Scientific Network Tags: Packet and Flow Marking

scitags.org

Marian Babik (CERN), Shawn McKee (Univ. of Michigan)
net-wg@cern.ch | www.scitags.org
On behalf of the Research Networking Technical Working Group
GridPP Technical Meeting

History

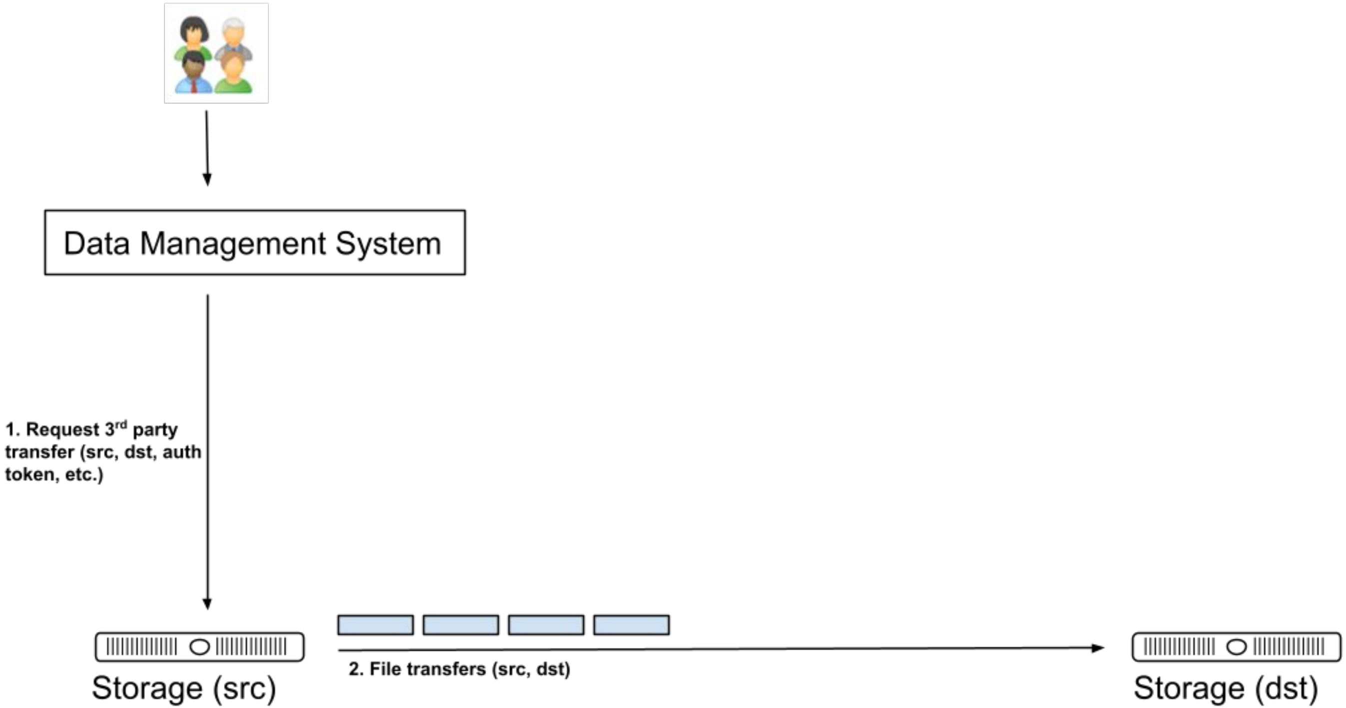
- HEPiX Network Functions Virtualisation Working Group
    - Working Group Report was published at the end of 2019 with three chapters
        - Could Native DC Networking
        - Programmable Wide Area Networks
        - Proposed Areas of Future Work
- LHCOPN/LHCONE workshop (spring 2020)
    - Requirements on networks from the WLCG experiments
- Research Networking Technical Working Group
    - Formed after the workshop in response to the requirements discussion
    - 95 members from ~ 50 organisations have joined
    - Three main areas of work:
        - Packet and Flow Marking - viewed as the appropriate first step; regular meetings every ~2 months since summer 2020
            - Packet Marking Document
                - Outlines available technologies, standards and stakeholders perspectives
                - This has led to Scientific Network Tags (scitags) initiative, which is presented today
        - Traffic Shaping
        - Network Orchestration - followed up by GNA-G, SENSE and FABRIC

