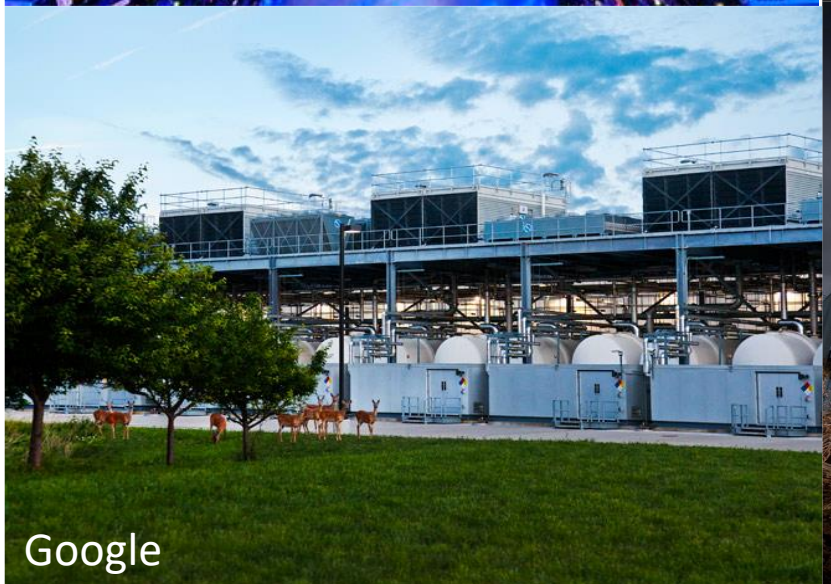
Data Center Network (DCN)

