Scientific Network Tags: Packet and Flow Marking

scitags.org

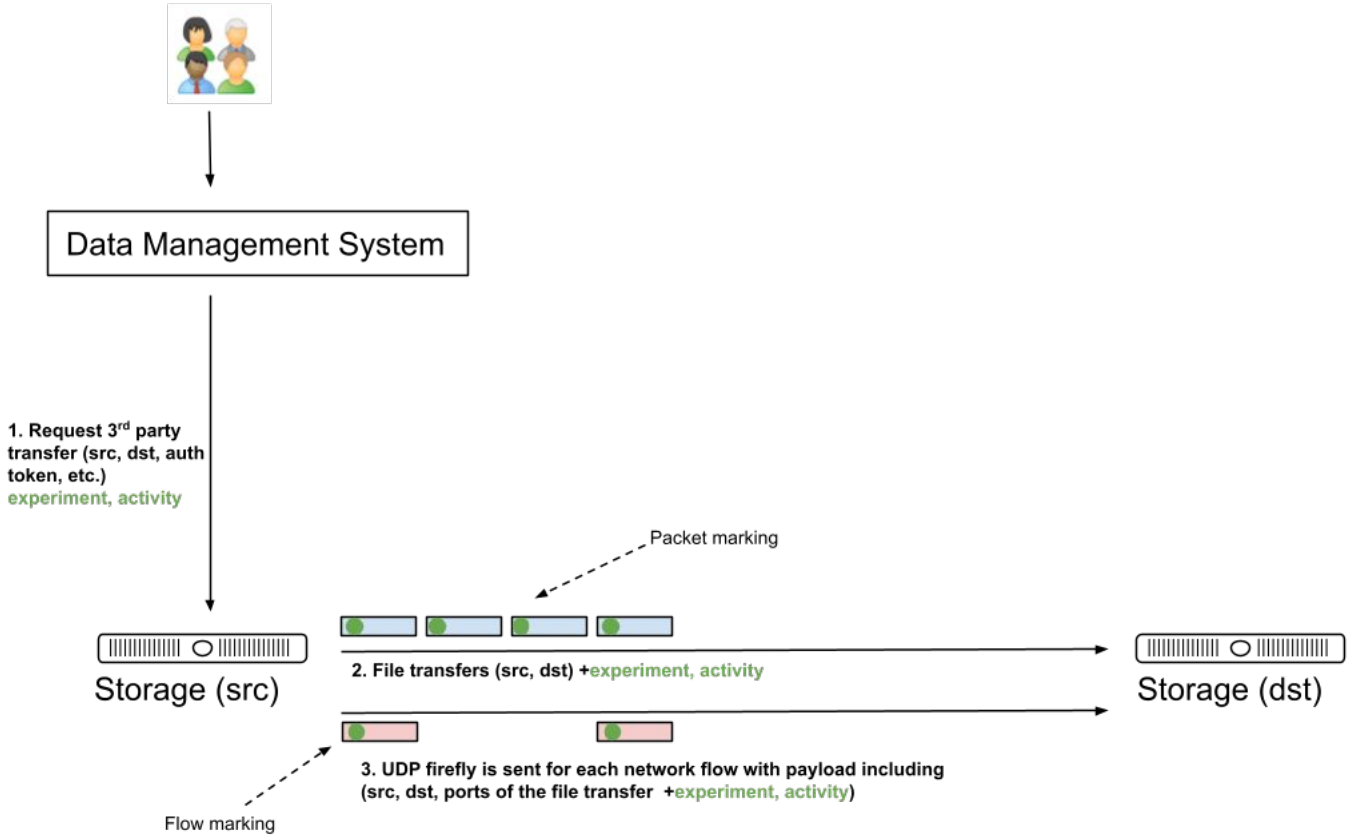
Marian Babik (CERN), Shawn McKee (Univ. of Michigan)
net-wg@cern.ch | www.scitags.org
On behalf of the Research Networking Technical Working Group
WLCG DOMA BDT Meeting

What and why

- Scientific Network Tags (scitags) is an initiative promoting identification of the science domains and their high-level activities at the network level.
  - One of the activity of the Research Networking Technical WG
    - 95 members from ~ 50 organisations
    - R&D in network technologies in the areas of network visibility (marking), throughput (shaping) and SDN (orchestration)

- Enable tracking and correlation of our transfers with Research and Education Network Providers (R&Es) network flow monitoring
- Experiments can better understand how their network flows perform along the path
  - Improve visibility into how network flows perform (per activity) within R&E segments
  - Get insights into how experiment is using the networks, get additional data from R&Es on behaviour of our transfers (traffic, paths, etc.)
- Sites can get visibility into how different network flows perform
  - Network monitoring per flow (with experiment/activity information)
    - E.g. RTT, retransmits, segment size, congestion window, etc. all per flow

