lecture 03:
centralized control

5590: software defined networking

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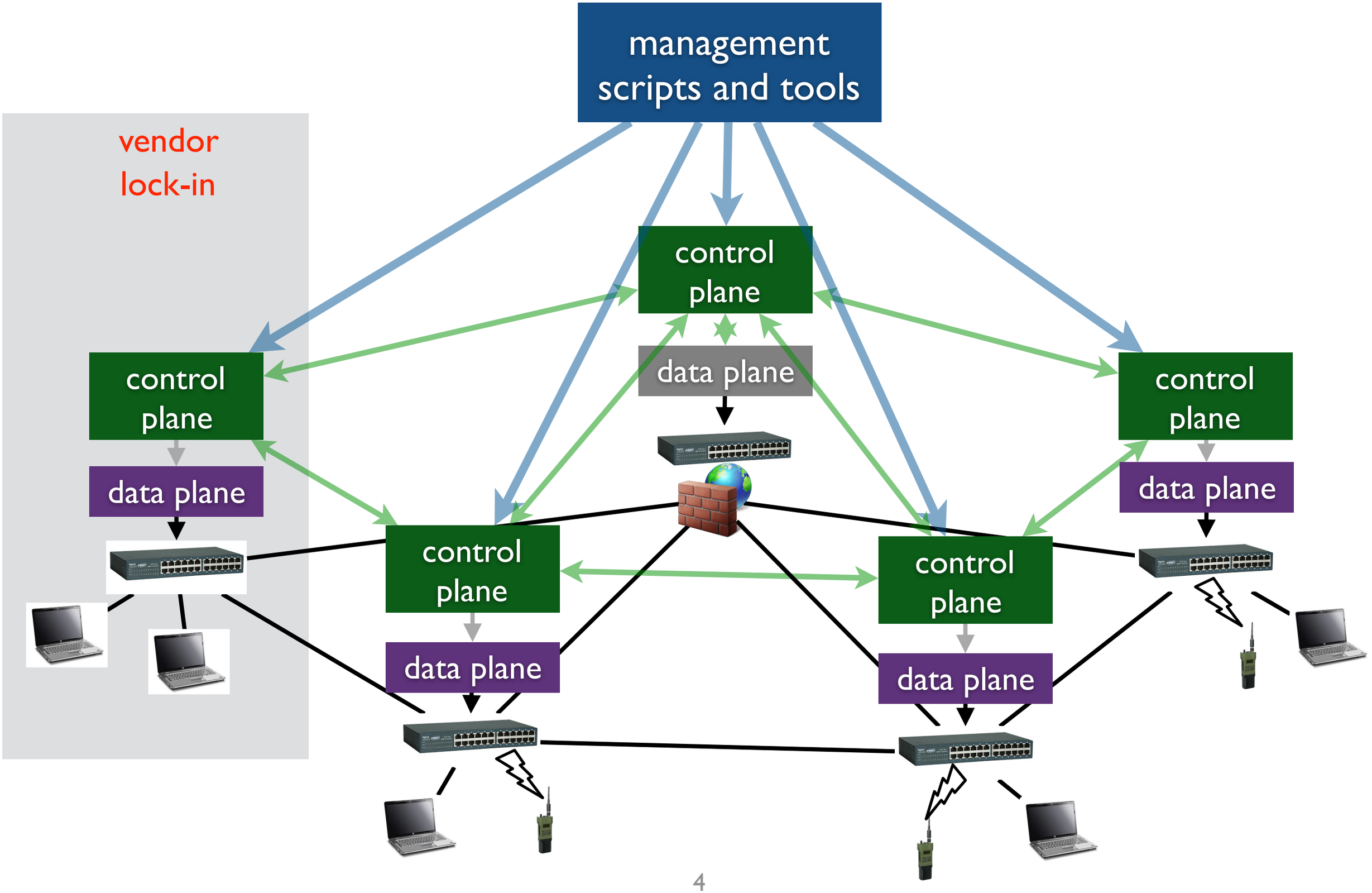
TTLMAN 402, R 17:30-20:00

some materials in this slide are based on lectures by

Jennifer Rexford https://www.cs.princeton.edu/courses/archive/fall13/cos597E/

Nick Feamster http://noise.gatech.edu/classes/cs8803sdn/fall2014/

data, control, and management planes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scripts and tools
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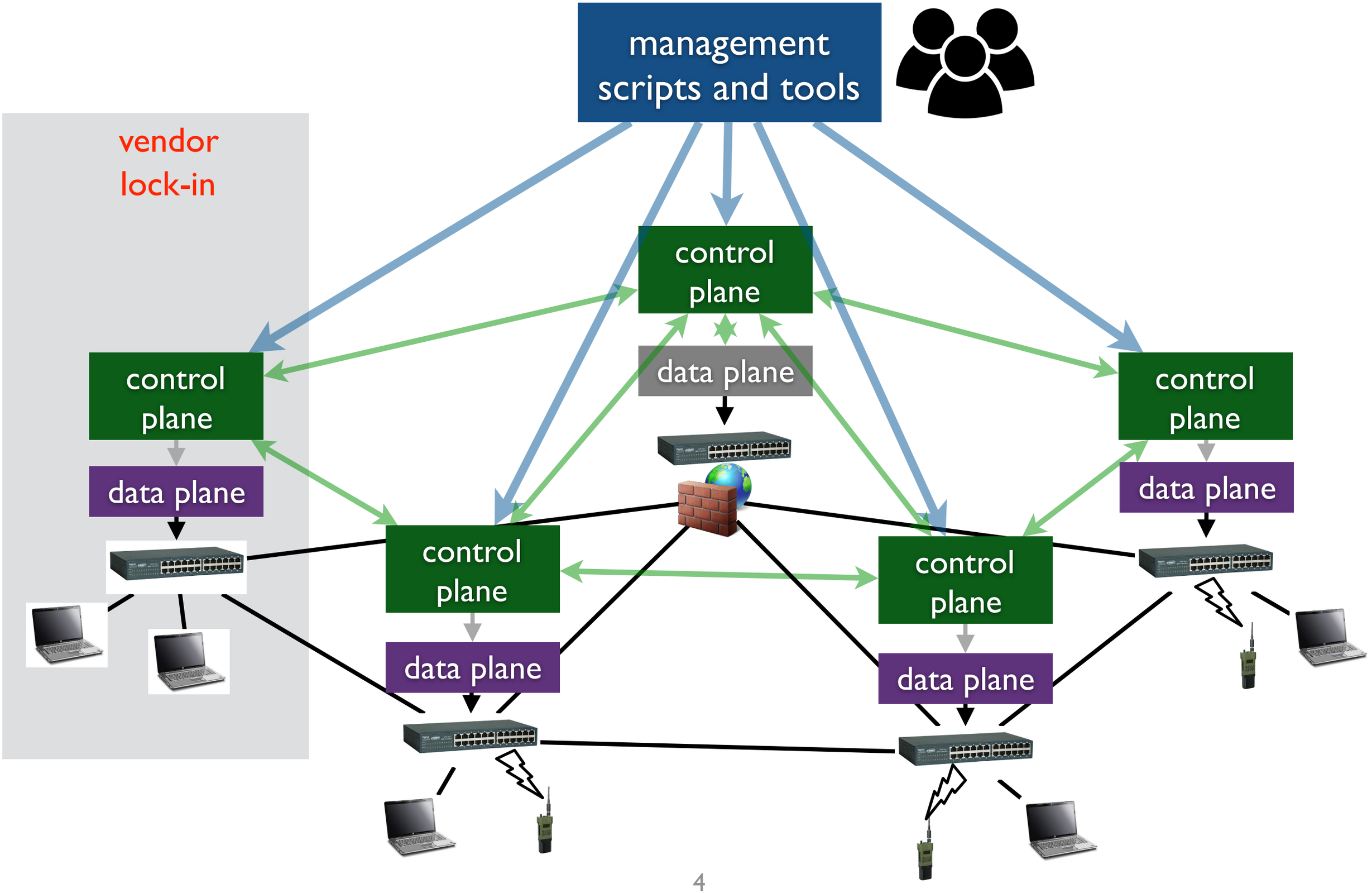
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management plane

