TCSS 558: APPLIED DISTRIBUTED COMPUTING

Distributed Systems: Types and Architectures

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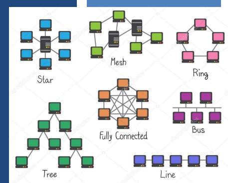

OBJECTIVES

- Feedback from 10/3
- Types of distributed systems
  - Cloud. . .
  - Distributed information systems
  - Pervasive systems
- Assignment 0
- Ch. 2 - Architectural styles
  - Layered
  - Object-based
  - Resource-centered
  - Event-based
- Research directions

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FEEDBACK – 10/3

- Virtualization vs. containerization?
  - Three approaches:
  - (1) Virtualization only – the original
  - (2) Containerization only – private server
  - (3) Virtualization + containerization – public cloud
  - Reflects how many layers of abstraction exist between the hardware and software
  - What is the benefit of removing the hypervisor?

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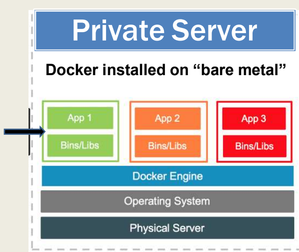
CONTAINERIZATION ONLY

Containerization



No hypervisor

2 layers

No Virtualization

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VIRTUALIZATION ONLY

Virtual Machines

This is really one layer

2 layers

Virtualization

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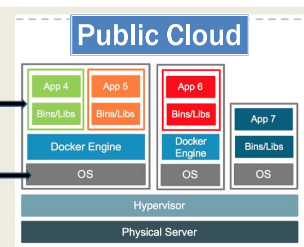
VIRTUALIZATION + CONTAINERIZATION

Containers

VM - Host OS can vary



Type 1 hypervisor – XEN

3 layers

Containerization & Virtualization

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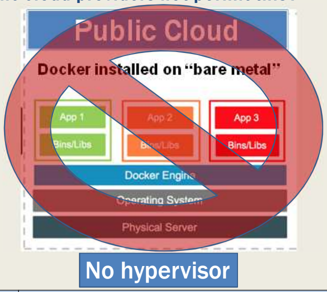
BARE METAL CONTAINERS

- Why do public cloud providers not permit this?



FEEDBACK - 2

- AWS: How does Amazon handle heavy load during holiday shopping season/sales?
- The AWS cloud has grow to include huge infrastructure much larger than that required to host the retail operation of Amazon.com
- 14 regions !

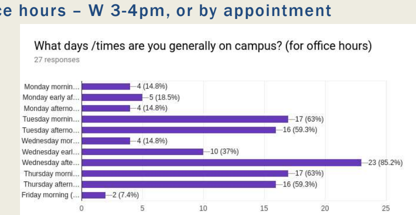
US East (N. Virginia)
US East (Ohio)
US West (N. California)
US West (Oregon)
Canada (Central)
EU (Ireland)
EU (Frankfurt)
EU (London)
Asia Pacific (Singapore)
Asia Pacific (Sydney)
Asia Pacific (Seoul)
Asia Pacific (Tokyo)
Asia Pacific (Mumbai)
South America (São Paulo)

FEEDBACK - 3

- What is the difference between a thin and thick client?
- Click "thickness" refers to how much of the computational work of an application is handled on board the client vs. the server
- Thick client is "heavy", performs considerable work
  - Requires high-end devices (multi-core tablets, phones)
- Thin client is "lightweight", very little work done onboard
- Open research – where to place (disperse) computation?
  - client/IOT device, edge, fog, cloud

FEEDBACK - 4

- Is it possible to upload the ppt/pptx on canvas?
  - Can upload PDF, not ppt
  - Format preference? 2-up, 4-up, 6-up format
- Office hours – W 3-4pm, or by appointment

