HyperFlow
A Distributed Control Plane for OpenFlow

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Brief Overview of OpenFlow

- Root cause of network mgmt. & control complexity:
  - Tight coupling of control and data planes.

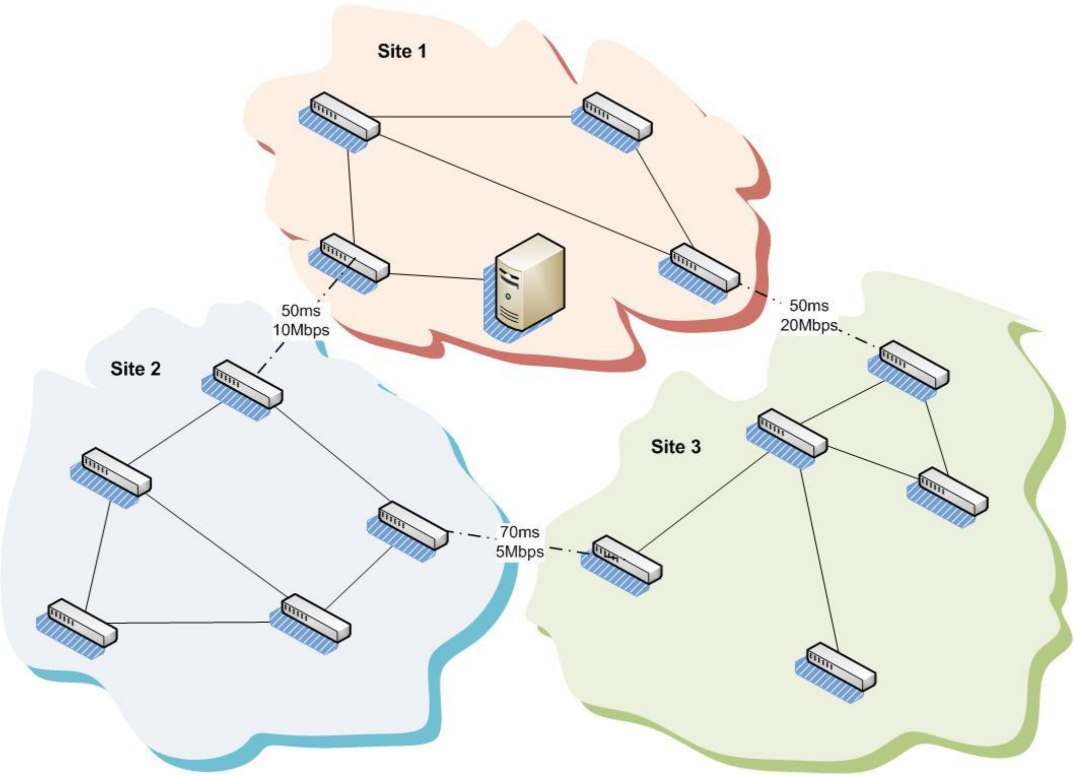
- OpenFlow separates the data and control planes:
  - Abstracts switches as programmable flow tables.
  - A ***logically centralized*** controller programs them.

- But current setups do not scale well.

OpenFlow extremely simplifies network control & mgmt.

A Network with a Single Centralized Controller Does Not Scale.

