lecture 02: review of “how the Internet works”

5590: software defined networking

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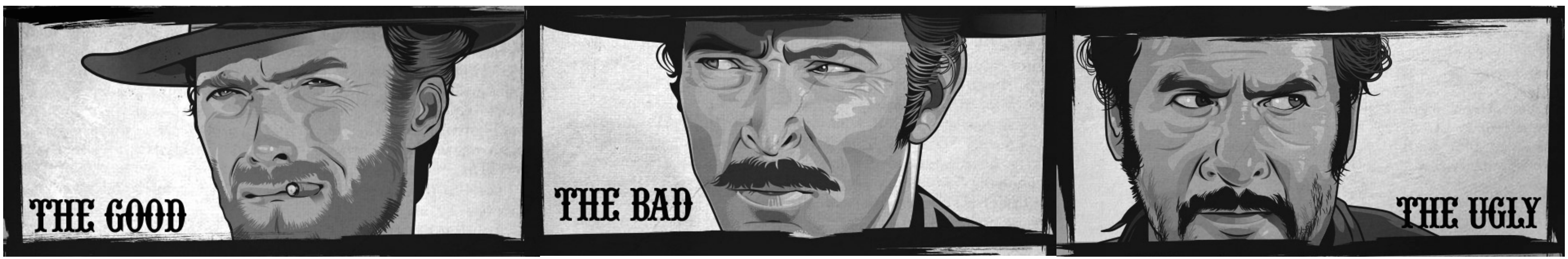
T 17:30-20:00

some materials in this slide are based on lectures by

Jennifer Rexford https://www.cs.princeton.edu/courses/archive/fall13/cos597E/


THE GOOD
THE BAD
THE UGLY

why review

SDN interacts with “legacy” networks

- unmodified end-host computers
- hybrid deployment of SDN
- connecting to non-SDN domains

SDN is a reaction to legacy networks

- retain the “good”
- improve on the “bad” and the “ugly”

outline

brief review

- defining characteristics

“the good, the bad and the ugly” by examples

- traffic engineering in IP networks
- Ethernet
- VLAN usage in campus networks

defining characteristics

- packet switching
- layering

packet switching

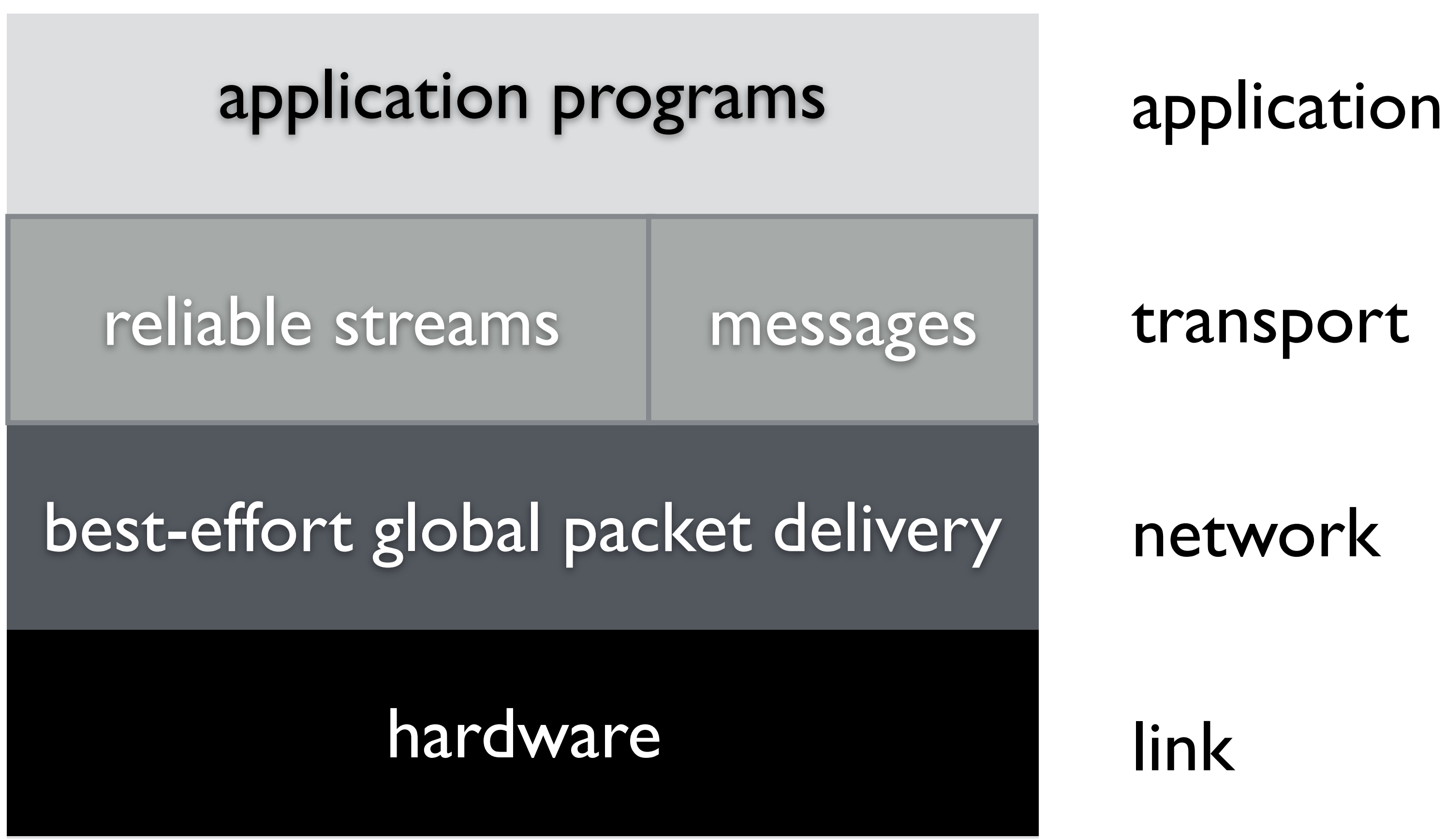
the simple and transparent core network

- the datagram, connectionless service
  - carries data without knowing what data it is
- effective for multiplexed utilization of shared interconnected networks
- open to new applications, hardwares, and new protocols

