Securing the Internet and 5G Infrastructure
The network as a programmable platform

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Stanford University

With: Nate Foster, Jen Rexford,
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and the whole Pronto team


2005
2020
2030
+10 years

1: A change of who is in control

Compute mainframes

Network mainframes

Server running control plane

Whitebox switch

Closed & proprietary
Bloated & power hungry
Little incentive to improve
"Internet ossification"

Networks hard to manage
Unreliable, hard to secure
Hard to scale

Homegrown
Merchant silicon
Linux based
Open source

Easier to fix
Add new features:
- Traffic engineering
- Faster recovery
- Intrusion detection

Faster innovation

20

Phase 1

Network owners take control of their software

2020

1: A change of who is in control

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Phase 1

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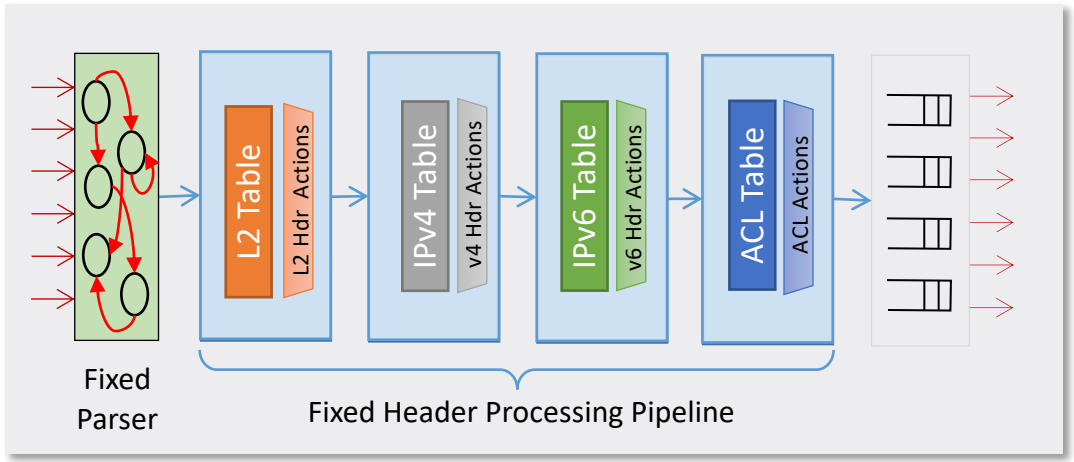
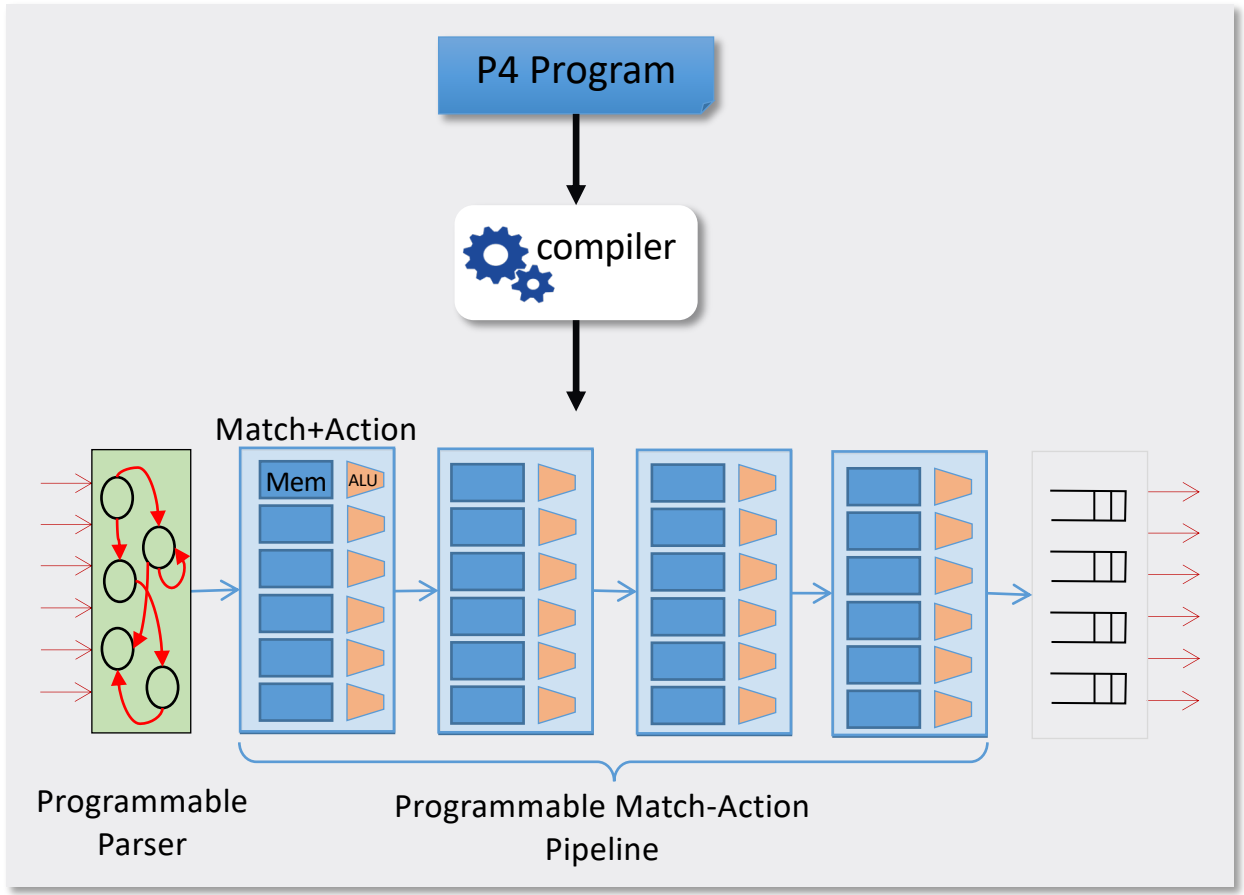
Phase 2

