# TCSS 558:
# APPLIED DISTRIBUTED COMPUTING

**Types of Distributed Systems**

Wes J. Lloyd
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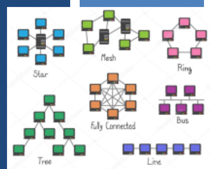


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## OBJECTIVES – 1/10

- Questions from 1/5
- Activity: Design goals of distributed systems
- Chapter 1.3 – Types of distributed systems
  - HPC, Cluster, Grid, Cloud
  - Distributed information systems
    - Transactions
    - Application Integration: Shared files, DBs, RPC, RMI, Message-oriented middleware
  - Pervasive Systems
    - Ubiquitous computing systems
    - Mobile systems
    - Sensor networks

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## TCSS 558 OFFICE HOURS – WINTER 2023

- Office hour - Tuesdays after class
  - ~4:00 – 5:00p CP 229 and Zoom
- Additional hours will be added as needed
- Also by email appointment: wlloyd@uw.edu

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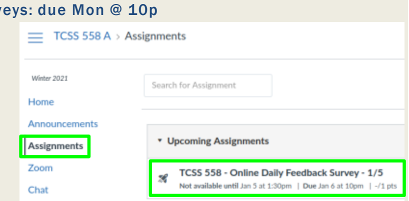
## ONLINE DAILY FEEDBACK SURVEY

- Daily Feedback Quiz in Canvas – Available After Each Class
- Extra credit available for completing surveys ***ON TIME***
- Tuesday surveys: due by Wed @ 10p
- Thursday surveys: due Mon @ 10p

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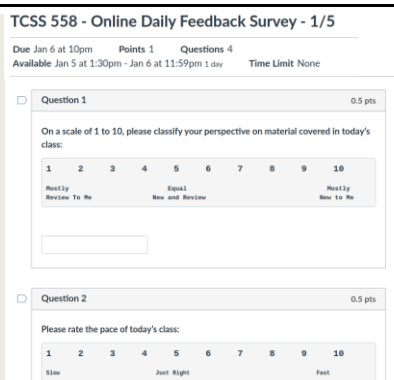


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## MATERIAL / PACE

- Please classify your perspective on material covered in today's class (33 respondents):
- 1-mostly review, 5-equal new/review, 10-mostly new
- **Average – 6.12 (↓ - *previous 6.65*)**
- Please rate the pace of today's class:
- 1-slow, 5-just right, 10-fast
- **Average – 5.43 (↓ - *previous 5.91*)**

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## FEEDBACK FROM 1/5

- ***I am confused regarding replication.***
  ***Do all nodes have copies of other nodes (data)?***
- Chapter 7 is on Consistency and Replication
- Question ties into Chapter 7.4 Replica management
- Data can be replicated in a variety of ways across a distributed system
- Three levels of data replication in distributed systems:
  - **FULL replication**: all data is replicated at every node
  - **PARTIAL replication**: only some fragments of data are replicated
    - As seen in Chapter 7.4
    - Not every node in the system replicates full dataset
    - Instead there are **permanent replicas**, **server-initiated**, and **client-initiated** replicas, and the **client** itself can even replicate data
  - **NO replication**: data exists at only one location, data is sharded

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## FEEDBACK - 2

- ***Per the example question between the frameworks (.NET remoting, Java RMI, and HTTP-REST), why was the HTTP-REST considered the most ~~portable~~ open?***
  - An HTTP-REST interface will support the greatest variety of clients backed by different Operating Systems (e.g. Windows, Linux, etc.), Languages (Java, Python, .NET, etc.), and system architectures (x86, ARM, etc.)
- ***How were we measuring ~~portability~~ openness?***
  - Count number of heterogeneous clients supported

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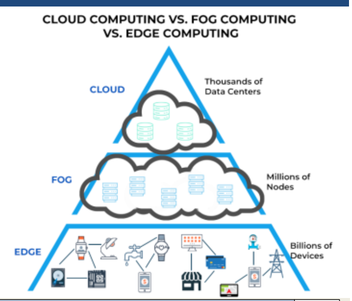
## EDGE / FOG / CLOUD