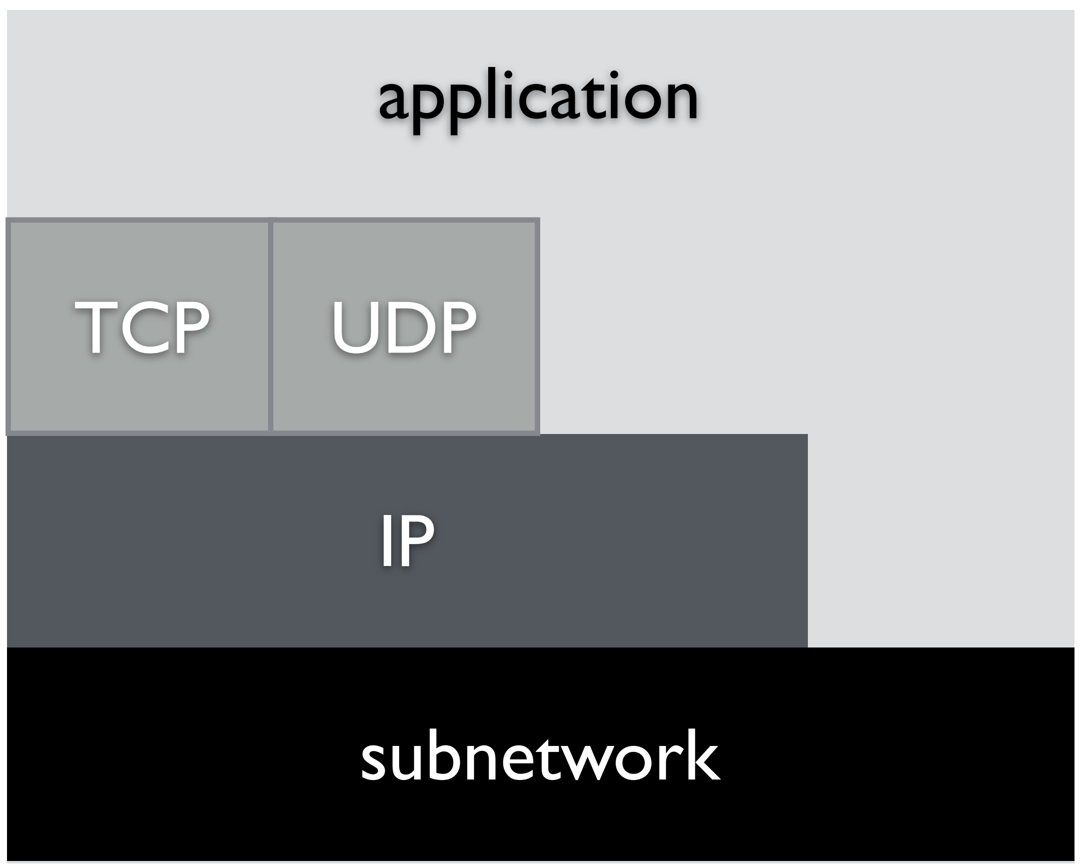
intelligence at the edges

- end hosts can run arbitrary applications

protocol layering for modularity



protocol layering for modularity



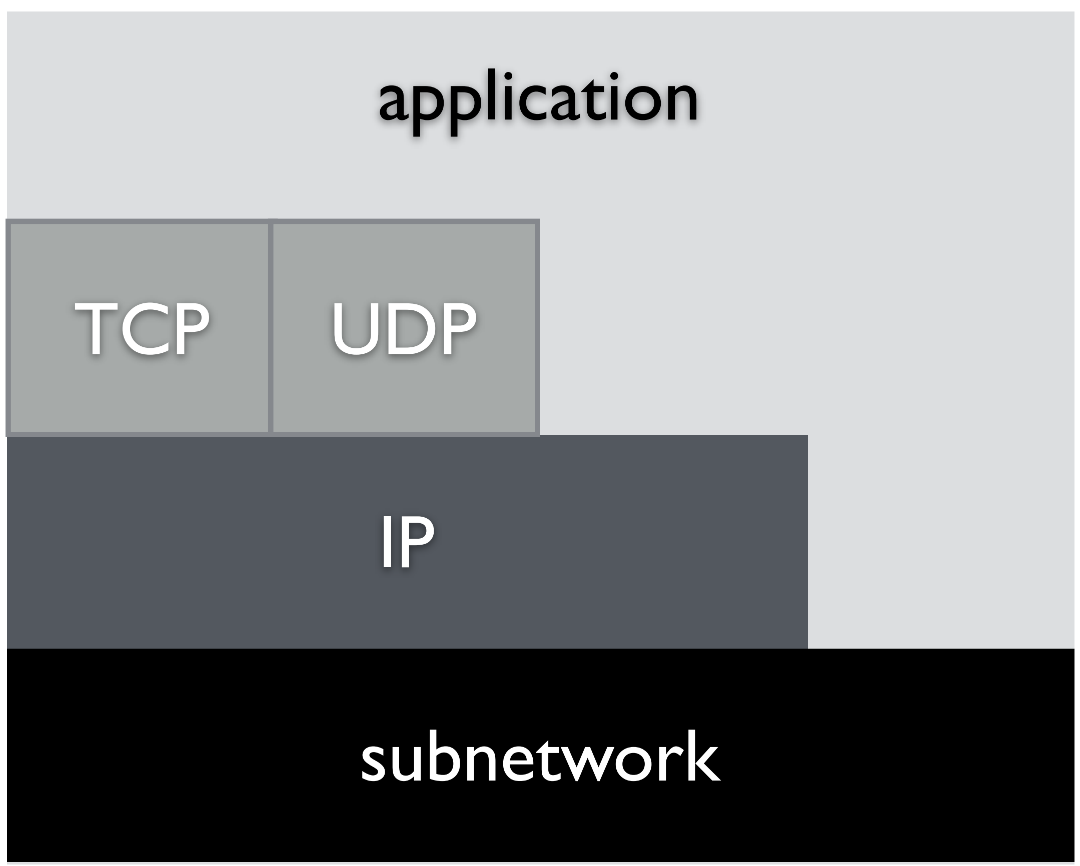
layer 7

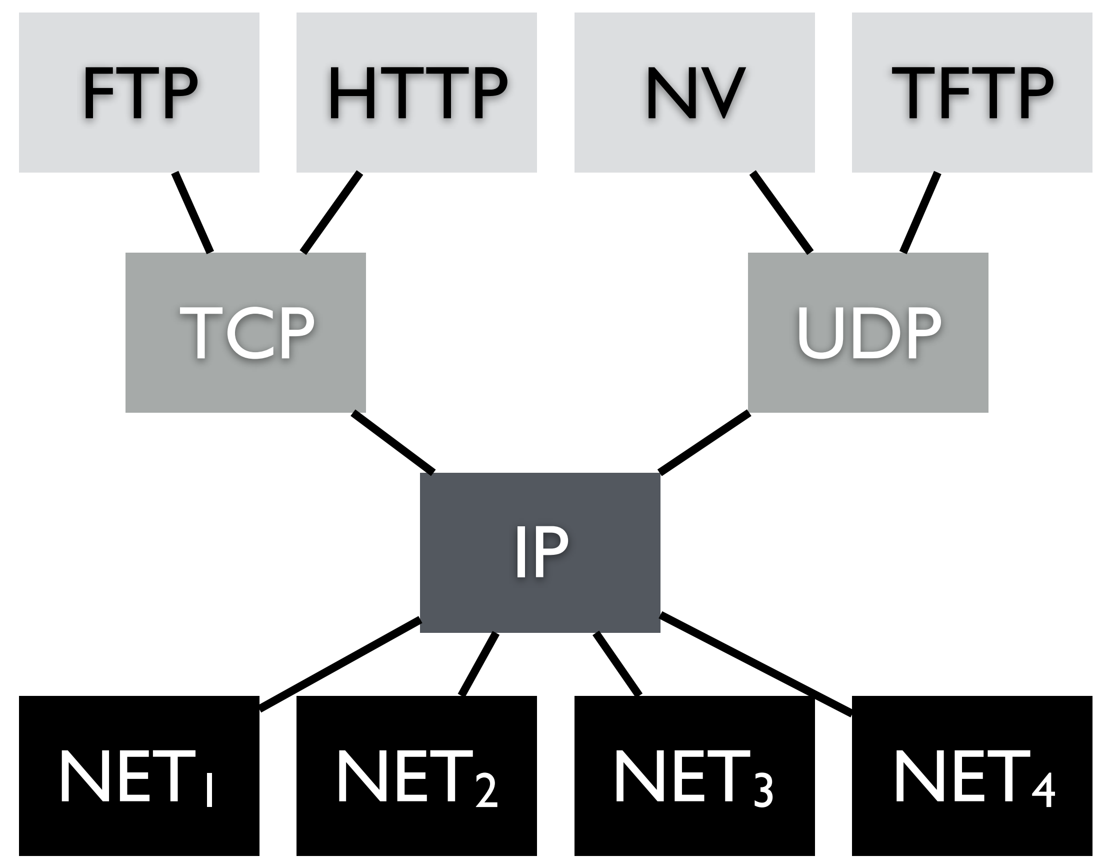
layer 4

layer 3

layer 2

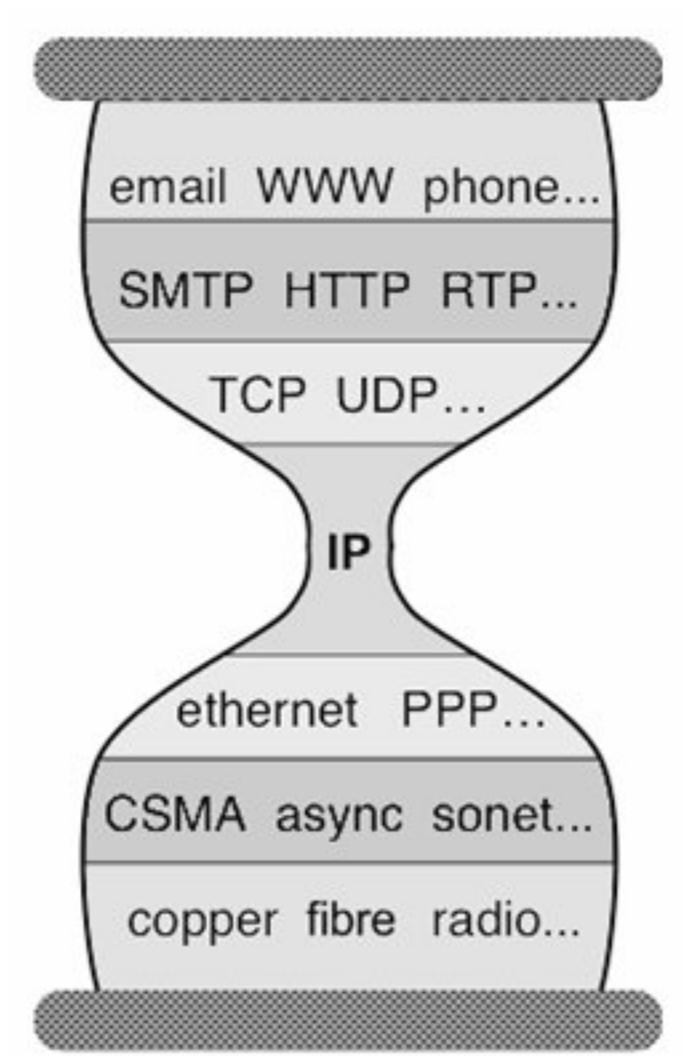
protocol layering for modularity

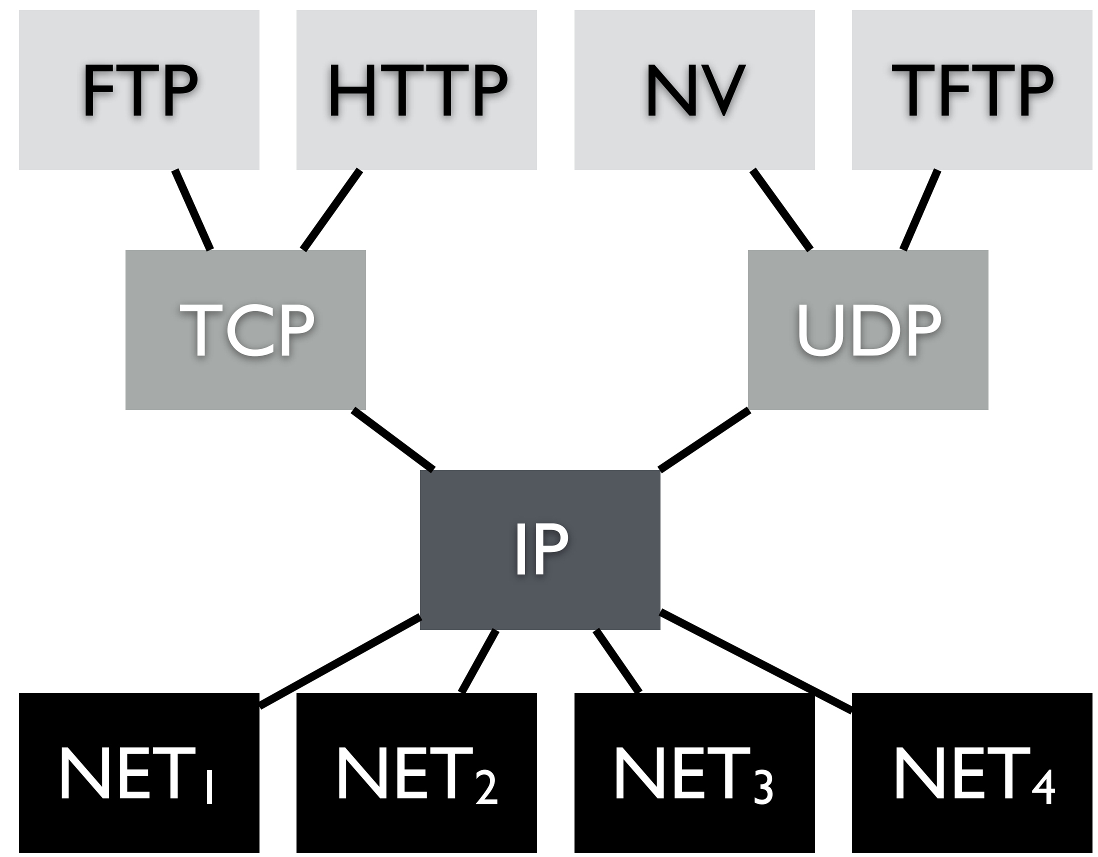




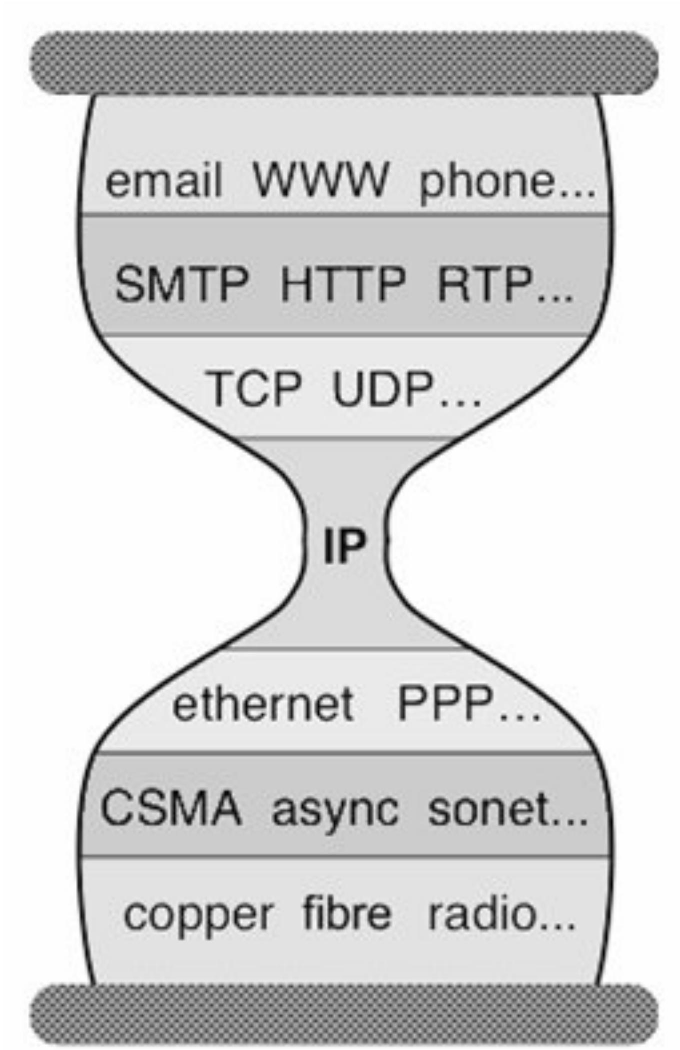
protocol layering for modularity

the hourglass





packet switching + layering



tension

- high-level network-wide objectives understood by the edges
- low-level network management of the core

the Internet is increasingly complex and notoriously hard to operate

outline

brief review

- significant ideas

“the good, the bad and the ugly” by examples

- traffic engineering in IP networks
- Ethernet
- VLAN usage in campus networks

traffic engineering
with
traditional IP routing protocols

further reading: https://www.cs.princeton.edu/~jrex/papers/ieeecomm02.pdf

traffic engineering

IP network manages itself

- end hosts running TCP adapt their sending rates to network congestion
- but, a particular link might be congested despite the presence of under-utilized links