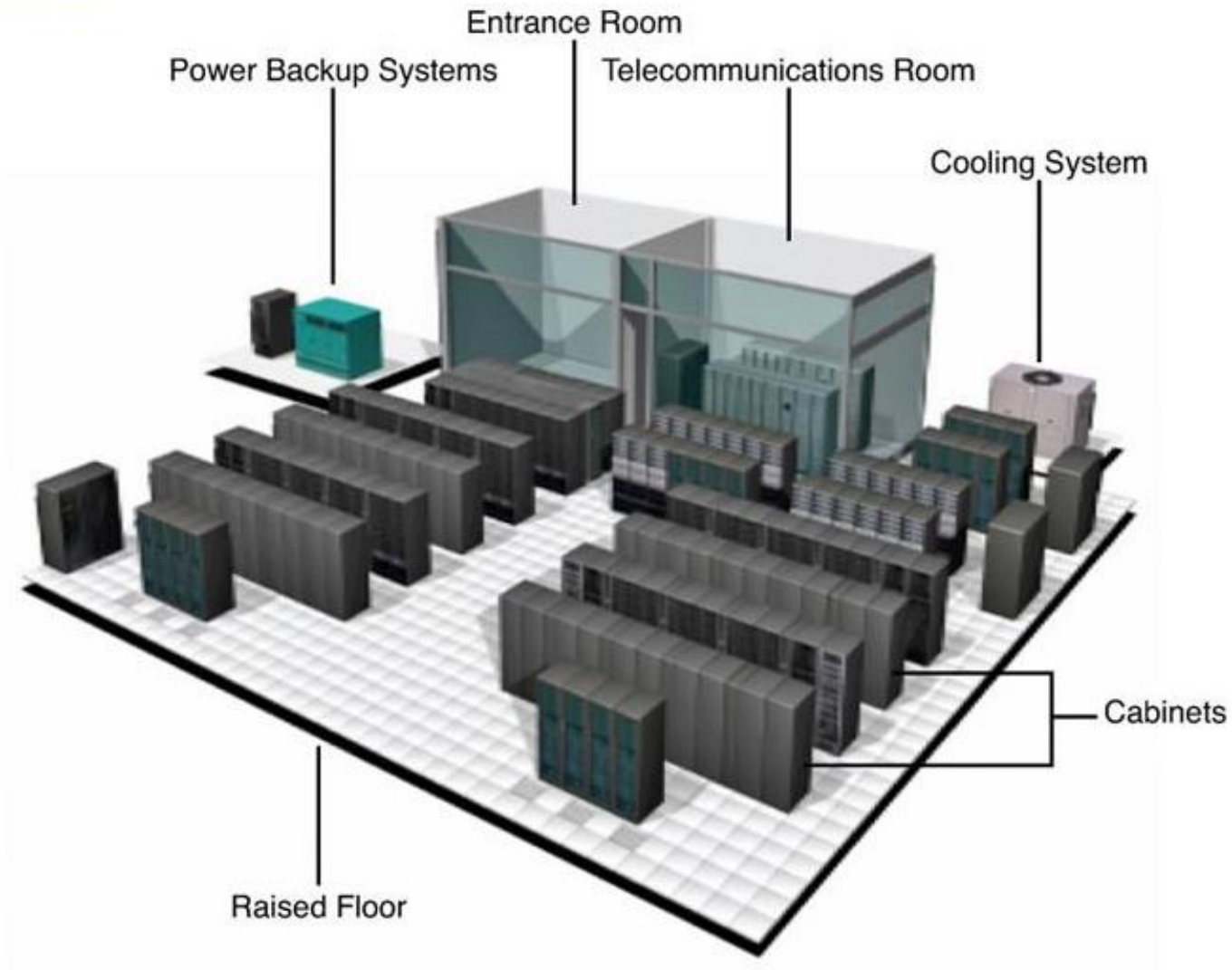
Data Center Network

- Data Center Networks are large clusters of servers interconnected by network switches.
- These servers are used to host applications which provide different concurrent services.
- DCN Usage Scenarios:
  - Compute Intensive: Heavily loaded servers, but low inter-server comm.
    - Ex: HPC
  - Data Intensive: Huge intra-DCN data transfer, but low load at servers.
    - Ex: Video and File Streaming
  - Balanced: Communication links and computing servers are proportionally loaded.
    - Ex: Geographic Information System

