P4PI: P4 on Raspberry PI for Networking Education

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Teaching Computer Networks

- P4 is ideal for teaching computer networks
  - Quick to learn, easy to use
- Hands on experience
  - Increases students' engagement
  - Improves student's understanding
- Software solutions (e.g., BMv2 + Mininet)
  - Can't build a network of students' devices
  - Don't provide real-world experience
  - Not so exciting!

Existing Hardware Platforms

- High cost

- Closed-source (some)

- Long learning curve

- Availability

Teaching P4 Using Hardware - Today

- **P4 programmable switch-ASIC**
  - Too expensive for many (>1000's of $)
  - Closed / partially closed source
- **NetFPGA**
  - Cost ~$1500
  - Open-source
  - Requires FPGA design knowledge
- **SmartNICs**
  - Cost $1000-$2000
  - Closed source
  - Requires micro-architecture knowledge

Equipping a class is expensive

$$$

What Is The Ideal Platform For Teaching?

- **Low cost**
  - Less than $100
- **Easy to learn**
  - And easy to use
- **High Availability**
  - Worldwide, in-stock
  - Long term support
- **Open-source**
  - Both hardware and software
- **Training resources available**
- **Wireless + Wired connectivity**
  - Students can use their laptops
  - ...or existing lab machines
- **Network performance**
  - "Home" level

RaspberryPI 4 Model B 4GB
Quad-core ARM64 processor
On-board WiFi, 1GbE RJ-45
$60-$80, availability

