CSE 550: Systems for all

Au 2022

Ratul Mahajan

What is SDN?

Not quite “software-defined”

- Network control planes were always software defined

Not quite “centralized control”

Separation of control and data planes

- Enables centralization but not centralization is not prerequisite

Why separate control and data plane?

Arbitrary control over how packets are forwarded

- Complex requirements can be hard to specify as distributed, local rules
  - Suppose you want all paths in the network to be of length 10

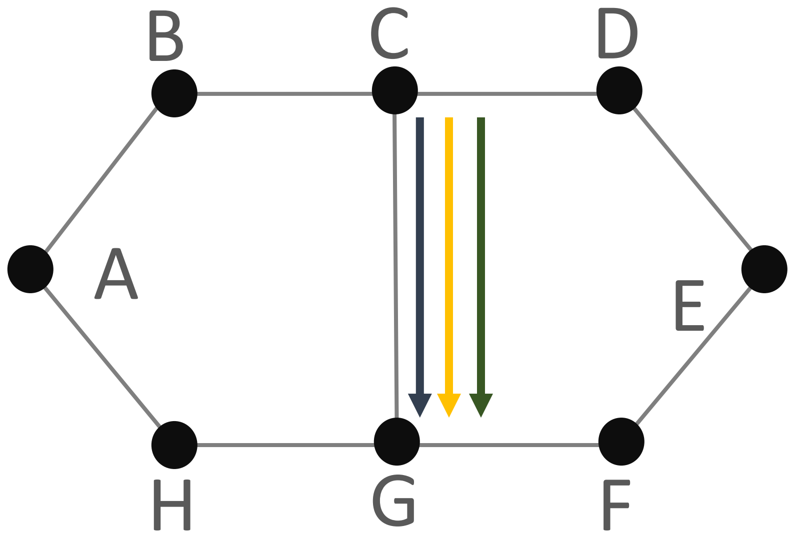
Efficiency

Traffic engineering case study

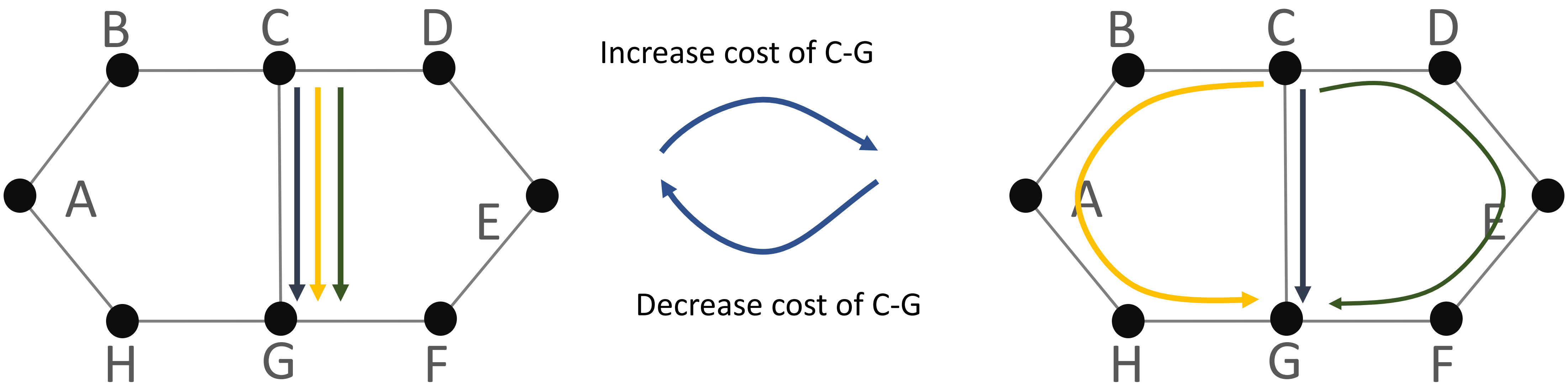
Traffic engineering journey

1. SPF with static cost
2. SPF with load-based cost – BAD!
3. CSPF (used in MPLS)
4. SDN

Limitations of static-cost SPF



Limitations of SPF with load-based costs



CSPF

Each ingress router measure traffic that it is sending to other routers

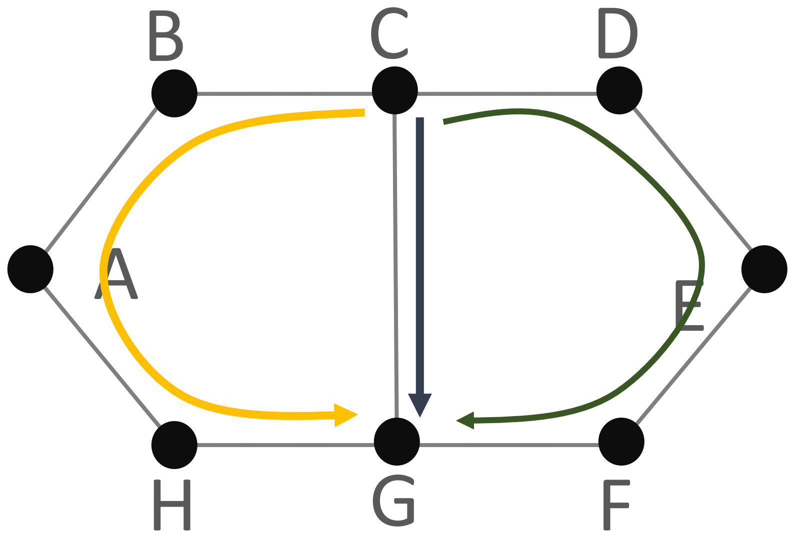
Ingress router finds paths that can accommodate its traffic

