MAY 18-20
2021 P4 Workshop
Hosted by ONF

From Programmable Switches to Programmable Networks

Nate Foster
Cornell University

2021 P4 Workshop
Hosted by ONF

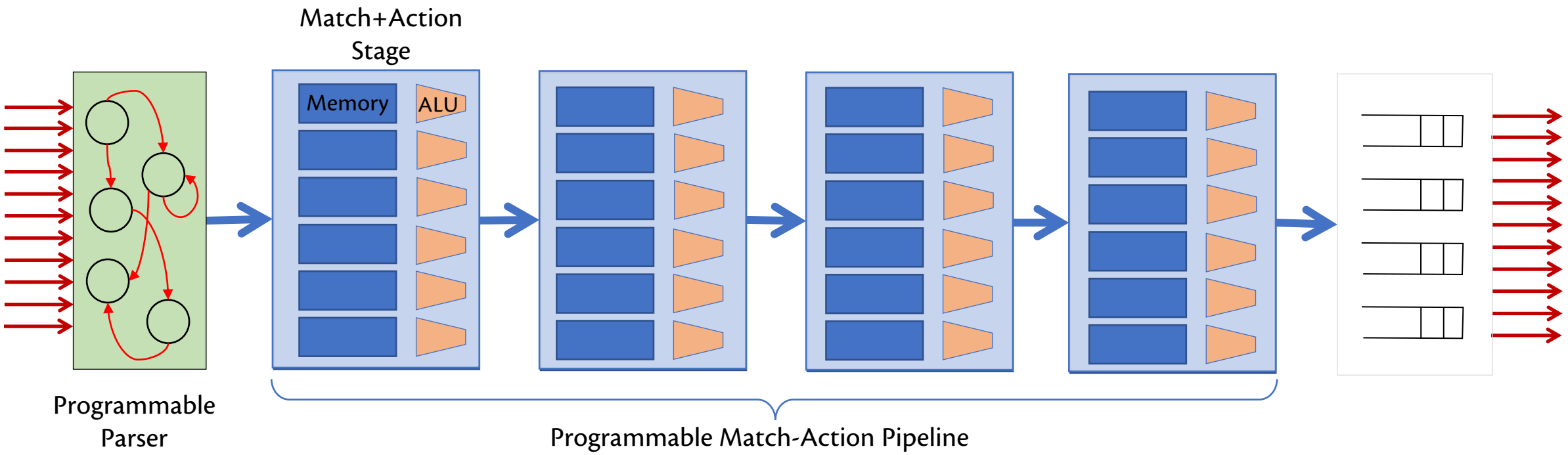
Please join the conversation!

Join the **#p4-2021-workshop** Slack channel on the ONF Community Slack workspace, to interact with workshop speakers and the broader community.

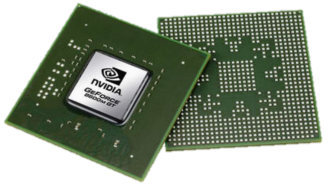
If you are not a member of the ONF Community Slack, you can sign up at:
https://onf-community.slack.com/

Vote for your favorite novel use of P4 on the 2021 P4 Workshop website!

PISA: Protocol Independent Switch Architecture



Domain Specific Processors

Computers	Graphics	Signal Processing	Machine Learning		Networking
Java	OpenCL	Matlab	TensorFlow	>>>	Language
Compiler	Compiler	Compiler	Compiler		Compiler
					?
CPU	GPU	DSP	TPU		

