University of CINCINNATI

History & Building Blocks of Cloud Computing

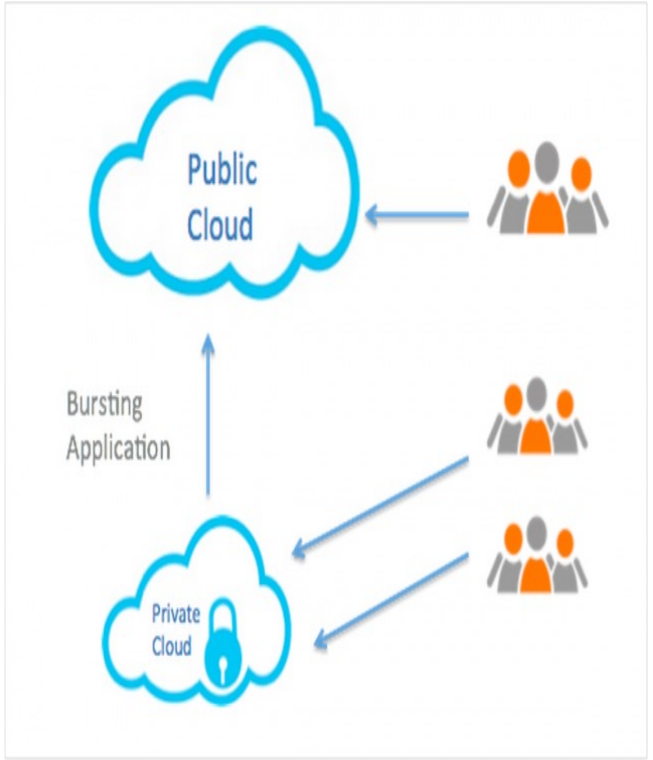
(Mastering Cloud Computing: Chapter#1)

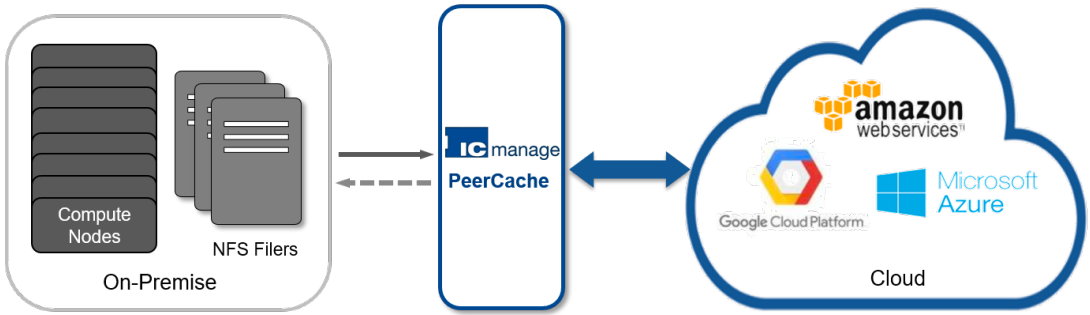
Rashmi Kansakar

What is cloud bursting?

University of CINCINNATI

Cloud bursting is an application deployment model in which an application runs in a private cloud or data center and bursts into a public cloud when the demand for computing capacity spikes. The advantage of such a hybrid cloud deployment is that an organization only pays for extra compute resources when they are needed.





Distributed Systems

University of CINCINNATI

A distributed system is a collection of independent computers that appears to its users as a single coherent system

- Tanenbaum

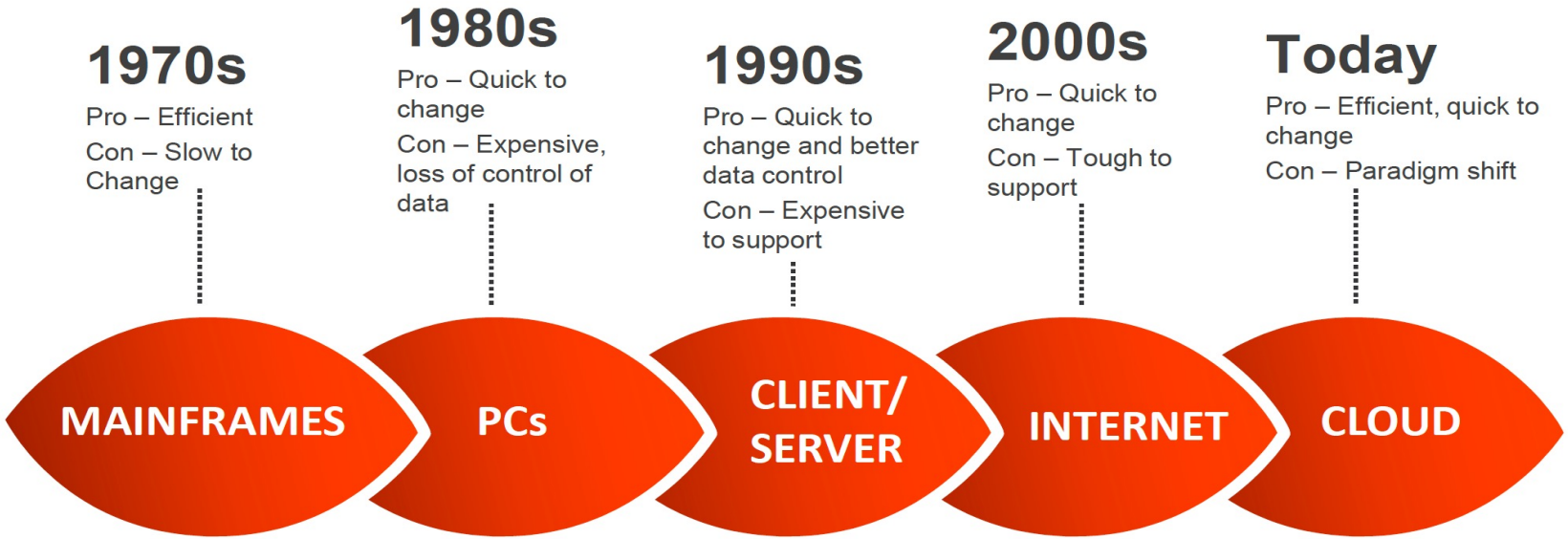
➢ **To share resources for better utilization.**

CEAS offers a course in Distributed Systems!

How did we get here?

