Datacenter Networks

Lecture 22

COS 461: Computer Networks

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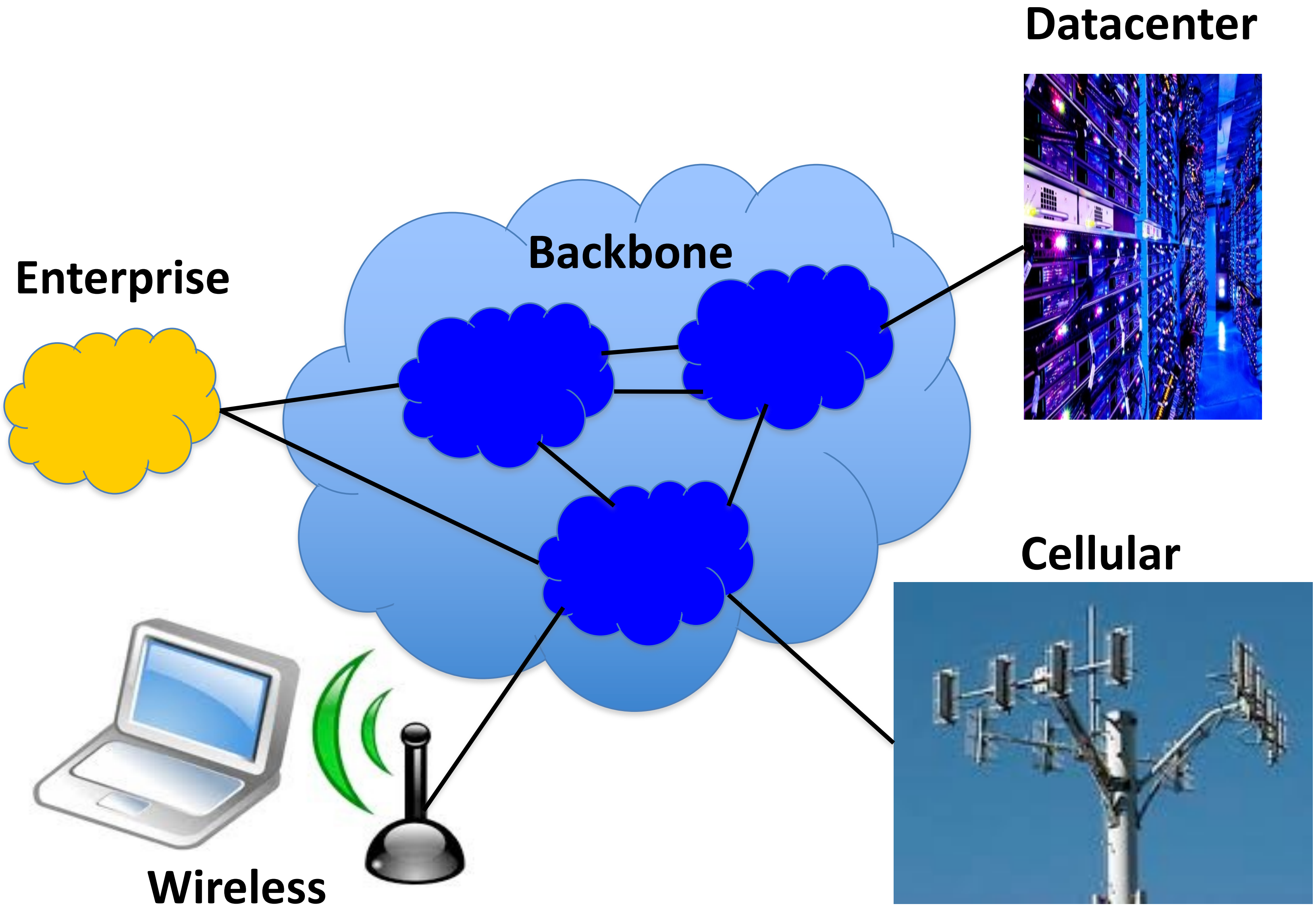
Networking Case Studies



Datacenter

Backbone

Enterprise

Cellular

Wireless

Cloud Computing

Cloud Computing

- Demand-elastic resources
  - Expand & contract resources as demand dictates
    - Pay-per-use; Infrastructure on demand

- Multi-tenancy
  - Multiple independent users
  - Security and resource isolation
  - Amortize the (shared) infrastructure cost
  - Flexible service management

Cloud Service Models

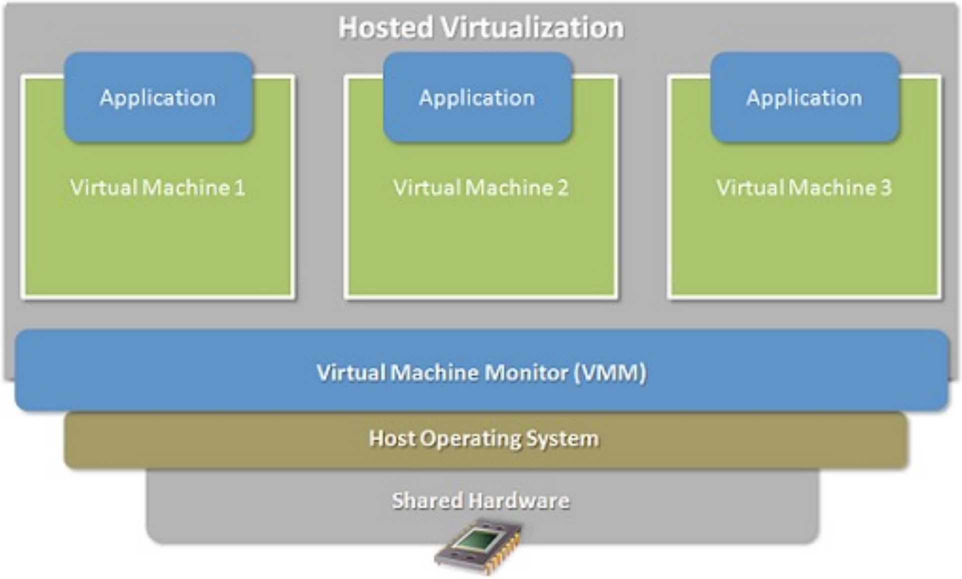
- Software as a Service
  - Provider licenses applications to users as a service
  - e.g., customer relationship management, e-mail, ..
  - Avoid costs of installation, maintenance, patches