defines network composition, control plane configuration, and monitoring schemes
example: CLI, scripts

control plane

generates forwarding tables and filters for the data plane
example: distributed routing protocols

data plane

handles packets
example: forwarding

management plane

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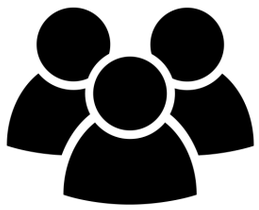

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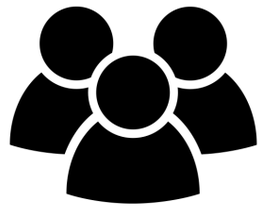

control plane

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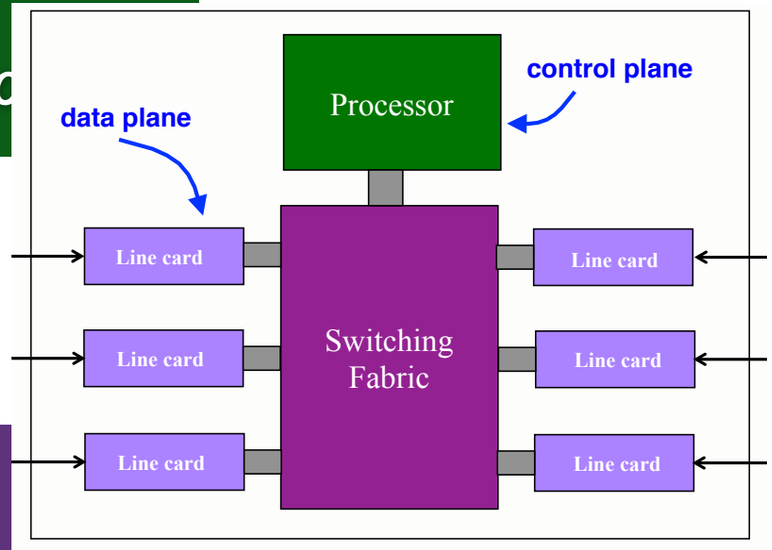
example: distributed routing protoco



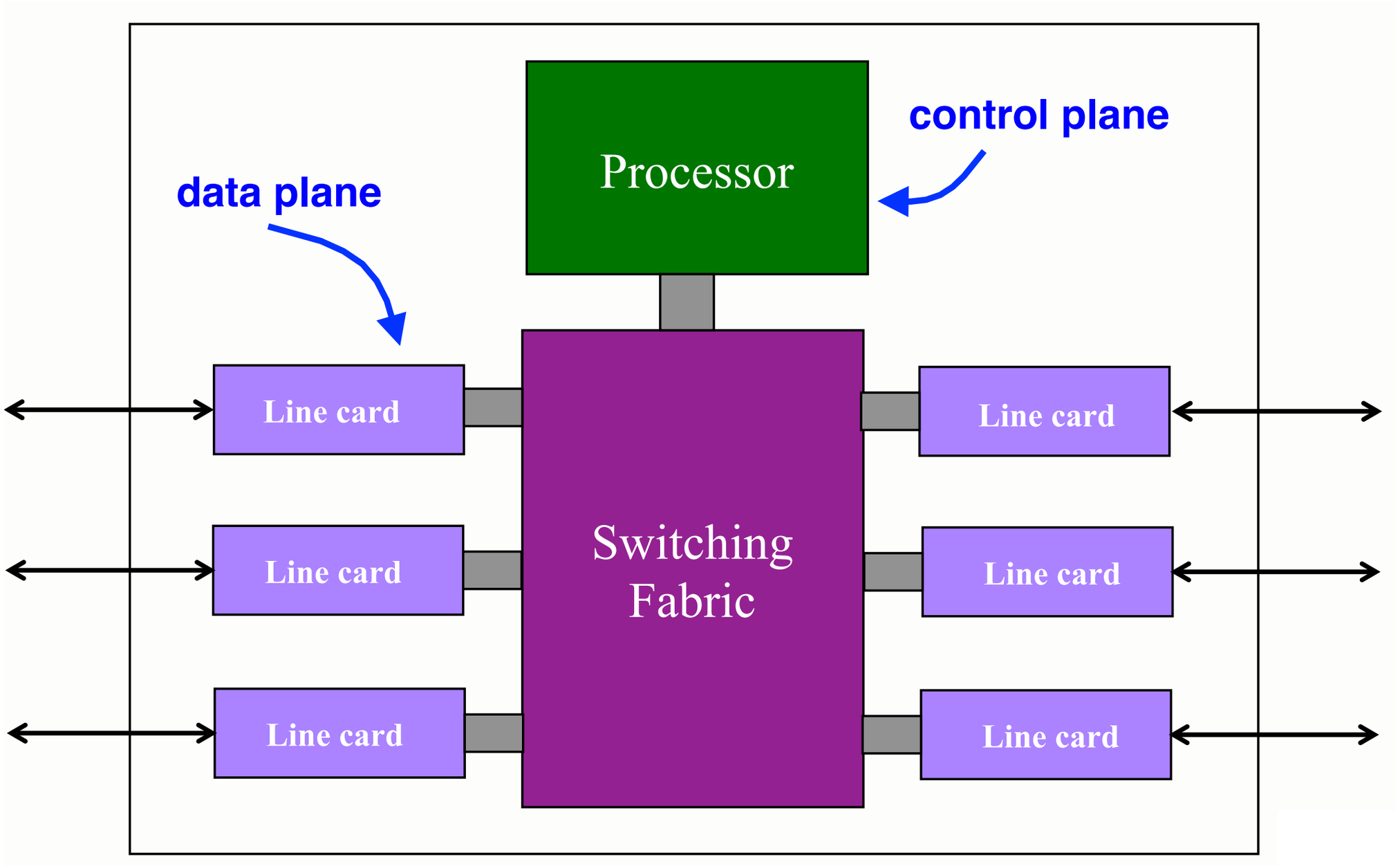
data plane

handles packets
example: forwarding

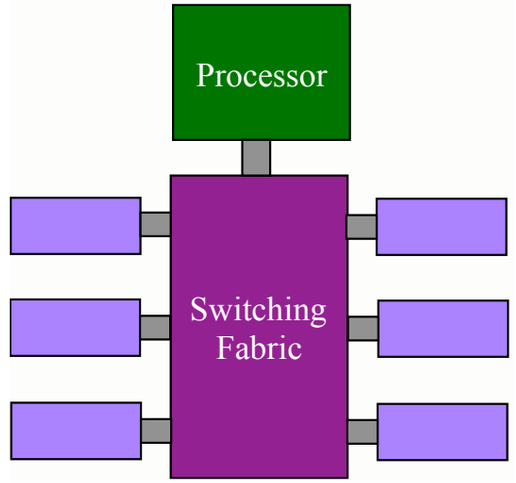
timescales

	Data	Control	Management
Time-scale	Packet (nsec)	Event (10 msec to sec)	Human (min to hours)
Tasks	Forwarding, buffering, filtering, scheduling	Routing, circuit set-up	Analysis, configuration
Location	Line-card hardware	Router software	Humans or scripts