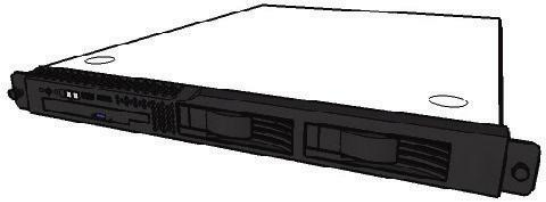
Data Centers with 100,000+ Servers

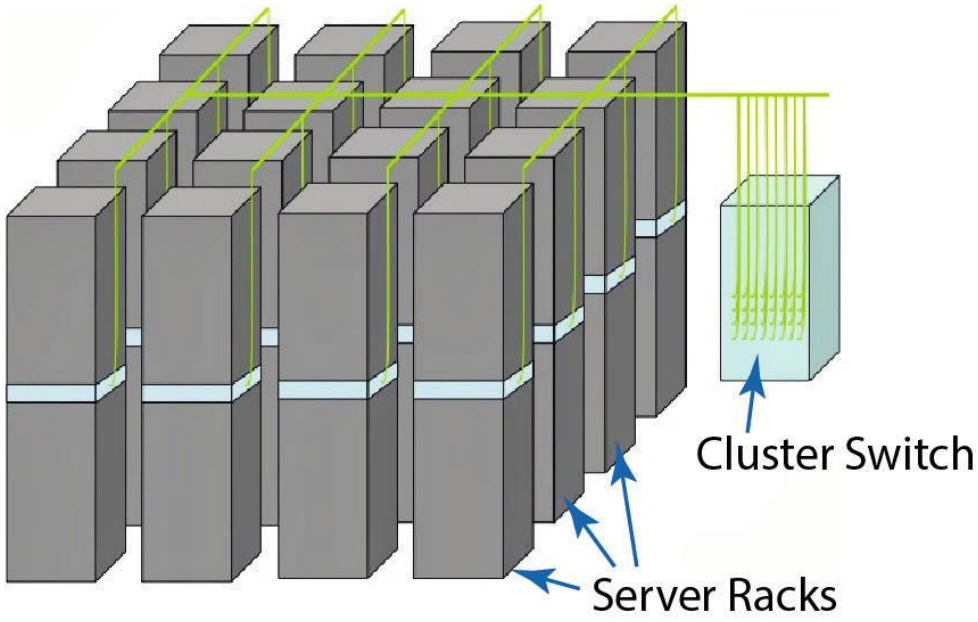


Data Center Physical Layout



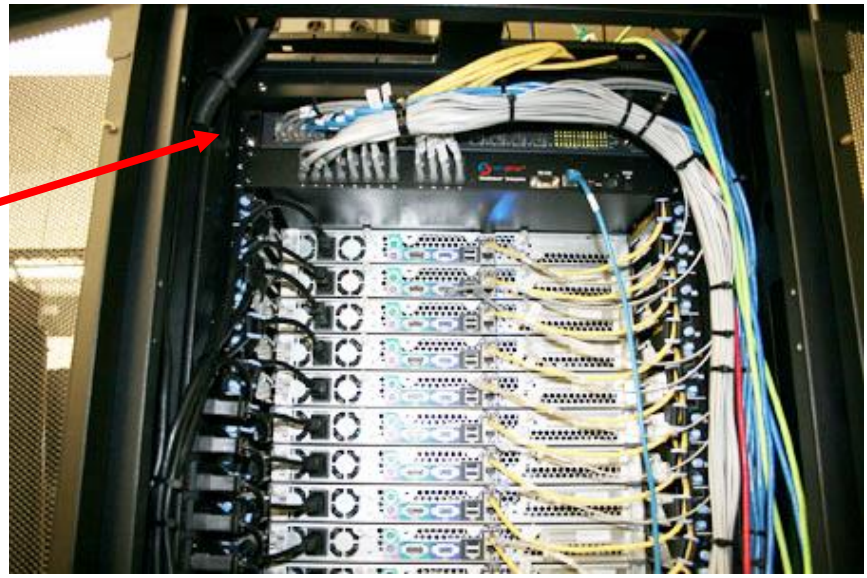
Building Blocks of Modern Data Centers



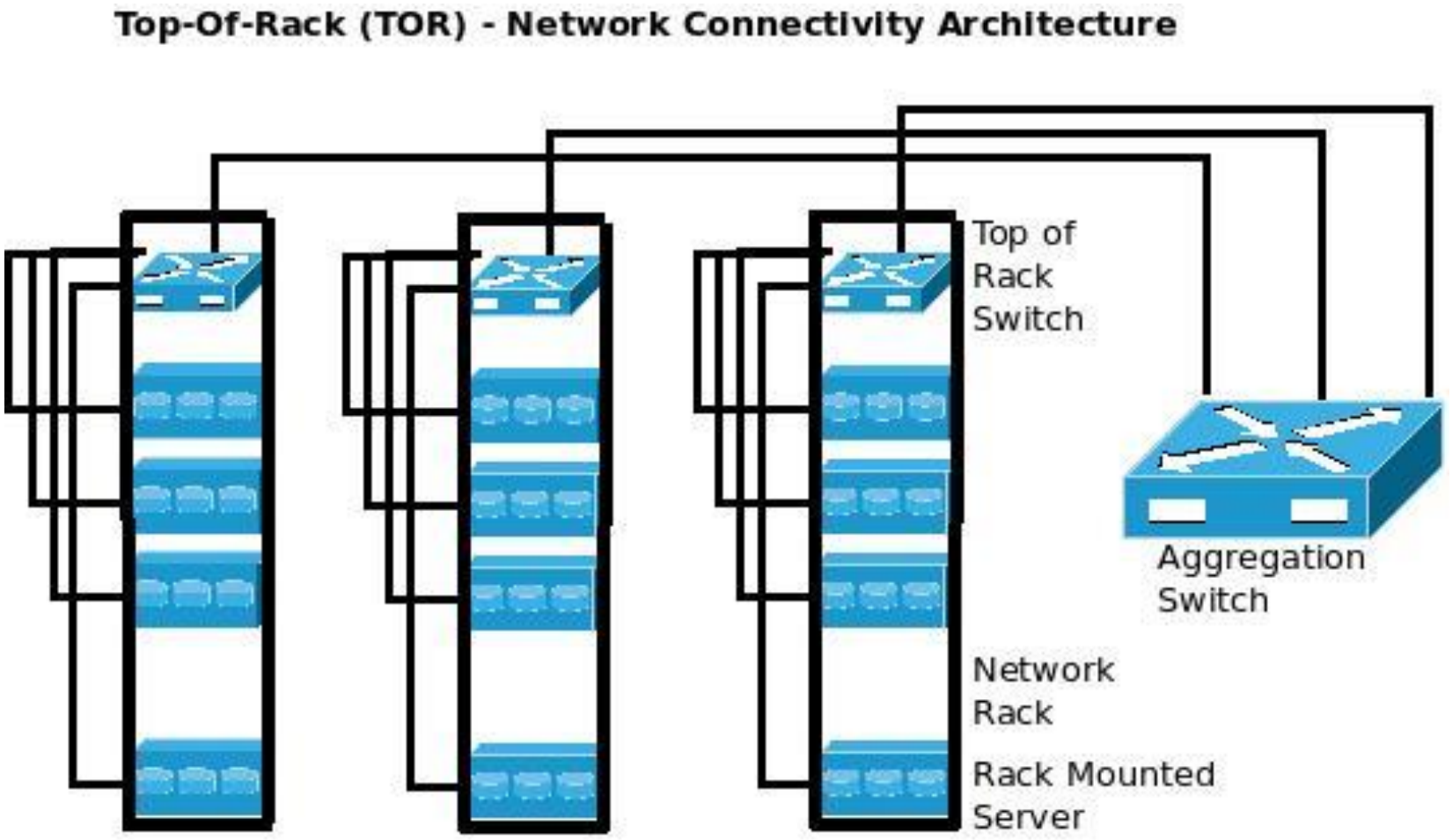


Top-of-Rack Architecture

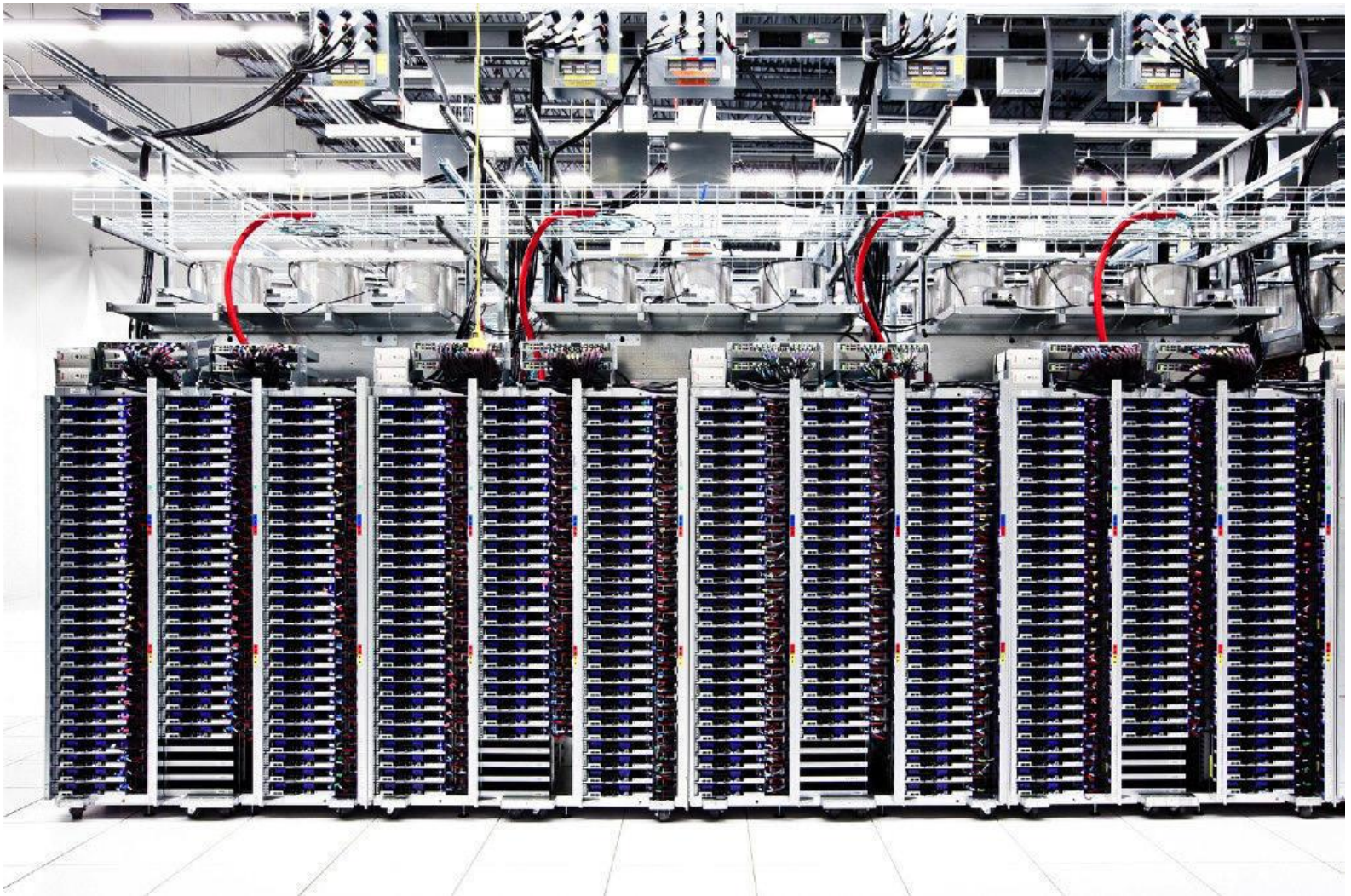
- Rack of servers
  - Commodity servers
  - Top-of-rack switch
- Modular design
  - Preconfigured racks
  - Power, network, and storage cabling
- Aggregate to the next level



Top-of-Rack Architecture



Racks of servers (Google)



Top-of-Rack Architecture (Facebook)

DCN Design Goals

- Availability and Fault tolerance: Multiple paths and replicated servers. Graceful Degradation.
- Scalability: Incrementally increase DCN size as and when needed.
- Low Cost: Lower power and cooling costs.
- Throughput: The number of requests completed by the data center per unit of time. (Compute + Transmission+ Aggregation Time)
- Economies of scale: Utilize the benefits of its huge size.
- Scalable interconnect bandwidth: Host to host communication at full bisection bandwidth.
- Load balancing: Avoid hot-spots, to fully utilize the multiple paths.

