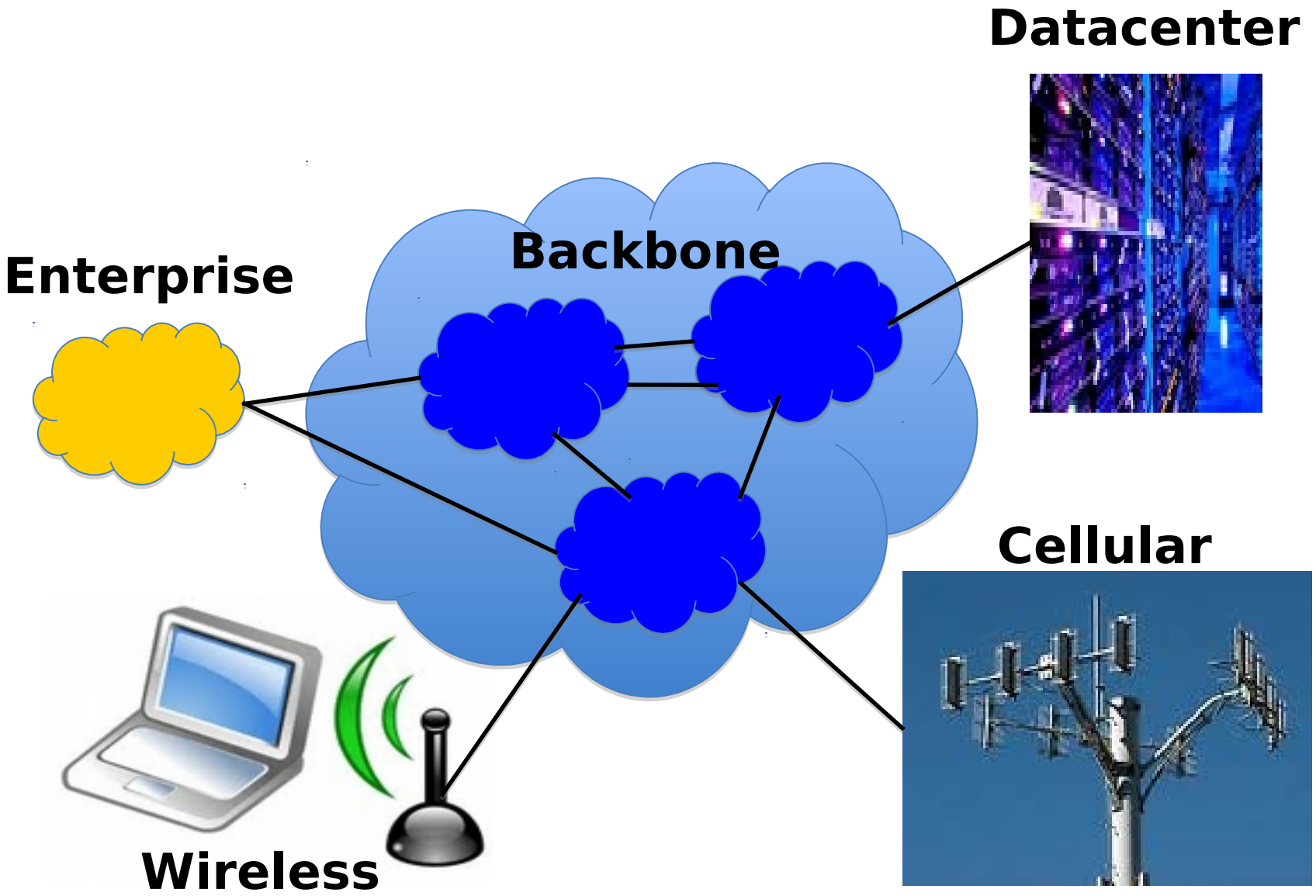
Datacenter

Networking Case Studies



Cloud Computing

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**

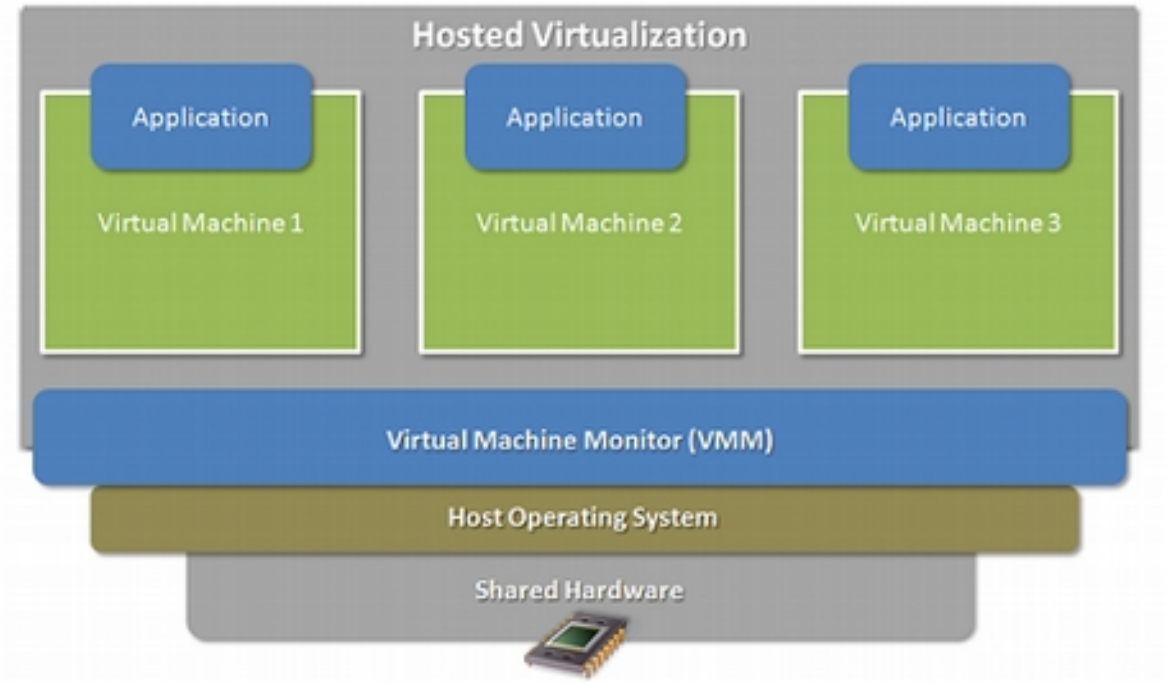
Cloud Service Models

- **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 and estimating resource needs**

Enabling Technology: Virtualization



- Multiple virtual machines on one physical machine
- Applications run unmodified as on real machine
- VM can migrate from one computer to another

