Dynamic Data Plane Updates using Lua and libmoon

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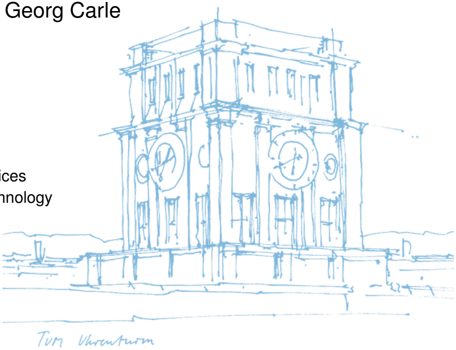

Introduction

Motivation

- Modern communication networks have to offer high-performant and reliable connections
- Interrupt-free, dynamic data plane updates increase network resilience
  - application migration (e.g., for failovers)
  - tenant-specific processing
- Just-in-time (JIT) compiled languages seem to be a promising candidates for on-the-fly function updates

Contribution

- LuaJIT/libmoon-based prototype implementation for dynamic network functions
- Investigation of applicability and performance consequences

Background

libmoon

- Lua(JIT)-based wrapper for DPDK
- Allow flexible, high-level, but high-performant packet processing

DPDK

- High-performance packet processing framework
- Bypassing Linux networking kernel stack

Previous and Related Work

Active Networking

- **Capsule-based active networking** [6]: Capsules/packets carry their "own" program fragments
- **Tiny packet programs (TTPs)** [4]: active packets with very restricted number of instructions

P4

- **Active RMT** [1]: Instruction set in P4 allowing changegable functionality
- **FlexCore** [7]: Runtime partial reprogrammable switch architecture
- **In-situ Programmable Data Plane** [3]: Switch architecture and reconfigurable P4 (rP4) for runtime updates

P4/eBPF

- **Dynamic eBPF in P4 pipeline** [5]: Runtime-updatable eBPF processors within P4 pipeline

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[5] M. Simon, H. Stubbe, S. Gallenmüller, and G. Carle. Honey for the Ice Bear - Dynamic eBPF in P4, *eBPF Workshop @ SIGCOMM 2024*

Implementation

Prototype

- Implemented in *libmoon* using LuaJIT

Flow Table

- Every flow has its own function
- Hashtable mapping flows to the (network) function

Function Update

- Lua's built-in `loadstring()` function returns pointer for given source code
- LuaJIT can JIT compile the code
- Several JIT optimization schemes possible (`-O0`, `-O1`, `-O2`, `-O3`)

Implementation

INC ①

payload: 0

DYN ①

```
local pkt = buf:getUDP4IncPacket();
pkt.inc:setPayload(54321);
```

INC ②

payload: 0

INC ①

payload: 0

Flow	Function pointer
Flow ①	`forward`
Flow ②	`forward`
...	...
default	`forward`

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forward():
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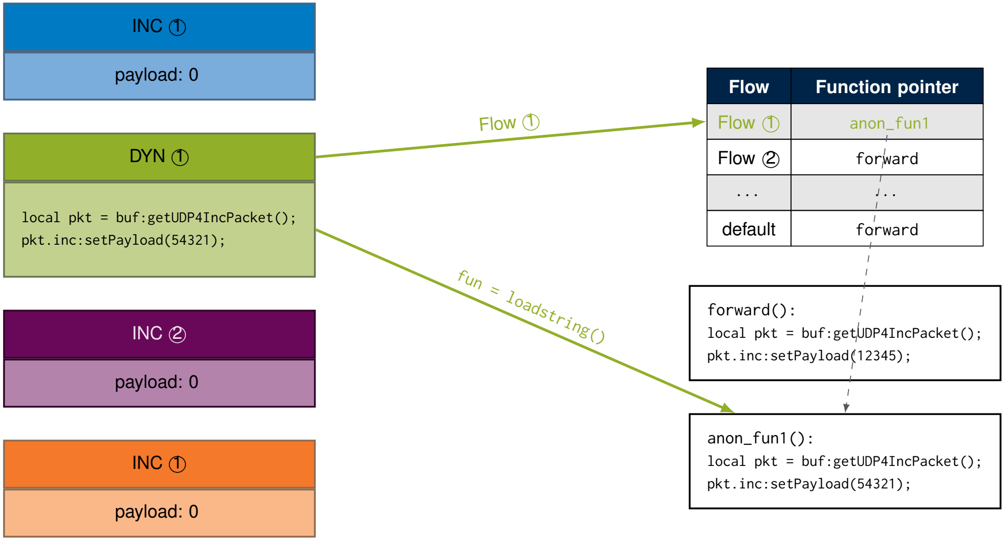

