Update on the Packet Marking WG

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on behalf of the RNTWG

HEPiX IPv6 Working Group - Virtual F2F Meeting

January 19, 2021

Overview

- Last fall we presented on the **R**esearch **N**etwork **T**echnical **W**orking **G**roup (RNTWG) and its Packet Marking working group at the September IPv6 WG meeting
- Since then we have had one meeting on November 23, 2020, focused on the packet marking work
- Our goal was to have some level of WLCG related traffic being marked by the start of 2021.
- Today we will review our status and provide updates since the last presentation.

Motivation: Making our Network Use Visible

Understanding HEP 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. **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 our RENs (Research and Education Networks)**

- The proposed work is to identify how we might label our traffic at the **packet level** to indicate which **experiment** and **activity** it is a part of.

- The technical work encompasses how to **mark traffic** at the network level, defining a standard set of markings, **provide the tools** to the experiments to make it easy for them to participate and define how the NRENs can **monitor/account** for such data.

Review: RNTWG Workplan

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- Based upon the interests of the experiments, sites and R&E networks, we are working to implement specific capabilities which can provide benefits as quickly as possible
- The experience learned during the monthly USATLAS, USCMS and ESnet Network Blueprinting meetings put the focus on marking our traffic
  - This seemed to be the low-hanging fruit and the one which would be easiest and quickest to deliver upon.
- We had a Kickoff meeting for the whole RNTWG in April 2020 and then moved to Packet Marking sub-group mtgs.

RNTWG Meetings Since Start

- 21 Apr - Kickoff meeting - presented charter
- 04 June - Created draft documents and shared Drive
  - Started working on packet marking; had a long discussion on it during the meeting
  - Agreed that forwarding decisions and policing bits is out of scope for this work
  - **Decided: we focus on IPv6 and if possible backport to IPv4**
- 30 June - More in-depth discussion related to IPv6 packet marking
  - Looked at Linux kernel IPv6 implementation status
    - Agreed to go ahead with IPv6 labels and come up with concrete proposal (and shim prototype) as well as to look further at the other (IPv6 marking) options to better understand the status of their implementation and how they would match our use cases
- 15 September - Focus on implementing prototype
  - Agreed to target ipv6 flow label (20bits, IPv6 header field)
    - Proposal is to use 9 bits for science domain and 6 bits for activity, leaving 5 bits for flow entropy and/or consistency (e.g., XOR, hamming code, etc.). So there are 511 possible science domains with 63 activities per domain
  - It is set per flow (via setsockopt) not per-packet
- Our last meeting was November 23, 2020 (next slide)

Packet Marking Meeting - 23 Nov 20

This meeting focused on **implementation status**

- Fernando Gont is working on IPv6 tools for verifying labels pass to destination
- We have a perfSONAR mesh using flow labels
- Sample code is available on Github for setting flow-labels at the socket level
- We discussed the draft label communication method from the Xrootd devs
- Edoardo/CERN reported they are hiring a technical student to work on trying to consume the flow labels
- We ended the meeting with a nice presentation from Yiannis Yiakoumis / selfie-networks (https://www.selfie-networks.com/) who described their network tokens initiative and how it might be relevant for packet marking
    - Options from selfie: STUN packets and IPv6 extension headers
    - Working on SDK to allow existing apps to utilize their work

eBPF (New Marking Option)

