SDN Usecases

ECE/CS598HPN

Radhika Mittal

Logistics

- No class this Friday, Sept 15th.
- Warm-up assignment due next Wednesday (Sept 20th).
    - *Have you found a grading partner?*
- Would you like your opinions to be anonymous or is name calling ok?

B4: Experience with a Globally-Deployed Software Defined WAN

Google

SIGCOMM'13

B4: Google's Software-Defined WAN

- Google operates two separate backbones:
  - B2: carries Internet facing traffic
    - Growing at a rate faster than the Internet
  - B4: carries inter-datacenter traffic
    - More traffic than B2
    - Growing faster than B2

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B4: Google's Software-Defined WAN

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  - **B4: carries inter-datacenter traffic**
    - **More traffic than B2**
    - **Growing faster than B2**

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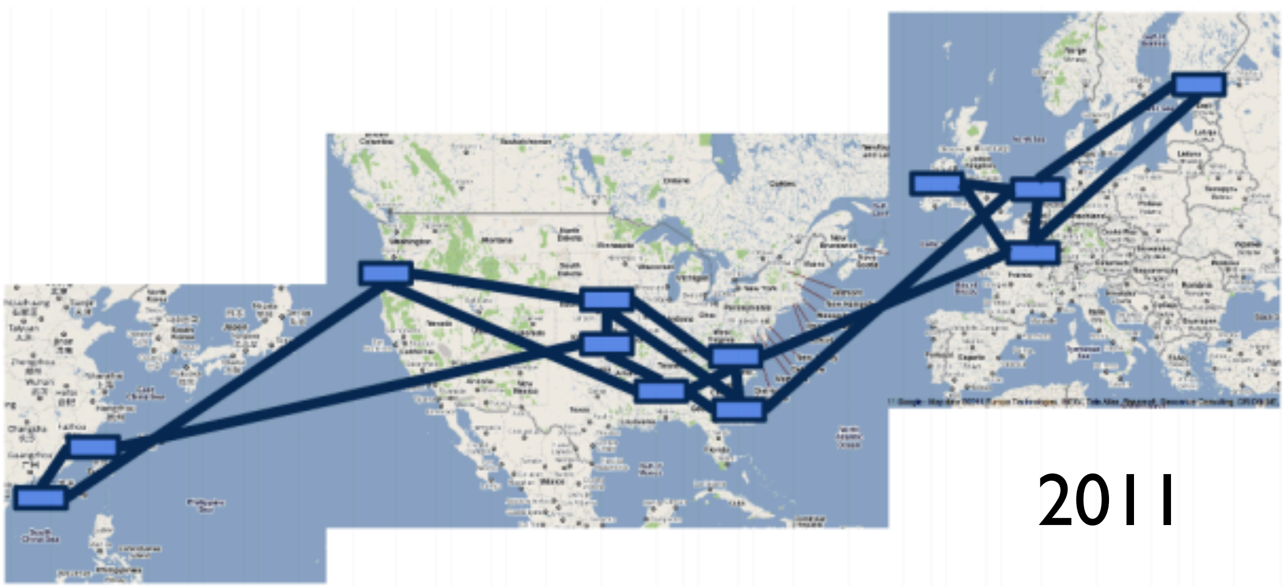
B4: Google's Software-Defined WAN

Among the first and largest SDN/OpenFlow deployment.



2011

Why SDN/OpenFlow?

- Opportunity to reason about global state
  - Simplified coordination and orchestration.
- Exploit raw speed of commodity servers.
  - Latest generation servers are much faster than embedded switch processors.
- Decouple software and hardware evolution.
  - Control plane software can evolve more quickly.
  - Data plane hardware can evolve slower based on programmability and performance.

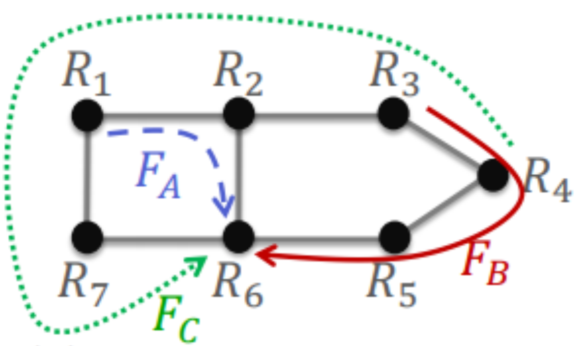
What did B4 use SDN for?

- Centralized routing.
  - Basic functionality.
  - Allowed Google to develop and stress test the SDN architecture.

- Centralized traffic engineering.
  - Allocating routes (and bandwidth) to groups of flows.
  - Also allows prioritizing some flows over others.
  - Enables running the WAN at higher utilization.

Traffic Engineering

- Traditionally accomplished via MPLS tunnels.
  - Tunnels defines routes and priority.
  - Ingress routers locally and greedily map flows to tunnels.



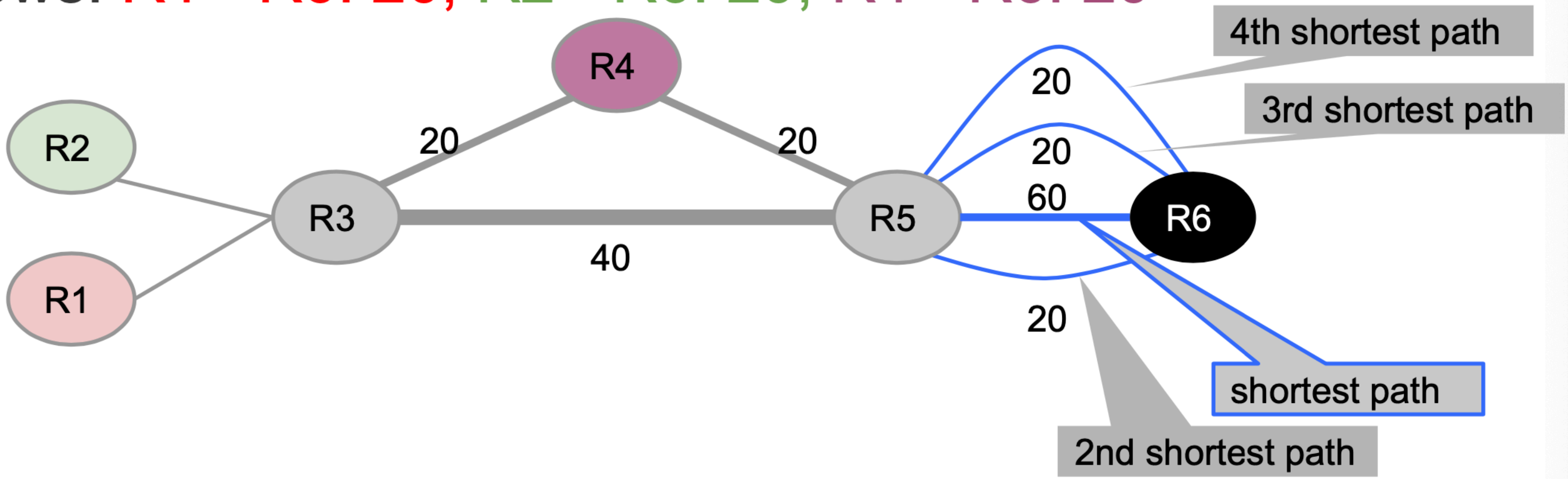
(a) Local path selection

- Centralized TE using SDNs allows closer to optimal routes.