data and control planes



data plane



streaming algorithms on packets

- matching on some bits
- perform some actions

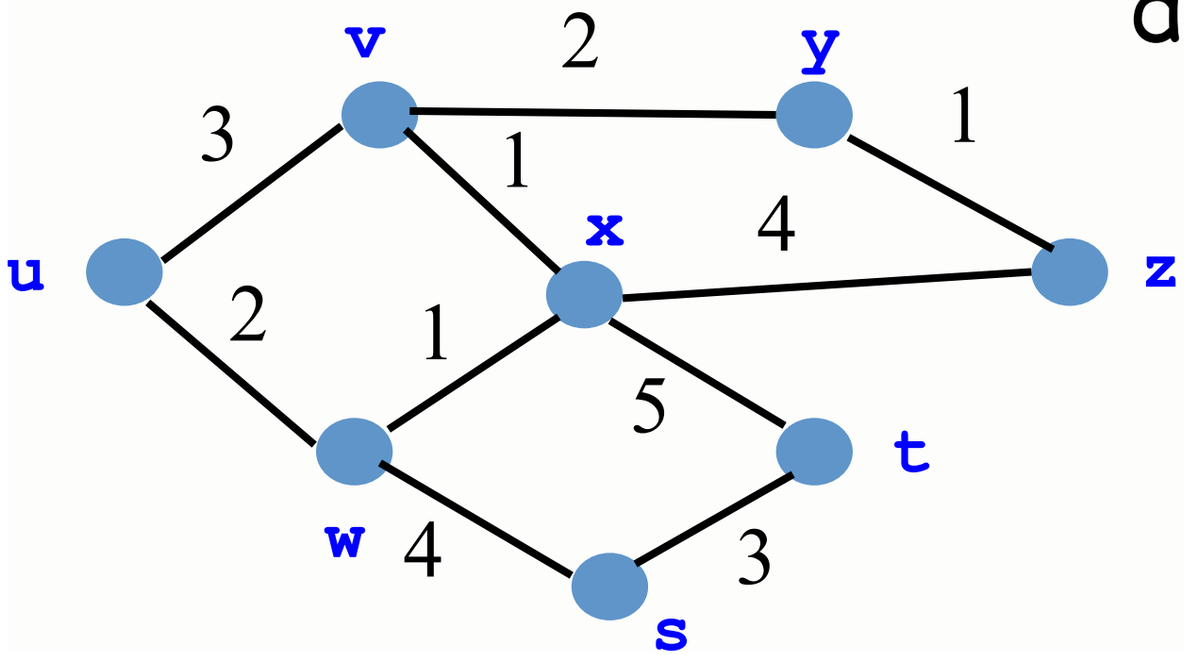
wide range of functionality

- forwarding
- access control
- traffic monitoring
- packet inspection

distributed control plane

example: distance-vector routing: RIP

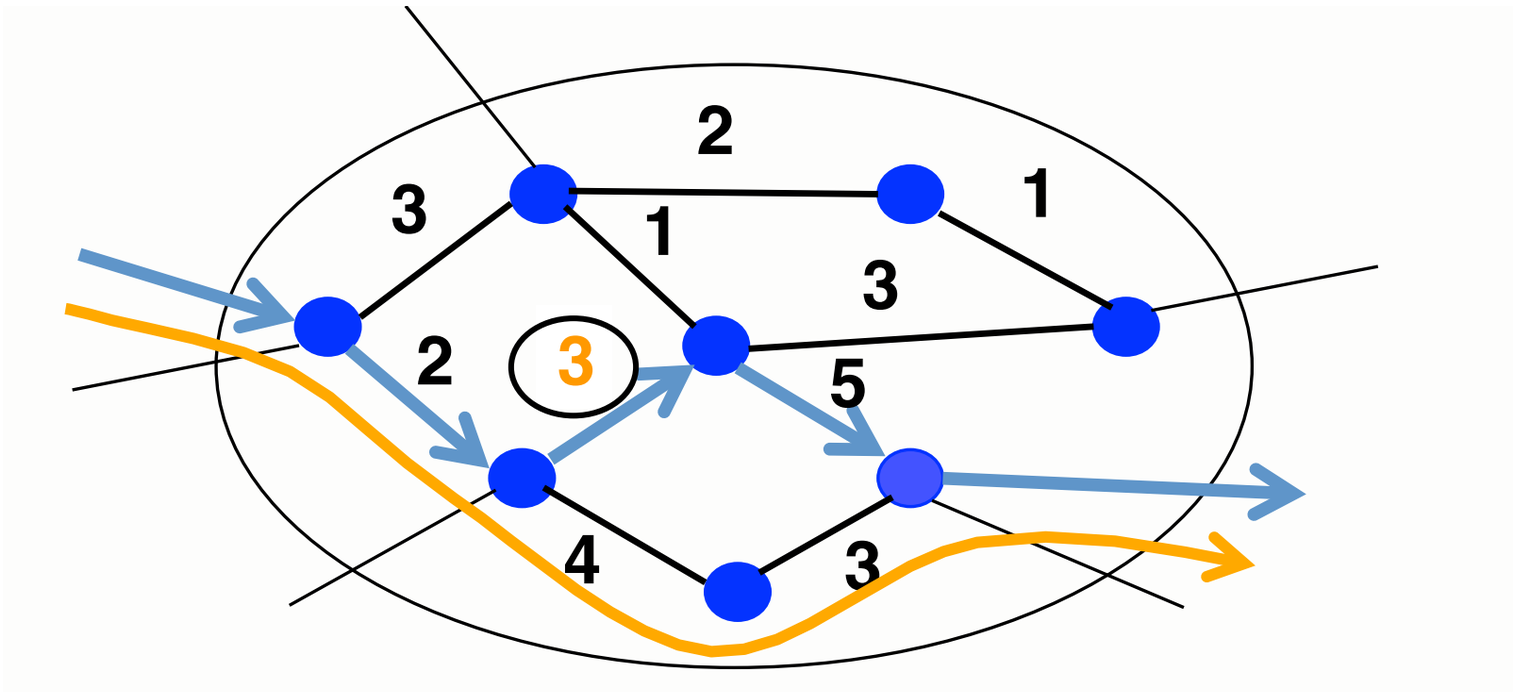
- each node computes path cost
  - …based on neighbor's path cost
  - Bellman-Ford algorithm



$$d_u(z) = \min\{c(u,v) + d_v(z),\ c(u,w) + d_w(z)\}$$

management plane

example: set weights for traffic engineering



management plane

Aaron Gember-Jacobson., et al. “Management Plane Analytics” IMC 2015

management plane

diverse management practice

- design practice
  - set physical network composition (heterogeneity), logical structure (spanning tree)
- operation practice
  - change network for diverse purposes (router, middle-box)
- *tedious, error-prone*