- ***What is the difference between edge, fog, and cloud ?***

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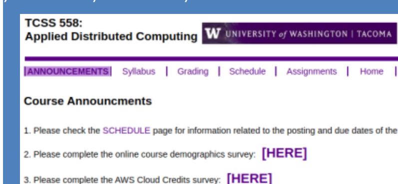
## SURVEY LINKS

**AT:**
http://faculty.washington.edu/wlloyd/courses/tcss558/announcements.html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ANNOUNCEMENTS | Syllabus | Grading | Schedule | Assignments | Home |

**Course Announcments**

1. Please check the SCHEDULE page for information related to the posting and due dates of the a
2. Please complete the online course demographics survey: [HERE]
3. Please complete the AWS Cloud Credits survey: [HERE]

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## CLASS ACTIVITY 1

- We will form groups of ~2-3
  - Remote students will use Canvas breakout rooms
- Each group will complete a Google Doc worksheet
- Add names to Google Doc as they appear in Canvas
- Once completed, **one person** submits a PDF of the Google Doc to Canvas
- Instructor will score all group members based on the uploaded PDF file
- To get started:
  - Log into your UW Google Account
  - Link to shared Google Drive
  - Follow link:
    https://tinyurl.com/2p95hdby

October 7, 2020 | TCSS562: Software Engineering for Cloud Computing [Fall 2020] School of Engineering and Technology, University of Washington - Tacoma | L3.12

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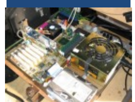
# WE WILL RETURN AT 2:40PM



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# TECHNOLOGY INNOVATIONS LEADING TO CLOUD COMPUTING

- Super computers
  - Huge multiprocessor systems with shared memory/RAM
  - Technically "not distributed"
  - Hardware all in one location
  - Initially expensive with proprietary designs
  - Traditionally supported HPC – High Performance Computing scientific applications
    - Weather forecasting
    - Molecular dynamics simulation
    - Protein modeling
  - Cost millions of dollars
  - Large systems consume MWs of electricity


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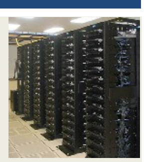
# INNOVATIONS LEADING TO CLOUD COMPUTING - 2

- Cluster computing
  - Group of interconnected homogeneous servers
  - Design emphasizes redundancy as server components are easily interchanged to keep overall system running
- Grid computing
  - Distributed heterogeneous servers organized into logical pools of loosely coupled resources connected by the internet
  - geographically dispersed
  - middleware software supports workload distribution and coordination functions
- Virtualization
- Others



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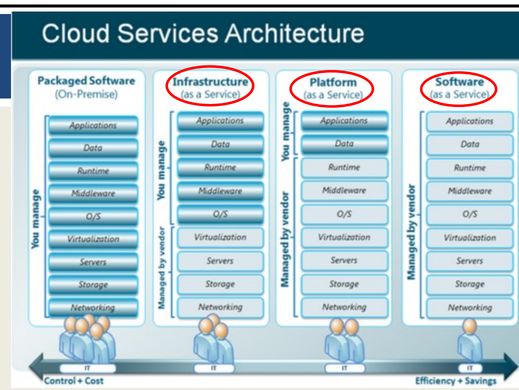


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## PUBLIC CLOUD COMPUTING

- Offers computing, storage, communication at ¢ per hour
- No premium to scale:

```
        1000 computers    @   1 hour
=        1 computer       @ 1000 hours
```

- Illusion of infinite scalability to cloud user
- As many computers as you can afford
- Leading examples:
  Amazon Web Services, Google App Engine, Microsoft Azure
- Amazon runs its own e-commerce on AWS!
- Billing models are becoming increasingly granular
  - By the minute, second, tenth of a second
  - Example: AWS Lambda $0.0000002 per request
    $0.000000208 to rent 128MB / 100-ms

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## PUBLIC CLOUD COMPUTING - 2

**m4.large ec2 virtual machine:**
2 vCPU cores, 8 GB RAM, Intel Xeon E5-2666 v3
10¢ an hour, 24 hrs/day,
30 days/month → $72.00/month
on-demand EC2 instance

**AWS Lambda Function-as-a-Service (FaaS) w/o free tier:**
2 vCPU cores, 3GB RAM, Intel Xeon E5-2666 v3 (maybe?)
as 2,592,000 x 1-sec service calls
24 hrs/day, 30 days/month:
**$130.14** **(8GB = $347.04)**

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## 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

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## DISTRIBUTED INFORMATION SYSTEMS

- **Enterprise-wide** integrated applications
  - Organizations confronted with too many applications
  - Interoperability among applications was difficult
  - Led 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.

