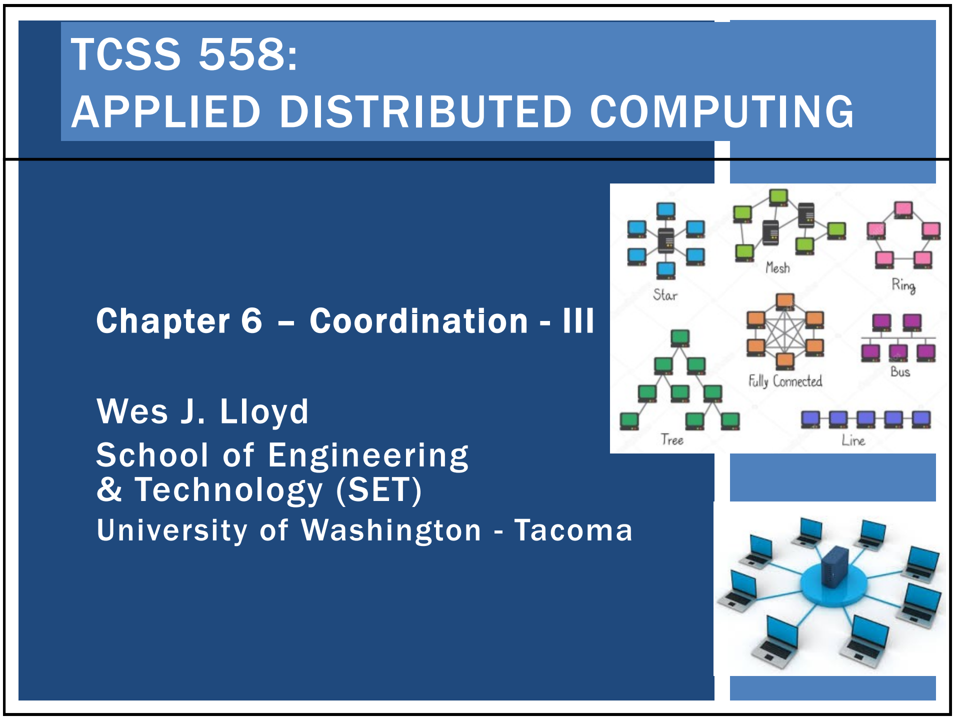
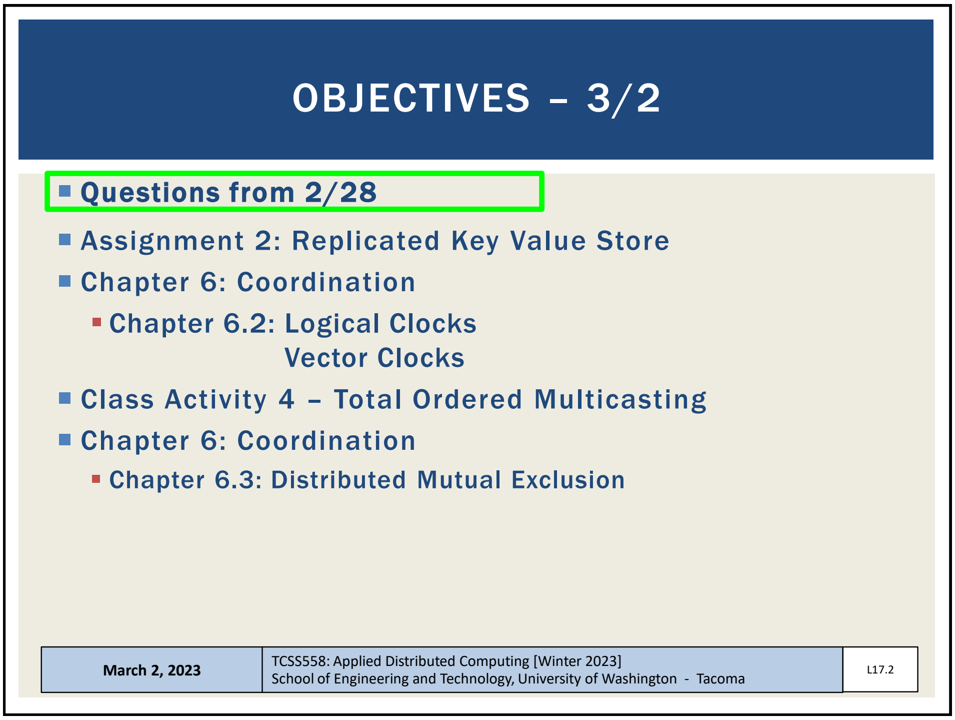


TCSS 558:
APPLIED DISTRIBUTED COMPUTING

Chapter 6 – Coordination - III

Wes J. Lloyd
School of Engineering
& Technology (SET)
University of Washington - Tacoma

1



OBJECTIVES – 3/2

- **Questions from 2/28**
- Assignment 2: Replicated Key Value Store
- Chapter 6: Coordination
  - Chapter 6.2: Logical Clocks
    Vector Clocks
- Class Activity 4 – Total Ordered Multicasting
- Chapter 6: Coordination
  - Chapter 6.3: Distributed Mutual Exclusion