Domain Specific Processors

Computers	Graphics	Signal Processing	Machine Learning	Networking
Java	OpenCL	Matlab	TensorFlow	P4
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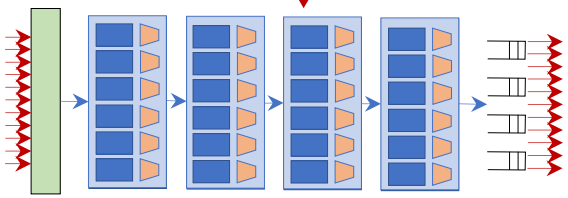
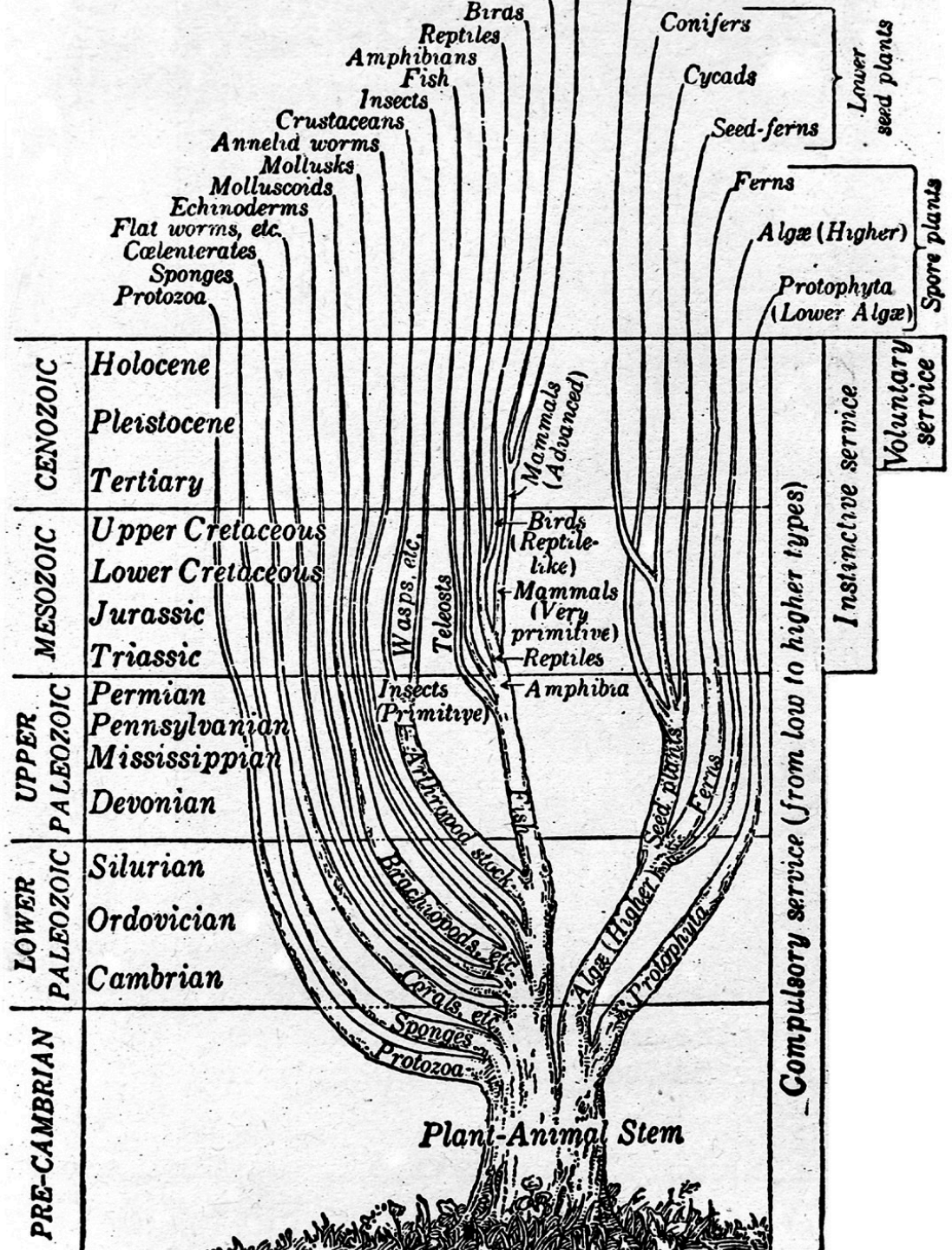
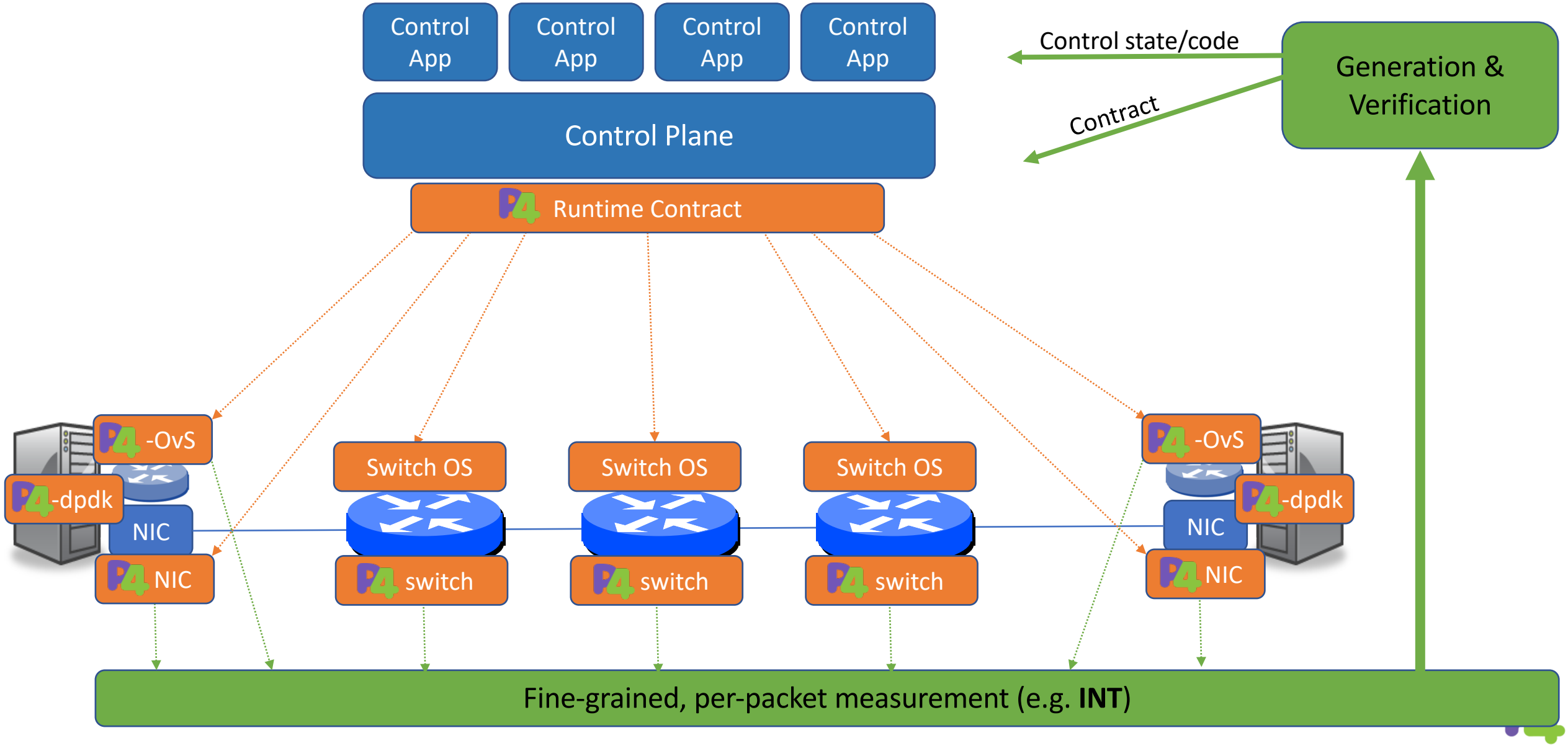
				
CPU	GPU	DSP	TPU	PISA

We are on the cusp of a Cambrian explosion!



Deep Programmability



State of P4 in 2021

New Features

- Continued evolution of $P4_{16}$ Language, P4Runtime, and P4 architectures (PSA, PNA, etc.)
- Open-source developers contributing to a growing set of software targets and tools

New Targets

- User-space (e.g., p4-dpdk)
- Kernel networking (e.g., P4-OvS)
- FPGAs and SmartNICs (multiple vendors)

New Applications

- Hardware offloads
- Congestion control
- Security

$P4_{16}$ Language Specification v1.2.2 (May 2021)

- Added new features to parsers, tables, expressions, statements, etc.
- Generalized P4's type system to make it more flexible and expressive
- Revised several aspects of the specification to clarify the intended meaning
- Changes are increasingly being guided by formal specifications of the P4 language

$P4_{16}$ Language Specification

version 1.2.2

The P4 Language Consortium

2021-05-17

Abstract

P4 is a language for programming the data plane of network devices. This document provides a precise definition of the $P4_{16}$ language, which is the 2016 revision of the P4 language (http://p4.org). The target audience for this document includes developers who want to write compilers, simulators, IDEs, and debuggers for P4 programs. This document may also be of interest to P4 programmers who are interested in understanding the syntax and semantics of the language at a deeper level.

