FASTNETMON

Network Telemetry on modern routers

Hello

I'm a software engineer with passion in computer networks and CTO / co-founder of FastNetMon LTD, London, UK

Ways to contact me

- linkedin.com/in/podintsov
- github.com/pavel-odintsov
- twitter.com/odintsov_pavel
- IRC, Libera Chat, pavel_odintsov
- pavel@fastnetmon.com

Disclaimer

None of the issues covered on this presentation are caused by vendor's implementation. All of them are directly or indirectly caused by design of underlying protocols or standards.

Network telemetry on modern routers

- Netflow v5, v9
- IPFIX
- sFlow v5
- Port mirror
- Sampled port mirror (including GRE option)
- Raw headers over IPFIX or Netflow v9

Netflow v5

Protocol design: header

Bytes	Contents	Description
0-1	version	NetFlow export format version number
2-3	count	Number of flows exported in this packet (1-30)
4-7	SysUptime	Current time in milliseconds since the device booted
8-11, 12-15	unix_secs, unix_nsecs	Current count of seconds / nanosec since 1970
16-19	flow_sequence	Sequence counter of total flows seen
20	engine_type	Type of flow-switching engine
21	engine_id	Slot number of the flow-switching engine
22-23	sampling_interval	2 bits sampling mode and 14 bits sampling value

https://www.cisco.com/c/en/us/td/docs/net_mgmt/netflow_collection_engine/3-6/user/guide/format.html

Protocol design: flows, part 1

0-3	srcaddr	Source IP address
4-7	dstaddr	Destination IP address
8-11	nexthop	IP address of next hop router
12-13	input	SNMP index of input interface
14-15	output	SNMP index of output interface
16-19	dPkts	Packets in the flow
20-23	dOctets	Total number of Layer 3 bytes
24-27	First	SysUptime at start of flow
28-31	Last	SysUptime at for end of flow
32-33	srcport	TCP/UDP source port number or equivalent
34-35	dstport	TCP/UDP destination port number or equivalent

Protocol design: flows, part 2

36	pad1	Unused (zero) bytes
37	tcp_flags	Cumulative OR of TCP flags
38	prot	IP protocol type (TCP = 6; UDP = 17)
39	tos	IP type of service (ToS)
40-41	src_as	ASN of the source
42-43	dst_as	ASN of the destination
44	src_mask	Source address prefix mask bits
45	dst_mask	Destination address prefix mask bits
46-47	pad2	Unused (zero) bytes

Benefits of Netflow v5

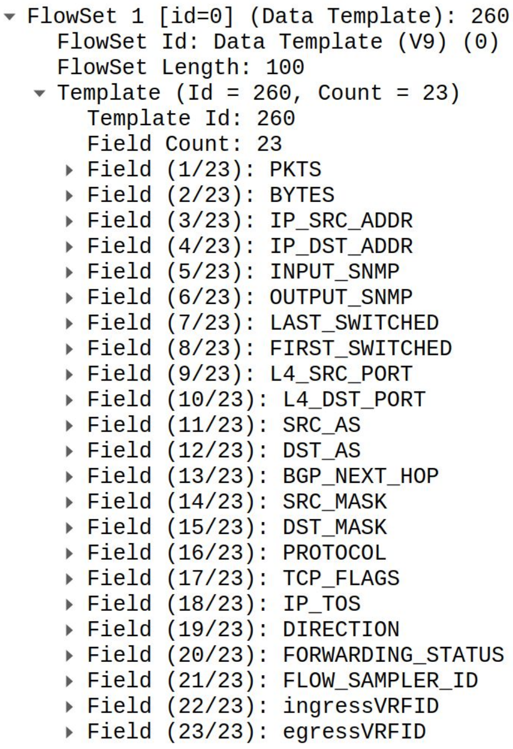
- Supported even by very old equipment
- Simple parser implementation due to static structures
- Simple sampling rate encoding (available in each packet)