- Shortest path that meets the capacity constraint (CSPF)

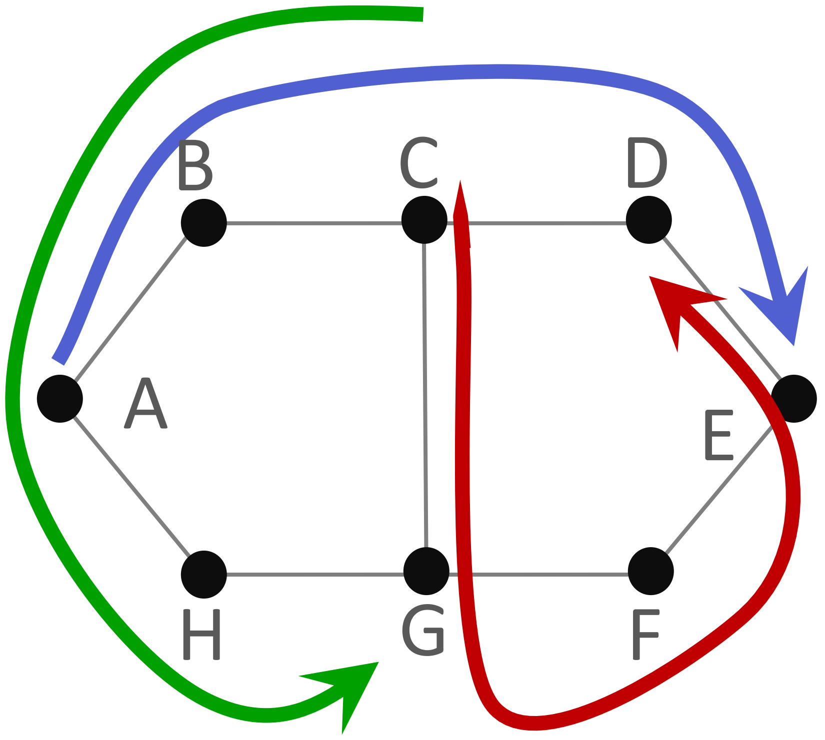
Ingress router asks other routers if they can use the path