- Platform as a Service
  - Provider offers platform for building applications
  - E.g., Google's App-Engine, Amazon S3 storage
  - Avoid worrying about scalability of platform

Cloud Service Models

- Infrastructure as a Service
  - Provider offers raw computing, storage, and network
  - E.g., Amazon's Elastic Computing Cloud (EC2)
  - Avoid buying servers & estimating resource needs

Enabling Technology: Virtualization



- Multiple virtual machines on one physical machine
- Applications run unmodified as on real machine
- Recently: Lighter-weight virtualization through "containers"
- Can migrate from one machine to another
- Autoscale by spinning up/down VMs & containers

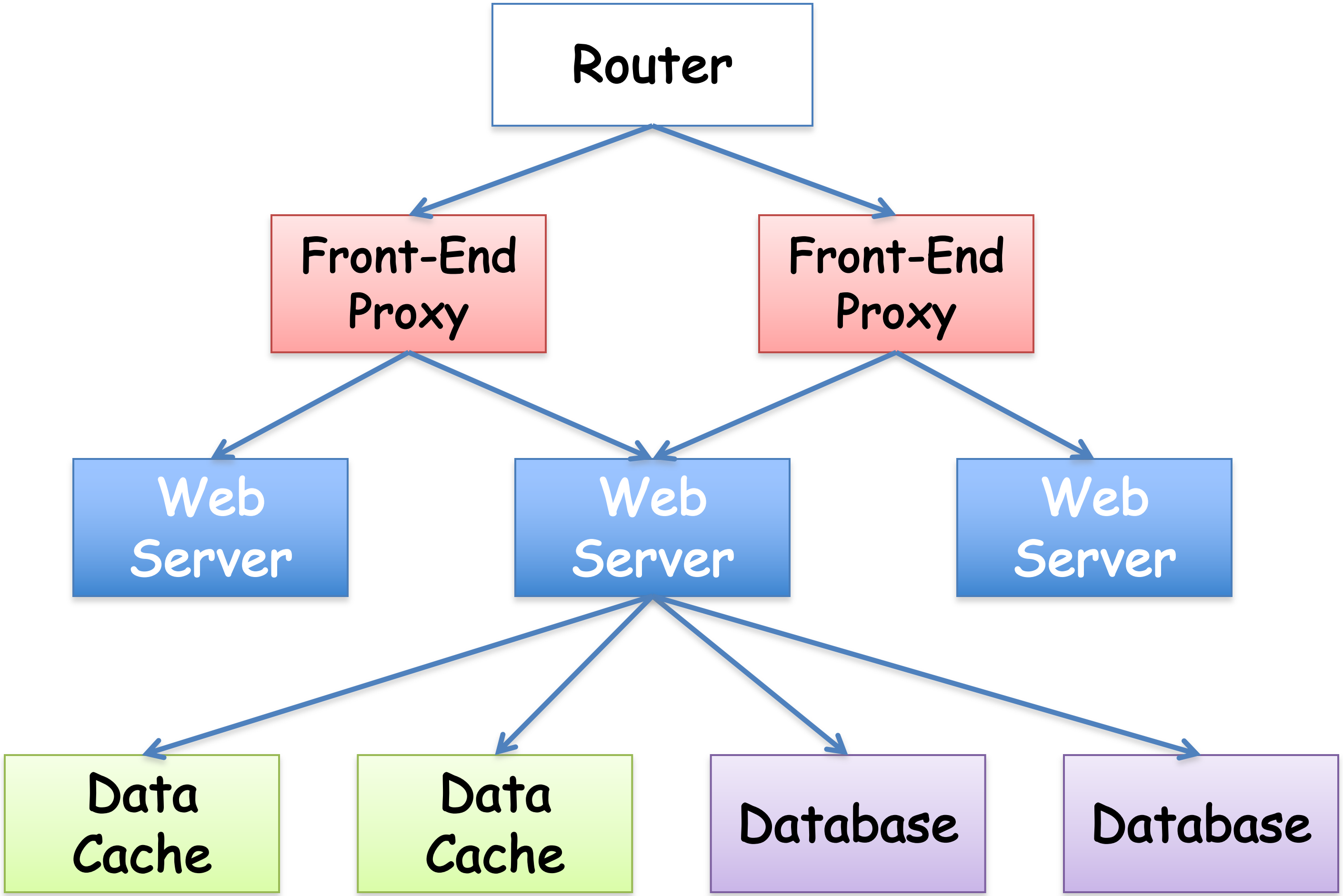
Multi-Tier Applications

- Applications consist of tasks
  - Many separate components
  - Running on different machines
- Commodity computers
  - Many general-purpose computers
  - Not one big mainframe
  - Easier scaling

Componentization leads to different types of network traffic

- "North-South traffic"
  - Traffic to/from external clients (outside of datacenter)
  - Handled by front-end (web) servers, mid-tier application servers, and back-end databases
  - Traffic patterns fairly stable, though diurnal variations
- "East-West traffic"
  - Traffic within data-parallel computations within datacenter (e.g. "Partition/Aggregate" programs like Map Reduce)
  - Data in distributed storage, partitions transferred to compute nodes, results joined at aggregation points, written back to storage
  - Traffic may shift on small timescales (e.g., minutes)