Issues with Netflow v5

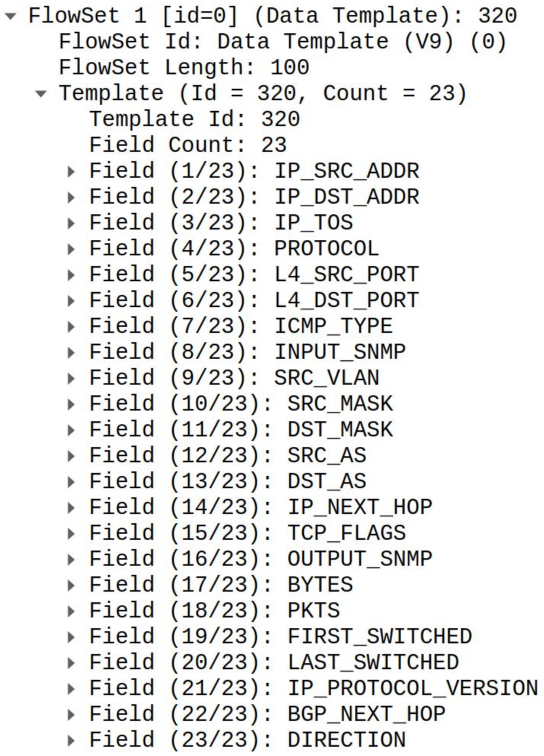
- Official standard does not exist
- Lack of IPv6 support
- Sampling cannot exceed 1:16384 due to 14bit
- Impossible to extend due to static structures
- Flow delays in range of 1-30 seconds before export

Netflow v9

Protocol design: template based

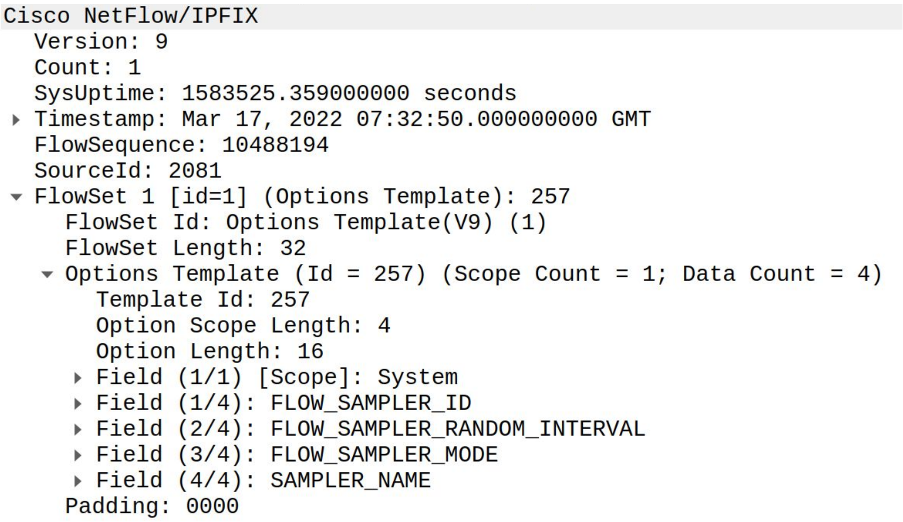


```
▾ FlowSet 1 [id=0] (Data Template): 260
    FlowSet Id: Data Template (V9) (0)
    FlowSet Length: 100
  ▾ Template (Id = 260, Count = 23)
      Template Id: 260
      Field Count: 23
    ▸ Field (1/23): PKTS
    ▸ Field (2/23): BYTES
    ▸ Field (3/23): IP_SRC_ADDR
    ▸ Field (4/23): IP_DST_ADDR
    ▸ Field (5/23): INPUT_SNMP
    ▸ Field (6/23): OUTPUT_SNMP
    ▸ Field (7/23): LAST_SWITCHED
    ▸ Field (8/23): FIRST_SWITCHED
    ▸ Field (9/23): L4_SRC_PORT
    ▸ Field (10/23): L4_DST_PORT
    ▸ Field (11/23): SRC_AS
    ▸ Field (12/23): DST_AS
    ▸ Field (13/23): BGP_NEXT_HOP
    ▸ Field (14/23): SRC_MASK
    ▸ Field (15/23): DST_MASK
    ▸ Field (16/23): PROTOCOL
    ▸ Field (17/23): TCP_FLAGS
    ▸ Field (18/23): IP_TOS
    ▸ Field (19/23): DIRECTION
    ▸ Field (20/23): FORWARDING_STATUS
    ▸ Field (21/23): FLOW_SAMPLER_ID
    ▸ Field (22/23): ingressVRFID
    ▸ Field (23/23): egressVRFID
```