Motivation

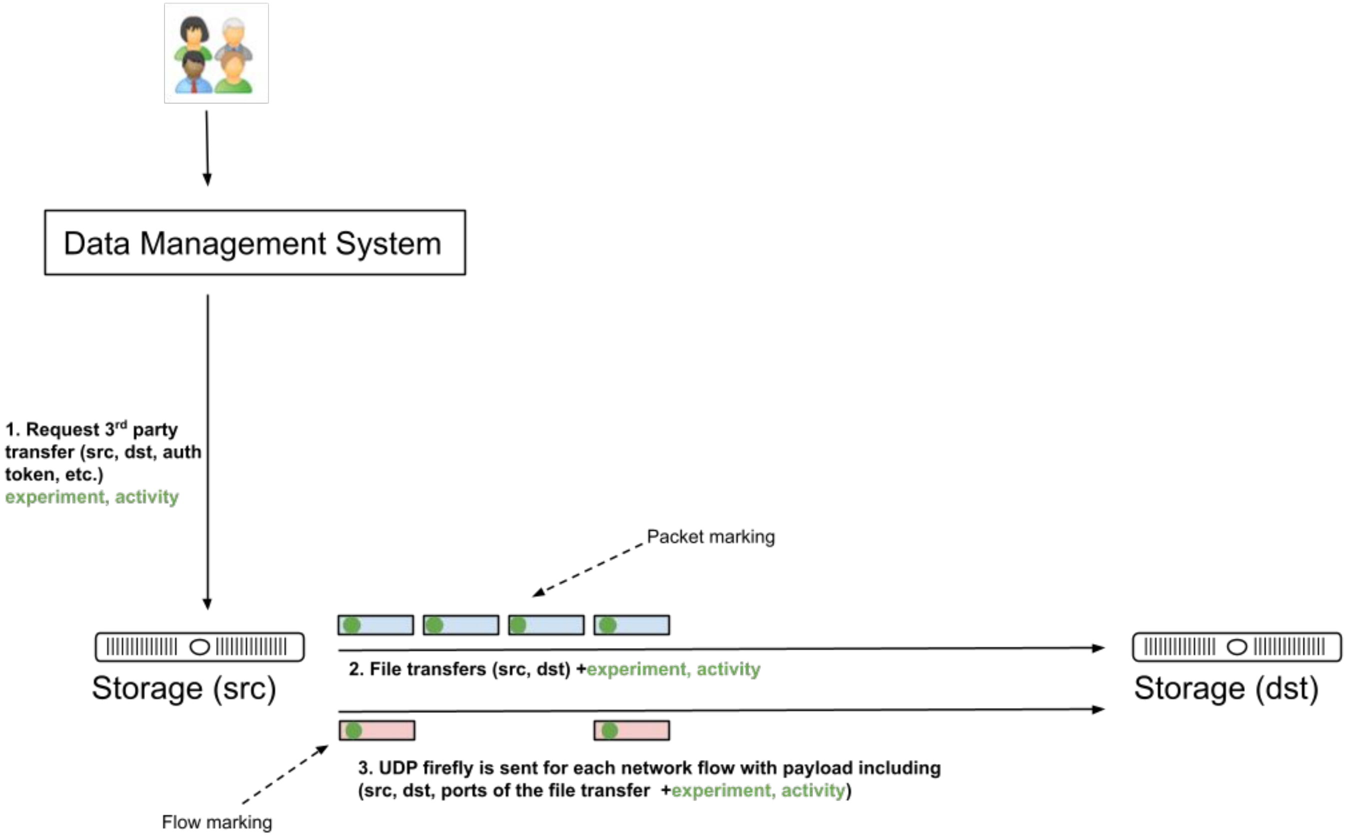
- Networks are becoming more programmable and capable with technologies such as P4, SDN, virtualisation, eBPF, etc.
- But with less and less context about the traffic they carry
  - Cloud deployments, Kubernetes, encryption, tunneling, privacy, etc.
- Understanding scientific traffic flows in detail is critical for understanding how our complex systems are actually using the network.
  - Current monitoring/logging tell us where data flows start and end, but is unable to understand the data in flight.
  - Dedicated L3VPNs can be created to track high throughput science domains, but with more domains requiring high throughput this will become expensive, it won't scale, won't work at big sites having to support multiple domains at the same time
- In general the monitoring we have is experiment specific and very difficult to correlate with what is happening in the network. We suggest this is a general problem for users of the Research and Education Networks (RENs)

