Making the Linux TCP stack more extensible with eBPF

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Supporting new TCP option

The standard way to extend TCP

But implementation?

requires kernel changes

Supporting new TCP option is hard

True for just experiment

More with deployment: upstreaming patches?

Stand on the shoulders of giants...

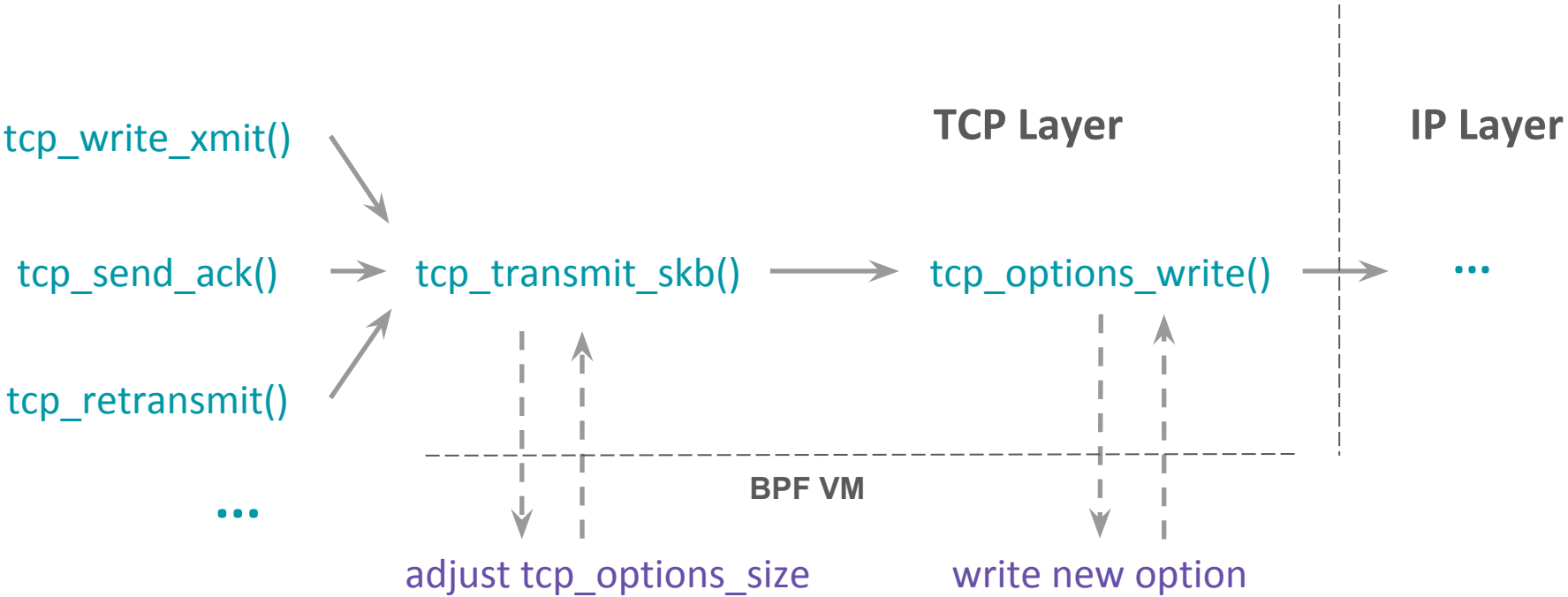
Based on TCP-BPF by Lawrence Brakmo

TCP-BPF (since 4.13) already has:

- Hooks at different phases of a TCP connection

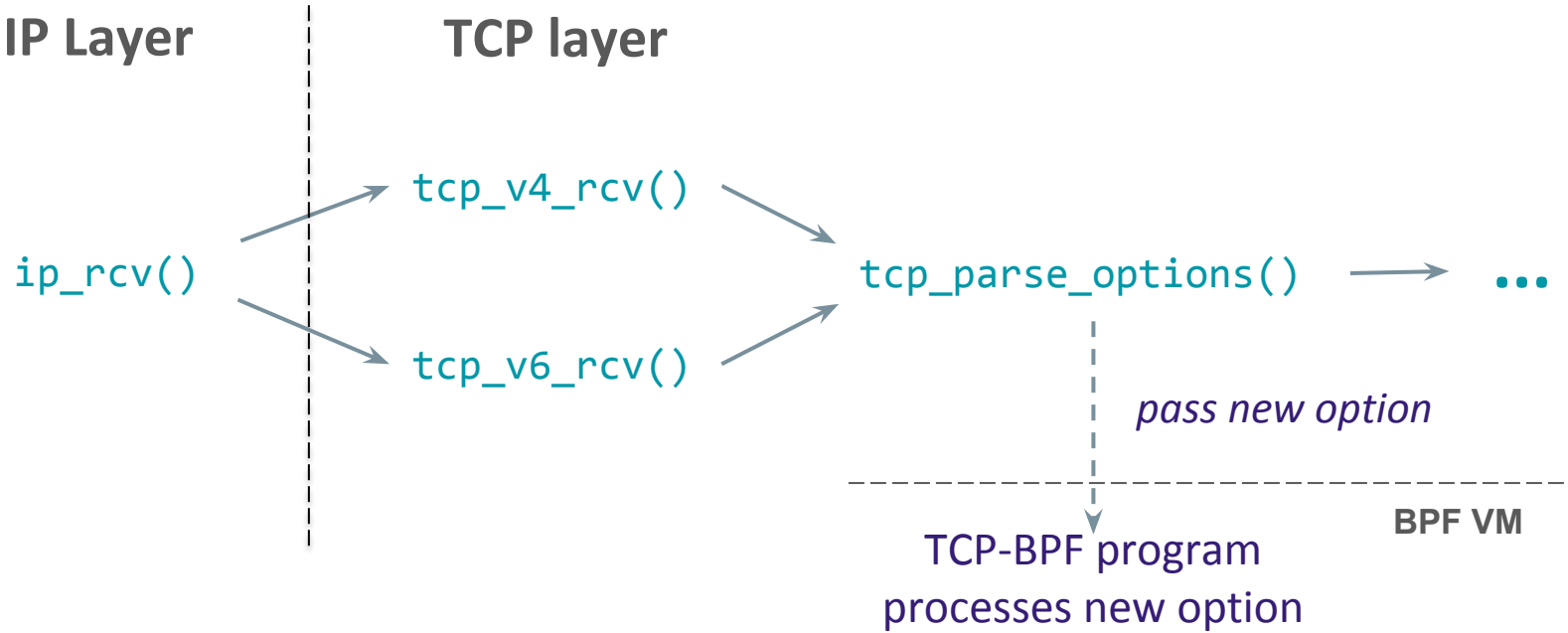
  or when connection state changes
- Read & write to many fields of tcp_sock
- Indirect access with bpf_getsockopt, bpf_setsockopt
- ...

Add new option: 2 steps



One more thing: update current MSS

Parse new option



Overhead

Disable hooks by default

Benchmark:

- on local host
- trigger on every packet

Overhead: Goodput

Disable hooks by default

Benchmark:

on local host
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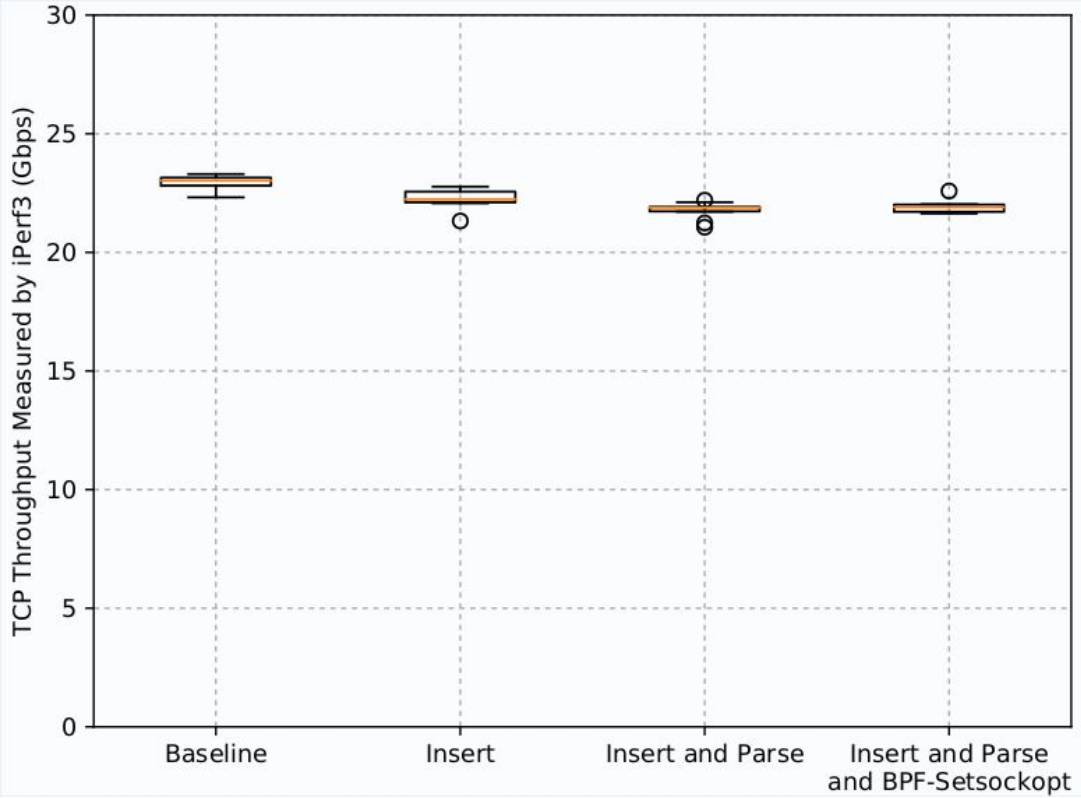
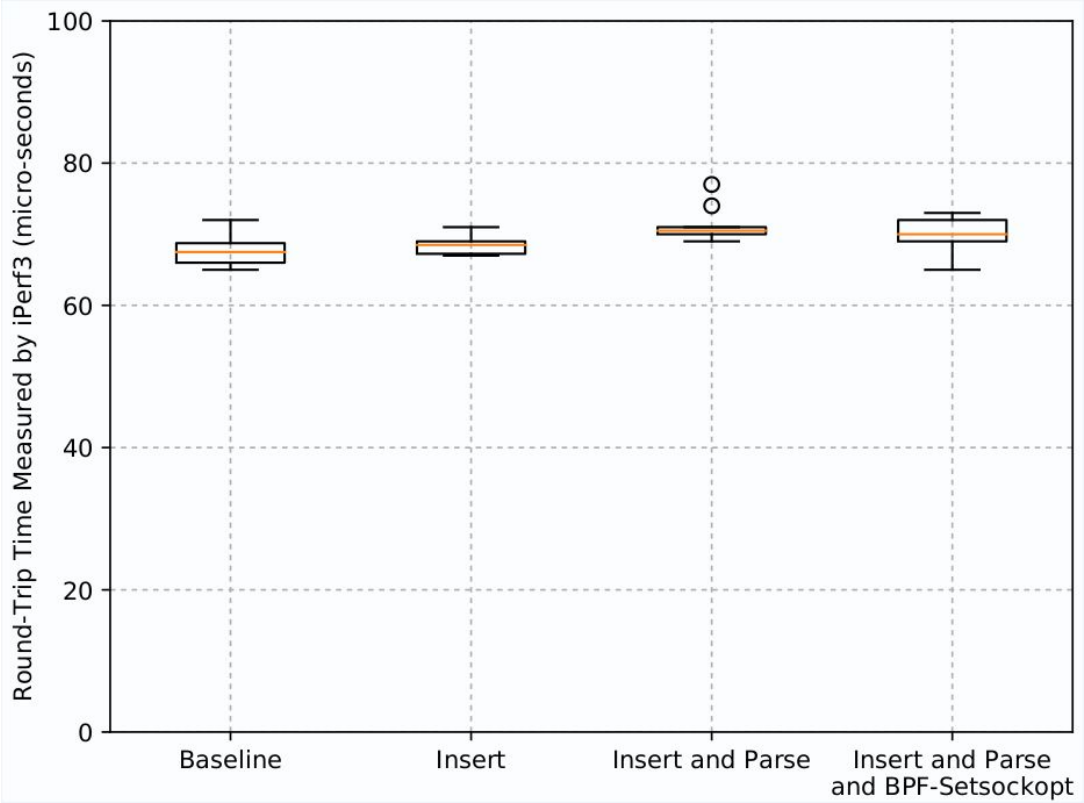


