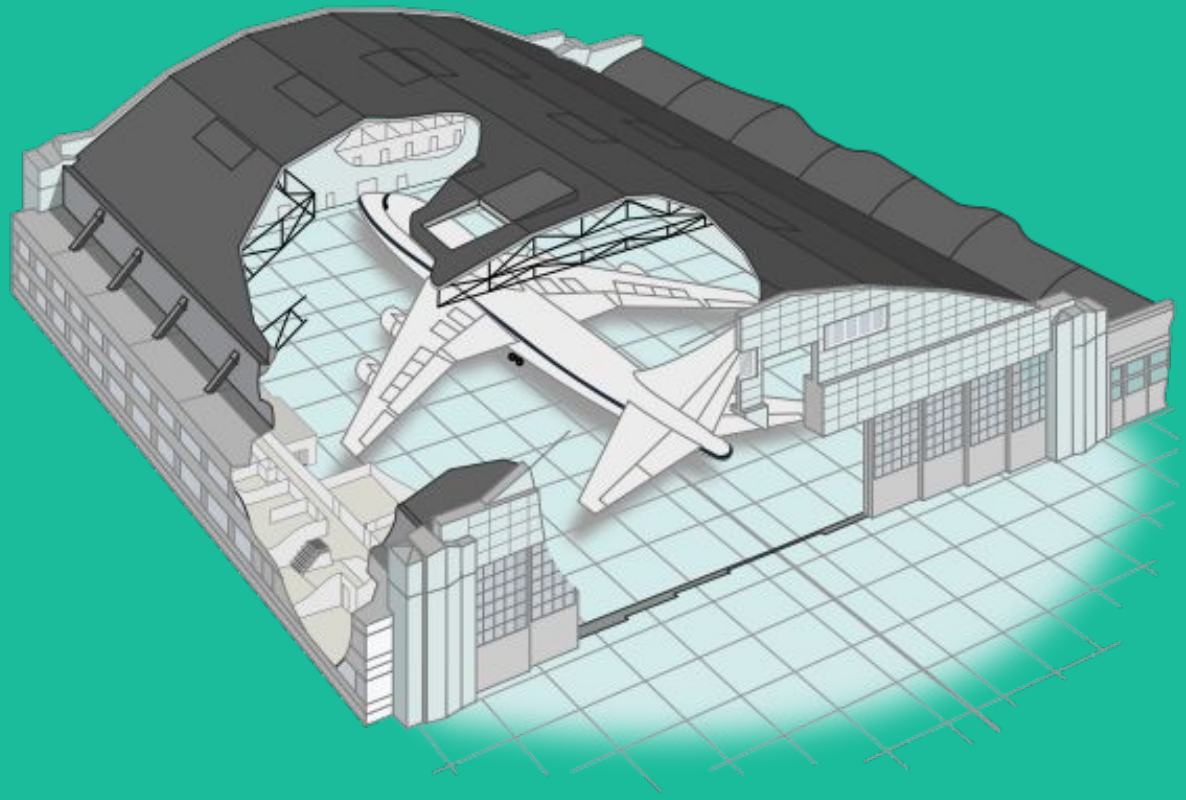
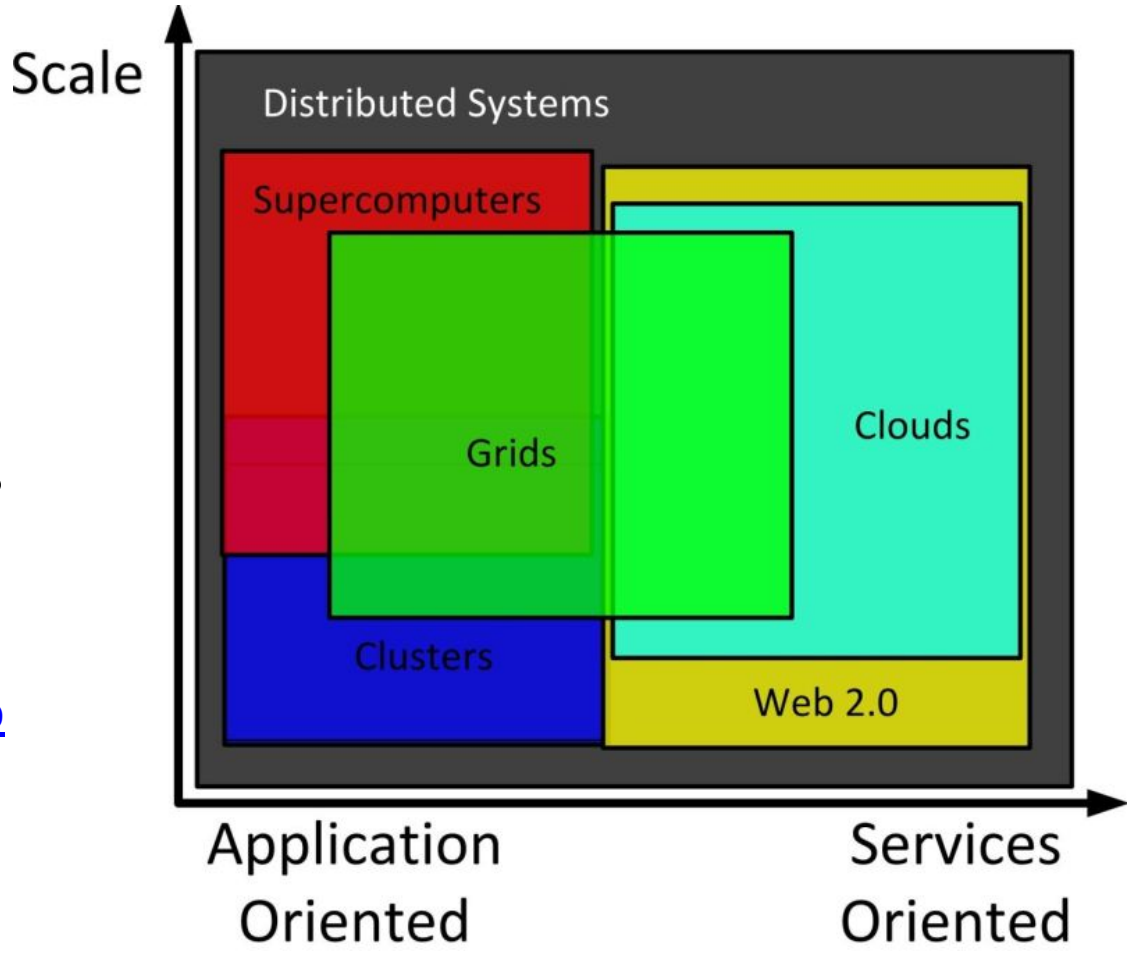


Chapter 6. Anatomy of a Data Center

Bilkent University | CS443 | 2020, Spring | Dr. Orçun Dayıbaş

Introduction

- **Grid computing vs. Cloud computing**
  - Clusters
    - Computer clusters with commodity hardware & software
  - Supercomputers / HPCs
    - Clusters with highly customized hardware & software
    - https://www.top500.org/resources/top-systems/
  - Grids
    - Generally multiple clusters
    - Typically loosely coupled, heterogeneous, and geographically dispersed



Source: https://arxiv.org/pdf/0901.0131.pdf

Introduction

- **Data Center**
  - Definition: a physical facility that is used to house critical applications and data of an organization.
  - Modern data centers are very different than they were just a short time ago (Specific HW → Software-defined X/Y/Z).
    - Infrastructure has shifted from traditional on-premises physical servers to virtualized infrastructure.