Example from Microsoft's SWAN, SIGCOMM'13

Traffic Engineering: another example

Flows: R1->R6: 20; R2->R6: 20; R4->R6: 20



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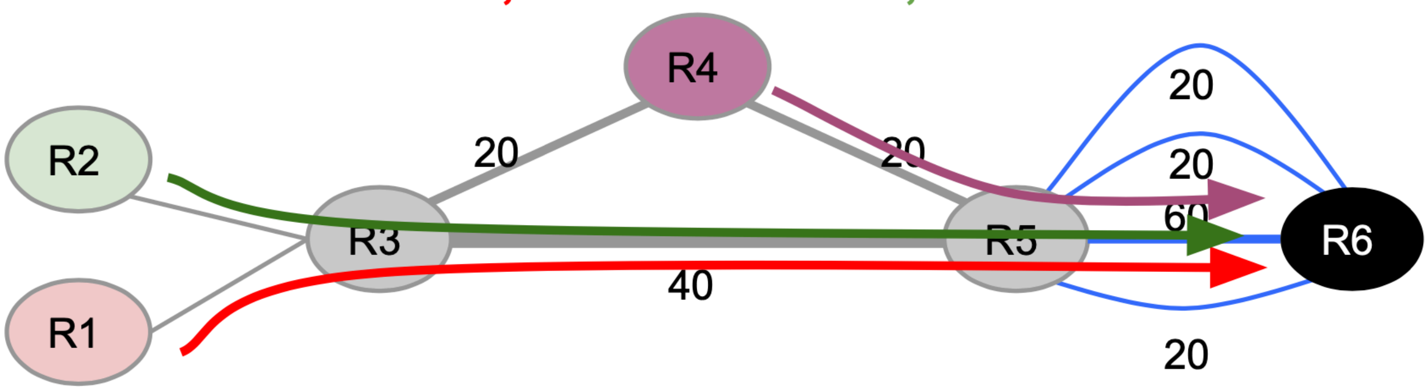

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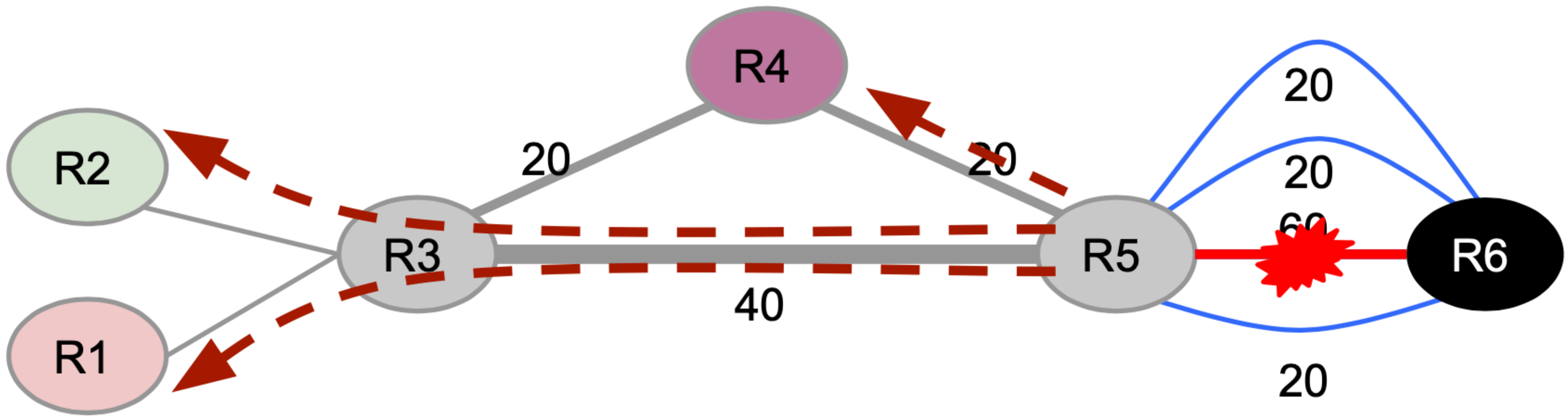

R5-R6 link fails

- R1, R2, R4 *autonomously* find next best path

Traffic Engineering: another example

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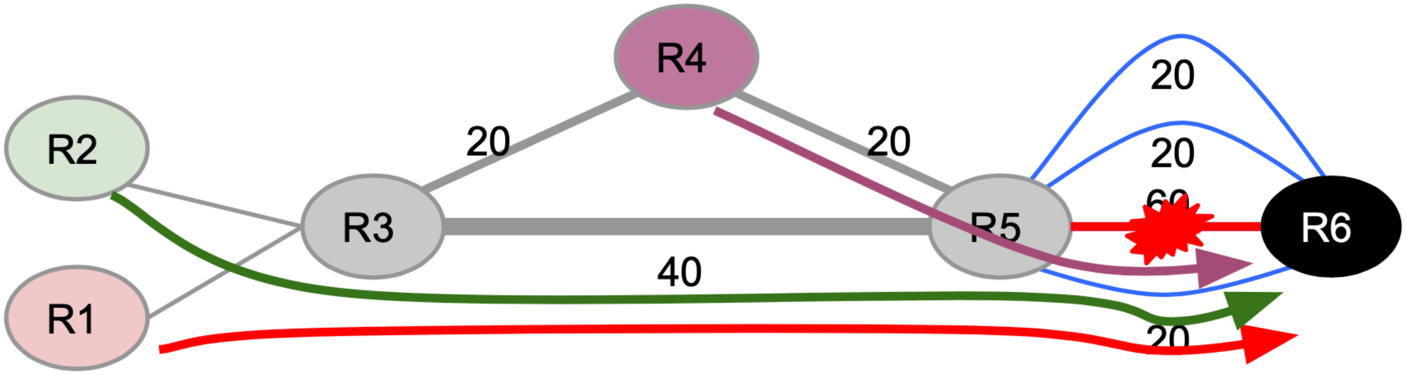