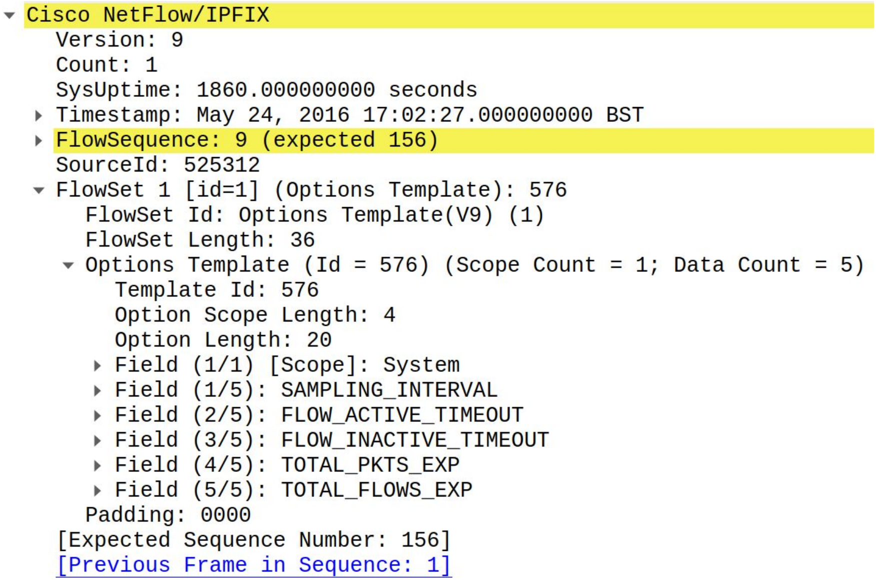


```
▾ FlowSet 1 [id=0] (Data Template): 320
    FlowSet Id: Data Template (V9) (0)
    FlowSet Length: 100
  ▾ Template (Id = 320, Count = 23)
      Template Id: 320
      Field Count: 23
    ▸ Field (1/23): IP_SRC_ADDR
    ▸ Field (2/23): IP_DST_ADDR
    ▸ Field (3/23): IP_TOS
    ▸ Field (4/23): PROTOCOL
    ▸ Field (5/23): L4_SRC_PORT
    ▸ Field (6/23): L4_DST_PORT
    ▸ Field (7/23): ICMP_TYPE
    ▸ Field (8/23): INPUT_SNMP
    ▸ Field (9/23): SRC_VLAN
    ▸ Field (10/23): SRC_MASK
    ▸ Field (11/23): DST_MASK
    ▸ Field (12/23): SRC_AS
    ▸ Field (13/23): DST_AS
    ▸ Field (14/23): IP_NEXT_HOP
    ▸ Field (15/23): TCP_FLAGS
    ▸ Field (16/23): OUTPUT_SNMP
    ▸ Field (17/23): BYTES
    ▸ Field (18/23): PKTS
    ▸ Field (19/23): FIRST_SWITCHED
    ▸ Field (20/23): LAST_SWITCHED
    ▸ Field (21/23): IP_PROTOCOL_VERSION
    ▸ Field (22/23): BGP_NEXT_HOP
    ▸ Field (23/23): DIRECTION
```

Protocol design: sampling encoding



```
Cisco NetFlow/IPFIX
    Version: 9
    Count: 1
    SysUptime: 1583525.359000000 seconds
  ▸ Timestamp: Mar 17, 2022 07:32:50.000000000 GMT
    FlowSequence: 10488194
    SourceId: 2081
  ▾ FlowSet 1 [id=1] (Options Template): 257
        FlowSet Id: Options Template(V9) (1)
        FlowSet Length: 32
      ▾ Options Template (Id = 257) (Scope Count = 1; Data Count = 4)
            Template Id: 257
            Option Scope Length: 4
            Option Length: 16
          ▸ Field (1/1) [Scope]: System
          ▸ Field (1/4): FLOW_SAMPLER_ID
          ▸ Field (2/4): FLOW_SAMPLER_RANDOM_INTERVAL
          ▸ Field (3/4): FLOW_SAMPLER_MODE
          ▸ Field (4/4): SAMPLER_NAME
        Padding: 0000
```



```
▾ Cisco NetFlow/IPFIX
      Version: 9
      Count: 1
      SysUptime: 1860.000000000 seconds
    ▸ Timestamp: May 24, 2016 17:02:27.000000000 BST
    ▸ FlowSequence: 9 (expected 156)
      SourceId: 525312
    ▾ FlowSet 1 [id=1] (Options Template): 576
          FlowSet Id: Options Template(V9) (1)
          FlowSet Length: 36
        ▾ Options Template (Id = 576) (Scope Count = 1; Data Count = 5)
              Template Id: 576
              Option Scope Length: 4
              Option Length: 20
            ▸ Field (1/1) [Scope]: System
            ▸ Field (1/5): SAMPLING_INTERVAL
            ▸ Field (2/5): FLOW_ACTIVE_TIMEOUT
            ▸ Field (3/5): FLOW_INACTIVE_TIMEOUT
            ▸ Field (4/5): TOTAL_PKTS_EXP
            ▸ Field (5/5): TOTAL_FLOWS_EXP
          Padding: 0000
      [Expected Sequence Number: 156]
      [Previous Frame in Sequence: 1]
```