North-South Traffic



Router

Front-End Proxy

Front-End Proxy

Web Server

Web Server

Web Server

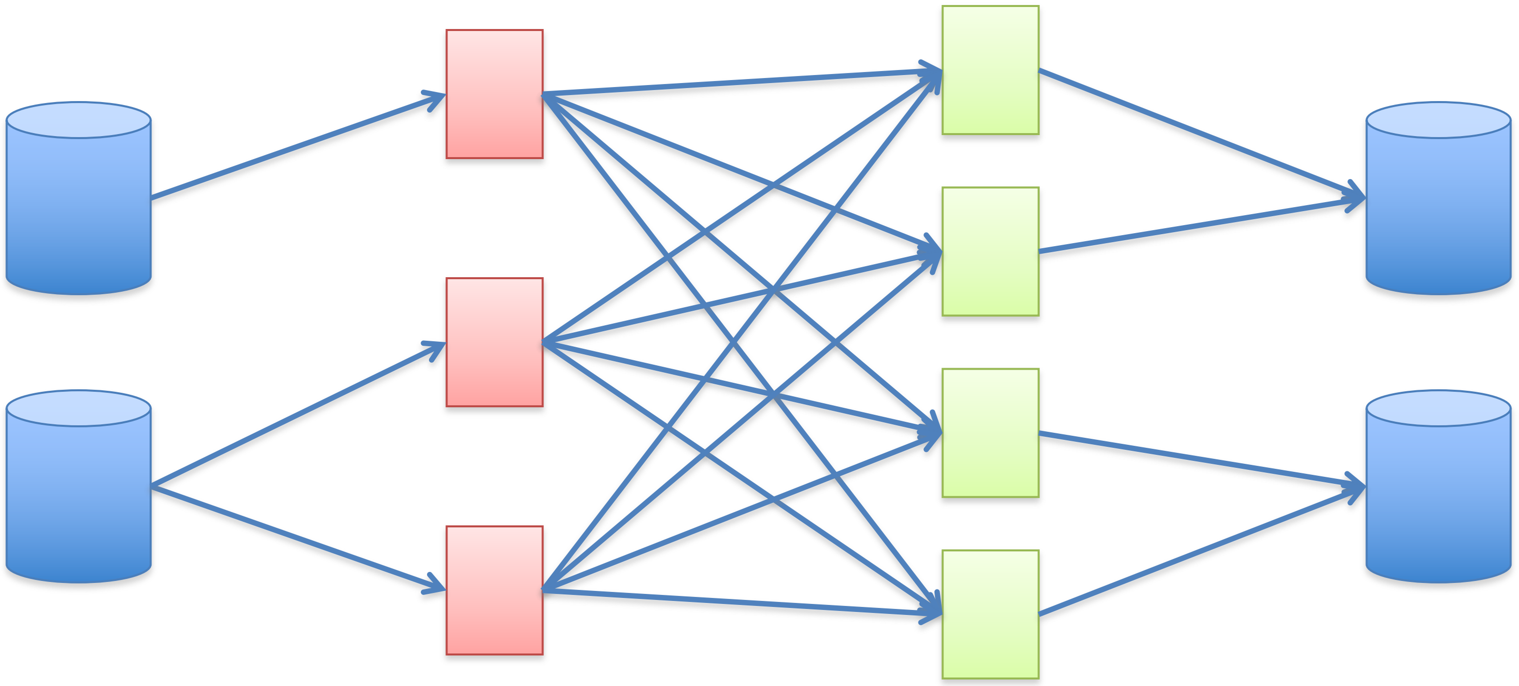
Data Cache

Data Cache

Database

Database

East-West Traffic



Distributed Storage

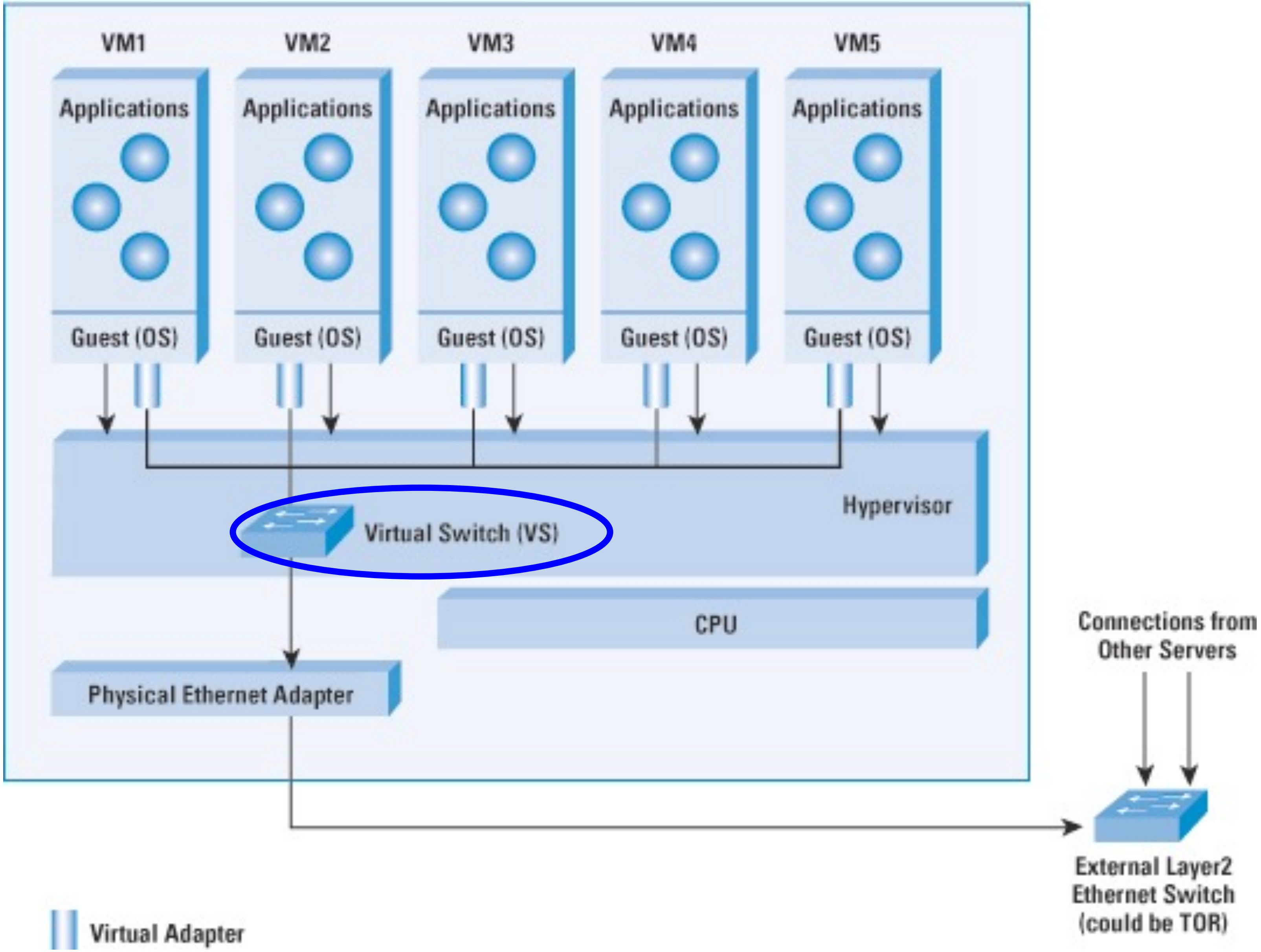
Map Tasks

