Software-Defined Networks

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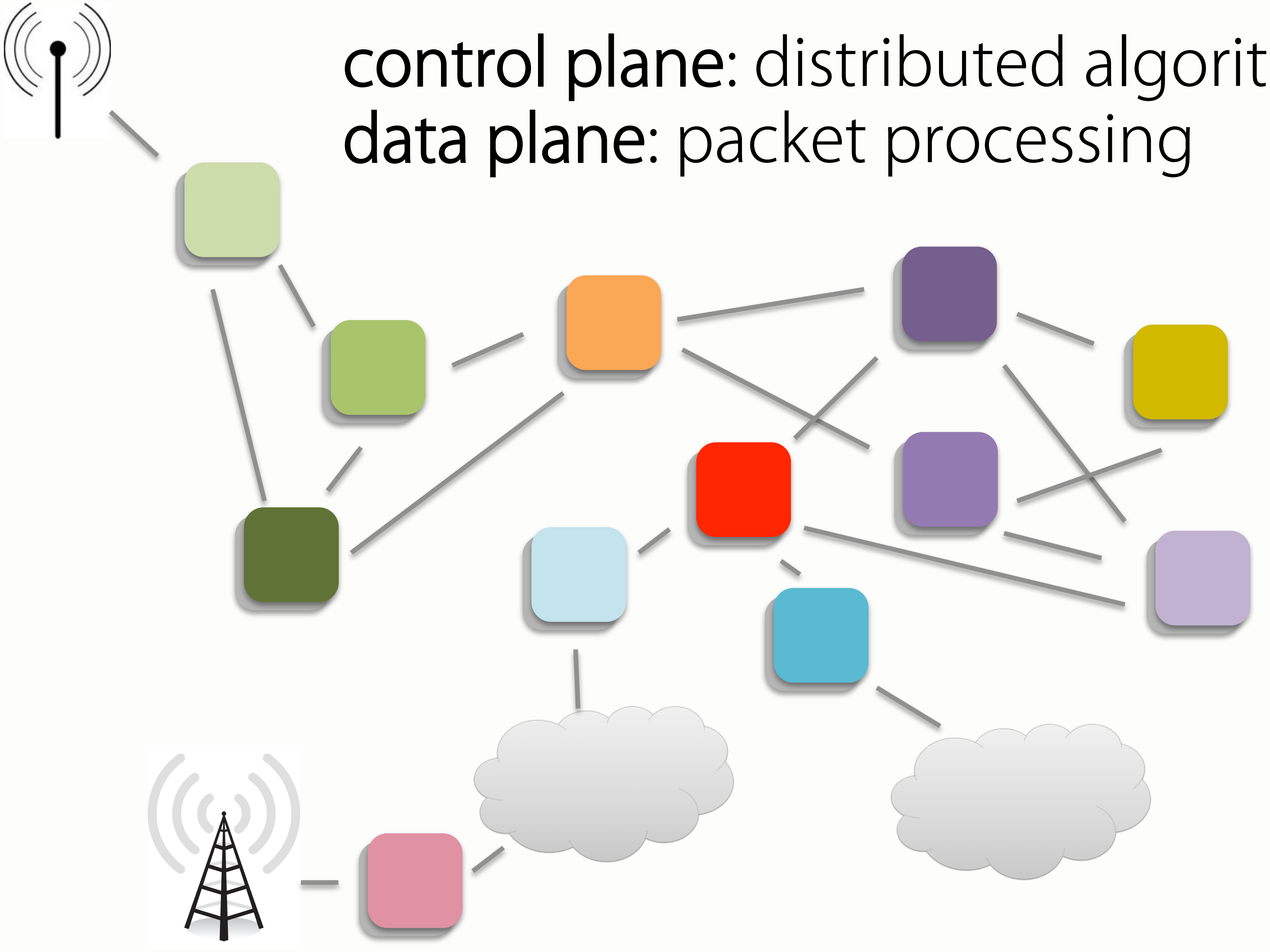
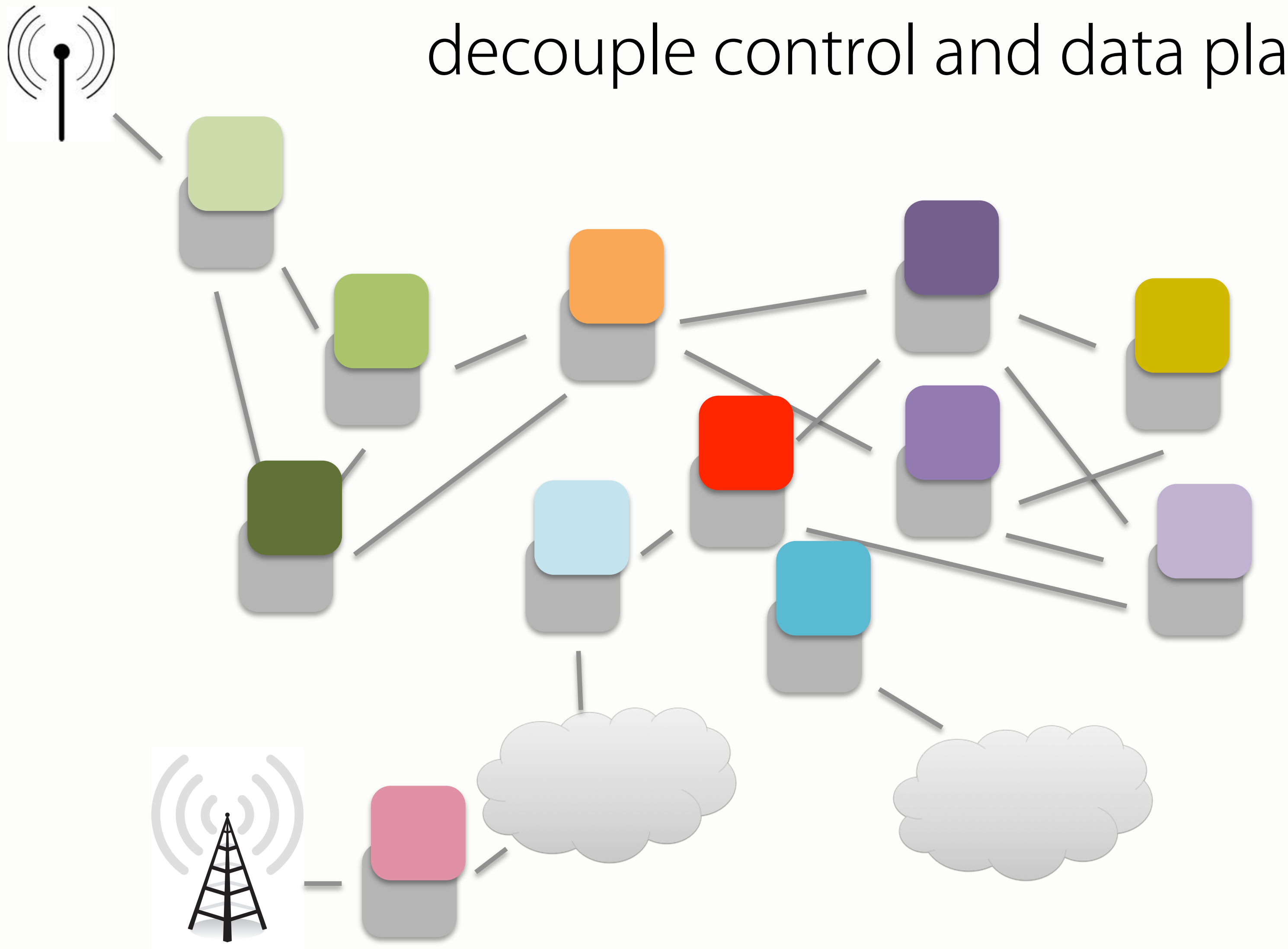
Traditional Networks