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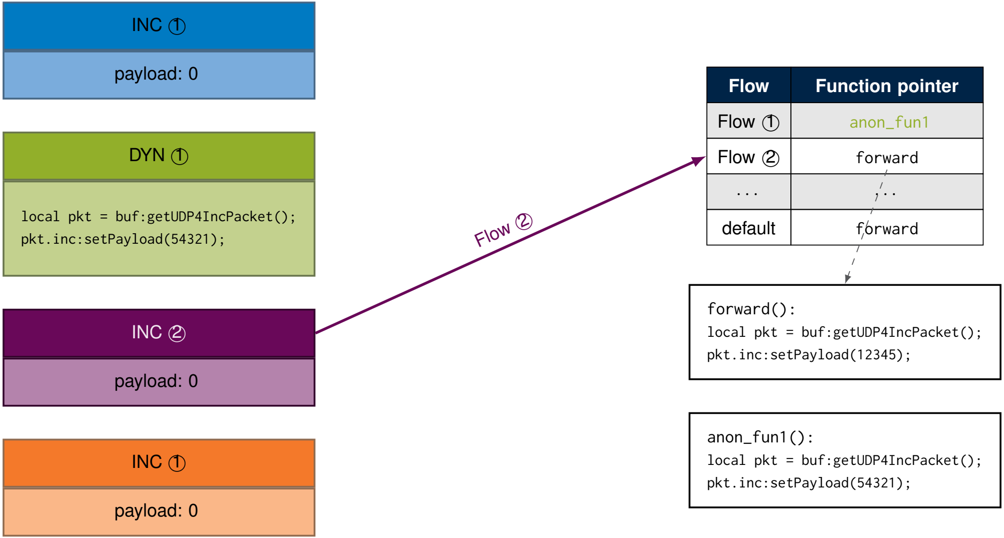

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anon_fun1():
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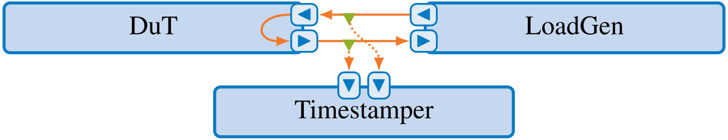
Measurement Setup

Setup



DuT

- Intel Xeon D-1518 2.2 GHz, 32 RAM
- libmoon with batch size of one

LoadGen

- MoonGen [2] is used to generate traffic
- Packet size 200 B

Timestamper

- Packet streams duplicated using optical splitter
- Timestamps each packet incoming packet
- Resolution: 12,5 ns

Measurement Setup

Procedure

Two flows

- For *flow 1*, the function will be changed during runtime
- For *flow 2*, the function remains unaffected

Procedure

- First, 50 000 INC packets are sent → default/forwarding function
- Then, one DYN packet updates the code for *flow 1*
- Afterward, another 200 000 INC packets are sent and processed

Network Function

- Default function: Set a constant in a specific header field
- Changed function: sets another constant

⇒ minimum possible overhead

Measurement Setup

Methodology

We want to answer the following questions:

1. **What is the overhead when changing the network function during runtime?**
   - $\rightarrow$ DYN packet

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2. **How does the change affect other flows and CPU cores (cross-flow and cross-core dependencies)**
   → using *one* or *two* threads/tasks/cores on the DuT

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3. **How does JIT compilation influence the performance during and after changing the code?**
   - $\rightarrow$ enabling/disable LuaJIT