+

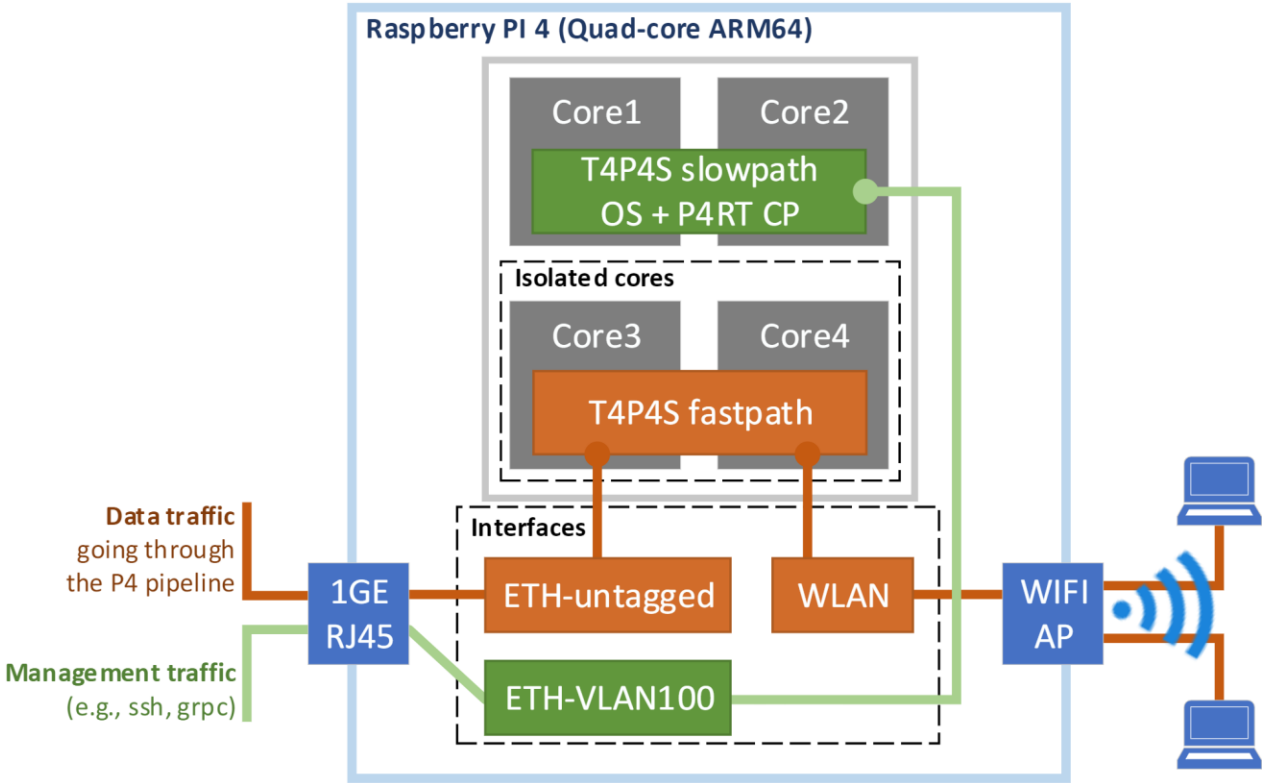
T4P4S Compiler

T4P4S P4 Compiler
Open source, supports multiple backends incl. DPDK & v1model

P4PI Is More Than a Hardware Platform

- **Training Materials**
  - Tutorials, exercises etc.
- **P4PI Repository**
  - P4PI source code, wiki, tools, reference programs.
- **Community engagement**
- A P4 Education Workgroup project

P4PI Reference Architecture

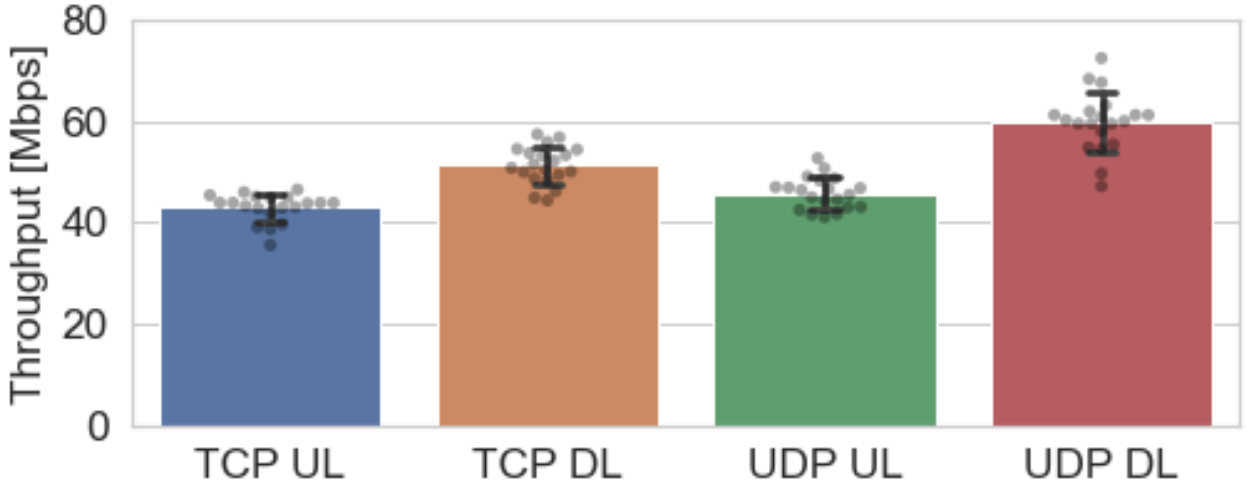


P4PI Reference Architecture

- **T4P4S using DPDK backend**
  - Packet processing on 2 isolated CPU cores
  - Executing the P4 program
  - Using TUN/TAP PMDs
- **WLAN interface in AP mode**
- **Separate management interface**
  - e.g., for SSH
- **Integration with standard networking tools**
  - E.g., DHCP, NAT with iptables, etc.

P4PI Performance Over WiFi (Preliminary)