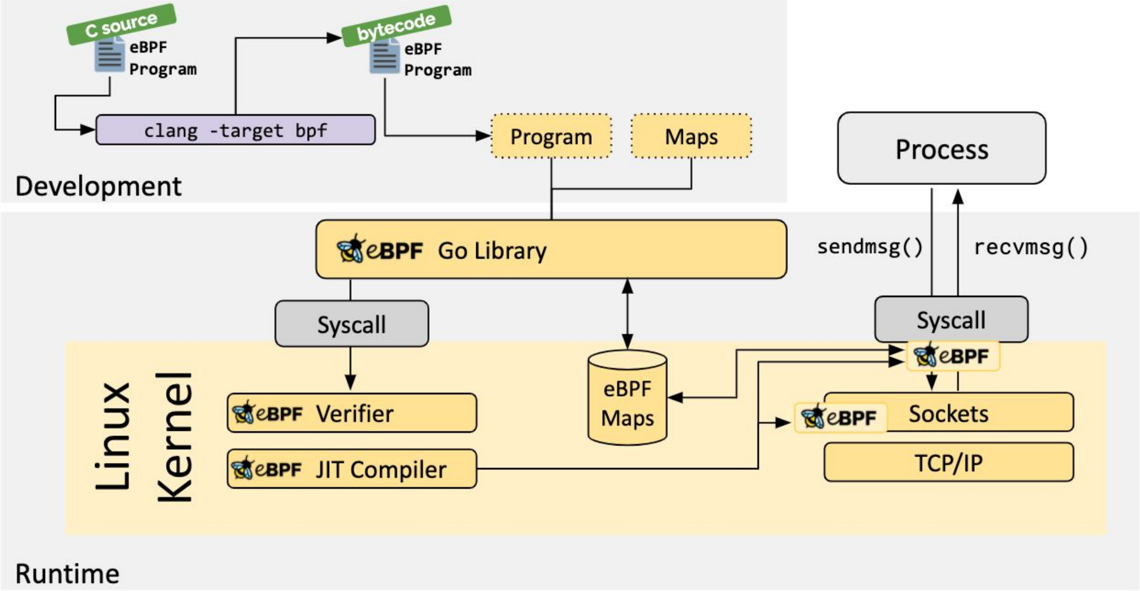
Tristan Sullivan / U Victoria, is replacing Rolf Seuster supporting networking activities for the Canadian Cloud.

Tristan asked about the use of eBPF as a possible marking mechanism

eBPF (extended Berkeley Packet Filter) is a project to allow linux kernel interactions without kernel models

Shown on the right is an example diagram using GO. Bytecode can be generated to perform various manipulations which are executed by various Syscalls.

Could we use eBPF to support our packet marking use case?



Reminder: Packet Marking Challenges

We would like this to be applicable for ALL significant R&E network users/science domains, *not just HEP*

- Required us to think broadly during design

How best to use the number of bits we can get?

- We have standardized bits (next few slides) and published
- Now we need to **maintain** it!!

What can we rely on from the Linux network stack and what do we need to provide?

Are the bits easily consumed by hardware / software?

What can the network operators provide for accounting?

Packet Marking - IPv6 Flow Label

The group is focusing on IPv6 and use of the flow-label

IPv6 incorporates a “Flow Label” in the header (20 bits)

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																																

Review: Packet Marking Scheme

The draft packet marking scheme is in a Google sheet.

We started with **20 bits** (matching the size of the flow-label)

- We add 5 entropy bits to try to match the spirit of RFC6436
- We use **9 bits** to define the **Science Domain** (reserving 3 for non-Astro/HEP domains)
- We use **6 bits** to define the **Application/Type** of traffic
- We organize the bits to allow for potential adjustments in the future.

The next few slides detail what we have arrived at

Application Marking Scheme

The 6 bits for Application are divided into two types: common across Science Domain (3 MSB = 0) and Science Domain specific

Note: some rows are hidden

We show the “**decimal value**” of the specific applications, assuming all the entropy bits are zero.

This makes it easy to add application+domain+entropy value to determine the final flow-label.

		MSB					LSB	
DecimalValue	Application	Hdr Bit 24	Hdr Bit 25	Hdr Bit 26	Hdr Bit 27	Hdr Bit 28	Hdr Bit 29	
		Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	
0	Reserved	0	0	0	0	0	0	Standardize for all Astro/HEP
4	perfSONAR	0	0	0	0	0	1	
8	Cache	0	0	0	0	1	0	
12		0	0	0	0	1	1	
16		0	0	0	1	0	0	
20		0	0	0	1	0	1	
24		0	0	0	1	1	0	
28		0	0	0	1	1	1	
32		0	0	1	0	0	0	Science Domain Specific
100		0	1	1	0	0	1	
104		0	1	1	0	1	0	
108		0	1	1	0	1	1	
112		0	1	1	1	0	0	
116		0	1	1	1	0	1	
120		0	1	1	1	1	0	
124		0	1	1	1	1	1	
128		1	0	0	0	0	0	
132		1	0	0	0	0	1	
136		1	0	0	0	1	0	
140		1	0	0	0	1	1	
144		1	0	0	1	0	0	
148		1	0	0	1	0	1	
152		1	0	0	1	1	0	
156		1	0	0	1	1	1	
160		1	0	1	0	0	0	
164		1	0	1	0	0	1	
168		1	0	1	0	1	0	
172		1	0	1	0	1	1	