Benefits of Netflow v9, part 1

- Supported by almost all vendors
- IPv6 support
- Can carry sampling rate in any range
- Well documented and most of the implementations are reasonably close to original implementation

Benefits of Netflow v9, part 2

- Offers almost unlimited extensibility
- Some fields are documented as part of IPFIX RFCs

Issues with Netflow v9, part 1

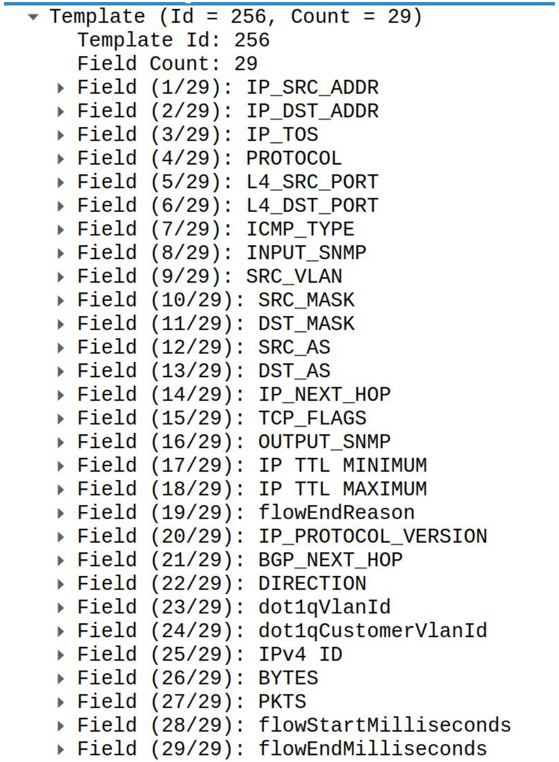
- Complicated data encoding for collector
- Sampling encoding is complicated and vendor specific
- Issues with flow duration encoding on some vendors
- Official standard does not exist

Issues with Netflow v9, part 2

- Tricky encoding for dropped by BGP Flow Spec traffic
- Lack of agreement between vendors about new fields
- Limited by subset of fields selected by vendor
- Flow export delay in range of 1-30 seconds