Network owners take control of packet processing too

2: Taking control of packet processing, too

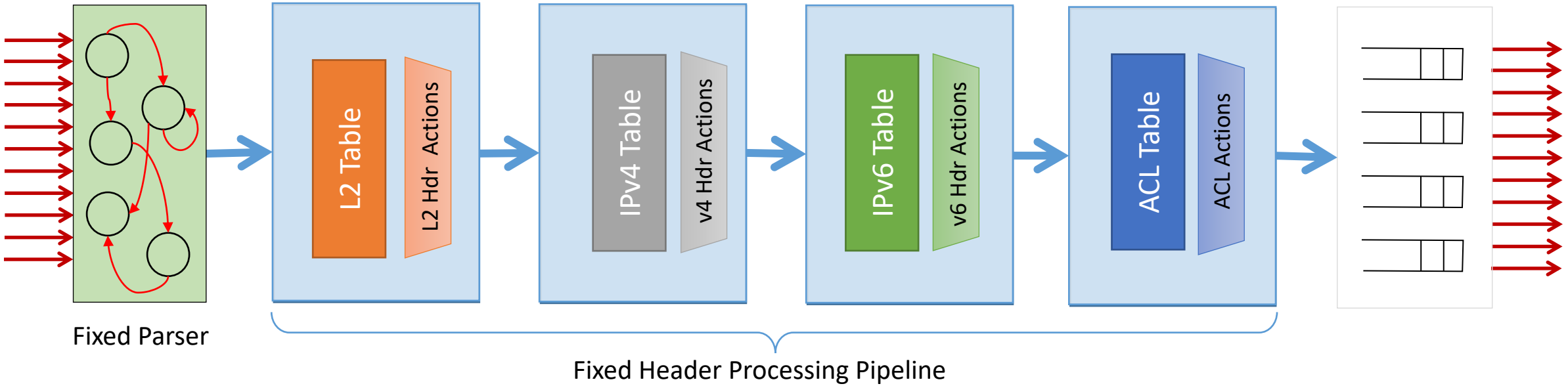


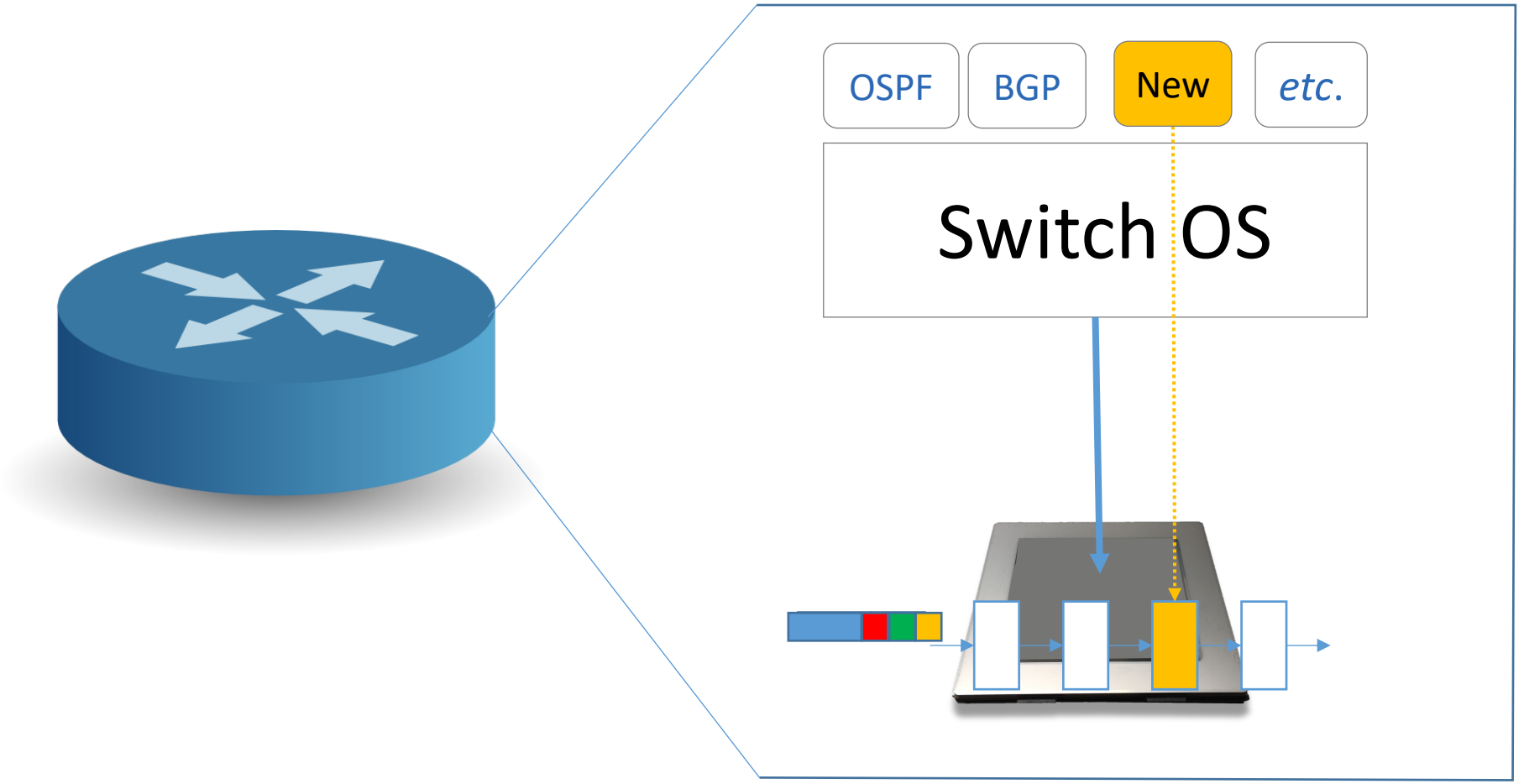
Fixed function switches and NICs



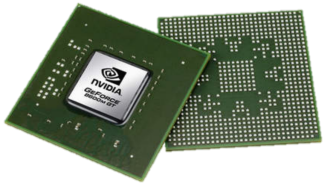
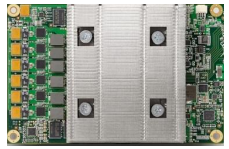
Programmable switches and smartNICs

Switch with fixed function pipeline




OSPF
BGP
New
etc.
Switch OS

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

Java

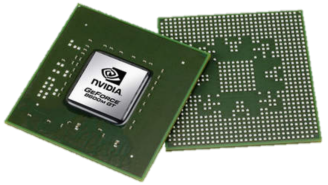
Compiler

CPU

Graphics

OpenCL

Compiler



GPU

Signal Processing

Matlab

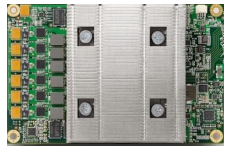
Compiler

DSP

Machine Learning

TensorFlow

Compiler

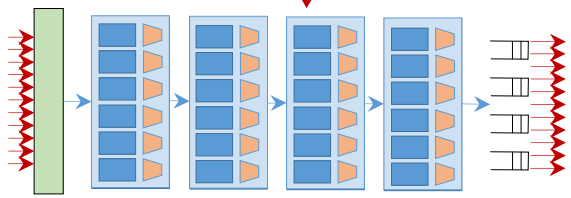


TPU

Networking

P4

Compiler



PISA

“Programmable switches run 10x slower, consume more power and cost more.”