Contents

P4Runtime v1.3.0 (December 2020)

- Obtained an IANA assigned TCP port 9559
- Added detailed treatment of security considerations for P4Runtime servers
- Adopted inclusive terminology (e.g., primary/backup)
- Clarified role of annotations in P4Info files

P4Runtime Specification

version 1.3.0

The P4.org API Working Group

2020-12-01

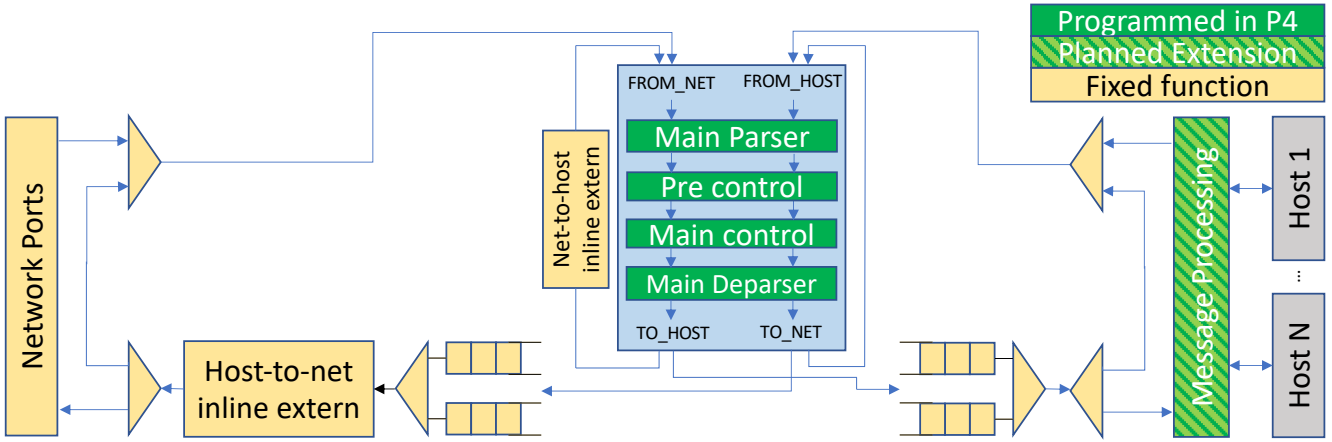
Abstract

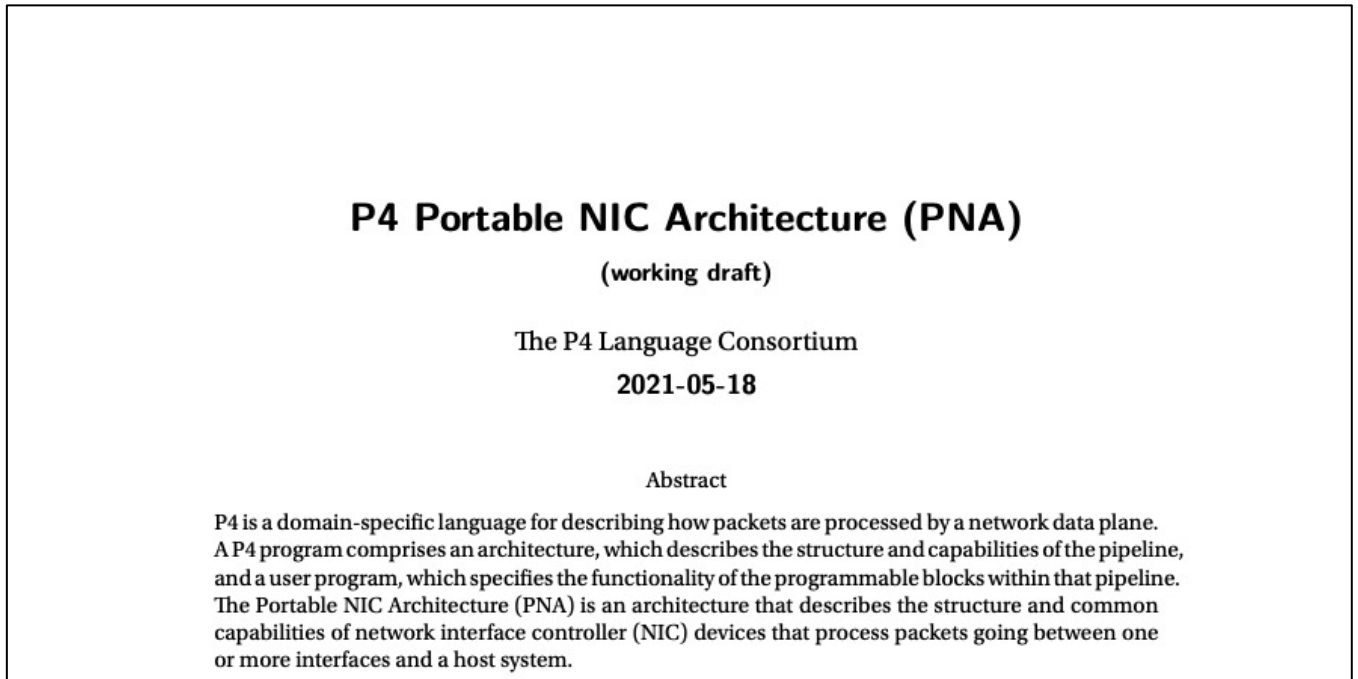
P4 is a language for programming the data plane of network devices. The P4Runtime API is a control plane specification for controlling the data plane elements of a device defined or described by a P4 program. This document provides a precise definition of the P4Runtime API. The target audience for this document includes developers who want to write controller applications for P4 devices or switches.

Contents

Portable NIC Architecture v0.5 (May 2021)

- An initial design intended to provide enough features to implement a virtual switch
- Main features:
  - Pipeline structure
  - Inline externs
  - Connection tracking
- Planned extensions to support message processing in the future
- See Andy Fingerhut's on-demand talk for more!





P4 Portable NIC Architecture (PNA)

(working draft)