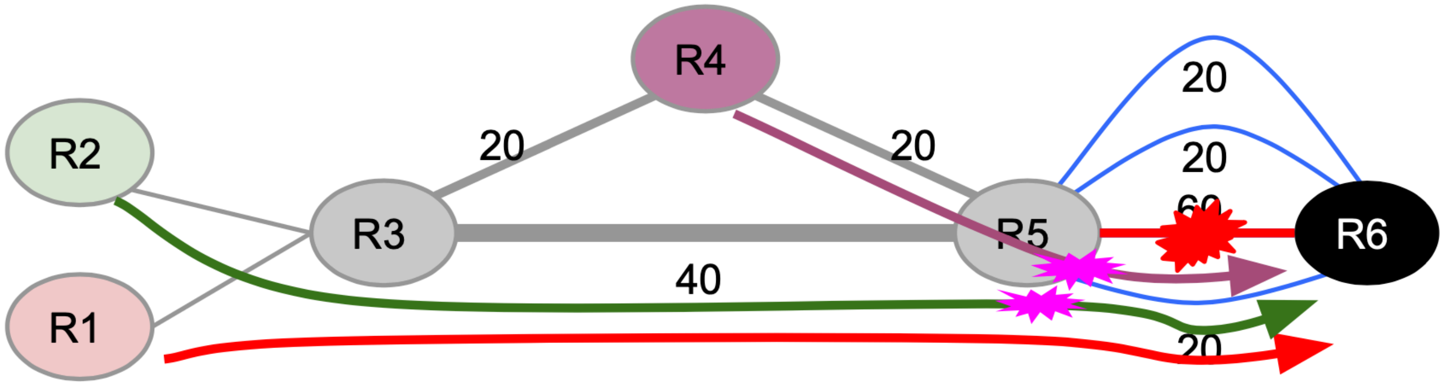
No Traffic Engineering

R5-R6 link fails

- R1, R2, R4 *autonomously* try for next best path
- R1, R2, R4 push **20** altogether

Traffic Engineering: another example

Flows: R1->R6: 20; R2->R6: 20; R4->R6: 20



Distributed Traffic Engineering Protocols

e.g. MPLS + RSVP

R5-R6 link fails

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- R1 wins, R2, R4 retry for next best path

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Traffic Engineering: another example

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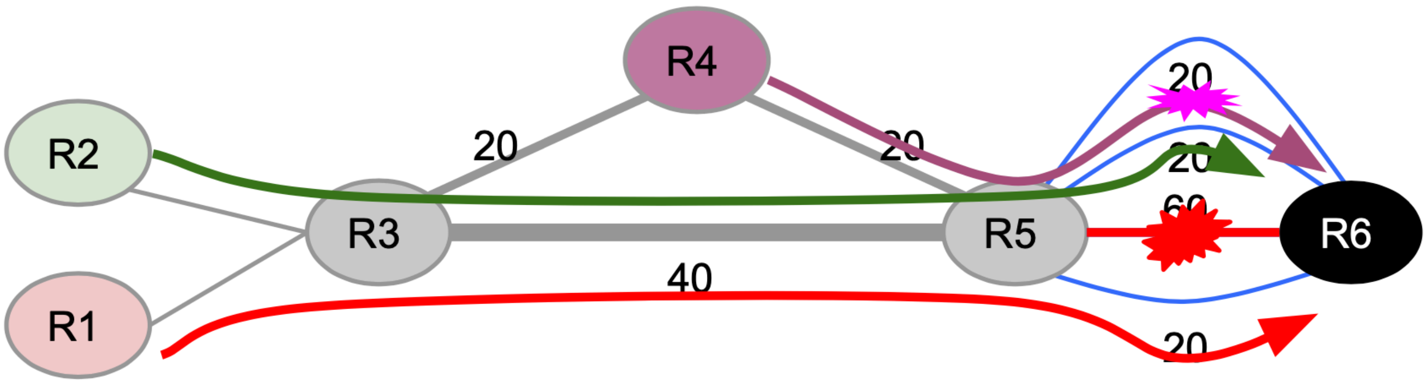

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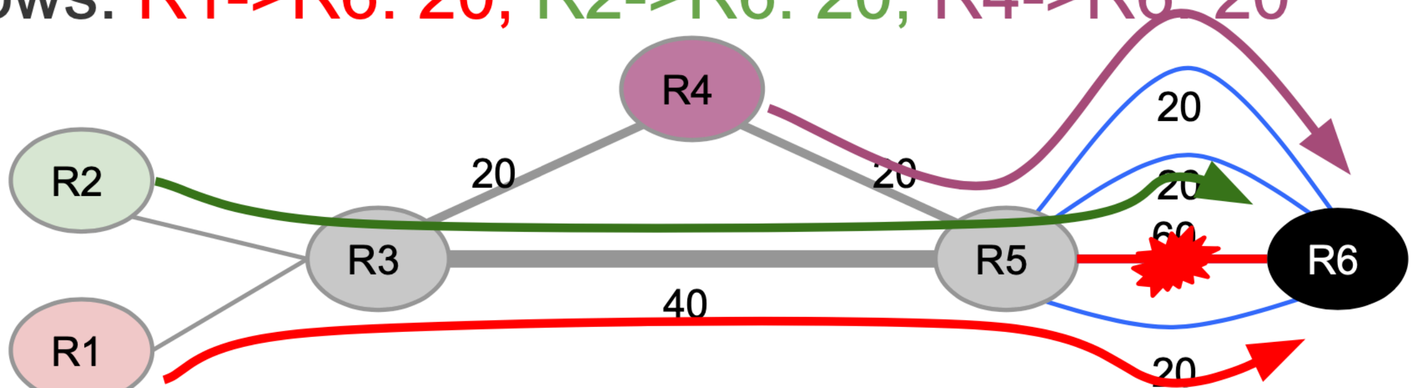

Distributed Traffic Engineering Protocols

e.g. MPLS + RSVP

R5-R6 link fails

- R1, R2, R4 *autonomously* try for next best path
- R1 wins, R2, R4 retry for next best path
- R2 wins this round, R4 retries again
- R4 finally gets third best path!