control plane: distributed algorithms
data plane: packet processing



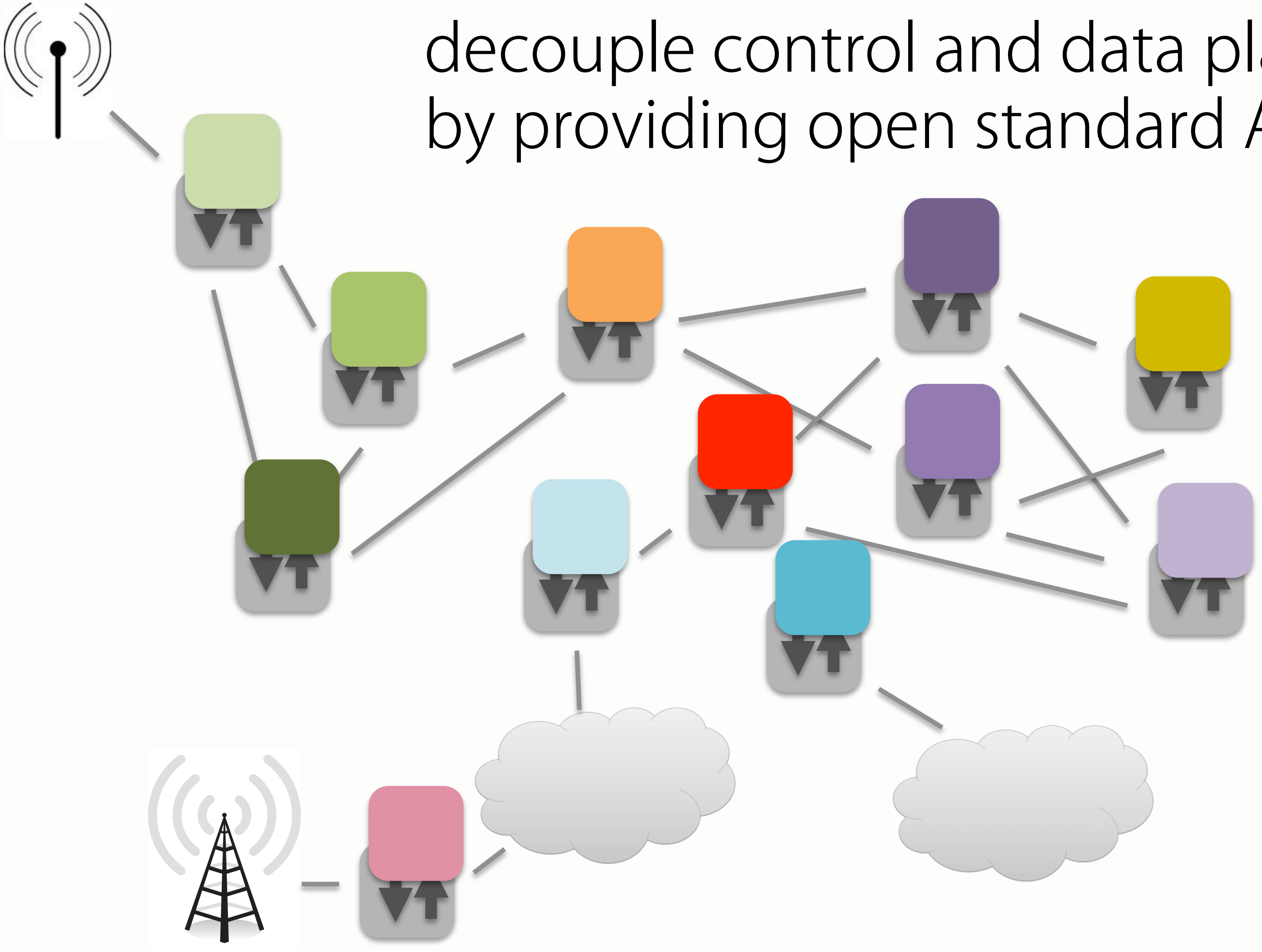
Software Defined Networks

decouple control and data planes



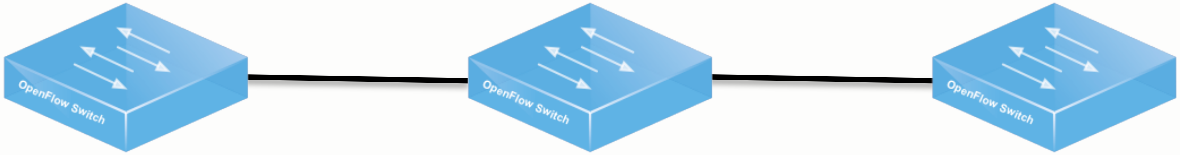
Software Defined Networks

decouple control and data planes