- Necessary because all ingress routers are operating independently

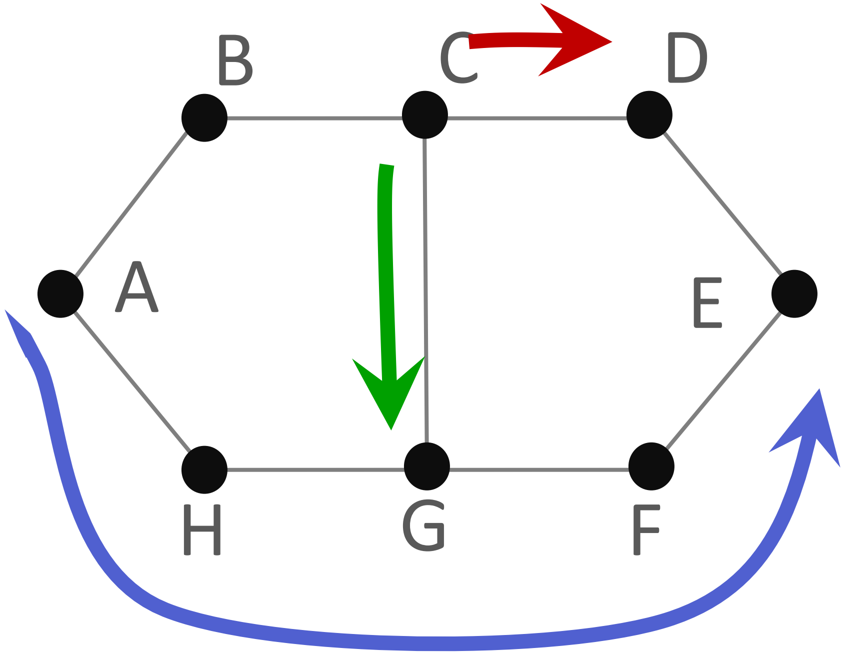
Possible solution with CSPF



But CSPF has issues too



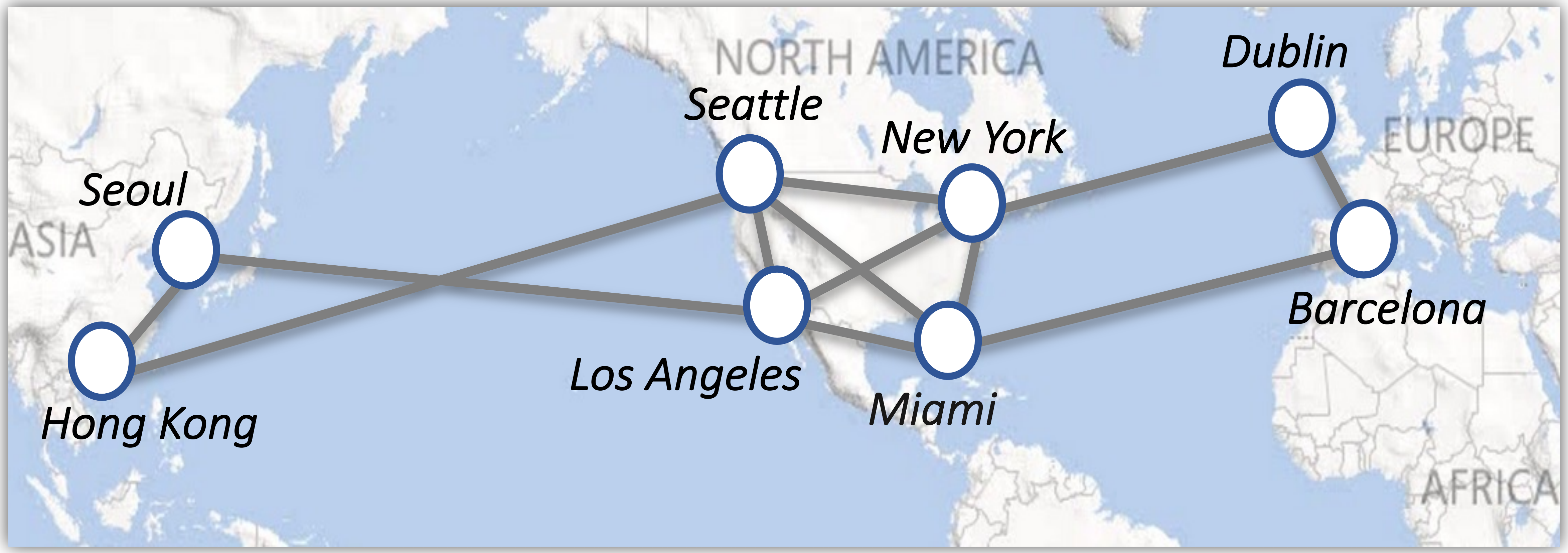
Local, greedy allocation
(Distributed CSPF)



Globally optimal allocation
(Centralized)