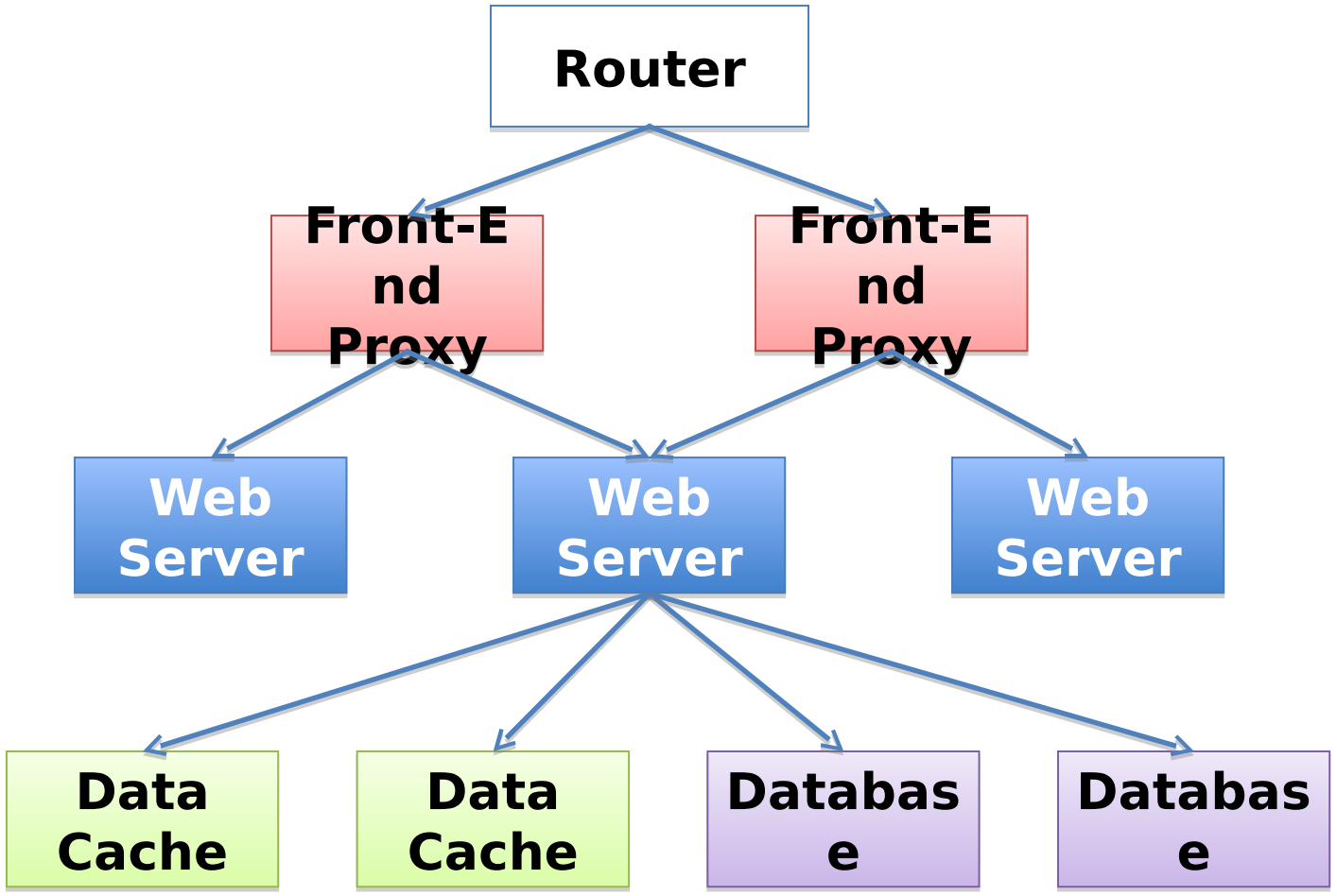
Multi-Tier Applications

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

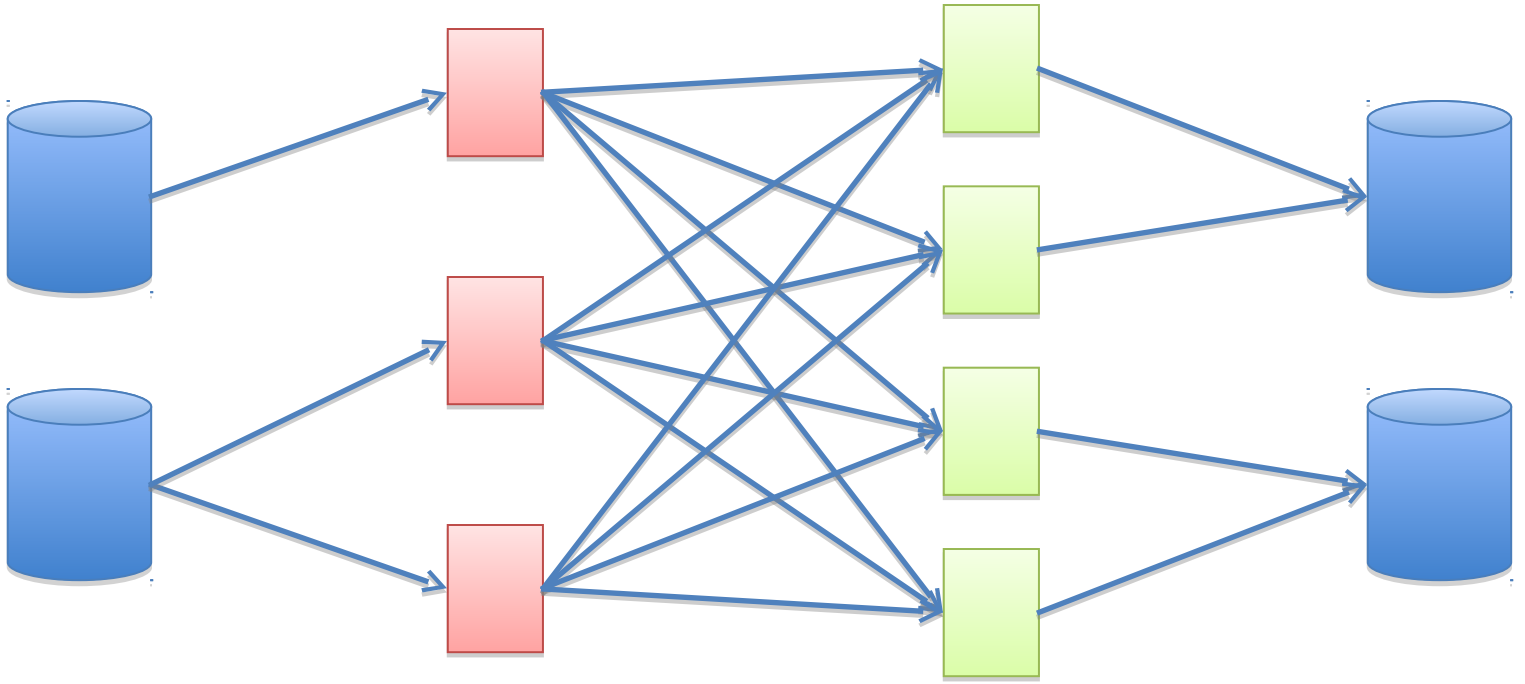
Componentization leads to different types of network traffic