by providing open standard API



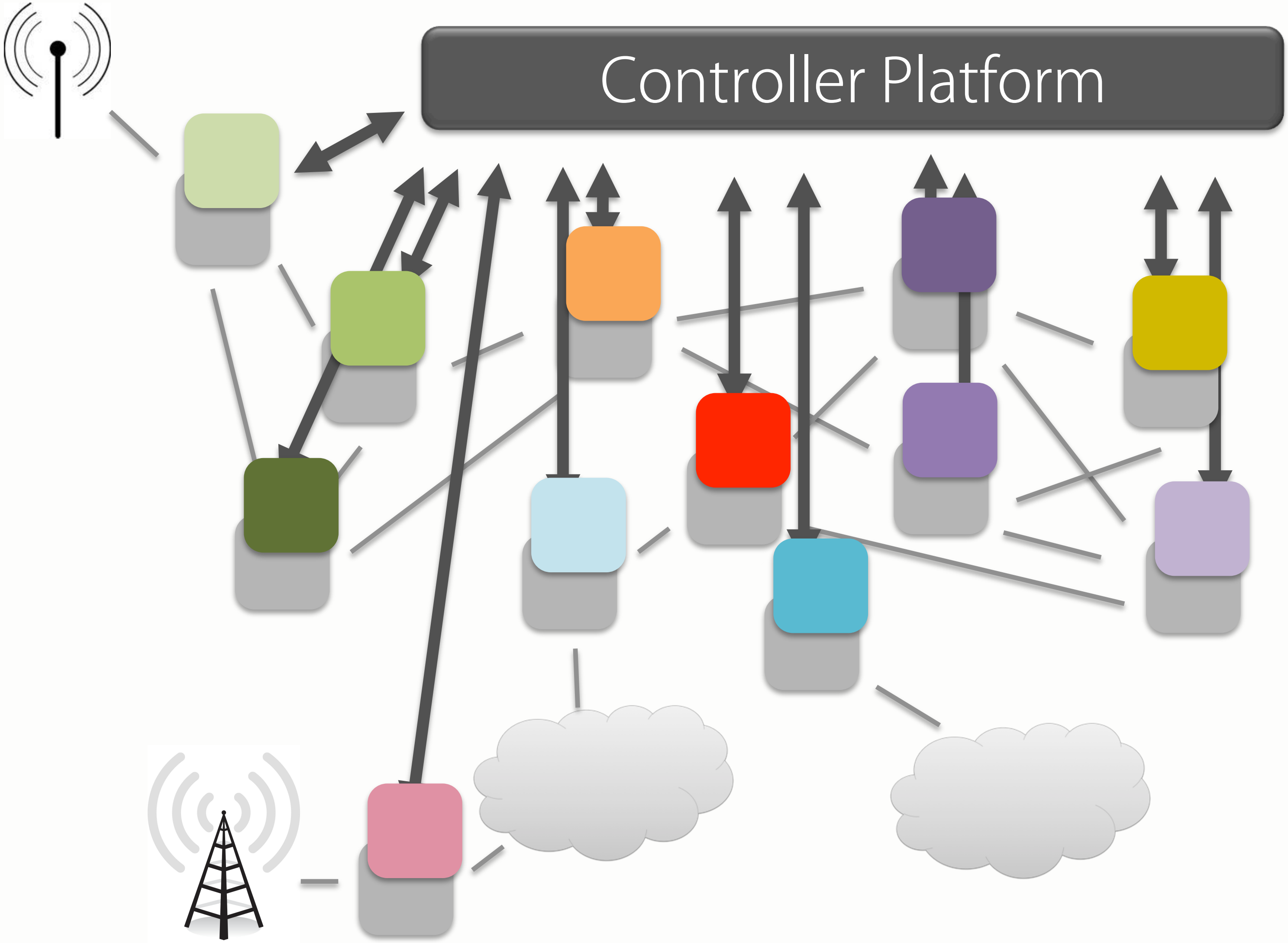
Simple Data-Plane API

- Prioritized list of rules
  - Pattern: match packet header bits
  - Actions: drop, forward, modify, send to controller
  - Priority: disambiguate overlapping patterns
  - Counters: #bytes and #packets



