SDN Usecases

ECE/CS598HPN

Radhika Mittal

Logistics

- Do all of you receive my emails?
- Are you all submitting your reading assignments?
- Do you have access to Illinois media space?
- Warm-up assignment due on Thursday. Have all of you found grading partners?
- Sign up for the project proposal meeting next week!
- 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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    - **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.

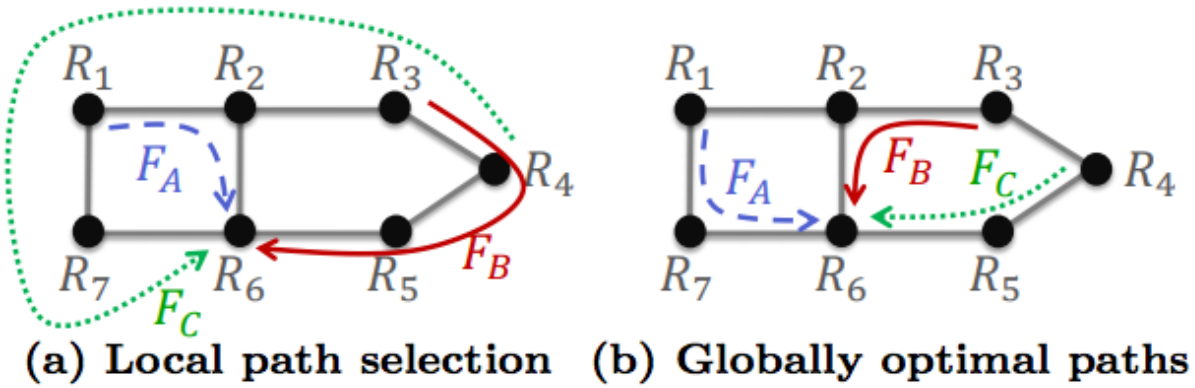
What did B4 use SDN for?

- 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.

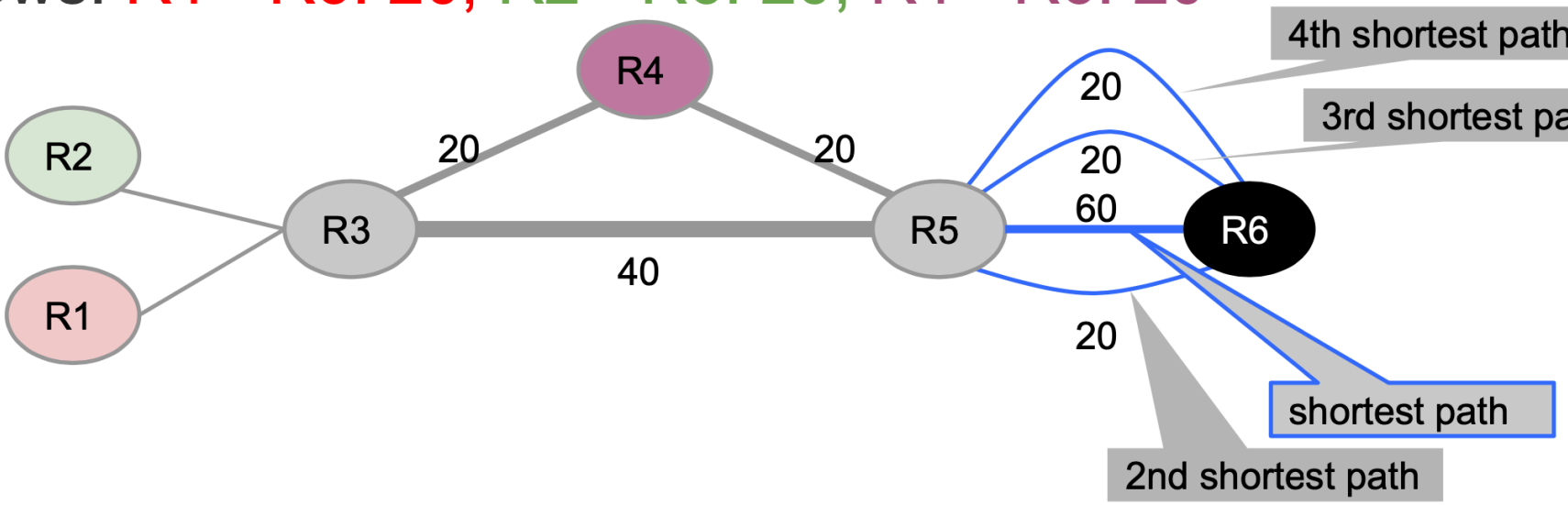


- Centralized TE using SDNs allows closer to optimal routes.

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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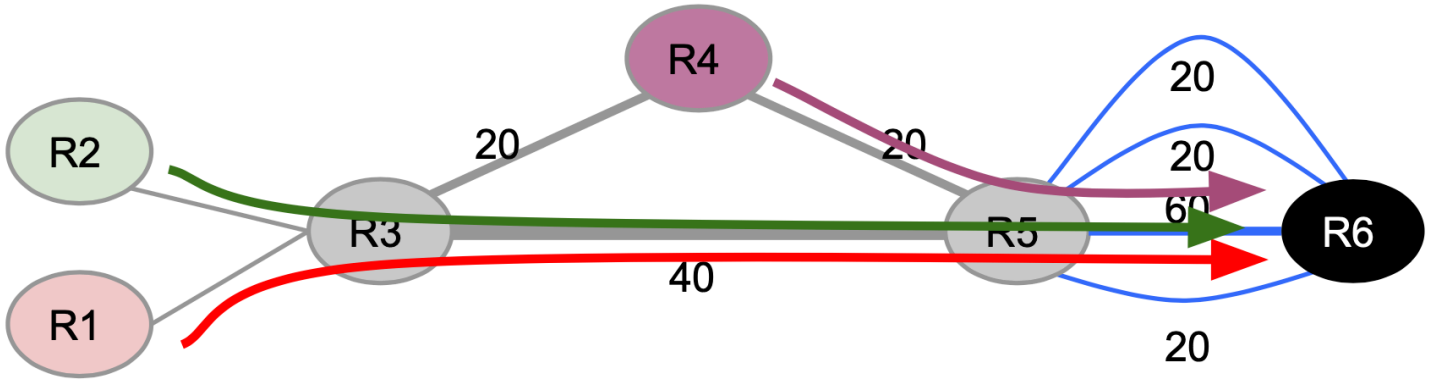