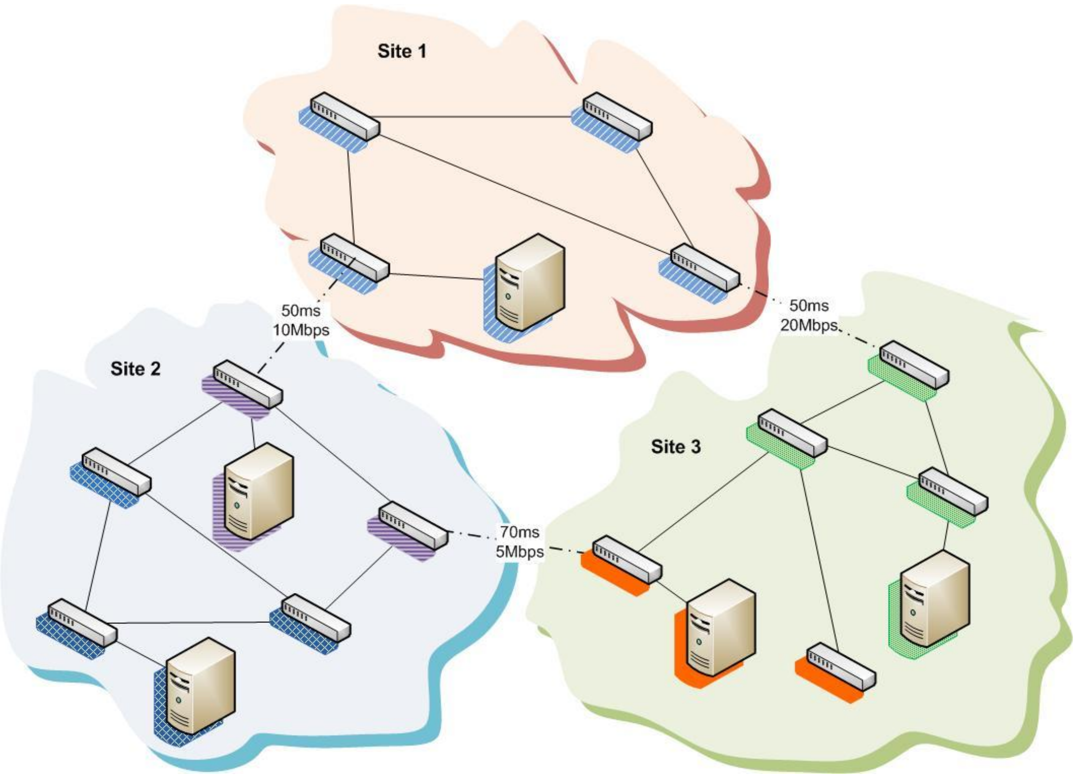
- Flow setup time for switches farther from controller is larger.
- Single controller can handle a limited number of datapath requests.
- End-to-end control bandwidth is limited.



Network operators need to deploy multiple controllers.

Distributed Control Plane Must Not Sacrifice Simplicity for Scalability!

- Key to OpenFlow's simplicity:
  - Network control logic centralization.
- Trade-off:
  - Scalability (complete distribution)
  - Simplicity
- Distributed cp should be scalable, yet transparent to the control logic.



A distributed cp must keep network control logic centralized.

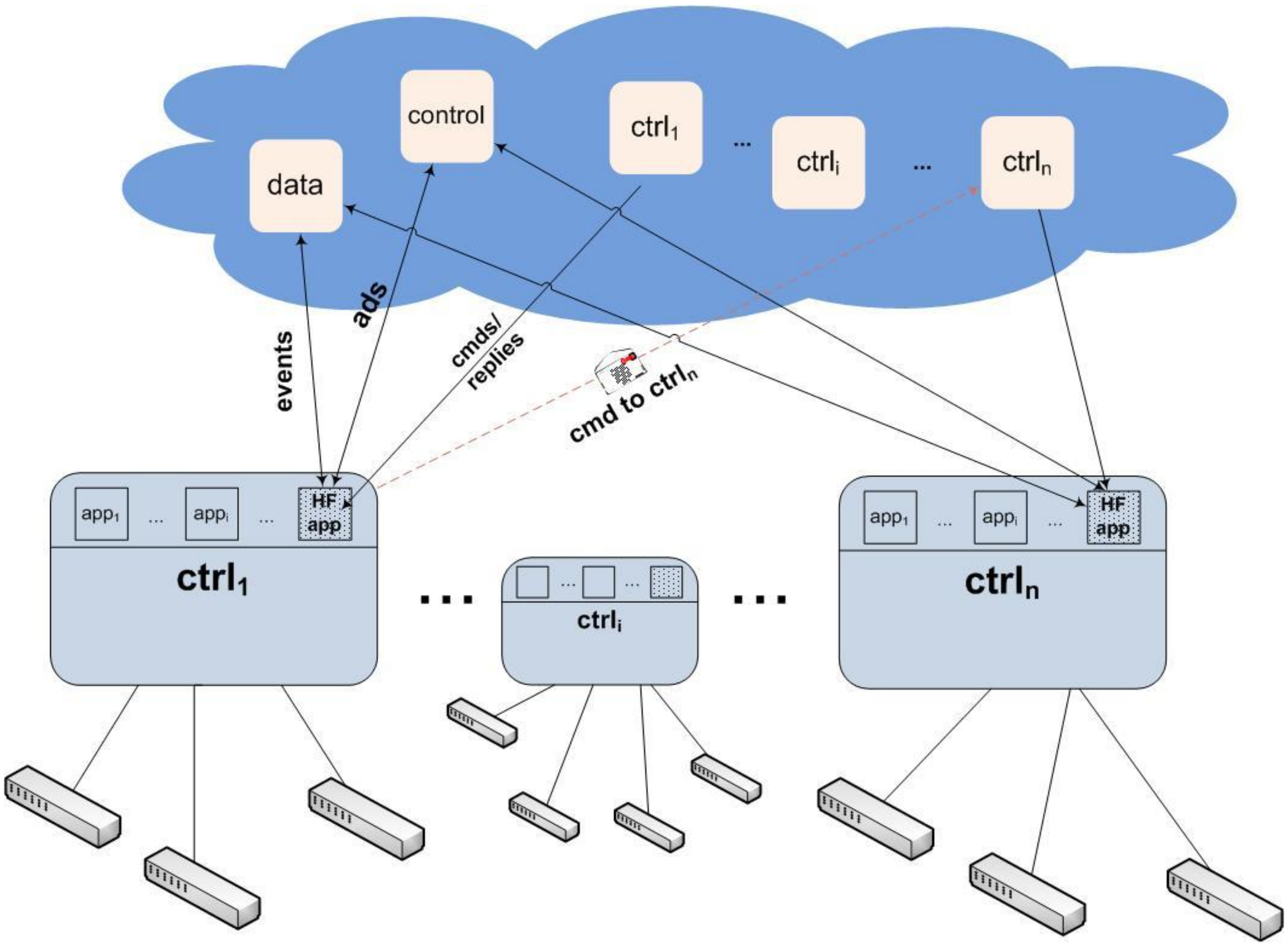
Our Approach: Push All State to All Controllers