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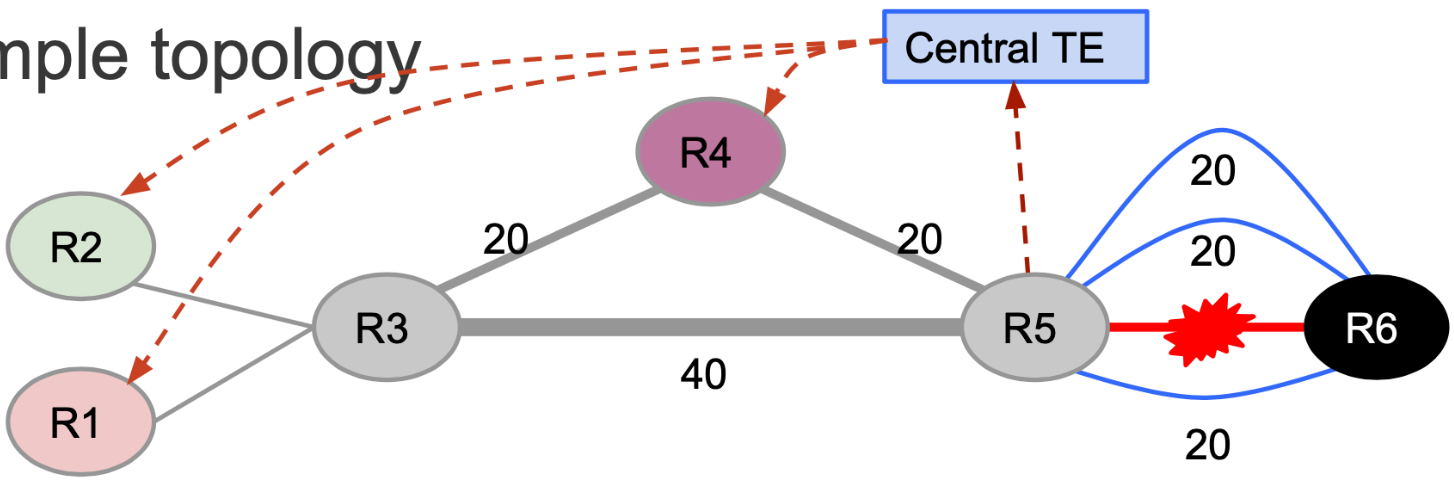
Traffic Engineering: another example

Simple topology



Centralized Traffic Engineering Protocols

Flows:

- R1->R6: 20; R2->R6: 20; R4->R6: 20

R5-R6 fails

- R5 informs TE, which programs routers in one shot

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Limitation of OpenFlow faced by B4

- Needs somewhat fancier switch behavior.
  - TE enforced using IP-in-IP tunnels.
  - Switches should understand how to parse headers for tunneling.
    - Encapsulate with tunnel IP at source ingress.
    - Decapsulate tunnel IP at destination egress.

- Developed their own switches that supported a slightly extended version of OpenFlow.

B4 SDN architecture

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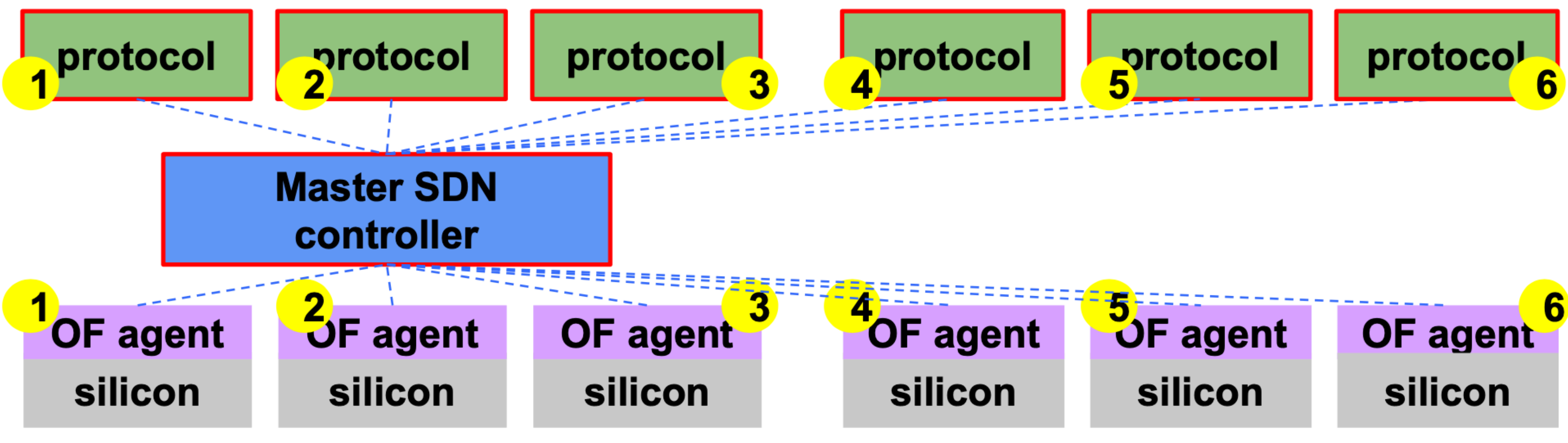

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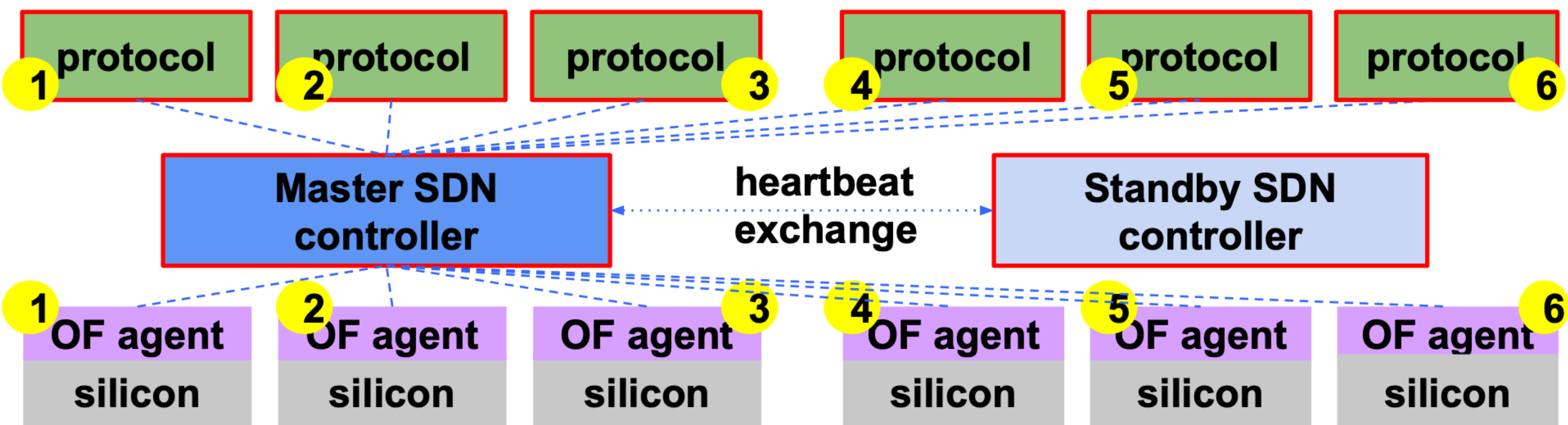
B4 SDN architecture