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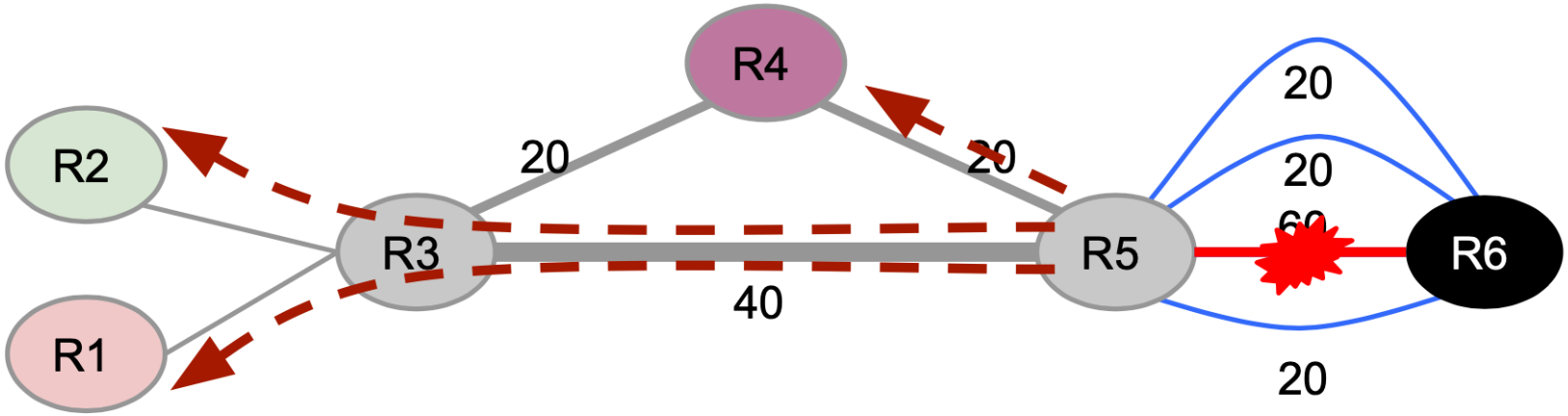

R5-R6 link fails

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

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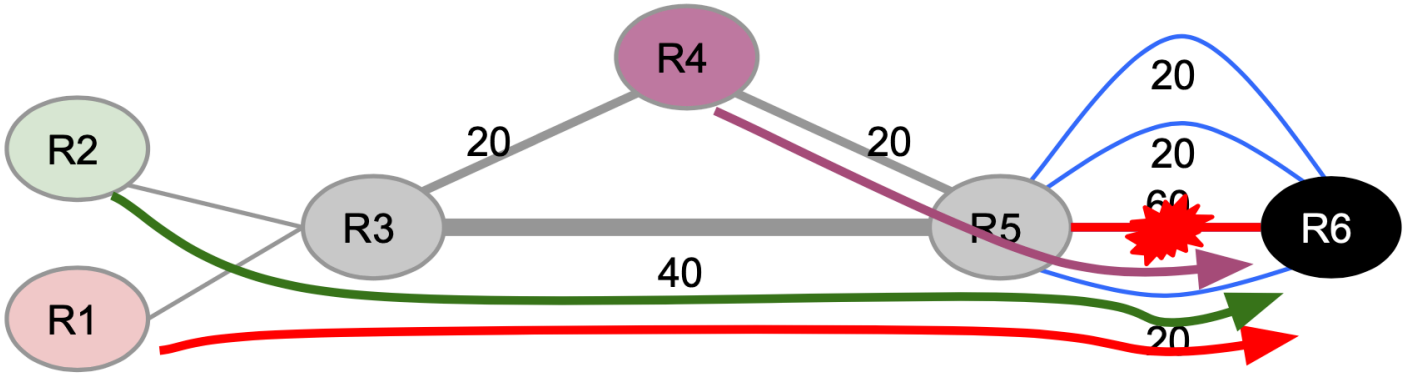

No Traffic Engineering

R5-R6 link fails

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

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Traffic Engineering: another example

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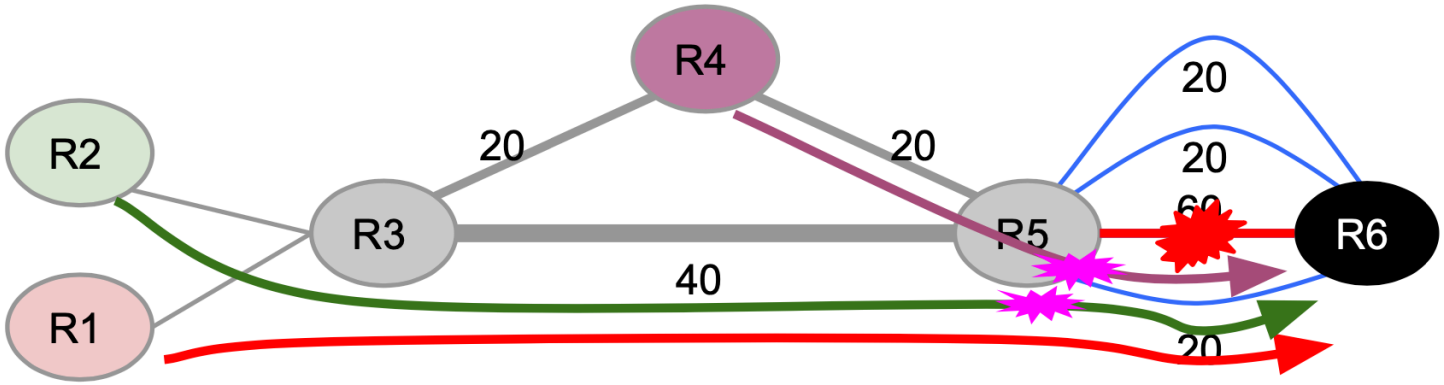