Conventional wisdom in 2010

Not true any more

3: The rise of open-source networking software

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Phase 1

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Open source

Networking Software

Phase 2

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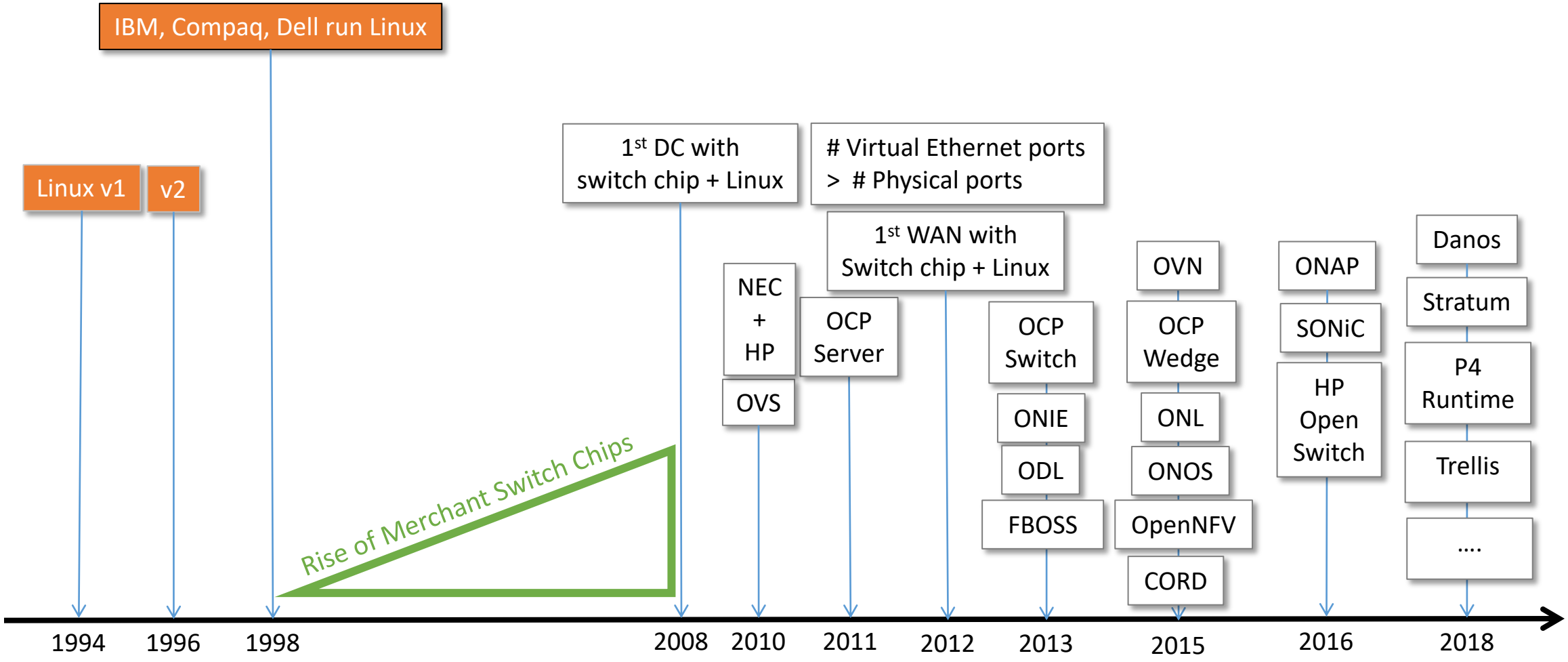
3: The rise of open-source networking software

Open source has re-emerged as a legitimate and trustworthy way to control networks

e.g. OVS, SONiC, FBOSS, FRR, ONOS …

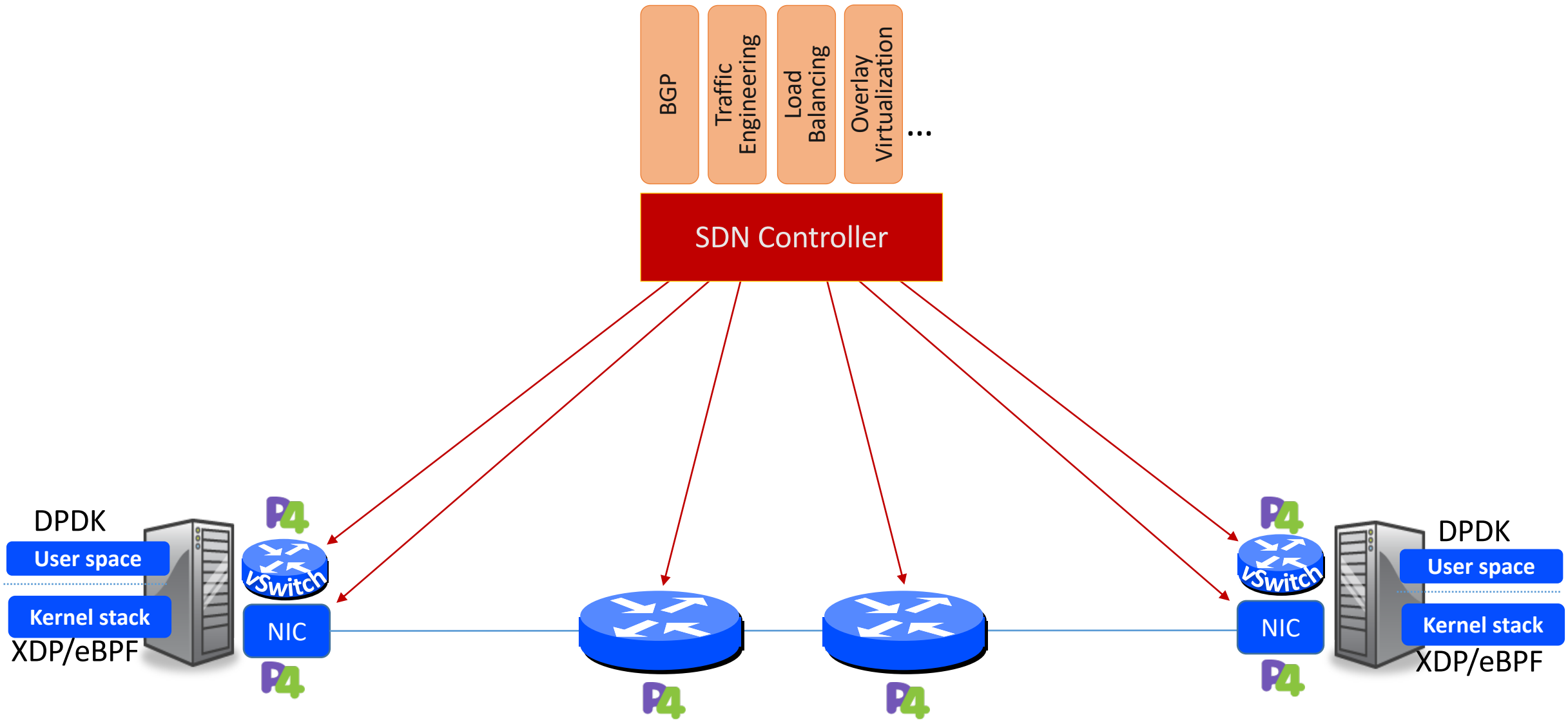
- Network code that was opaque and closed has become transparent and open