Introduction

- **Core Components**
  - Physical infrastructure
    - Location, DC facility
    - Power subsystems, uninterruptible power supplies (UPS), ventilation, cooling systems, fire suppression, backup generators, and connections to external networks.
  - Network infrastructure
    - This connects servers (physical and virtualized), data center services, storage, and external connectivity to end-user locations.
  - Storage infrastructure
    - Data is the fuel of the modern data center. Storage systems are used to hold this valuable commodity.
  - Computing resources
    - Applications are the engines of a data center. These servers provide the processing, memory, local storage, and network connectivity that drive applications.

Physical Infrastructure

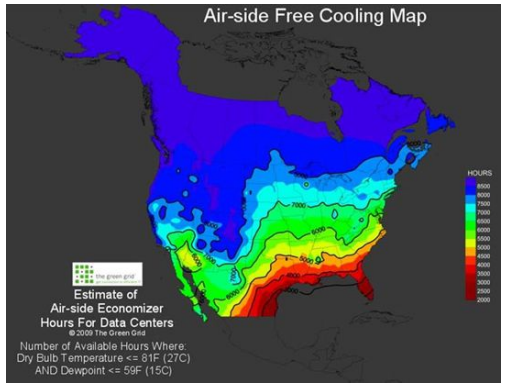
- **Building & Location**
  - It is important because it will affect the efficiency
  - Yahoo “Chicken Coop” DC design
  - Barcelona’s Mare Nostrum “Divine Data Cruncher” DC

Physical Infrastructure

- **Building & Location**
  - Microsoft Dublin DC
  - On average, half of the power consumed in a DC is used for cooling
    - Dublin = free cooling ;)
    - What is the best DC location on earth?

Physical Infrastructure

- **HVAC Systems**
  - AC, Liquid Cooling, Air Side Economizers, etc.
- **UPS (Uninterruptible Power Supply)**
  - Provides power to avoid outages during power failure lasting seconds or minutes
  - Provides time to shutdown, failover, or initiate backup power for longer outages
- **PDU (Power Distribution Unit)**
  - Transforms the voltage to std. voltage for distribution
  - Provides power monitoring/conditioning



Physical Infrastructure

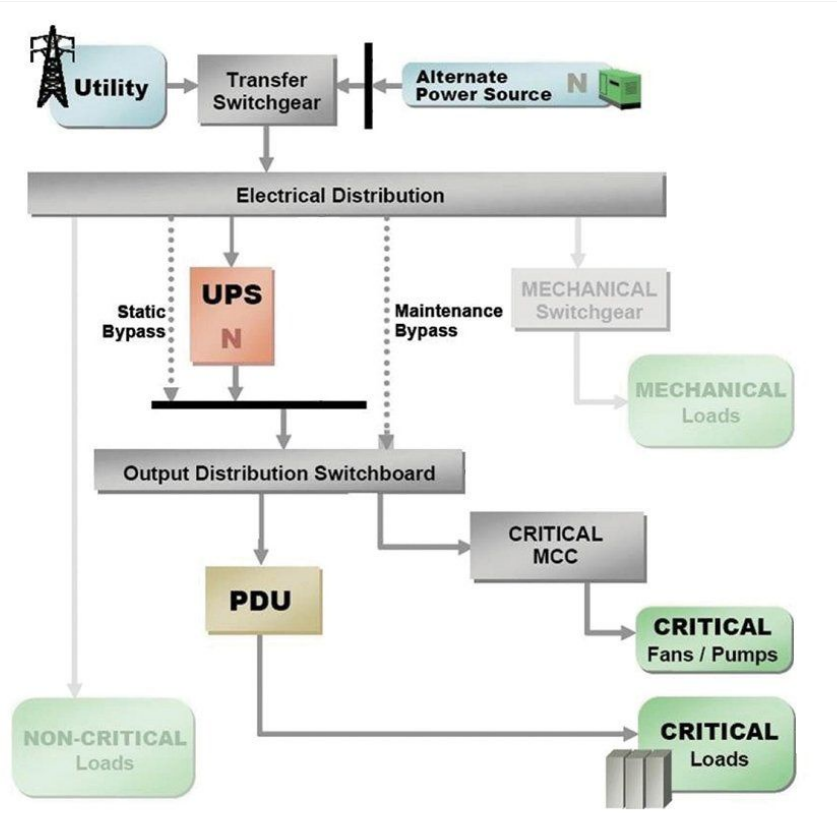
- **ANSI/TIA-942 Certification**
  - It is a standard issued by a non-profit organization (+TIA is accredited by ANSI)
  - The standard is publicly available & transparent
  - The standard covers all aspects of the physical data center including site location, architecture, security, safety, fire suppression, electrical, mechanical and telecommunication
  - Three types of certification:
    - ANSI/TIA-942 Design Certification
      - Design documents are reviewed for conformity
    - ANSI/TIA-942 Site Certification
      - Facility is physically inspected for conformity
    - ANSI/TIA-942 Ready
      - A modular DC (e.g. pre-fabricated DC or container) design is inspected for conformity
      - Assurance of the indicated “rating level” when DC placed in the appropriate environment

Physical Infrastructure

- **ANSI/TIA-942 Certification**
  - Rating Levels
    - **Rated-1 (Basic Site Infrastructure):** A data center which has **single capacity components** and **a single, non-redundant distribution path**
    - **Rated-2 (Redundant Capacity Component Site Infrastructure):** A data center which has **redundant capacity components** and a **single, non-redundant distribution path** serving the computer equipment.
    - **Rated-3 (Concurrently Maintainable Site Infrastructure):** A data center which has **redundant capacity components** and **multiple independent distribution paths** serving the computer equipment.
    - **Rated-4 (Fault Tolerant Site Infrastructure):** A data center which has **redundant capacity components** and **multiple independent distribution paths** serving the computer equipment which all are active. The data center allows concurrent maintainability and one (1) fault anywhere in the installation without causing downtime.
  - These rating levels are commonly called as “Tiers” (a business jargon)

