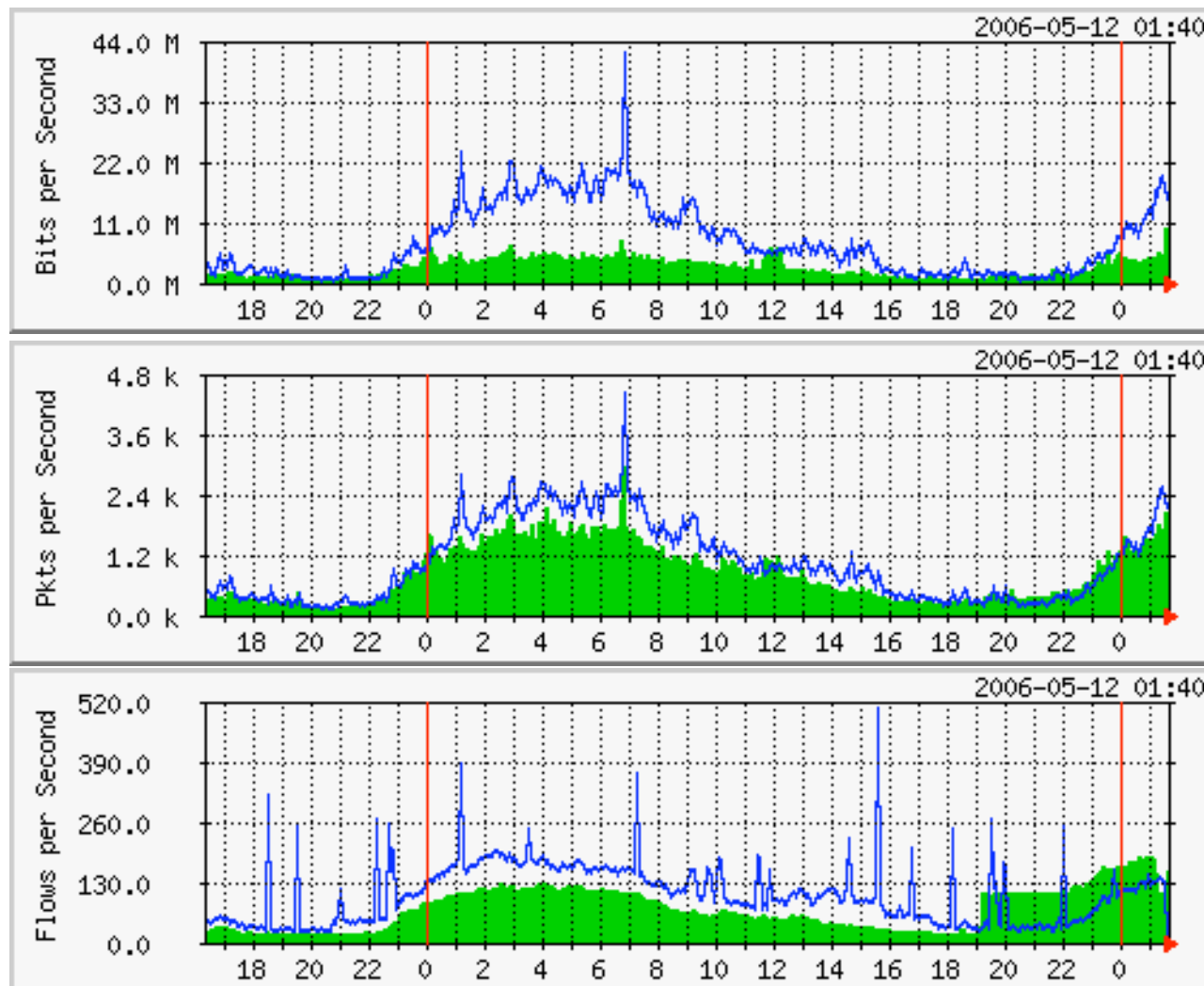
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SNMP and flows (cont'd)



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SNMP and flows (cont'd)



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Future directions

- IPFIX (IP Flow Information Exchange)
 - To make the flow format uniform and make it easier to write analysis tools
 - <http://www1.ietf.org/html.charters/ipfix-charter.html>
 - [Requirements for IP Flow Information Export \(RFC 3917\)](#)
 - Evaluation of Candidate Protocols for IP Flow Information Export (IPFIX) (RFC 3955)
 - RFC 5101, 5153, 5472

References

- Flow-tools:

<http://www.splintered.net/sw/flow-tools>

- IETF standards effort:

<http://www.ietf.org/html.charters/ipfix-charter.html>

References

- Abilene NetFlow Internet2 page
<http://abilene-netflow.itec.oar.net/>
- Flow-tools mailing list:
flow-tools@splintered.net
- Cisco Centric Open Source Community
<http://cosi-nms.sourceforge.net/related.html>

References

- <http://ensight.eos.nasa.gov/FlowViewer/>
- <http://nfsen.sourceforge.net/>
- <http://www.netflowdashboard.com/>