Data Center Challenges

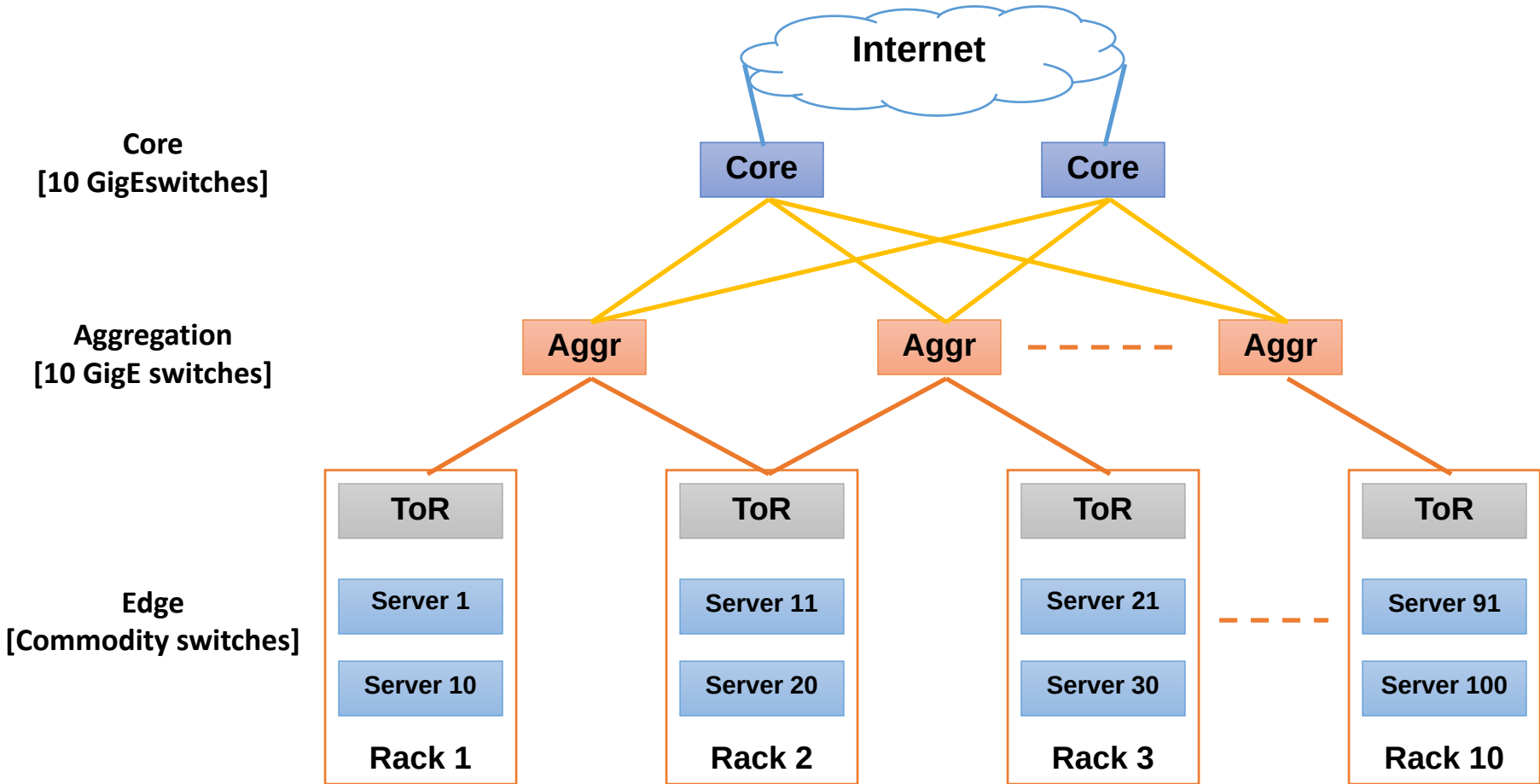
- Traffic load balancing
- Support for VM migration
- Achieving bisection bandwidth
- Power savings / Cooling
- Network management (provisioning)
- Security (dealing with multiple tenants)