Reduce Tasks

Distributed Storage

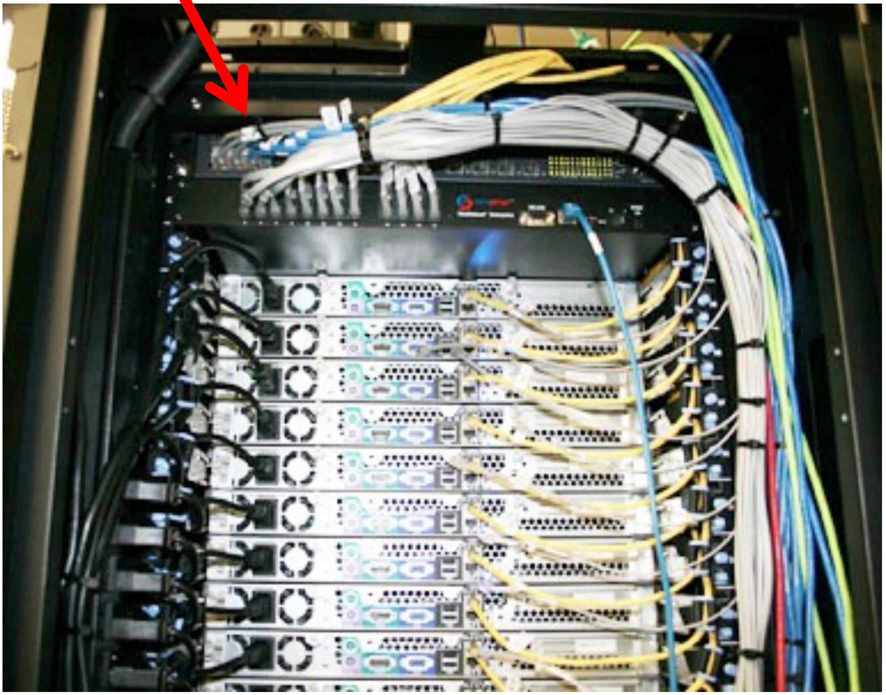
Datacenter Network

Virtual Switch in Server

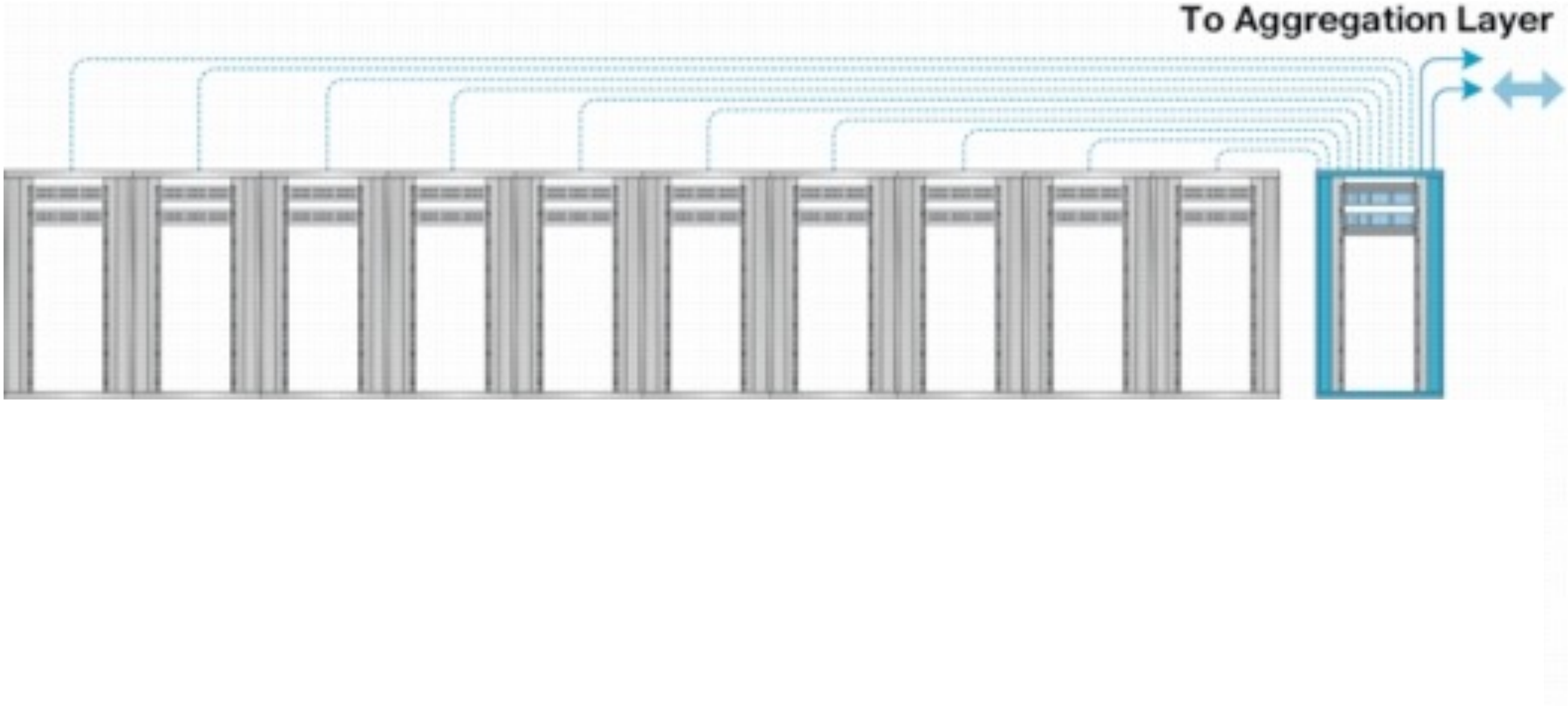


Top-of-Rack Architecture

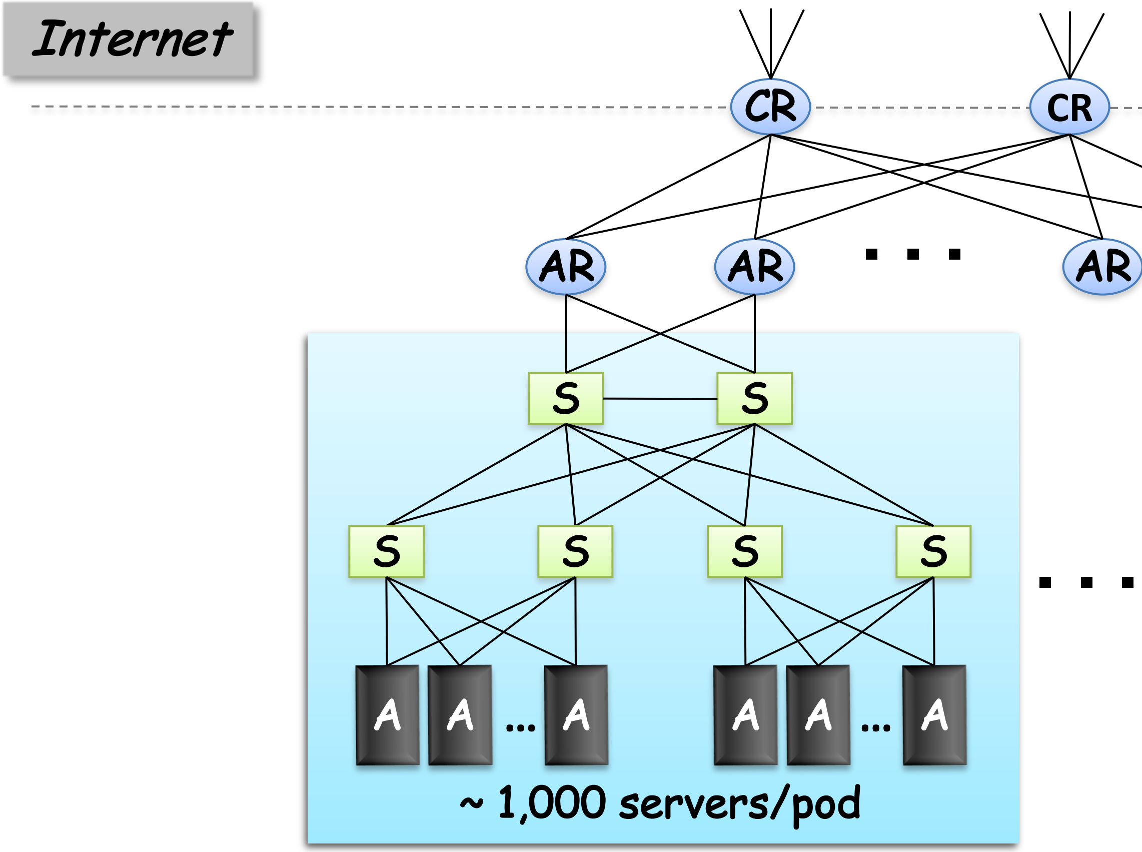
- Rack of servers
  - Commodity servers
  - And top-of-rack switch