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

North-South Traffic



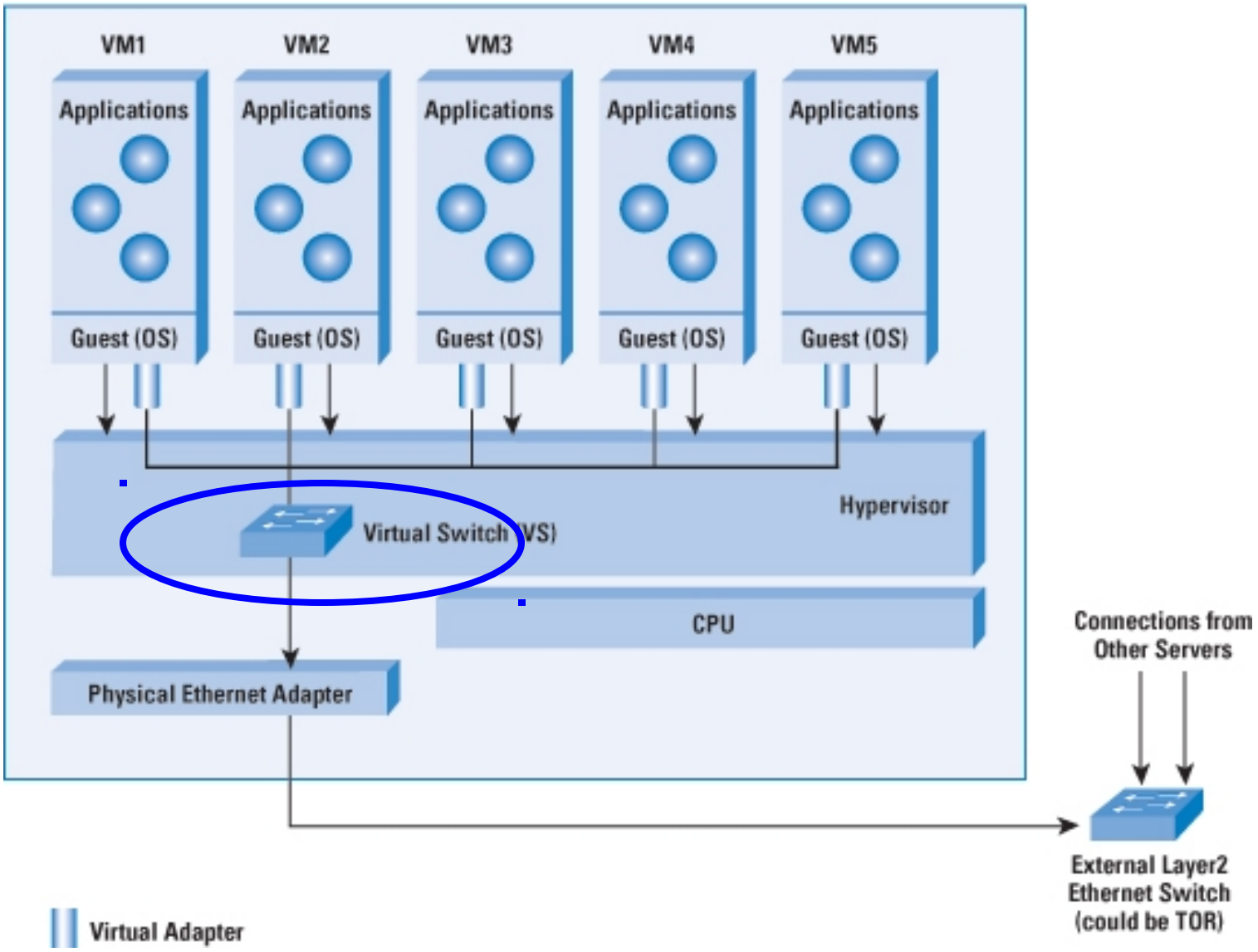
East-West Traffic



Distributed Storage **Map Tasks** **Reduce Tasks** **Distributed Storage**

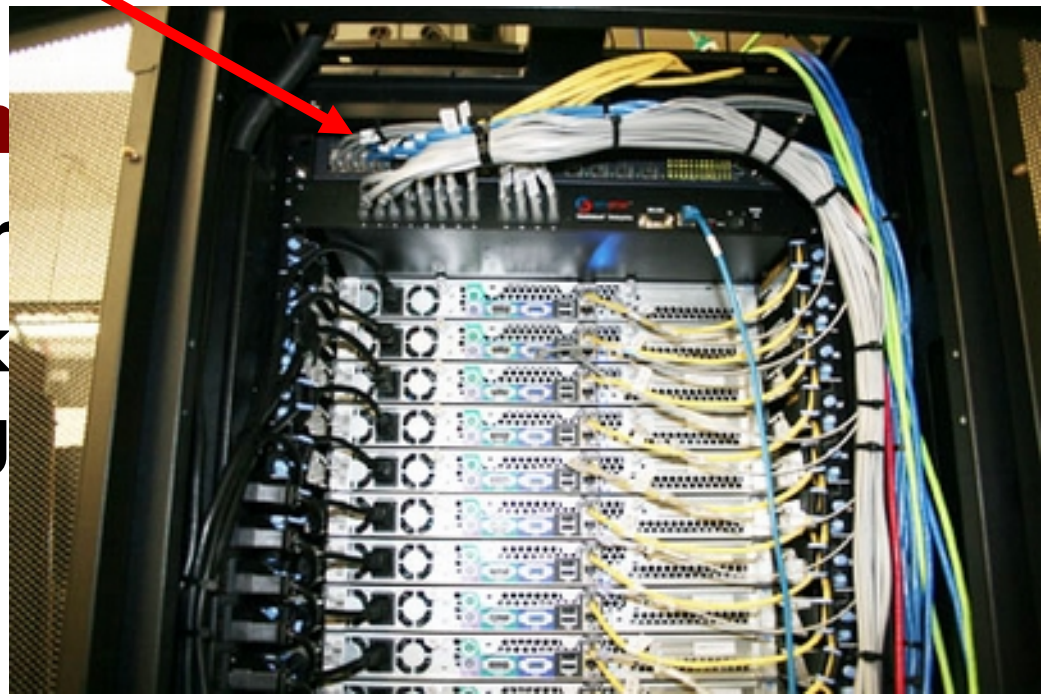
Datacenter Network