Data Center Network Architectures

DCNs need to be scalable and efficient to connect thousands of servers to handle the growing demands of Cloud computing

- Types of Data center network
  - Traditional DCN: Three-tier DCN
  - Fat tree DCN
  - DCell
  - Others
    - BCube, Camcube, FiConn, Jelly fish, and Scafida

Conventional DCN Architecture



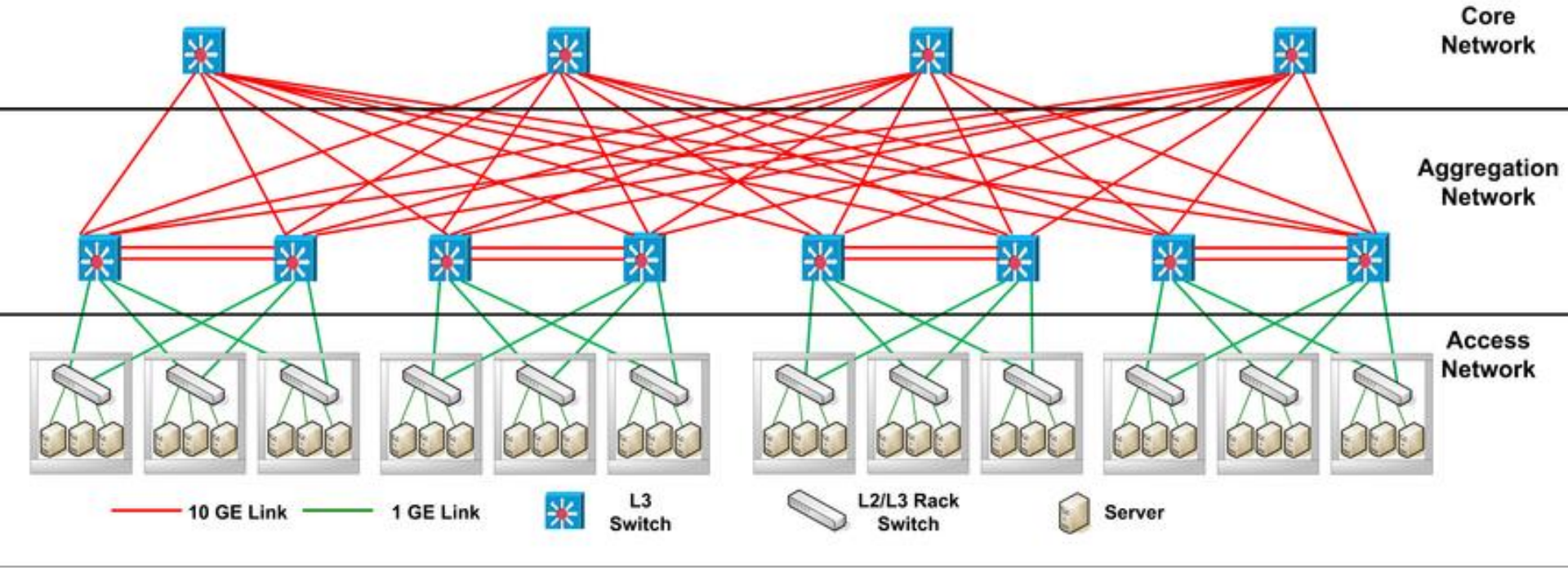
Problem of Traditional Network

- Cost
- Capacity scalability is not enough
- Long development time
- Multi tenant segmentation
- STP (spanning tree) problem
- Configuration difficulty

Three-tier DCN

- Multi-rooted tree based network topology
- 3 layers of network switches
  - Access layer:
  - Aggregate layer: Interconnects multiple access layer switches together
  - Core layer: Responsible for connecting the data center to the Internet
- Major problems
  - Scalability
  - Fault tolerance
  - Energy efficiency
  - Cross-sectional bandwidth
  - Higher layers are highly oversubscribed