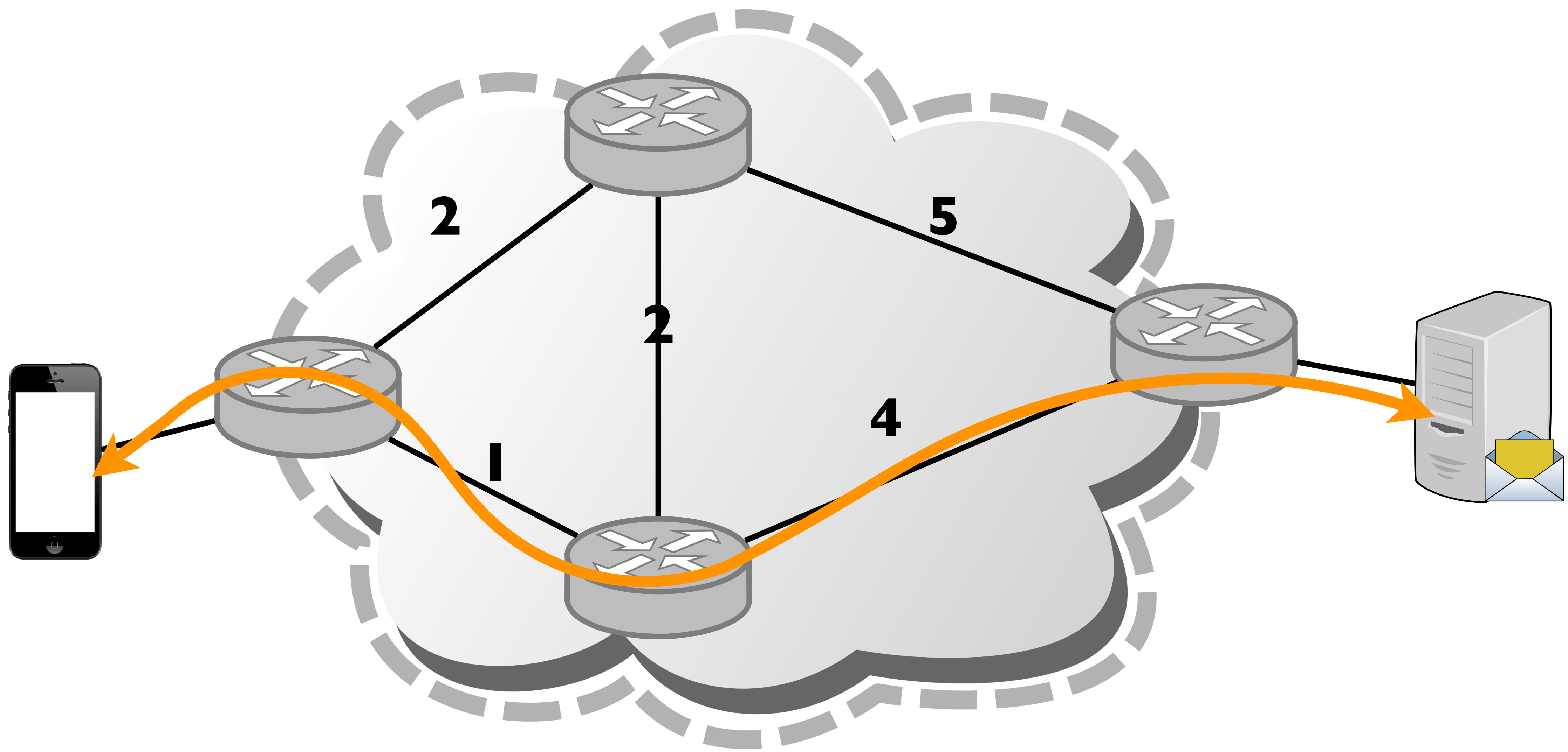
TCP/IP does not adapt the routing of traffic to the prevailing demand

- *a network-wide objective: improving user performance and making more efficient use of network resources*
- this task: traffic engineering

intradomain routing

shortest path routing

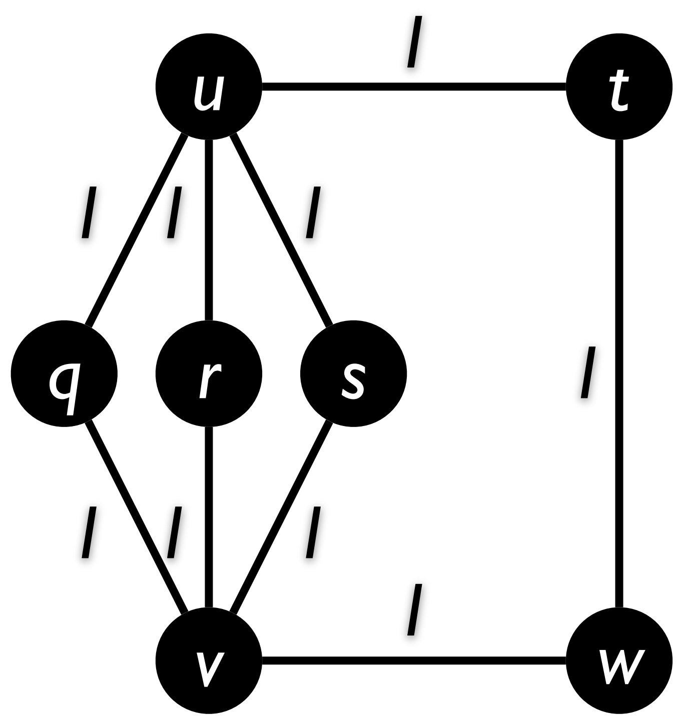
- route traffic through the shortest path within an Autonomous system based on OSPF weights



intradomain traffic engineering

routing the same demand with differing weights

- demand: *q,r,s,w* each has one unit of traffic to send to *t*



intradomain traffic engineering

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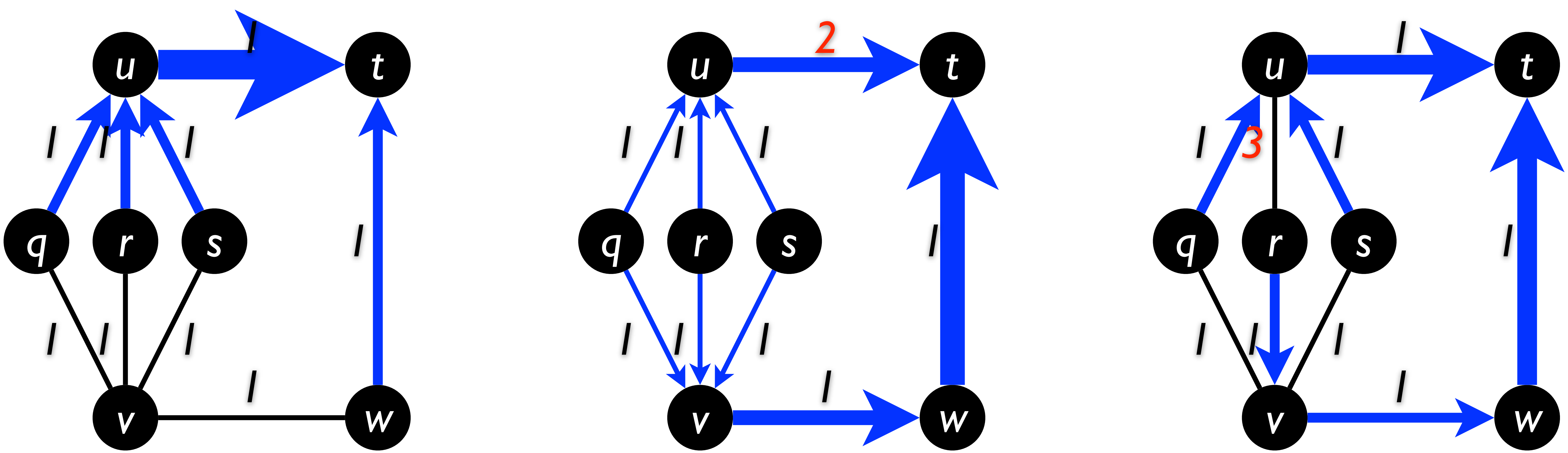