University of CINCINNATI

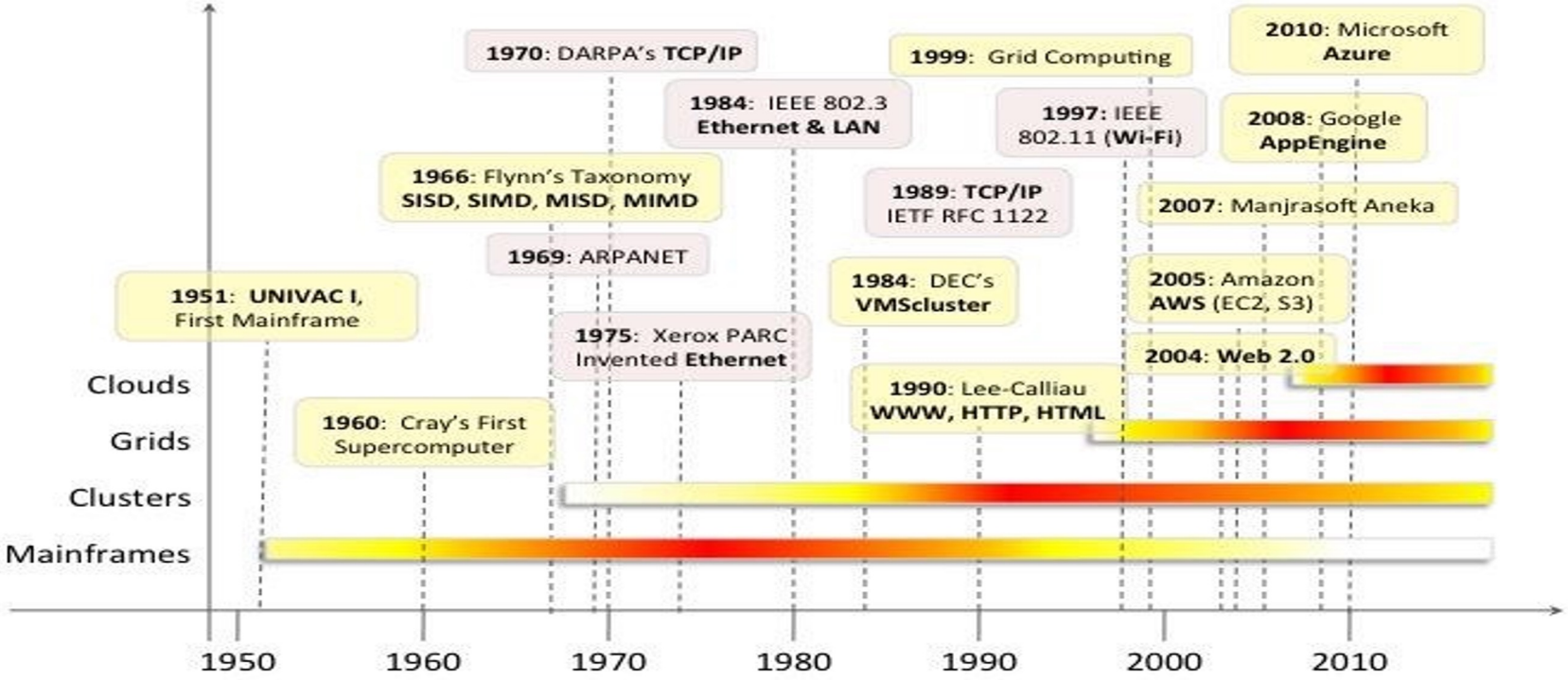
Persistent Goal: Efficient systems that respond to the business



"Cloud computing is based on the time-sharing model we leveraged years ago before we could afford our own computers. The idea is to share computing power among many companies and people, thereby reducing the cost of that computing power to those who leverage it. The value of time share and the core value of cloud computing are pretty much the same, only the resources these days are much better and more cost effective." – David Linthicum

Cycle (*what is old is new again...*)

University of CINCINNATI



Mainframes (*1951 onward*)

University of CINCINNATI

- Multiple processing units
- Powerful, reliable, IO optimized
- Time Sharing systems
- Replacement of components while running - always on
- Still used for transaction processing: banking, airline ticketing, registration

- **IBM z990**
- **2003**
- **256 GB RAM**
- **1k+ VM Linux**
- **11k SSL con/sec**

- **IBM EC12**
- **2012**
- **101 CPUs**
- **5.5Ghz hex core**
- **Integrated SSDs**
- **6k Linux VMs**

Clusters (*1968 onward*)

University of CINCINNATI

- Networked commodity (cheap) machines
- Physically close (room/building/LAN)
- Good for processing work, not IO
- Easy to expand
- Some use spare CPU cycles
- Condor, Beowulf Clusters, Message Passing Interface (MPI)
- Ohio Supercomputer

What is a Beowulf Cluster

University of CINCINNATI

- A Beowulf Cluster is one class of a cluster computer
- Uses Commercial Off The Shelf (COTS) hardware built in 1994 at NASA
- Typically contains both master and slave nodes
- Not defined by a specific piece of hardware
- As of 2014 Beowulf systems operate worldwide, chiefly in support of scientific computing.

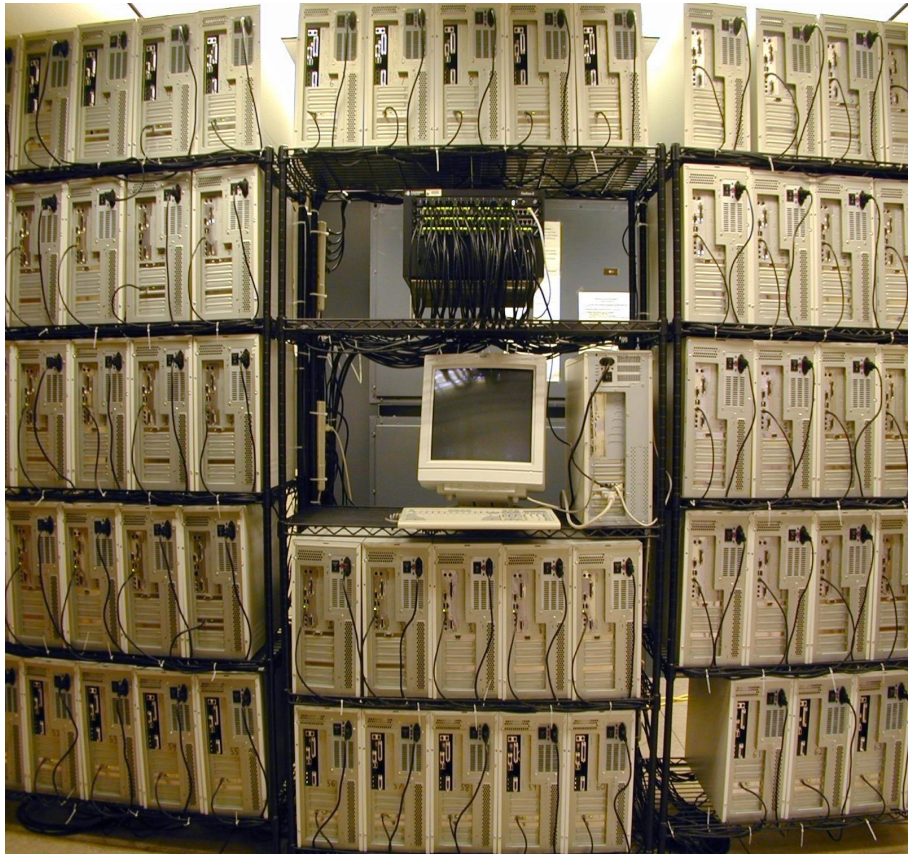
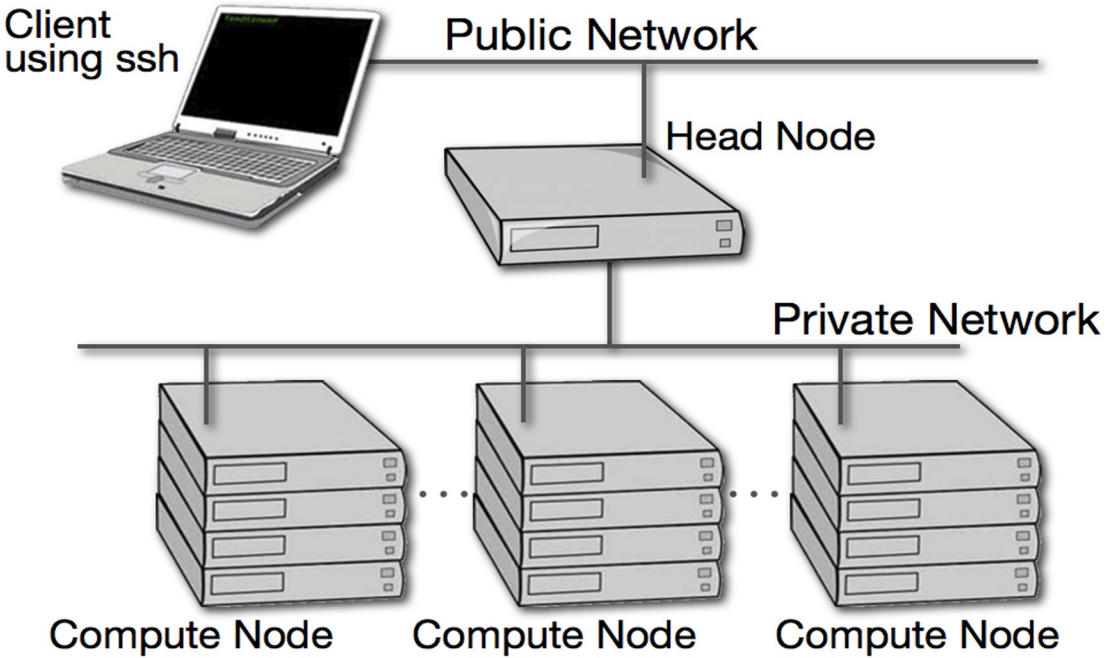