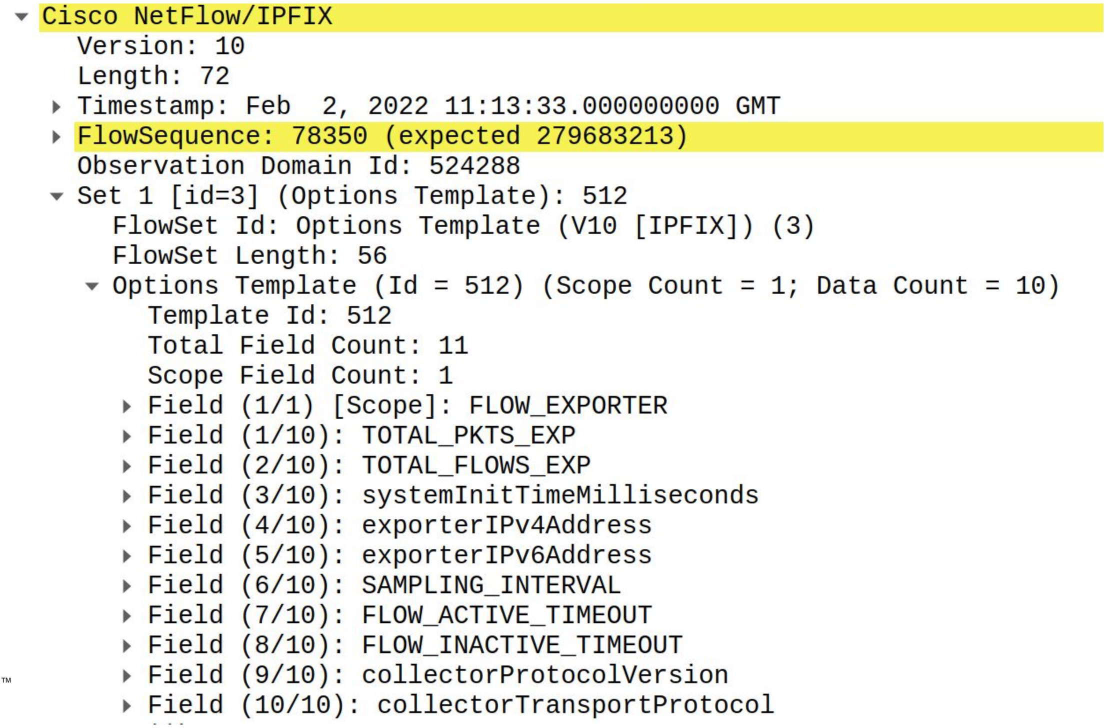
IPFIX

Protocol design: template based



```
▾ Template (Id = 256, Count = 29)
    Template Id: 256
    Field Count: 29
  ▸ Field (1/29): IP_SRC_ADDR
  ▸ Field (2/29): IP_DST_ADDR
  ▸ Field (3/29): IP_TOS
  ▸ Field (4/29): PROTOCOL
  ▸ Field (5/29): L4_SRC_PORT
  ▸ Field (6/29): L4_DST_PORT
  ▸ Field (7/29): ICMP_TYPE
  ▸ Field (8/29): INPUT_SNMP
  ▸ Field (9/29): SRC_VLAN
  ▸ Field (10/29): SRC_MASK
  ▸ Field (11/29): DST_MASK
  ▸ Field (12/29): SRC_AS
  ▸ Field (13/29): DST_AS
  ▸ Field (14/29): IP_NEXT_HOP
  ▸ Field (15/29): TCP_FLAGS
  ▸ Field (16/29): OUTPUT_SNMP
  ▸ Field (17/29): IP TTL MINIMUM
  ▸ Field (18/29): IP TTL MAXIMUM
  ▸ Field (19/29): flowEndReason
  ▸ Field (20/29): IP_PROTOCOL_VERSION
  ▸ Field (21/29): BGP_NEXT_HOP
  ▸ Field (22/29): DIRECTION
  ▸ Field (23/29): dot1qVlanId
  ▸ Field (24/29): dot1qCustomerVlanId
  ▸ Field (25/29): IPv4 ID
  ▸ Field (26/29): BYTES
  ▸ Field (27/29): PKTS
  ▸ Field (28/29): flowStartMilliseconds
  ▸ Field (29/29): flowEndMilliseconds
```

Protocol design: sampling encoding



```
▾ Cisco NetFlow/IPFIX
    Version: 10
    Length: 72
  ▸ Timestamp: Feb  2, 2022 11:13:33.000000000 GMT
  ▸ FlowSequence: 78350 (expected 279683213)
    Observation Domain Id: 524288
  ▾ Set 1 [id=3] (Options Template): 512
      FlowSet Id: Options Template (V10 [IPFIX]) (3)
      FlowSet Length: 56
    ▾ Options Template (Id = 512) (Scope Count = 1; Data Count = 10)
        Template Id: 512
        Total Field Count: 11
        Scope Field Count: 1
      ▸ Field (1/1) [Scope]: FLOW_EXPORTER
      ▸ Field (1/10): TOTAL_PKTS_EXP
      ▸ Field (2/10): TOTAL_FLOWS_EXP
      ▸ Field (3/10): systemInitTimeMilliseconds
      ▸ Field (4/10): exporterIPv4Address
      ▸ Field (5/10): exporterIPv6Address
      ▸ Field (6/10): SAMPLING_INTERVAL
      ▸ Field (7/10): FLOW_ACTIVE_TIMEOUT
      ▸ Field (8/10): FLOW_INACTIVE_TIMEOUT
      ▸ Field (9/10): collectorProtocolVersion
      ▸ Field (10/10): collectorTransportProtocol
```