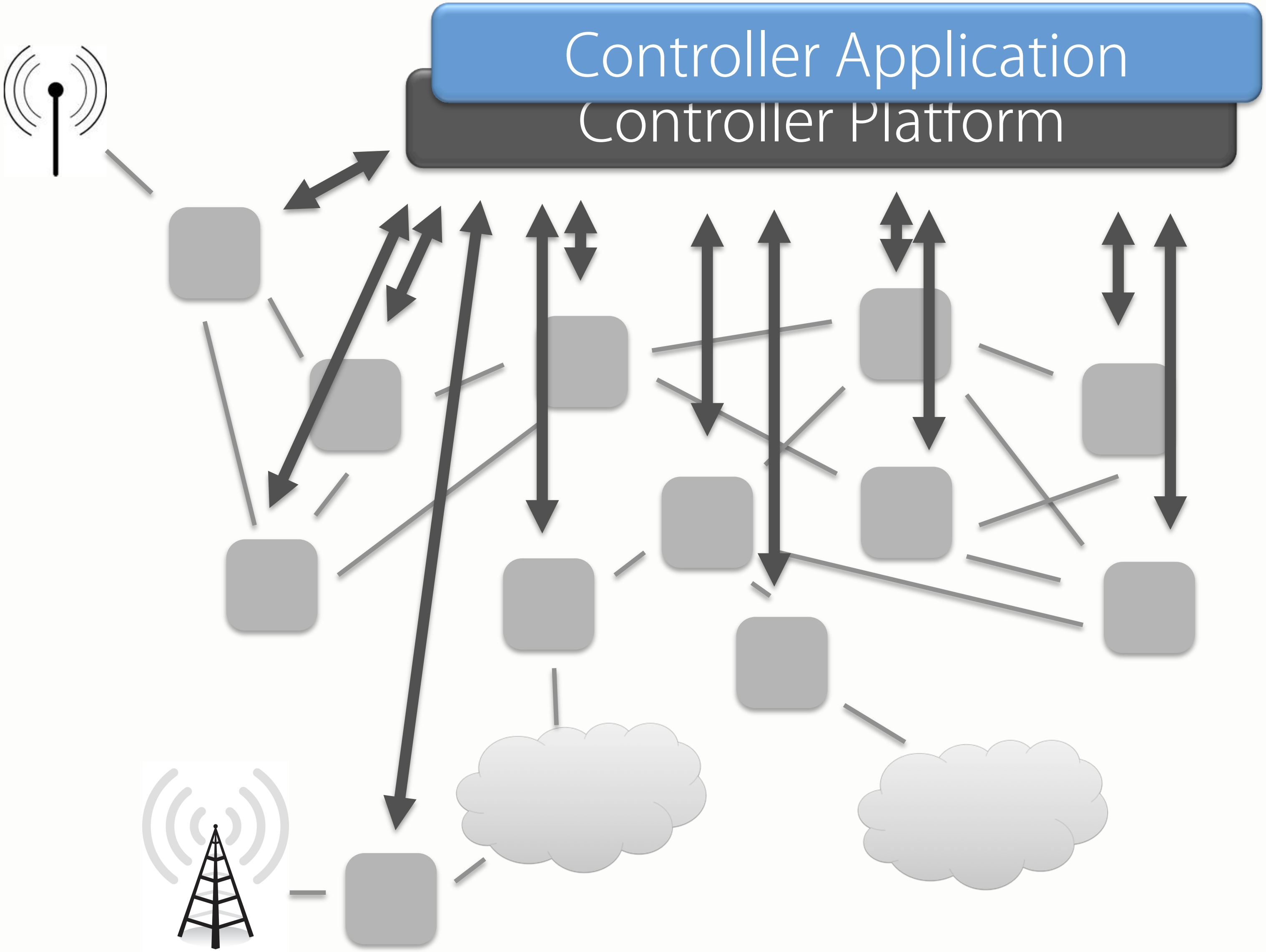
1. srcip=1.2.*.*, dstip=3.4.5.* → drop
2. srcip=*.*.*.*, dstip=3.4.*.* → forward(2)
3. srcip=10.1.2.3, dstip=*.*.*.* → send to controller