initial unit weights

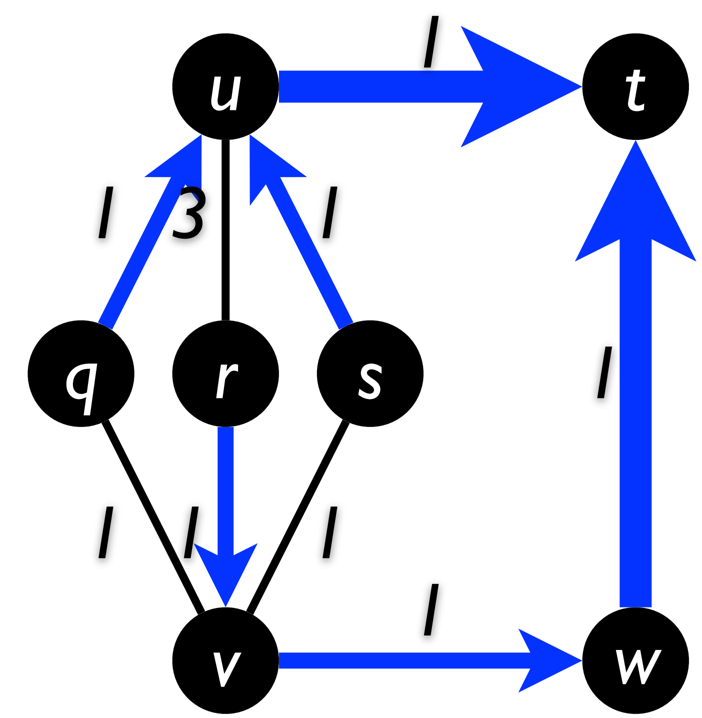
local change of the congested link

global optimization of link weights

intradomain traffic engineering

globally optimized link weights

- alleviate congestion
- attractive alternative to buying additional bandwidth



traffic engineering framework

routing model

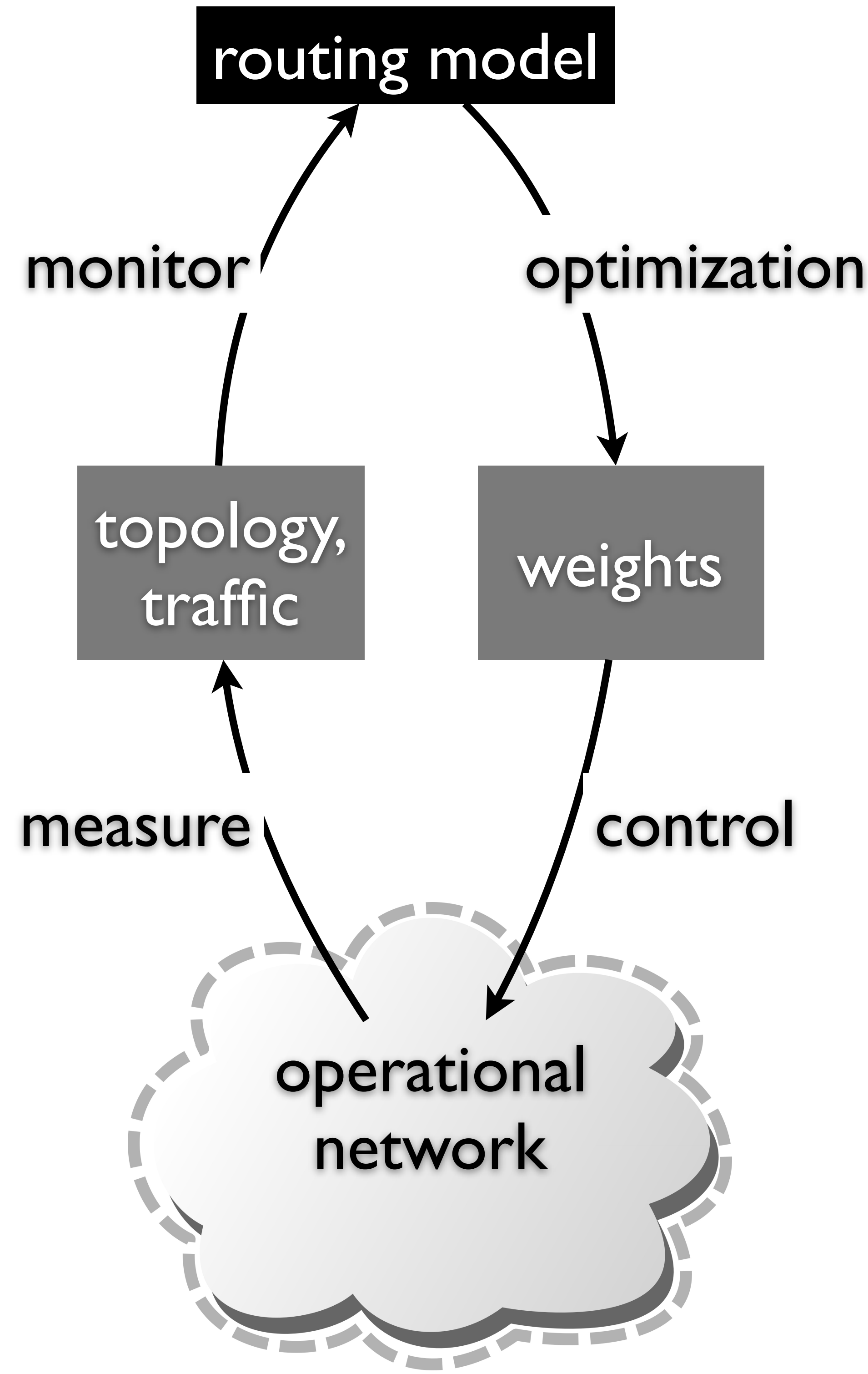
- path selection (shortest path) based on IGP weights

measurement

- lively and accurate view of the network — topology, traffic demand

reconfiguring weights

- optimize a network-wide objective
  - e.g., minimize the max-utilization
  - e.g., keep max-utilization under 60%