Science Domain Marking

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The 9 bits assigned for Science Domain are in reverse bit-order to keep the currently reserved (non-Astro/HEP) bits closest to the entropy bit, in case we need to adjust later. (Bits 11-9 != 0 are Non-Astro/HEP)

		LSB								MSB
DecimalValue	ScienceDomain	Hdr Bit 14	Hdr Bit 15	Hdr Bit 16	Hdr Bit 17	Hdr Bit 18	Hdr Bit 19	Hdr Bit 20	Hdr Bit 21	Hdr Bit 22
		Bit 17	Bit 16	Bit 15	Bit 14	Bit 13	Bit 12	Bit 11	Bit 10	Bit 9
0	Reserved	0	0	0	0	0	0	0	0	0
65536	ATLAS	1	0	0	0	0	0	0	0	0
32768	CMS	0	1	0	0	0	0	0	0	0
98304	LHCb	1	1	0	0	0	0	0	0	0
16384	ALICE	0	0	1	0	0	0	0	0	0
81920	BelleII	1	0	1	0	0	0	0	0	0
49152	SKA	0	1	1	0	0	0	0	0	0
114688	LSST	1	1	1	0	0	0	0	0	0
73728	DUNE	1	0	0	1	0	0	0	0	0
8192		0	0	0	1	0	0	0	0	0

Summary: Packet Marking Scheme

We can combine the previous two tables for Science Domain and Application, along with **5 entropy bits** to produce the master table of bit definitions for our 20 bits.

The spreadsheet **Reference Table** allows selection by bit patterns. The table below shows selecting on the "perfSONAR" Application type (**note** some columns are hidden), X = 0 or 1

BitPattern	ScienceDomain	Application	Hdr Bit 12	Hdr Bit 13	Hdr Bit 14	Hdr Bit 15	Hdr Bit 16	Hdr Bit 17	Hdr Bit 18	Hdr Bit 23	Hdr Bit 24	Hdr Bit 29	Hdr Bit 30	Hdr Bit 31
xx100000000x000001xx	ATLAS	perfSONAR	x	x	1	0	0	0	0	x	0	1	x	x
xx010000000x000001xx	CMS	perfSONAR	x	x	0	1	0	0	0	x	0	1	x	x
xx110000000x000001xx	LHCb	perfSONAR	x	x	1	1	0	0	0	x	0	1	x	x
xx001000000x000001xx	ALICE	perfSONAR	x	x	0	0	1	0	0	x	0	1	x	x
xx101000000x000001xx	BelleII	perfSONAR	x	x	1	0	1	0	0	x	0	1	x	x
xx011000000x000001xx	SKA	perfSONAR	x	x	0	1	1	0	0	x	0	1	x	x
xx111000000x000001xx	LSST	perfSONAR	x	x	1	1	1	0	0	x	0	1	x	x
xx000100000x000001xx	DUNE	perfSONAR	x	x	0	0	0	1	0	x	0	1	x	x

perfSONAR Packet Marking

- The first application used to test flow-label marking was perfSONAR Iperf3
  - **PWA** was able to centrally configure `--flow-label` for IPv6 **Iperf3** tests
  - Labels were manually verified via `tcpdump` at the destination
  - We now set a flow label on one perfSONAR test mesh (**US ATLAS**: CERN, AGLT2, MWT2, BNL, BU, LUNET, NERSC and Stanford; the flow label (65540) is set on iperf3 tests for this mesh.)
- Tim Chown has started an engagement with the **perfSONAR** developers, bringing in IPv6 expert Fernando Gant
  - Fernando and Mark Feit are discussing creating a new tool/test which sets a flow-label in the packet header and sends the same label as the data, then verifies they match (or not) at the destination? **Work has stalled here.**
- perfSONAR, as an extensible framework, should be a good tool to use for the Packet Marking work
  - Can we get all standard perfSONAR tools to support a centrally defined `--flow-label` option? (traceroute already supports it but not in **PWA**)

Packet Marking for Storage Elements

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The bulk of WLCG traffic is generated by our storage elements.