Scientific Network Tags (scitags) is an initiative promoting identification of the science domains and their high-level activities at the network level.

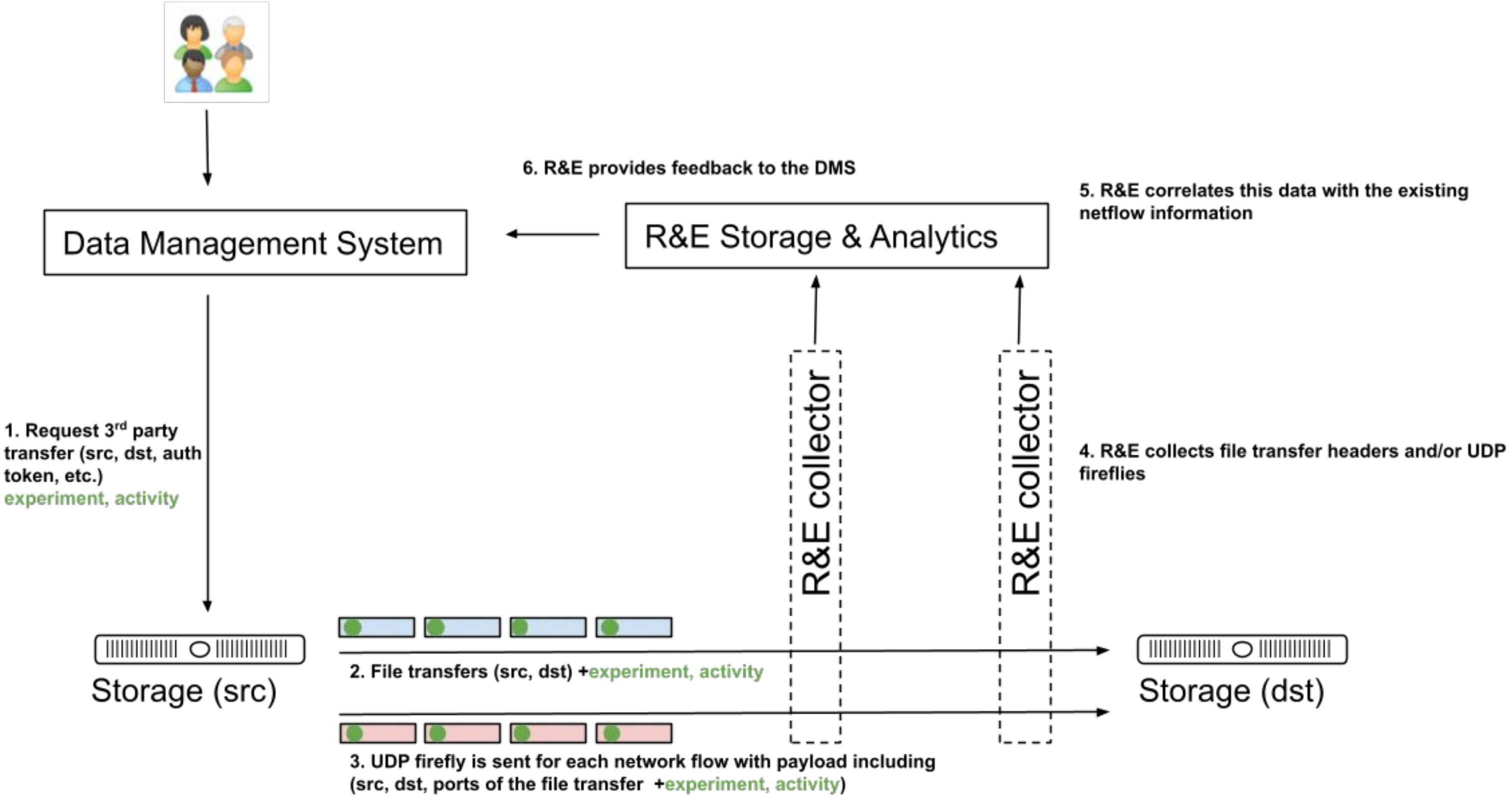
How scitags work



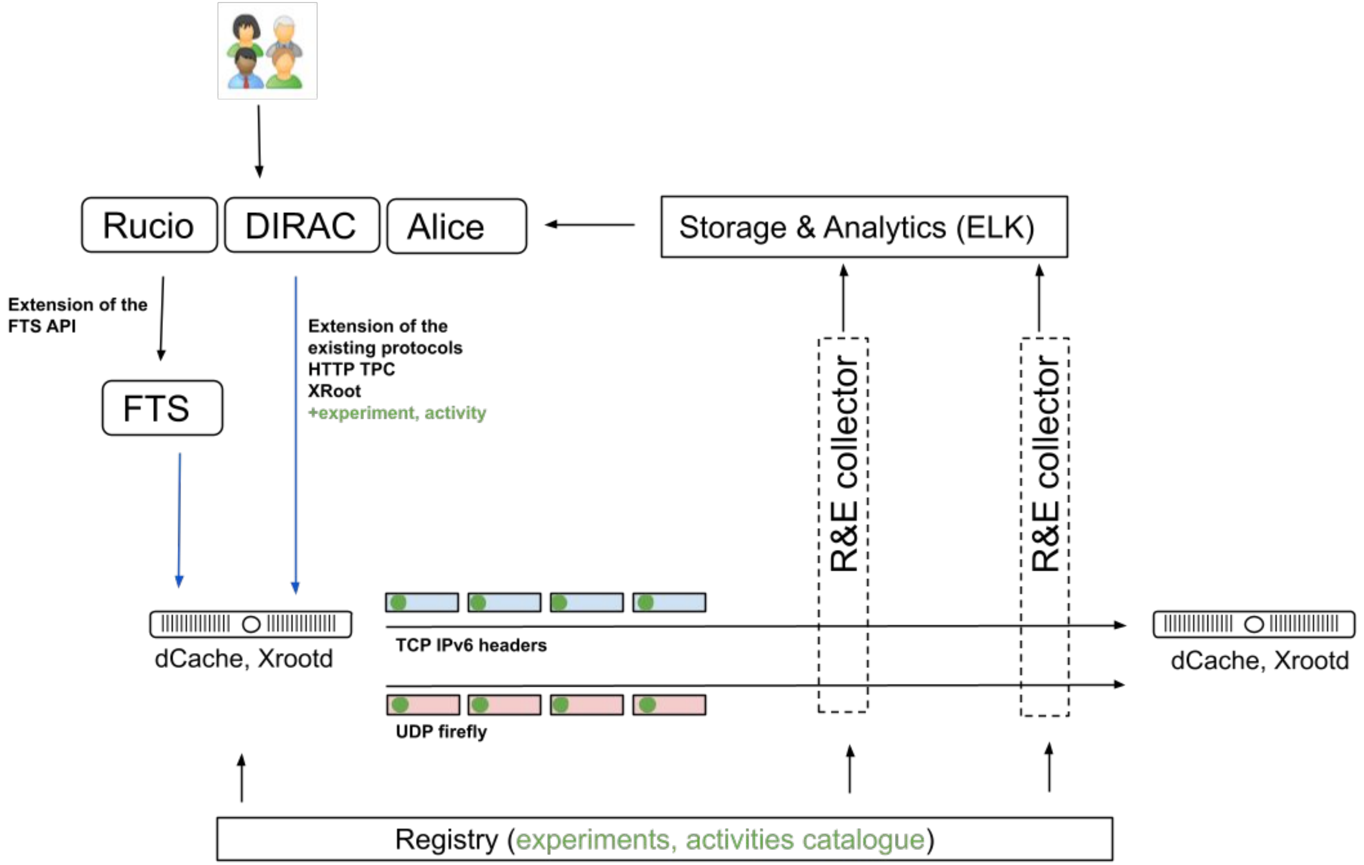
How scitags work



How scitags work



Scitags Architecture



Concepts

- Marking is based on two different approaches
  - **Flow marking** using UDP fireflies (works for both IPv4 and IPv6)
  - **Packet marking** using IPv6 flow label and/or header extensions
- Both carry **flow identifier**, which at present is an encoded representation of experiment/science domain and activity
  - For UDP fireflies flow id can be extended with other fields in the future
  - For packet marking the space is restricted due to number of bits available in the headers
- Experiments and activities need to be registered prior to their usage
  - Registry serves this purpose and ensures RENs and DDMs have consistent view
- Designed to work with proxies, cached proxies and private networks
- Generators, collectors, storage and analytics can evolve independently