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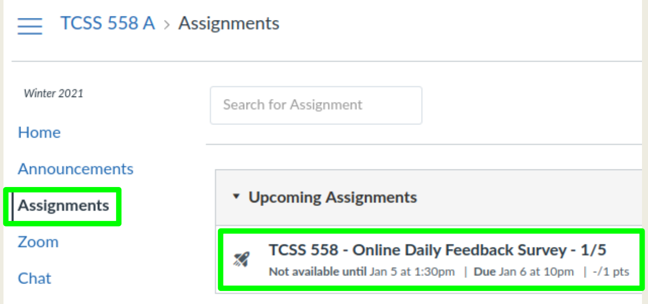
2

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



TCSS 558 - Online Daily Feedback Survey - 1/5
Not available until Jan 5 at 1:30pm | Due Jan 6 at 10pm | -/1 pts

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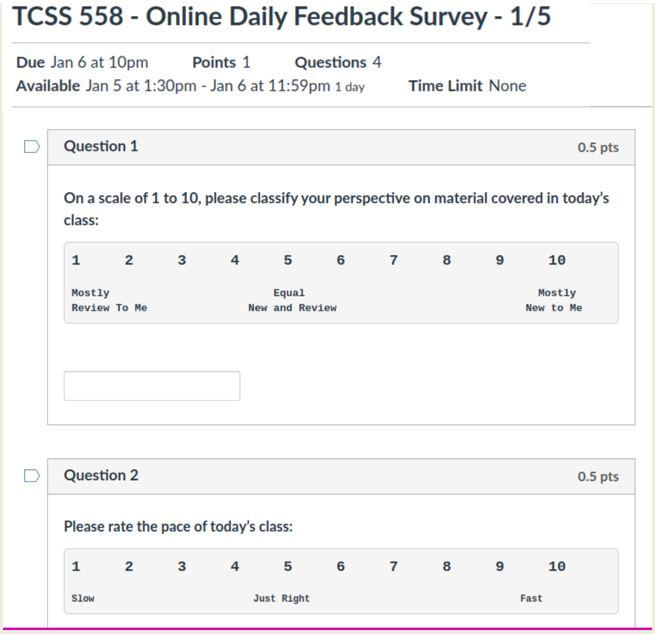
3



TCSS 558 - Online Daily Feedback Survey - 1/5

Due Jan 6 at 10pm **Points** 1 **Questions** 4
Available Jan 5 at 1:30pm - Jan 6 at 11:59pm 1 day **Time Limit** None

Question 1 0.5 pts

On a scale of 1 to 10, please classify your perspective on material covered in today's class:

```
1     2     3     4     5     6     7     8     9     10

Mostly                Equal                       Mostly
Review To Me          New and Review              New to Me
```

Question 2 0.5 pts

Please rate the pace of today's class:

```
1     2     3     4     5     6     7     8     9     10

Slow                  Just Right                  Fast
```

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4

MATERIAL / PACE

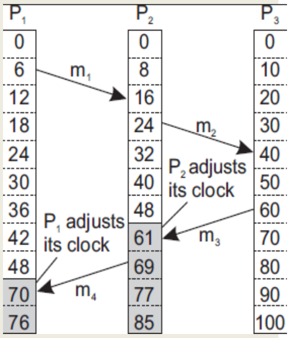
- Please classify your perspective on material covered in today's class (24 respondents):
- 1-mostly review, 5-equal new/review, 10-mostly new
- **Average – 6.25 (↓ - *previous 6.57*)**

- Please rate the pace of today's class:
- 1-slow, 5-just right, 10-fast
- **Average – 5.65 (↓ - *previous 5.81*)**

5

FEEDBACK FROM 2/28

- ***Will adjusting the time using Lamport's algorithm affect the order of other messages in the process?***
- Node P_2 receives a message m_3 from node P_3 at time=56
- The timestamp of m_3 from P_3 is time=60
- We assume that P_3 sends the message at time=60
- P_2 must receive m_3 at P_3's time+1
- P_2's clock is adjusted to time=61
- Because of the happens-before relation, we still say m_1 and m_2 happen before m_3
- What if m_5 arrives at P_3 from P_4 at time=50
- M5 is time stamped at time=24
- Does the sending of m_2 from P_2 happen before the sending of m_5 from P_4?
- This question asks about causality