Aaron Gember-Jacobson., et al. "Management Plane Analytics" IMC 2015

management plane

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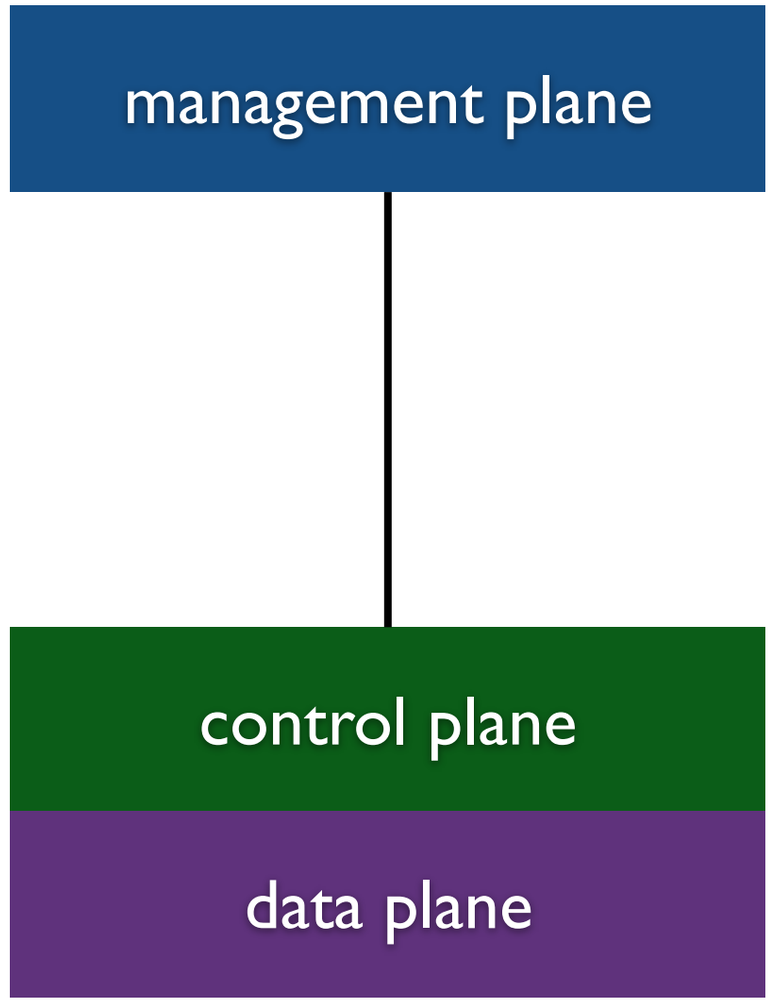
lacking principled understanding of management practice

- how practice impacts network health (performance, availability)?

Aaron Gember-Jacobson., et al. "Management Plane Analytics" IMC 2015

network management today: mastering complexity

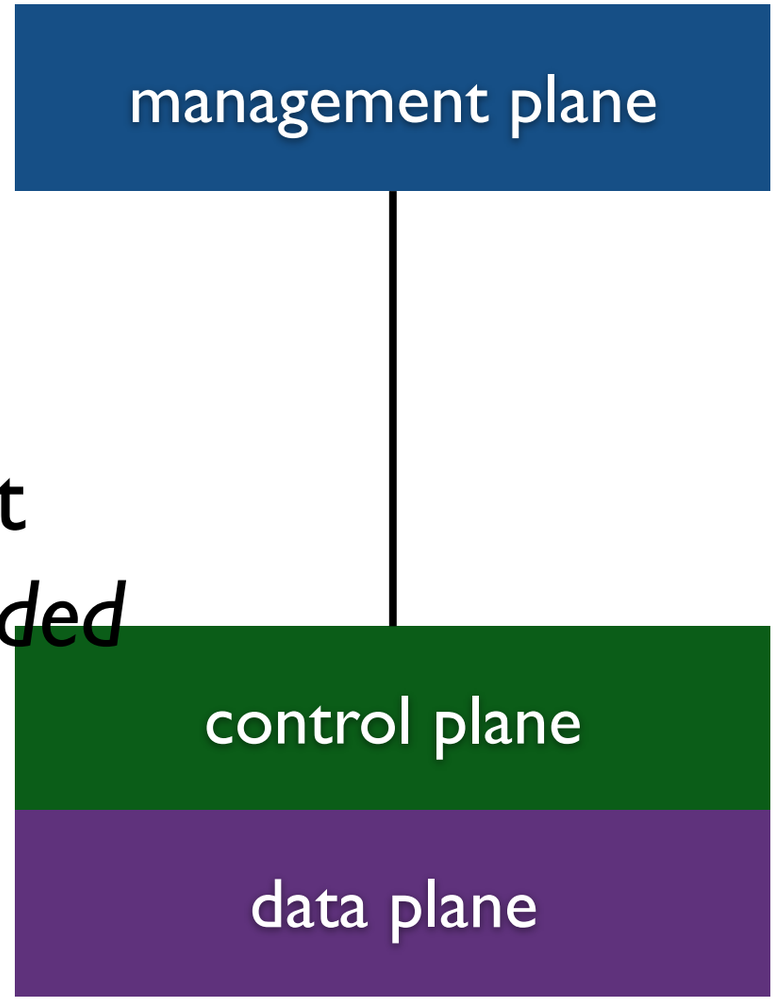
complexity



complexity

control logic and packet handling

- bundled in distributed switching element
- management objectives implicitly *embedded*



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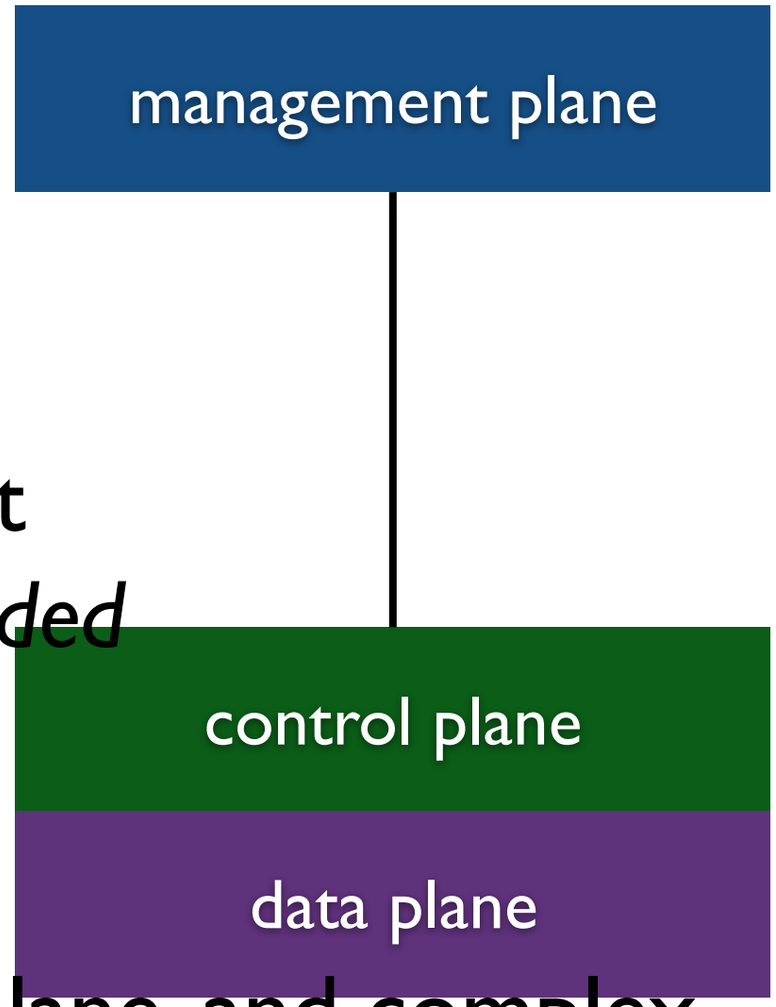
tension