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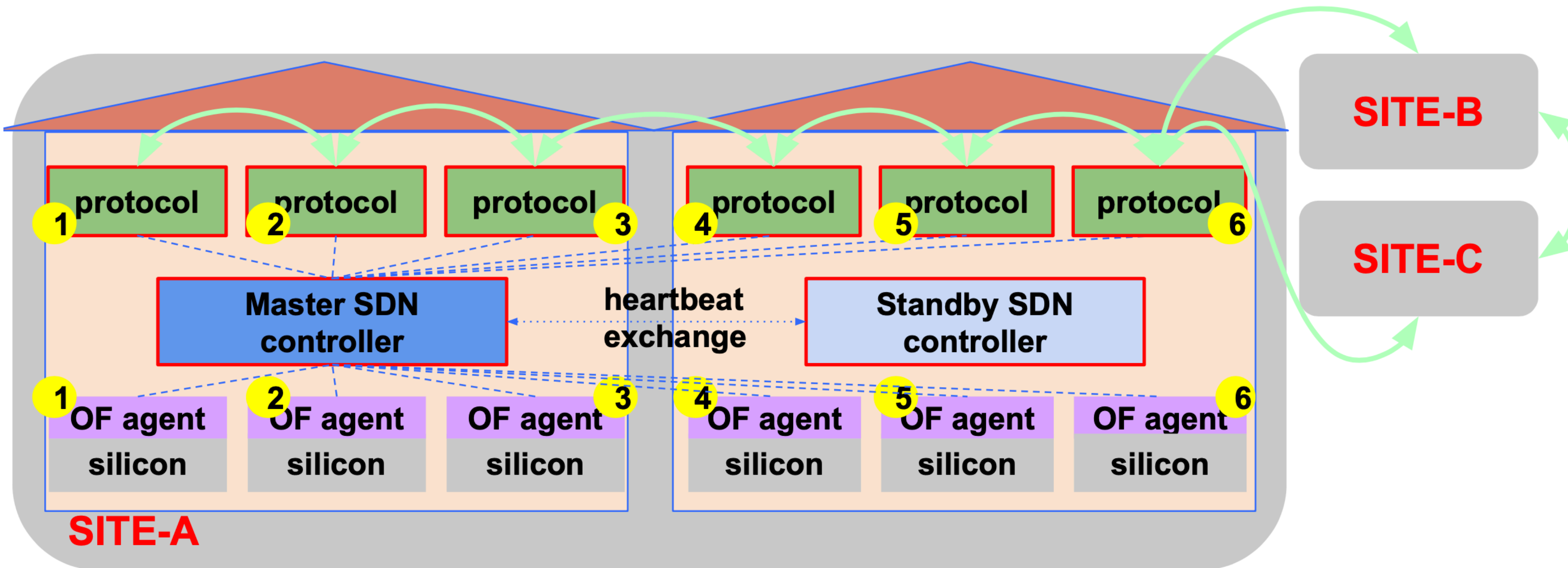
B4 SDN architecture



Unit of management is a site = fabric

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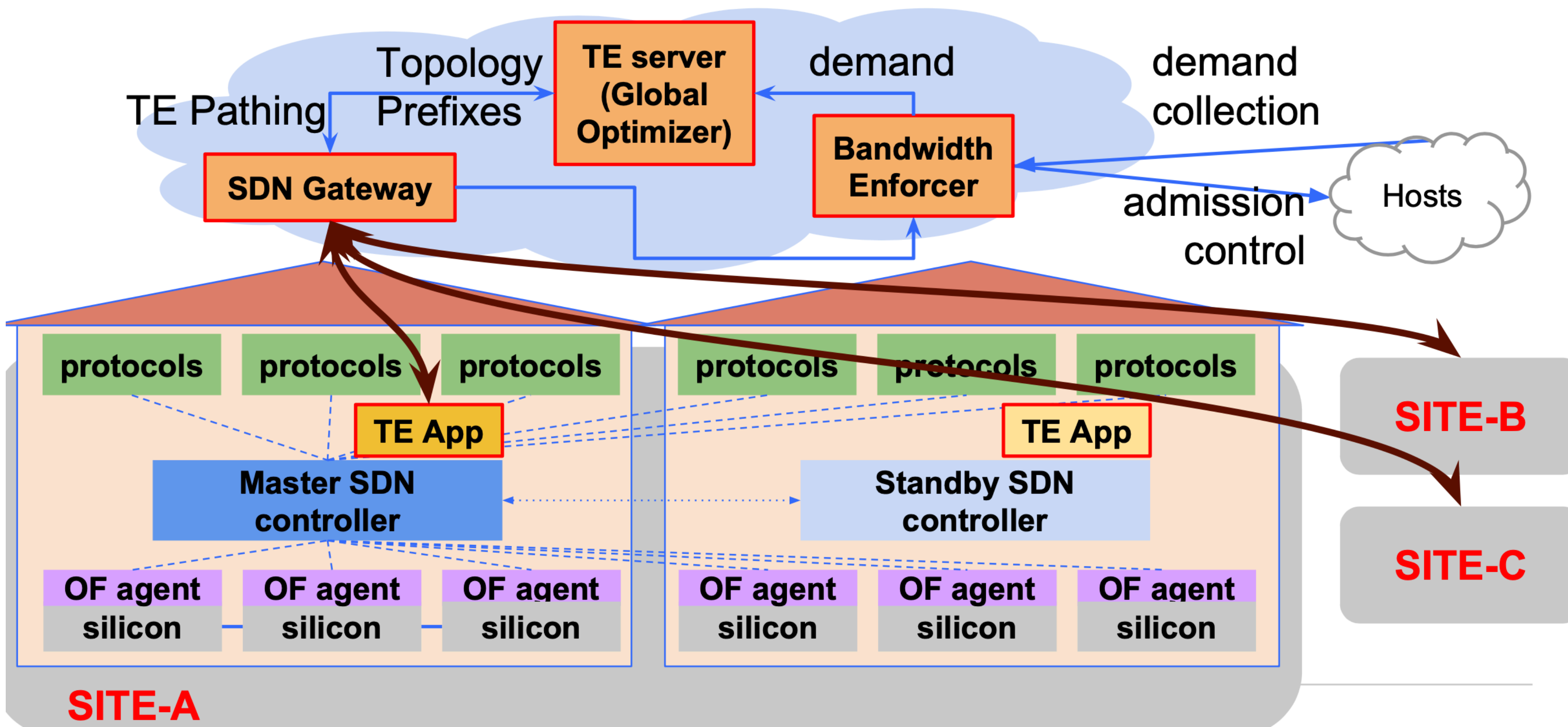
B4 SDN architecture