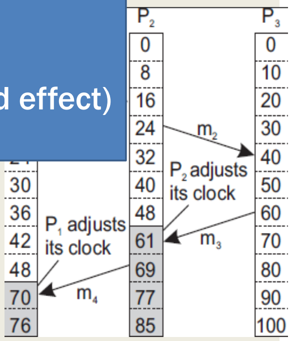


6

FEEDBACK FROM 2/28

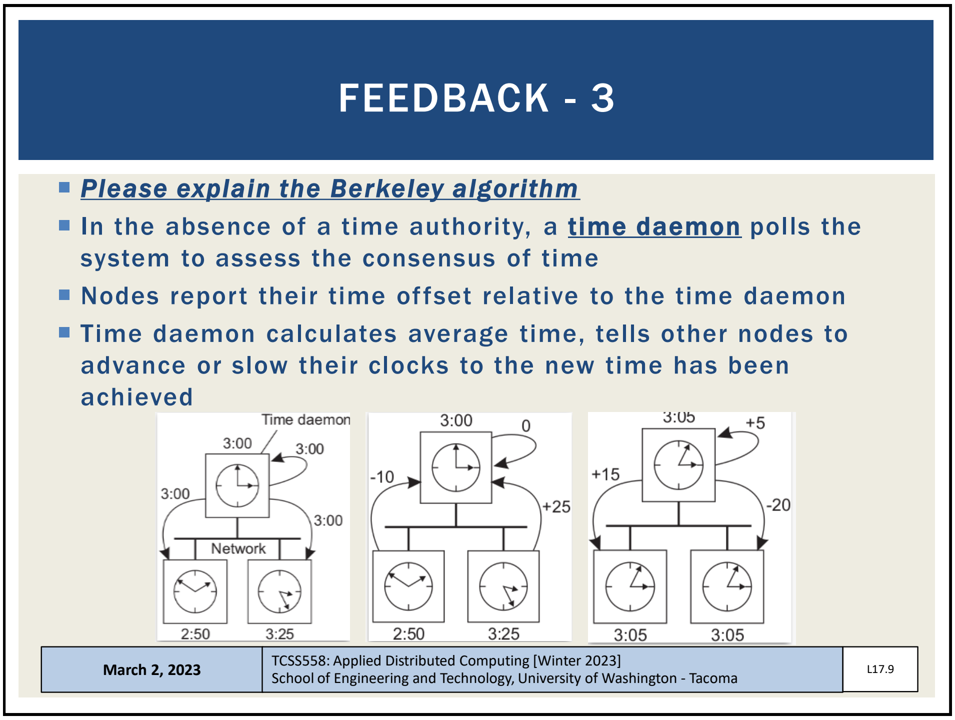
- ***Will adjusting the time using Lamport's algorithm affect the order of other messages in the process?***
- Node P_2
- The tim
- We assu time=60
- P_2 must
- P_2's clo
- Because we still say m_1 and m_2 happen before m_3
- What if m_5 arrives at P_3 from P_4 at time=50
- M5 is time stamped at time=24
- Does the sending of m_2 from P_2 happen before the sending of m_5 from P_4?
- This question asks about causality

KEY CONCEPT:
Lamport clock's are insufficient
to determine causality (cause and effect)



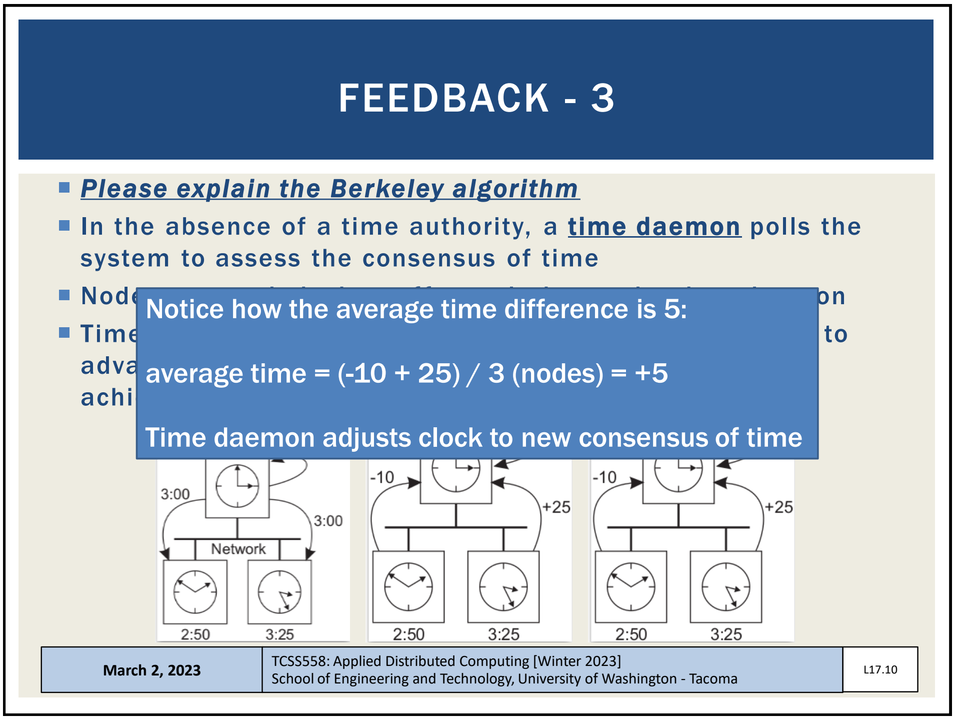
FEEDBACK - 2

- ***What is the difference between clock time accuracy vs. precision?***
- **Accuracy** is how close a given set of time measurements are to their true value
- Assume the atomic clock (UTC receiver) is the authority
- For a given node A, the time **accuracy** will be the error relative to the authority,
- **Precision** is how close two time measurements are to each other
  - Here neither is an authority
- **Example:**
- Consider if the UTC receiver indicates the time is 12:00:00 AM
- Node A and Node B both indicate the time is 12:00:25 AM
- What is the accuracy of Node A and B's sense of time?
- What is the precision of time between Node A and Node B?