Benefits of IPFIX

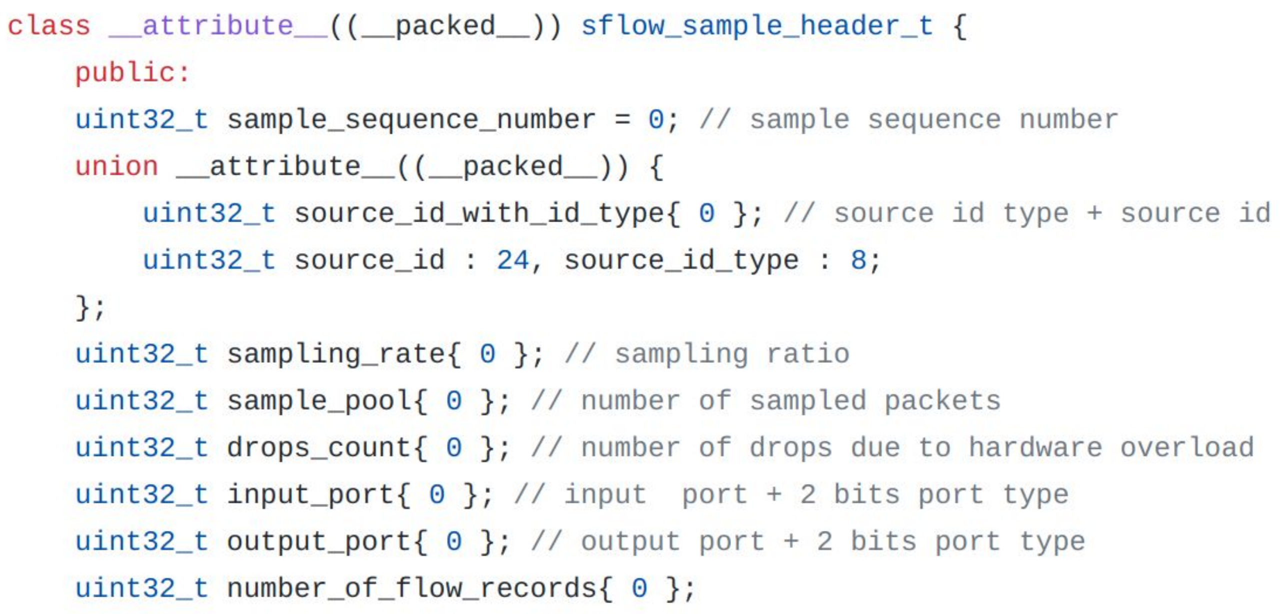
- Well documented RFC standard
- IPv6 support
- Unlimited flexibility

Issues of IPFIX

- Complicated encoding for collector
- Tricky encoding for dropped by BGP Flow Spec traffic (some vendors)
- Many vendors still do not support it
- Limited by subset of fields selected by vendor

sFlow

Protocol design: meta plus header



```
class __attribute__((__packed__)) sflow_sample_header_t {
    public:
    uint32_t sample_sequence_number = 0; // sample sequence number
    union __attribute__((__packed__)) {
        uint32_t source_id_with_id_type{ 0 }; // source id type + source id
        uint32_t source_id : 24, source_id_type : 8;
    };
    uint32_t sampling_rate{ 0 }; // sampling ratio
    uint32_t sample_pool{ 0 }; // number of sampled packets
    uint32_t drops_count{ 0 }; // number of drops due to hardware overload
    uint32_t input_port{ 0 }; // input  port + 2 bits port type
    uint32_t output_port{ 0 }; // output port + 2 bits port type
    uint32_t number_of_flow_records{ 0 };
```

Benefits of sFlow v5

- Almost instant export (< 1 second)
- Provides access to packet header
- Simple sampling encoding

Issues with sFlow v5, part 1

- Sampling rate control is broken on almost all vendors
- Sampling rate selection process is tricky to grasp
- Traffic parsing is complicated and very hard to do in secure manner (IPv6 headers, MPLS, QnQ)