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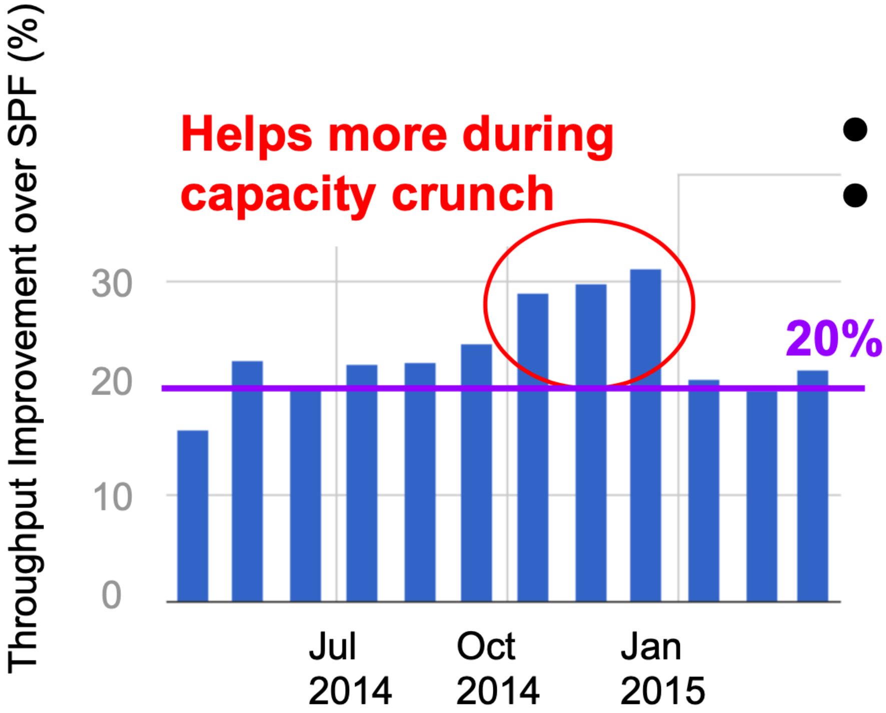
B4 Traffic Engineering

- Objective: max-min fairness
  - A: 10Gbps, B: 5Gbps, total link capacity = 12Gbps
    - B = 5Gbps
    - A = 7 Gbps
  - A: 10Gbps, B: 5Gbps, C: 2Gbps, link capacity = 12Gbps
    - C = 2Gbps
    - B = 5Gbps
    - A = 5Gbps
  - Same demands, W(A) = 2, W(B) = 1, W(C) = 1, link capacity = 12Gbps
    - C = 2Gbps
    - B = 3.33Gbps
    - A = 6.67Gbps
- Greedy (water-filling) heuristic to do this across multiple paths.
- *Bandwidth Enforcer, SIGCOMM'15 has more details on TE algorithms*

Benefit of Centralized TE



- ~20% increase in throughput over SPF
- Larger benefits during capacity crunch

Lowers the requirement for bandwidth provisioning

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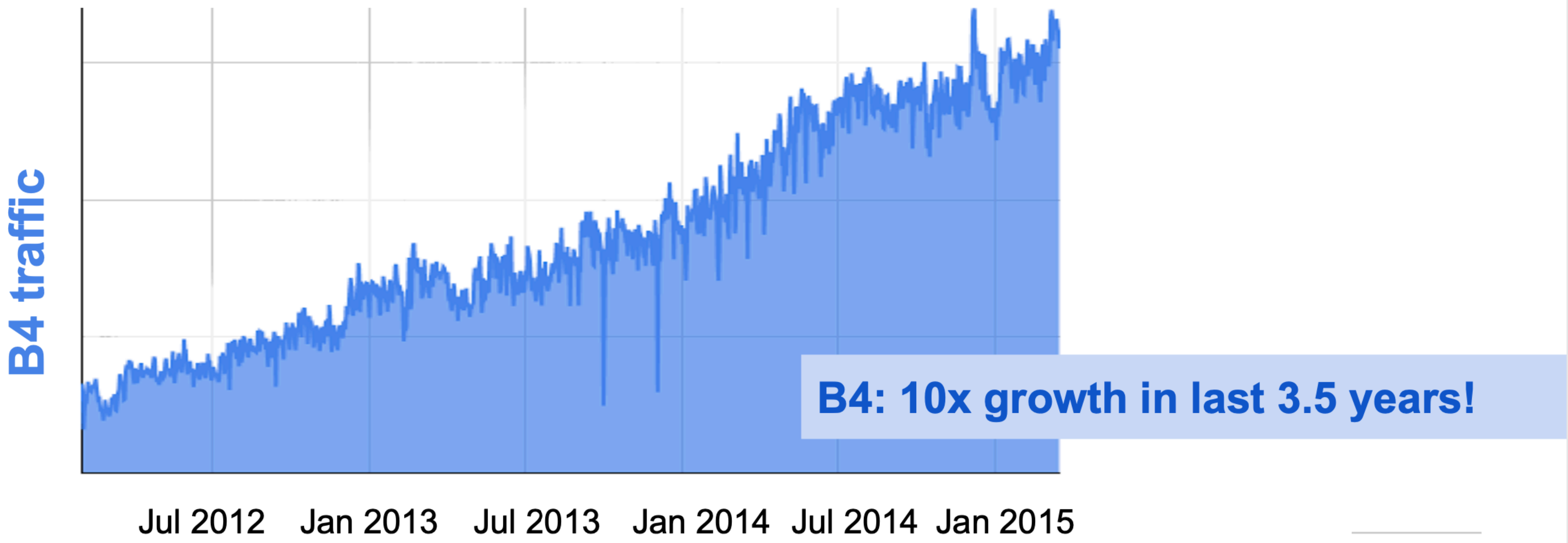
Benefit of Centralized TE