Virtual Switch in Server

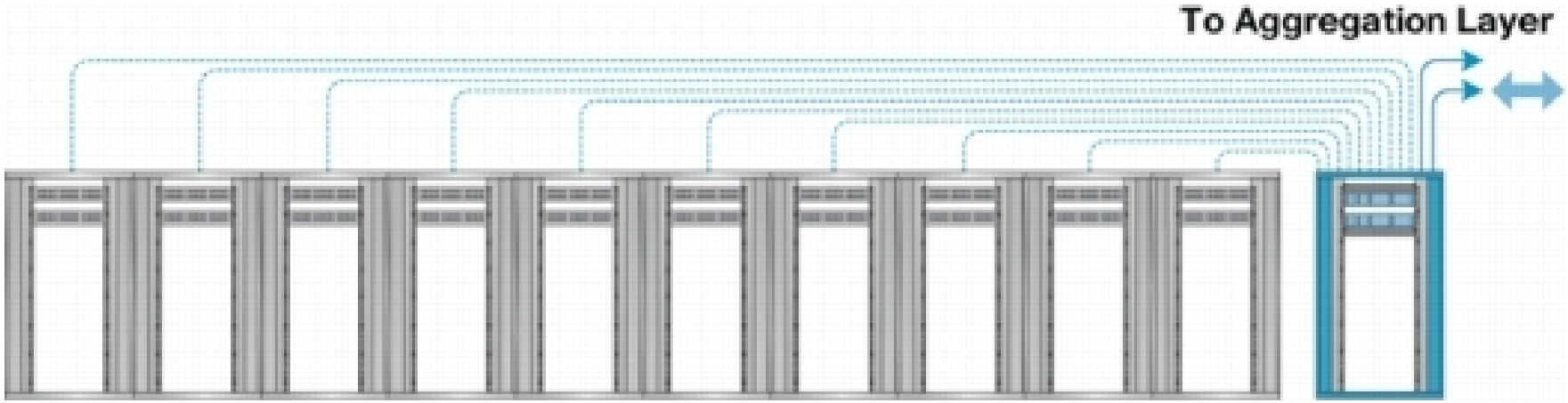


Top-of-Rack Architecture

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



Aggregate to the Next Level

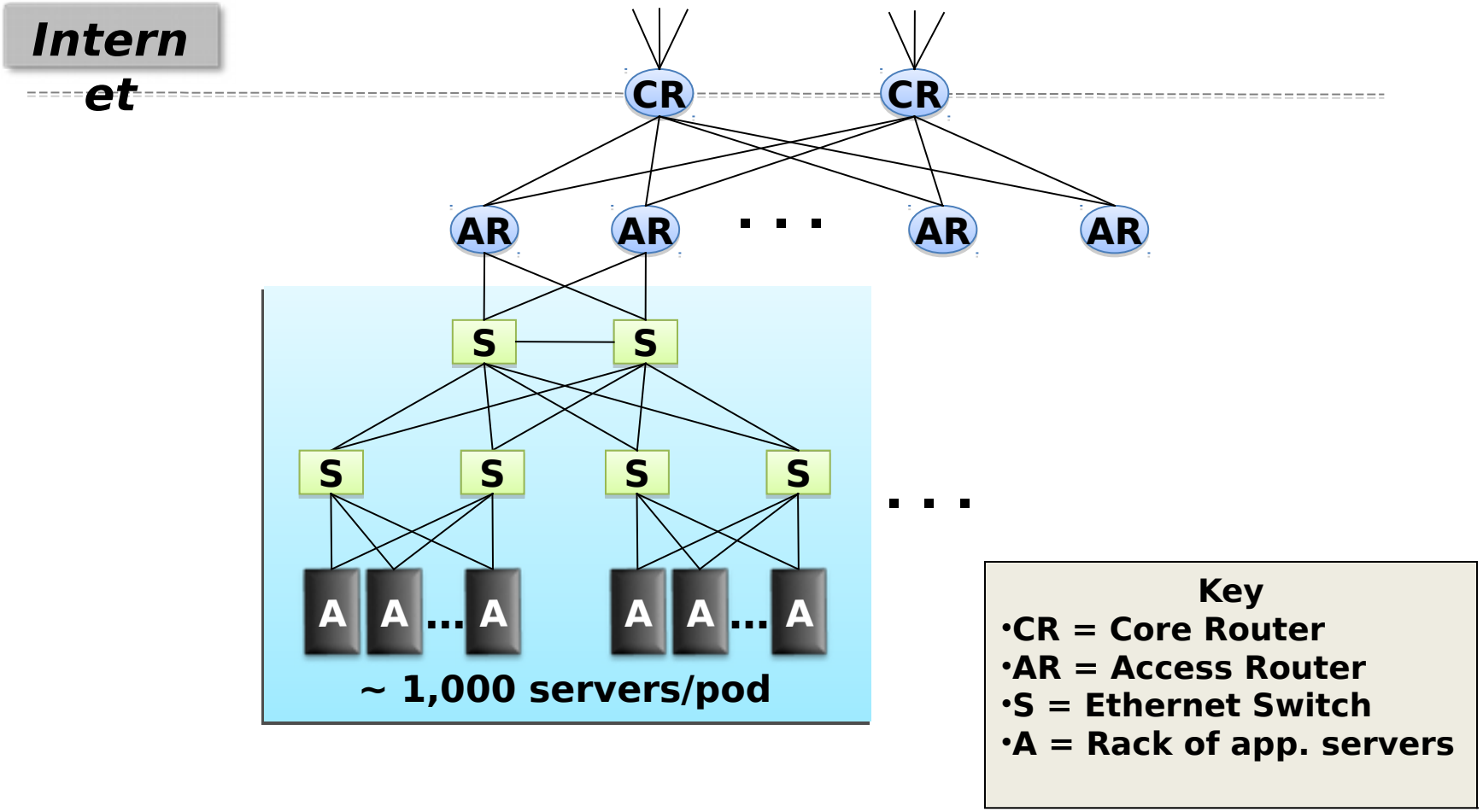


Modularity, Modularity, Modularity

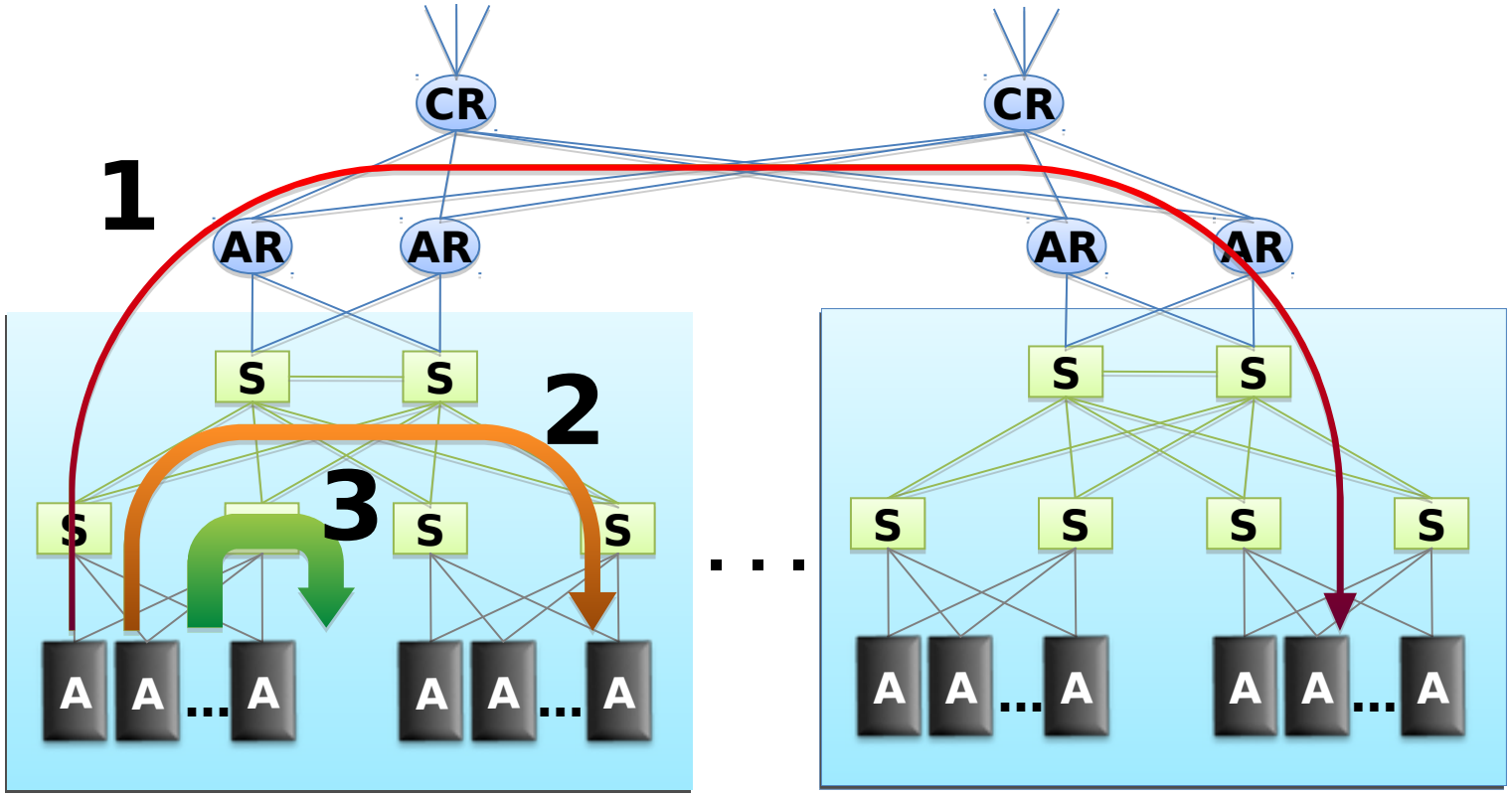