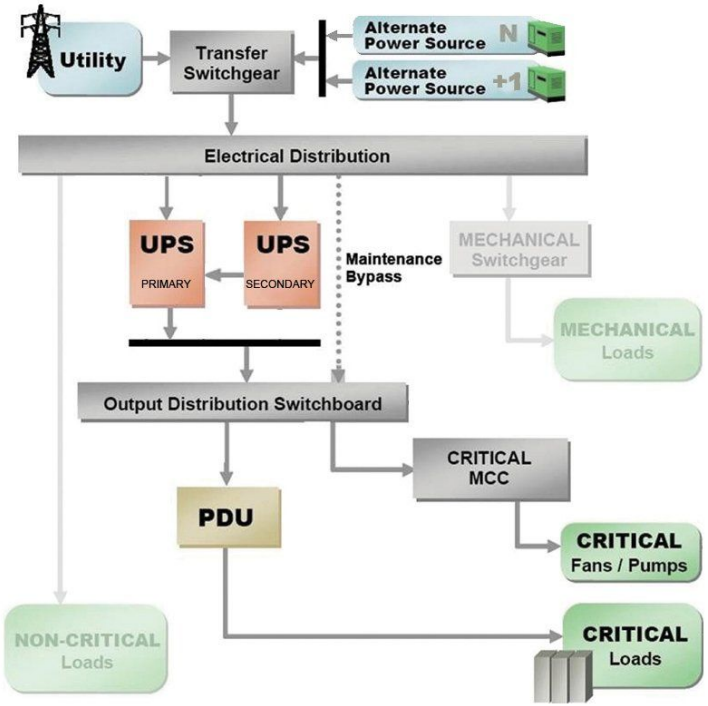
Physical Infrastructure

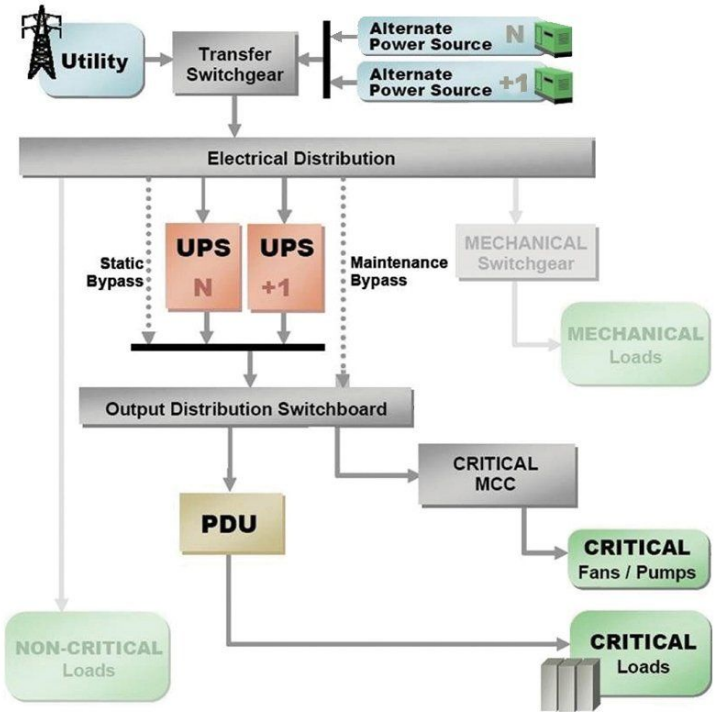
- **Tier-1 Data center**
  - A basic server room
  - Non-redundant capacity components (single uplink, single power path, etc.)
  - **Ex:** UPS (Unint. Power Supp.)
  - Pros
    - Cost effective
    - Easy to implement
    - Small footprint
    - Uncomplicated
  - Cons
    - Has many single points of failure, which means the system is only as reliable as its weakest point



Physical Infrastructure

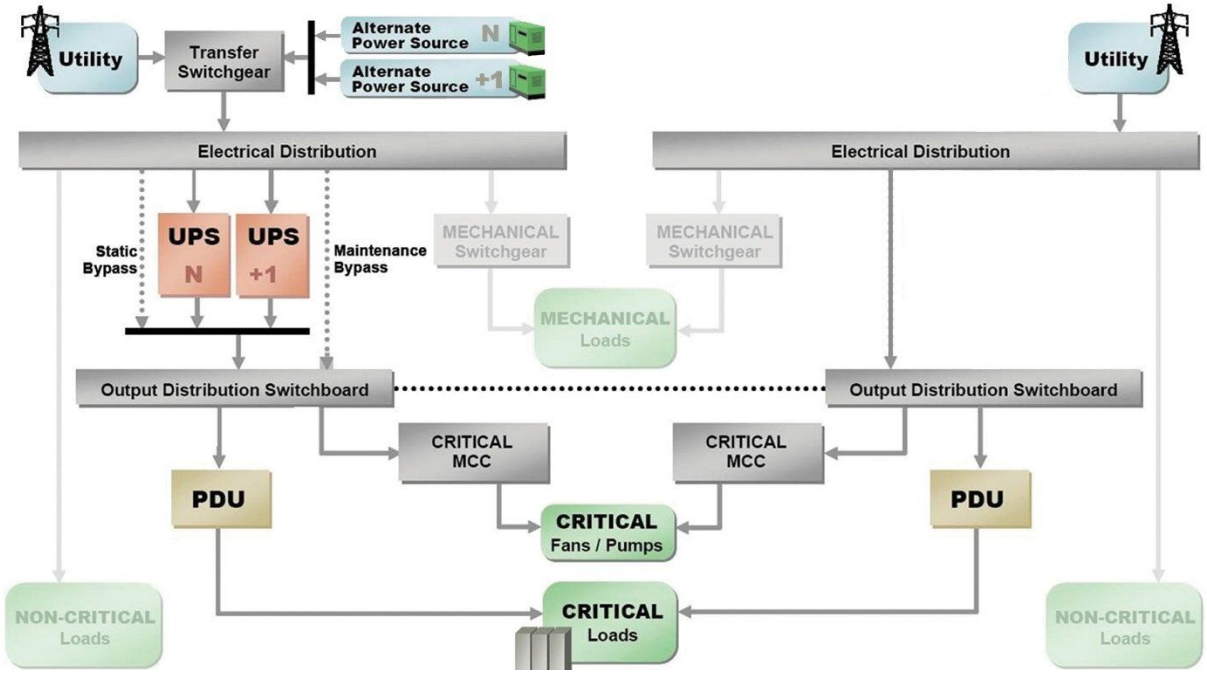
- **Tier-2 Data center**
  - Tier-1 + redundant capacity components
  - **Ex:** UPS redundancy (2 configuration alternatives)
    - Isolated Redundant (Hot Standby)
    - Parallel Redundant





