Datacenter Networks

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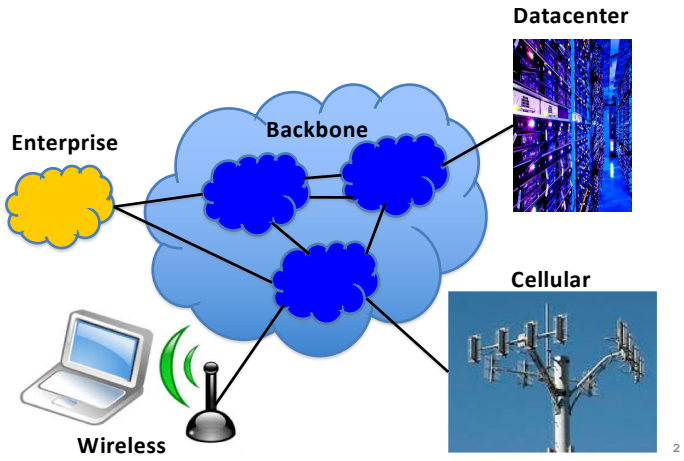
COS 461: Computer Networks

http://www.cs.princeton.edu/courses/archive/spr20/cos461/

Networking Case Studies



2

Cloud Computing

3

Cloud Computing

- Elastic resources
  - Expand and contract resources
  - Pay-per-use
  - Infrastructure on demand
- Multi-tenancy
  - Multiple independent users
  - Security and resource isolation
  - Amortize the cost of the (shared) infrastructure
- Flexible service management

4

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

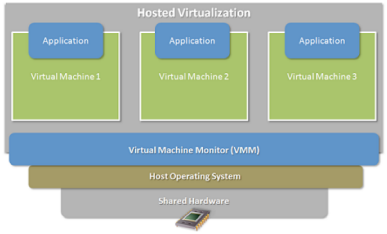
5

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 and estimating resource needs

6

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

7

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

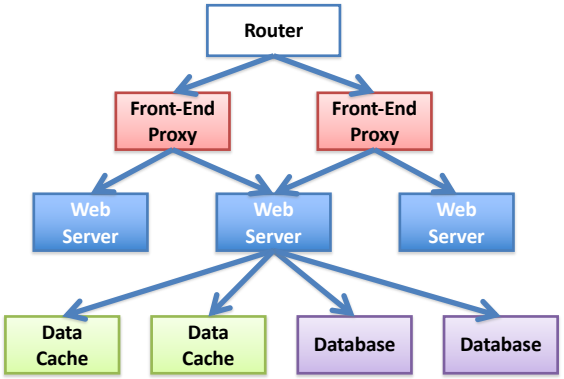
8

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, stored back into FS
  - Traffic may shift on small timescales (e.g., minutes)