The P4 Language Consortium

2021-05-18

Abstract

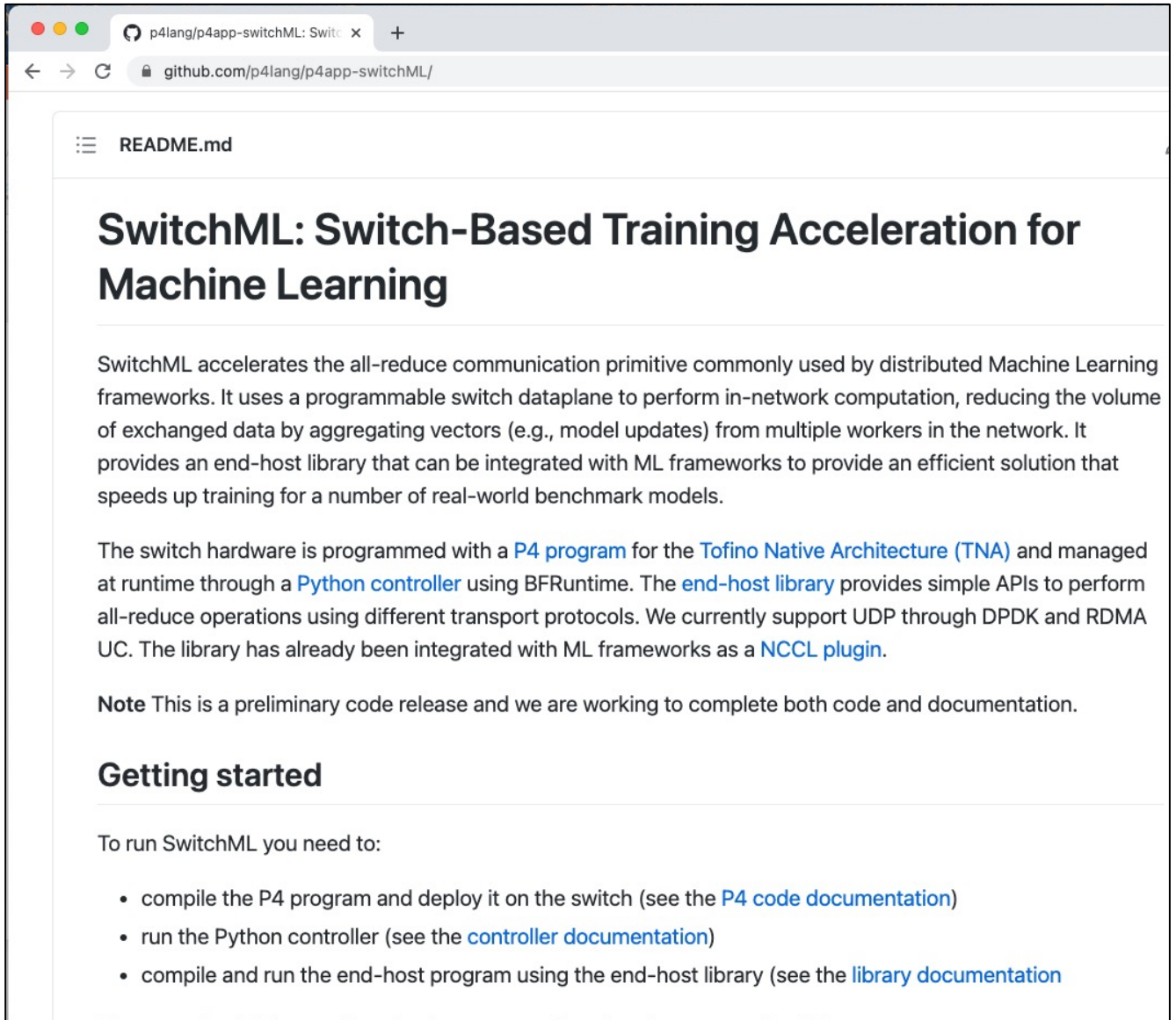
P4 is a domain-specific language for describing how packets are processed by a network data plane. A P4 program comprises an architecture, which describes the structure and capabilities of the pipeline, and a user program, which specifies the functionality of the programmable blocks within that pipeline. The Portable NIC Architecture (PNA) is an architecture that describes the structure and common capabilities of network interface controller (NIC) devices that process packets going between one or more interfaces and a host system.

P4 Apps Repository (April 2021)

A P4 code repository on GitHub

Two categories of contributions:

- P4 Libraries
  - Goal: community access
  - Example: reference implementations of standard protocols in P4
- P4 Systems
  - Goal: community contributions
  - Example: switchML (by MSR, KAUST, Intel)
- Intel's OpenTofino is a key catalyst for sharing open-source code



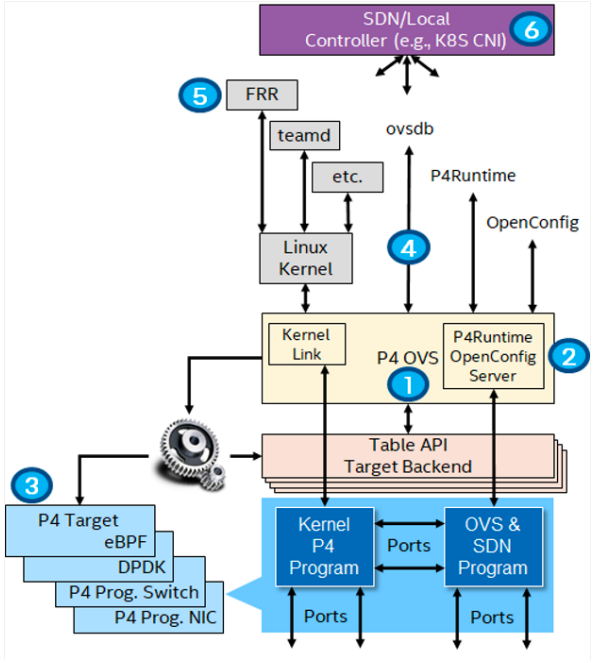
P4 Software Targets

P4-OvS

- A framework for executing P4 code in the Linux kernel
- Integrates with the standard networking stack as well as SDN controllers
- See on demand tutorial, presented by ONF, Orange, and Intel for more!

p4-DPDK

- A new compiler backend based on DPDK
- Facilitates fast user-space processing on CPUs
- See on-demand talk by Han Wang and Christian Dumitrescu for more!



P4 Semantics

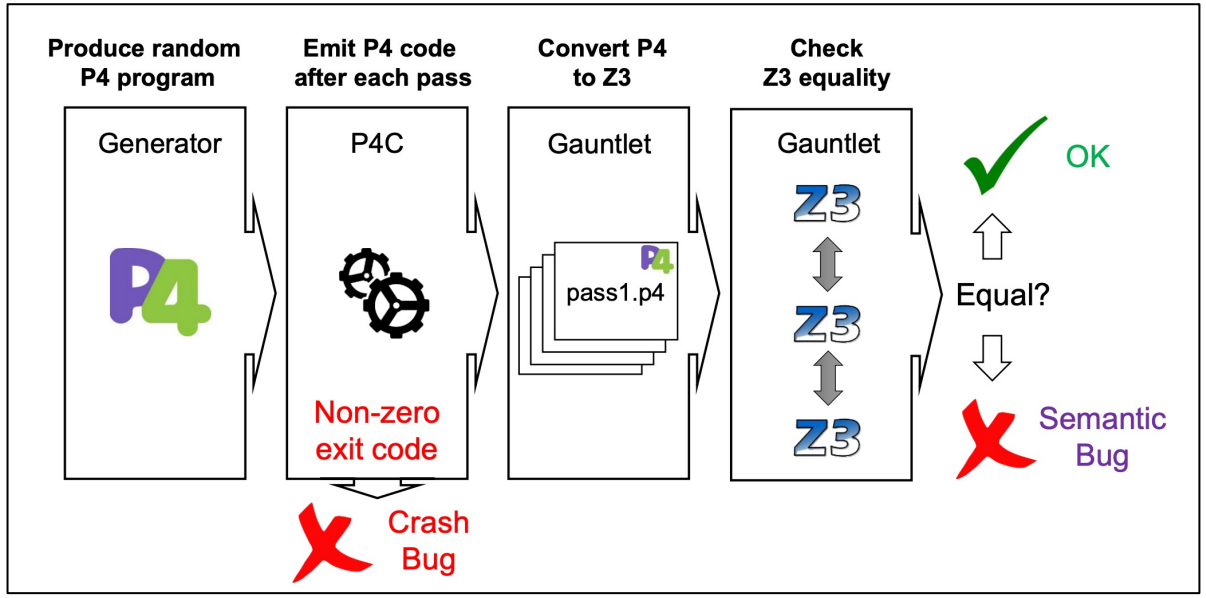
Some academics have started to build tools for reasoning about P4 code