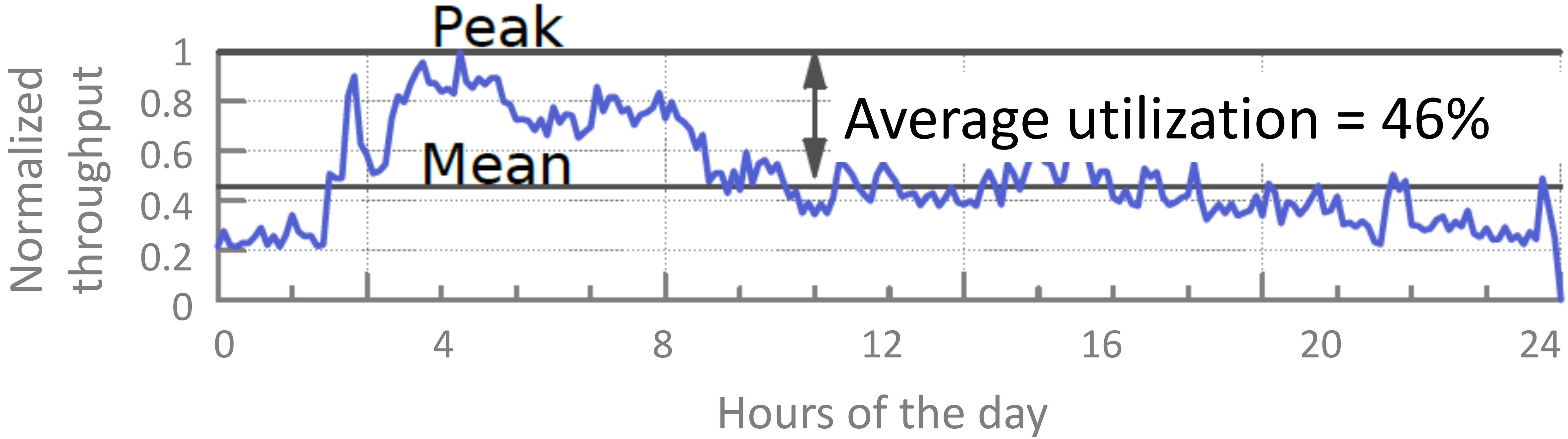
SWAN: SDN based TE

Inter-DC WAN: A critical, expensive resource



But it was being used highly inefficiently

Inefficiency of the inter-DC WAN



Normalized traffic on a busy link between data centers

Root cause: Service-level allocations

Operators configure individual services with maximum sending rate

	S1	S2	S3	…..
SEA → NYC (80)	10	15	5	….
SEA → CHI (100)	20	20	10	….
……				

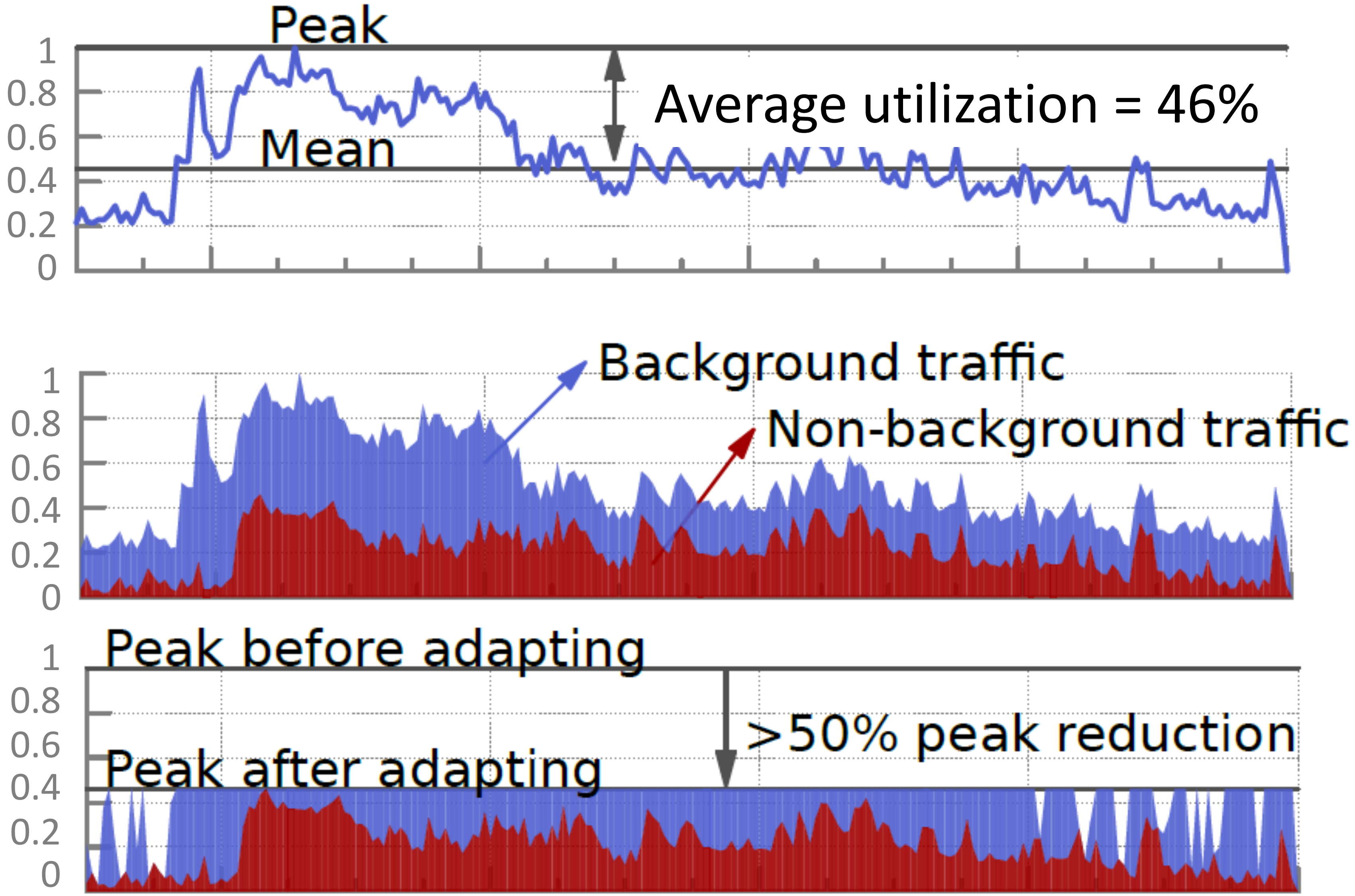
Inefficient: The combined maximum is uncommon