- Modular design
  - Preconfigured racks
  - Power, network, and storage cabling



Aggregate to the Next Level

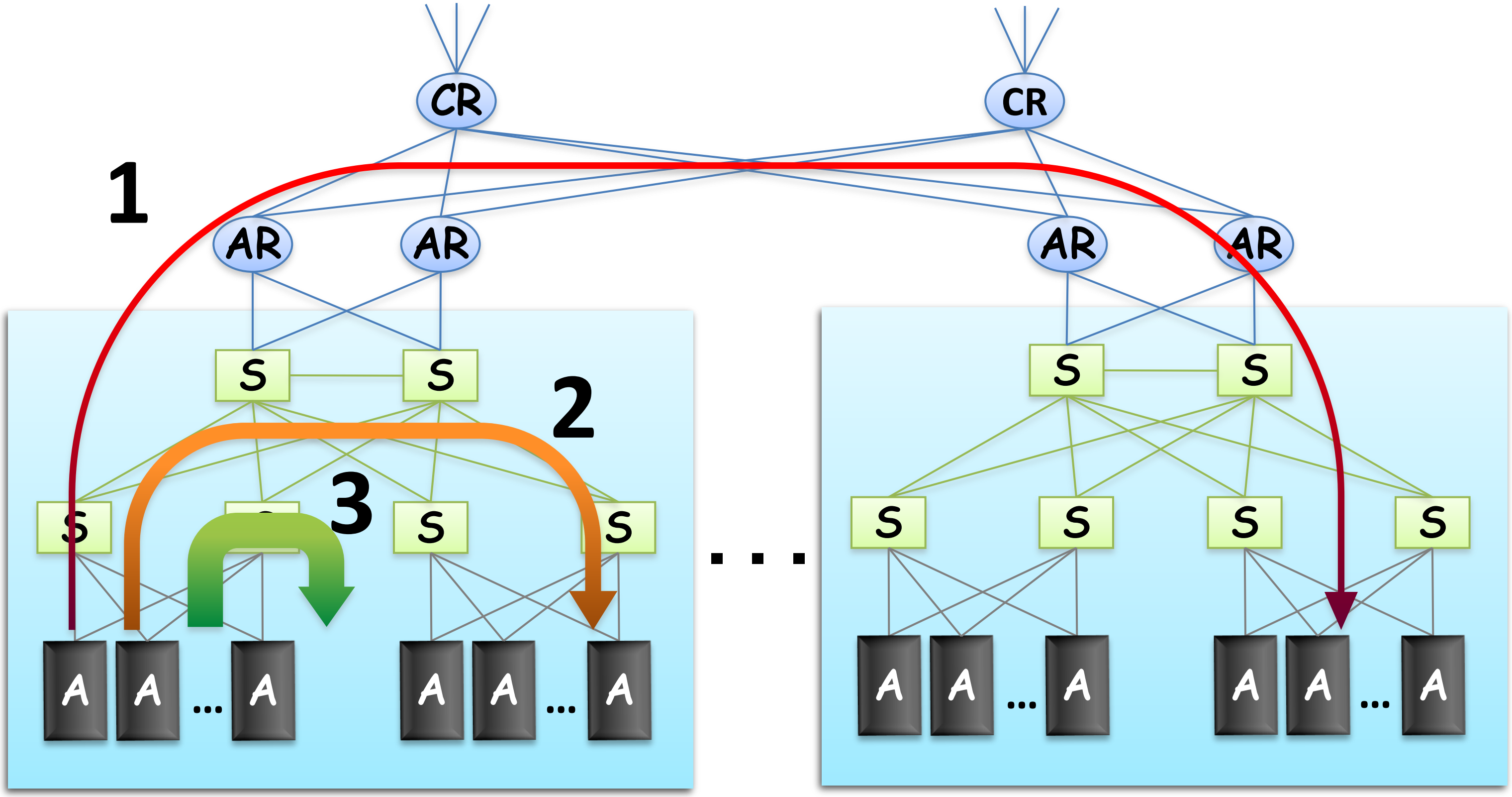


Datacenter Network Topology



Key
- CR = Core Router
- AR = Access Router
- S = Ethernet Switch
- A = Rack of app. servers