The primary challenge here is in two areas:

1. Augmenting the existing storage system to be able to set the appropriate bits in the network packets
2. Communicating the appropriate bits as part of a transfer request
    a. Likely need some protocol extension to support this
    b. We have a document from the Xrootd developers discussing this.

Packet Marking for Jobs

We would also like to account for traffic generated by production and user jobs.

As jobs source data onto the network OR pull data into the job, we should try to ensure the corresponding packets are marked appropriately

- Containers and VMs may help this to be more easily put in place
- Jobs will need configuration options that specify the right bits
- Signaling to the “source” about what those bits are also needs to be in place

RNTWG High Level Notes

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We continue to be guided by what is useful but also feasible and possible.

Marking and shaping/pacing **must happen on the source**

Longer term work on shaping and orchestration will be informed by what we create for **packet marking** our traffic. Orchestration is much more feasible once marking is in place

Current Plans and Schedule

- Continue to focus on **IPv6 Flow Label** option
  - Very important to provide examples for how to mark packets
    - Marian has provided code example at https://github.com/marian-babik/ipv6_flow_label (done)
    - New marking option being explored by Tristan Sullivan: eBPF
- **Applications** - We need to enable packet marking in as many HEP applications as possible; target storage systems first?
  - We are targeting: perfSONAR, XRootD ASAP (~Q1 2021)
    - We have initial xrootd plan, describing the work needed (meet soon)
    - Need broader engagement: FTS, Rucio, dCache, STORM,HTTP, etc
- Consuming / Utilizing the bits (Start work when enough traffic has marks)
  - Work with R&E networks and sites to try to capture and measure the marked traffic
  - Verify traffic markings consistently pass end-to-end
  - Differentiate intentionally marked traffic vs standard flow-label use
- Testing in our R&E networks (ASAP)

Questions, Comments, Suggestions?

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We are working on IP packet marking which has been identified as an important capability WLCG and R&E networks.

From this group's perspective, one important aspect is that there is now **another good reason to implement IPv6!**

Want to be involved? We could use effort on:

Helping provide tools to enable marking.

Testing tools/options for marking.

Creating or testing "consuming" the marked bits inside the network or at the ends.

Questions, Comments, Suggestions?

Acknowledgements

We would like to thank the **WLCG**, **HEPiX**, **perfSONAR** and **OSG** organizations for their work on the topics presented.

In addition we want to explicitly acknowledge the support of the **National Science Foundation** which supported this work via:

- OSG: NSF MPS-1148698
- IRIS-HEP: NSF OAC-1836650

References

Packet marking document
Research Networking Technical WG Google folder
RNTWG Wiki
RNTWG mailing list signup
RNTWG/NFV WG Meetings and Notes: https://indico.cern.ch/category/10031/
NFV WG Report

SDN/NFV Tutorial: https://indico.cern.ch/event/715631/
2018 IEEE/ACM Innovating the Network for Data-Intensive Science (INDIS) – http://conferences.computer.org/scw/2018/#!/toc/3
OVN/OVS overview: https://www.openvswitch.org/
GEANT Automation, Orchestration and Virtualisation (link)
Cloud Native Data Centre Networking (book)
MPLS in the SDN Era (book)

Backup slides

Introduction / Overview

The LHCOPN/LHCONE meeting at CERN a year ago, brought in the LHC/HEP experiments who described their networking needs, interests and use-cases.