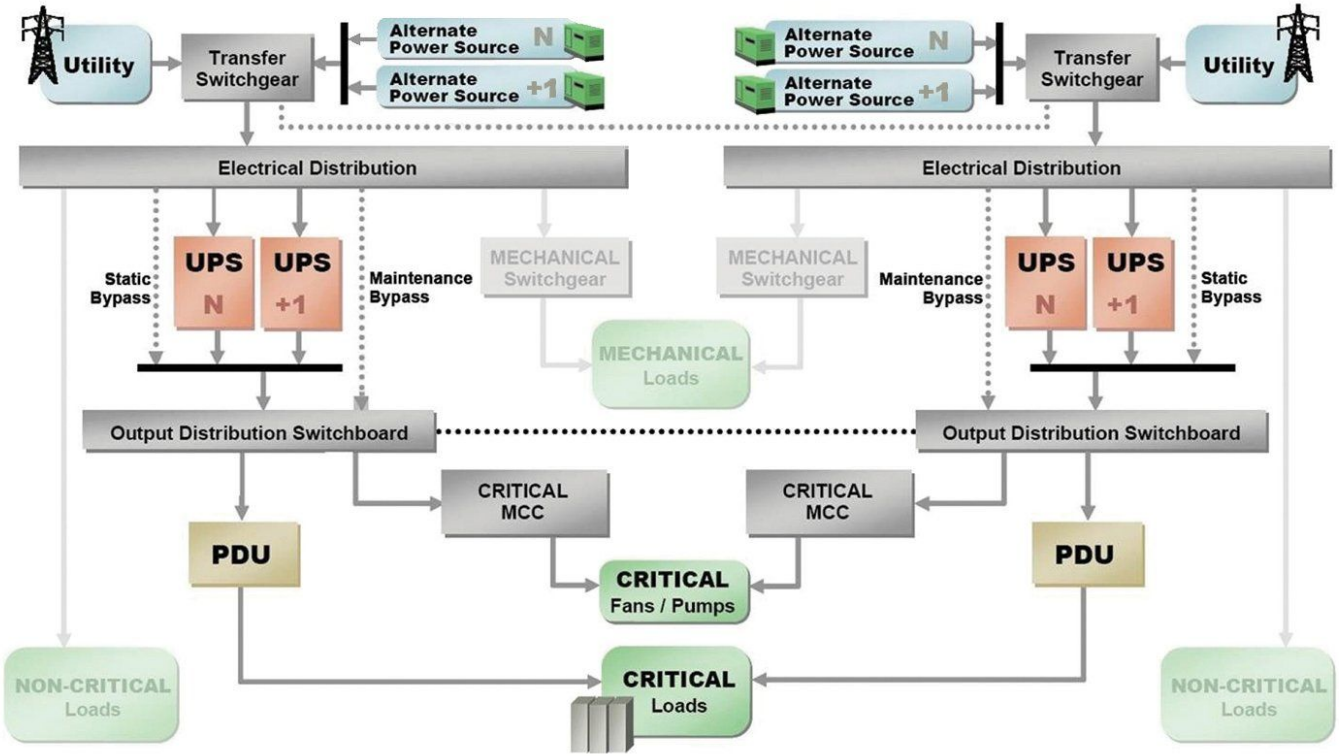
Physical Infrastructure

- **Tier-3 Data center**
  - Tier-2 + Dual-powered equipment & multiple uplinks
  - Offers redundancy (N + 1) as well as several sources of cooling and power
  - **Ex:** UPS redundancy



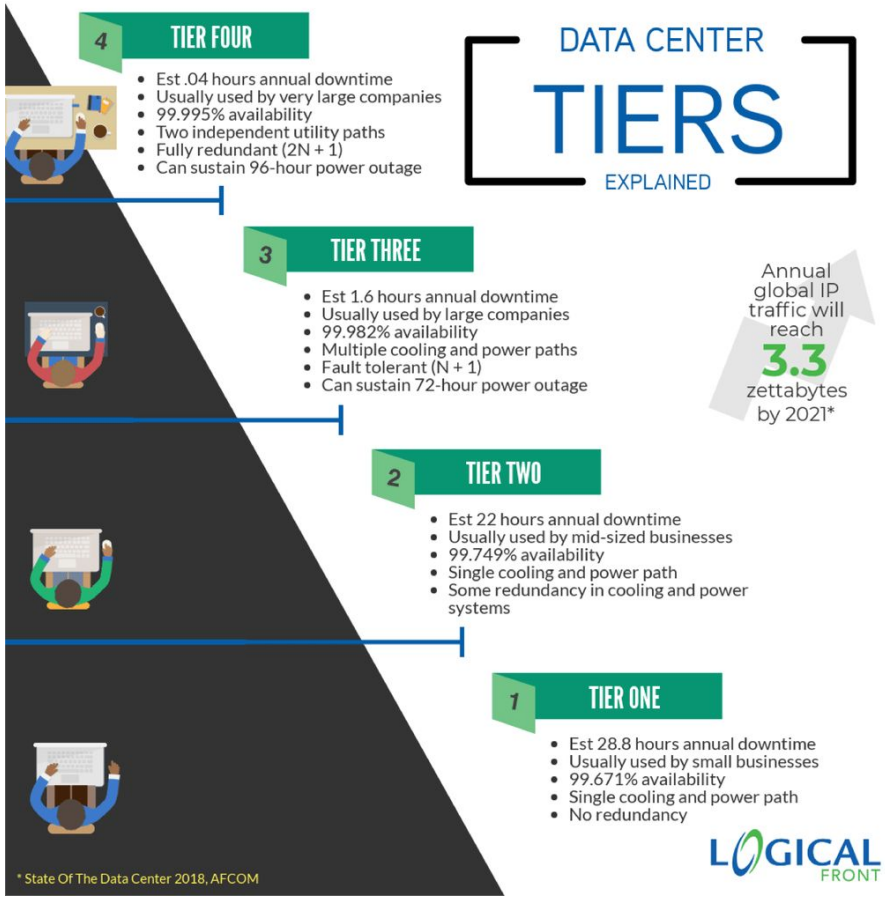
Physical Infrastructure

- **Tier-4 Data center**
  - All components are fully fault tolerant (e.g. uplinks, servers, storage, HVAC system)
  - Fully redundant (2N + 1) and can sustain a 96-h power outage
  - **Ex:** UPS redundancy



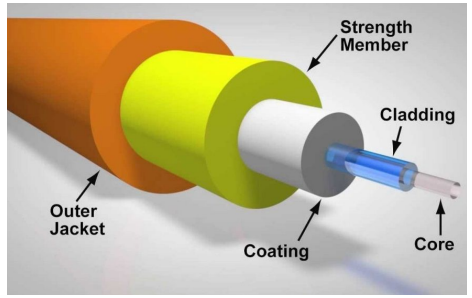
Physical Infrastructure

- **Comments**
  - Companies that don't have real-time product sales/services generally use Tier 1 and 2 DCs.
  - Larger companies, or those with advanced software and requirements will use Tier 3 and 4 centers.
  - Tier 4 data centers offer the best features and highest level of protection available.
    - They are a must-have for any company that simply can't afford downtime.
    - Boasting a **99.99% availability**→ only down for an average of **26.3 min/year**.