R5-R6 link fails

- R1, R2, R4 *autonomously* try for next best path
- R1 wins, R2, R4 retry for next best path

Distributed Traffic Engineering Protocols

e.g. MPLS + RSVP

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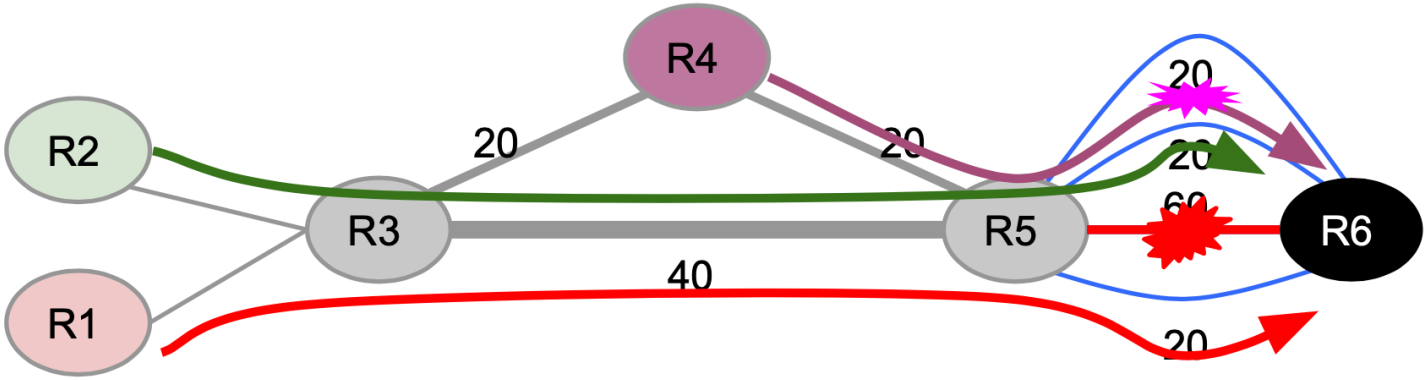

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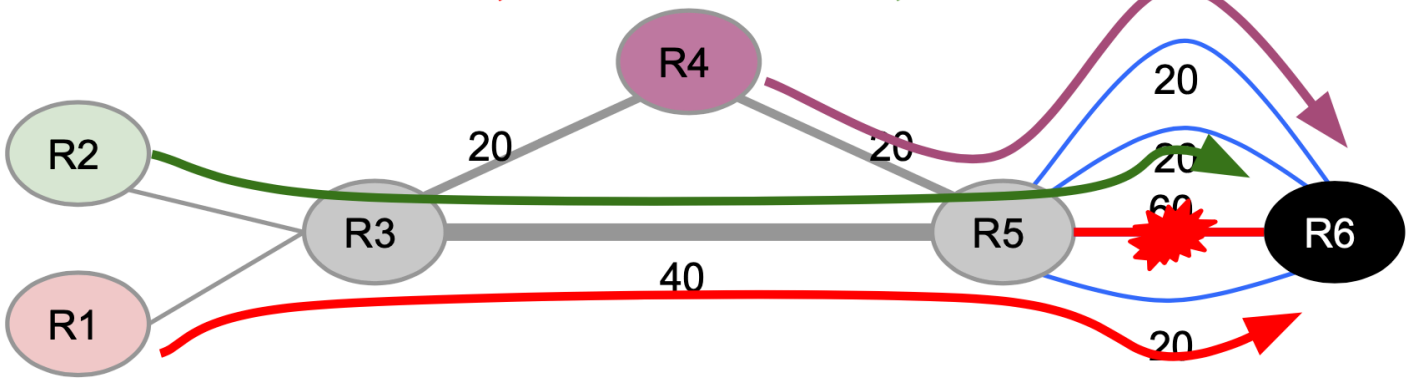

R5-R6 link fails

- 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!