How scitags work



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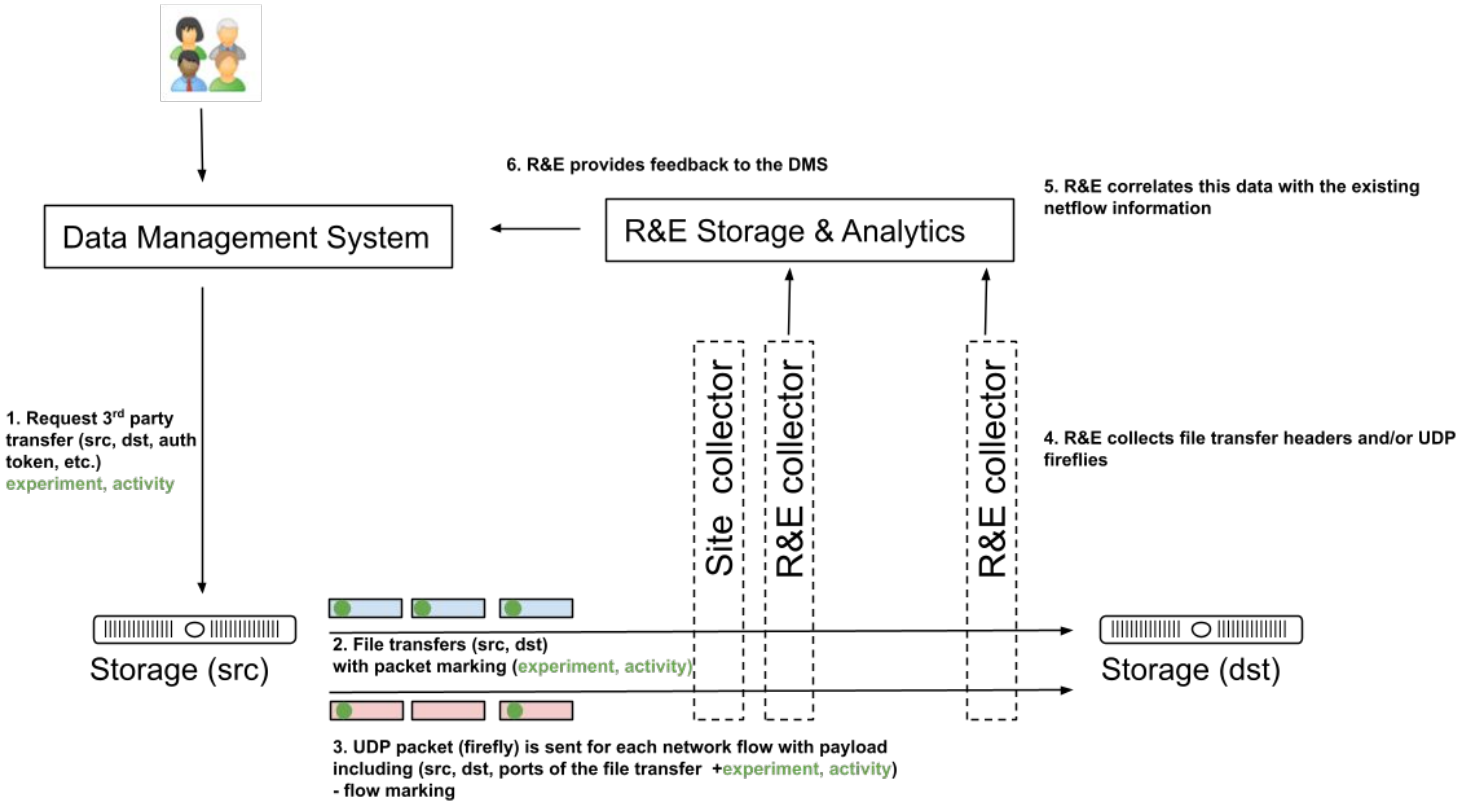