Network Infrastructure

- **Cabling**
  - Copper Cables (Coaxial, Twisted Pair)
    - Pros: Cost-efficient (2-5x less), less power (+req. less cooling), high MTBF
    - Cons: Limited reach (7-10m)
  - Fiber Cables
    - Pros: No shielding (less bulky), higher bandwidth, very low attenuation (Good reach)
    - Cons: Cost, reliability (lower MTBF), diff. to install

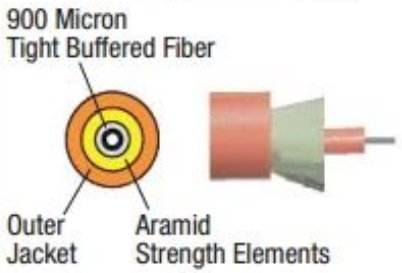
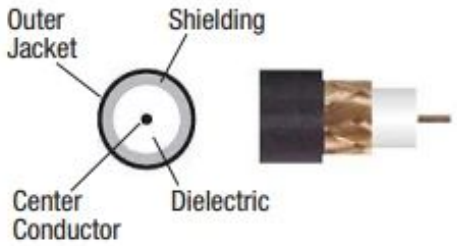


Communication Standard	Application	Cable Type	Connector Type
Fiber Optic	High-Speed Ethernet	Multimode (High-bandwidth, Short Distance) Single Mode (High-speed, Long Distance)	LC, SC, ST, FDDI, MTP, MTRJ, FC, etc.
Fiber Channel	High Speed Ethernet	Twinaxial or Fiber	Infiniband, QSFP, SFP+, 10G - CX4,LC, SC, ST
40 or 100Gbps	40 or 100Gig Ethernet	Cat7a	GG45, TERA
10Gbps (10GBase-T)	10Gig Ethernet	Cat 6a, Cat7, Cat7a	RJ45, GG45, TERA
1000Mbps (Gigabit or 1000Base-T)	Gigabit Ethernet	Cat 5e, Cat 6, Cat 6a, Cat7, Cat 7a	RJ45
10/100Mbps (100Base-TX)	Ethernet	Cat 5e, Cat 6, Cat 6a, Cat7, Cat 7a	RJ45

SMARTECH cables

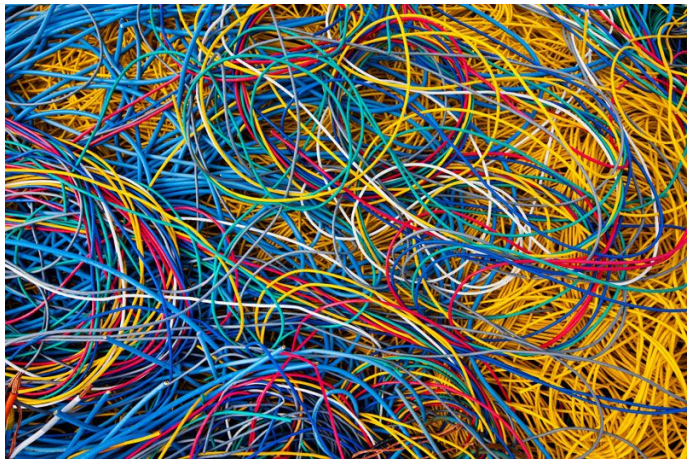
Network Infrastructure

- **Cabling**

Type:	Fiber Optic Cabling	Unshielded Twisted Pair Cabling (Copper)	Coaxial Cabling (Copper)
			
Typical Bandwidth:	<10 GHz	<100 MHz (cat 5E)	<1 GHz (RG6)
Typical Use:	Data communication Broadcast	Structured wiring in local area networks	Cable TV / Broadcast Test and instrumentation
Benefits:	Most bandwidth. Fastest transmission speeds. Immune to EMI/RFI.	Inexpensive, relatively easy to install and terminate	Inexpensive, relatively easy to install and terminate. Can span longer distances than UTP.
Limitations:	Difficult to terminate. Most expensive cost / foot.	Maximum distance of 100m. Can be affected by EMI/RFI.	Can be affected by EMI/RFI.

Network Infrastructure

- **Cabling**
  - Attenuation
    - Fiber only loses 3% of the signal over distances greater than 100 meters, compared to copper's 94% loss of signal
  - Copper (in cabinet) and fiber (inter cabinet) makes a good couple
  - Design in advance and leave room for expansion
    - Unstructured vs. structured cabling



Network Infrastructure

- **Cabling**
  - Cabling under raised floor provides better cooling

Network Infrastructure

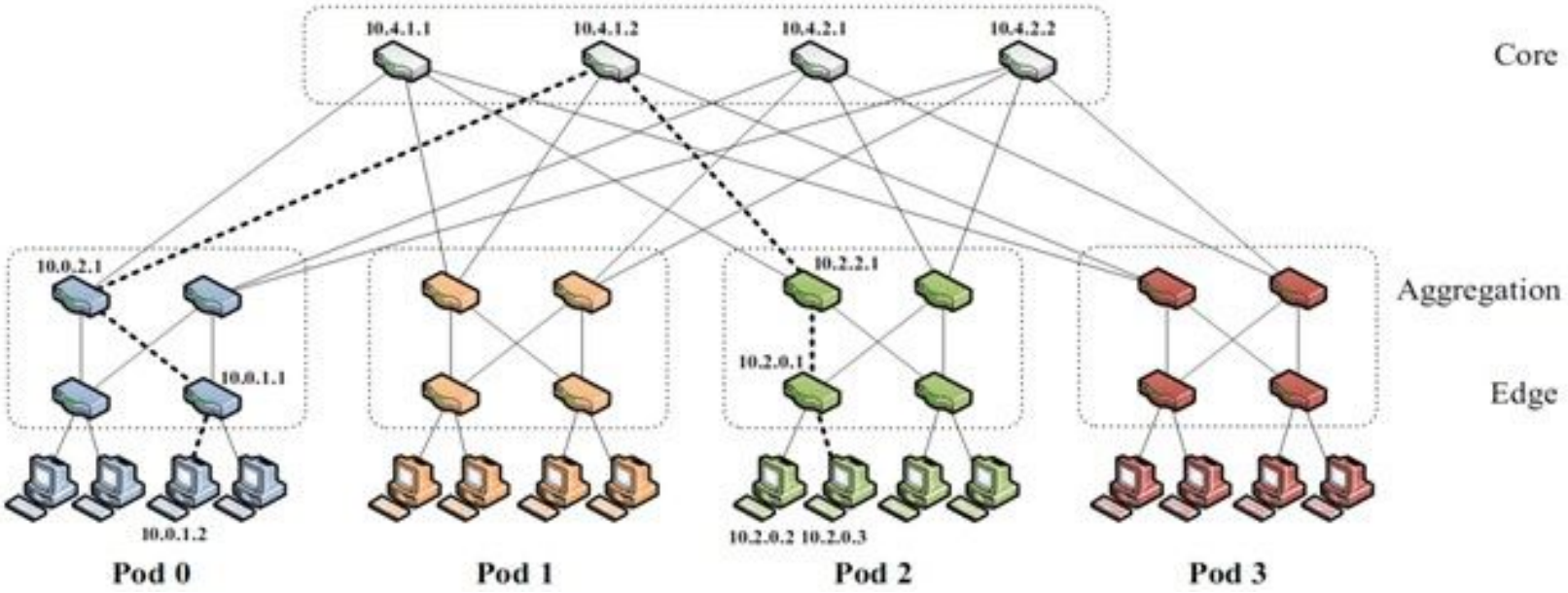
- **Connectivity**
  - Having multiple connectivity options provides a great deal of redundancy, ensuring that the facility will almost always have access to the outside internet
- **Routers & Switches**
  - **Edge (Access) router:** the gateway connecting the local network to the external, wide area network (WAN)
    - All data packets coming into a network must go through the edge router
    - Since the inbound data is coming from a wider array of sources, this router needs **to be able to filter, queue, and police everything** before it can be directed to the network's core routers
    - Ultimately responsible for the security of the network (first point of contact)
  - **Core router:** responsible for directing data traffic within a network
    - They are designed with high-speed interfaces to forward traffic through the network as quickly as possible

Network Infrastructure

- **Routers & Switches**
  - **Core router**
    - Since these devices manage traffic inside the data center networking architecture, they're more accurately described as **switches**.
    - This collection of core switches is called **the aggregation level** because they direct all traffic within the data center environment.
    - When data needs to travel between servers that aren't physically connected, it must be relayed through **the core switches**.
  - **PoD (Point of Delivery):** a module of network, compute, storage, and application components that work together to deliver networking services
    - Since individual servers communicating with one another would require **a huge list of addresses** for the core to manage and **compromise speed**, data center networks avoid this problem by connecting batches of servers to a second layer of switches.
    - These groups are called "pods" and encode data packets in such a way that **the core only needs to know which pod to direct traffic toward** rather than handling individual server requests.