Image Source: http://www.cse.mtu.edu/Common/cluster.jpg

Cluster Components

University of CINCINNATI



- Processors
- OS
- Network / Interfaces
- Cluster middleware
  - Beowulf…
  - Rock…
- Execution Environment
  - PVM/MPI

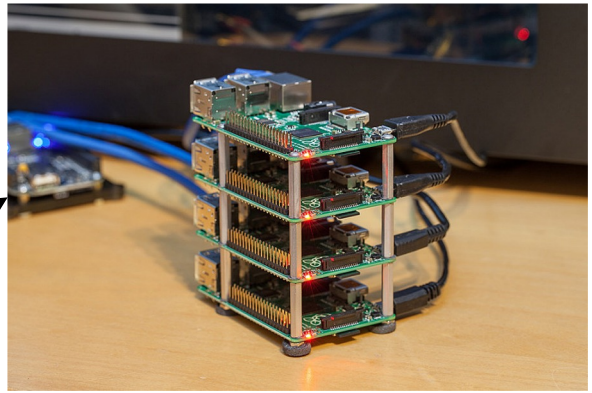
Compute node can also be called as worker node

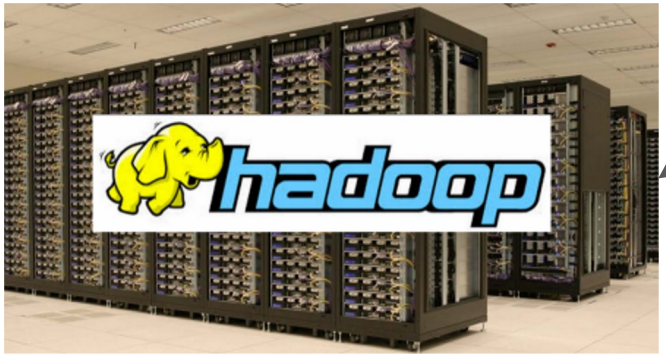
Different Clusters

University of CINCINNATI

Playstation 3 Supercomputing Cluster

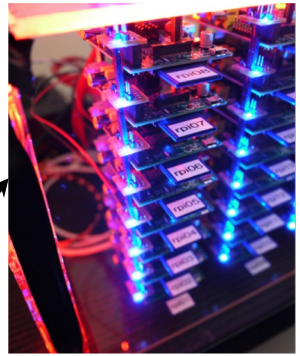
Raspberry Pi Cluster

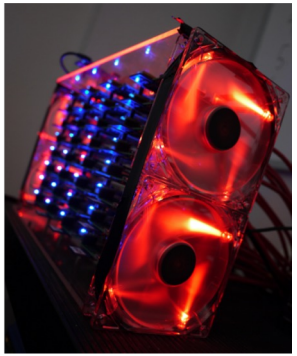




Hadoop Cluster

Raspberry Pi [Beauwolf](#) Cluster





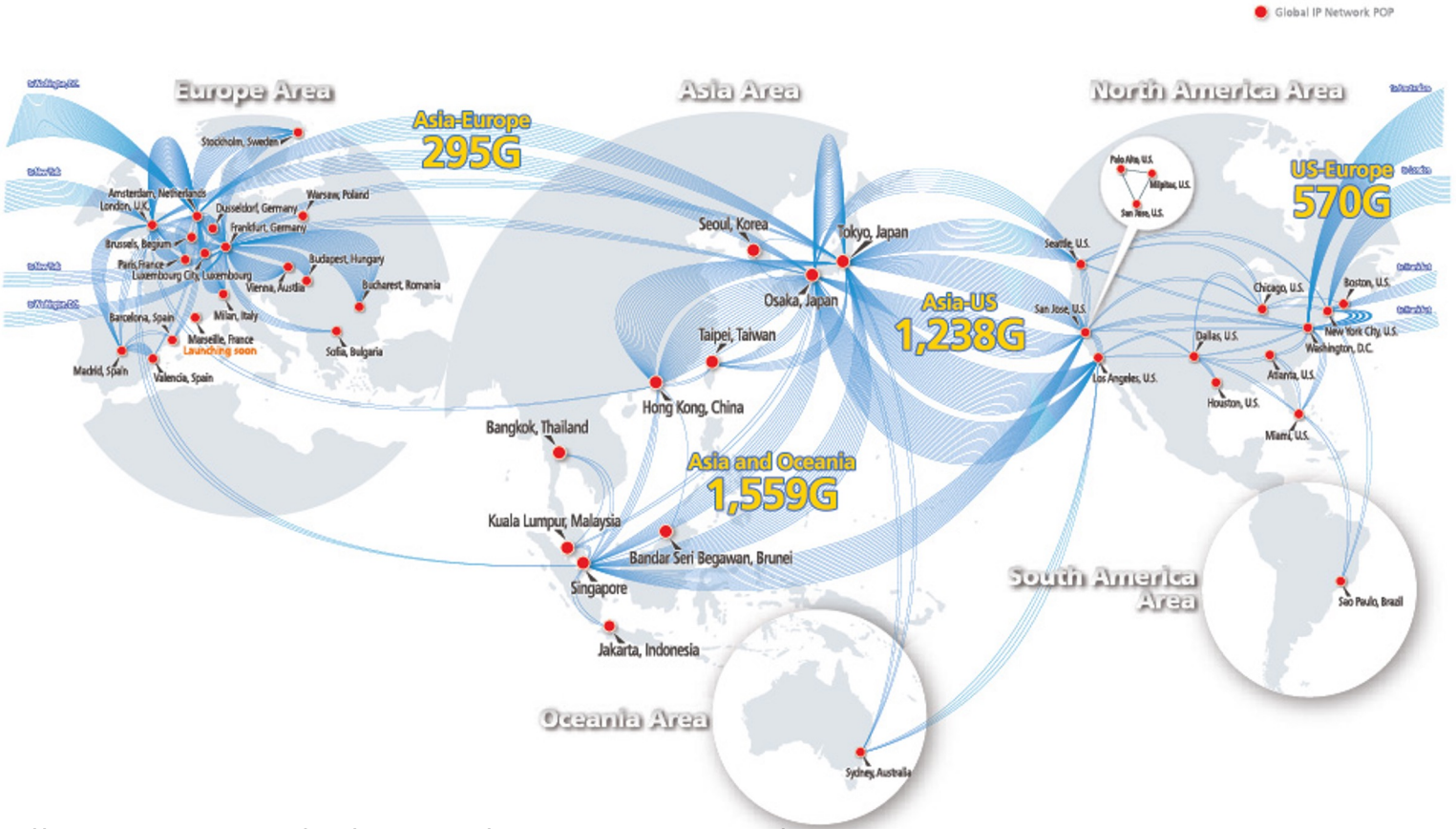
Grid Computing (*1990 onward*)