FEEDBACK - 3

- ***Please explain the Berkeley algorithm***
- In the absence of a time authority, a **time daemon** polls the system to assess the consensus of time
- Nodes report their time offset relative to the time daemon
- Time daemon calculates average time, tells other nodes to advance or slow their clocks to the new time has been achieved



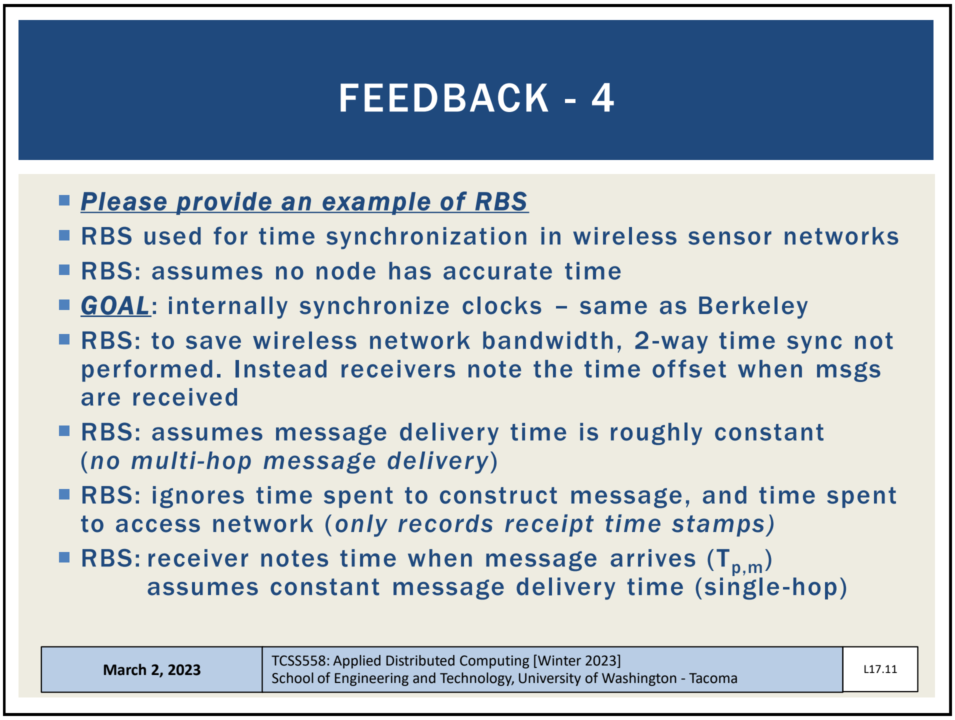
FEEDBACK - 3

- ***Please explain the Berkeley algorithm***
- In the absence of a time authority, a **time daemon** polls the system to assess the consensus of time
- Node on
- Time to
  adva
  achi

Notice how the average time difference is 5:

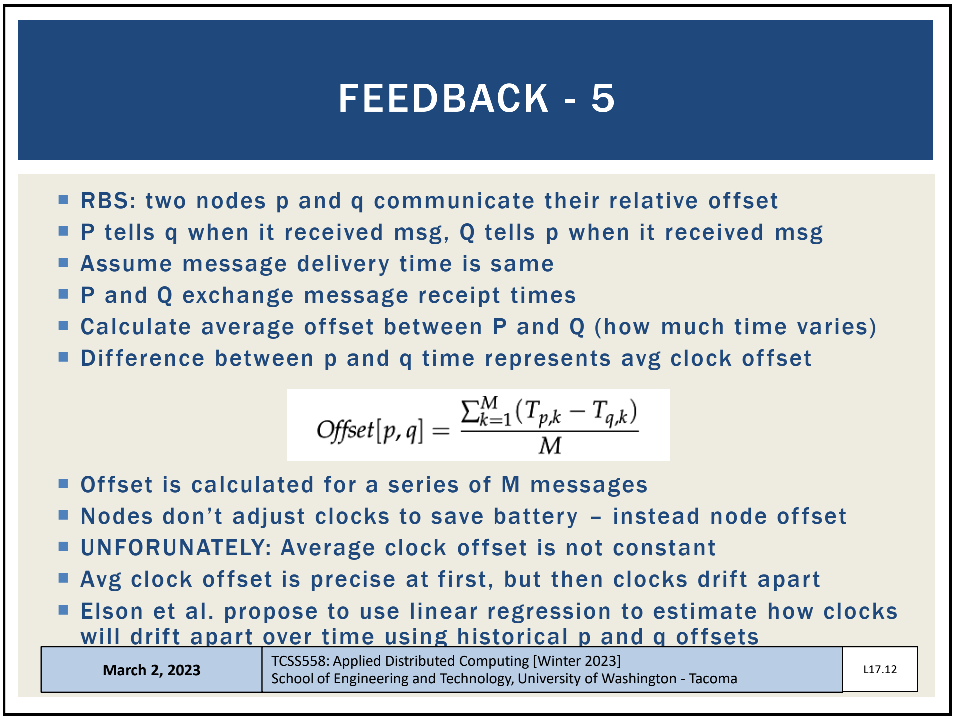
average time = (-10 + 25) / 3 (nodes) = +5

Time daemon adjusts clock to new consensus of time



FEEDBACK - 4

- ***Please provide an example of RBS***
- RBS used for time synchronization in wireless sensor networks
- RBS: assumes no node has accurate time
- ***GOAL***: internally synchronize clocks – same as Berkeley
- RBS: to save wireless network bandwidth, 2-way time sync not performed. Instead receivers note the time offset when msgs are received
- RBS: assumes message delivery time is roughly constant (*no multi-hop message delivery*)
- RBS: ignores time spent to construct message, and time spent to access network (*only records receipt time stamps*)
- RBS: receiver notes time when message arrives ($T_{p,m}$)
  assumes constant message delivery time (single-hop)