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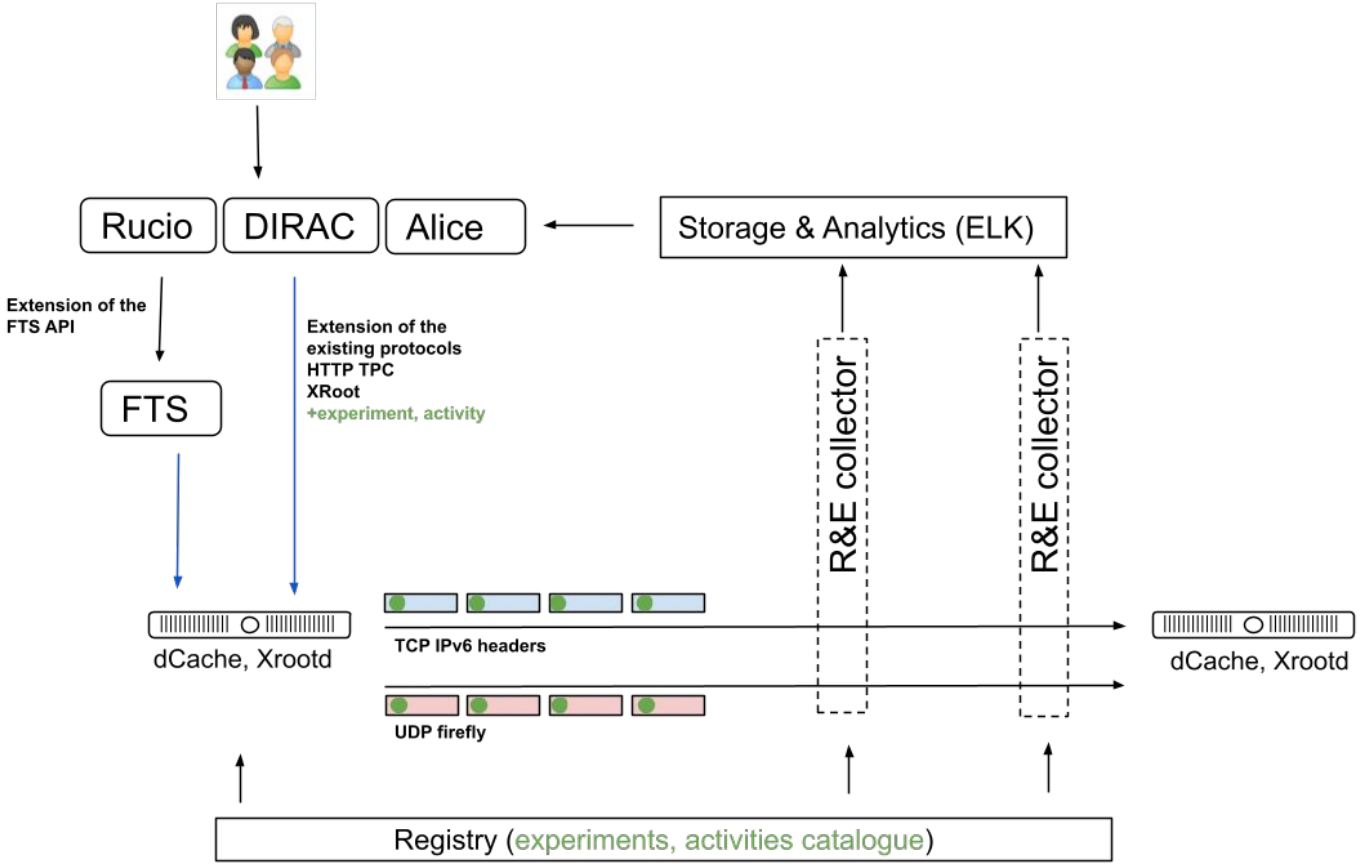

Status

- **Flow Marking** (UDP firefly) implementations
  - Xrootd 5.4.0 supports UDP fireflies
    - https://xrootd.slac.stanford.edu/doc/dev54/xrd_config.htm#_pmark
    - map2exp - can be used to map particular path to an experiment
    - map2act - can be used to map particular user/role to an activity
  - Flowd - prototype service
    - Issue fireflies from netstat for a given experiment (only for dedicated storages)
- **Collectors**
  - ESnet and Jisc/Janet*
- **Registry**
  - Provides list of experiments and activities supported
  - Exposed via JSON at api.scitags.org
- Simplified deployment was tested during the last DC
  - Flowd + ESnet collector + Registry
  - **AGLT2, BNL, KIT, UNL and Caltech** participated
  - Brunel, Glasgow and QMUL interested to help with further testing

Next steps

- In the context of WLCG DOMA BDT
  - Test and validate ways to propagate flow identifier (experiment + activity)
    - Engage experiments and data management systems
    - Discuss/propose ways how best to achieve this technically (protocol extensions, etc.)
    - Explore other possibilities for flow identifier propagation
    - Flow identifiers are potentially useful also in the transfer monitoring
  - Help with the validation and testing of the Xrootd implementation
    - Provide feedback to the existing implementations
  - Help to promote the activity
    - Involve other storage systems (dCache, etc.); discuss possible design/implementation

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

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).

Packet Marking - IPv6

IPv6 header

Fixed 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	Version				Traffic Class								Flow Label																			
4	32	Payload Length																Next Header								Hop Limit						
8	64	Source Address																															
12	96																																
16	128																																
20	160																																
24	192	Destination Address																															
28	224																																
32	256																																
36	288																																

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	I-D Exists New

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