Network Infrastructure

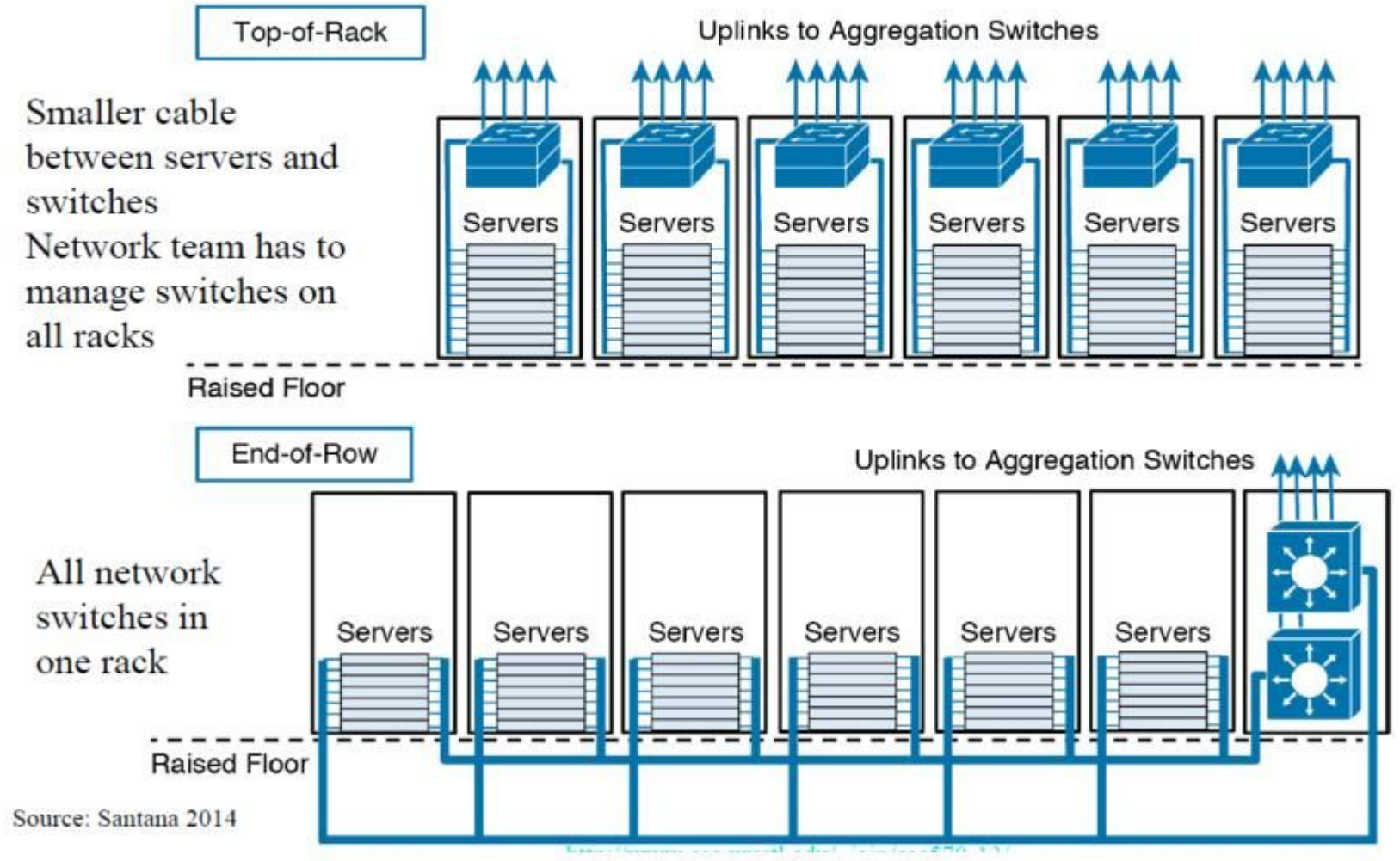
- **Routers & Switches**
  - Ex: K-ary Fat tree topology (3 layer: core, agg., edge)



- each pod consists of $(k/2)^2$ servers & 2 layers of k/2 k-port switches
- each edge switch connects to k/2 servers & k/2 aggr. switches
- each aggr. switch connects to k/2 edge & k/2 core switches
- $(k/2)^2$ core switches: each connects to k pods

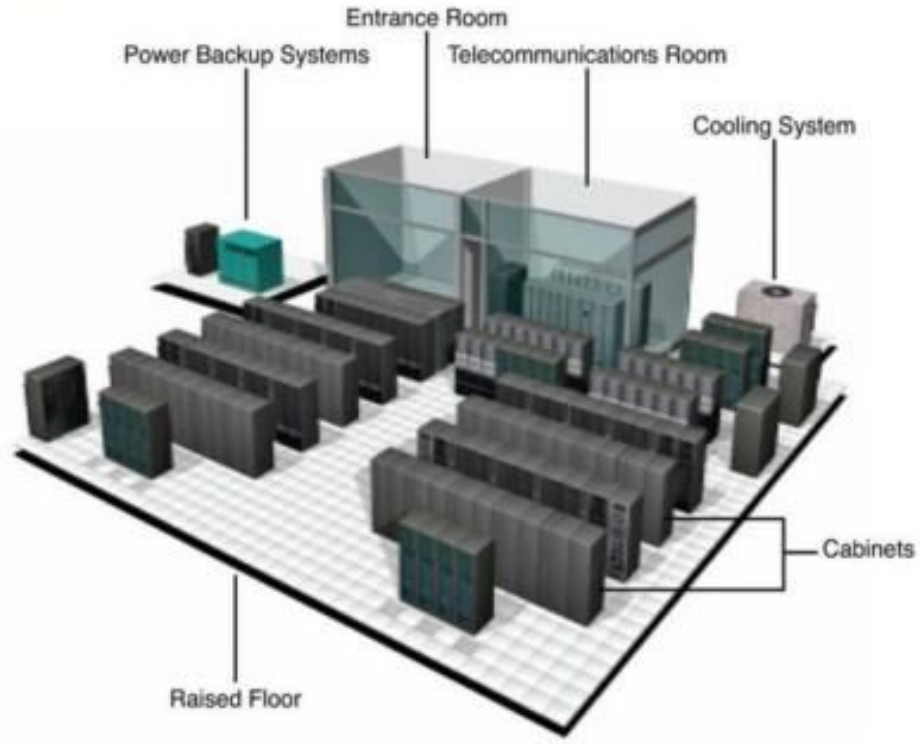
Network Infrastructure

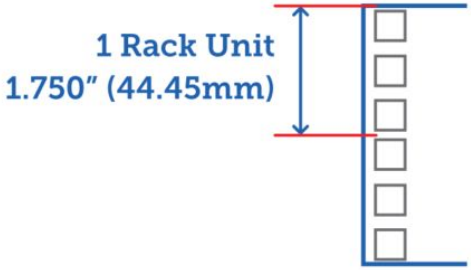
- **Switch locations**



Network Infrastructure

- **Servers**
  - Generally housed in rack cabinets
  - “RU”/”U”/“Rack Unit” is used to measure rack spaces