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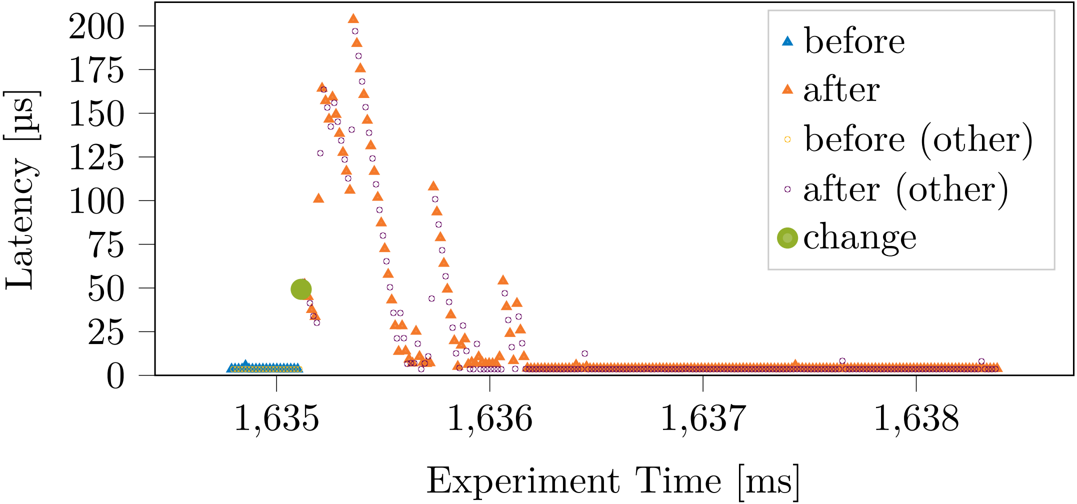
2. **How does the change affect other flows and CPU cores (cross-flow and cross-core dependencies)**
   → using *one* or *two* threads/tasks/cores on the DuT
3. **How does JIT compilation influence the performance during and after changing the code?**
   → enabling/disable LuaJIT
4. **What are the reasons for performance changes?**
   → manipulating the default function

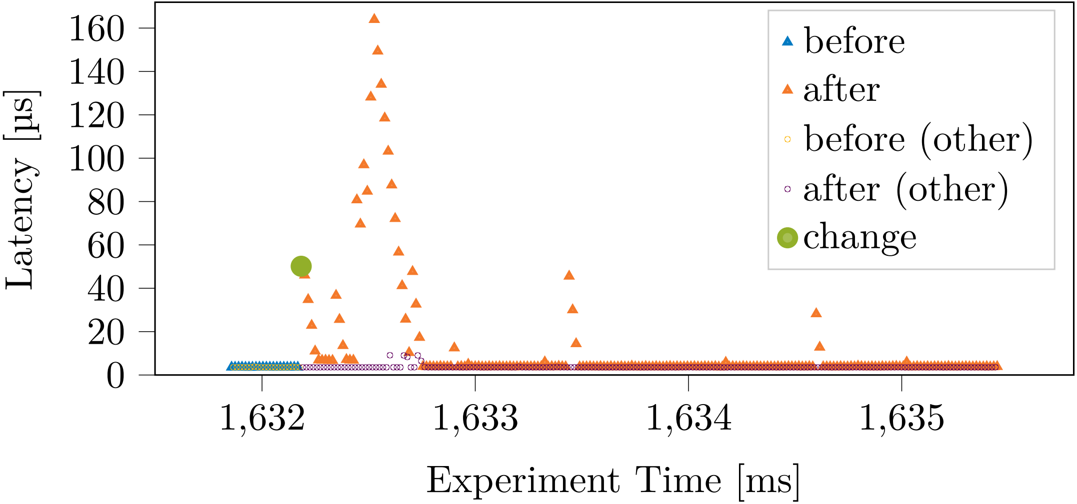
Evaluation

Dynamic program change (one task) (zoomed)



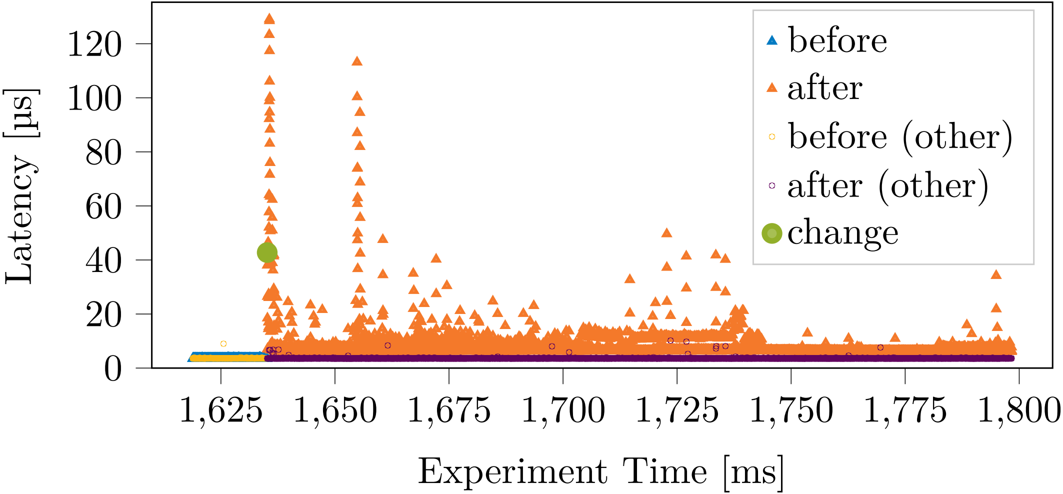
Evaluation

Dynamic program change (two tasks) (zoomed)