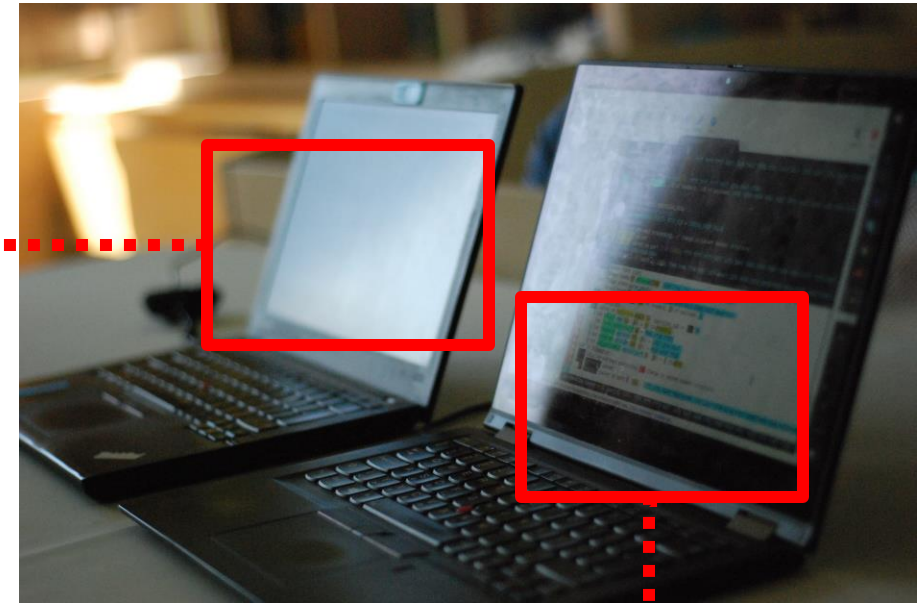
- **Setup**
  - Laptop + RPi located in different rooms (~5m distance)
  - Using iperf3 - upstream & downstream, TCP and UDP
  - PortForwarding P4 program using T4P4S and tun/tap pmd



Using P4PI In Class

- **Option 1: A P4PI node per student**
  - Students working independently
  - One laptop per node, using ssh for access and sending test traffic
- **Option 2: A P4PI node per group of students**
  - Still a single network device
  - … But more complex test scenarios can be implemented
- **Option 3: Multiple P4PI nodes, creating a network**
  - A class of students engaging and collaborating
  - Interoperability between students' projects
  - Implementing a more complex applications

DEMO: P4Calc on P4PI



Setup

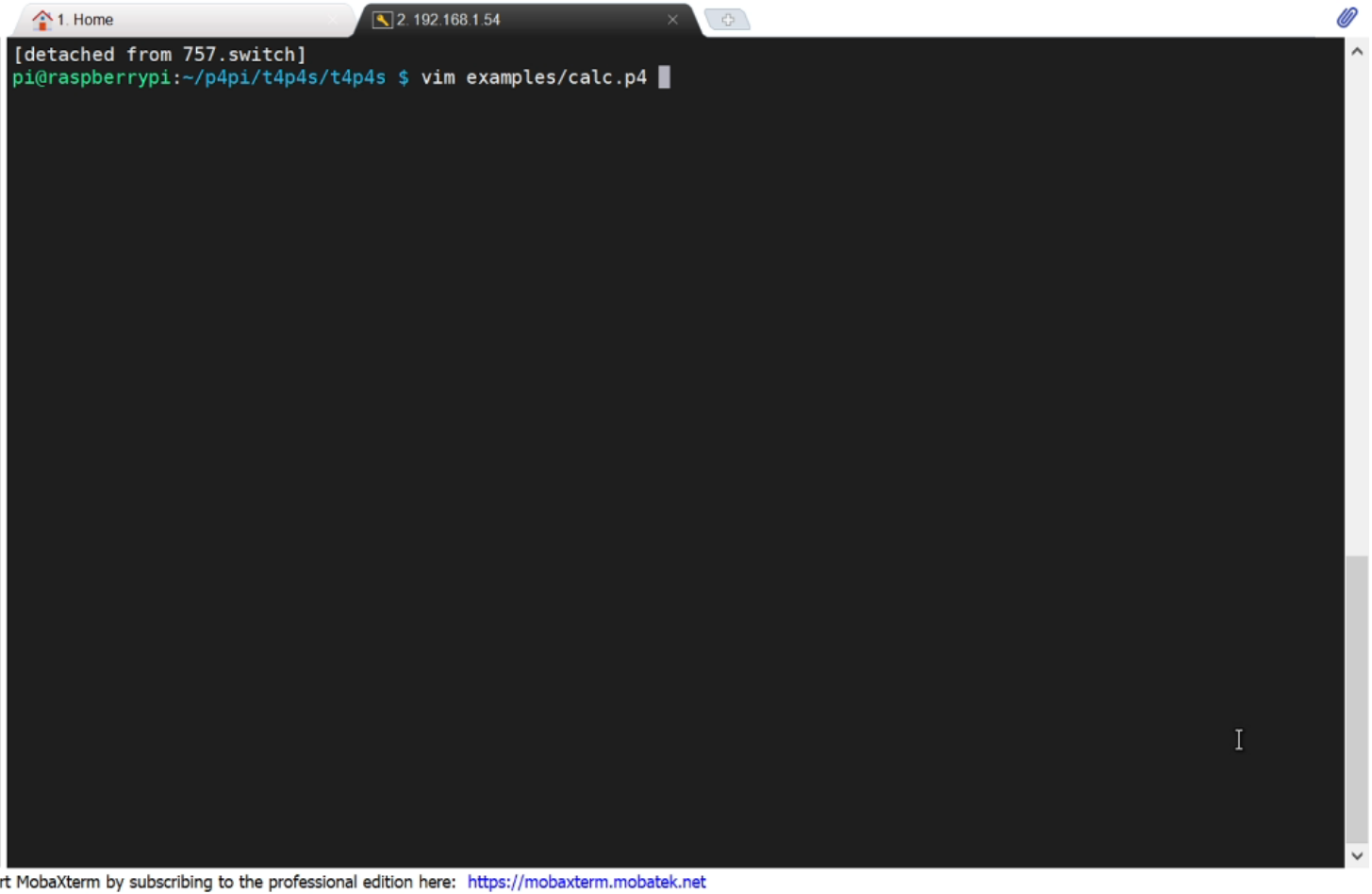
- P4PI
- Laptop 1 - Tester: Test traffic generator
- Laptop 2 - Ctrl: Control machine on the management network