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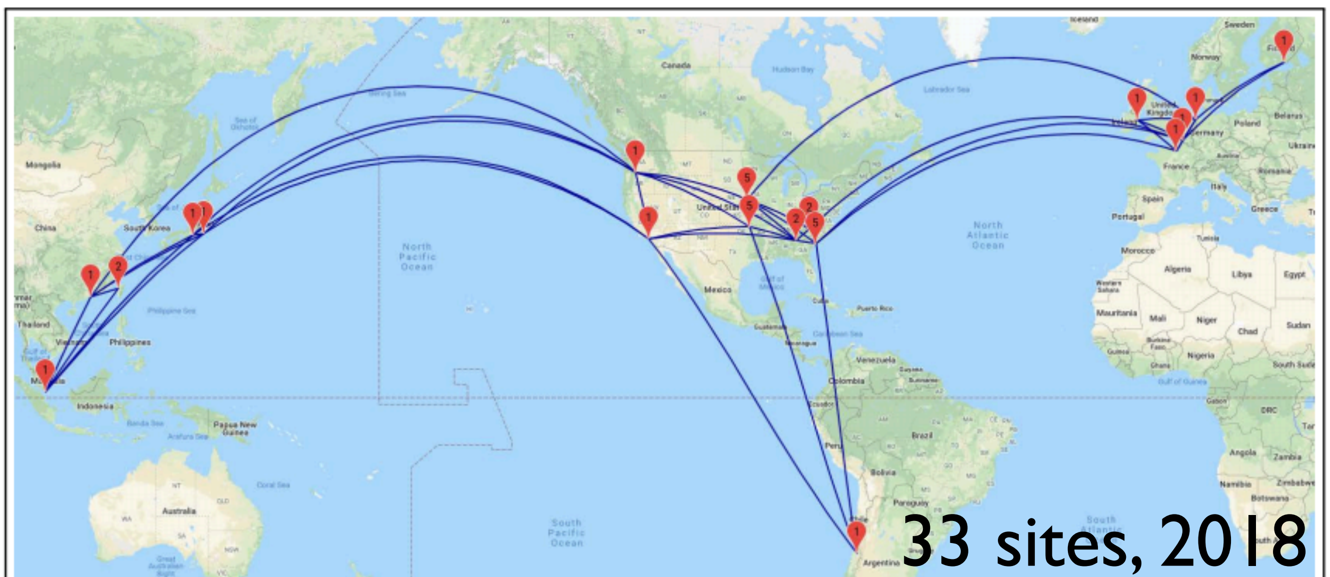
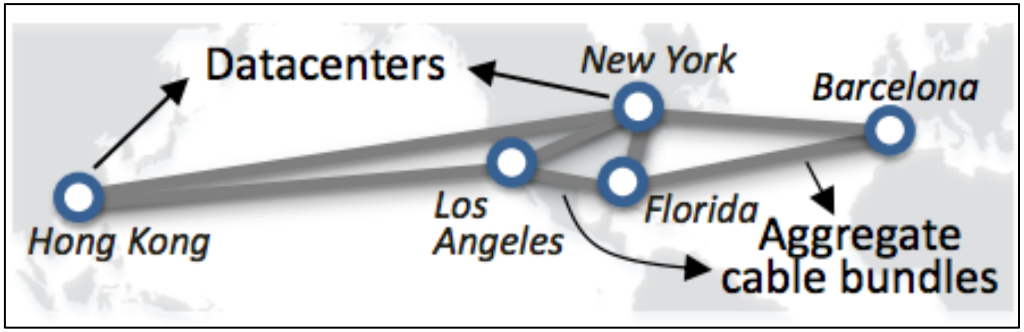
B4 and After: SIGCOMM'18

- Growth in traffic: more sites, larger sites, more paths.
  - Flat topology scales poorly:
    - Hierarchical topology at each site.
  - Hierarchical traffic engineering.



Another software-defined WAN

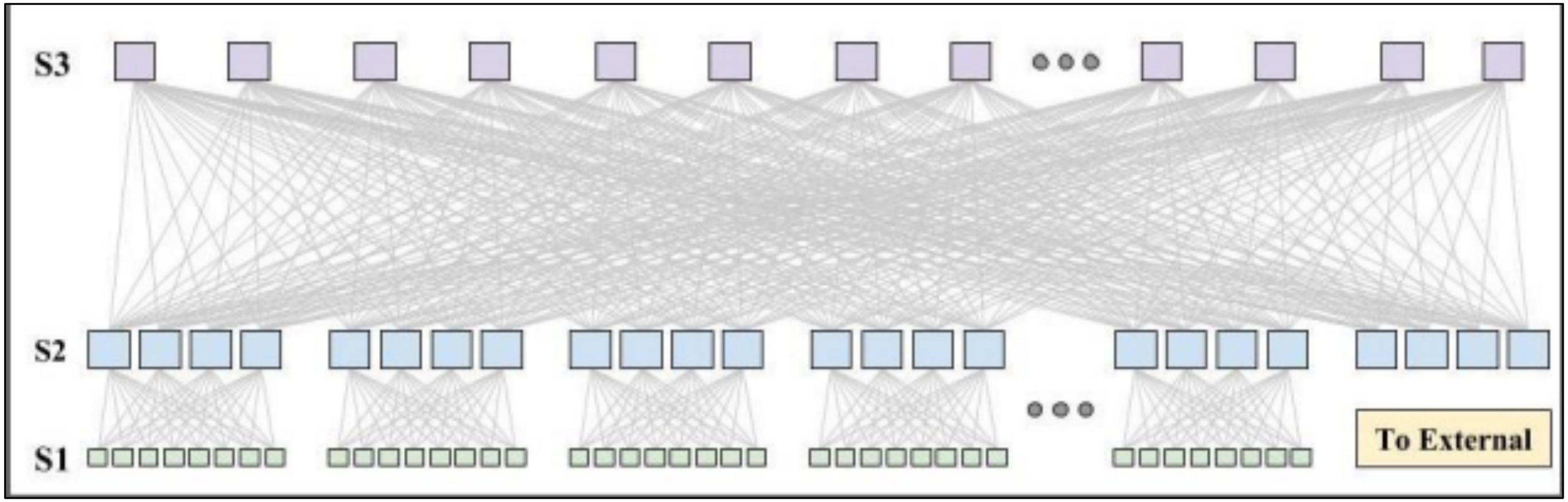
- SWAN (WAN connecting Microsoft's datacenter)
  - Goal: increase WAN link utilization.
    - Centralized and global traffic engineering.



Other SDN usecases at Google

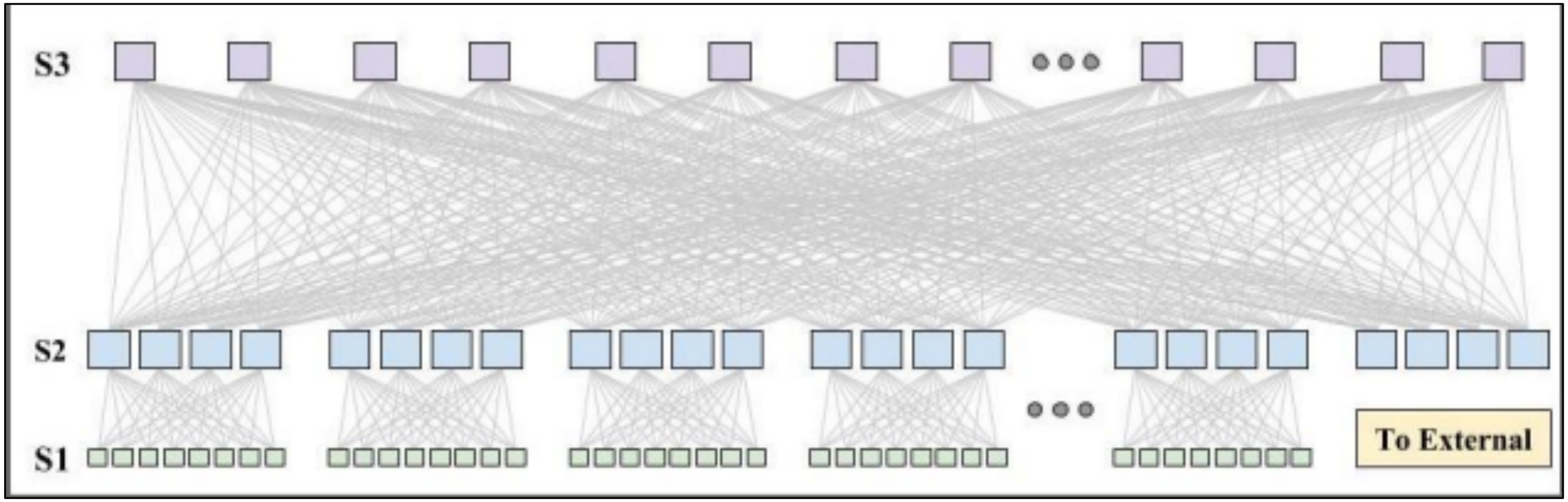
Datacenter routing

- Few 100-1000 switches distributed across clusters.
- High communication overhead for distributed routing.
- Symmetric topology: multipath equal cost forwarding.