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## 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

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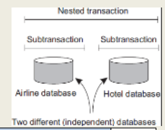
## TRANSACTIONS: ACID PROPERTIES

- Atomic: The transaction occurs indivisibly
- Consistent: Transaction does not create variant states across nodes during slow updates (e.g. system variants)
  - Replicas remain constant until all updated
  - Two phase commit: data pushed first, then the commit
- 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



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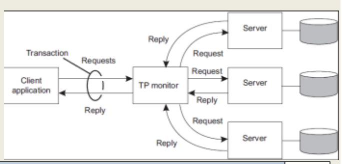
## TRANSACTION PROCESSING MONITOR

- 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



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## 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 – led to tight coupling
- Client and server endpoints must be up and running
- Interfaces coupled to specific languages and not *interoperable*
- This led to evolution of: Message-oriented middleware (MOM)



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## MESSAGE-ORIENTED MIDDLEWARE

- Publish and subscribe systems:
  - Rabbit MQ, Apache Kafka, AWS SQS
- Reduces tight coupling of RPC/RMI
- Applications indicate interest for specific type(s) of messages by sending requests to logical contact points
- Communication middleware delivers messages to subscribing applications



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## CHALLENGES WITH VARIOUS APPLICATION INTEGRATION METHODS

- Integration via shared data files and transfers
  - Shared data files (e.g. XML)
  - Leads to file management challenges (concurrent updates, etc.)
- 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 (***limited scalability***)
- 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 on, can receive messages



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## 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 aspects of a user's behavior
  - Myriad of actuators to collect information, provide feedback
- **TYPES OF PERVASIVE SYSTEMS:**
  - Ubiquitous computing systems
  - Mobile systems
  - Sensor networks



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## PERVASIVE SYSTEM TYPE: 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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## UBIQUITOUS COMPUTING DEVICES EXAMPLES

- Apple Watch
- Amazon Echo Speaker
- Amazon EchoDot (single speaker design)
- Fitbit
- Electronic Toll Systems
- Smart Traffic Lights
- Self Driving Cars
- Home Automation



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## UBIQUITOUS COMPUTING SYSTEM EXAMPLE

- **Domestic ubiquitous computing environment example:**
- Interconnect lighting and environmental controls with personal biometric monitors woven into clothing so that illumination and heating conditions in a room might be modulated, continuously and imperceptibly
- IoT technology helps enable ubiquitous computing

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## PERVASIVE SYSTEM TYPE: 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 location: leverage mobile adhoc network (MANET)
- MANET is an ad hoc network that can change locations and configure itself on the fly. MANETs are mobile, they use wireless connections to connect to various networks.
- VANET (Vehicular Ad Hoc Network), is a type of MANET that allows vehicles to communicate with roadside equipment.

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## PERVASIVE SYSTEM TYPE: 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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## PERVASIVE SYSTEM TYPE: 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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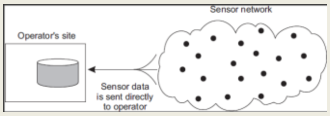
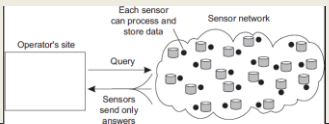
## CENTRALIZED VS. DECENTRALIZED DATA STORAGE

- Centralized:




- Decentralized:



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## WHO AGGREGATES AND STORES DATA?

- Consider the **tradeoff space** for:
  - sensor network data storage and processing

**Centralized** ←――――――→ **Decentralized**

- Single point-of-failure
- No node coordination
- No node processing or storage
- "Dumb" nodes
- Less expensive node
- More network traffic

- Nodes require high compute power
- "Smart" nodes
- Expensive nodes
- Less network traffic



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## SENSOR NETWORKS - 3

- 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?



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## QUESTIONS



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