Recent Updates

- New domain and web site (www.scitags.org)
- New github organisation (https://github.com/scitags)
  - Serves www.scitags.org via github pages
- Flow and Packet Marking Technical Specification
- Implementation
  - Flow service (flowd, https://github.com/scitags/flowd)
  - Initial implementation in Xrootd
- Participation in the Data Challenge

Technical Specification Updates

- Content
    - Packet and Flow Marking Definitions
    - Flow Service
    - Flow Identifier Lifecycle
        - Provides overview of the expected functionality from each storage/transfer component
        - Proposes extension to Xroot and HTTP TPC protocols
    - Prototype Implementation Plan

- Protocols updates
    - Xroot protocol extension with <scitag.flow> attribute to pass flow identifier as part of the URL
    - HTTP TPC protocol extension (passing flow identifier as part of the HTTP headers)
- UDP firefly packet specification
    - Payload is a syslog message that conforms to RFC5424
        - Last part of the syslog message is a structured data specification (in JSON)
        - JSON schema for the structured data is also available
- Flow registry specification
    - Maps experiments and activities to IDs
    - Draft JSON schema, which is already used in the API
    - https://www.scitags.org/api.json

Implementation

- **Flow service (flowd)** - developed to help test and validate the approach
  - Provides reference implementation of the technical specification
  - Storage systems can either provide their own implementation or use flowd
  - Written in python, runs as Linux service (integrates with systemd/journal, supports CC8/C8/docker)
- Provides **pluggable** system to test different flow/packet marking strategies.
  - Currently supports flow marking (UDP fireflies) via sampling plugin (netstat) or storage API
  - Sampling plugin using netlink instead of netstat is also in development
    - Can provide additional information per connection (TCP cong. algo, RTT/RTO, CWND, bytes sent/rcvd)
  - Possibility to combine storage API to mark start/end flow and sampling plugin to add additional information
    - This might be needed for storages that don't have access to the underlying socket interface