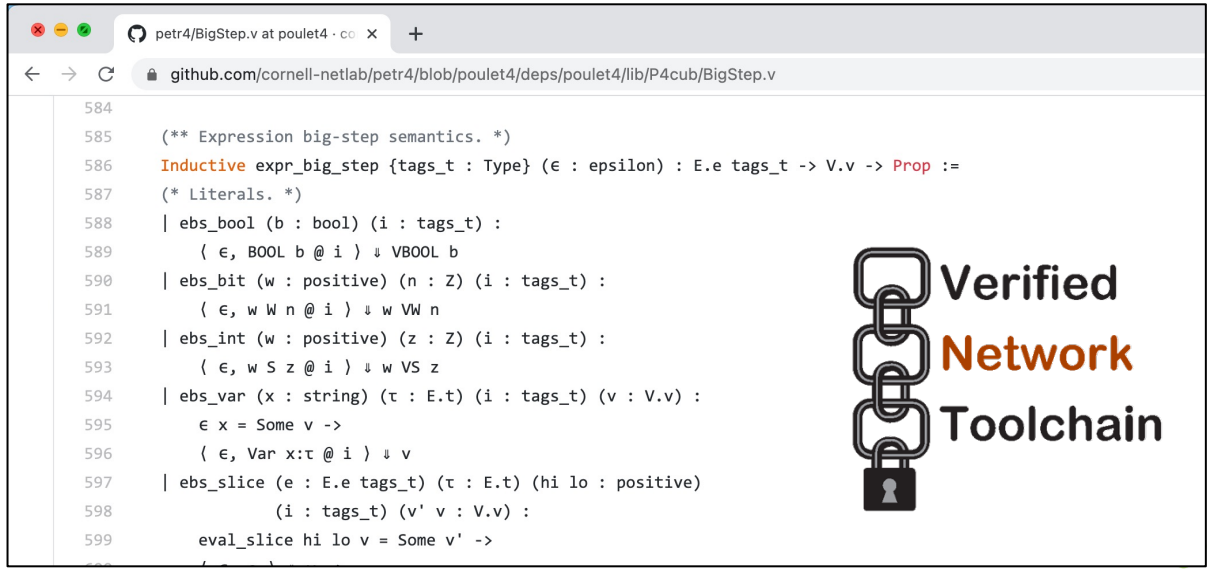
Gauntlet [OSDI '20]

- Fuzzing and translation validation
- Used to validate every commit to the open-source P4 compiler

Petr4 [POPL '21]

- Formalization of $P4_{16}$'s type system and operational semantics
- Semantics is mechanized in Coq
- Being used by Princeton in DARPA's OPS-5G program





Future Directions

Language Design

Enhance flexibility, support modular programming, interface with other languages

Architecture

Develop PSA, PNA, and P4-StdLib

APIs

Integration with industry-standard network operating systems

Applications

Cultivate standard implementations and nurture emerging use cases

Education

Develop P4-based teaching materials for users around the world

P4 Community Updates

Distinguished Service Award

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Distinguished Service Award

Noa Zilberman
Oxford University

"For dedicated service to the P4 community as an evangelist and promoter of the P4 language, designer of the P4 -> NetFPGA workflow, and co-chair of the P4 Education Working Group."