University of CINCINNATI

- Like cluster, but heterogeneous nodes
- Large physical distances
- Utility computing idea
- Needed high bandwidth connections (Internet)
- Good for processing work, not IO
- SETI@Home, BOINC

Building Blocks (*Network*)

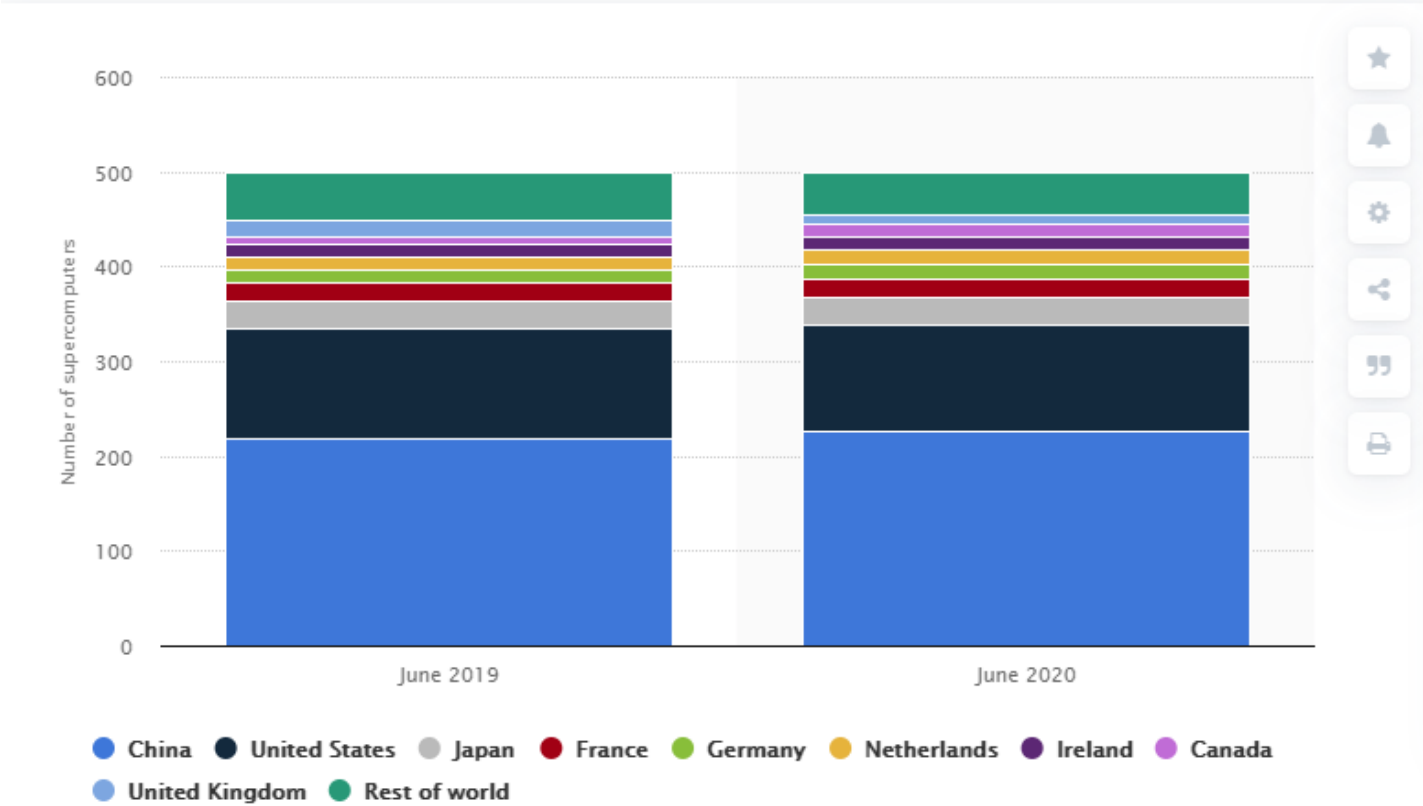
University of CINCINNATI



Source: http://www.hknet.com/en/network/dedicated-internet/service-diagram.html

Building Blocks (*Computing Power*)

University of CINCINNATI

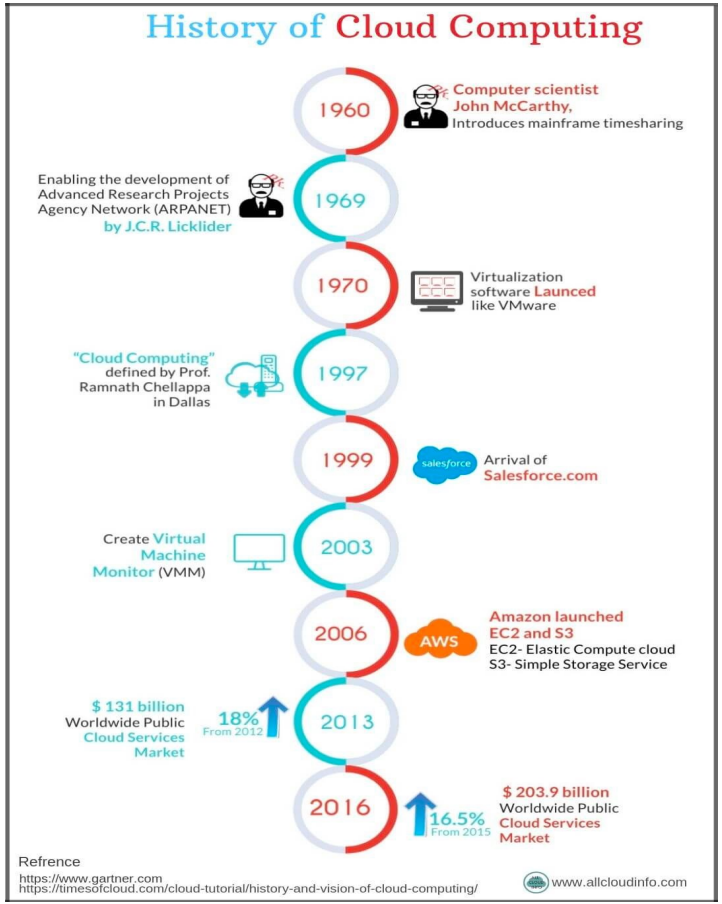


Source: https://www.statista.com/statistics/264445/number-of-supercomputers-worldwide-by-country/

Building Blocks (*Data Storage*)

University of CINCINNATI

1. The Citadel – Tahoe Reno, Nevada
2. Range Range International Information Group – Langfang, China
3. Switch Switch SuperNAP – Las Vegas, Nevada
4. DFT Data Center – Ashburn, Virginia
5. UTAH Data Center – Bluffdale, Utah
6. Microsoft Data Center – West Des Moines, Iowa
7. Lakeside Technology Center – Chicago, Illinois
8. Tulip Data Center – Bangalore, India
9. QTS Metro Data Center – Atlanta, Georgia
10. Next Generation Data Europe – Wales, UK