Distributed Traffic Engineering Protocols

e.g. MPLS + RSVP

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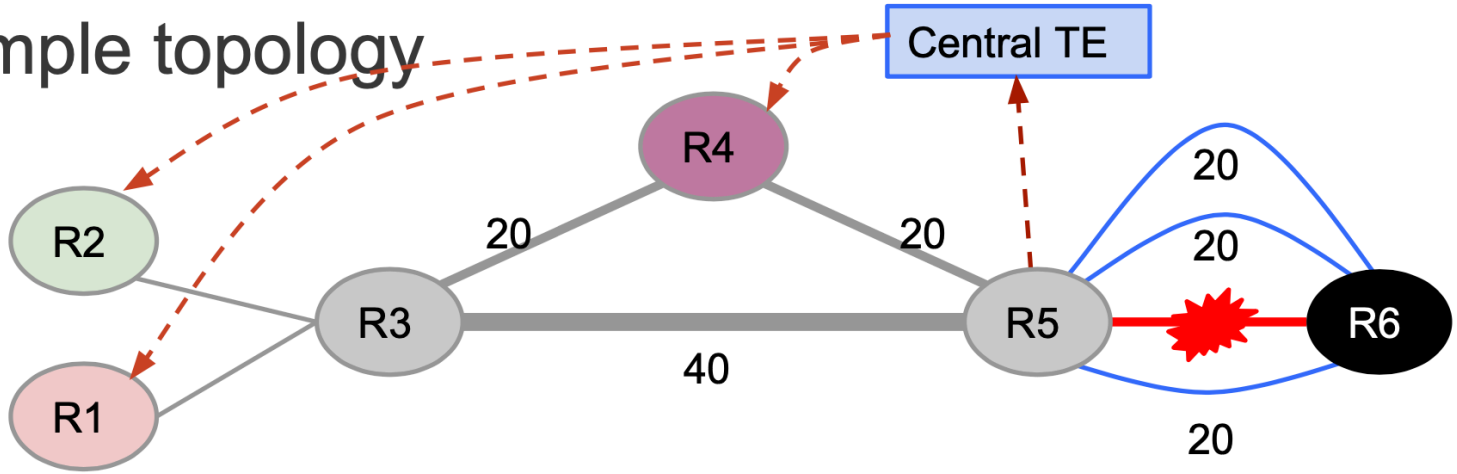
Traffic Engineering: another example

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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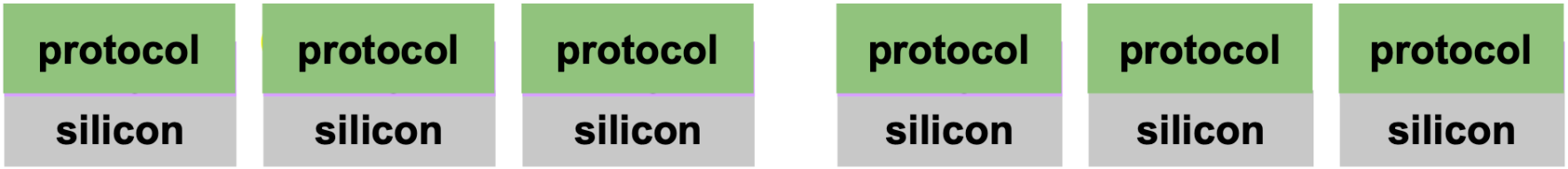
Limitation of OpenFlow faced by B4

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

B4 SDN architecture



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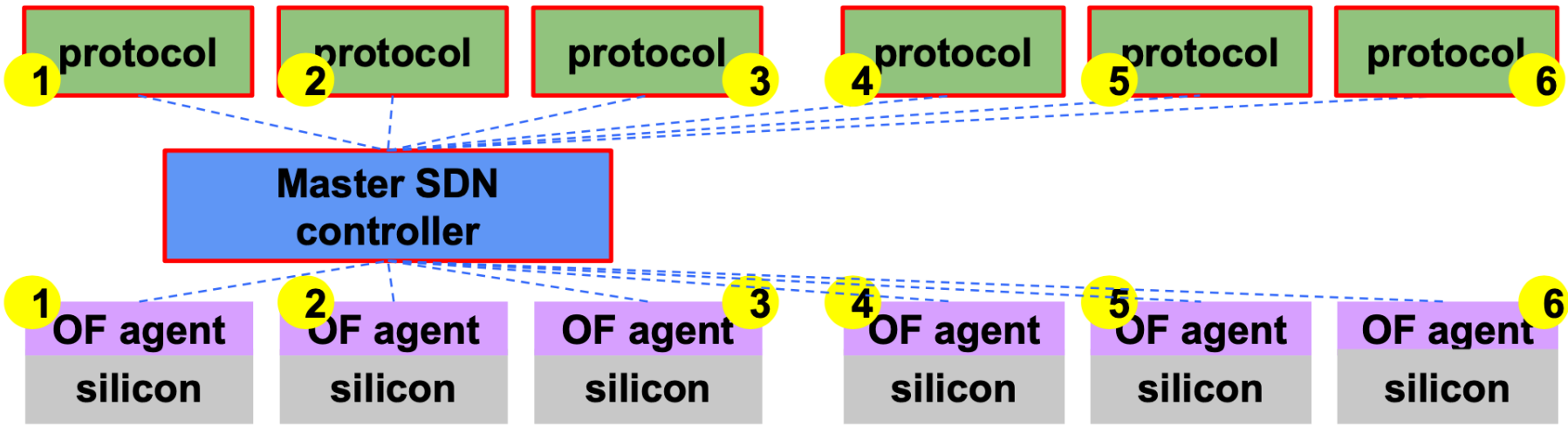