- ever-evolving management requirement
- incremental point solutions to control plane, and complex management tools "coax" the control plane



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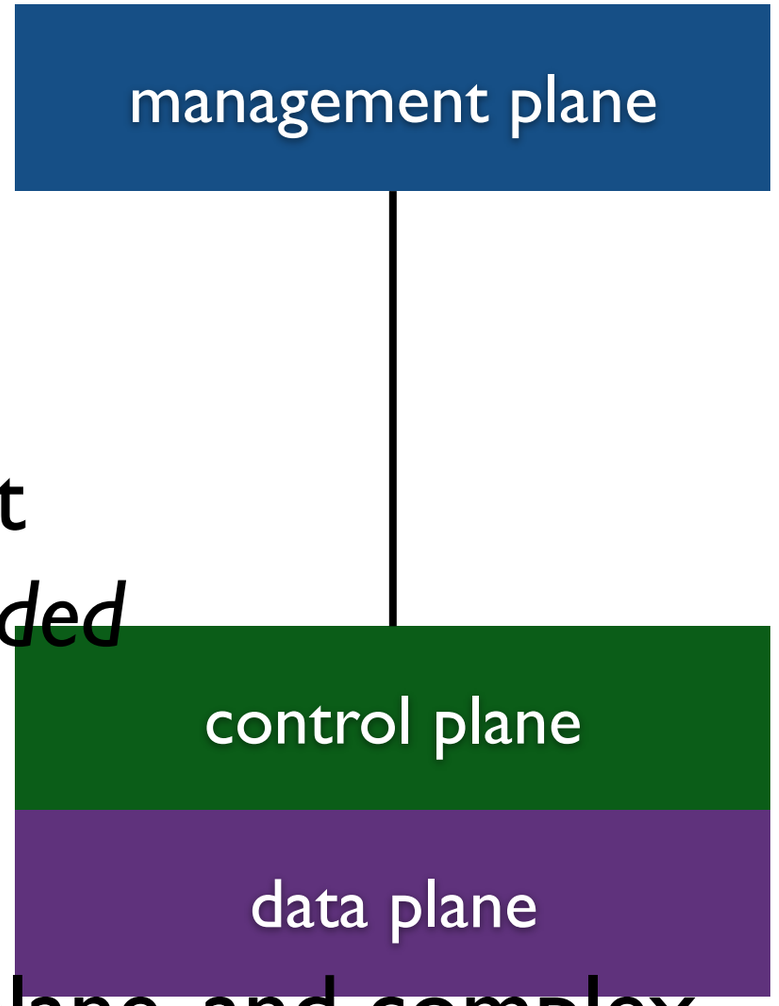
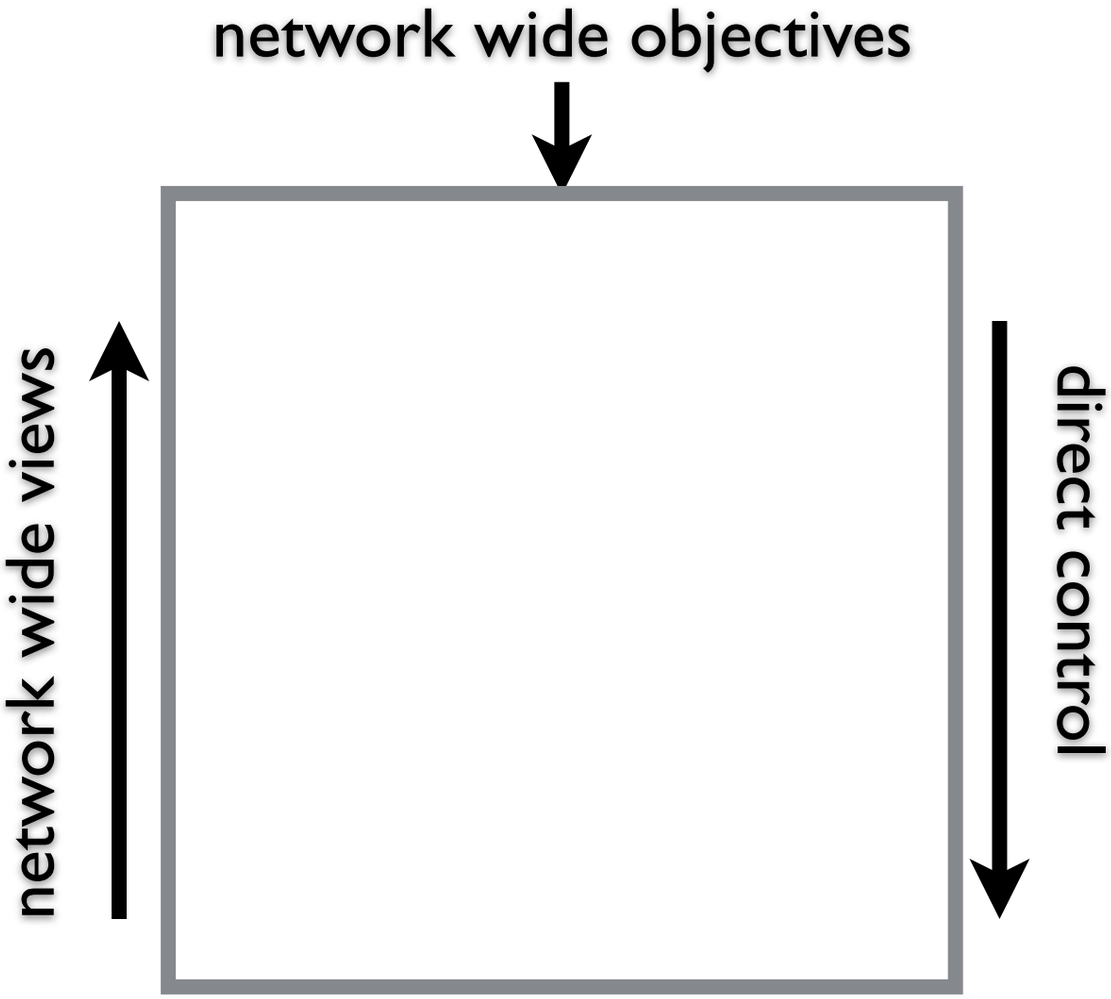
challenge