The experiments reinforced what the HEPiX NFV phase I report suggested were useful areas to focus effort upon:

- Making our network use visible (Packet Marking)
- Shaping WAN data flows (Traffic Shaping)
- Orchestrating the network (Network Orchestration)

In response we formed the Research Networking Technical Working group with three sub-groups focused on the above areas.

Today we are providing an update on our activities and plans focused primarily on the Packet Marking effort.

Research Networking Technical WG

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Charter:

https://docs.google.com/document/d/1l4U5dpH556kCnoIHzyRpBI74IPc0gpgAG3VPUp98lo0/edit#

Mailing list:

http://cern.ch/simba3/SelfSubscription.aspx?groupName=net-wg

Members (90 as of today, in no particular order):

Christian Todorov (Internet2) Frank Burstein (BNL) Richard Carlson (DOE) Marcos Schwarz (RNP) Susanne Naegele Jackson (FAU)
Alexander Germain (OHSU) Casey Russell (CANREN) Chris Robb (GlobalNOC/IU) Dale Carder (ESnet) Doug Southworth (IU)
Eli Dart (ESNet) Eric Brown (VT) Evgeniy Kuznetsov (JINR) Ezra Kissel (ESnet) Fatema Bannat Wala (LBL) Joseph Breen (UTAH)
James Blessing (Jisc) James Deaton (Great Plains Network) Jason Lomonaco (Internet2) Jerome Bernier (IN2P3) Jerry Sobieski
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Tim Chown (Jisc) Tom Lehman (ESnet) Vincenzo Capone (GEANT) Wenji Wu (FNAL) Xi Yang (ESnet) Chin Guok (ESnet)
Tony Cass (CERN) Eric Lancon (BNL) James Letts (UCSD) Harvey Newman (Caltech) Duncan Rand (Jisc)
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Shan Zeng (IHEP) Jin Kim (KISTI) Richard Cziva (ESnet) Phil Demar (FNAL) Justas Balcas (Caltech) Bruno Hoeft (FZK)

Packet Marking Validity Option

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One concern expressed during our discussions was “pollution” of our results from packets that use the flow-label to provide entropy.

We can minimize this by calculating a Hamming code, using our 5 entropy bits to create parity bits. This maximizes the distance (bit-wise) between valid flow-labels for our marking use-case/

The table below shows how to rearrange the bits for this:

	Entropy Bit		Science Bit		Application		Hamming													
	Hdr Bit 12	Hdr Bit 13	Hdr Bit 14	Hdr Bit 15	Hdr Bit 16	Hdr Bit 17	Hdr Bit 18	Hdr Bit 19	Hdr Bit 20	Hdr Bit 21	Hdr Bit 22	Hdr Bit 23	Hdr Bit 24	Hdr Bit 25	Hdr Bit 26	Hdr Bit 27	Hdr Bit 28	Hdr Bit 29	Hdr Bit 30	Hdr Bit 31
	Bit 19	Bit 18	Bit 17	Bit 16	Bit 15	Bit 14	Bit 13	Bit 12	Bit 11	Bit 10	Bit 9	Bit 8	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
	x	x	0	0	0	0	0	0	0	0	0	x	0	0	0	0	0	0	x	x
	Hdr Bit 12	Hdr Bit 13	Hdr Bit 14	Hdr Bit 23	Hdr Bit 15	Hdr Bit 16	Hdr Bit 17	Hdr Bit 30	Hdr Bit 18	Hdr Bit 19	Hdr Bit 20	Hdr Bit 21	Hdr Bit 22	Hdr Bit 24	Hdr Bit 25	Hdr Bit 31	Hdr Bit 26	Hdr Bit 27	Hdr Bit 28	Hdr Bit 29
	Bit 19	Bit 18	Bit 17	Bit 8	Bit 16	Bit 15	Bit 14	Bit 1	Bit 13	Bit 12	Bit 11	Bit 10	Bit 9	Bit 7	Bit 6	Bit 0	Bit 5	Bit 4	Bit 3	Bit 2
	p	p	d	p	d	d	d	p	d	d	d	d	d	d	d	p	d	d	d	d
Bit Position	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
Parity Bits Needed	2^0	2^1		2^2				2^3								2^4				