(Logically) Centralized Controller



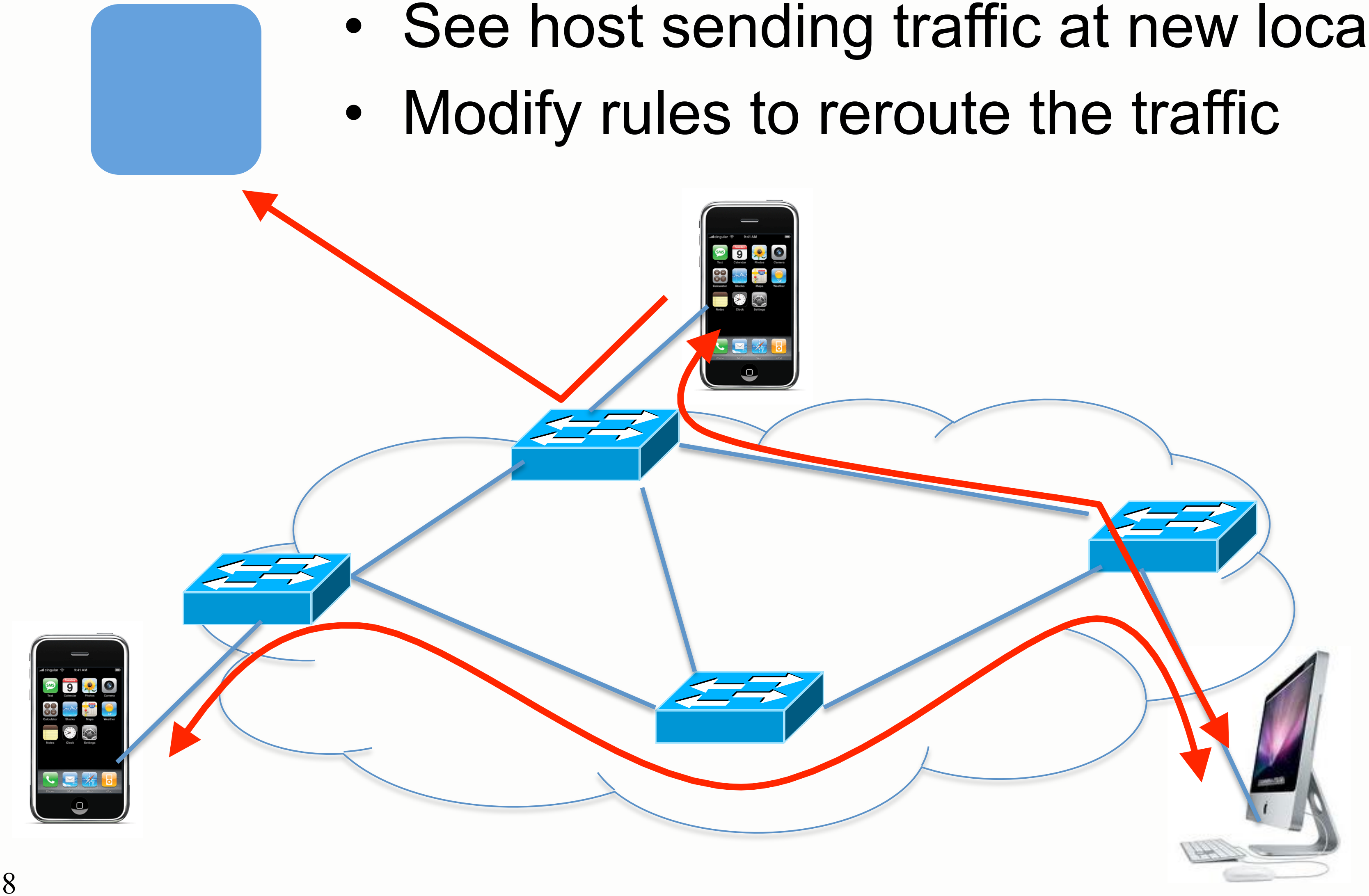
Controller Platform

Protocols ➔ Applications



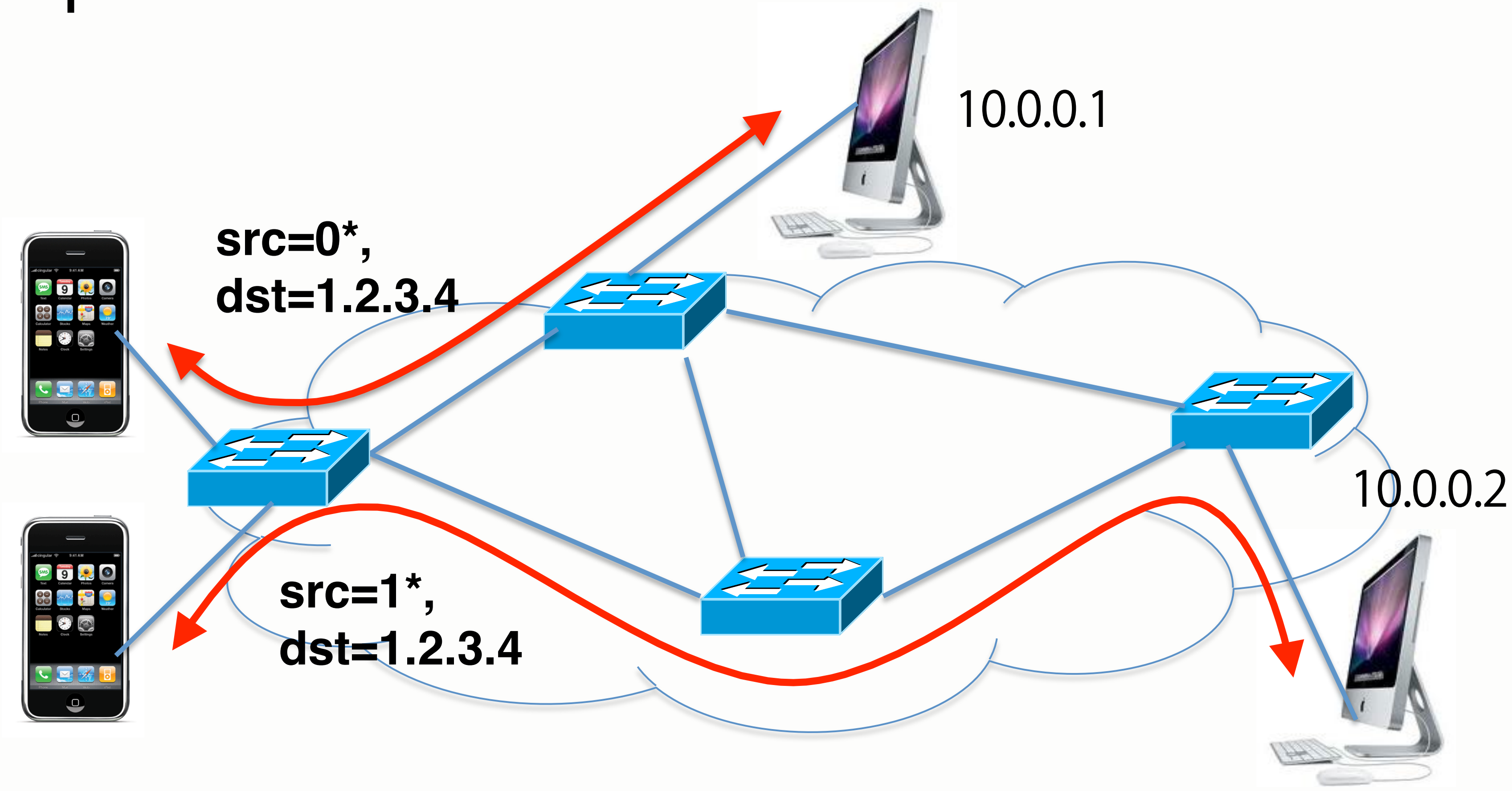
Seamless Mobility

- See host sending traffic at new location
- Modify rules to reroute the traffic



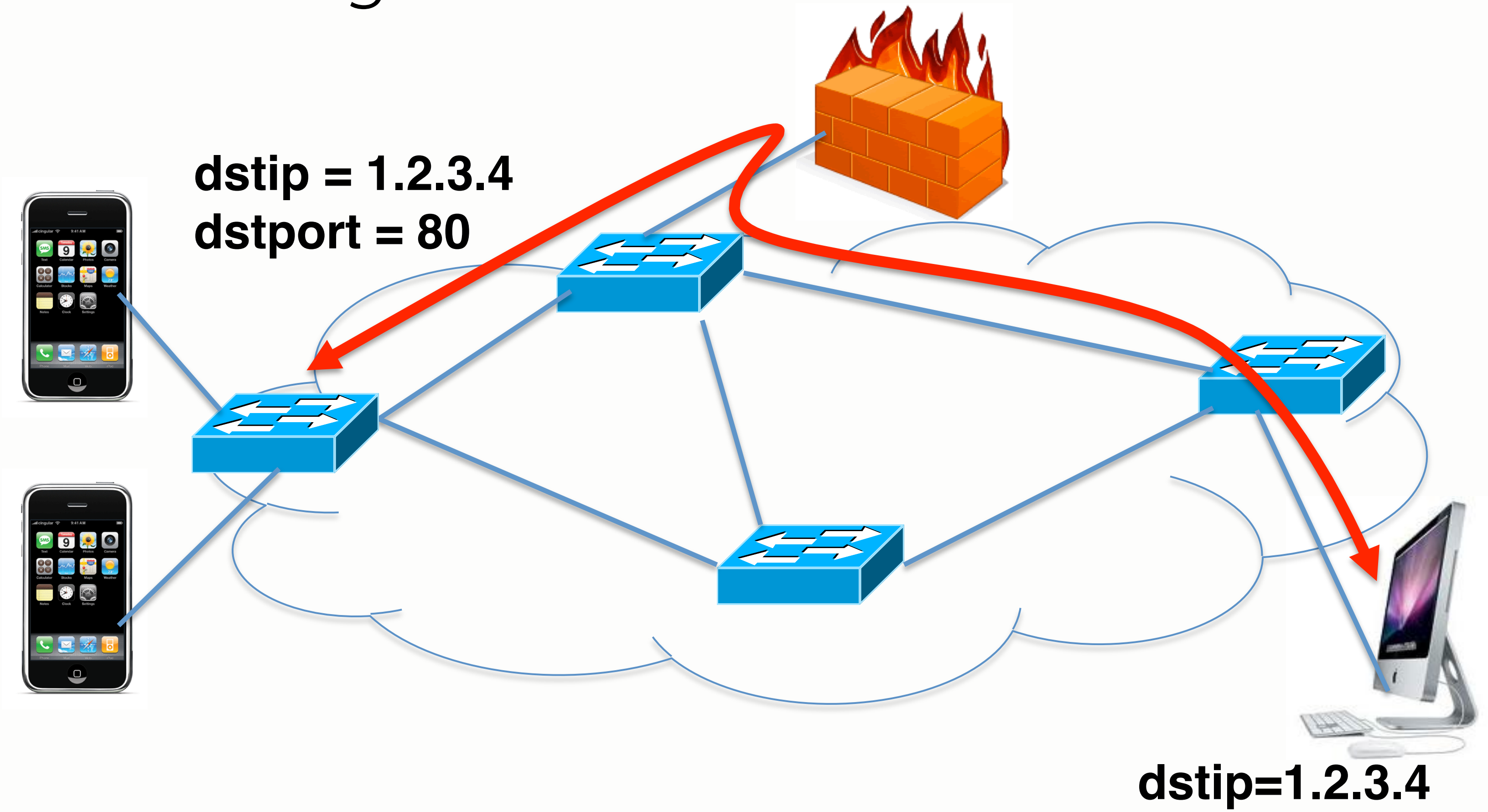
Server Load Balancing

- Pre-install load-balancing policy
- Split traffic based on source IP



Middlebox Traffic Steering