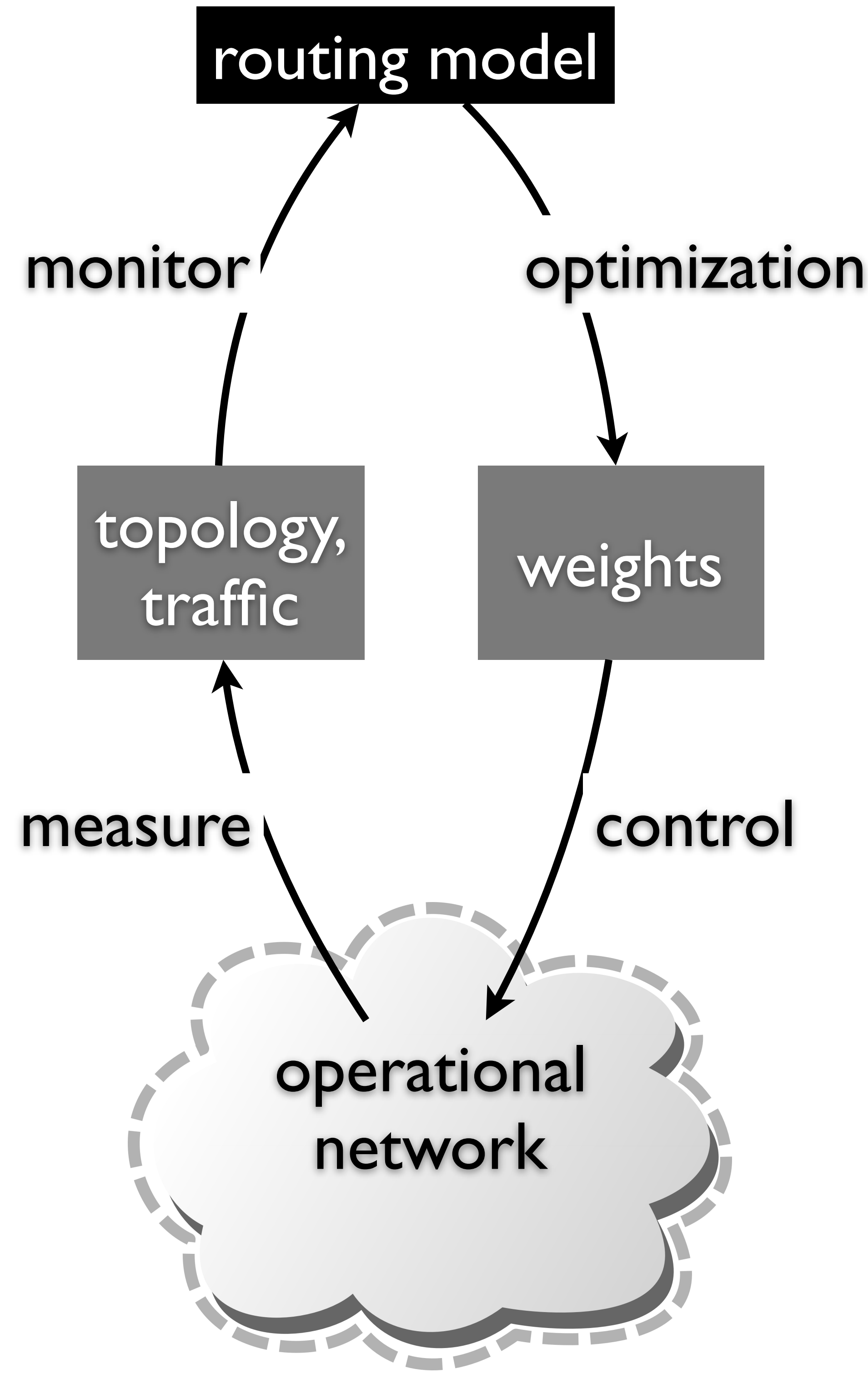
traffic engineering framework

centralized control

- stable
- lower overhead
- diverse performance objective

link weights express the routing configuration

- compatibility
- concise
- default weights and backup routes



performance

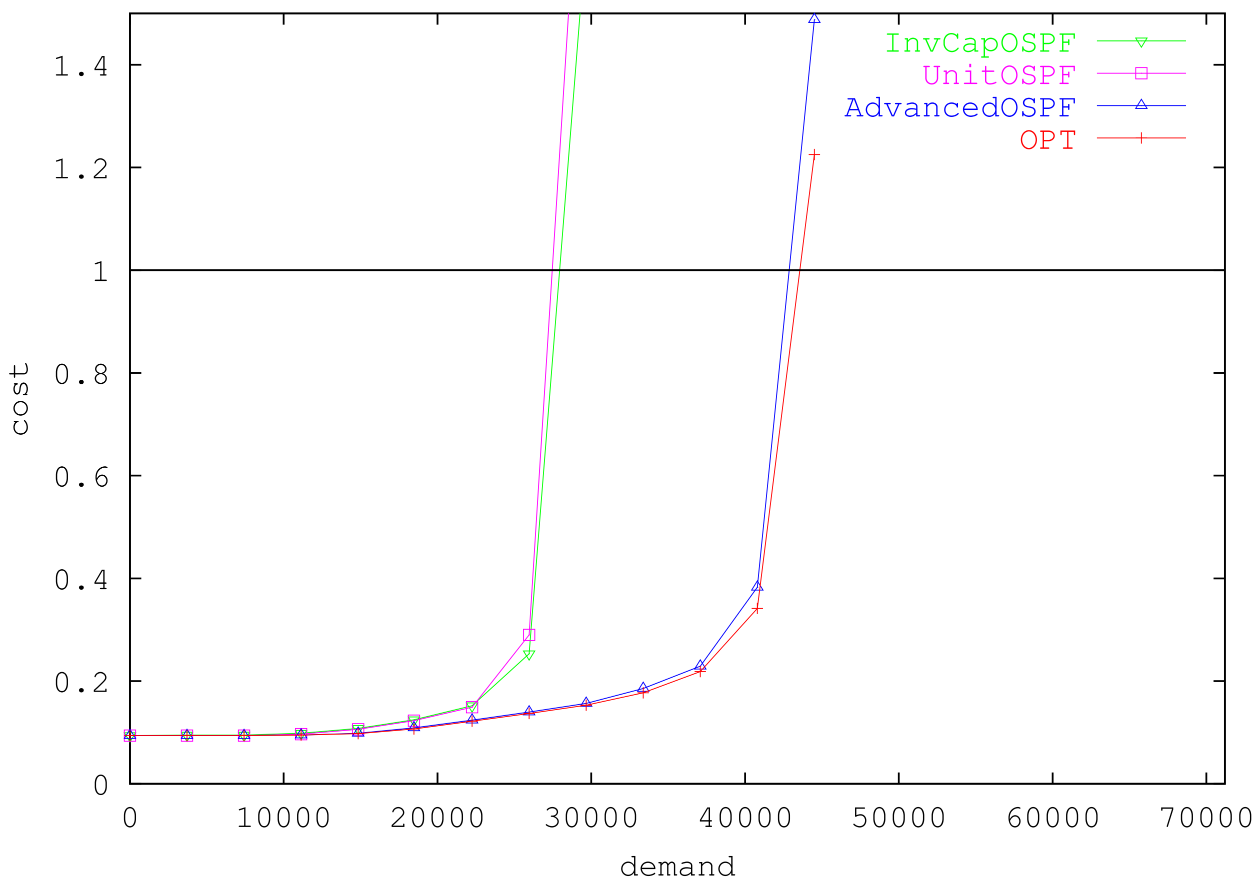
objective: link cost

- cost of using a link increases with utilization, explosive growth as utilization exceeds 100%

global optimization close to optimal

- can handle 70% more demands than Cisco or unit weights

OPT: can direct traffic along any paths in any proportions
InvCapOSPF: (Cisco) set link weight inversely proportional to its capacity
UnitOSPF: set all weights to 1
AdvancedOSPF: global optimization



results on an AT&T backbone with a projected traffic matrix

discussion

centralized control

- stable
- lower overhead
- diverse performance objective

link weights express the routing configuration

- compatibility
- concise
- default weights and backup routes

the good

- centralized control, shared with SDN
- can express diverse network-wide objective

the bad and the ugly?

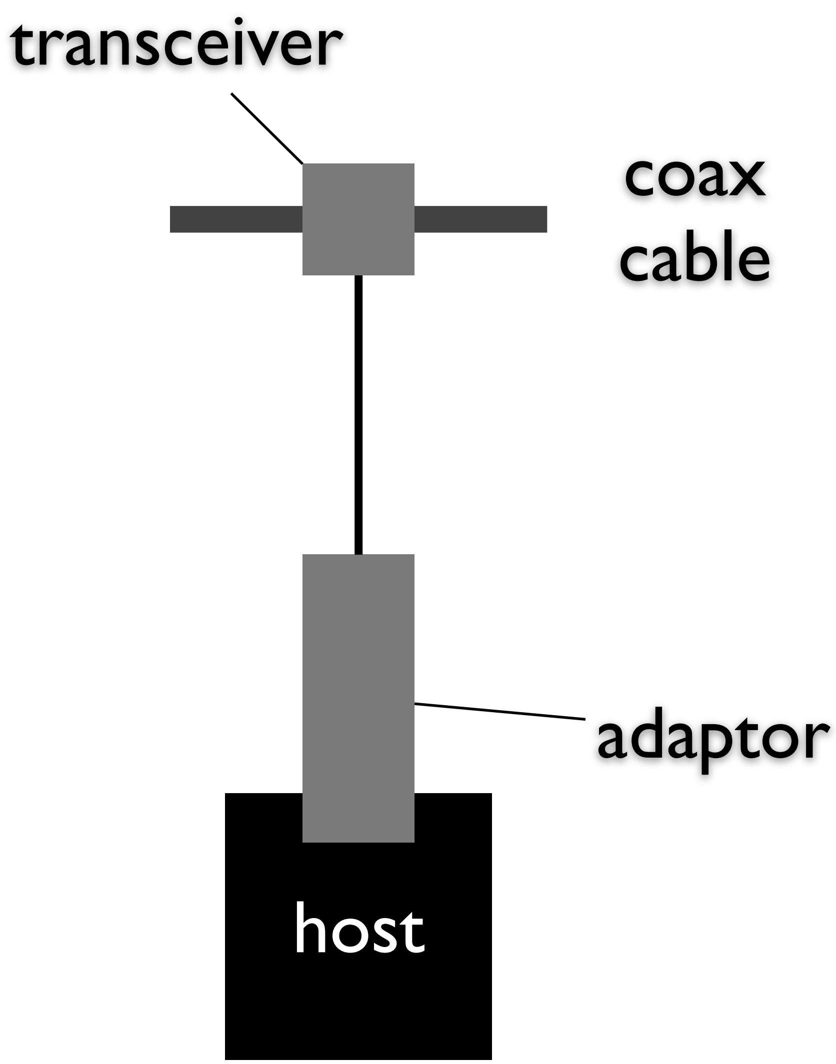
- inflexible: limited expressiveness
- indirect: link weights do not embed any semantics of higher-level network-wide goals