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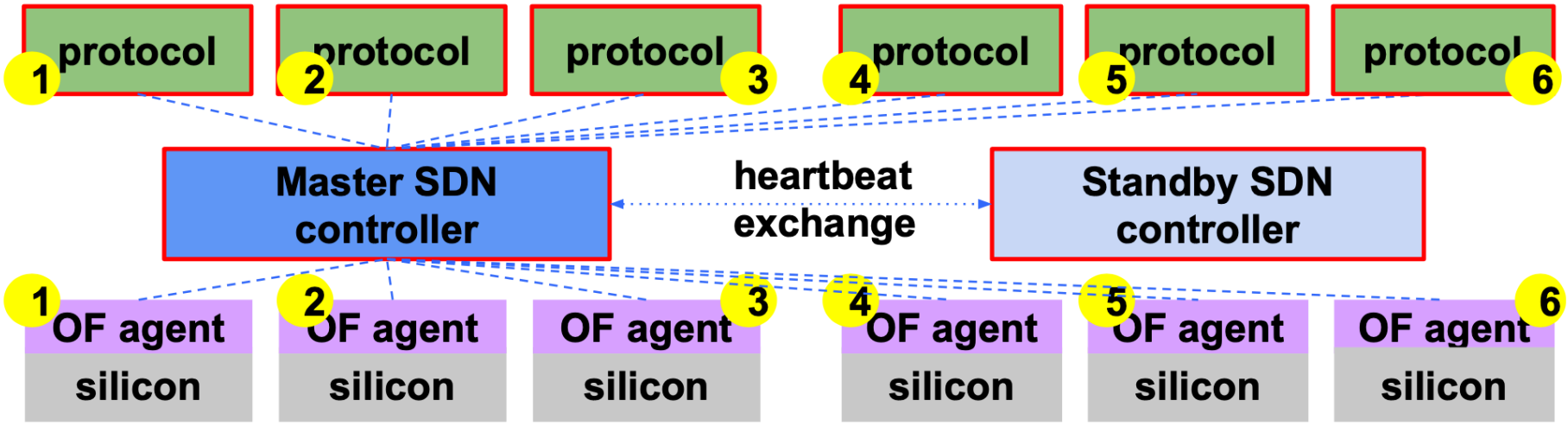
B4 SDN architecture



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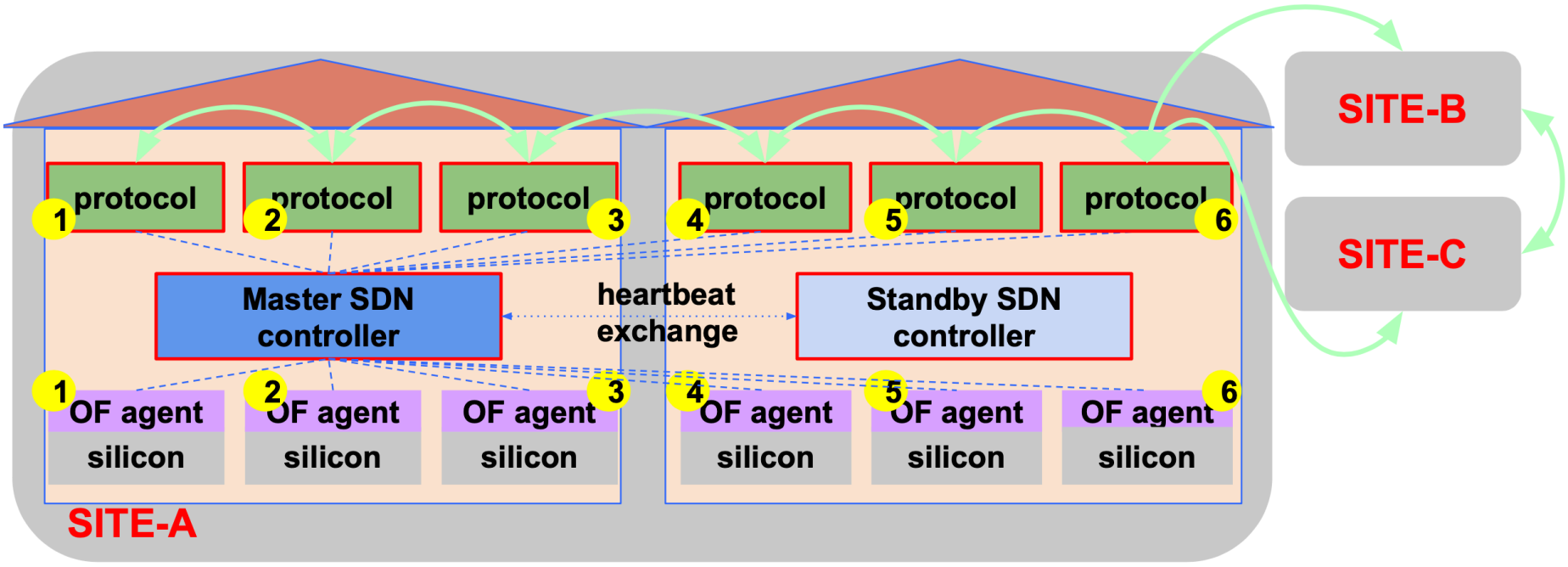