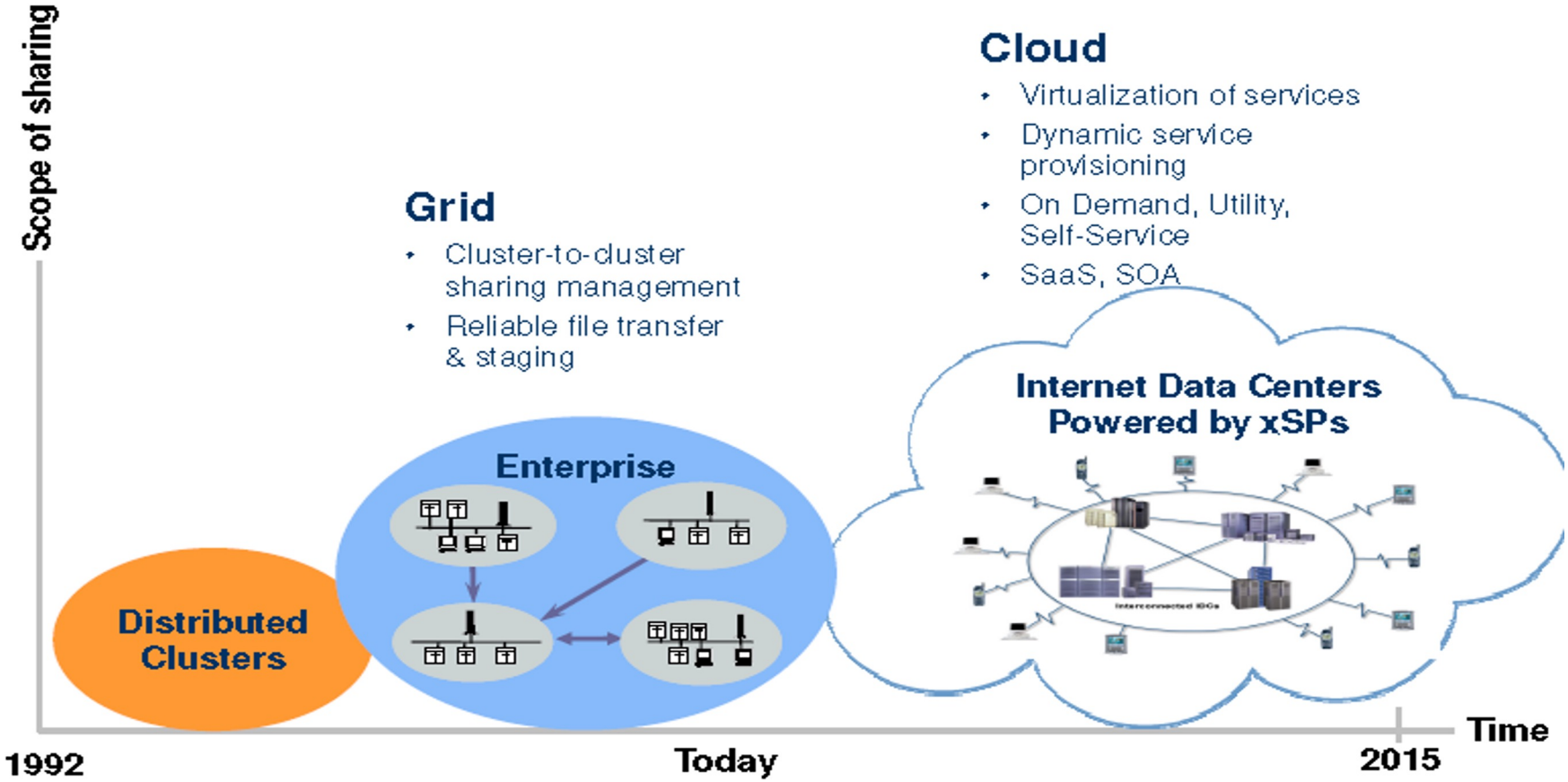


But what about latency!?!

University of CINCINNATI

- A semi full of hard drives has HUGE bandwidth!
- We get sold with bandwidth, but low latency is what we're after.
- But the speed of light is fixed!
  - Significant drop in sales for > 500 ms response
  - Google goal is < 200ms
  - NY to LA is 74ms RTT
- Grids may be good for some workloads, but HORRIBLE for others (IO and communication)
- Mainframe->Cluster->Grid, latency between nodes increases.
- Data location matters, and how your app uses data.

Commercial Grids - Not Successful → Cloud Computing Evolved



Cloud Computing

University of CINCINNATI

- Next evolution after grid computing
- Infinite capacity
- Resilient to failures
- Always on
- Built using commodity machines
- Pay-per-use (Utility vision)

Key Technologies that enabled Cloud

The implementation and wider use of distributed systems theory to build distributed databases and file systems allowed cloud computing to take off.

- ➔ Huge datasets (multiple petabytes)
- ➔ Vector clocks (Lamport timestamps)
- ➔ Paxos - Protocol to arrive at consensus in a network of unreliable processors (Wiki)

Virtualization

University of CINCINNATI

- Abstract core computing elements away
  - Processor
  - Storage
  - Networking
- Hardware virtualization (VMware, VirtualBox, XEN, EC2, etc.…)
  - Most performance issues solved
- Process virtualization (Google AppEngine, Azure, Java)

Web 2.0

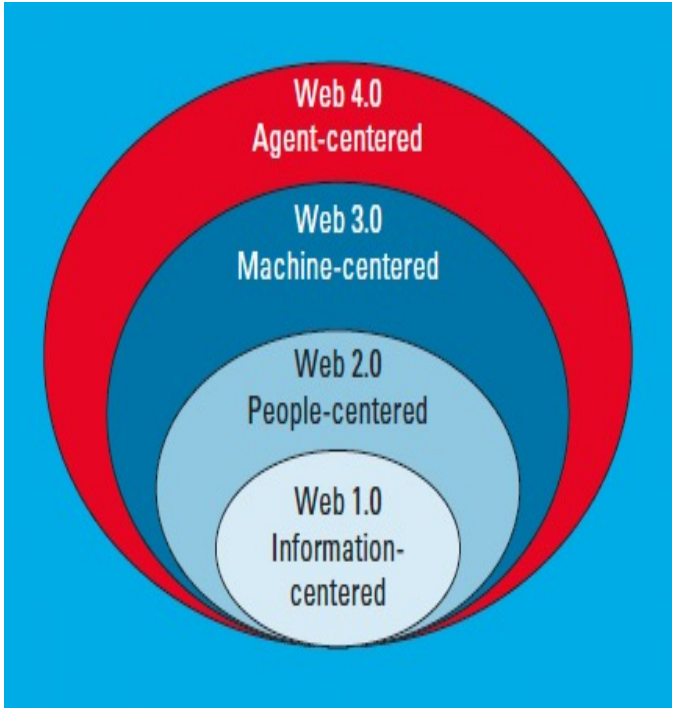
University of CINCINNATI

- Web 1.0? - Static pages
- Web 2.0 is:
  - “Web as platform” - John Battelle and Tim O'Reilly
  - Interactivity & flexibility - Allow users to change a site’s content!
  - Asynchronous JavaScript and XML (AJAX)
  - Web Services
- Not a ‘next version’ of the web, but a way of using HTTP/HTML
- Examples: Google Docs, Facebook, YouTube, Wikipedia

Web 2.0. Future of Internet Web 3.0

University of CINCINNATI

1900-early 2000s Static platform	Current Centralized Social-media driven	Decentralized Autonomous p2p
Web 1.0 	**Web 2.0** 	**Web 3.0** 
Mostly Read-Only	Wildly Read-Write	Portable & Personal
Company Focus	Community Focus	Individual Focus
Home Pages	Blogs / Wikis	Lifestreams / Waves
Owning Content	Sharing Content	Consolidating Content
Web Forms	Web Applications	Smart Applications
Directories	Tagging	User Behavior
Page Views	Cost Per Click	User Engagement
Banner Advertising	Interactive Advertising	Behavioral Advertising
Britannica Online	Wikipedia	The Semantic Web
HTML/ Portals	XML / RSS	RDF / RDFS / OWL
Crawl	Walk	Run



Service-Oriented Computing (SOA)

University of CINCINNATI

- A component that can perform any function (web services).
  - Loosely coupled
  - Reusable
  - Programming language independent
  - Location transparent
- By layering services we can build a service-oriented architecture

Service-Oriented Computing…

University of CINCINNATI

Important attributes:

- Quality of Service (QoS)
  - Service attributes, response times, security, uptime, etc…
- New software delivery model
  - Can sell components, not entire programs
  - Access through the internet
  - HTTP
  - Web Service Description Language (WSDL)
  - Simple Object Access Protocol (SOAP)

Utility-Oriented Computing

University of CINCINNATI

- Storage, compute, applications, infrastructure, all on a pay-per-use basis.