- Make each controller think it is the only controller.
- Passively synchronize state among controllers.
  - With minor modifications to applications.
- How to synchronize state with minimal modification?
  - Capture controller events which affect controller state.
    - Controller events: e.g., OpenFlow messages (Packet_in_event, …).
    - The number of such events is very small.
  - Replay these events on all other controllers.

HyperFlow Design

- HyperFlow has two components:
  - Controller component:
    - An event logger, player, and OpenFlow command proxy.
    - Implemented as a C++ NOX application.
  - Event propagation system:
    - A publish/subscribe system.
- Switches are connected to close controllers.
- Upon controller failure:
  - Switches are reconfigured to connect to another controller.

Overview of HyperFlow



HyperFlow Controller Component

- Event logger captures & serializes some ctrl events.
  - Only captures events which alter the controller state.
  - Serializes and publishes the events to the pub/sub.
- Event player deserializes & replays captured events.
  - As if they occurred locally.
- Command proxy sends cmds to appropriate switch.
  - Sends the replies back to the original sender.

Event Propagation System

- The pub/sub system has a network-wide scope.
- It has three channel types:
  - Control channel: controllers advertise themselves there.
  - Data channel: events of general interest published here.
  - Individual controllers' channels: send commands and replies to a specific controller.
- Implemented using WheelFS, because:
  - WheelFS facilitates rapid prototyping.
  - WheelFS is resilient against network partitioning.

Are Controllers in Sync?

- How rapidly can network changes occur in HF?
  - Yet guarantee a bounded inconsistency window.
- The bottleneck could be either:
  - The control bandwidth.
  - The publish/subscribe system.
- The publish/subscribe system localizes the HyperFlow sync traffic.
  - The control bandwidth problem could be alleviated.

How many events can HF exchange with pub/sub per sec?

How Frequent Can a Network Change?

- Benchmarked WheelFS:
  - The number of 3KB-sized files HF can serialize & publish:
    - 233 such events/sec → not a concern (multiple publishers)
  - The number of 3KB-sized files HF can read & deserialize:
    - 987 such events/sec.

- However, HF can handle far larger number of events.
  - During spikes inconsistency window is not bounded.

Switch/Host/Link changes

10s of events/sec for thousands of hosts

No. of network changes on avg must be < 1000 events/sec.

Summary

- HyperFlow enables deploying multiple controllers.
  - Keeps network control logic centralized.
  - Yet, provides control plane scalability.
- It synchronizes network-wide view among controllers.
  - By capturing, propagating & playing *a few* ctrl events.
- It guarantees bounded window of inconsistency:
  - If network changes occur at a rate < 1000 event/sec.
- It is resilient to network partitioning.
- It enables interconnection of OpenFlow islands.

Current/Future Work

- We designed OpenBoot to bootstrap controller state very quickly.
  - Uses checkpoint/restart + event logging
  - Enables rapid recovery from controller failures.
  - Enables adaptive control plane scaling.
  - ***Enables continuous control plane operation.***

- Improvements to the publish/subscribe system.
- Evaluation on a large testbed with realistic data.

Thanks for your attention.

Questions?

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