Unreliable: Load can exceed capacity when failures occur

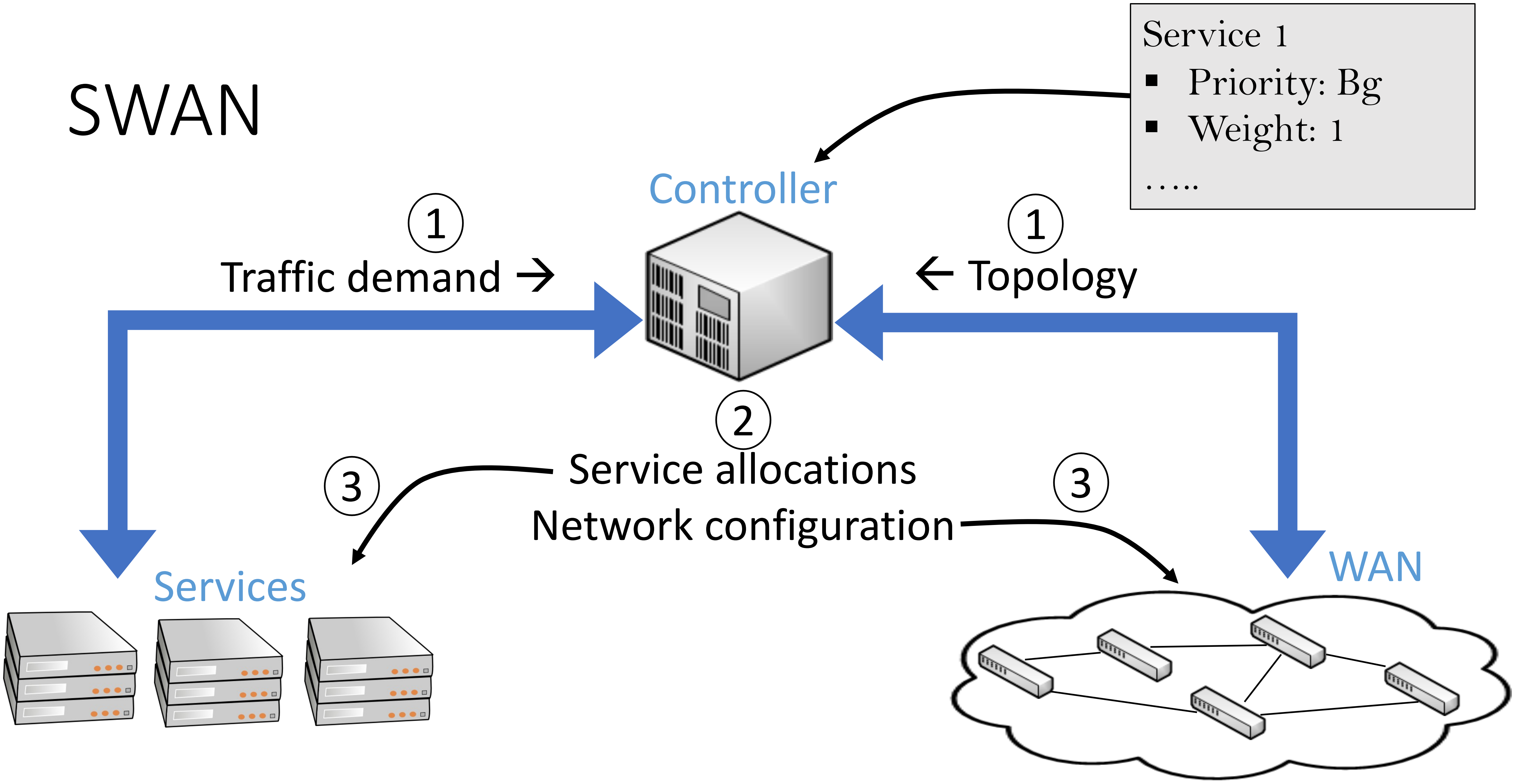
Slow to change: Must change all allocations to add services or network links

Centralized control can increase efficiency

```
Service 1
▪ Priority: Bg
▪ Weight: 1

Service 2
▪ Priority: Bg
▪ Weight: 2

Service 3
▪ Priority: Non-bg
▪ Weight: 1

......
```