Issues with sFlow v5, part 2

- Lack of useful meta information (MPLS tags, VRF IDs, next hop)
- Long list of constraints and limitations from routers side (lack of LAG support for example)

Port mirror

Benefits of port mirror

- Complete access to all information in packet
- Supported by almost any router

Issues of port mirror

- Requires a lot of CPU time for collector to parse traffic
- Lack of meta information (ASN, VRF IDs, source and destinations ports)
- Requires spare ports on router
- Requires high performance network cards on collector

Sampled port mirror

Benefits of sampled port mirror

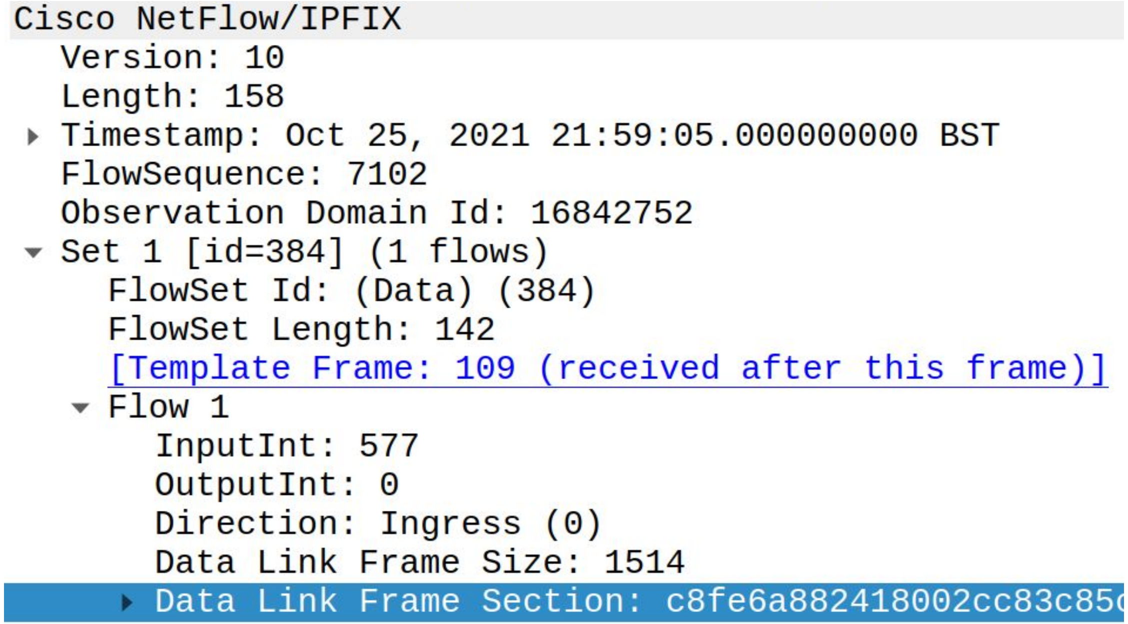
- Requires less port capacity
- Requires way less CPU on collector
- No need in high performance NICs

Issues of sampled port mirror

- Many vendors do not support it
- No way to get sampling rate, needs static setup
- Lack of meta information (ASN, VRF IDs, source and destinations ports)
- GRE requires MTU tuning to deliver 1500b+ packets