- indirect, coordinated control
- interacting protocols and mechanisms



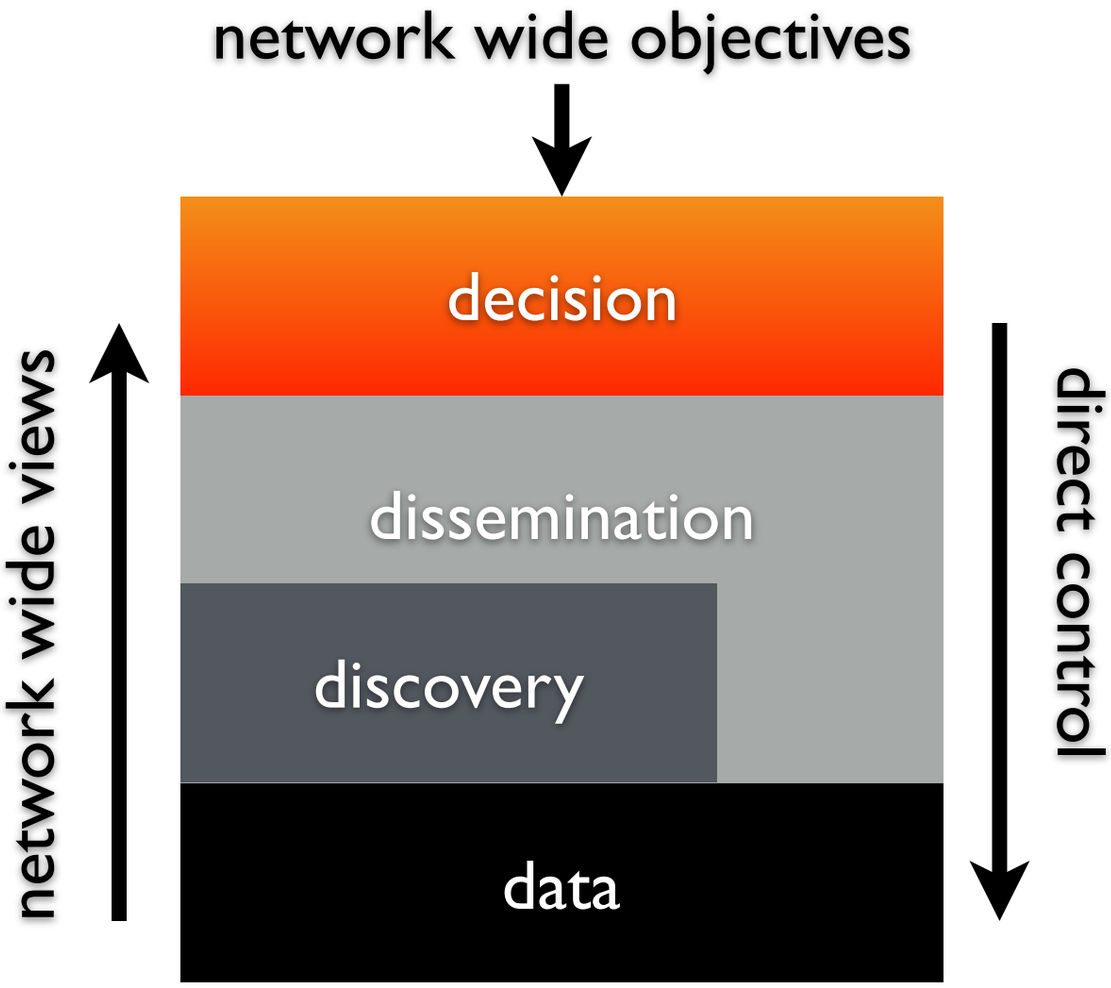
4D

4D goals



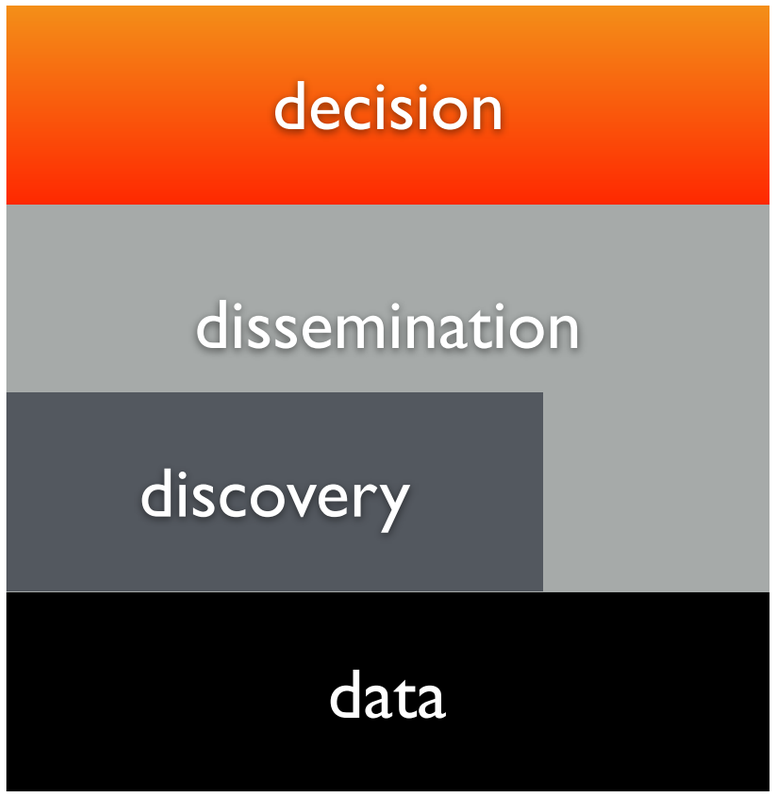
- network-wide objectives
  - observe and control
- network-wide views
  - complete visibility
- direct control
  - direct, sole control

4D architecture



- refactoring network functionality
- extreme design point
  - decoupled, centralized control

4D and Ethane



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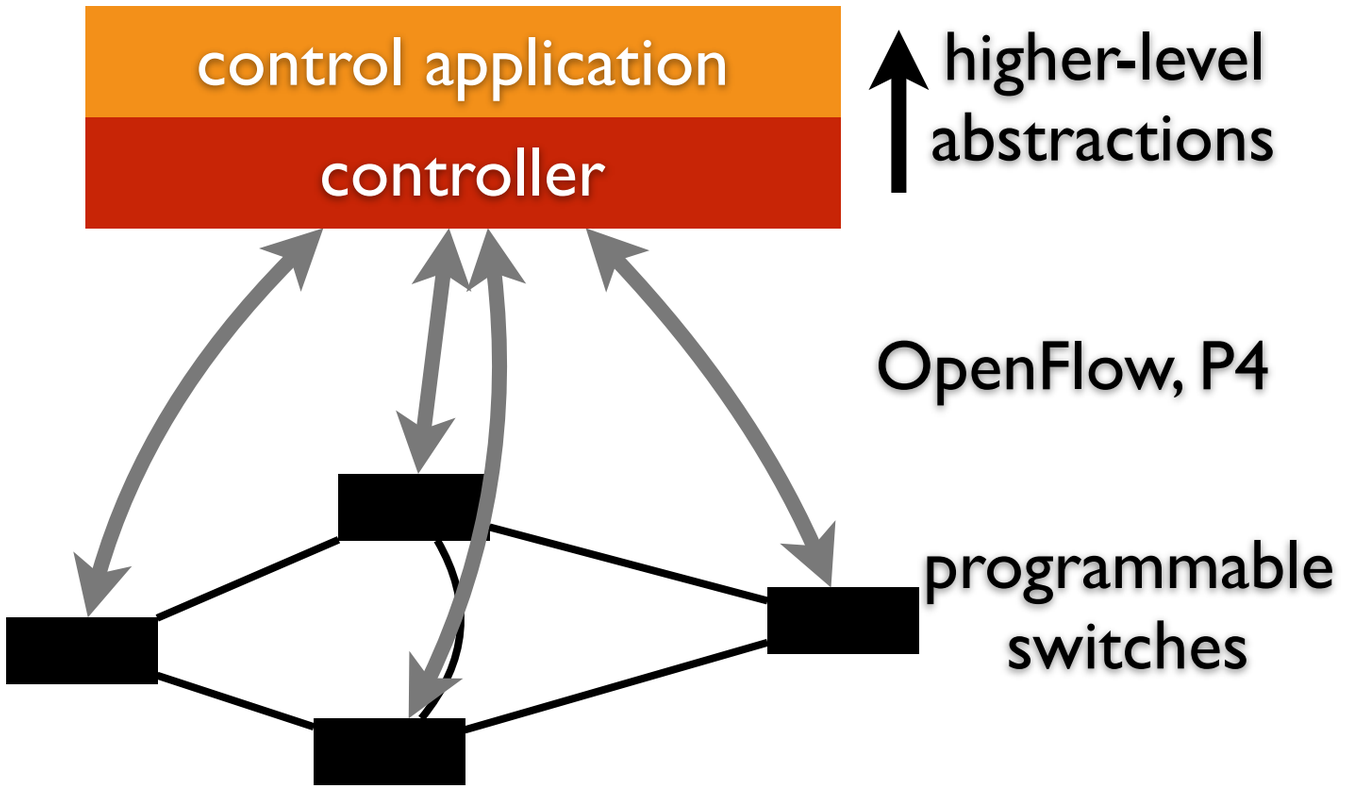