Old idea..

- job queueing systems, OS time-slicing, all developed in mainframes to charge for use.
- Buying services/products online common now.

Current Platforms

University of CINCINNATI

- Amazon Web Services (AWS) - Current leader in IaaS: Elastic Compute Cloud (EC2), Simple Storage Service (S3), many many others…..
- Google Cloud Platform (GCP) - PaaS - Python, Java, Go
- MS Azure - IaaS & PaaS
- Hadoop - Open Source framework for MapReduce
- Force.com & Salesforce.com
- Serverless Architecture

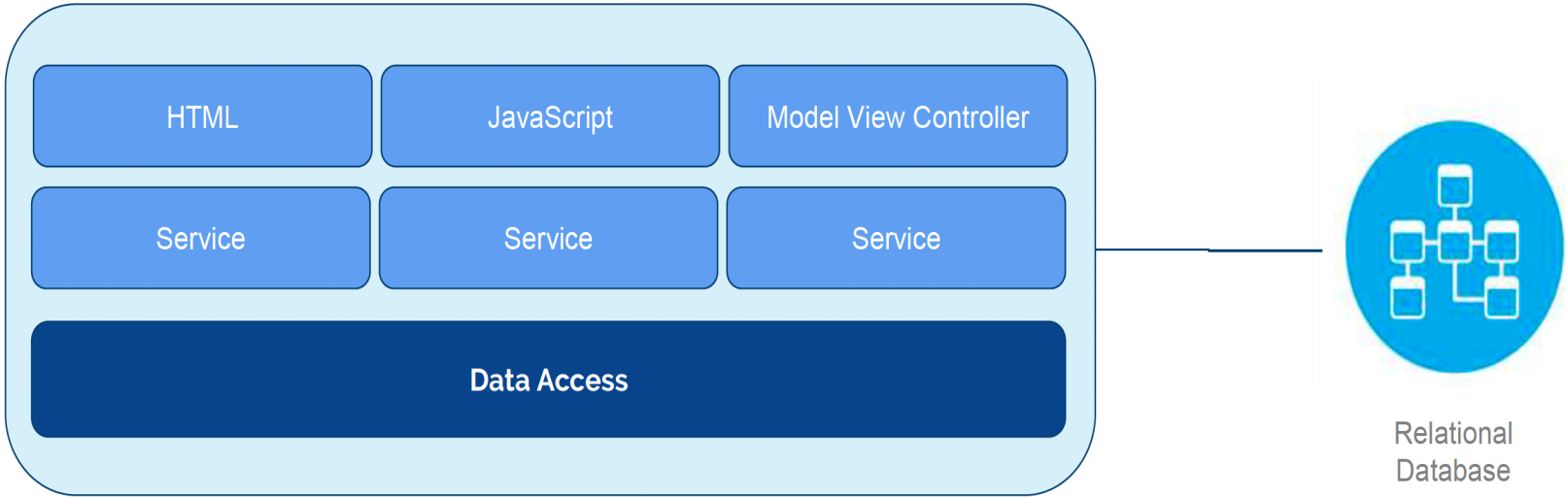
Serverless Architectures

University of CINCINNATI

- Microservice architecture (decompose service into microservice)
- CloudFoundry
- Amazon Lambda
- BlueMix
- Predix
- Microsoft Services Framework

Monolithic Architectures

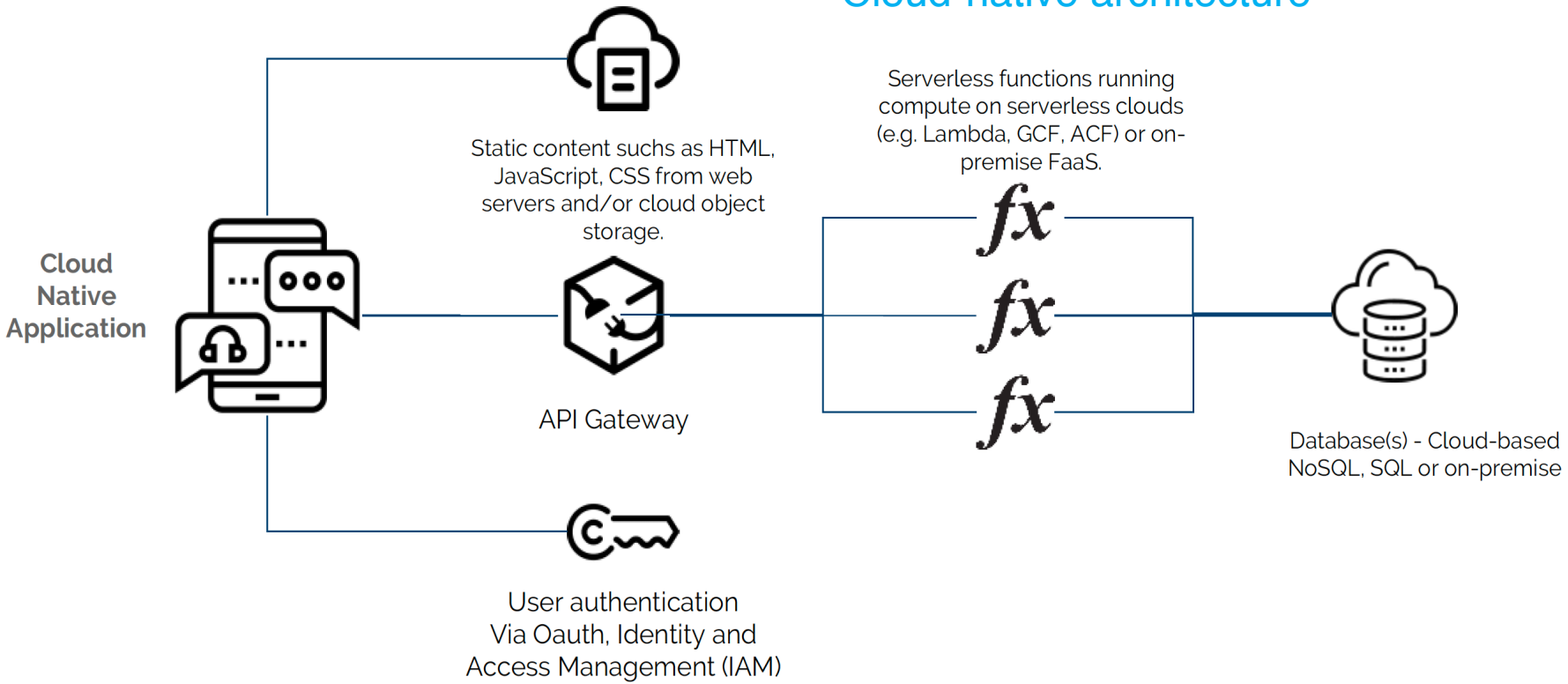
University of CINCINNATI



Serverless Architectures

University of CINCINNATI

Cloud-native architecture



TriggerMesh – Multicloud Serverless Management Platform

Serverless is the future (sort of)

University of CINCINNATI

Continuous integration, continuous deployment is going to change and that's where things like microservices, containers are playing a massive role in the outer loop, but one of the things that I think is going to completely change how we think about logic is **serverless**.
Serverless computation will fundamentally, not only change the economics of what is backing computing, but it's going to be the core of the future of distributed computing. So this application paradigm shift of intelligent cloud and intelligent edge is going to be pervasively changing everything ….