- **Containers**

- **Many containers**

Datacenter Network Topology



Capacity Mismatch?



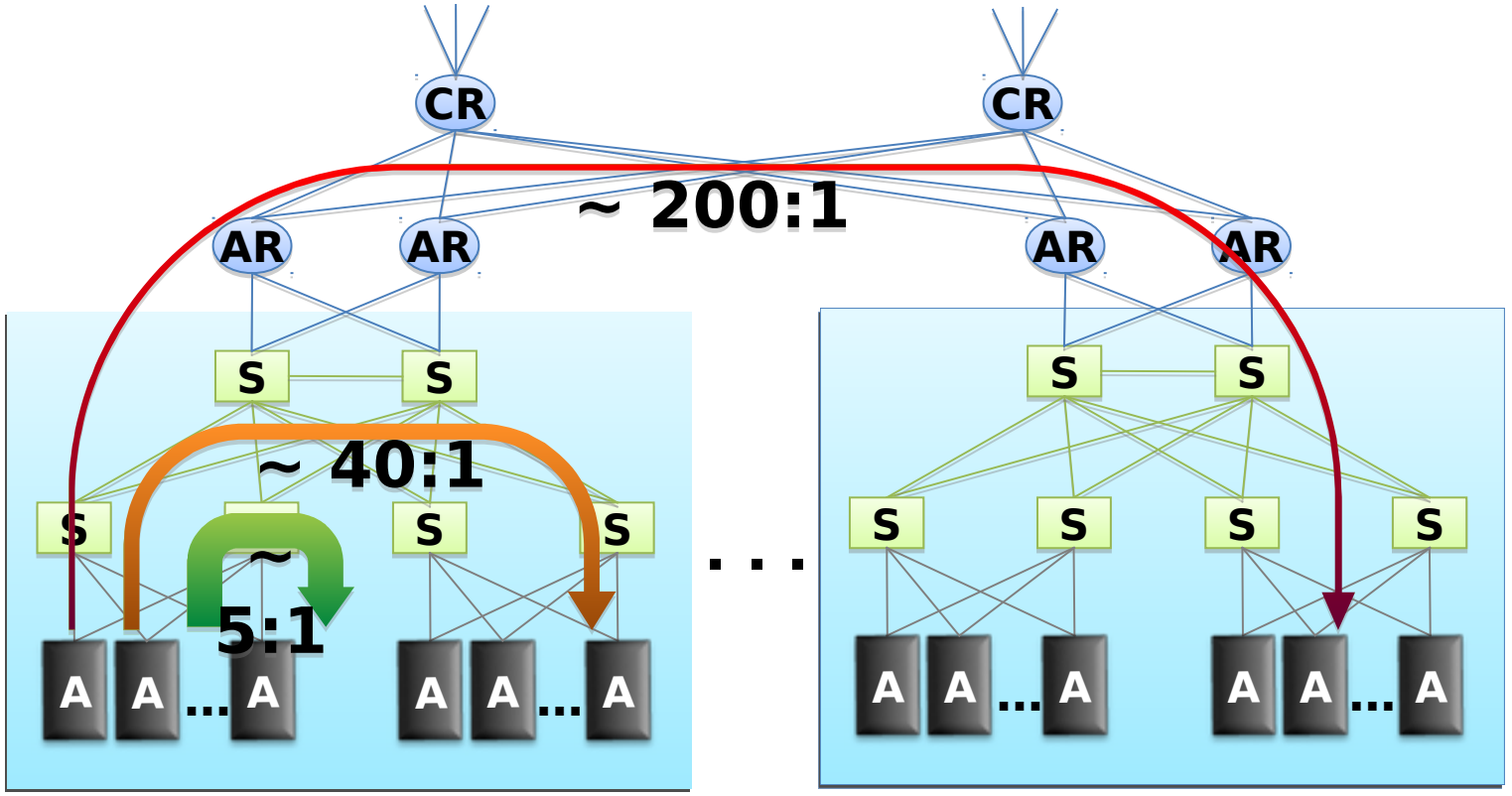
“Oversubscription”: Demand/Supply

A.1 > 2 > 3

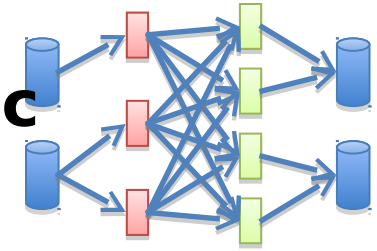
B.1 < 2 < 3

C.1 = 2 = 3

Capacity Mismatch!