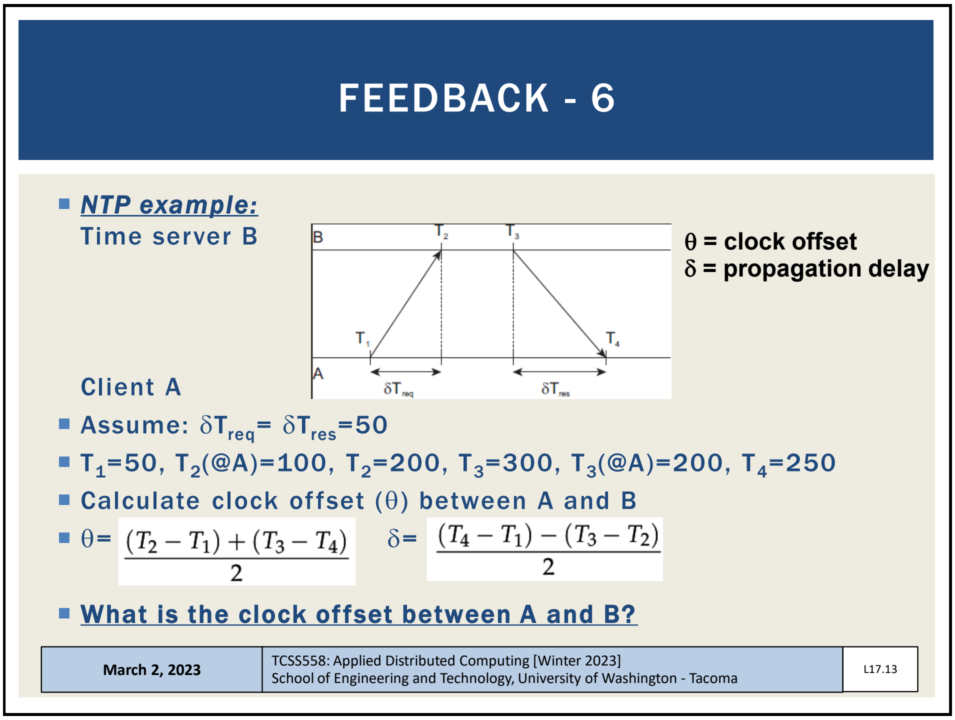


FEEDBACK - 5

- RBS: two nodes p and q communicate their relative offset
- P tells q when it received msg, Q tells p when it received msg
- Assume message delivery time is same
- P and Q exchange message receipt times
- Calculate average offset between P and Q (how much time varies)
- Difference between p and q time represents avg clock offset

$$Offset[p,q] = \frac{\sum_{k=1}^{M}(T_{p,k} - T_{q,k})}{M}$$

- Offset is calculated for a series of M messages
- Nodes don't adjust clocks to save battery – instead node offset
- UNFORUNATELY: Average clock offset is not constant
- Avg clock offset is precise at first, but then clocks drift apart
- Elson et al. propose to use linear regression to estimate how clocks will drift apart over time using historical p and q offsets



FEEDBACK - 6

- ***NTP example:***
  Time server B

  Client A

θ = clock offset
δ = propagation delay

- Assume: $\delta T_{req} = \delta T_{res} = 50$
- $T_1=50$, $T_2(@A)=100$, $T_2=200$, $T_3=300$, $T_3(@A)=200$, $T_4=250$
- Calculate clock offset (θ) between A and B
- $\theta = \frac{(T_2 - T_1) + (T_3 - T_4)}{2}$ $\delta = \frac{(T_4 - T_1) - (T_3 - T_2)}{2}$
- **What is the clock offset between A and B?**

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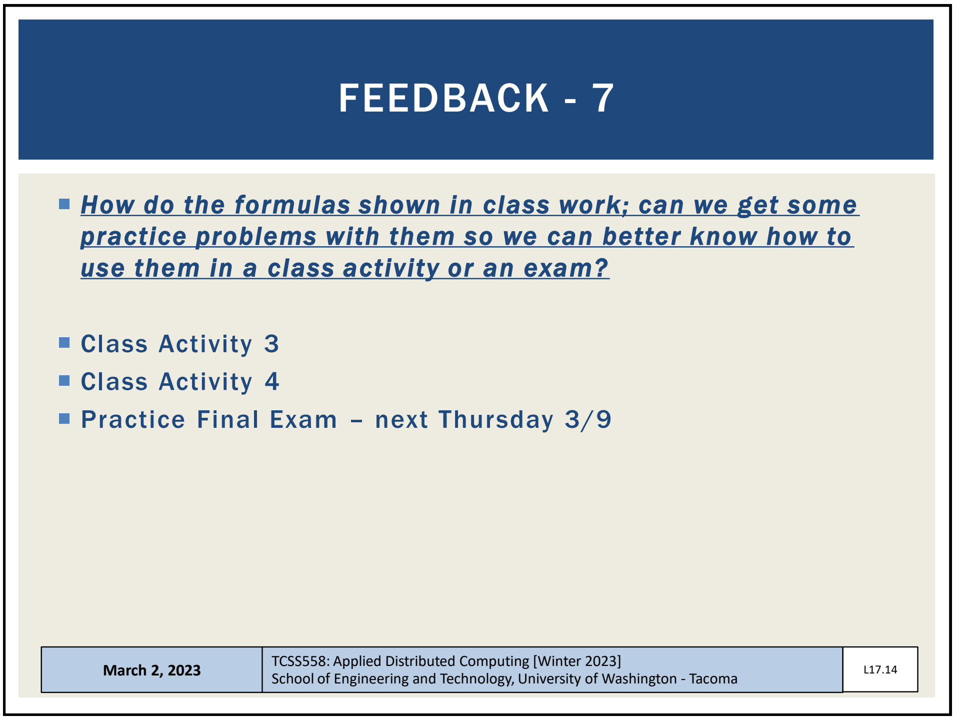