Unit of management is a site = fabric

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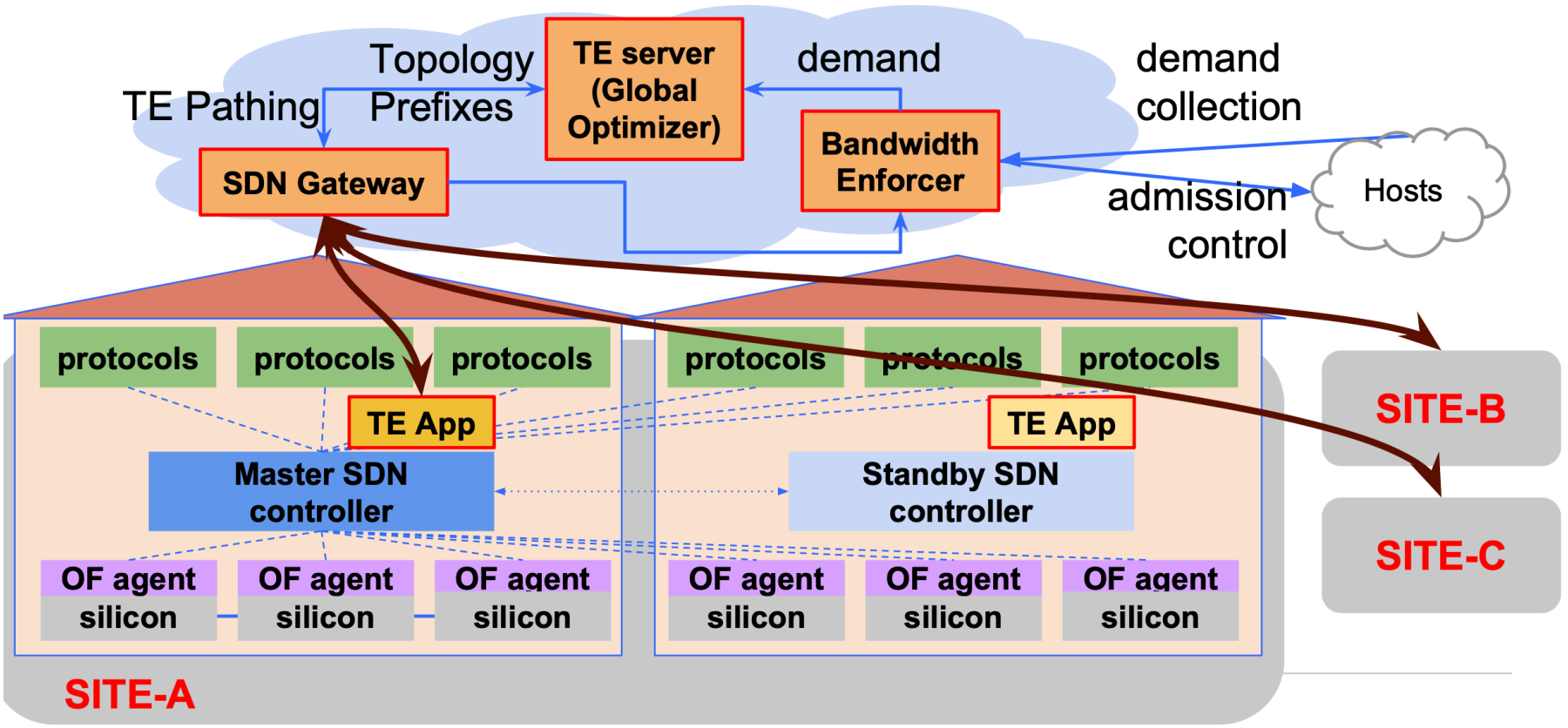
B4 SDN architecture



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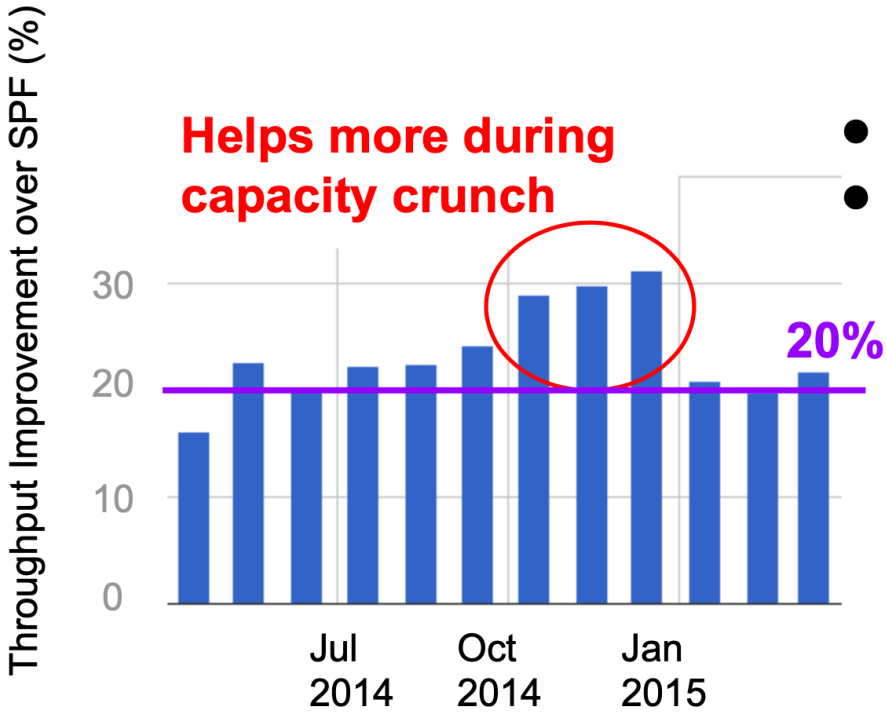
Benefit of Centralized TE



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

Lowers the requirement for bandwidth provisioning

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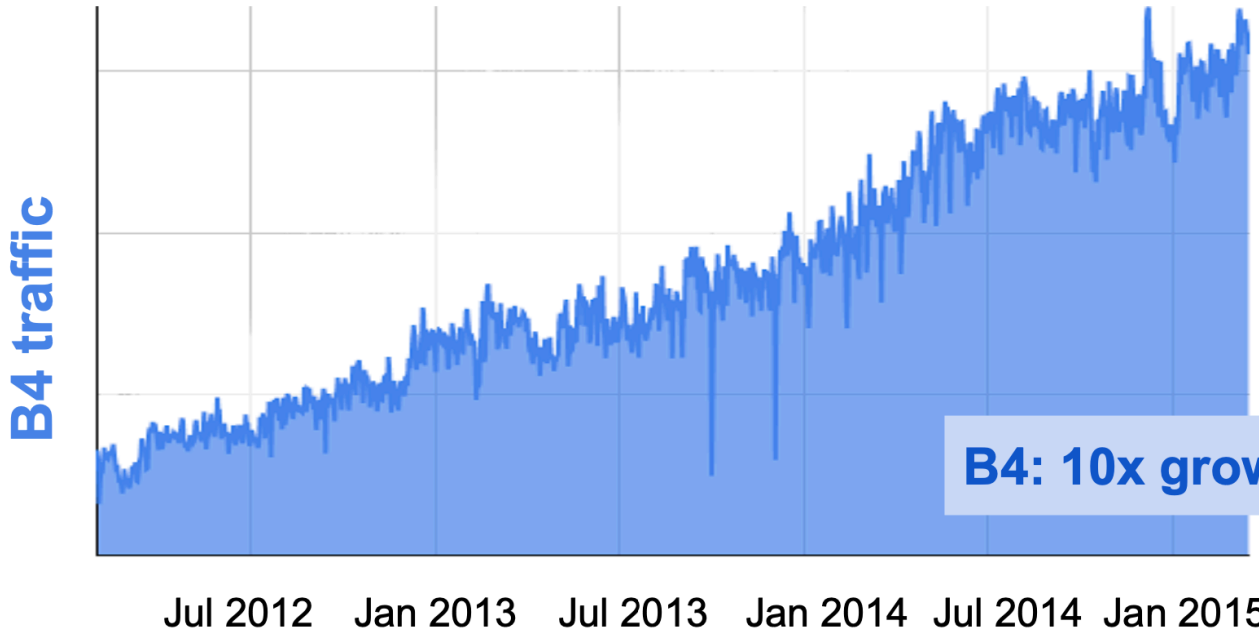
Benefit of Centralized TE