SWAN

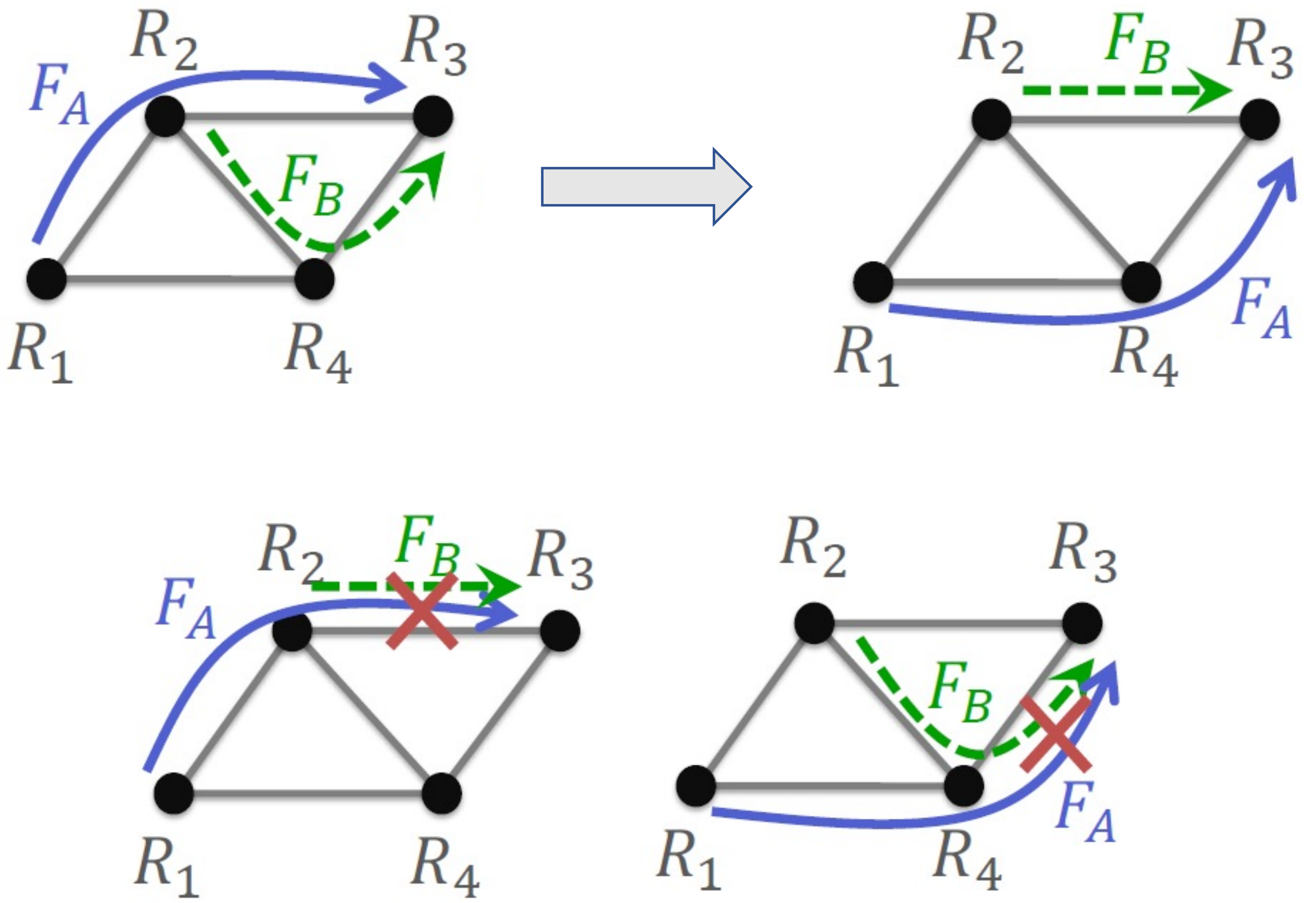


Service 1
Priority: Bg
Weight: 1
…..
Controller
1
Traffic demand →
1
← Topology
2
Service allocations
Network configuration
3
3
Services
WAN