Three-tier DCN



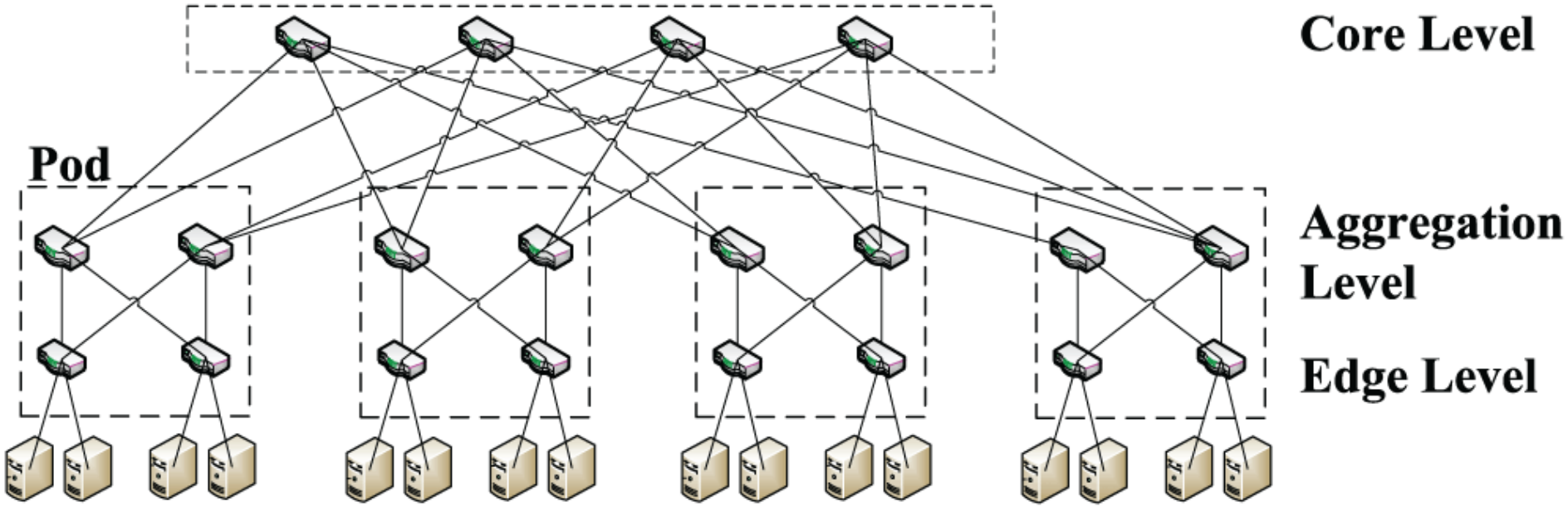
Fat-tree DCN

- Handles the oversubscription and cross section bandwidth problem faced by the three-tier DCN
- 3 layers of network switches
  - Access (Edge) layer:
  - Aggregate layer: Interconnects multiple access layer switches together
  - Core layer: Responsible for connecting the data center to the Internet
- Number of network switches is much larger than the three-tier DCN

Fat-tree DCN

- Advantages:
  - Full Bisection BW: 1:1 Oversubscription ratio
  - Low Cost: Commodity switches
- Disadvantage:
  - Scalability: Maximum number of pods is equal to the number of ports in each switch
  - Agility and Performance Isolation: Not supported