Satya Nadella
Keynote - Microsoft Build 2017 conference

Serverless is the future (sort of)

University of CINCINNATI

The torrid pace of adoption and innovation in the **serverless** (Lambda) space has totally blown us away,
In particular, Lambda, AWS's main serverless service, has "grown like crazy," with hundreds of thousands of active customers using it in the last 30 days. That's 300%-plus year-over-year growth.
"When we launched Lambda, the first serverless compute service, it was a watershed moment,"
...large generations of customers will skip instances and containers and go right to serverless -- in fact, if Amazon.com were starting today, it would go serverless.
Andy Jassy
Amazon Web Services Inc. Chief Executive
Re:Invent 2017

Where serverless is a good idea?

University of CINCINNATI

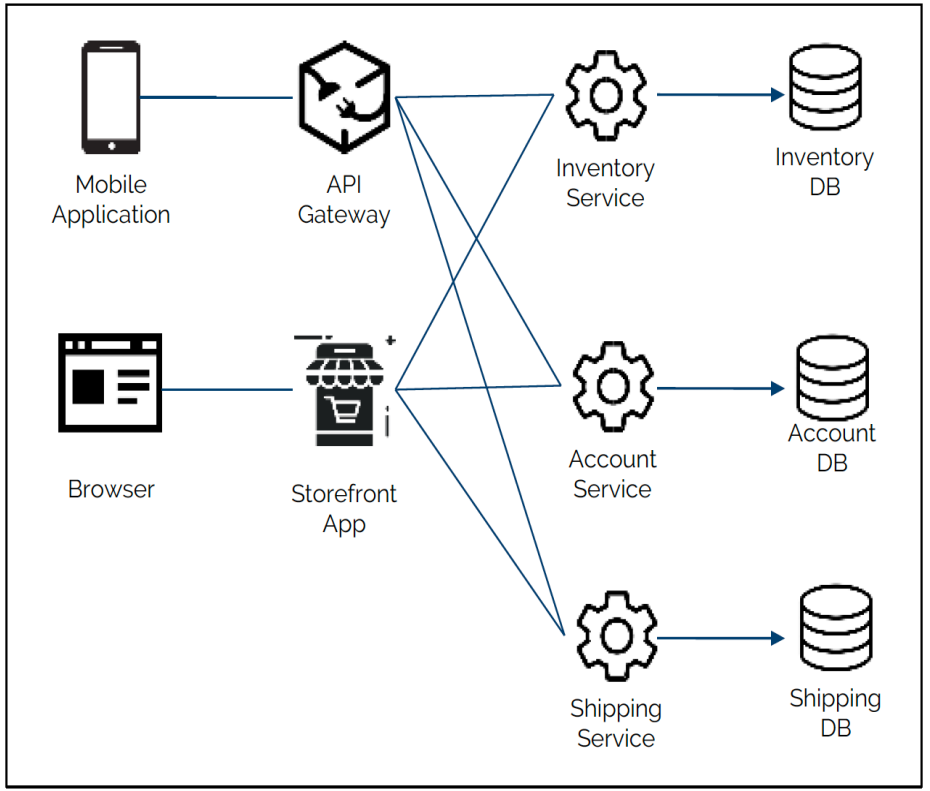
- ✓ Abstraction of backend infrastructure completely
- ✓ Execution environment for single purpose functions
- ✓ Hosted in public cloud or on-premise
- ✓ Serverless functions have a runtime in a stateless container
  - E.g. Node.js, JavaScript, Go, Python, Java
- ✓ Event-driven startup triggers/instant scale out or in.
- ✓ Micro-billing instead of per-hour/month billing.
- ✓ Criteria for using serverless
  - Asynchronous, concurrent
  - Infrequent or has sporadic demand
  - Stateless, ephemeral
  - Highly dynamic in terms of changing business requirements

Microservices

University of CINCINNATI

- ✓ Single purposes functions that deliver accomplish a single task
- ✓ Can run on a server, container or in a serverless infrastructure
- ✓ Microservices are typically combined to deliver a cloud native application via presentation layer.

Microservices in a Storefront Application



Some Security Implications

University of CINCINNATI

- ✓ Provisioning in software - automated, online, hands-off
- ✓ Full-system imaging & snapshotting, assists forensics investigation
- ✓ Partitioning - Better isolation between applications than virtual web hosting servers
- ✓ Software networking - pros / cons
- ✓ Insecure Deployment Configuration
- ✓ Broken Authentication
- ✓ Overprivileged Function Permissions and Roles
- ✓ Inadequate Function Monitoring and Logging
- ✓ Insecure Third-Party Dependencies
- ✓ Insecure Application Secrets Storage
- ✓ Denial-of-Service and Financial Resource Exhaustion
- ✓ Business Logic Manipulation, Function Event-Data Injection
- ✓ Improper Exception Handling and Verbose Error Messages
- ✓ Legacy/Unused Functions & Cloud Resources
- ✓ Cross-Execution Data Persistency

Web 2.0

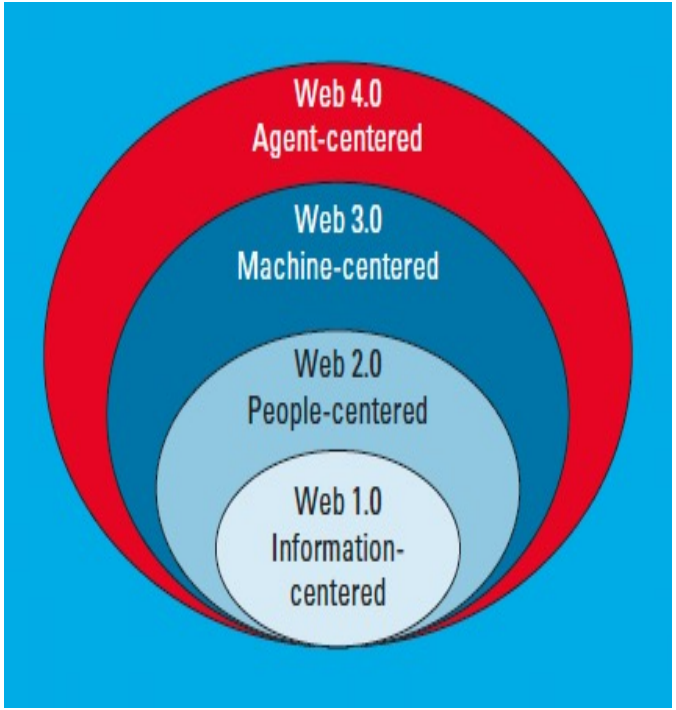
University of CINCINNATI

- Web 1.0? - Static pages
- Web 2.0 is:
  - “Web as platform” - John Battelle and Tim O'Reilly
  - Interactivity & flexibility - Allow users to change a site’s content!
  - Asynchronous JavaScript and XML (AJAX)
  - Web Services
- Not a ‘next version’ of the web, but a way of using HTTP/HTML
- Examples: Google Docs, Facebook, YouTube, Wikipedia