Evaluation

Dynamic program change (two tasks) (**no** JIT)



Evaluation

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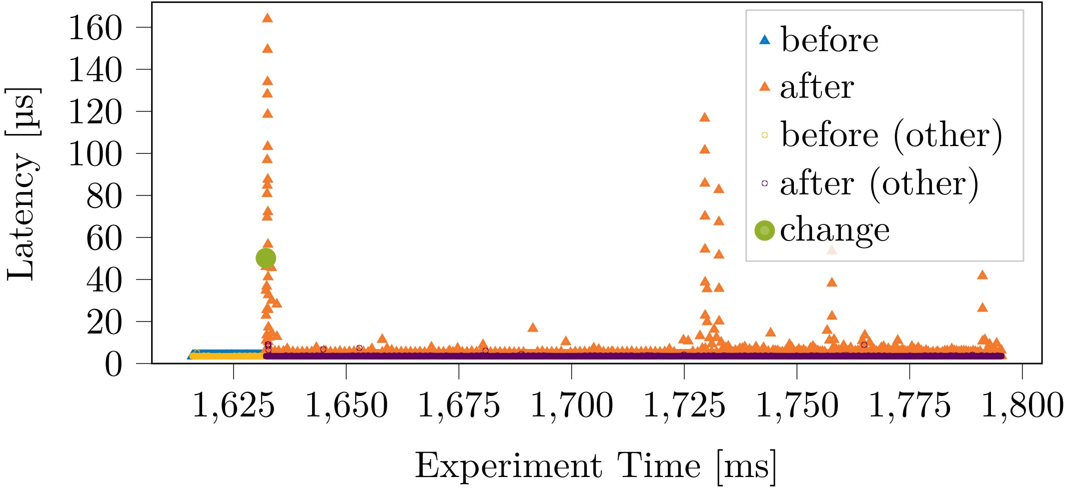
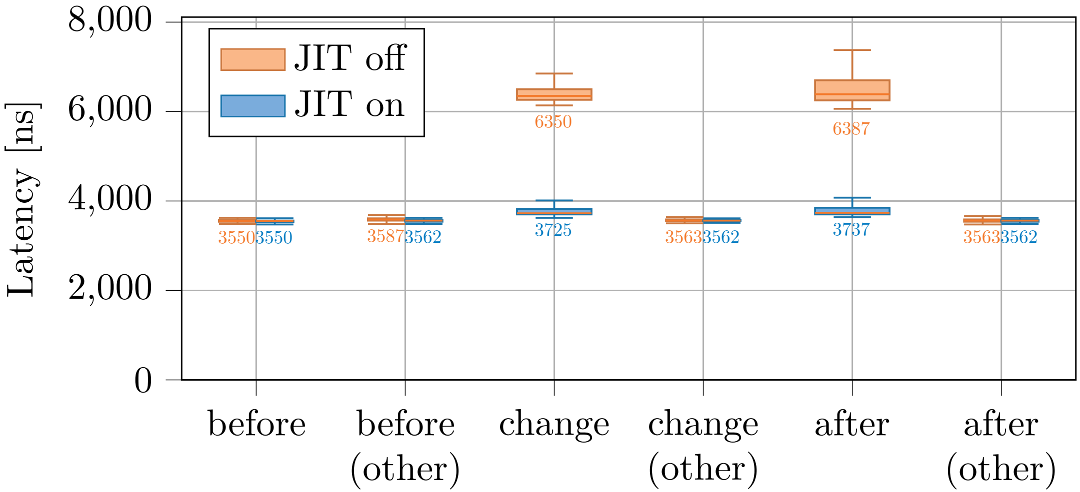


Evaluation

Latencies *before*, 5000 packets after the *change*, and there*after*)



Conclusion

Results

- It is feasible to perform dynamic changes with uncompiled source code
- Overhead only for flows processed on the same core
- JIT improves long-term performance, adds minimal overhead to the exchange itself
- Function pointer returned by `loadstring()` adds performance overhead

Future Work

- Investigate different programs (not only baseline overhead)
- Analyze the influence of JIT settings
- Compare to other implementations, e.g., eBPF, XDP
- Investigate the offloading potential such dynamic function to SmartNICs

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