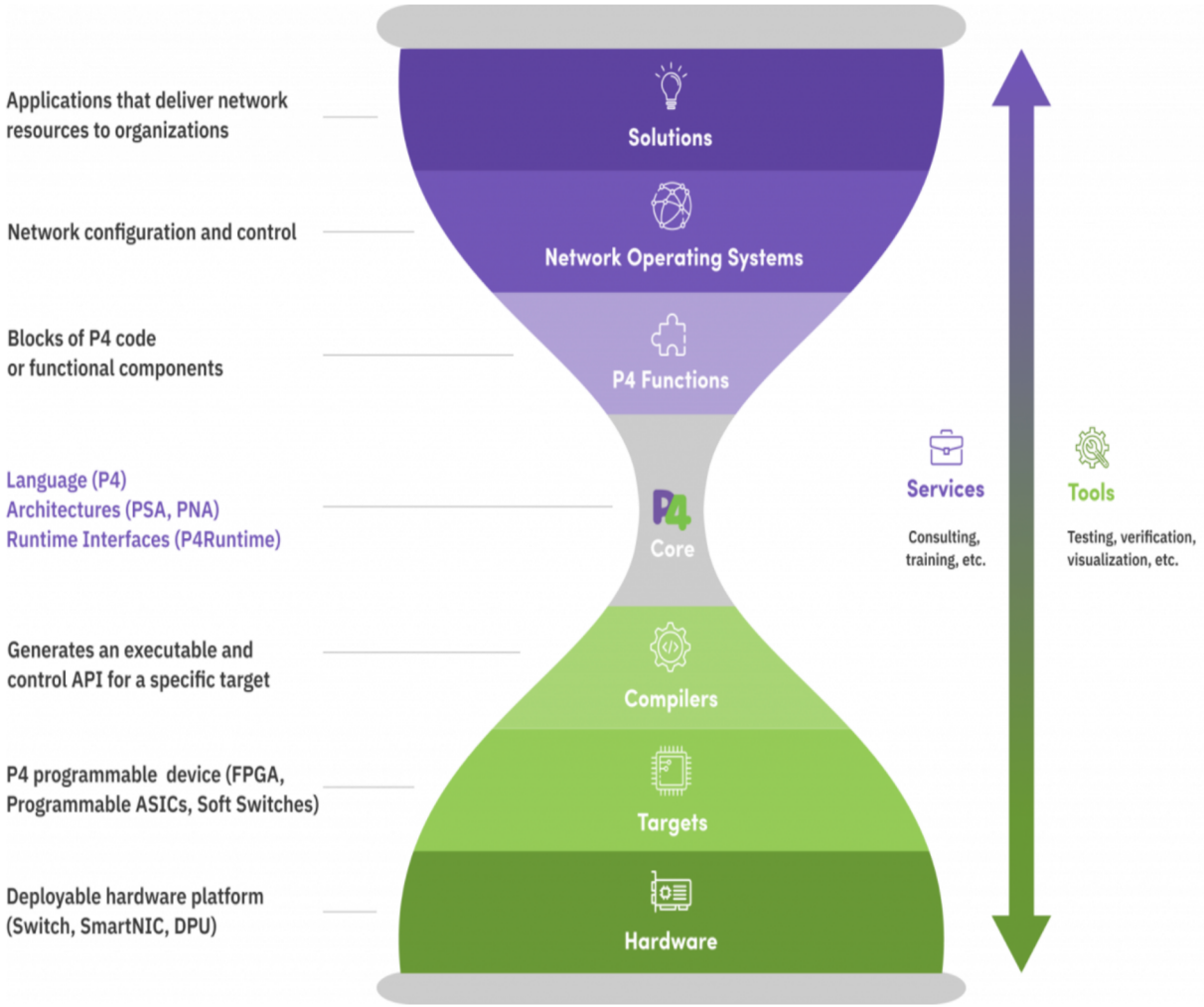
p4.org

What: A new online home for the P4 community

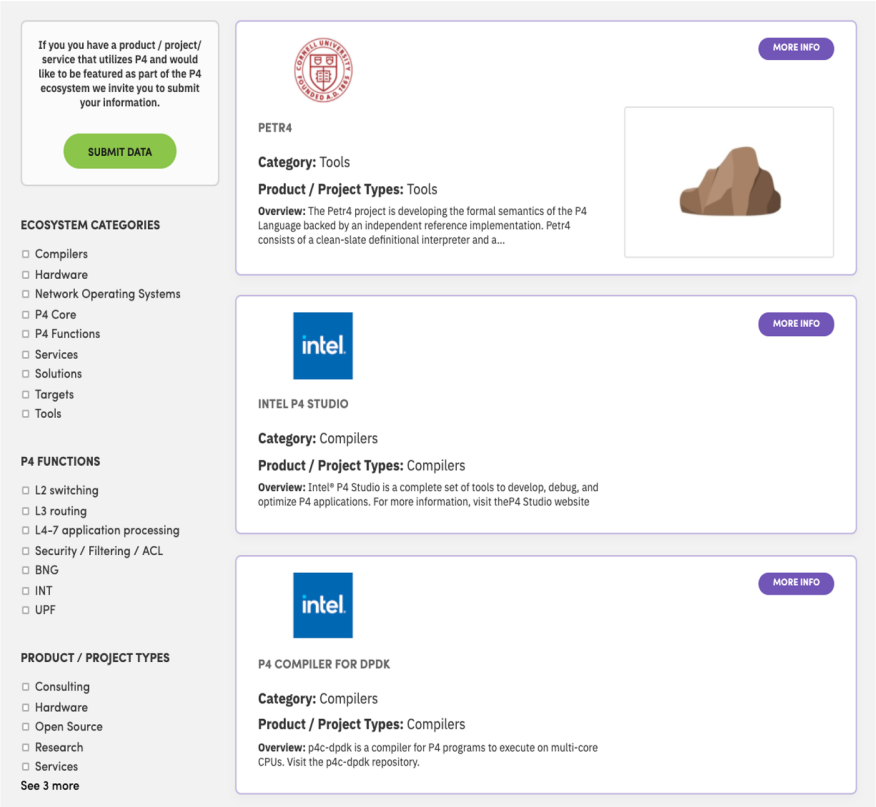
Features

- Specifications
- Community
- Ecosystem
- Blog
- Learning resources
- Forms for contributing
- Fun videos

P4 Ecosystem



- **What:** A one-stop shop for P4 projects, products, and services
- Submit your data to be included!