Web 2.0. Future of Internet Web 3.0

University of CINCINNATI

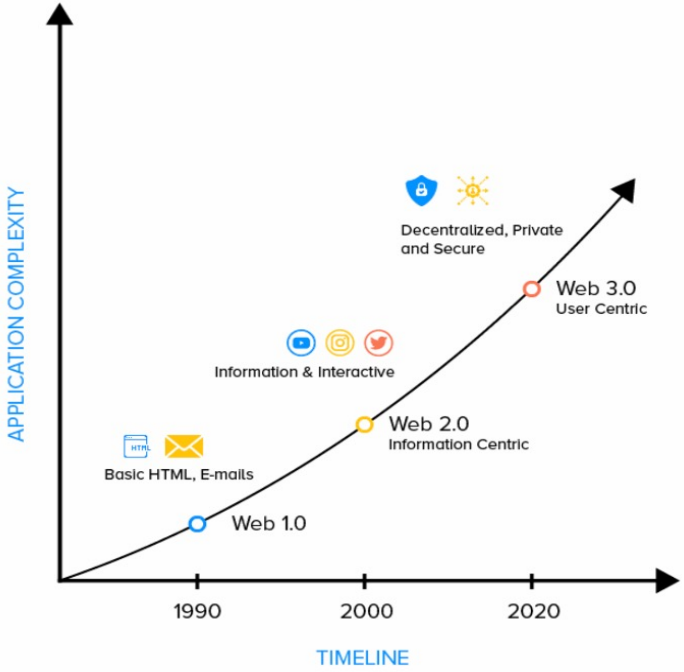
1900-early 2000s Static platform	Current Centralized Social-media driven	Decentralized Autonomous p2p
Web 1.0 	**Web 2.0** 	**Web 3.0** 
Mostly Read-Only	Wildly Read-Write	Portable & Personal
Company Focus	Community Focus	Individual Focus
Home Pages	Blogs / Wikis	Lifestreams / Waves
Owning Content	Sharing Content	Consolidating Content
Web Forms	Web Applications	Smart Applications
Directories	Tagging	User Behavior
Page Views	Cost Per Click	User Engagement
Banner Advertising	Interactive Advertising	Behavioral Advertising
Britannica Online	Wikipedia	The Semantic Web
HTML/ Portals	XML / RSS	RDF / RDFS / OWL
Crawl	Walk	Run



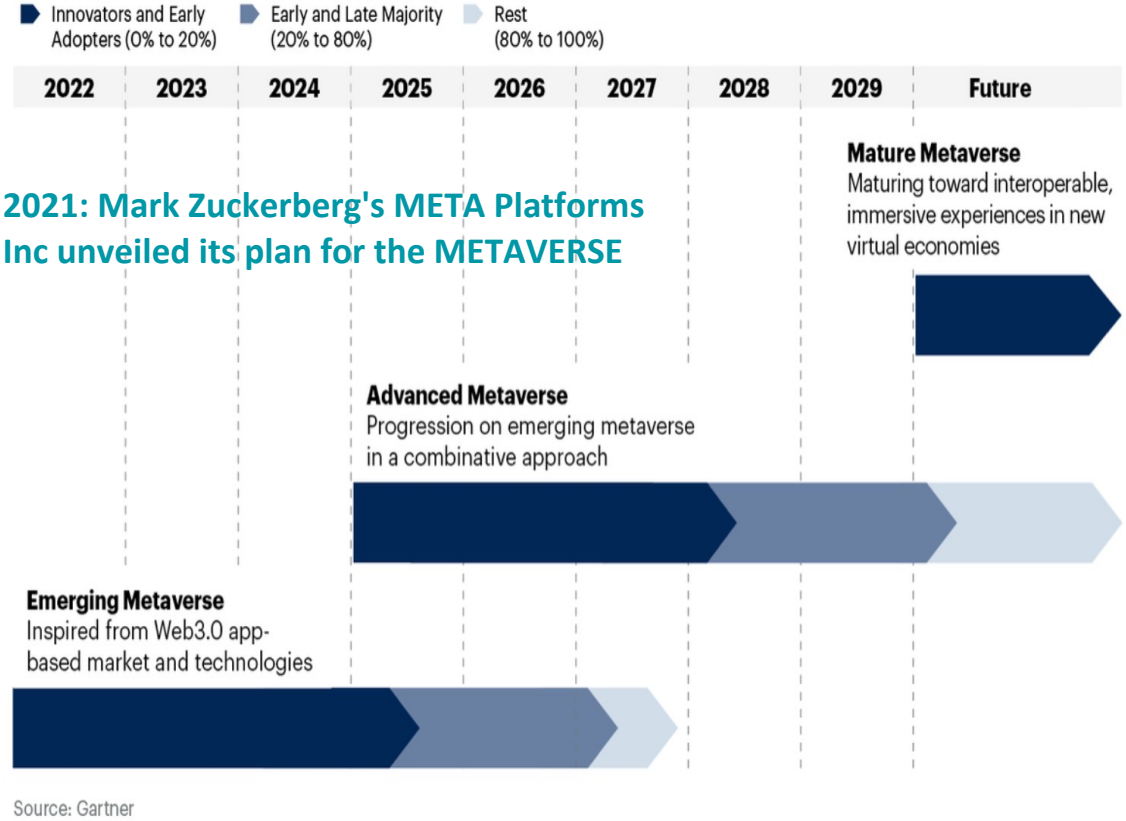
What is after Cloud Computing?

University of CINCINNATI

The technology to create a Metaverse is still in its infancy and a 'Metaverse' does not yet exist. Even what exactly it will be like when it does is largely undefined.

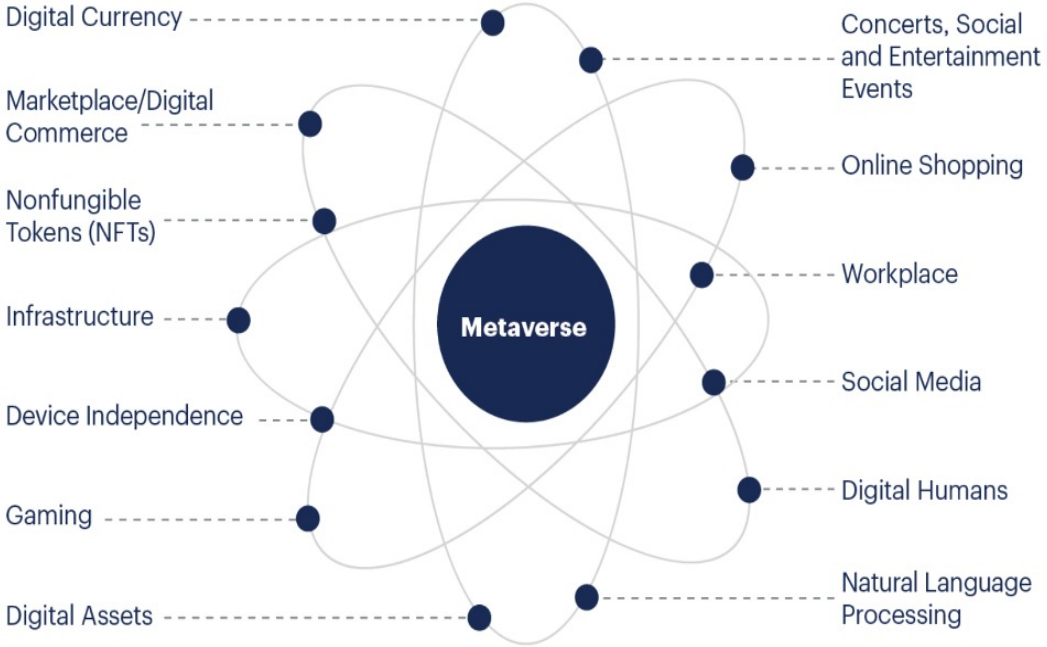


2021: Mark Zuckerberg's META Platforms Inc unveiled its plan for the METAVERSE



Future of METAVERSE

University of CINCINNATI



gartner.com

Source: Gartner

Gartner

- **A collective virtual shared space, created by the convergence of virtually enhanced physical and digital reality.**
- **Metaverse is persistent, providing enhanced immersive experiences, and once matured it will serve as a device-independent ecosystem for further innovation.**

[The metaverse explained in 14 minutes | Matthew Ball]

Moving fast in cloud, but is it fast enough?

University of CINCINNATI

Build Planes in the Air https://www.youtube.com/watch?v=JVSiooNywfg

cowboys herding cats https://www.youtube.com/watch?v=Pk7yqlTMvp8