B4: 10x growth in last 3.5 years!

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B4 – your opinions

- Understandability of the paper:
  - Routing details were difficult to follow.
    - Quagga: routing protocol implementation on Linux.
  - TE algorithm was difficult to understand.
    - 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
  - *Bandwidth Enforcer, SIGCOMM'15 has more details on TE algorithms*

B4 – your opinions

- Pros:
  - Good example of use of OpenFlow
    - Nothing new and fancy, straight-forward application of OpenFlow.
  - Large-scale deployment, beyond campus networks
  - Concrete design
    - Cost budget
    - Considers single-point of failure / has a fault-tolerance mechanism
  - Aggregated TE – more scalable!
  - Able to achieve very high utilizations.
  - Real-deployment experiences (e.g. outage)

B4 – your opinions

- Cons:
  - Applicability to other WANs? Too specific to Google?
  - Does not work with commodity switches / needs custom hardware.
  - Net neutrality??
  - Why the greedy heuristic for TE? How close to optimal is it?
  - Why only 4 path choices?
  - "Why's" not explained very well.
  - More details on failure handling needed.
    - What happens when an entire site goes down?
  - State consistency across control protocols not explained well.
  - Evaluation results over multiple days.
  - More example applications.

B4 – your opinions

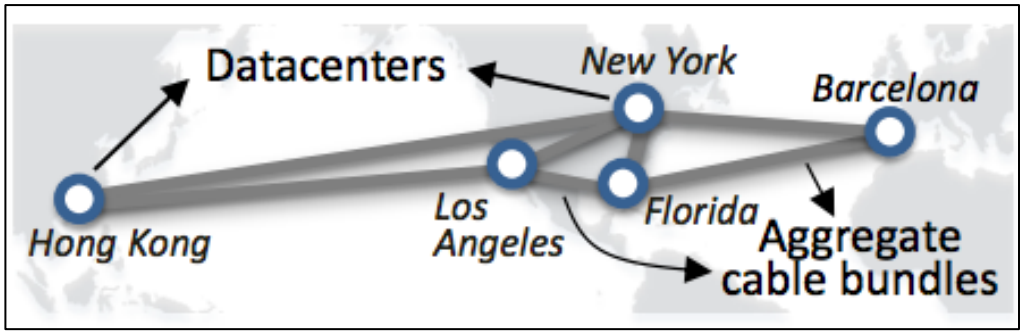
- Ideas:
  - Minimize communication overhead between control and data plane.
  - More logging amd monitoring, more route attributes (loss rates, delay, etc)
  - Analysis of TE solutions.
  - Better network availability guarantees.
  - Increased scalability.
  - Can ISPs provide more customized services to their customers?
  - What about Google's other WAN?

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

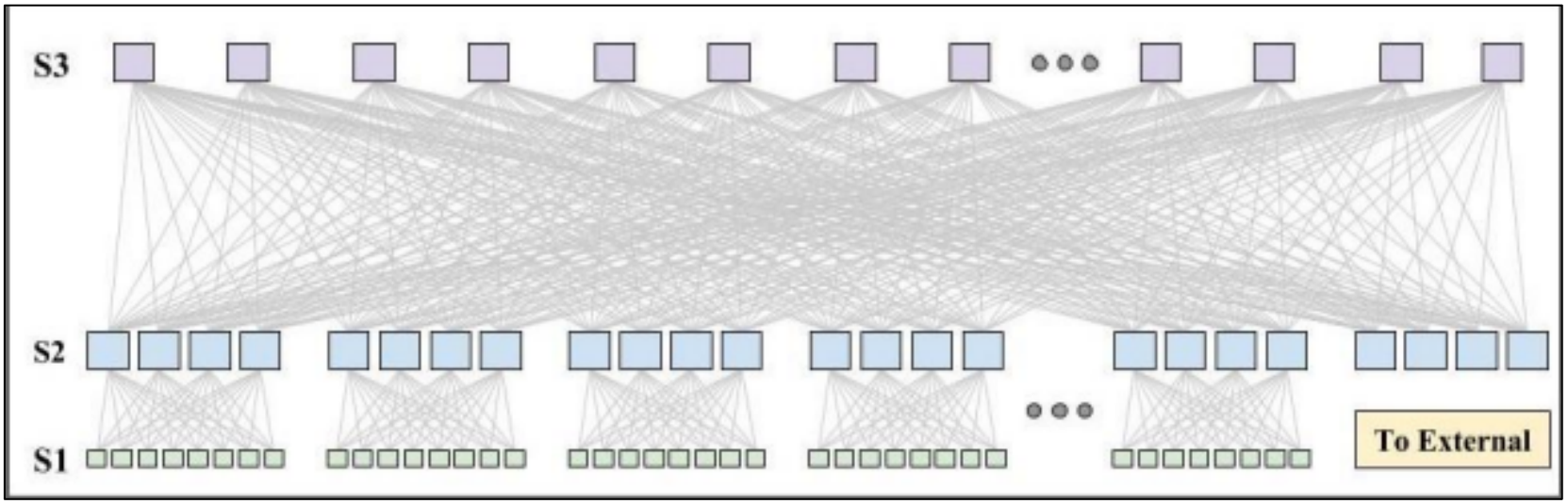
- SWAN (WAN connecting Microsoft's datacenter)
  - Goal: increase WAN link utilization.
    - Centralized and global traffic engineering.