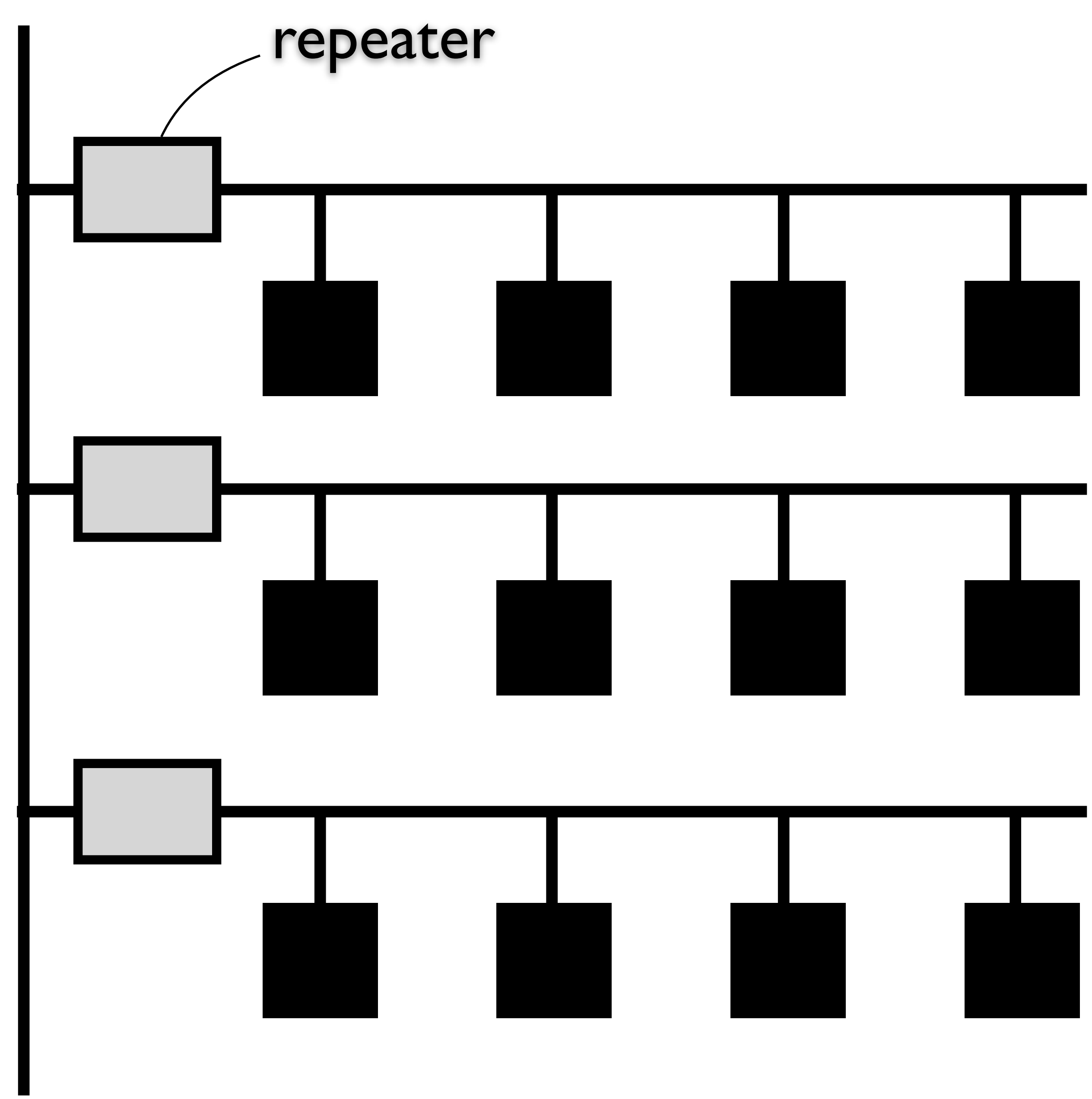
Ethernet

further reading: Ethernet: Distributed Packet Switching for Local Computer Network, https://www.cl.cam.ac.uk/teaching/1920/CompNet/files/p395-metcalfe.pdf

Ethernet

a local area network (LAN)





Ethernet

broadcast communication

- message placed on the Ethernet is broadcast over

media access control (MAC) algorithm

- 1-persistent
  - adaptor with a frame to send transmits with probability 1 whenever busy line goes idle
- exponential backoff
  - upon detection of collision, adaptor stops transmission, waits a certain amount of time (and doubles before trying again)

Ethernet — "the" LAN technology

"zero" configuration

- extremely simple to configure and maintain: no switch, no routing, no configuration tables

inexpensive

- cable is cheap
- only cost: the adaptor

switched Ethernet …

discussion

distributed control

- coordination of access is distributed among contending senders
  - colliding senders: random retransmission intervals
- switching is distributed among the recipients

SDN abandons distributed control for simplicity

no central controller

- eliminate the reliability problem

reliability, a challenge for SDN

zero configuration

a goal shared with SDN

discussion

Ethernet is a real gem

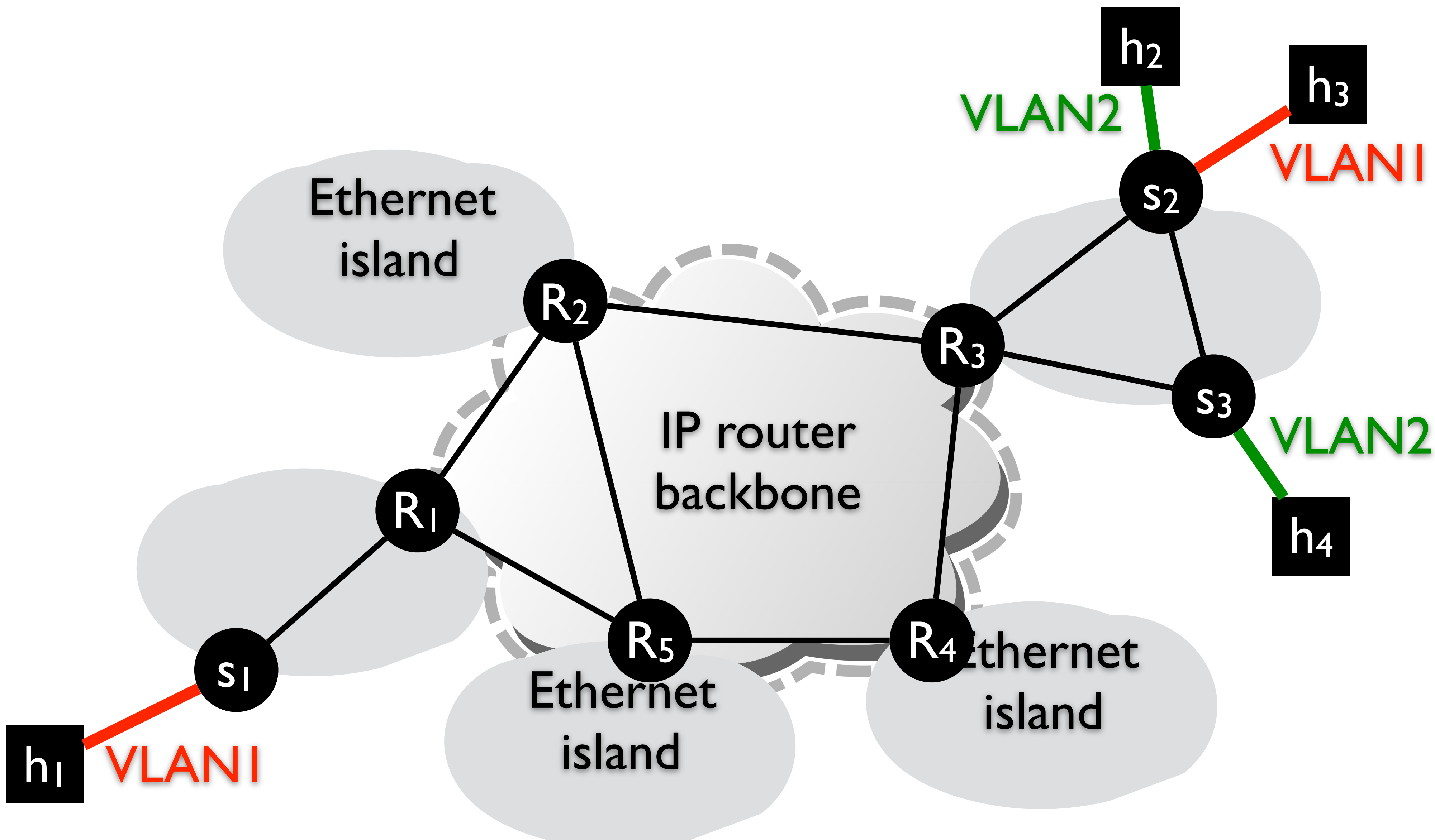
- despite limitations — scalability, best effort delivery
- a rare combination of distributed control and simplicity
- arbitration of conflicting transmission demands is both distributed and statistical

VLAN for campus networks

further reading: A Survey of Virtual LAN Usage in Campus Networks,
http://minlanyu.seas.harvard.edu/writeup/commag11.pdf