- ONF: Open Networking Foundation
- Linux Foundation
- TIP: Telecom Infrastructure Project



So what happens next?

PROGRAMMABLE END-TO-END & TOP-TO-BOTTOM



We will think of a network as a programmable platform.

We will describe the desired behavior at the top, then partitioned, compiled and run across elements.

Cloud, ISP and 5G networks will be programmed and tailored locally.

Who better to improve the reliability and security of networks than their owners?

Fine-grain per-packet measurement
will monitor function and performance.

Software engineering techniques will be used routinely:
formal verification and on-the-fly checking of correctness.

Future networks will be programmed by many.

And operated by few.

OPEN SOURCE: END-TO-END & TOP-TO-BOTTOM

Networks, for the first time, will be

- Programmable end-to-end
- Specified top-to-bottom
- Defined entirely by software.

Traffic Engineering

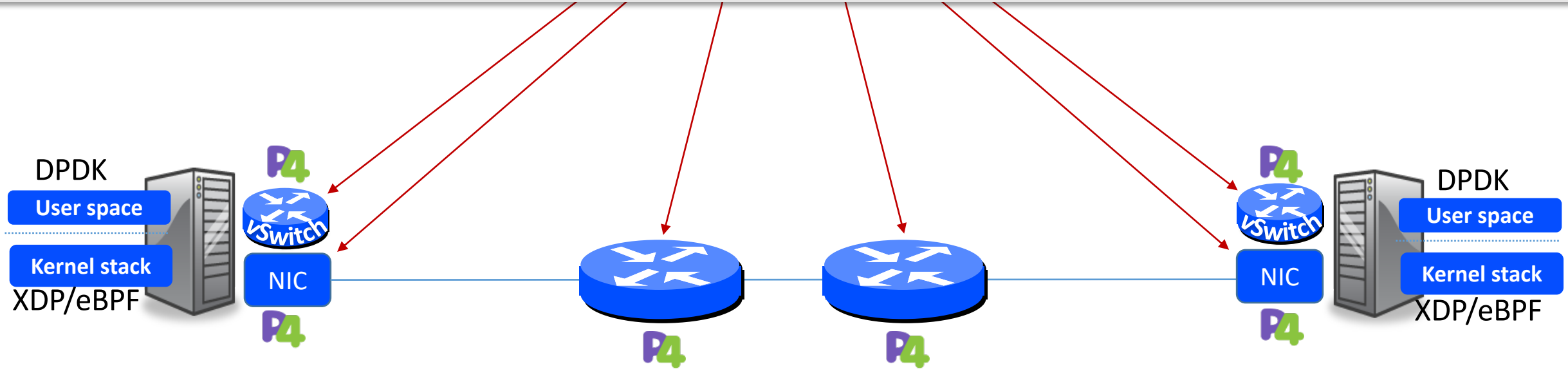
Load

SDN Controller

This creates new possibilities

- To verify networks are “correct by construction”.
- To measure and validate, in real-time against the network specification.
- To correct bugs through closed-loop control.

Because of open-source, we (the research community) get to take part.