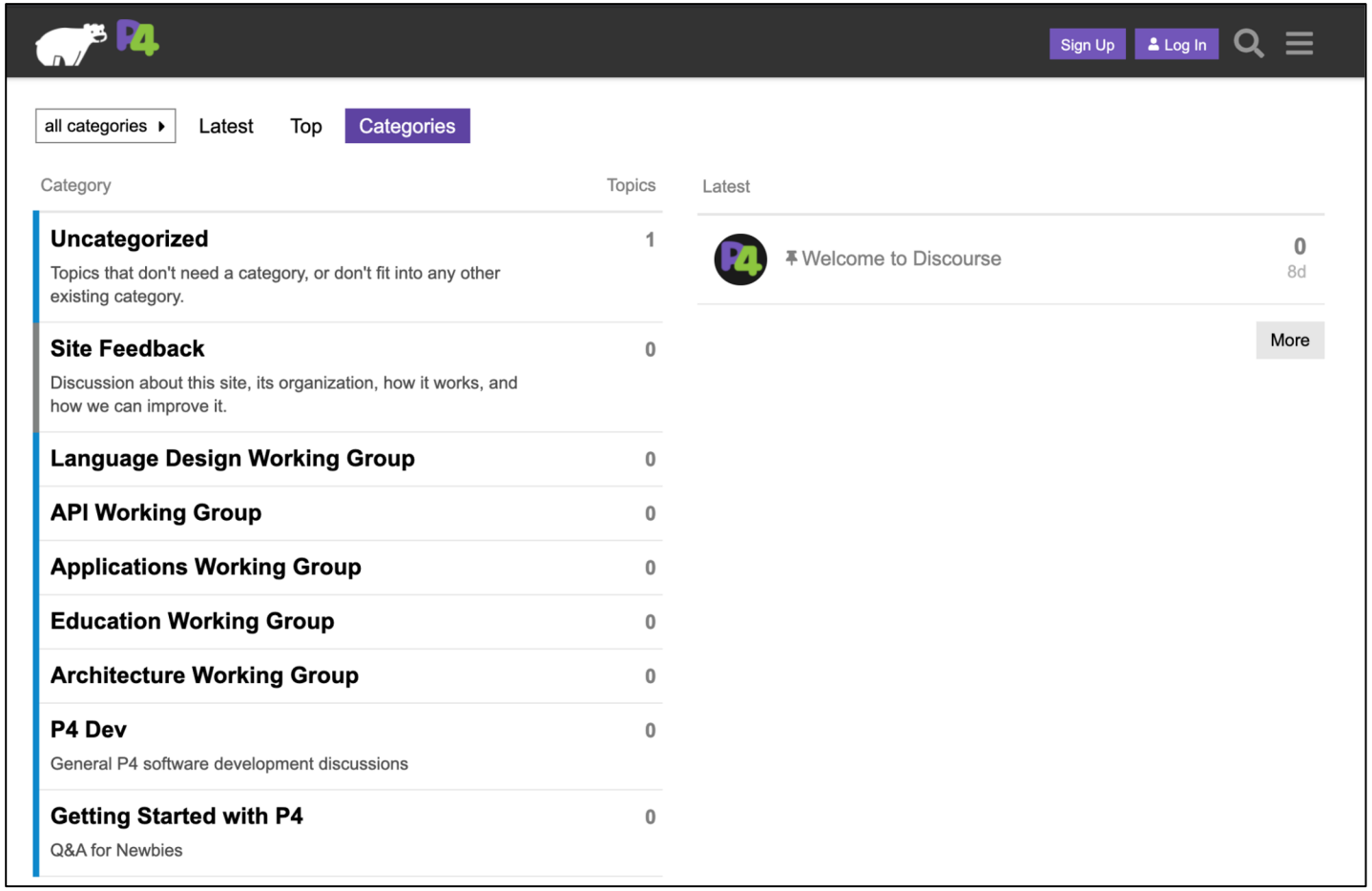


forum.p4.org

What: A new discussion forum for the P4 community

Features: Q&A, search, badges, permanent storage

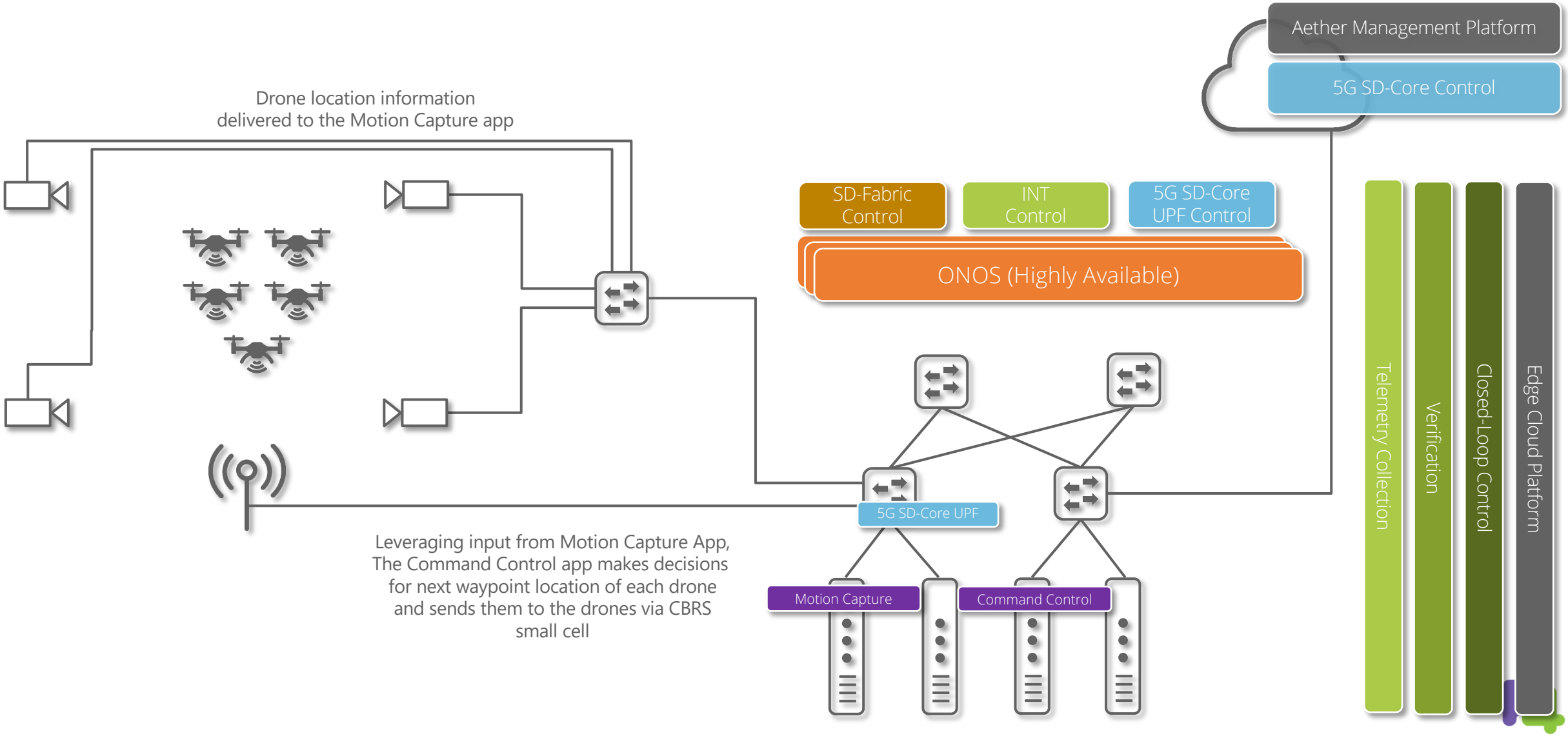
Getting started: Create an ONF account, log in, and start posting!



A Neat Use Case…

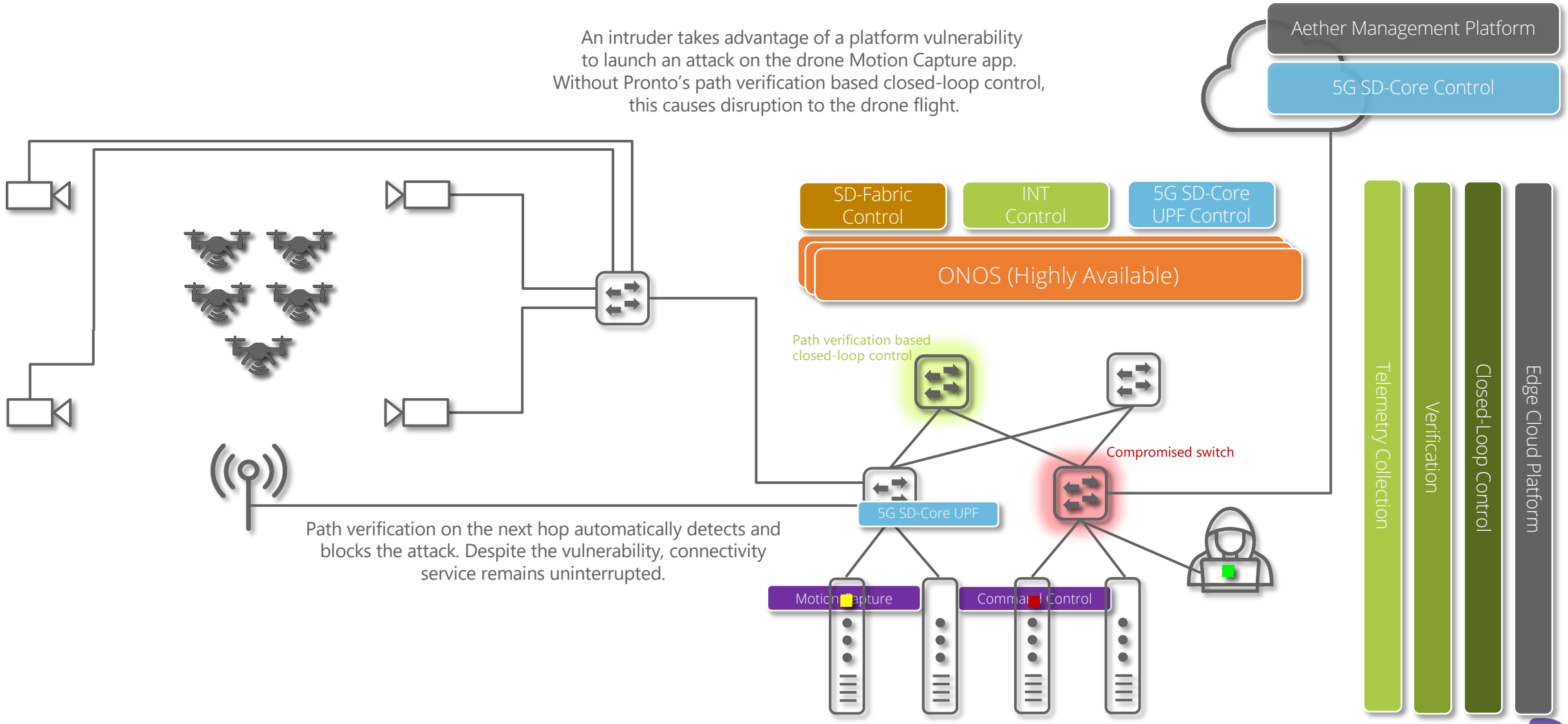
with Sundararajan Renganathan,
Bruce Sprang,
Nick McKeown,
the entire Pronto Team