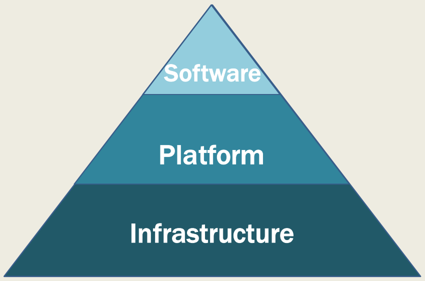


TYPES OF DISTRIBUTED SYSTEMS

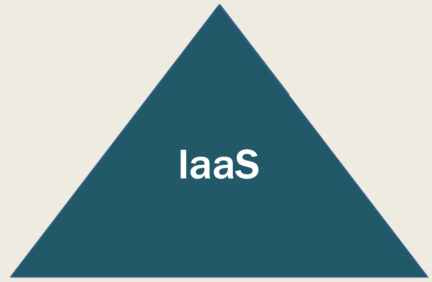
TYPES OF DISTRIBUTED SYSTEMS

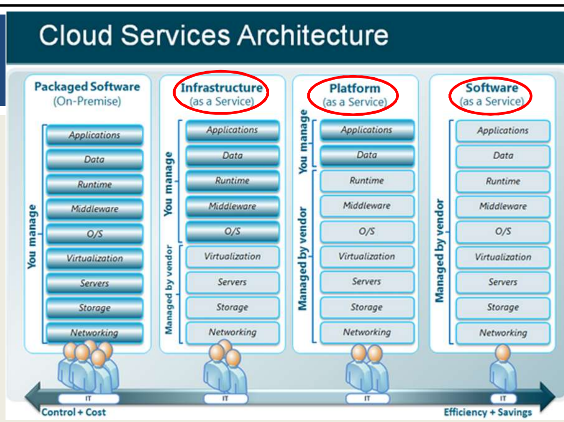
- Super computers / High Performance Computing (HPC)
- Cluster computing
- Grid computing
- Cloud computing
- Virtualization
- Distributed information systems
- Pervasive systems
  - Ubiquitous computing systems
  - Mobile systems
  - Sensor networks

CLOUD COMPUTING STACK



CLOUD COMPUTING STACK





PUBLIC CLOUD COMPUTING

- Offers computing, storage, communication at ¢ per hour
- No premium to scale:
- Illusio
- As ma
- Leadin
  Amazo ... ure
- Amaz
- Billing
  - By the minute, second, tenth of a second
  - Obfuscated pricing-Lambda $0.0000002 per request
    $0.000000208 to rent 128MB / 100-ms

m4.large example
2 vCPU cores, 8 GB RAM, Intel Xeon E5-2666 v3
10¢ an hour
24hrs/day
30 day/month → $72.00/month
on-demand EC2 instance

AWS Lambda? **$346.51**

PAAS SERVICES IMPLEMENTATION

- PaaS services often built atop of IaaS
  - Amazon RDS, Heroku, Amazon Elasticache
- Scalability
  - VM resources can support fluctuations in demand
- Dependability
  - PaaS services built on highly available IaaS resources

DISTRIBUTED INFORMATION SYSTEMS

- Enterprise-wide integrated applications
  - Organizations confronted with too many applications
  - Interoperability among applications was difficult
  - Lead to many middleware-based solutions
- Key concepts
  - Component based architectures - database components, processing components
  - **Distributed transaction** – Client wraps requests together, sends as single aggregated request
  - Atomic: ***all*** or ***none*** of the individual requests should be executed
- Different systems define different ***action*** primitives
  - Components of the atomic transaction
  - Examples: send, receive, forward, READ, WRITE, etc.

DISTRIBUTED INFORMATION SYSTEMS - 2

- Transaction primitives

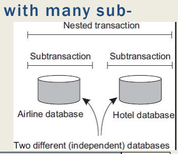
Primitive	Description
BEGIN_TRANSACTION	Mark the start of a transaction
END_TRANSACTION	Terminate the transaction and try to commit
ABORT_TRANSACTION	Kill the transaction and restore the old values
READ	Read data from a file, a table, or otherwise
WRITE	Write data to a file, a table, or otherwise

- Transactions are all-or-nothing
  - All operations are executed
  - None are executed

TRANSACTIONS: ACID PROPERTIES

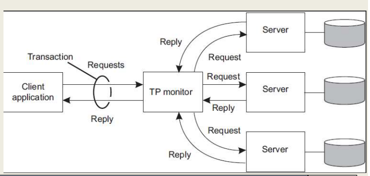
- Atomic: The transaction occurs indivisibly
- Consistent: The transaction does not violate system invariants
  - Replicas remain constant until all updated
- Isolated: Transactions do not interfere with each other
- Durable: Once a transaction commits, change are permanent

- Nested transaction: transaction constructed with many sub-transactions
- Follows a logical division of work
- Must support "rollback" of sub-transactions



TRANSACTION PROCESSING MONITOR

- Allow an application to access multiple DBs via a transactional programming model
- TP monitor: coordinates commitment of sub-transactions using a distributed commit protocol (Ch. 8)
- Save application complexity from having to coordinate