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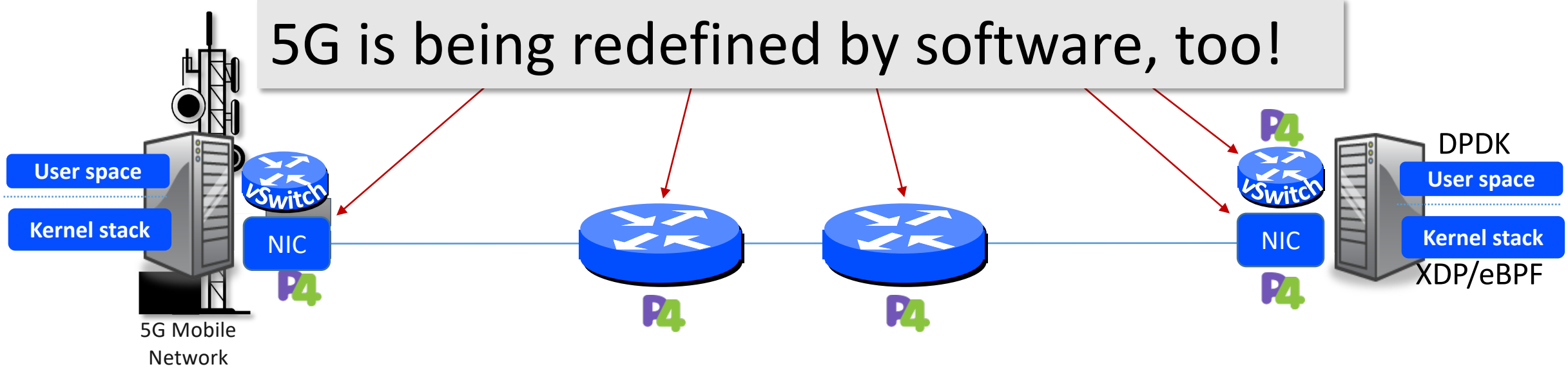
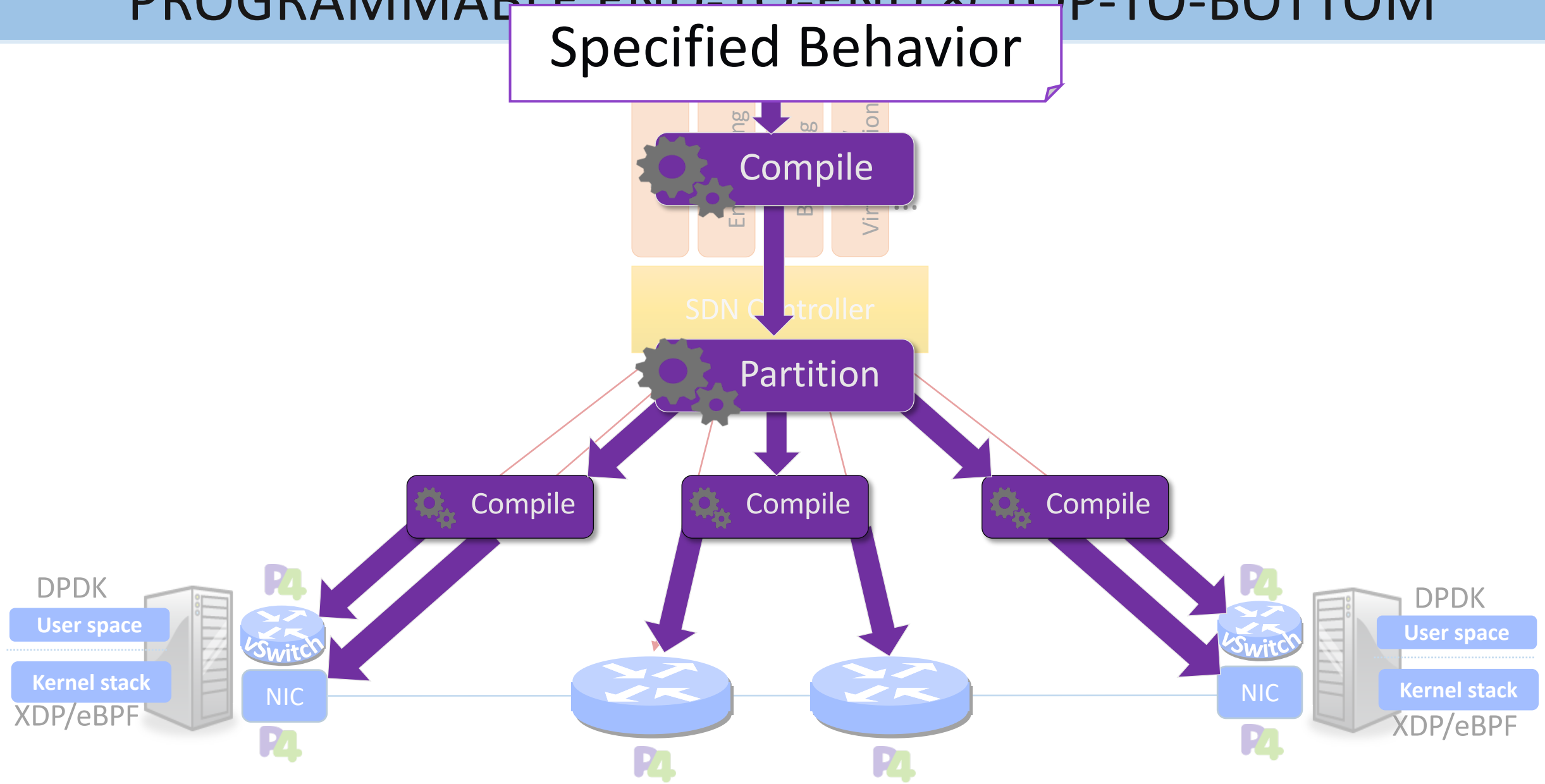
5G is being redefined by software, too!