Other SDN usecases at Google

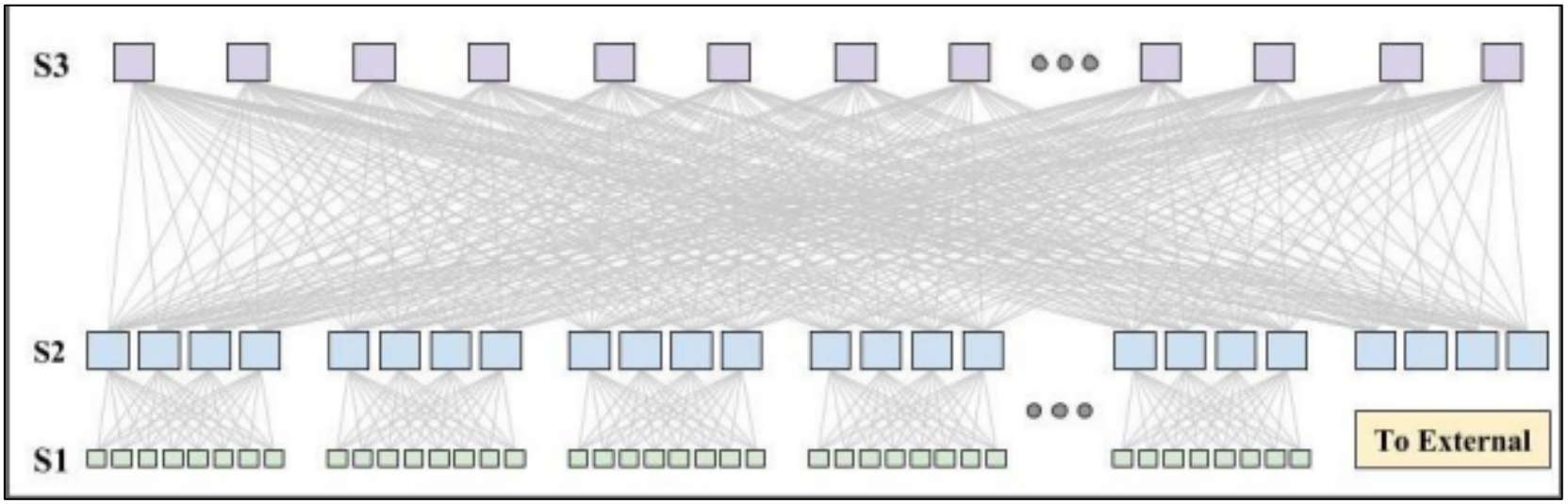
Datacenter routing

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



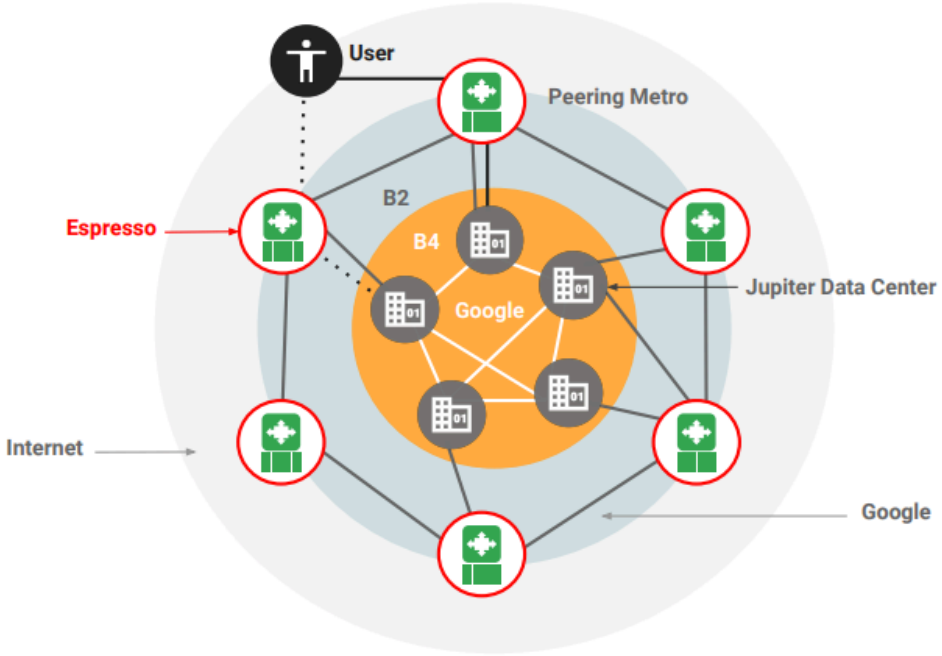
Datacenter routing

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



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:
  - Global software control plane to compute policies.
  - Local control plane to translate policy to forwarding rules.