Pronto Deployment at Stanford Flight Lab



Runtime Path Verification: DDoS Attack

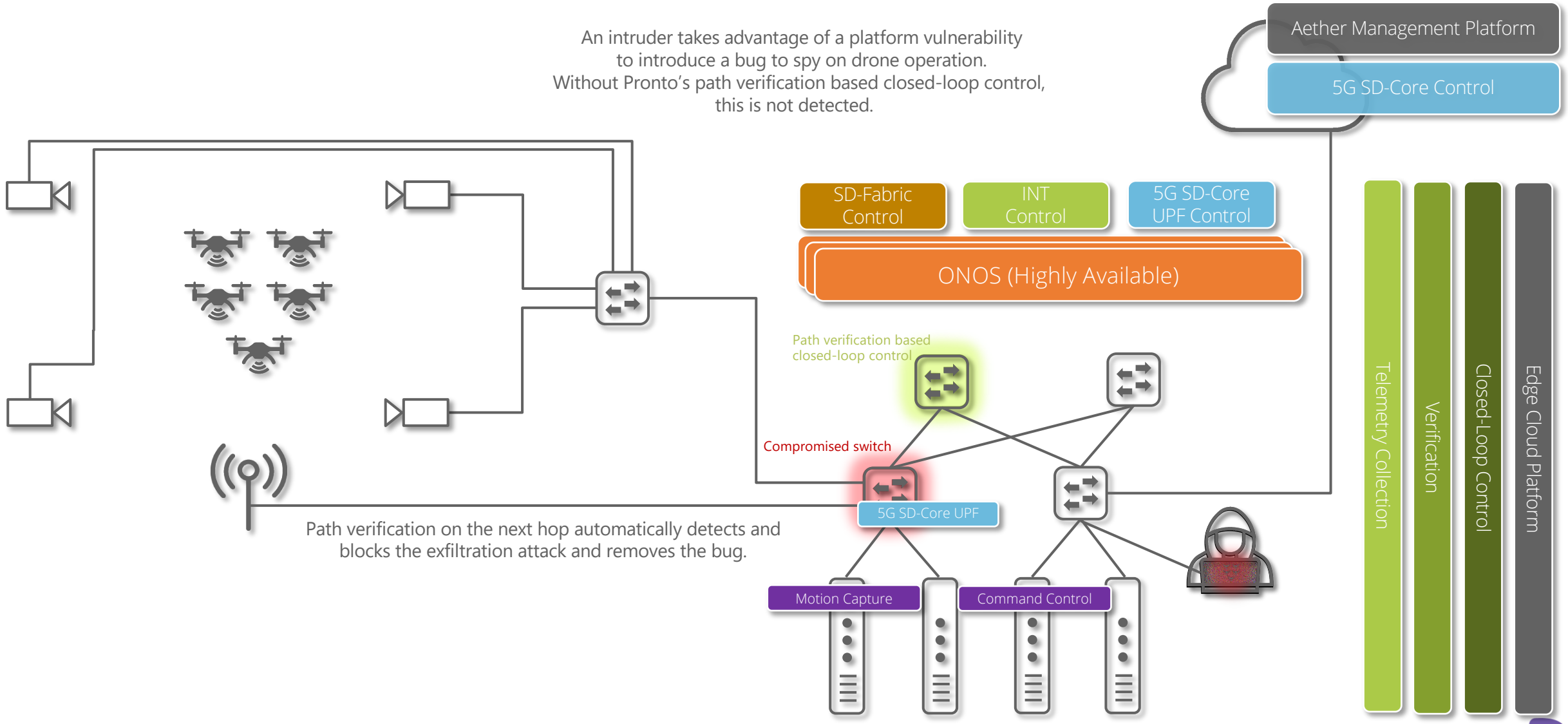
An intruder takes advantage of a platform vulnerability to launch an attack on the drone Motion Capture app. Without Pronto's path verification based closed-loop control, this causes disruption to the drone flight.



Path verification on the next hop automatically detects and blocks the attack. Despite the vulnerability, connectivity service remains uninterrupted.

Runtime Path Verification: Exfiltration

An intruder takes advantage of a platform vulnerability
to introduce a bug to spy on drone operation.
Without Pronto's path verification based closed-loop control,
this is not detected.



Path verification on the next hop automatically detects and
blocks the exfiltration attack and removes the bug.

PRONTO

Wrapping Up…

P4's Guiding Principles

Open Community

- Open to anyone who wants to participate
- Decisions based on technical merit (not business or politics)

Strategic Goals

- Make P4 *the* de facto standard for packet processing, whether in hardware or software
- Find synergies with related frameworks (e.g., eBPF, XDP, DPDK, etc.)

Core Philosophy

- Declarative features with clear semantics
- Domain-specific constructs familiar to practitioners
- Predictable resource utilization and performance

Get Involved

- **Join the P4 Project!**
  - No fee to participate
  - Lightweight legal agreement based on Apache2 License
  - Possible to become an ONF Collaborator or Member
- **Participate in Working Groups**
  - Anyone with a good idea can help shape the future of P4
  - Open governance model with code of conduct
  - Decisions made by consensus on technical merits
- **Contribute to P4 Software**
  - Compiler (p4c)
  - Software targets (bmv2, OvS, DPDK)
  - Control-plane APIs (P4Runtime)
  - Tutorials & Documentation
  - Applications (INT, SwitchML, etc.)

Thank You

P4 Advisory Board

- Nate Foster (Cornell)
- Nick McKeown (Stanford)
- Guru Parulkar (ONF)
- Jennifer Rexford (Princeton)
- Amin Vahdat (Google)

P4 Technical Steering Team

- Nate Foster (Cornell, chair)
- Robert Soulé (Yale)
- Amin Vahdat (Google)
- Larry Peterson (ONF)
- Stefan Heule (Google)
- Andy Fingerhut (Intel)

Working Group Co-Chairs

- ***Language:*** Mihai Budiu, Nate Foster
- ***APIs:*** Antonin Bas, Waqar Mohsin
- ***Architecture:*** Andy Fingerhut, Gordon Brebner
- ***Applications:*** Mukesh Hira, Jeongkeun Lee
- ***Education:*** Robert Soulé, Noa Zilberman

P4 Workshop Program Committee

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- Mario Baldi (Pensando)
- Dan Daly (Intel)
- Nate Foster (Cornell)
- Carmelo Cascone (ONF)
- Minlan Yu (Harvard)
- Noa Zilberman (Oxford)

P4 Workshop Organizers

- Denise Barton (ONF)
- Rachel Everman (Intel)
- Brian O'Connor (ONF)
- Guru Parulkar (ONF)
- Larry Peterson (ONF)
- Michelle Roth (ONF)
- Timon Sloane (ONF)

P4 Workshop Sponsors

- Alibaba
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- Open Compute Project
- Vector Data

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Enjoy!