Particularly bad for east-west traffic

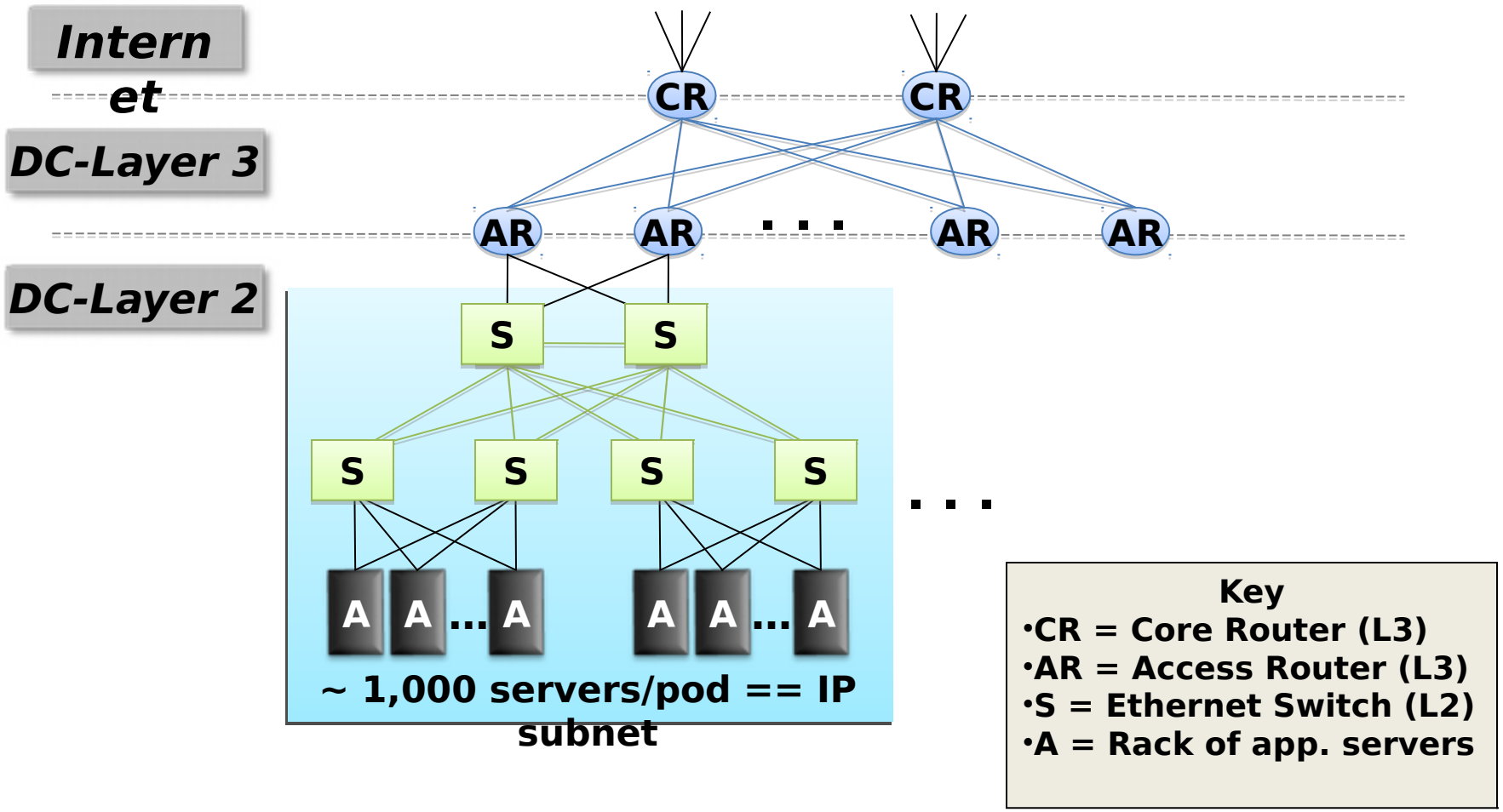


Layer 2 vs. Layer 3?

- **Ethernet switching (layer 2)**
  - **Cheaper switch equipment**
  - **Fixed addresses and auto-configuration**
  - **Seamless mobility, migration, and failover**

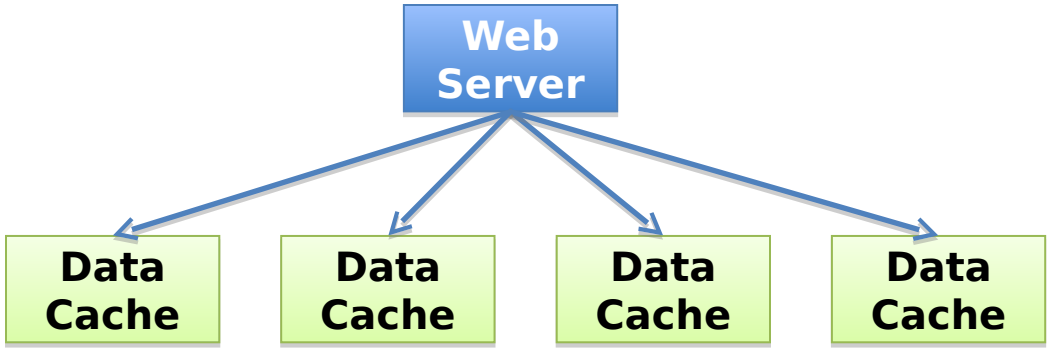
- **IP routing (layer 3)**
  - **Scalability through hierarchical addressing**
  - **Efficiency through shortest-path routing**
  - **Multipath routing through equal-cost multipath**

Datacenter Routing



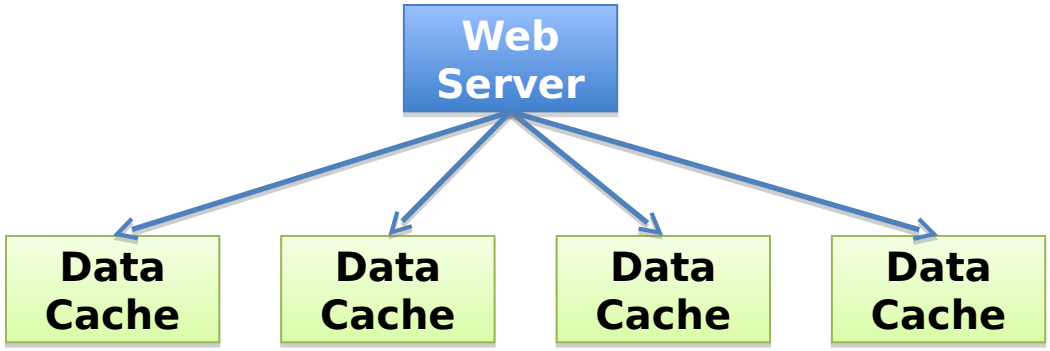
Outstanding datacenter networking problems remains…