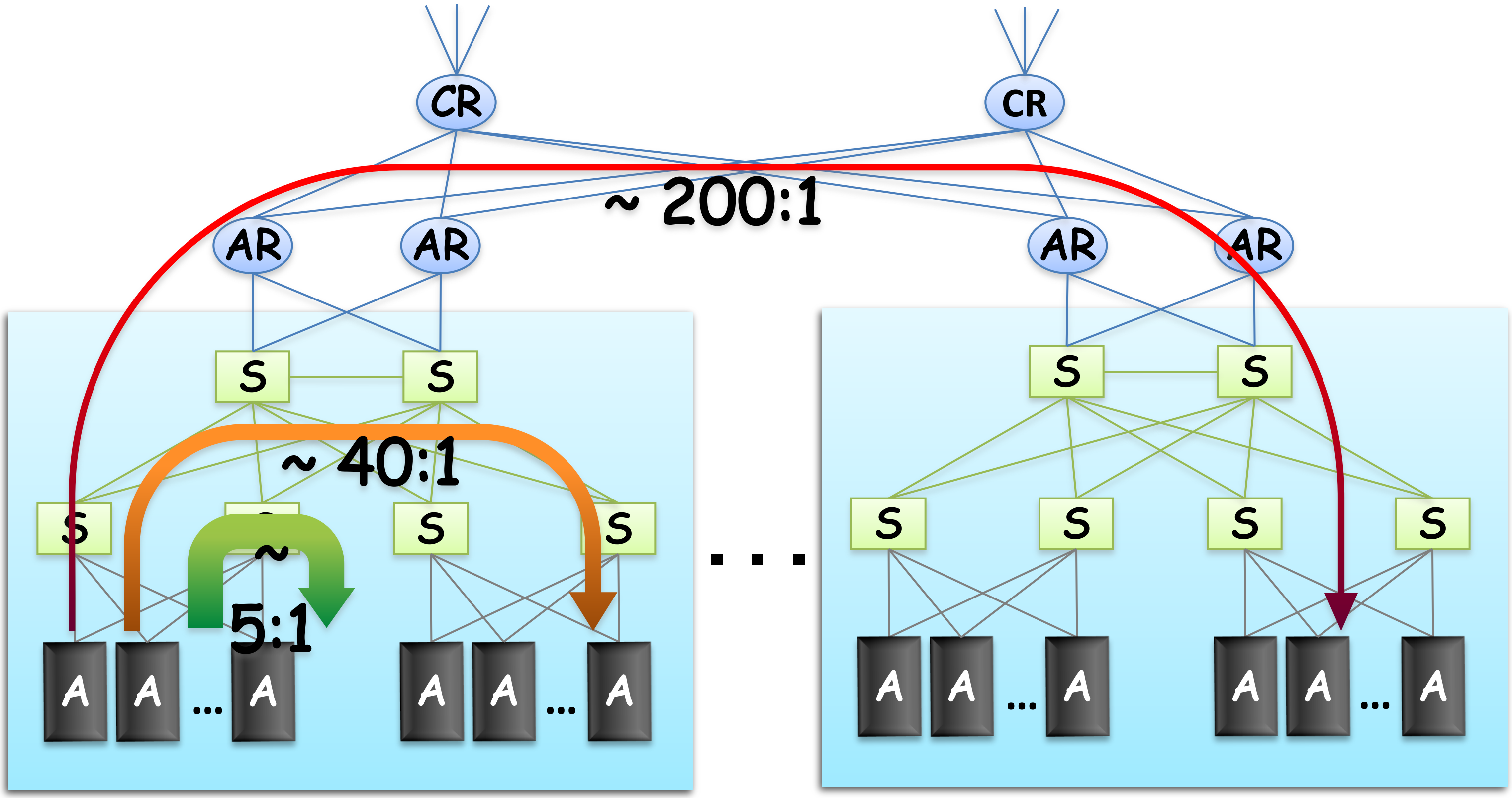
Capacity Mismatch?



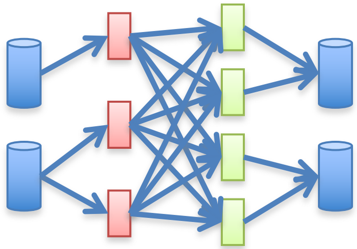
"Oversubscription":

Much more demand vs. supply for higher links

Capacity Mismatch!