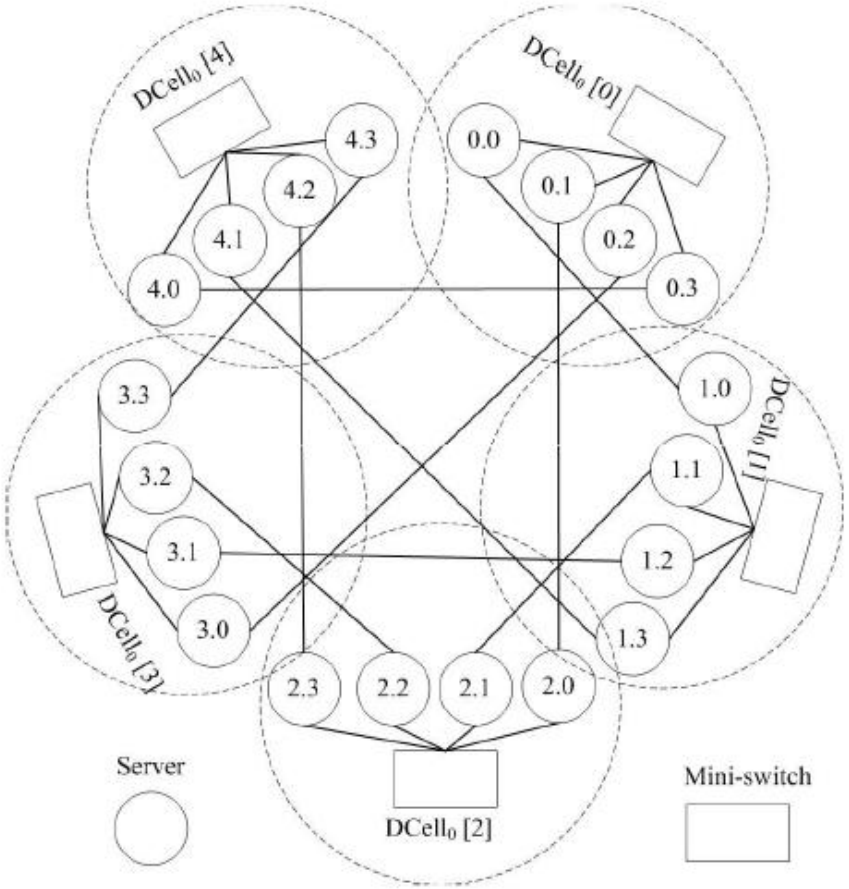
Fat-tree DCN



DCell

- DCell is a server-centric hybrid DCN architecture where one server is directly connected to many other servers
- A server in the DCell architecture is equipped with multiple Network Interface Cards (NICs)
- The DCell follows a recursively build hierarchy of cells

DCell


DCell$_0$ [4]
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DCell$_0$ [1]
DCell$_0$ [3]
DCell$_0$ [2]
4.3
4.2
4.1
4.0
0.0
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3.3
3.2
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2.3
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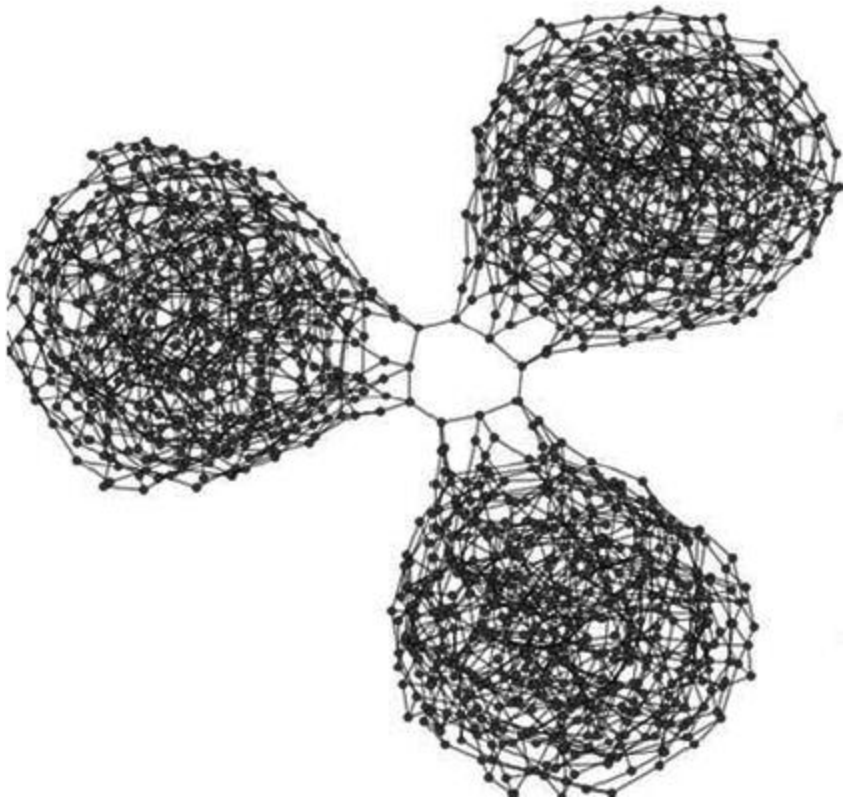
Server
Mini-switch



References

1. Malathi Veeraraghavan, Jogesh K. Muppala. Data Center Networking. IEEE ANTS 2012 Tutorial, 2012.
2. Chuanxiong Guo, Haitao Wu, Kun Tan, Lei Shiy, Yongguang Zhang, Songwu Lu. DCell: A Scalable and Fault-Tolerant Network Structure for Data Centers. Proceedings of the ACM SIGCOMM 2008 conference on Data communication, 2008. pp. 75-86.
3. Ankita Mahajan. Data Center Network Architecture.
4. Raj Jain. Data Center Network Topologies. Washington University in Saint Louis. 2013.
5. George Porter. Data Center Fundamentals: The Datacenter as a Computer. CSE 124, February 3, 2015.
6. Raj Jain. Protocols for Data Center Network Virtualization and Cloud Computing. Tutorial at 19th Annual International Conference on Advanced Computing and Communications (ADCOM) 2013, Chennai, India October 21, 2013.
7. Yuh Cheng. 從企業網路到大型數據中心的變革– 對交換機 IC 架構設計的影響. NTHU, Dec 13, 2016.