FEEDBACK - 7

- ***How do the formulas shown in class work; can we get some practice problems with them so we can better know how to use them in a class activity or an exam?***

- Class Activity 3
- Class Activity 4
- Practice Final Exam – next Thursday 3/9

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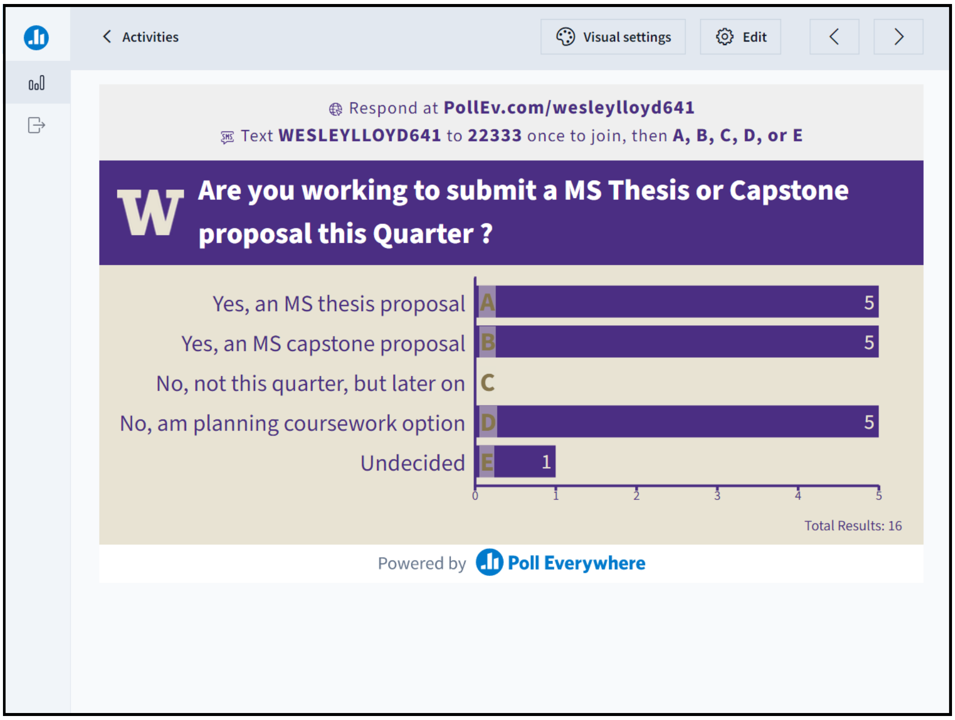


Respond at **PollEv.com/wesleylloyd641**
Text **WESLEYLLOYD641** to **22333** once to join, then **A, B, C, D, or E**

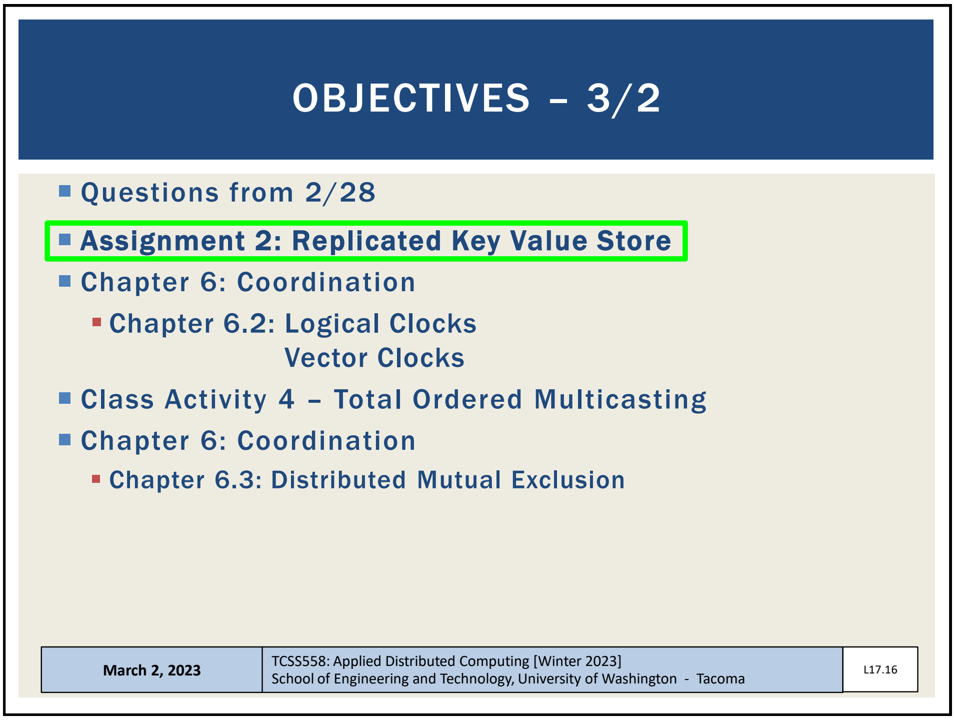
Are you working to submit a MS Thesis or Capstone proposal this Quarter ?