Overhead: RTT



Use cases

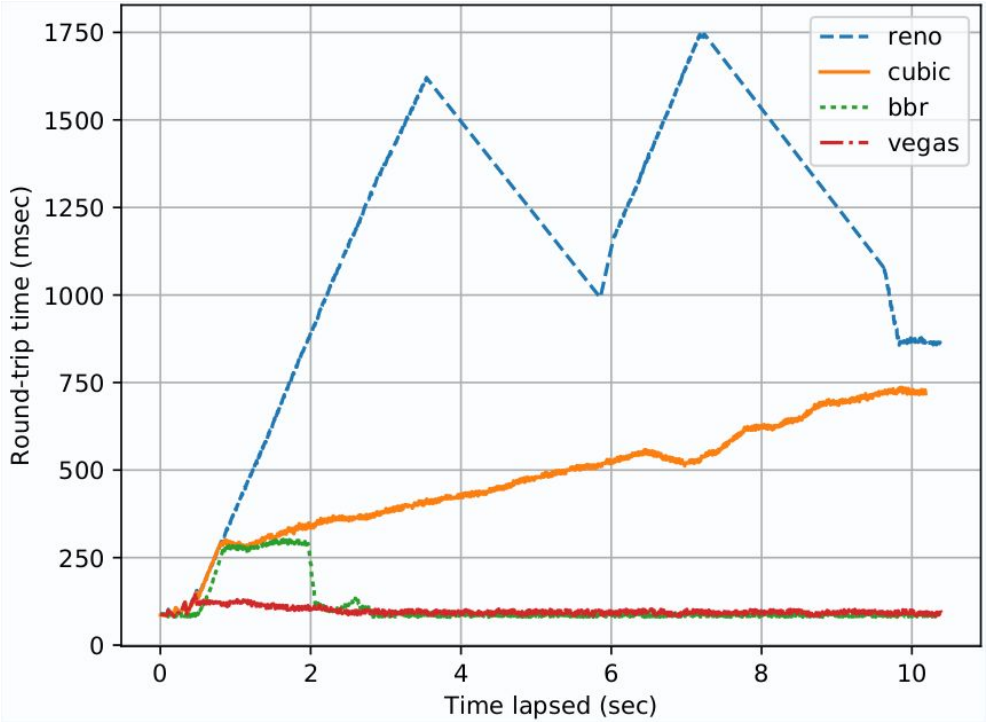
User Timeout Option

TCP User Timeout (UTO):

> max time waiting for the ACK of transmitted data
> before resetting the connection

RFC 5482: TCP option to announce/request this value

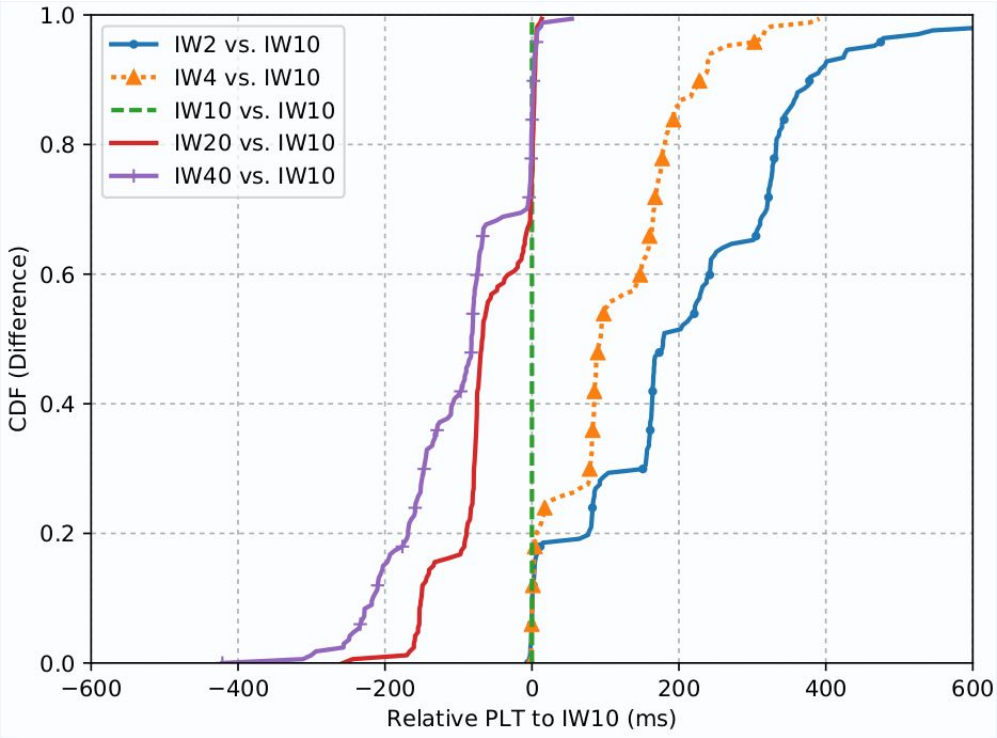
Congestion Control Request Option



Receiver requests the sender to use a desired CC algorithm for the connection

E.g.: Clients specify the preference for low-latency traffic

Initial CWND option



When the receivers know more about the network bottleneck.