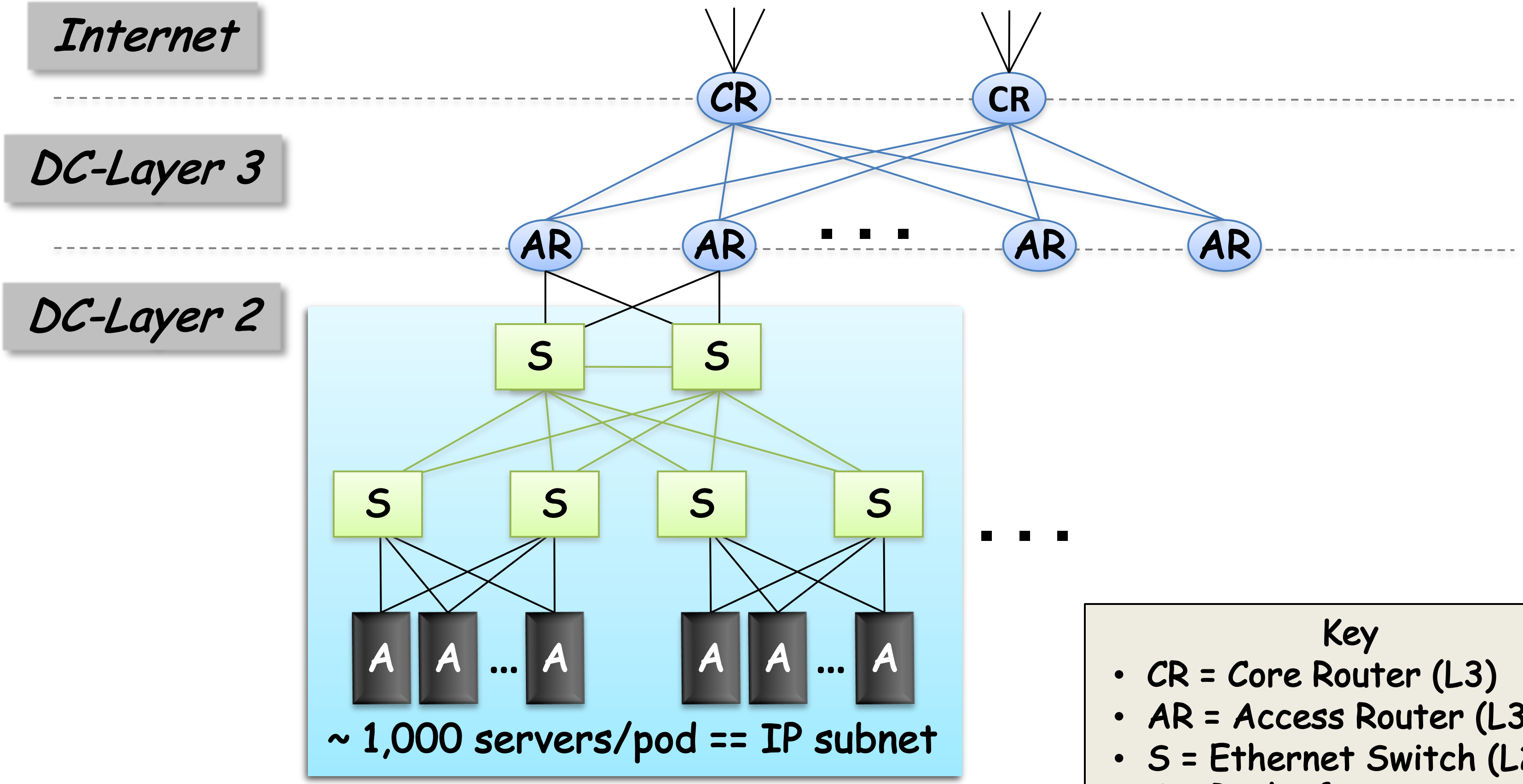
Particularly bad for east-west traffic



Layer 2 vs. Layer 3?

- Ethernet switching (layer 2)
  - Cheaper switch equipment
  - Fixed addresses and auto-configuration
  - Seamless mobility, migration, and failover
- IP routing (layer 3)
  - Scalability through hierarchical addressing
  - Efficiency through shortest-path routing
  - Multipath routing through equal-cost multipath

Datacenter Routing

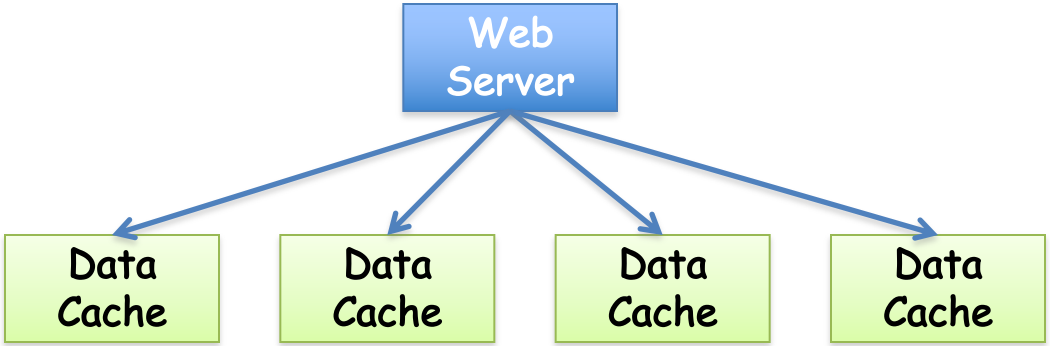


Key

- CR = Core Router (L3)
- AR = Access Router (L3)
- S = Ethernet Switch (L2)
- A = Rack of app. servers

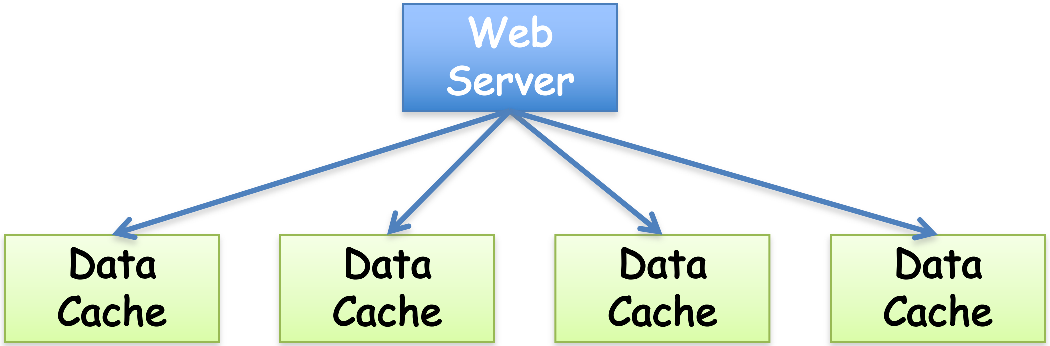
New datacenter networking problems have emerged…

Network Incast



- Incast arises from synchronized parallel requests
  - Web server sends out parallel request ("which friends of Johnny are online?"
  - Nodes reply at same time, cause traffic burst
  - Replies potentially exceed switch's buffer, causing drops

Network Incast



Solutions mitigating network incast…

A. Reduce TCP's min RTO (often use 200ms >> DC RTT)
B. Increase buffer size
C. Add small randomized delay at node before reply
D. Use ECN with instantaneous queue size
E. All of above