2016

discussion:

4D in the eyes of SDN

decision plane

realize network-wide objectives

- a language for expression (Pyretic, PGA…)
- leveraging network-wide structure (functions, graphs…)
- separation of timescales

coordinating multiple decision elements

- distributed election (Onix)
- independent decision elements

introducing hierarchy (Pane)

dissemination and discovery plane

control channel (eg: *OpenFlow*)

- dissemination paths that carry management information
- distinct protocols

direct control

- independent router updates
- network-wide commit
- full transactional distributed commit

discovery plane

- network OS (eg: *Nox*), measurement (eg: *FlowRadar*)

data plane

packet forwarding paradigm

- IP: longest-prefix match
- Ethernet: exact-match
- OpenFlow: flow-based, prioritized rules with wildcards

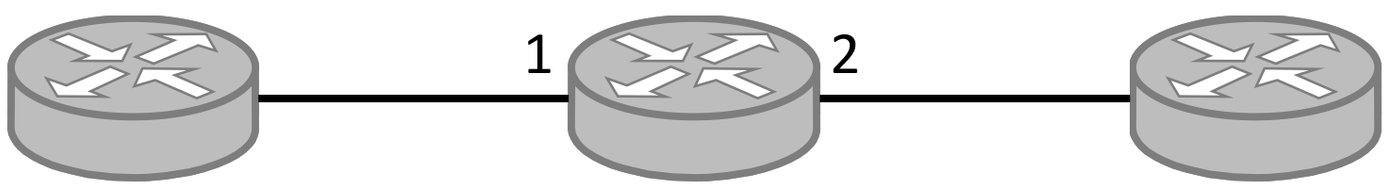
advanced features

- a single integrated mechanism to realize decision directives

OpenFlow: simple open dataplane API

prioritized list of rules

- pattern → action
  - pattern: match packet header bits
  - actions: drop, forward, modify, send to controller
- priority: disambiguate overlapping patterns



1. src=1.2.*.*, dest=3.4.5.* → drop
2. src = *.*.*.*, dest=3.4.*.* → forward(2)
3. src=10.1.2.3, dest=*.*.*.* → send to controller

Nick McKeown., et al. "OpenFlow: enabling innovation in campus networks"

advantages and challenges

separating networking logic from distributed system issues

- but the data plane remains a distributed system
- an insertion point for *interface and functionality (abstraction)* that alleviates complexity

robustness

security

accommodating heterogeneity

innovation and evolution

Ethane:

a realization of 4D for secure enterprise network

Ethane goals

enterprise networks

- strict reliability and security constraints
- operated by non-experts

goals

- policy over principals
- direct path selection
- binding packets and its origin

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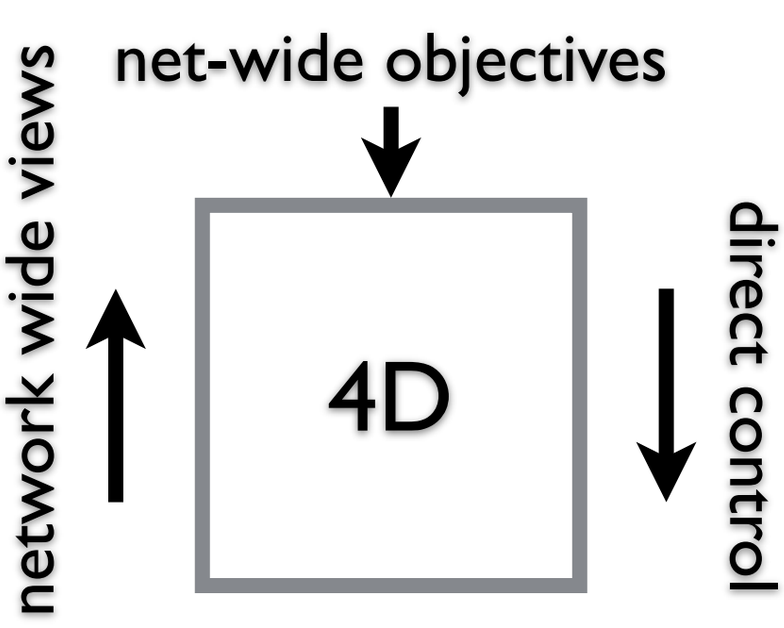