Delayed ACK Option

Motivation: Too many ACKs or too few ACKs is not good.

→ The need to know remote's ACK delay strategy
… or to request the desired configuration

This option carries two values:

- Delack timeout: relatively as a fraction of RTT
- Segs count: Number of received segs before sending an ACK

What about the middleboxes?

RFC 6994: “Shared Use of Experimental TCP Options”
(PROPOSED STANDARD)

Network operators “should” support (or fix it otherwise)

Code Status

	Kernel changes	BPF program
TCP Option framework	75	-
Use case: TCP User Timeout	16	76
Use case: Congestion Control	0	92
Use case: Initial Window	0	76
Use case: Delayed ACK	94	77

Caveats

Option size <= 4 Bytes, extensible to 16 Bytes

Decouple from cgroup-v2?

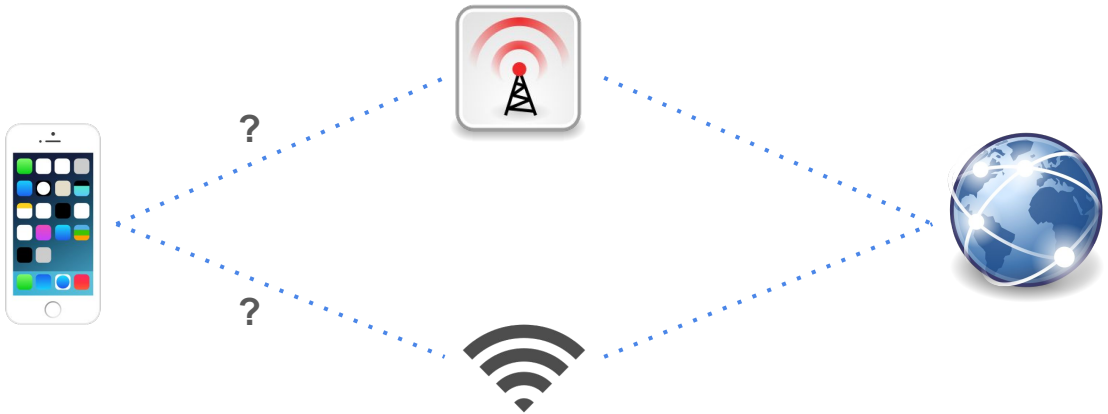
Making the Linux TCP stack more extensible with eBPF

Making the Linux MPTCP stack more extensible with eBPF

Path Manager

Which path to create/remove? Which address to announce?

→ Should be controlled by application / user



Slide from Netdev0x12.

Supporting user-defined Path Managers (PM)

Netlink-based PM framework

+ Available in mptcp-trunk branch (out-of-tree)
+ Control plane in uspace
+ Clean separation

Issues:

- Under high load, netlink messages may be lost
- Need separated facilities to support:
  - set/getsockopt (e.g. access subflow-level info)
  - TCP state change notification
  - policy to refuse the establishment of a subflow

What if eBPF-based approach

+ Performance
+ Built-in support for TCP state tracking
+ Easy to apply custom policy on subflow establishment
- Restricted by current eBPF limits
- Less layering separation?
- BPF program can be called from different contexts → Locking is trickier

Our prototype

To track events:	New TCP-BPF callbacks
To store local/remote addresses and subflows:	BPF maps
To open a subflow:	helper function

New TCP-BPF callbacks to track events

- MPTCP Session created
- MPTCP Session established
- MPTCP Session closed (e.g. fallback to regular TCP)
- Subflow established
- Subflow closed
- Remote IP address added/removed

Open subflows

via helper function mptcp_open_subflow()

- (meta_sk, srcIP+port, dstIP+port) as input
- if a field of tuple is unset: use existing or kernel-assigned IP/port

But usually, we are in softirq context: cannot open subflow directly

→ Schedule a workqueue instead

→ subflow is actually opened later

Examples

Two minimal PMs were implemented as BPF programs:

ndiffports PM: ~20 LoCs

fullmesh PM: ~200 LoCs

Open issues

Handle events of local IP address changed:
Need to send events to each BPF program in each cgroup

Open subflows: more than one work in workqueue?

Remove subflows: (already done automatically in kernel when receiving a REMOVE_ADDR option)

Dual-stack support: would be similar to bpf_bind()?

Multiple PMs? e.g. each PM per netns

Wrap up

More details in our paper

Git repository: https://github.com/hoang-tranviet/tcp-options-bpf

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Backup slides