- **XRoot 5.4.0 release**
  - Full implementation of the UDP firefly spec (marks start and end of each flow)
  - UDPs fireflies are sent to a dedicated endpoint
  - Supports different options to detect flow identifiers (both experiments and activities)
  - Connects to flow registry API
- Initial implementation of packet marking in XRoot also exists but requires further testing

WLCG Data Challenge

- Aim was to test and validate our approach in gradual steps, our initial goals:
  - Test flow service deployment directly on the site’s storages (done)
  - Generate UDP fireflies based on real traffic (done)
  - Capture UDP packets (initially using a dedicated endpoint) (done)
  - Understand how UDP firefly information can be correlated with R&E netflow data (on-going)
- Flow service (flowd) deployment
  - **Currently deployed at AGLT2, BNL, KIT, UNL and Caltech**
  - Runs directly on the storage nodes, uses netstat plugin
  - Generates UDP fireflies based on real traffic
- ESnet has setup a dedicated collector to capture the UDP fireflies
  - Will attempt to correlate them with their netflow data
- Results
  - Deployment, packet generation and collection worked fine
  - On-going - summary/results on the correlation with netflow

Plans

- Near-term objectives
  - Finalise validation and get feedback from ESnet correlation exercise
  - Extend testing to Xrootd using dedicated R&E collection endpoint(s) and partial-marking
    - Detect flow identifiers from storage path/url, activities from user role mapping
    - Test proxies, cached proxies, private networks (K8s)
  - Involve other storage systems (dCache, etc.); discuss possible design/implementation
  - Instrument Rucio/FTS to pass flow identifiers to the storages

- Continue with the validation and testing using the existing deployment
  - Improve existing prototypes based on the feedback from the initial DC tests

- Engage other R&Es and explore available technologies for collectors
  - Deploy additional collectors and perform R&D in the packet collectors
  - Improve existing data collection and analytics
- Test and validate ways to propagate flow identifiers
  - Engage experiments and data management systems
  - Validate, test protocol extensions and FTS integration
  - Explore other possibilities for flow identifier propagation, e.g. tokens
- R&D activities
  - Packet marking - further testing and validation is required for IPv6 flow label implementation.
  - Packet collectors - currently UDP fireflies are sent to a dedicated collector(s). R&D is needed to understand how to run generic collectors (that would capture UDP fireflies from real traffic).

Questions, comments ?

Draft Technical Specification available; Packet Marking Overview

Prototype testing as part of the WLCG Data Challenges effort in collaboration with ESnet

Prototype code of the flow service (flowd) implementing UDP fireflies

https://www.scitags.org

Backup slides

Packet Marking - IPv6

IPv6 header

Fixed header format

<table>
<tr><th>Offsets</th><th>Octet</th><th colspan="8">0</th><th colspan="8">1</th><th colspan="8">2</th><th colspan="8">3</th></tr>
<tr><th>Octet</th><th>Bit</th><th>0</th><th>1</th><th>2</th><th>3</th><th>4</th><th>5</th><th>6</th><th>7</th><th>8</th><th>9</th><th>10</th><th>11</th><th>12</th><th>13</th><th>14</th><th>15</th><th>16</th><th>17</th><th>18</th><th>19</th><th>20</th><th>21</th><th>22</th><th>23</th><th>24</th><th>25</th><th>26</th><th>27</th><th>28</th><th>29</th><th>30</th><th>31</th></tr>
<tr><th>0</th><th>0</th><td colspan="4">Version</td><td colspan="8">Traffic Class</td><td colspan="20">Flow Label</td></tr>
<tr><th>4</th><th>32</th><td colspan="16">Payload Length</td><td colspan="8">Next Header</td><td colspan="8">Hop Limit</td></tr>
<tr><th>8</th><th>64</th><td colspan="32" rowspan="4">Source Address</td></tr>
<tr><th>12</th><th>96</th></tr>
<tr><th>16</th><th>128</th></tr>
<tr><th>20</th><th>160</th></tr>
<tr><th>24</th><th>192</th><td colspan="32" rowspan="4">Destination Address</td></tr>
<tr><th>28</th><th>224</th></tr>
<tr><th>32</th><th>256</th></tr>
<tr><th>36</th><th>288</th></tr>
</table>