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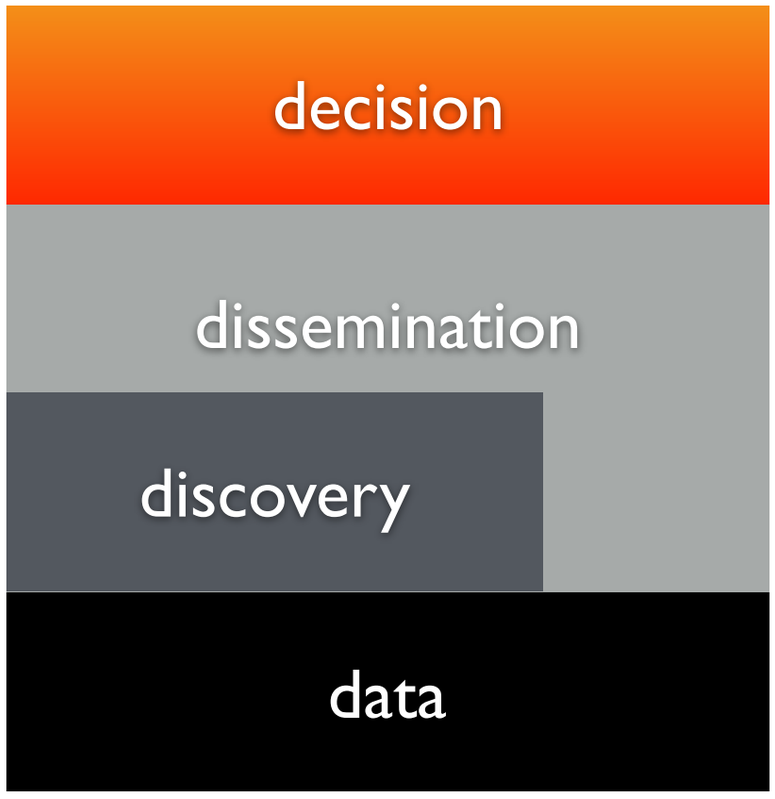
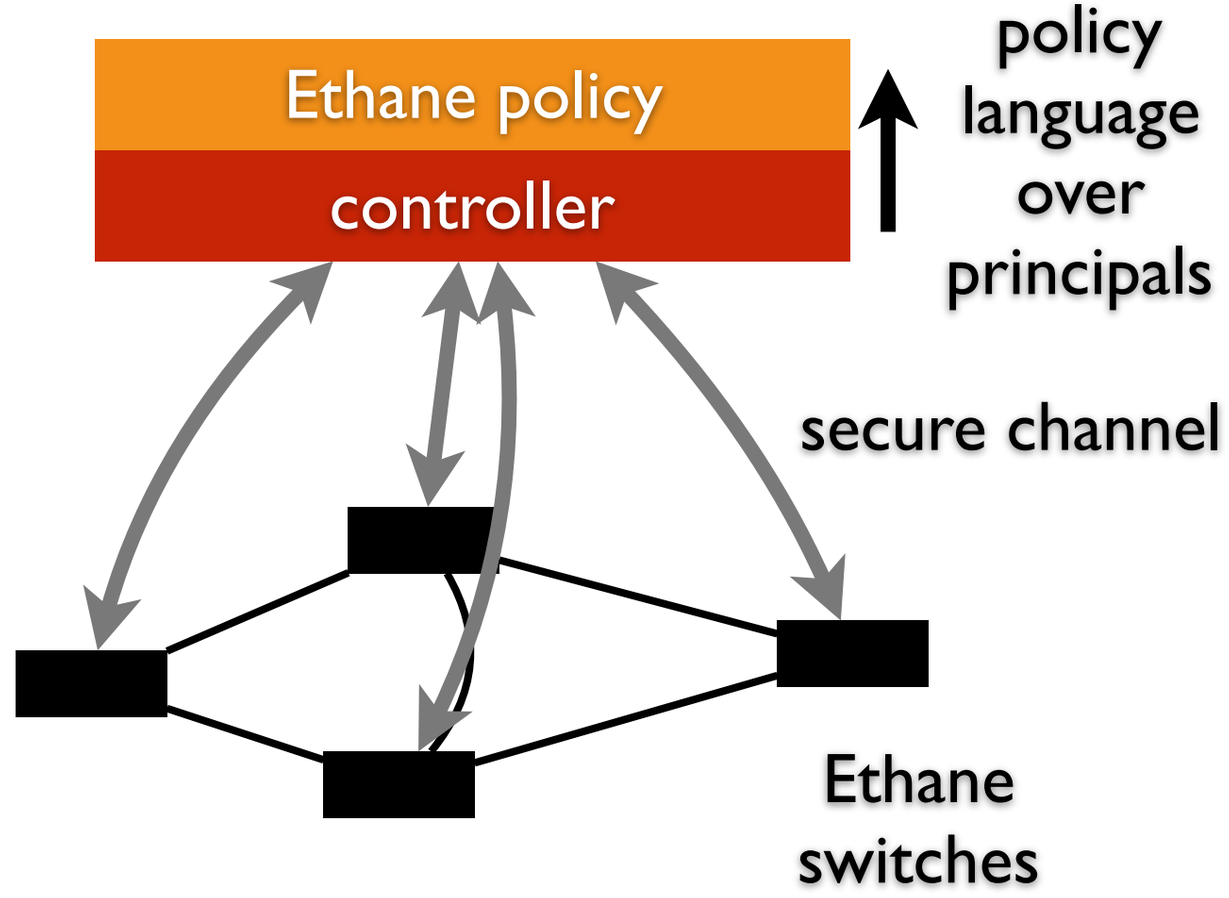
from 4D to Ethane

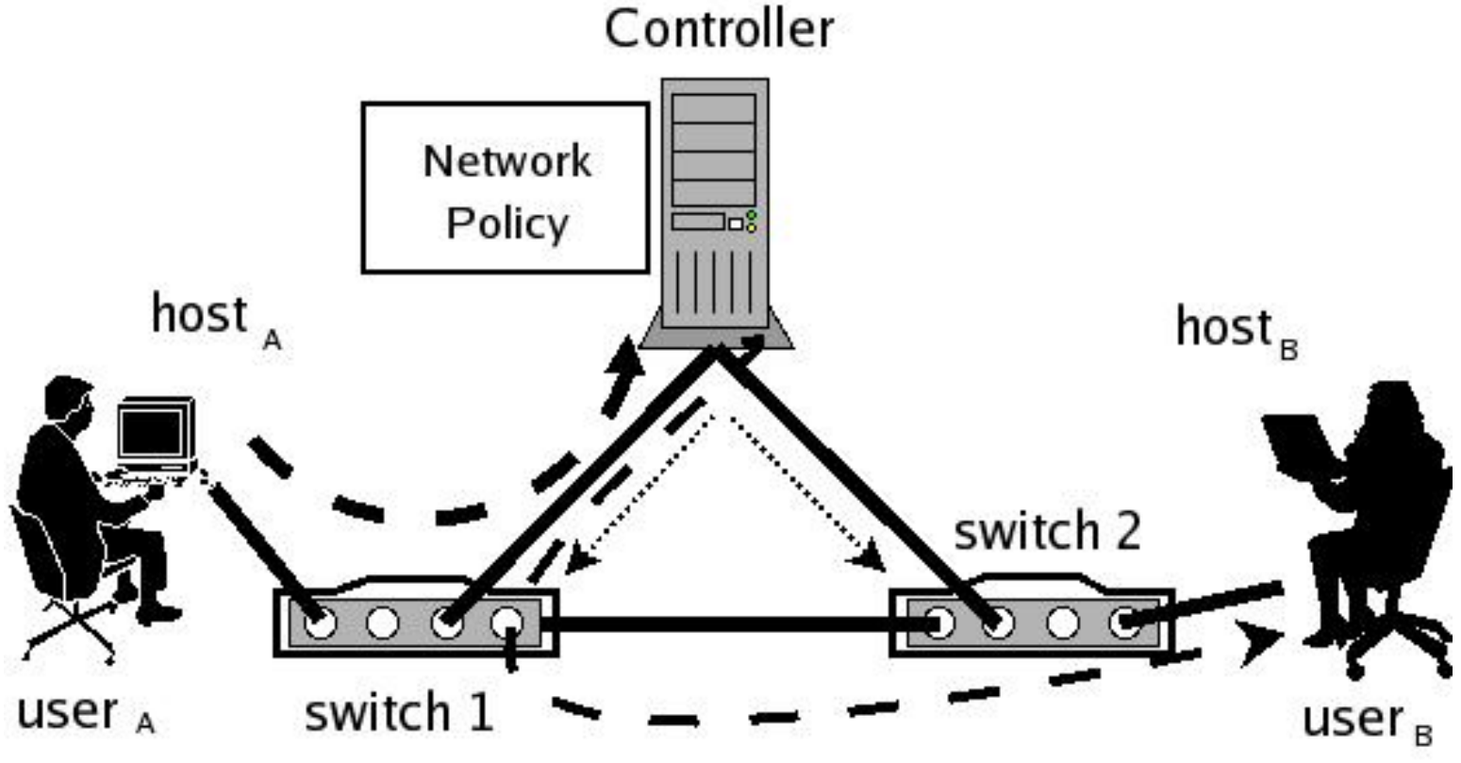




Ethane in action

three examples

- bootstrapping
- link failure
- replicating controller



Ethane and Ravel