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**

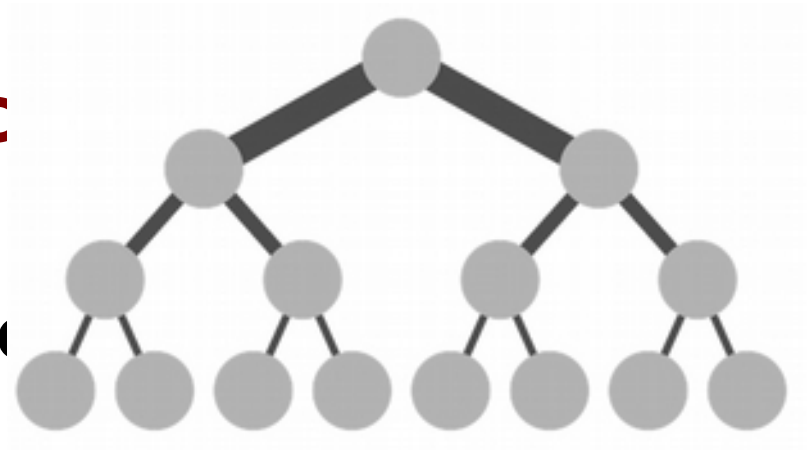
Network Incast



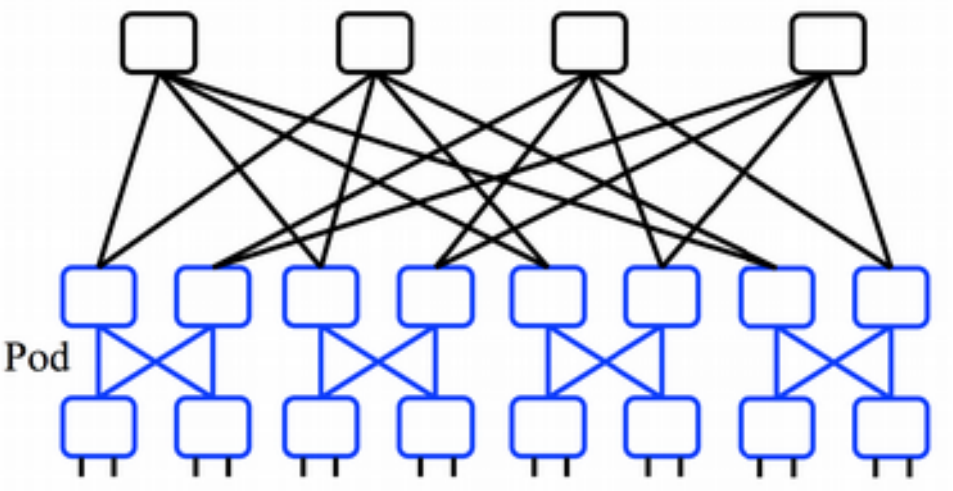
- **Solutions mitigating network incast**
  - A. Reduce TCP's min RTO (often use 200ms >> DC RTT)
  - B. Increase buffer size
  - C. Add small randomized delay at node before reply
  - D. Use ECN with instantaneous queue size
  - E. All of above

Full Bisection Bandwidth

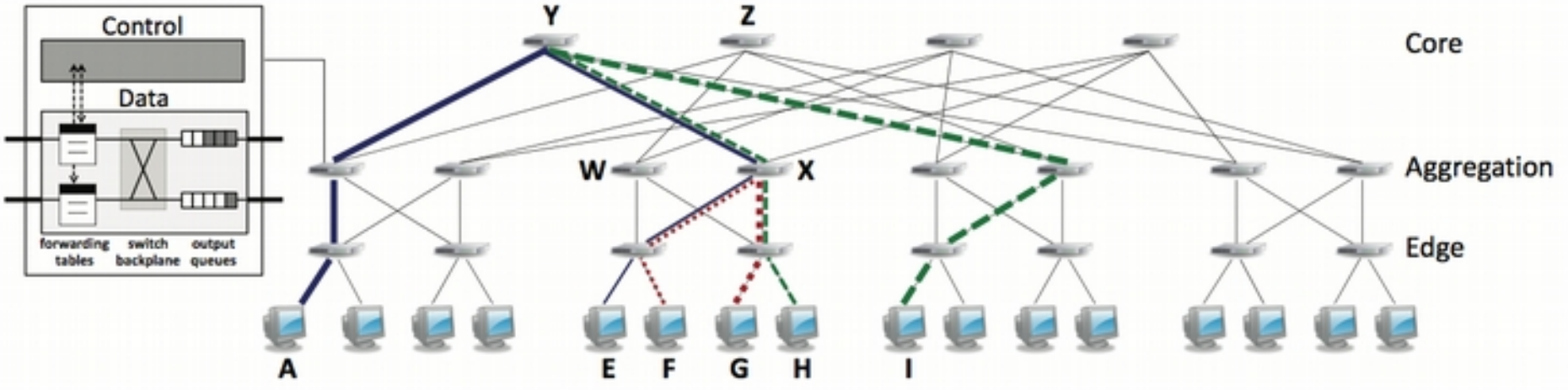
- **Eliminate oversubsc**
  - **Enter FatTrees**
  - **Provide static capa**



- **But link capacity doesn't "scale-up". Scale out?**
  - **Build multi-stag k–port switches**
  - **k/2 ports up, k/2**
  - **Supports $k^3/4$ ho 48 ports, 27,648**