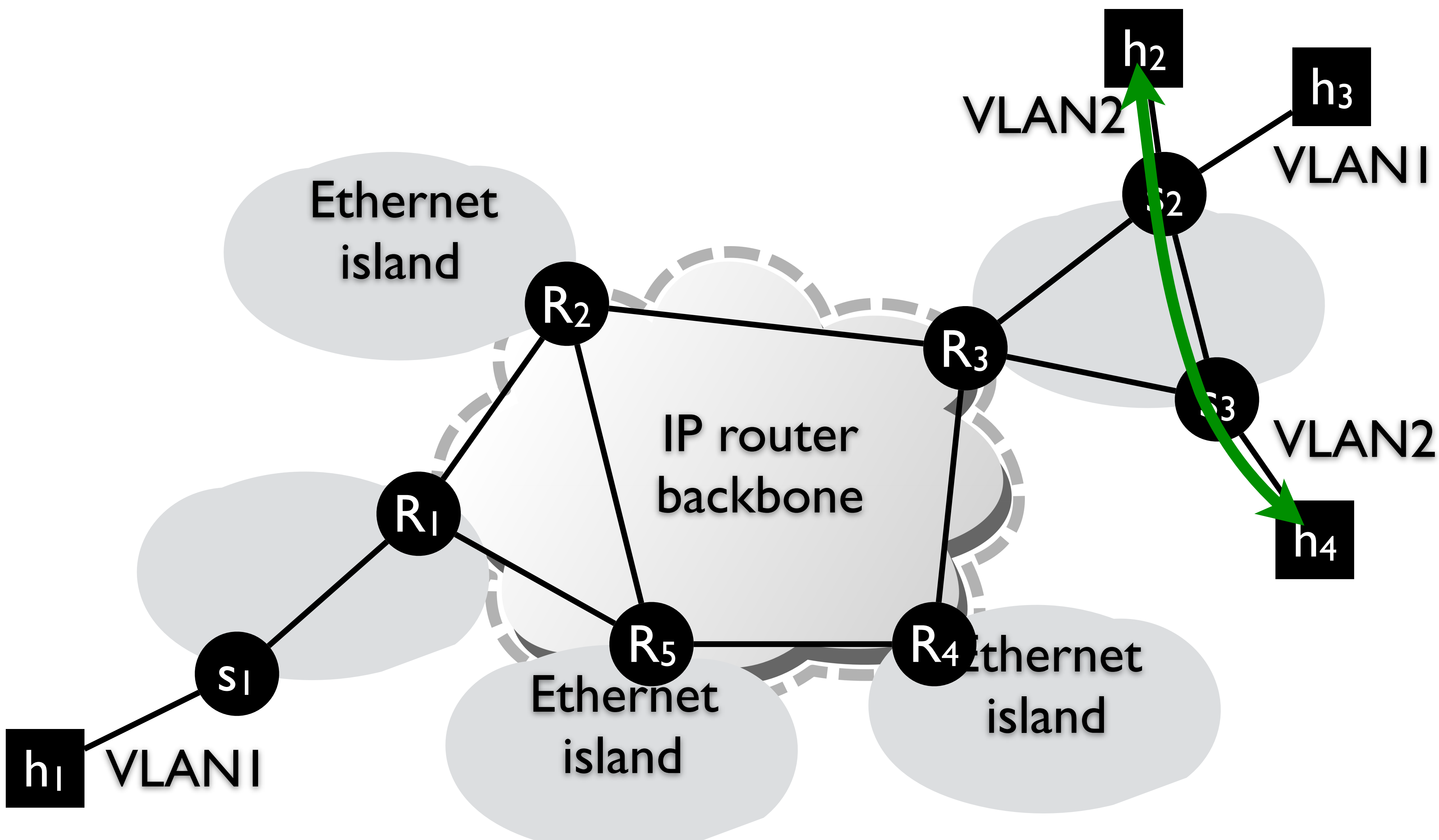
VLAN

connect hosts in the same broadcast domain, independent of their physical location



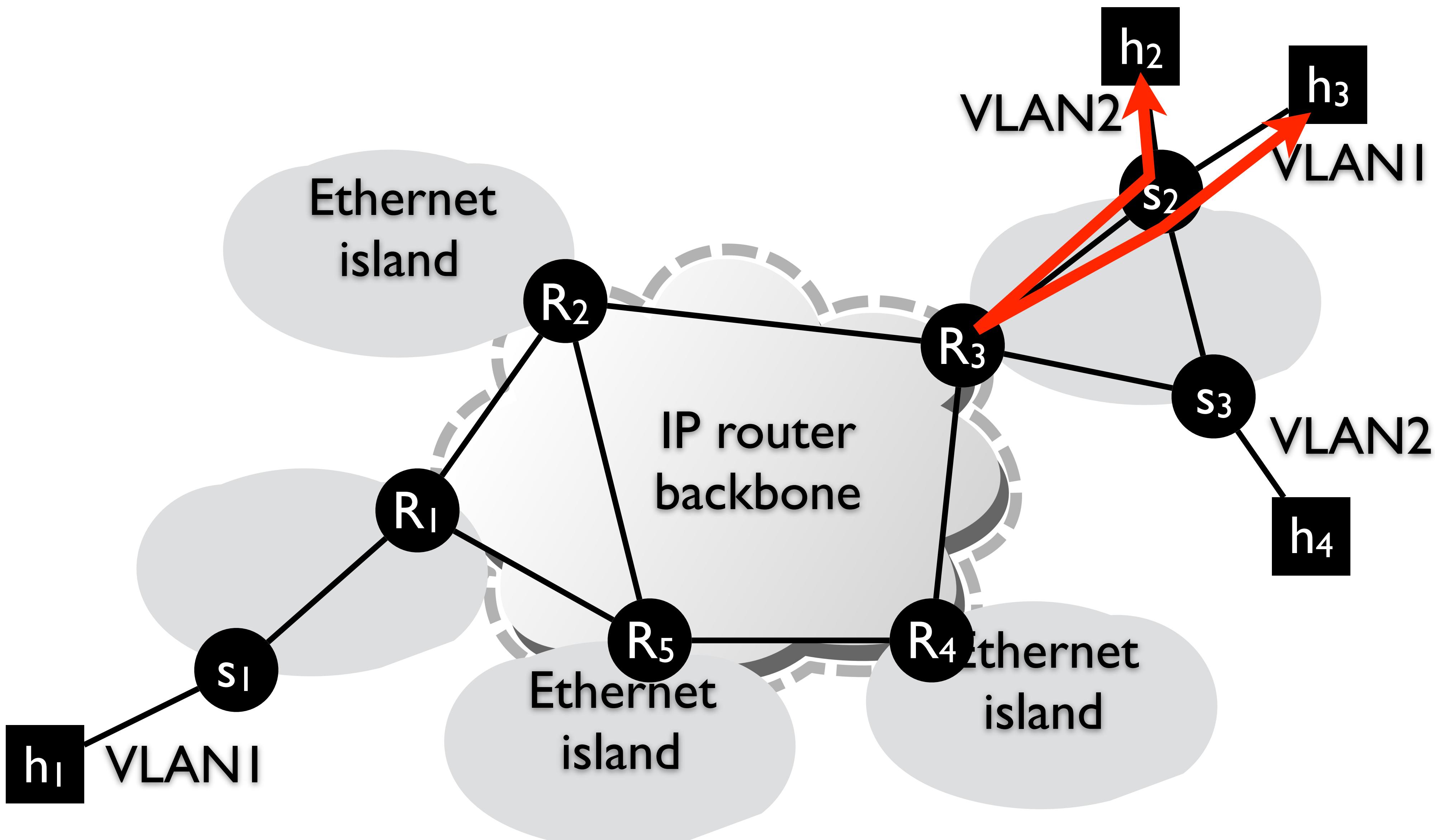
communication within a VLAN

h2 and h4 communicate over the spanning tree in VLAN2



communication between VLANs

- each VLAN has a IP prefix
- IP routers forward packets based on these prefixes



VLAN usage in campus networks

VLAN widely used for various policy objectives

- scoping broadcast traffic
  - limiting flood overhead
    - e.g., divide large networks into multiple VLANs
    - e.g., assign each building a different IP subnet, each grouped into a VLAN
  - protecting security and privacy
    - e.g., separate VLANs for faculty, students
- simplifying access control
  - VLANs group hosts with common access control policy
    - e.g., allow user machines (faculty, student VLANs) to server (infrastructure VLAN)
- decentralizing network management
  - delegate tasks to individual VLANs
    - e.g., one IT group manages “classroom VLAN” across 60 buildings
- enabling host mobility

problem: inexpressiveness

built-in protocol limitation

- number of VLANs < 4096 (12-bit header field)
  - multiple *isolated* group in the same VLAN
  - *isolated* VLANs share VLAN ID
- number of hosts per VLAN (flooding, spanning tree)
  - artificially divide large group into multiple VLANs

unfit for traffic grouping

- VLAN naturally groups end hosts
  - unexpected security bleach: student plugs into a hub in a faculty office
  - restricted policy: a faculty on faculty VLAN cannot participate in admin

problem: complex configuration

tight coupling between VLANs and IP

- wasting IP addresses, complex IP assignment

spanning tree computation

- explicitly configure switches to form spanning tree
  - determining which links participate in which VLAN is difficult
  - trunk links become inconsistent after network evolves
  - over-loading root bridge: same switch selected as the root in multiple VLANs

discussion: the bad and the ugly?

VLAN mechanism

- indirect and inflexible
  - VLAN creates broadcast domain for end-hosts
  - built-in protocol limitation
- low-level realization
  - explicit access port, trunk port

diverse high-level policy

- scoping traffic
- access control
- delegate management

SDN mechanisms

- **direct, flexible**
- **high-level abstraction**

the diverse high-level policy is a goal shared with SDN