Storage Infrastructure

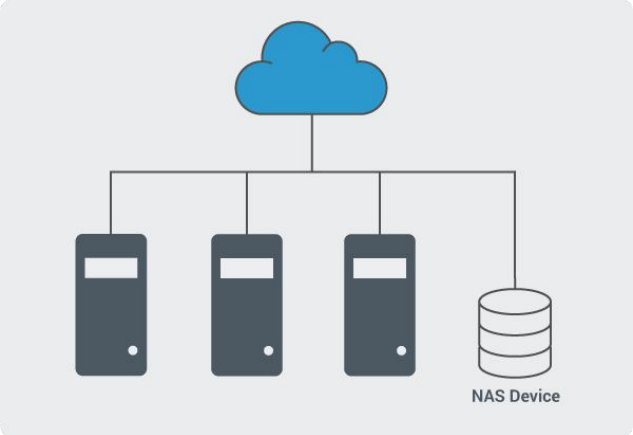
- **Network-based Data Storage**
  - NAS (Network Attached Storage)
    - NAS is a data storage device connected to a network providing data access to clients. At its base, it is built with SAS/SATA disks arranged in a RAID; it is then attached to devices over ethernet
    - NAS is a highly specialized file server and NAS only does storage
    - Typically, file sharing protocols (e.g. NFS, SMB or AFP) are used to implement a NAS solution
    - **Pros**
      - **Consolidated security:** a single system for file storage and distribution
      - **Simple architecture:** NAS is built just like a desktop or server. A simpler architecture means simplified management. Fewer moving parts equal fewer potential points of failure. This also means that using a NAS does not require any changes to your existing network architecture
      - **Inexpensive:** Although prices naturally vary based on the size and quality of the NAS, as a general rule of thumb a NAS is an affordable solution
      - **Specialization:** The very fact that a NAS does nothing but storage makes it more reliable

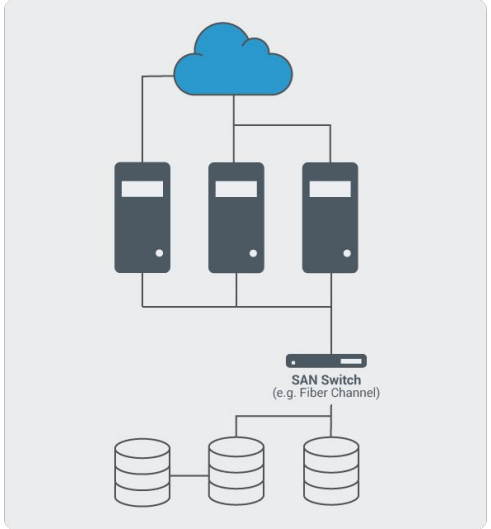
Storage Infrastructure

- **Network-based Data Storage**
  - NAS (Network Attached Storage)
    - **Cons**
      - **Limited scalability:** A NAS is limited to its own resources, meaning you can only scale by adding another NAS
      - **Minimal speed:** With low throughput and high latency, a NAS is not fast enough for high performance applications
      - **Network dependent:** Since files are typically shared with NAS devices over the LAN (also used for normal traffic), they can cause congestion or can be affected by other traffic on the LAN

Storage Infrastructure

- **Network-based Data Storage**
  - SAN (Storage Area Network)
    - **SAN is a dedicated network** that enables servers to share a pool of storage resources. SANs are complex, interwoven systems most frequently used with mission-critical data and databases
    - As a separate network, a SAN moves resources off of the LAN, **creating a separate, high-speed, more organized** environment that can be accessed by each client OS as if it were directly attached storage.
    - A SAN is more than just one device, it is a network of storage devices that work together as a single cluster.



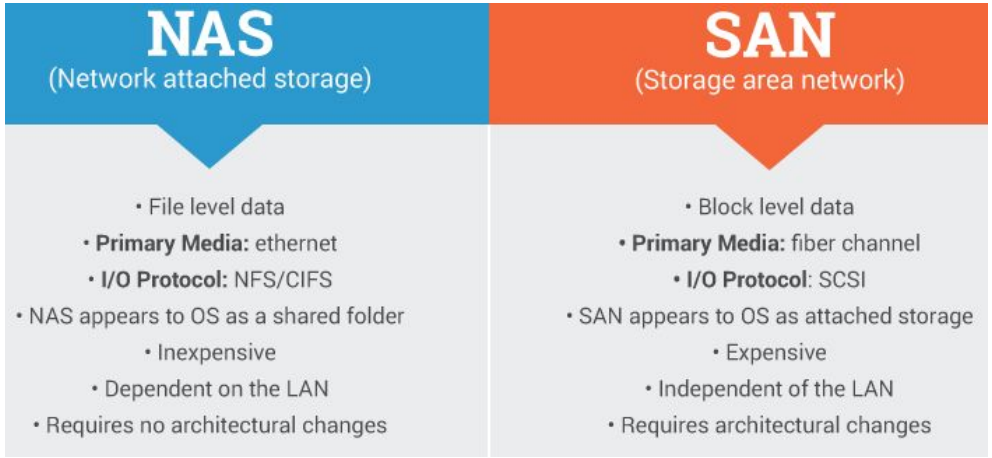


Storage Infrastructure

- **Network-based Data Storage**
  - SAN (Storage Area Network)
    - **Pros**
      - **High performance:** A SAN means that other devices in your network won't need to use local storage, allowing them to run more smoothly. With your servers using internal hard drives less (or not at all), they will naturally consume less power and run at a cooler temperature.
      - **Fast backup:** The fact that client OSs see the SAN as attached storage allows for more rapid backups. Even though the data from a SAN may travel, the SAN itself is transparent to the client OS, allowing the data to be stored quickly. As it is an entirely distinct network, SANs won't cause bottlenecks like other storage solutions might.
      - **Disaster recovery:** Replicating data from your primary location to an offsite SAN is easy. You can replicate rapidly and get your environment up and running quickly. This a major plus, because downtime is expensive.
      - **Better redundancy:** Since the servers within the SAN function as one cluster, you aren't necessarily accessing one particular device. If one of the servers goes down, the other devices within the same network pickup the slack.