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**

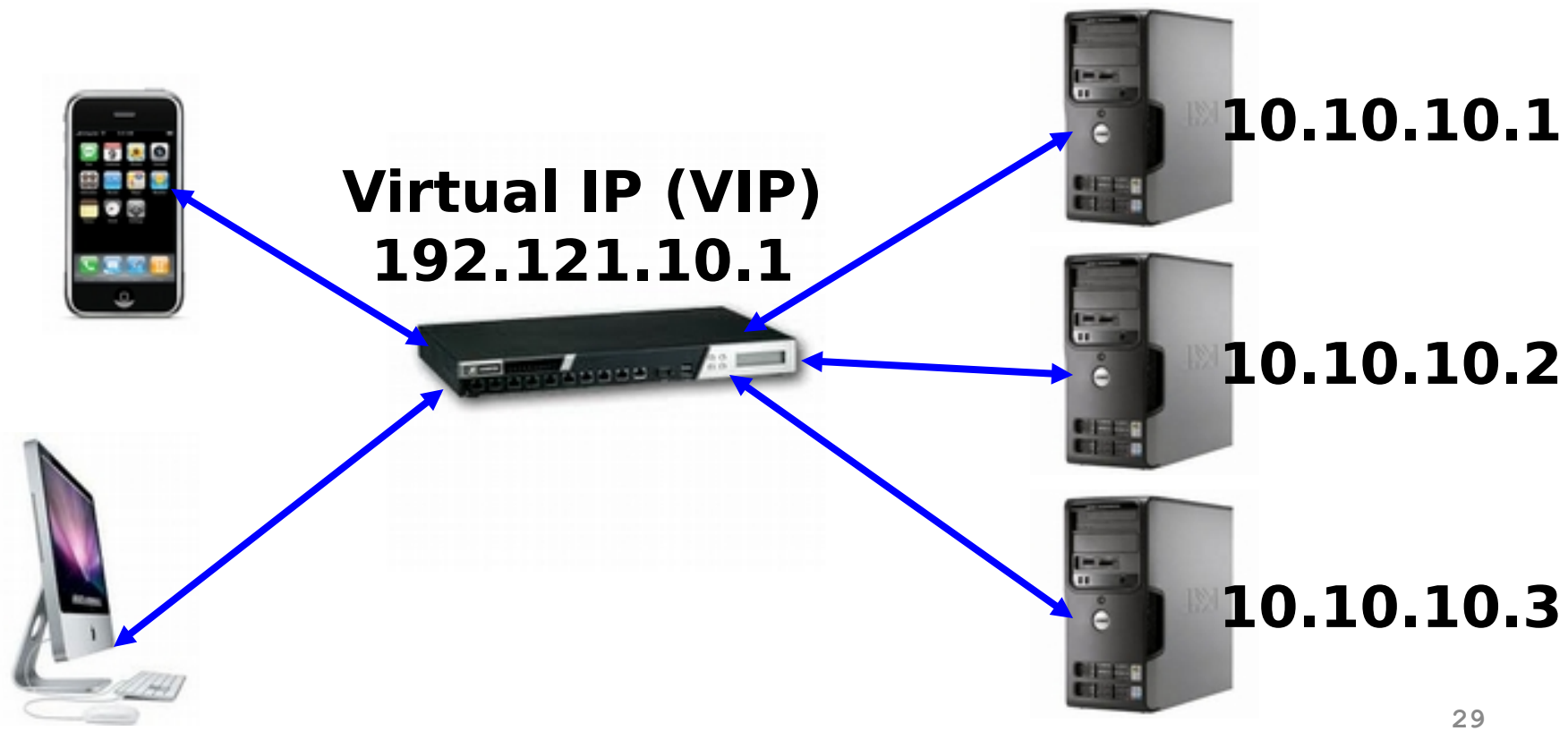
Conclusion

- **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**

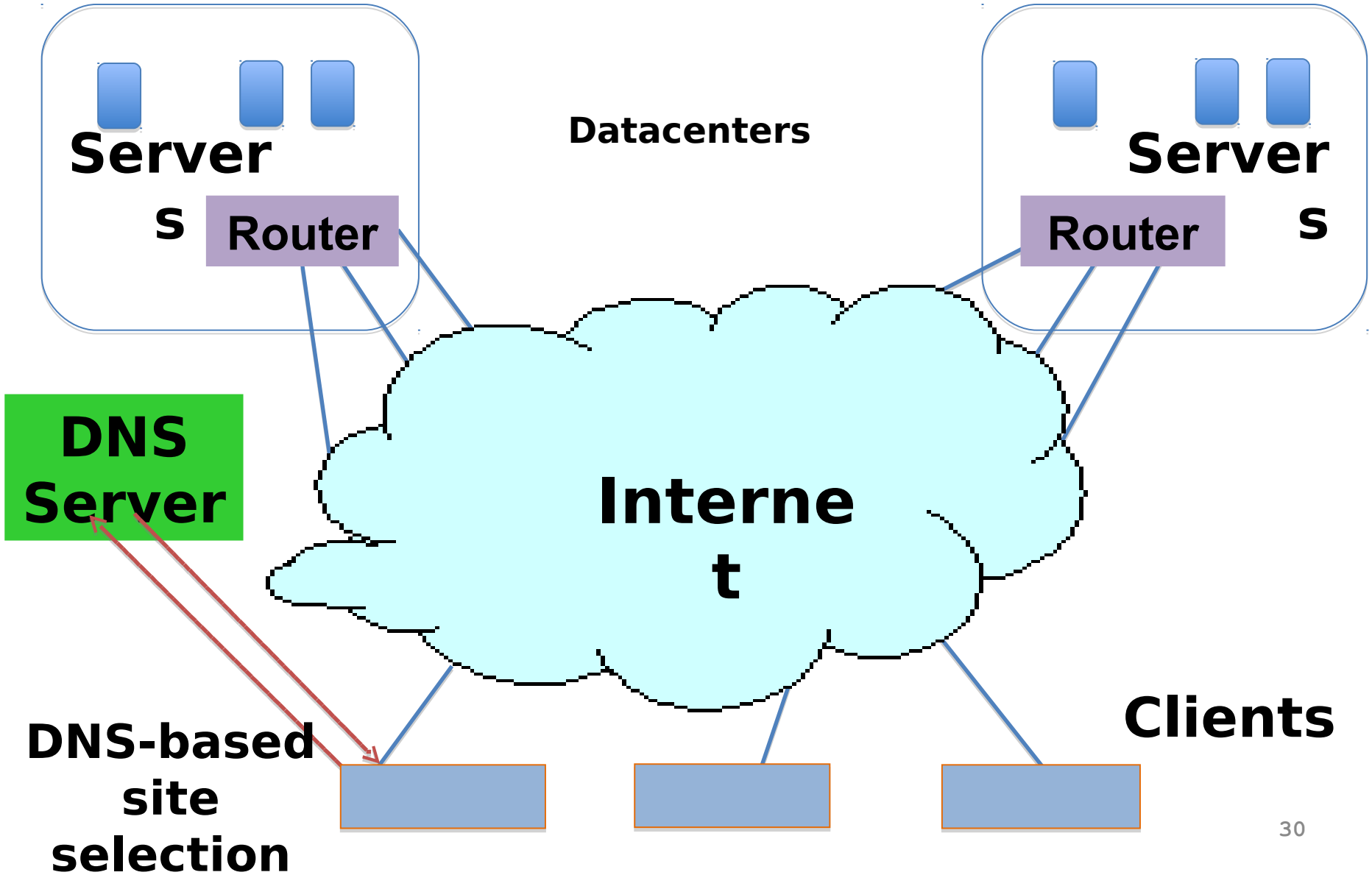
Load Balancing

Load Balancers

- **Spread load over server replicas**
  - **Present a single public address (VIP) for a service**
  - **Direct each request to a server replica**



Wide-Area Network



Wide-Area Network: Ingress Proxies