Challenge: Congestion during network updates

Link capacity: 10

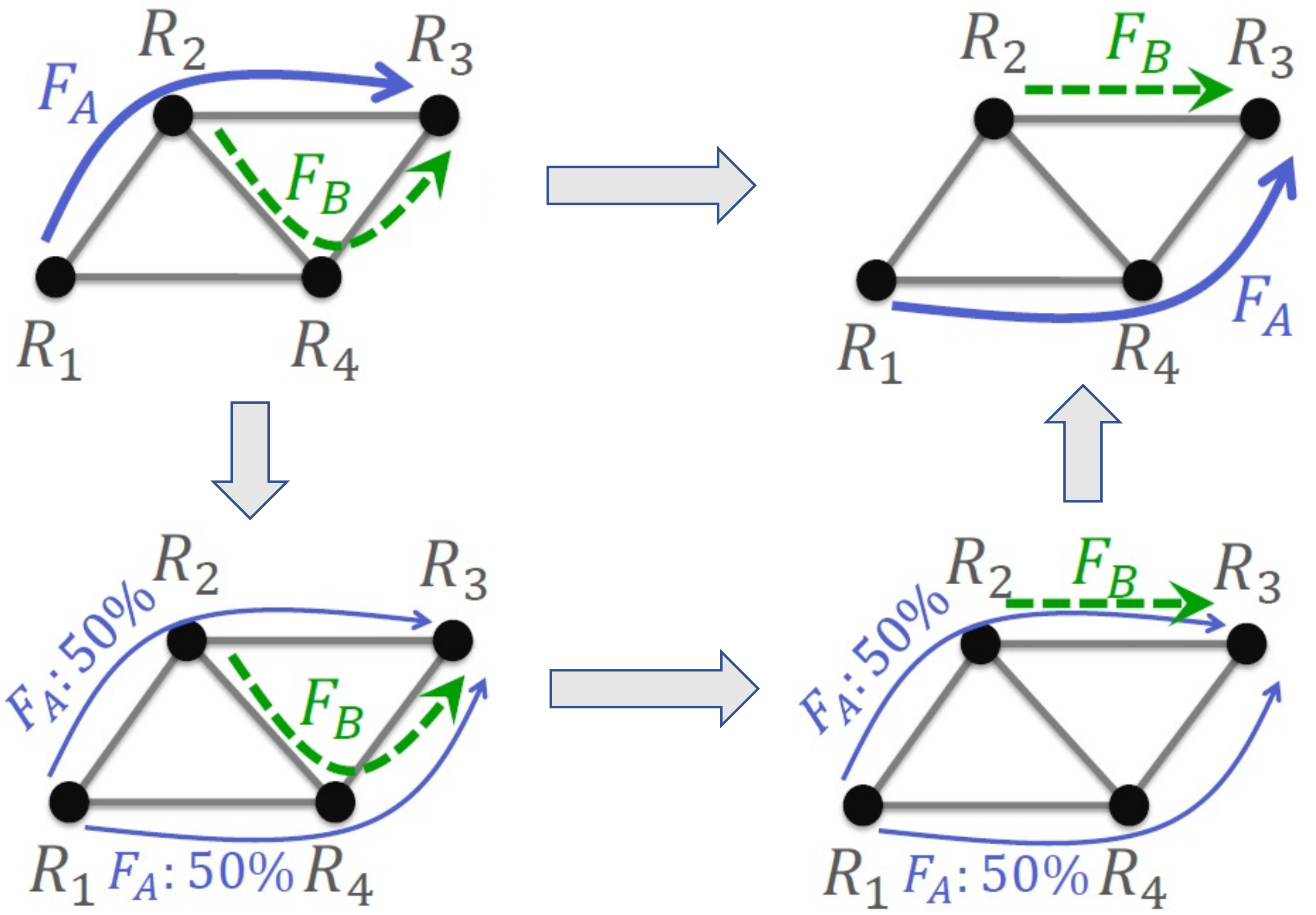
Flow size: 6.6



Solution: Congestion-free update plans

Link capacity: 10

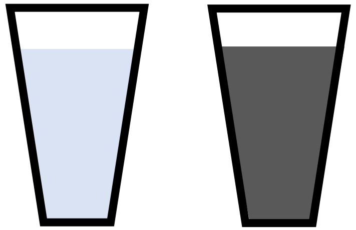
Flow size: 6.6



Computing congestion-free update plans

Leave scratch capacity s on each link

- Guarantees a plan with at most $\left\lceil \frac{1}{s} \right\rceil - 1$ steps



Find a plan with minimum number of steps using an LP

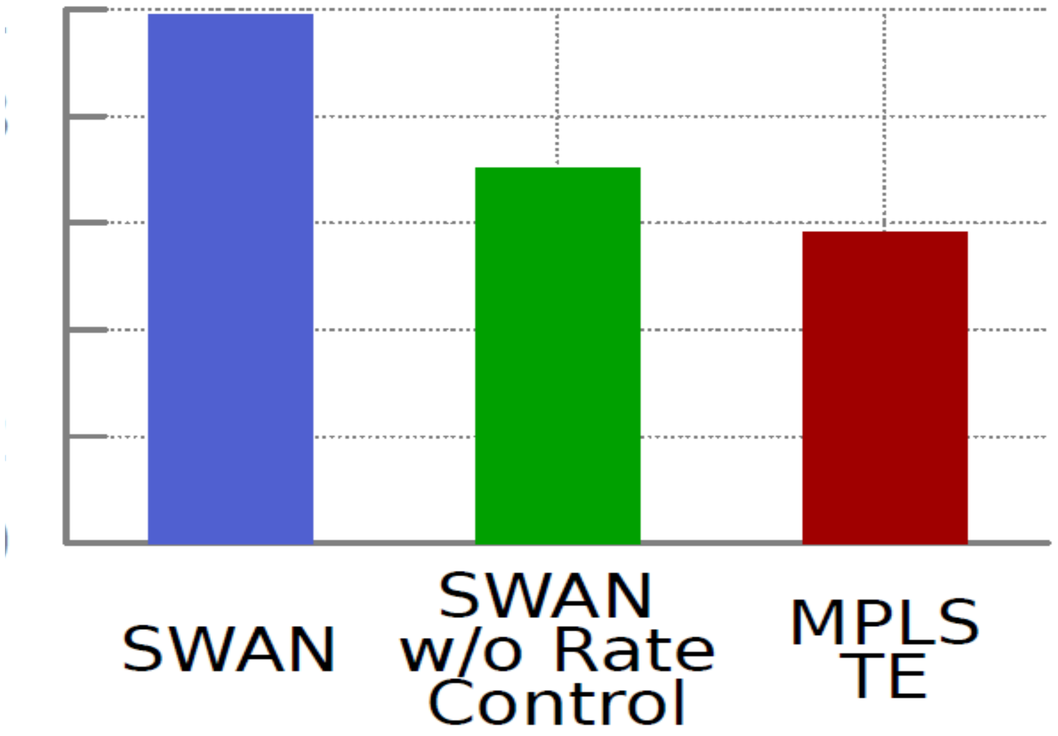
- Search for a feasible plan with 1, 2, …. max steps

Use scratch capacity for background traffic

- Bound its experienced congestion

Efficiency improvement with SWAN

Throughput
(relative to optimal)



Why not centralized traffic engineering?

Robustness (recall the first design goal of the internet)

- Controller failure (topic of next class)
- Communication failure

Scalability: Eventually need to distribute in some manner

Reaction time to *some types* of events

- On the other hand, convergence issues with distributed routing means that it too can be slow for some types of events

Can you implement any packet forwarding behavior with SDN?