Extension headers

For more details and discussion of various trade-offs please refer to the [Packet Marking Document]

IPv6 Ext. headers: Dst Option

The Destination Options header is used to carry optional information that need be examined only by a packet's destination node(s)

- Allocated as one or more blocks of 8 octets; options are TLV encoded

Can be set/changed using standard socket interface (IPV6_DSTOPTS), but requires the options to be built first

- This can be done using standard *ancillary data functions*

Reading options is performed via socket interface (IPV6_2292PKTOPTIONS)

Hop-by-Hop Options **and** ***Destination Options*** **extension header format**

Offsets	Octet	0								1								2								3							
Octet	Bit	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31
0	0	*Next header*								*Header extension length*								*Options and padding*															
4	32	*Options and padding*																															
8	64	Optional: more *Options and padding*																															
12	96																																

IPv6 Flow Label

RFCs (10 hits)		
RFC 1809 **Using the Flow Label Field in IPv6**	1995-06 6 pages	Informational RFC
RFC 3595 *(was draft-ietf-ops-ipv6-flowlabel)* **Textual Conventions for IPv6 Flow Label**	2003-09 6 pages	Proposed Standard RFC
RFC 3697 *(was draft-ietf-ipv6-flow-label)* **IPv6 Flow Label Specification**	2004-03 9 pages	Proposed Standard RFC Obsoleted by RFC6437
RFC 6294 *(was draft-hu-flow-label-cases)* **Survey of Proposed Use Cases for the IPv6 Flow Label**	2011-06 18 pages	Informational RFC
RFC 6436 *(was draft-ietf-6man-flow-update)* **Rationale for Update to the IPv6 Flow Label Specification**	2011-11 13 pages	Informational RFC
RFC 6437 *(was draft-ietf-6man-flow-3697bis)* **IPv6 Flow Label Specification**	2011-11 15 pages	Proposed Standard RFC
RFC 6438 *(was draft-ietf-6man-flow-ecmp)* **Using the IPv6 Flow Label for Equal Cost Multipath Routing and Link Aggregation in Tunnels**	2011-11 9 pages	Proposed Standard RFC
RFC 7098 *(was draft-ietf-intarea-flow-label-balancing)* **Using the IPv6 Flow Label for Load Balancing in Server Farms**	2014-01 13 pages	Informational RFC

Document	Date	Status
Active Internet-Drafts (2 hits)		
draft-filsfils-6man-structured-flow-label-00 **Structured Flow Label**	2021-03-16 12 pages New	I-D Exists

Flow Label in Linux Kernel

- Ways to implement:
  - **Advanced socket interface**
    - Native socket interface, uses kernel network subsystem directly
    - Comes with limitations due to the complexity of the network stack
  - eBPF (XDP, **TC-BPF**)
    - Sandbox programs running via JIT directly in Linux Kernel
  - **Netfilter**
    - Kernel module using netfilter subsystem/hooks
  - DPDK, VPP - vendor-specific technologies
  - Software switches (Open vSwitch) - requires OpenFlow
  - SmartNICs (via P4, etc.)
    - Requires dedicated HW, but can be very useful for analytics

Linux Flow Label Implementation Status

OS/ **Kernel**	**Flow Label Socket Interface**					**Netfilter**	**TC-BPF**
	Flow UDP client server	Flow TCP client	Flow TCP server	Remote flow read	Flow label change on client		
CC7 (**3.10**)	client only	ok	--	--	--	ok	--
C8 (**4.15**)	ok	ok	ok	ok	--	ok	ok
5.8	ok	ok	ok	ok	--	ok	ok