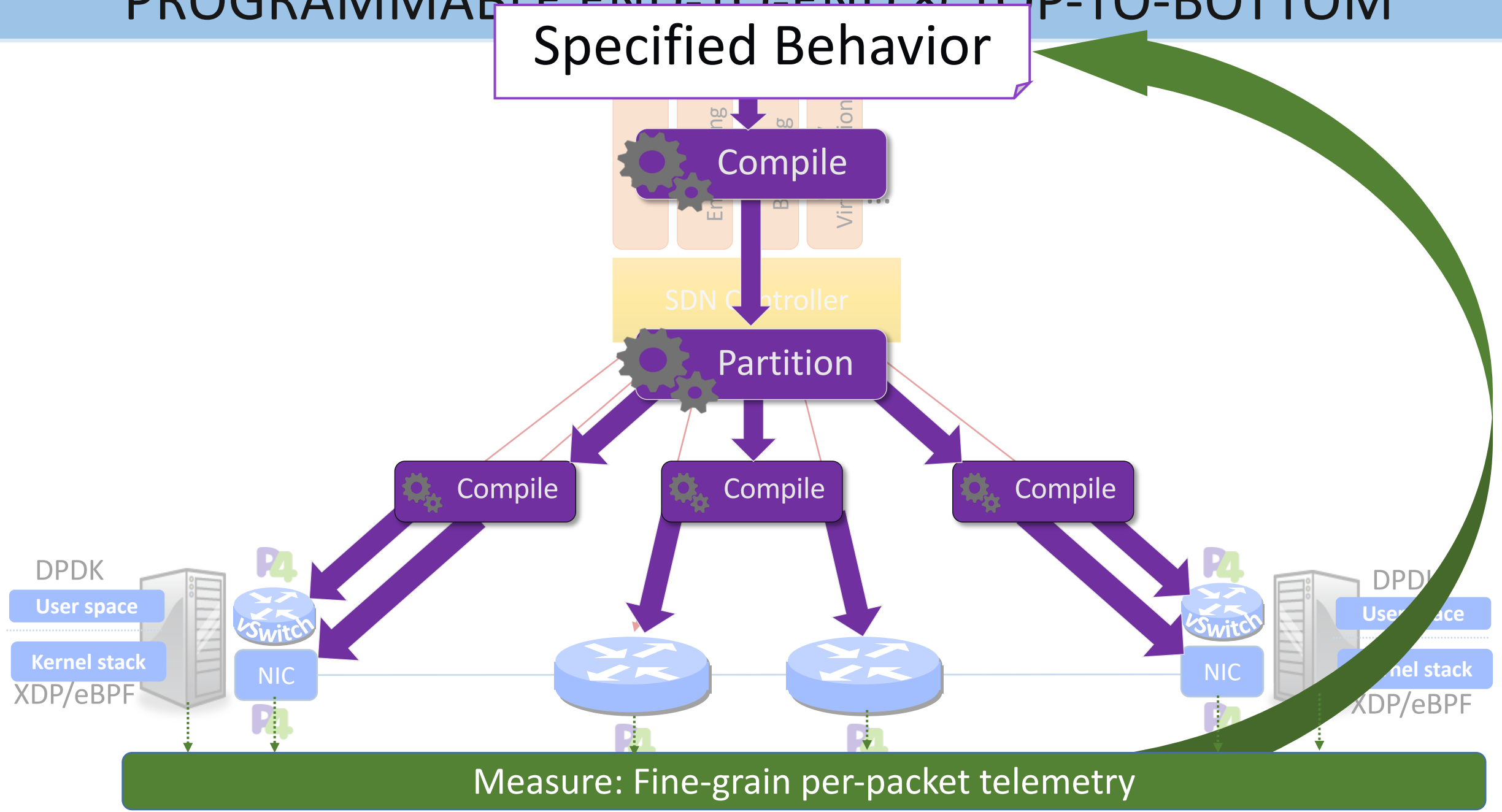
How it will happen

1. **Fine-grain telemetry**: Instrumenting *every* packet
2. **Verification**: Is every packet (and all state) “correct”?
3. **Control**: If needed, update state and programs