DEMO: P4Calc on P4PI

Step 1 – connecting Tester to P4PI via WiFi

DEMO: P4Calc on P4PI

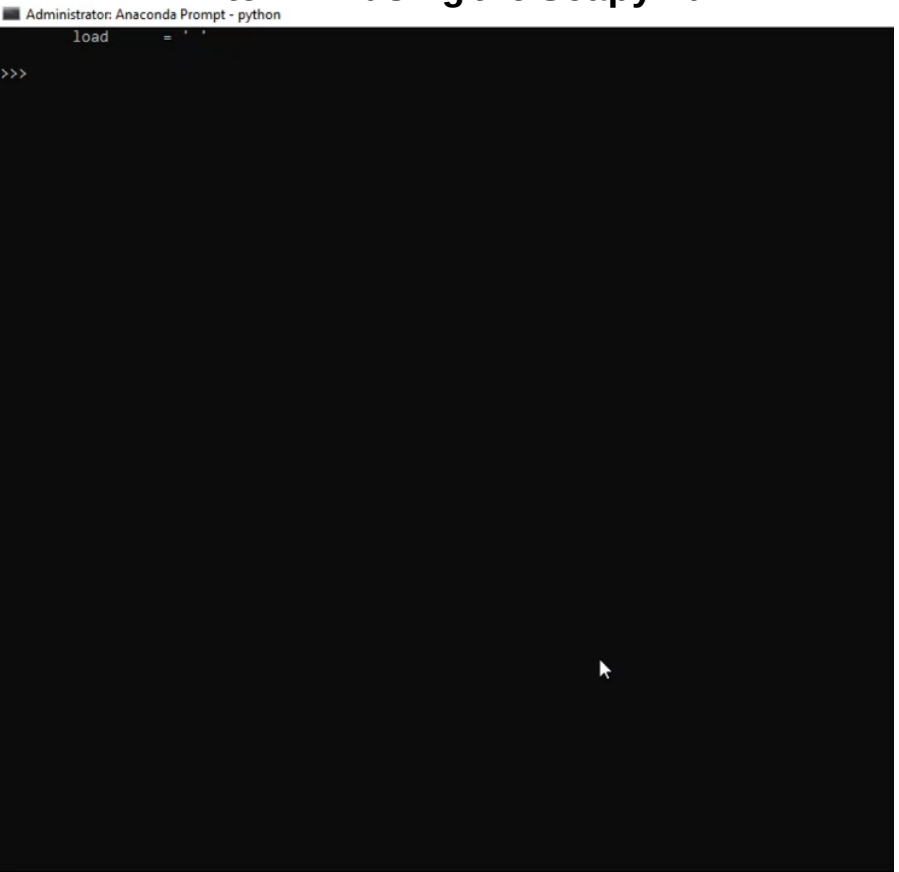
Step 2 – executing the P4 program on P4PI