ENTERPRISE APPLICATION INTEGRATION

- Support application components direct communication with each other, not via databases
- **Communication mechanisms**:
- Remote procedure call (RPC)
  - Local procedure call packaged as a message and sent to server
  - Supports distribution of function call processing
- **Remote method invocations** (RMI)
  - Operates on objects instead of functions

- RPC and RMI – lead to tight coupling
- Client and server endpoints must be up and running
- Interfaces not so interoperable
- Leads to **Message-oriented middleware** (MOM)

MESSAGE-ORIENTED MIDDLEWARE

- Publish and subscribe systems

- Reduces tight coupling of RPC/RMI

- Applications indicate interest for specific type(s) of message by sending requests to logical contact points

- Communication middleware delivers messages to subscribing applications

APPLICATION INTEGRATION METHODS

- File transfer
  - Shared data files (e.g. XML)
  - Leads to file management challenges
- Shared database
  - Centralized DB, transactions to coordinate changes among users
  - Common data schema required – can be challenging to derive
  - For many reads and updates, shared DB becomes bottleneck
- Remote procedure call – app A executes on and against app B data. App A lacks direct access to app B data.
- Messaging middleware ensures nodes temporarily offline later can receive messages

PERVASIVE SYSTEMS

- Existing everywhere, widely adopted…
- Combine current network technologies, wireless computing, voice recognition, internet capabilities and AI to create an environment where connectivity of devices is embedded, unobtrusive, and always available
- Many sensors infer various aspect's of a user's behavior
  - Myriad of actuators to collect information, provide feedback
- **Types:**
- Ubiquitous computing systems
- Mobile systems
- Sensor networks

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UBIQUITOUS COMPUTING SYSTEMS

- Pervasive and continuously present
- Goal: embed processors everywhere (day-to-day objects) enabling them to communicate information
- Requirements for a ubiquitous computing system:
  - **Distribution** – devices are networked, distributed, and accessible transparently
  - **Interaction** – unobtrusive (low-key) between users and devices
  - **Context awareness** – optimizes interaction
  - **Autonomy** – devices operate autonomously, self-managed
  - **Intelligence** – system can handle wide range of dynamic actions and interactions

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MOBILE SYSTEMS

- Emphasis on mobile devices, e.g. smartphones, tablet computers
- New devices: remote controls, pagers, active badges, car equipment, various GPS-enabled devices,
- Devices move, where is the device?
- Changing locations – mobile adhoc network (MANET)

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SENSOR NETWORKS

- Tens, to hundreds, to thousands of small nodes
- Simple: small memory/compute/communication capacity
- Wireless, battery powered (or battery-less)
- Limited: restricted communication, constrained power
- Equipped with sensing devices
- Some can act as actuators (control systems)
  - Example: enable sprinklers upon fire detection
- Sensor nodes organized in neighborhoods
- Scope of communication:
  - Node – neighborhood – system-wide

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SENSOR NETWORKS - 2

- Collaborate to process sensor data in app-specific manner
- Provide mix of data collection and processing
- **Nodes may implement a distributed database**
- Database organization: centralized to decentralized
- In network processing: forward query to all sensor nodes along a tree to aggregate results and propagate to root
- Is aggregation simply data collection?
- Are all nodes homogeneous?
- Are all network links homogeneous?
- How do we setup a tree when nodes have heterogeneous power and network connection quality?

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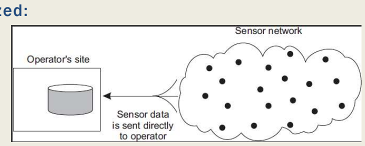
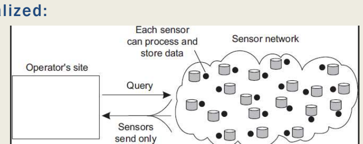
CENTRALIZED VS. DECENTRALIZED DATA STORAGE

- Centralized:



- Decentralized:



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WHO AGGREGATES AND STORES DATA?

- Tradeoff space: sensor network data storage and processing

Centralized ←——|——→ **Decentralized**

Centralized	Decentralized
Single point-of-failure	Nodes require high compute power
No node coordination	"Smart" nodes
No node processing or storage	Expensive nodes
"Dumb" nodes	Less network traffic
Less expensive node	
More network traffic	

SENSOR NETWORKS

- What are some unique requirements for sensor networks middleware?
  - Sensor networks may consist of different types of nodes with different functions
  - Nodes may often be in suspended state to save power
    - Duty cycles (1 to 30%), strict energy budgets
  - Synchronize communication with duty cycles
  - How do we manage membership when devices are offline?

QUESTIONS

EXTRA SLIDES