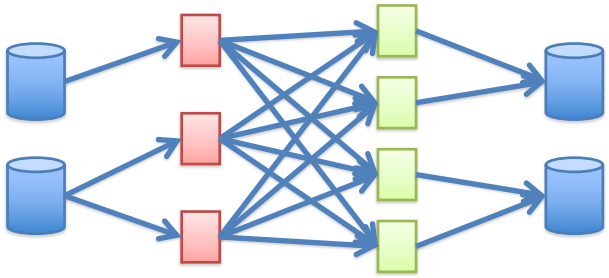
9

North-South Traffic



10

East-West Traffic

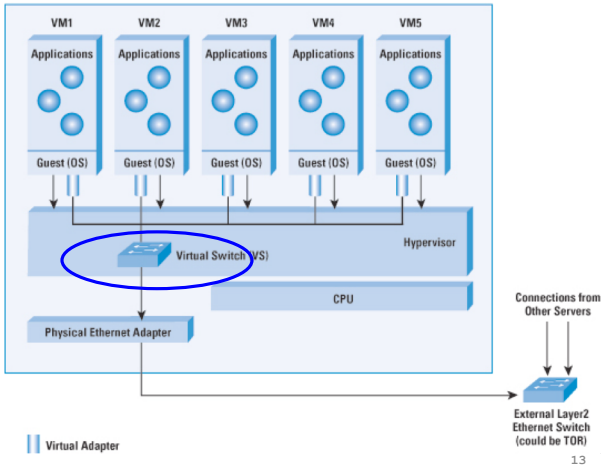


11

Datacenter Network

12

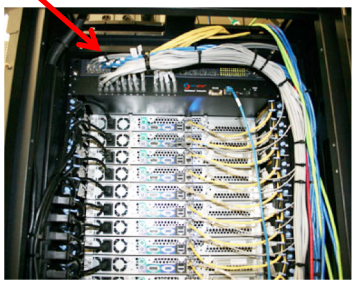
Virtual Switch in Server



13

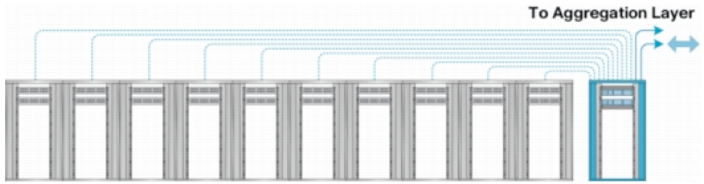
Top-of-Rack Architecture

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



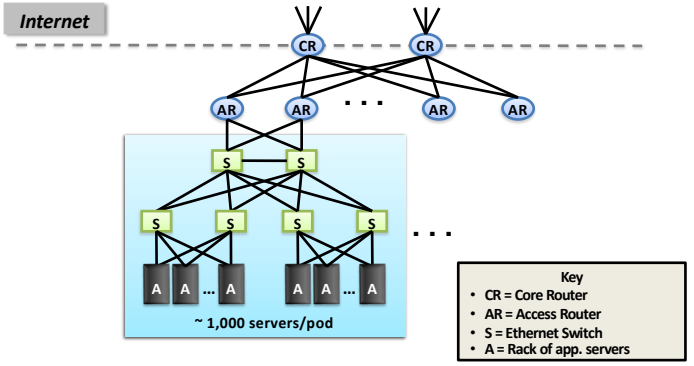
14

Aggregate to the Next Level



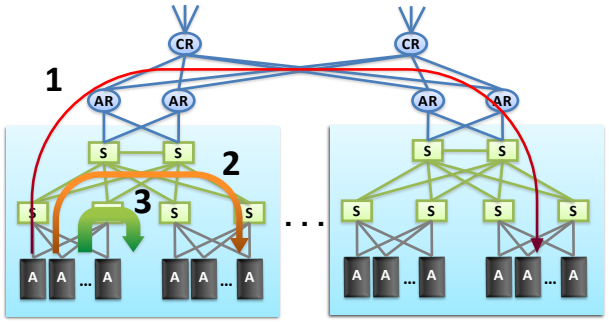
15

Datacenter Network Topology



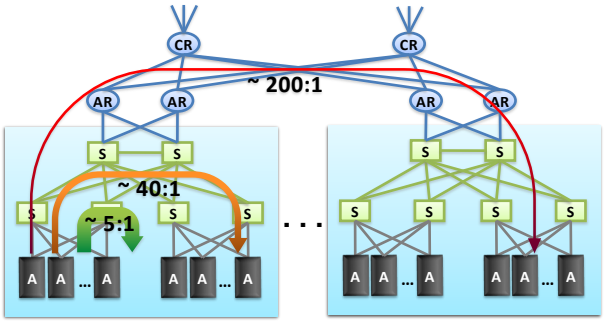
16

Capacity Mismatch?

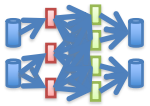


"Oversubscription":
Much more demand vs. supply for higher links

Capacity Mismatch!



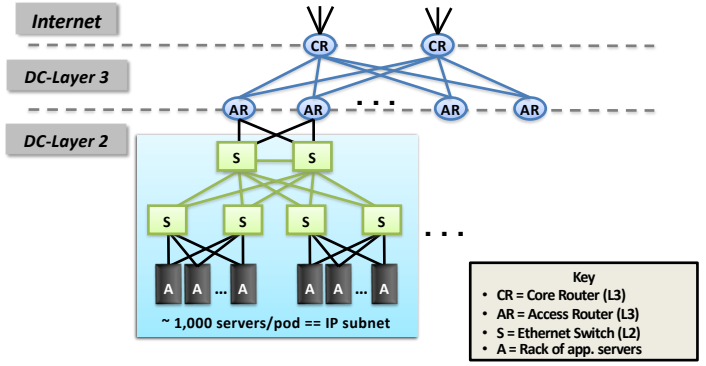
Particularly bad for east-west traffic



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

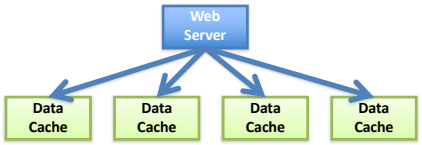
Datacenter Routing



New datacenter networking problems have emerged...

21

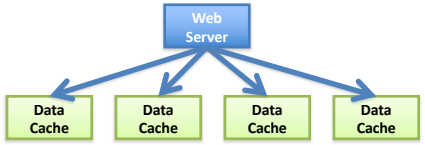
Network Incast



- 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 potential exceed switch's buffer, causing drops

22

Network Incast

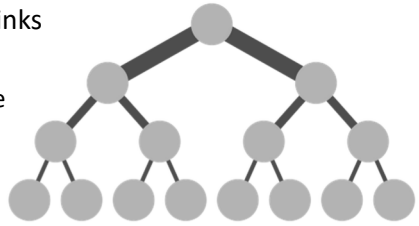


- Solutions mitigating network incast
  A. Reduce TCP's min RTO (often use 200ms >> DC RTT)
  B. Increase buffer size
  C. Add small randomized delay at node before reply
  D. Use ECN with instantaneous queue size
  E. All of above

23

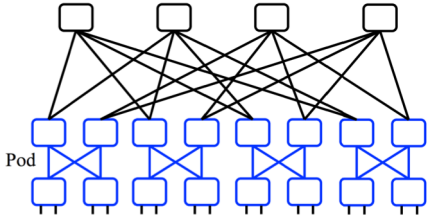
Full Bisection Bandwidth

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



24

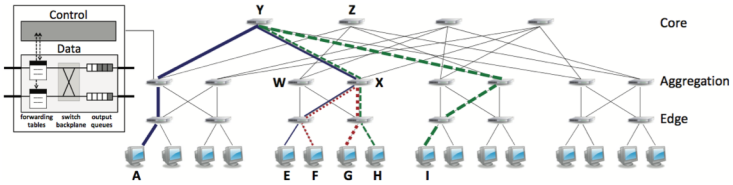
Full Bisection Bandwidth



- 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

25

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

26

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

27