Yes, an MS thesis proposal	A	5
Yes, an MS capstone proposal	B	5
No, not this quarter, but later on	C	
No, am planning coursework option	D	5
Undecided	E	1

Total Results: 16

Powered by Poll Everywhere

15



OBJECTIVES – 3/2

- Questions from 2/28
- **Assignment 2: Replicated Key Value Store**
- Chapter 6: Coordination
  - Chapter 6.2: Logical Clocks
    Vector Clocks
- Class Activity 4 – Total Ordered Multicasting
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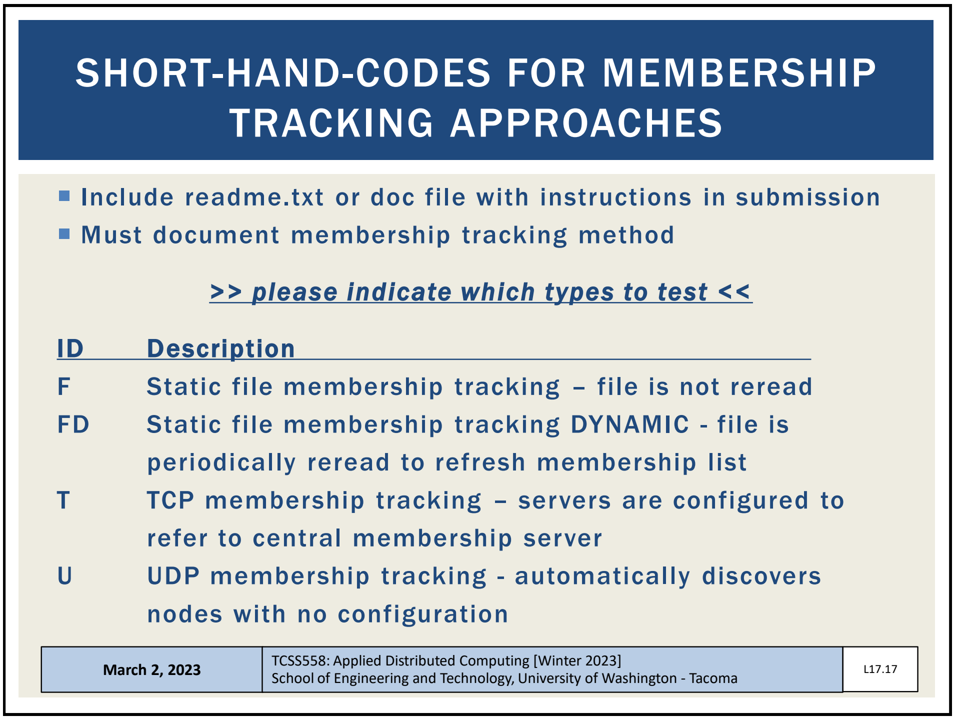
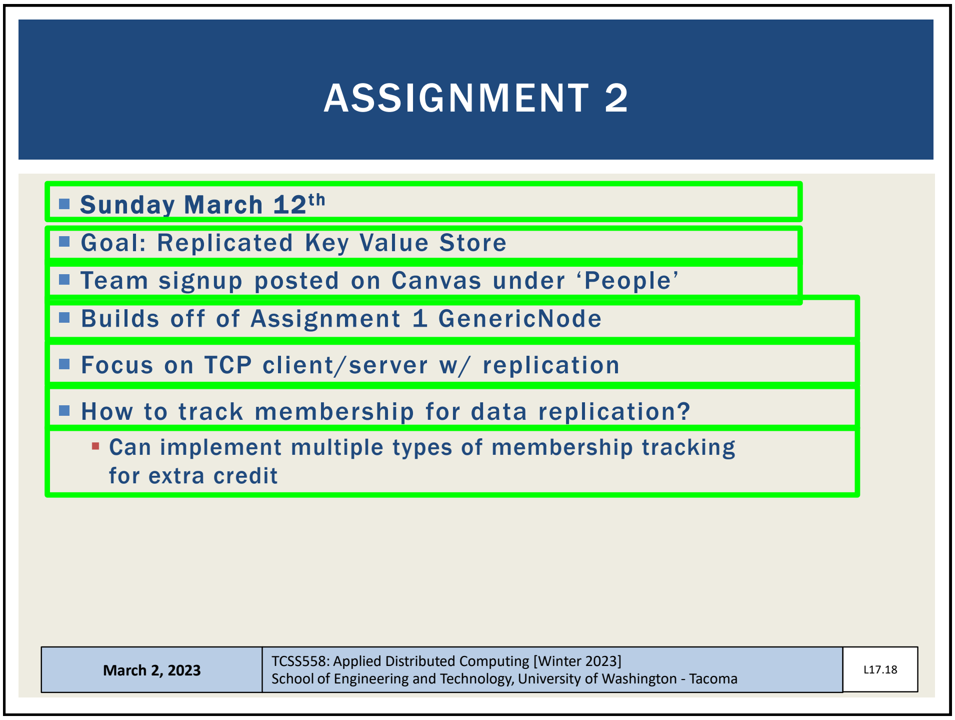


SHORT-HAND-CODES FOR MEMBERSHIP TRACKING APPROACHES

- Include readme.txt or doc file with instructions in submission
- Must document membership tracking method