PROGRAMMABLE END-TO-END & TOP-TO-BOTTOM



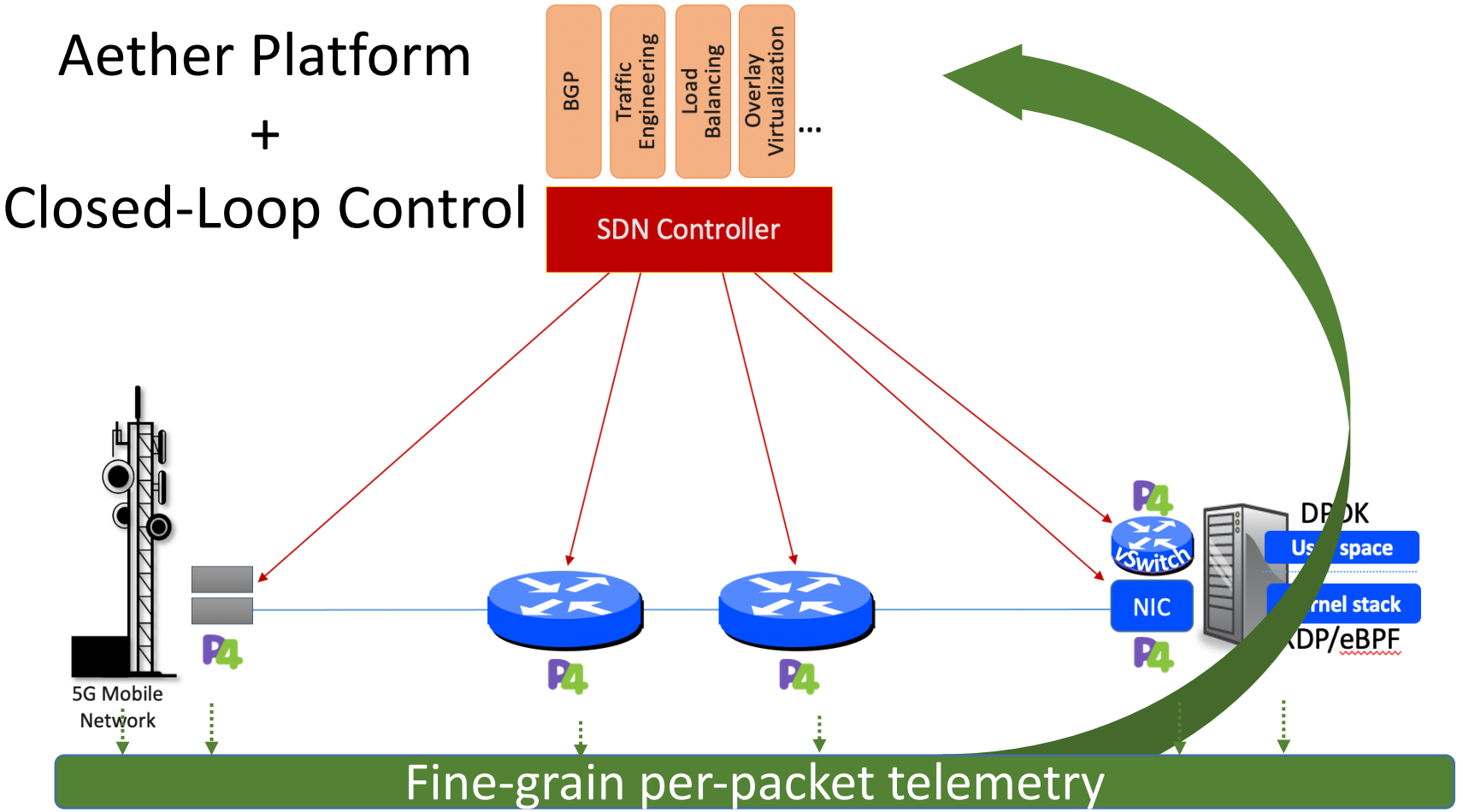
PROGRAMMABLE END-TO-END & TOP-TO-BOTTOM



Initial Aether Deployments

PRONTO

Aether Platform
+
Closed-Loop Control



How to find out more and get involved

Research

prontoproject.org

Watch…

1. Jen Rexford's talk about closed loop control, and
2. Nate Foster's talk about verification

Aether Platform

aetherproject.org

Watch…

Oguz Sunay and Larry's Peterson's talk (next)

Join us…

1. Campus: Deploy Aether edge and use it for research
2. Enterprise: Plan a trial for 5G connected edge cloud
3. Supply-chain: Join Aether open-source project

Thank you!