- Direct selected traffic (e.g., port 80)
- … through a chain of middleboxes



Example SDN Applications

- Seamless mobility and migration
- Server load balancing
- Steering traffic through middleboxes
- Dynamic access control
- Using multiple wireless access points
- Energy-efficient networking
- Blocking denial-of-service attacks
- Adaptive traffic monitoring
- Network virtualization
- <Your app here!>

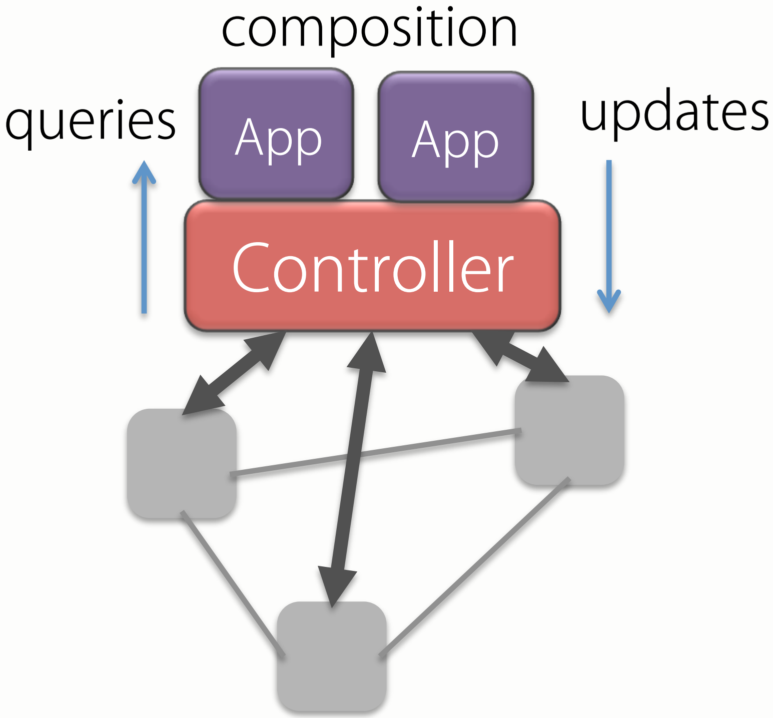
A Major Trend in Networking

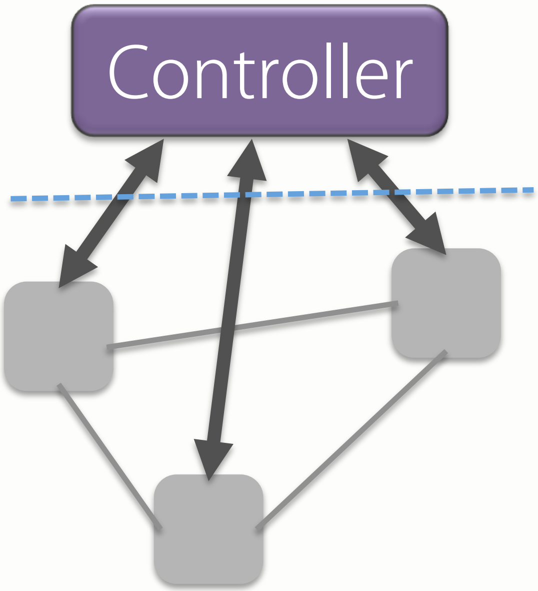
- SDN components
  - Switches: Open vSwitch, hardware switches, etc.
  - Controllers: ONOS, Floodlight, Ryu, Frenetic, …
- Commercial successes
  - Google's private backbone
  - Nicira's network virtualization platform
- Industry consortia
  - Open Networking Foundation (ONF)
  - Open DayLight (ODL)
  - Open Compute Project (OCP)