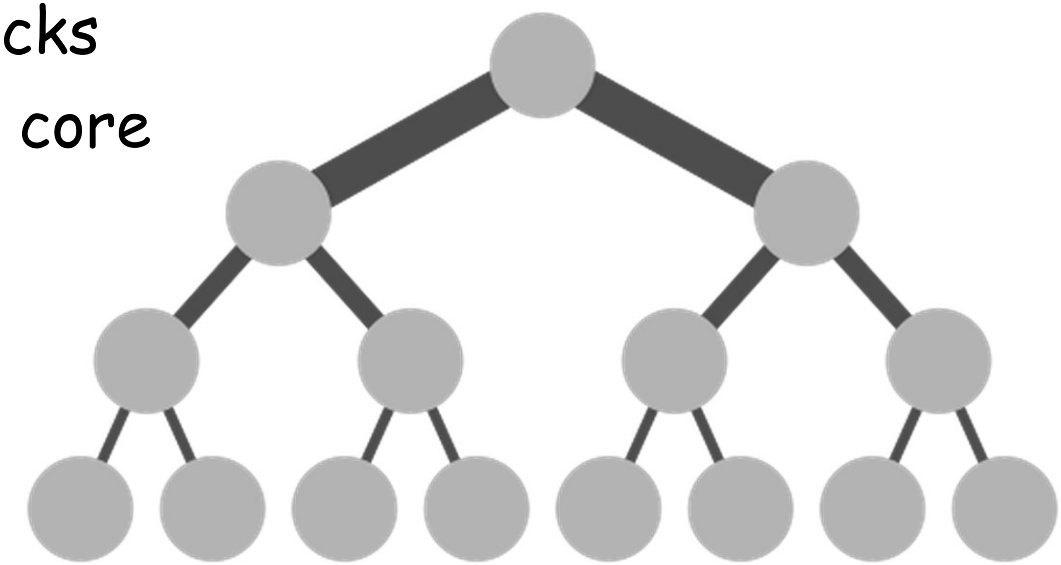
Network Bandwidth Measurements

- Bisection bandwidth: Split nodes into two halves such that bandwidth between the halves is minimal, that is the bisection b/w

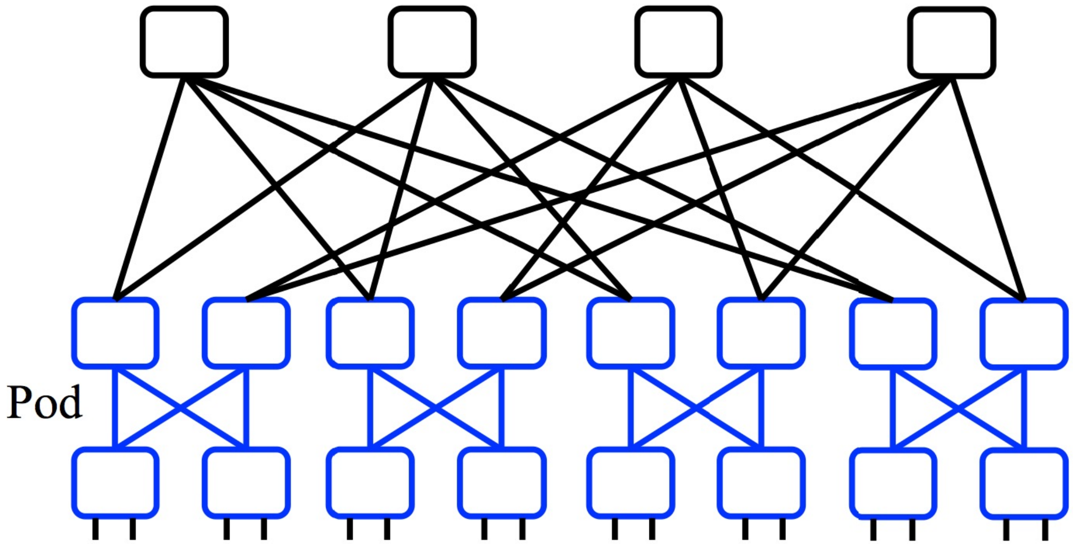
- Full bisection bandwidth: ½ of the nodes can communicate simultaneously with the other ½

Full Bisection Bandwidth

- Eliminate oversubscription?
  - Enter FatTrees
  - Provide static capacity
  - Heterogeneous Links
    - 1-10 GB in racks
    - 40-100GB to core

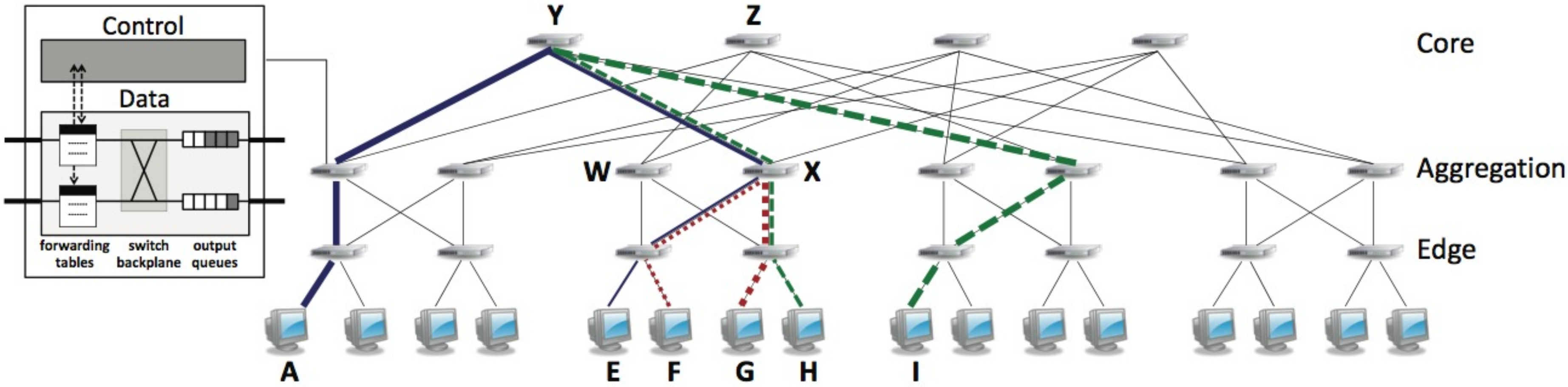


Full Bisection Bandwidth



- But "scale up" link capacity has limits
- New scale out architectures
  - Build multi-stage FatTree out of k-port switches
  - k/2 ports up, k/2 down
  - Supports $k^3/4$ hosts: 48 ports, 27,648 hosts

Full Bisection Bandwidth Not Sufficient



- Must choose good paths for full bisectional throughput
- Load-agnostic routing
  - Use ECMP across multiple potential paths
  - Can collide, but ephemeral? Not if long-lived, large elephants
- Load-aware routing
  - Centralized flow scheduling, end-host congestion feedback, switch local algorithms

Conclusion

- Cloud computing
  - Major trend in IT industry
  - Today's equivalent of factories
- Datacenter networking
  - Regular topologies interconnecting VMs
  - Mix of Ethernet and IP networking
- Modular, multi-tier applications
  - New ways of building applications
  - New performance challenges