No

- Example: Add 10 bytes to the packet at every hop

We haven’t fundamentally changed the data plane behavior

- We just changed where the control planes runs and how data plane is configured

Programmable data planes
Take 1: Active networking

Packet forwarding uses a program

- The program could be carried by the packet itself

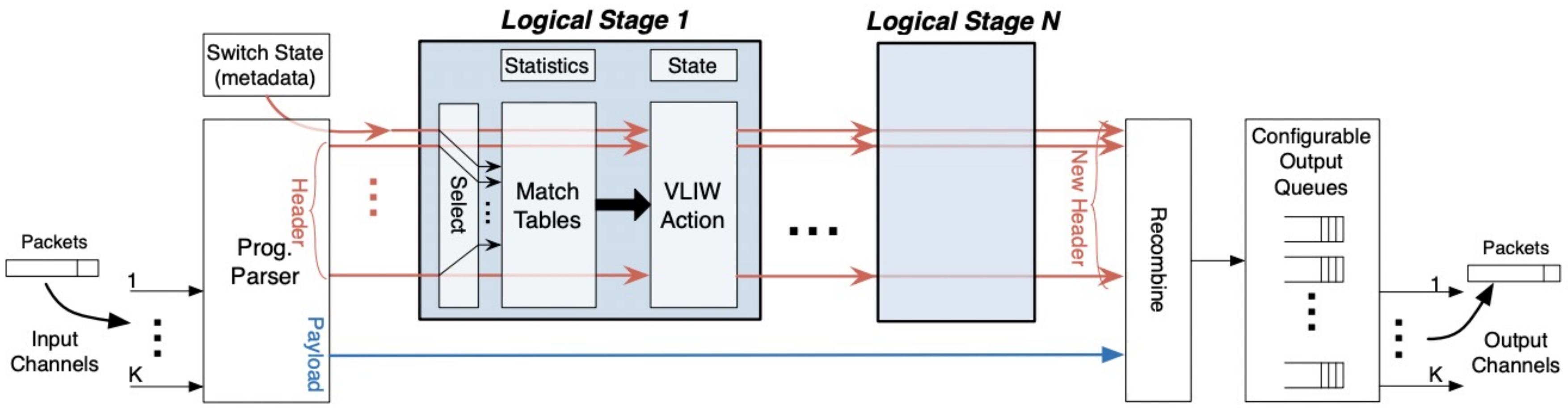
Good idea?

+ Most flexible

- Performance concerns

Programmable data planes
Take 2: PISA

PISA: Protocol independent switch architecture (originally called RMT reconfigurable match tables)



(a) RMT model as a sequence of logical Match-Action stages.

P4: A language to program such data planes

PISA cannot do everything

Not Turing complete

Examples of things not possible

- Schedule packets
- Manipulate payloads
- Manipulate state programmatically

Attempts a balance between high performance and flexibility

Network virtualization

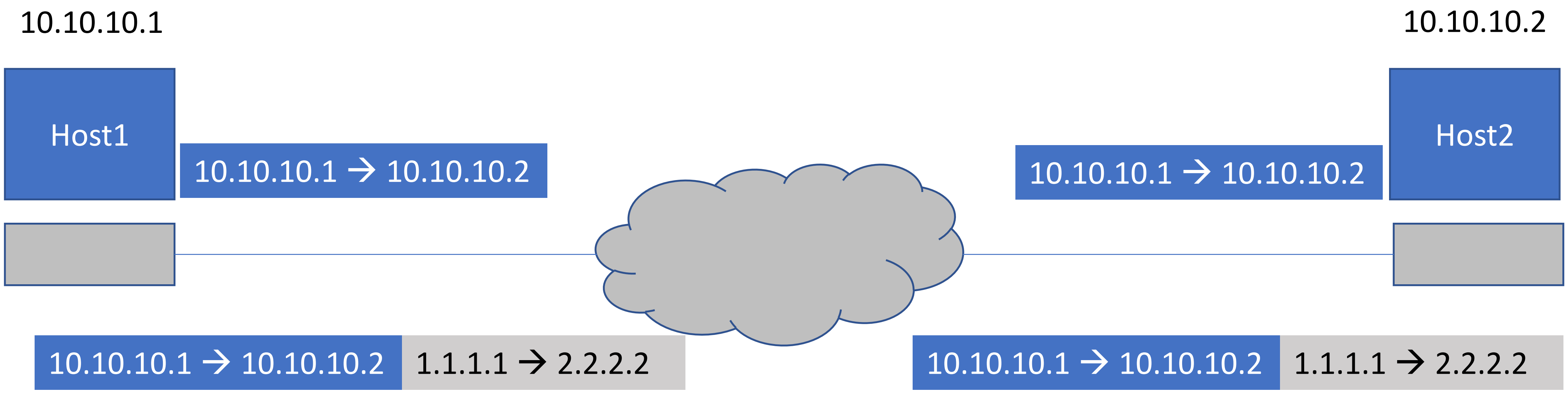
Hardware virtualization abstracts away the hardware from the operating system

Network virtualization abstracts away the physical network from the network stack

- Can run multiple virtual networks on the same physical network
- Can pretend to be a different network (e.g., pretend that all hosts are directly connected)

Works by intercepting and manipulating network packets

Network virtualization example



SDN and network virtualization

Not the same thing though often confused

SDN enables network virtualization

- Would be pretty hard to implement virtual networks if the control plane was co-located with data plane

Key takeaways

SDN: Separation of control and data plane

SDN use cases

- Easier implementation of policies (4D)
- Efficiency (e.g., SWAN)
- Network virtualization (e.g., cloud networks)

Data plane programmability via PISA is an area of active investigation