SSH session from Ctrl

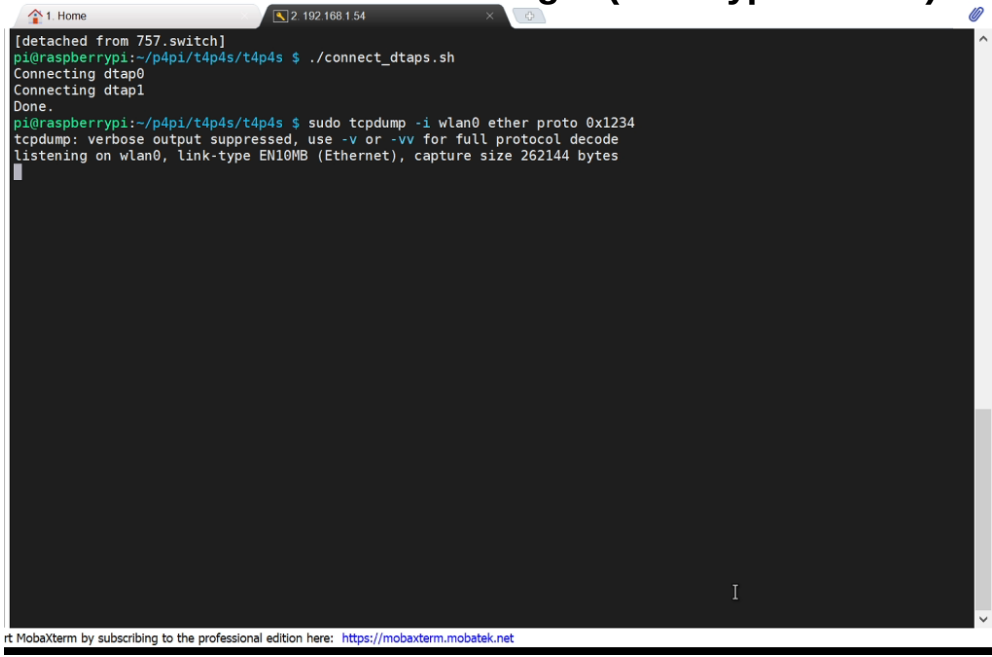
DEMO: P4Calc on P4PI

Tester – sends P4Calc messages to P4PI using the Scapy lib



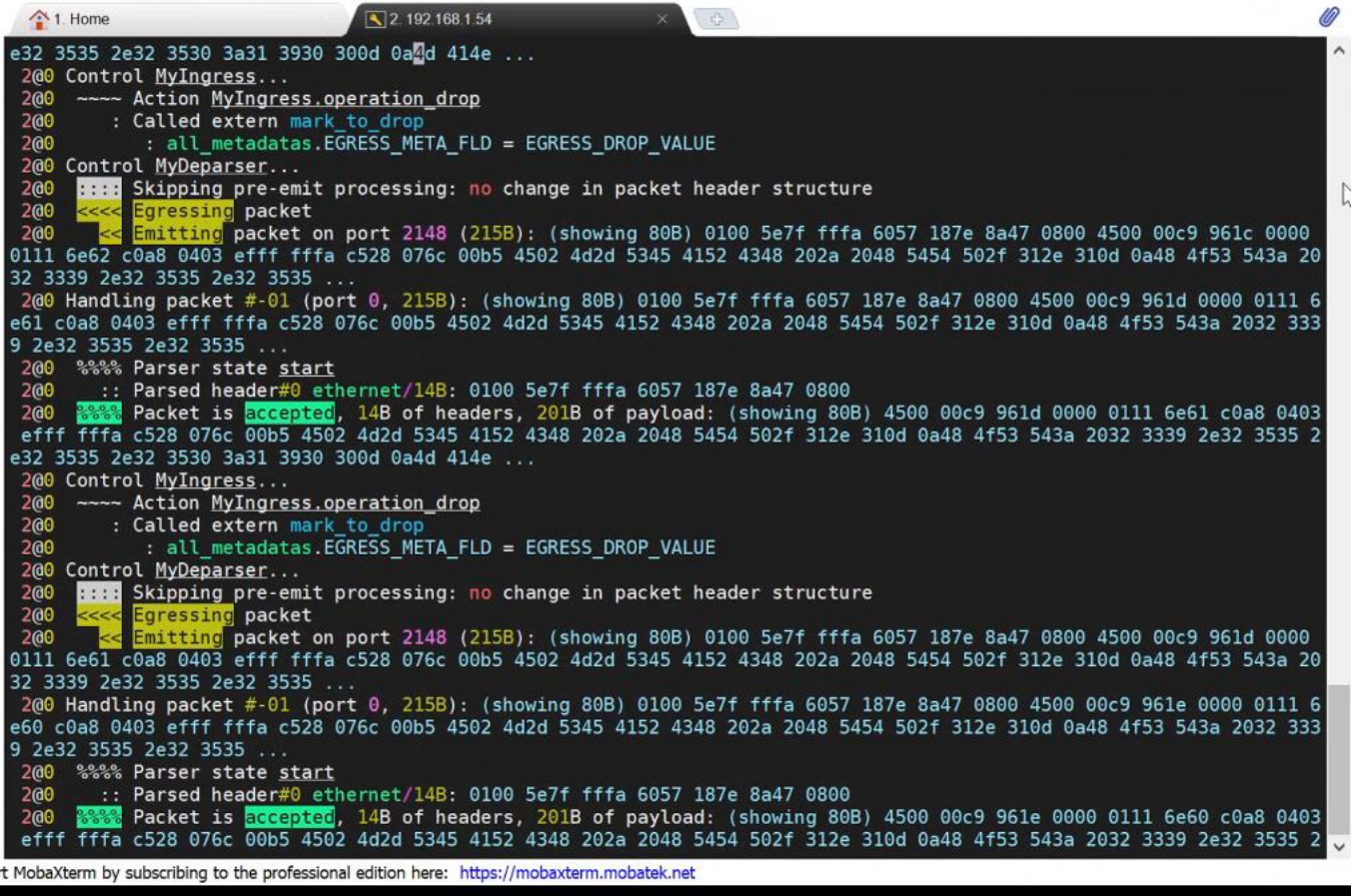
Step 3 – sending test traffic

Ctrl - Tcpdump on the wlan0 interface of P4PI to check the P4Calc messages (ethertype 0x1234)



DEMO: P4Calc on P4PI

Step 4 – In verbose mode, T4P4S provides details on packet processing



P4PI - Use Case Examples

- Simple applications (e.g., P4Calc)
- Load balancing
- Tunneling
- Firewall
- Network telemetry
- IoT applications (e.g., sensor data processing)

- **Don't use just one – build a network!**

Summary

- P4PI platform is **currently under development**
  - To be released this summer
  - https://github.com/p4lang/p4pi
- Developed **for networking education**
  - Cheap, available and open
  - Hands-on experience
- Making P4 available **for hobbyists**
  - Everyone need a P4 home gateway / AP
  - … and other crazy ideas

Hackathon at SIGCOMM 2021

Join us!

- August 23rd or 27th (TBD)
- P4 and P4PI tutorials
- **Educators track -** Practicing and developing teaching materials
- **Contributors track** - Porting projects to P4PI, improving tools etc.
- **Hackers track -** Exploring new use cases and cool ideas using P4PI
- Will provide Raspberry PI platforms to registered participants (limited)

Thank You

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P4PI: **coming soon**