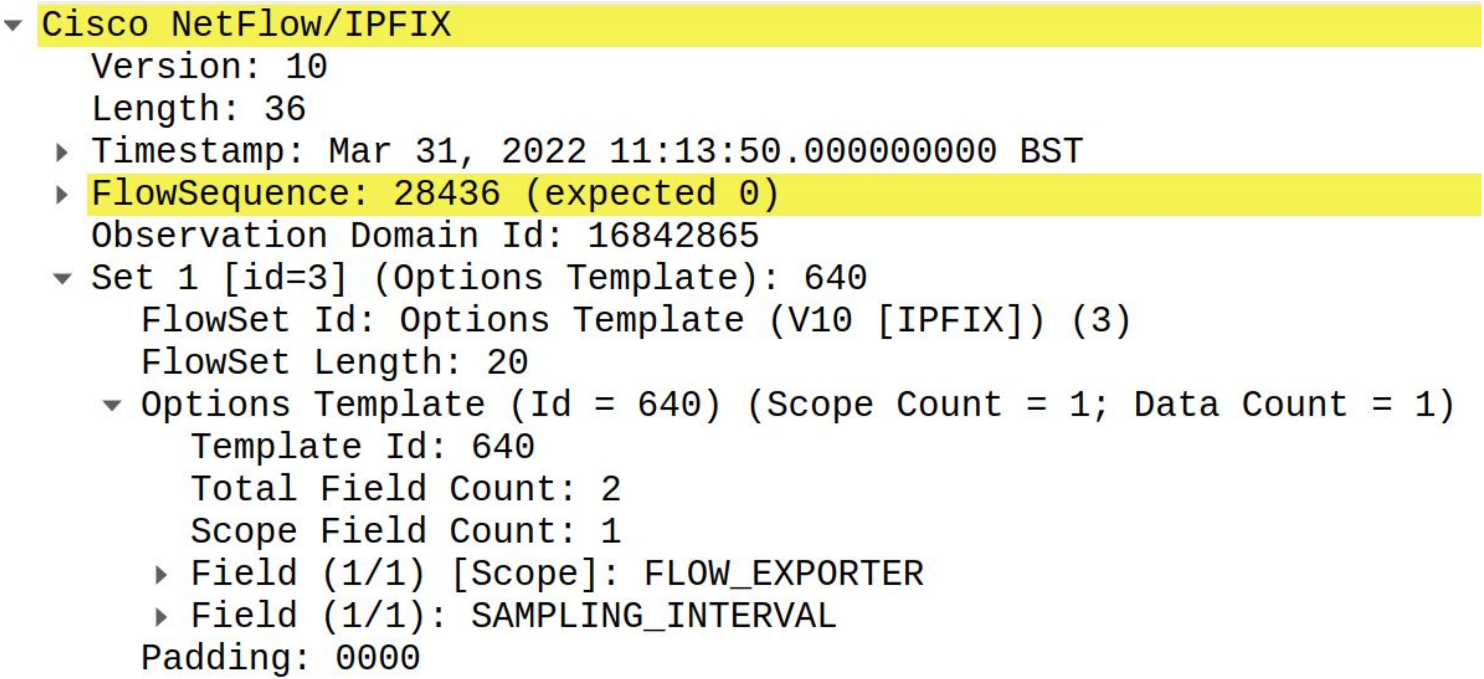
Payload via IPFIX or Netflow v9

IPFIX as transport for traffic headers



```
Cisco NetFlow/IPFIX
    Version: 10
    Length: 158
  ▸ Timestamp: Oct 25, 2021 21:59:05.000000000 BST
    FlowSequence: 7102
    Observation Domain Id: 16842752
  ▾ Set 1 [id=384] (1 flows)
        FlowSet Id: (Data) (384)
        FlowSet Length: 142
        [Template Frame: 109 (received after this frame)]
      ▾ Flow 1
            InputInt: 577
            OutputInt: 0
            Direction: Ingress (0)
            Data Link Frame Size: 1514
          ▸ Data Link Frame Section: c8fe6a882418002cc83c85
```

IPFIX options as transport for sampling



```
▾ Cisco NetFlow/IPFIX
    Version: 10
    Length: 36
  ▸ Timestamp: Mar 31, 2022 11:13:50.000000000 BST
  ▸ FlowSequence: 28436 (expected 0)
    Observation Domain Id: 16842865
  ▾ Set 1 [id=3] (Options Template): 640
      FlowSet Id: Options Template (V10 [IPFIX]) (3)
      FlowSet Length: 20
    ▾ Options Template (Id = 640) (Scope Count = 1; Data Count = 1)
        Template Id: 640
        Total Field Count: 2
        Scope Field Count: 1
      ▸ Field (1/1) [Scope]: FLOW_EXPORTER
      ▸ Field (1/1): SAMPLING_INTERVAL
      Padding: 0000
```

Benefits of payload over IPFIX / Netflow

- That best and most capable protocol on market
- Almost instant traffic delivery
- Well defined format for sampling rate encoding
- Provides all information available in header
- Provides meta information (interface numbers, direction)
- Can be extended easily

Issues with payload over IPFIX / Netflow

- Only few vendors support it
- Extremely high complexity of integration for collector side
- Limited by set of fields provided by vendor

THANKS!

- pavel@fastnetmon.com
- linkedin.com/in/podintsov