Storage Infrastructure

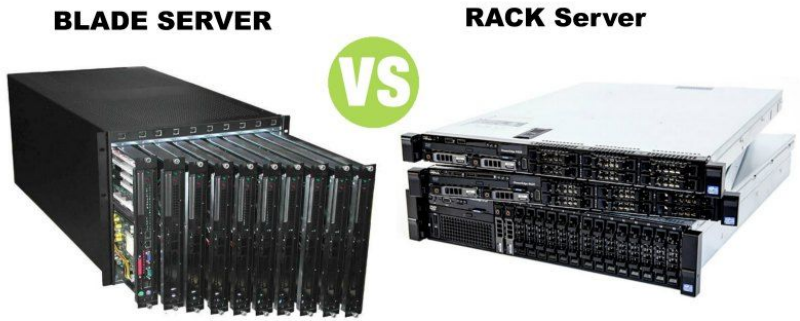
- **Network-based Data Storage**
  - SAN (Storage Area Network)
    - **Cons**
      - **High complexity:** Developing a SAN is no small feat. It is a network of interconnected devices and implementation entails major device and architectural changes.
      - **Upfront cost:** Simply put, a SAN is expensive. Although the ROI can be as quick as 12 months, the upfront costs of hardware and network implementation can be a major deterrence.
    - iSCSI (Internet Small Computer System Interface)



https://ccbtechnology.com/san-vs-nas-whats-right-for-you/

Computing Resources

- **Servers**
  - In its most basic definition, a server is a high functioning, high powered machine that pulls and pushes data between the itself and clients.
  - **East-west traffic:** significant server-to-server traffic as compared to server to user (solution; increase locality, use Pods, etc.)
    - Ex: One facebook request required 88 cache looks, 35 database lookups, 392 backend RPC calls
  - Hardware platform (Blade & Rack Servers)



Computing Resources

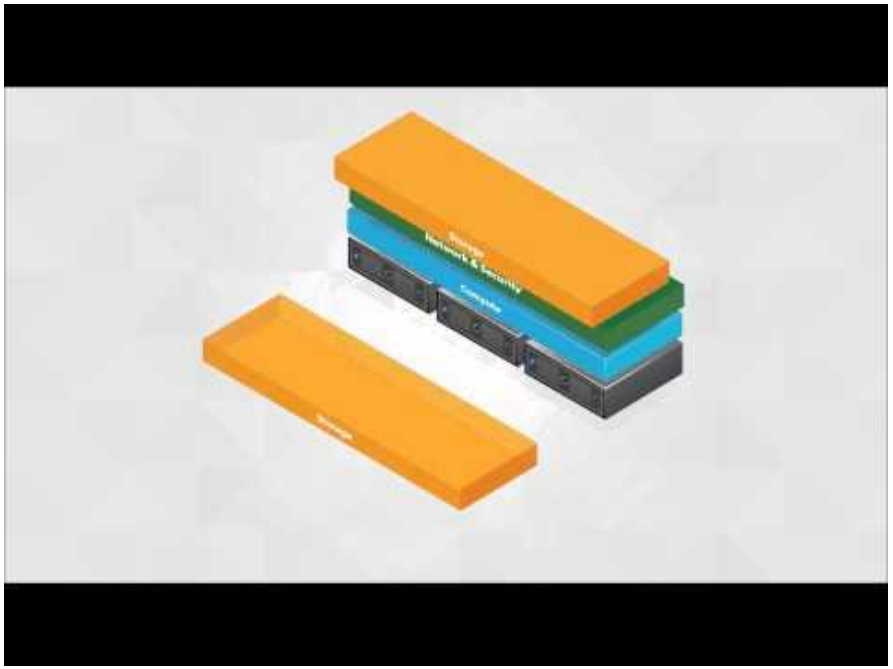
- **Servers**
  - Blade Servers
    - A blade server (ultra-dense server), packs a complete computer server on a single card, or blade, rather than a system unit.
    - Each blade server includes a processor, memory, hard disk, network card, and ports on the card.
    - The individual blades insert in a blade server chassis that can hold many blades.
    - Using blade servers allows an organization to fit 16 or more blades in the physical space occupied by a typical, single server.
    - Besides the savings in space offered by blade servers, blade servers require **less maintenance, use less energy, generate less heat, and easily are replaced or upgraded.**

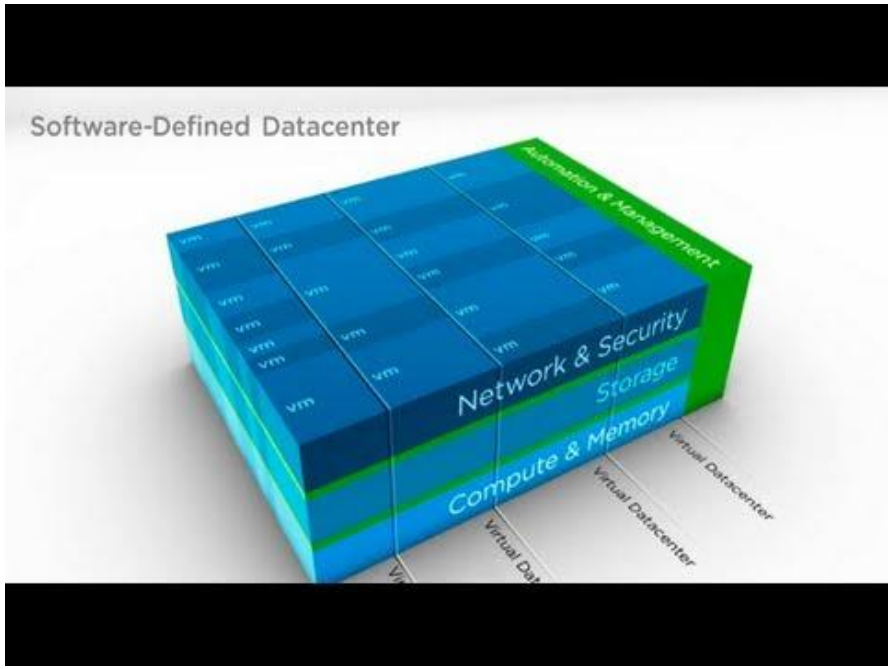
Computing Resources

- **Servers**
  - Rack Servers
    - Rack Server (Rack-Mounted Server) is a type of server which is designed to be placed in a framework known as Rack.
    - The Rack provides you with multiple bays, each bay is used to hold a hardware unit which is secured in a place locked with screws.
    - The connections of Rack Server also can be done through cabling among them.
    - The advantage of 1U rack server is that it adopts **standard** server design technology, standard peripherals, standard interface
    - Rack servers are more **cost-effective**. Because most of the blades and related products are more expensive than the corresponding rack products.
    - Rack servers are more **flexible**. For example, blades in high-performance database applications, the external RAID card cannot be equipped with a disk array.
- **Computing as “a resource”**
  - (following chapters cover the details)

Software Defined Data Center

- **Why?**
  - “Many data centers look like a museum of past IT decisions”
  - The SDDC results from years of evolution in server virtualization. **It extends virtualization from compute to storage and networking resources**, and it provides **a single software toolset to manage** those virtualized resources.
  - Plus, **policy-driven automation** of provisioning and management, which speeds delivery of resources and enhances efficiency.





Q/A