Example Research Areas

Languages and Verification

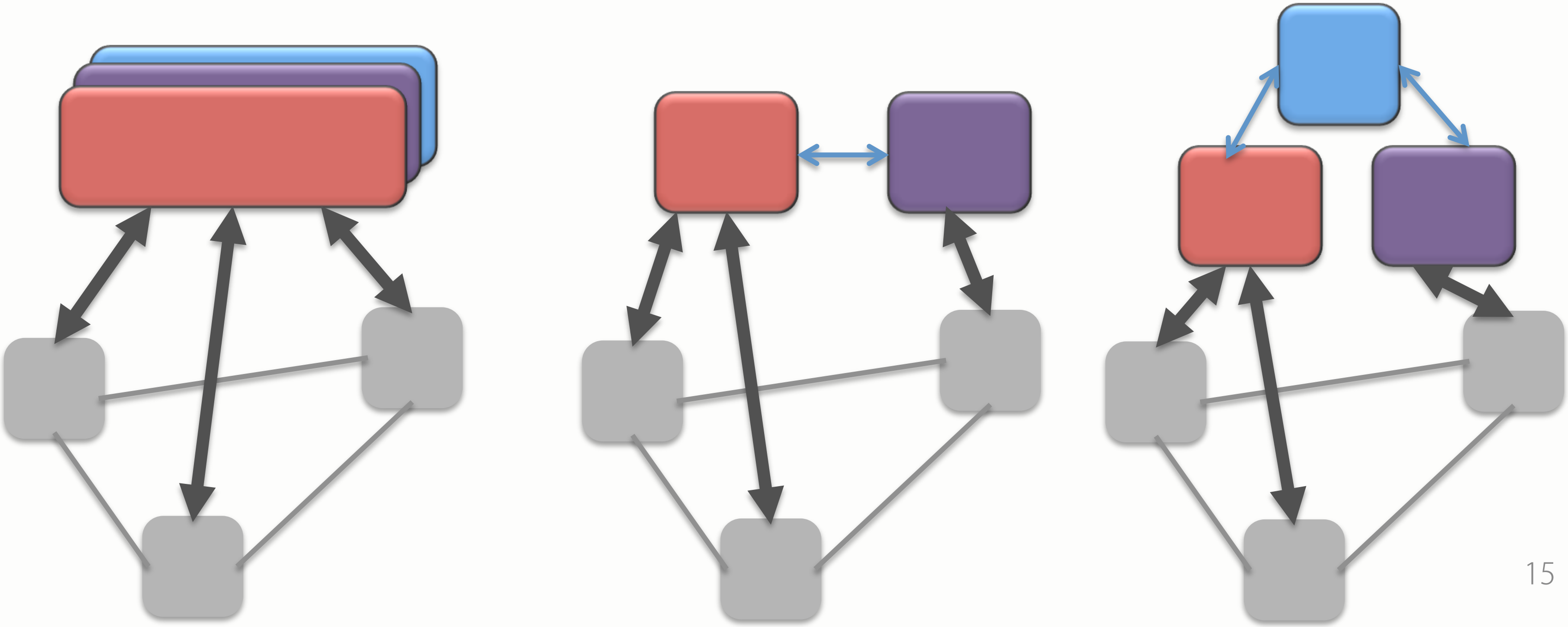
- Languages
  - Abstractions for apps
  - Compilation to switches
- Verification
  - Data-plane invariants
  - Control-plane correctness





Distributed Controllers

- Scalability, reliability, and performance
- Managing controller state or replicas
- Aggregating information about the network



More Sophisticated Switches

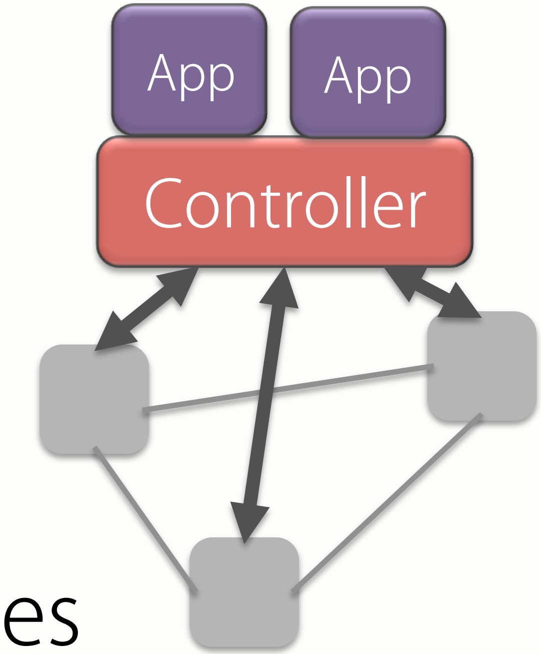
- OpenFlow 1.0
  - Single rule table and twelve header fields
- OpenFlow 1.3/1.4
  - Multiple match-action stages on different headers
- OpenFlow 2.0 (?)
  - Reconfigurable parsing and match-action tables
- White-box/bare-metal switches
  - Program the switch directly

Network Function Virtualization

- Network functions
  - Firewall, intrusion detection, NAT, transcoder, compression, proxy cache, monitoring, …
- Virtualized
  - Virtual machines that can run anywhere
- Challenges
  - Optimization (placement, steering, routing)
  - Platforms for hosting virtualized functions
  - Control protocols for managing the functions

SDN Security

- Securing the entire stack
  - Switches
  - Control protocol
  - Controller platform
  - Controller apps



- Example attacks/vulnerabilities
  - Worst-case traffic to DoS the controller
  - Rogue apps that violate user privacy
  - Compromising the controller platform

New Applications of SDN

- Cloud
  - Data centers
  - Private backbones
- Other networks
  - Enterprise
  - Cellular
  - Home
  - Exchange points
  - Optical networks
- Hybrid deployments
  - Overlay (SDN edge, legacy core)
  - Mix of SDN and legacy devices
- Beyond networking
  - Software Defined *Infrastructure*
  - Network, middleboxes, storage, compute, ⋯

Conclusions

- SDN is two main ideas
  - Logically centralized controller
  - Standard APIs to the data plane
- SDN is happening in practice
  - Protocol standards and white-box networking
  - Wide variety of switch and controller platforms
  - Real operational deployments
- Clean-slate research opportunity
  - … while still influencing the practice