Datacenter routing

- Jupiter (Google's Datacenter), SIGCOMM'15
  - Centralized configuration for baseline static topology.
  - Centralized dissemination of link state.
  - Each switch reacts locally to changes.

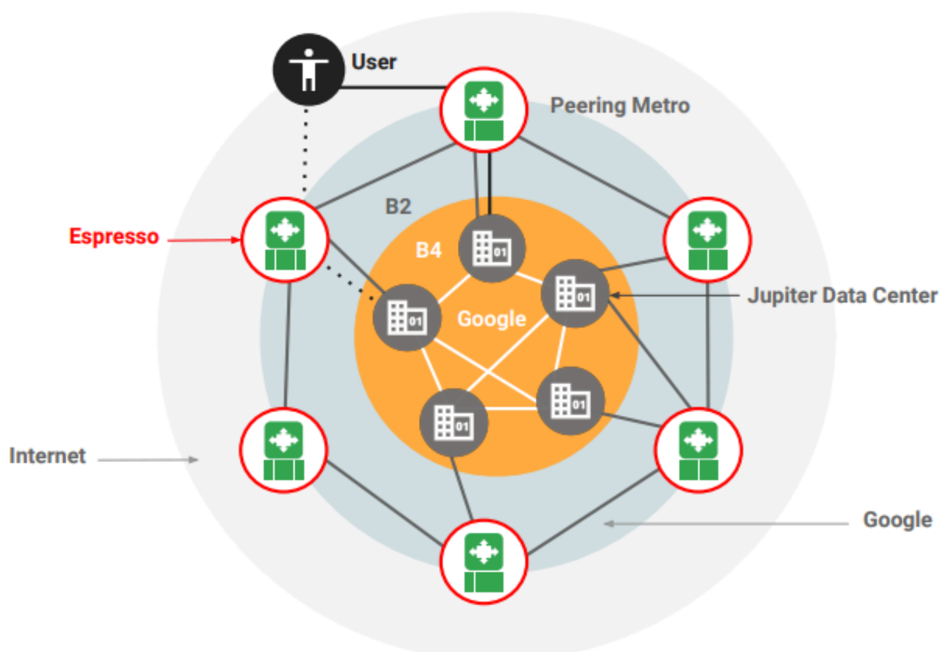


Datacenter routing

- Jupiter (Google's Datacenter)
  - Use of SDN was key to enabling evolution in Jupiter's topology
    - Jupiter evolving: transforming google's datacenter network via optical circuit switches and software-defined networking
    - SIGCOMM'22

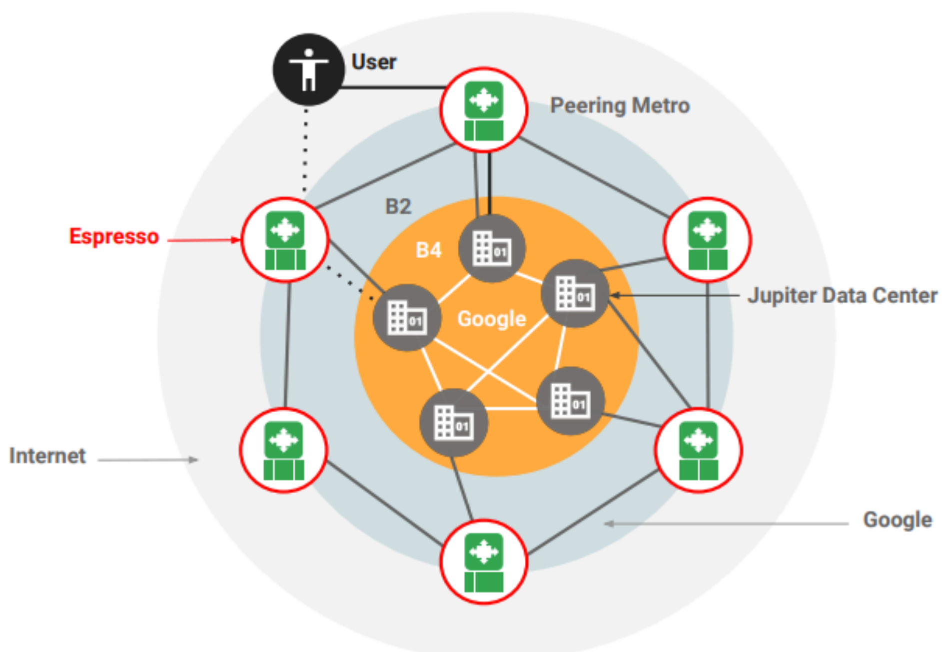
Policy enforcement at user-facing edge

- Internet edge routers implement rich set of features:
  - Access control, firewall, BGP routing policies.
- Policies require global, cross-layer optimizations.
  - Might also require switch upgrades, that affect availability.



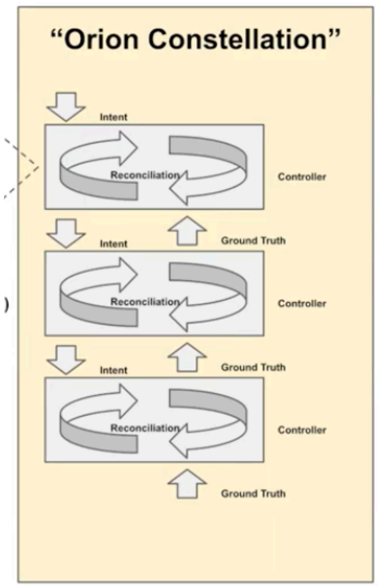
Policy enforcement at user-facing edge

- Espresso (SIGCOMM'17):
  - Global software control plane to compute policies.
  - Local control plane to translate policy to forwarding rules.



Google’s own control plane

- Orion: Google's Software-Defined Networking Control Plane (NSDI’21): used with Jupiter and B4.
  - modular micro-service based controller
  - multiple layers
    - Inter-block routing -> intra-block routing -> per-node flow programming.
  - intent flows down, ground truth flows up
    - pub-sub system



SDN in Stratosphere

- Loon's aerospace mesh network (SIGCOMM'22)