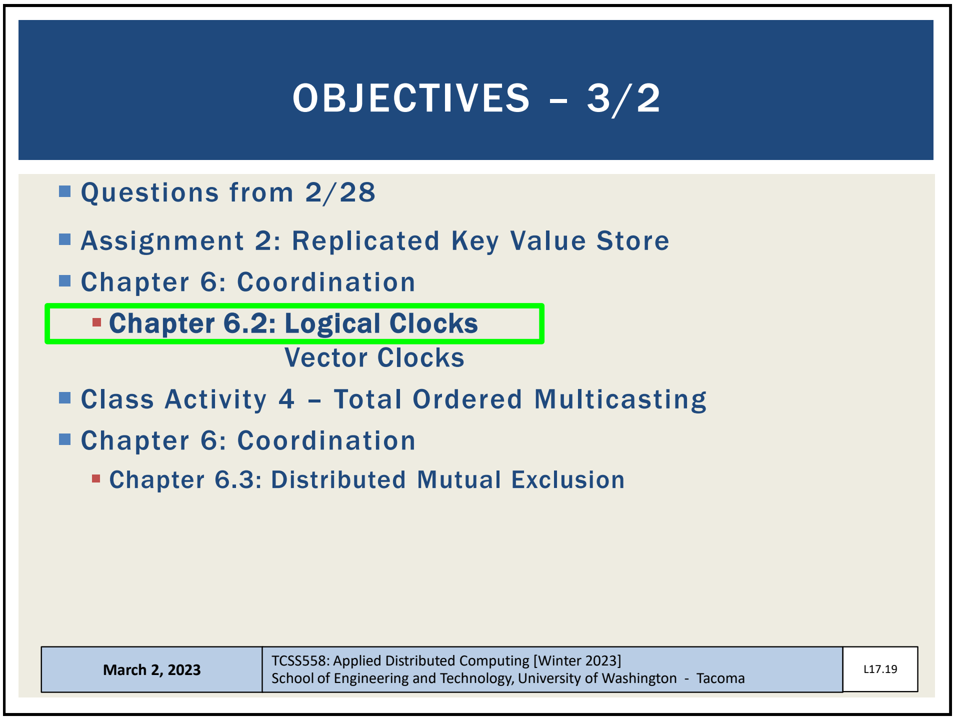
>> please indicate which types to test <<

ID	Description
F	Static file membership tracking – file is not reread
FD	Static file membership tracking DYNAMIC - file is periodically reread to refresh membership list
T	TCP membership tracking – servers are configured to refer to central membership server
U	UDP membership tracking - automatically discovers nodes with no configuration



ASSIGNMENT 2

- **Sunday March 12th**
- Goal: Replicated Key Value Store
- Team signup posted on Canvas under ‘People’
- Builds off of Assignment 1 GenericNode
- Focus on TCP client/server w/ replication
- How to track membership for data replication?
  - Can implement multiple types of membership tracking for extra credit



OBJECTIVES – 3/2

- Questions from 2/28
- Assignment 2: Replicated Key Value Store
- Chapter 6: Coordination
  - **Chapter 6.2: Logical Clocks**
    Vector Clocks
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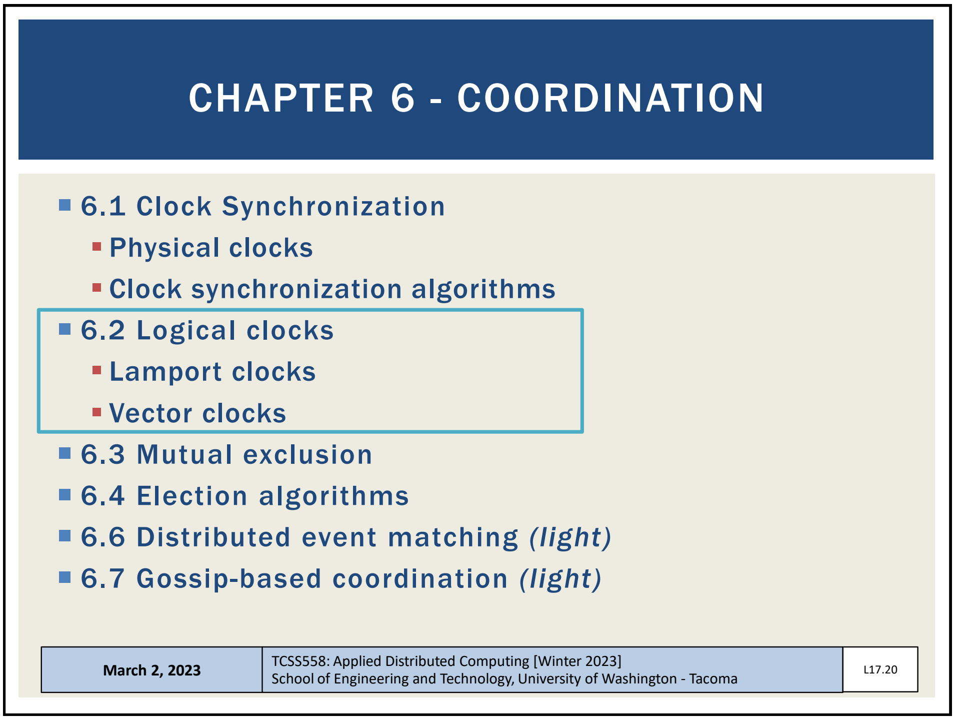
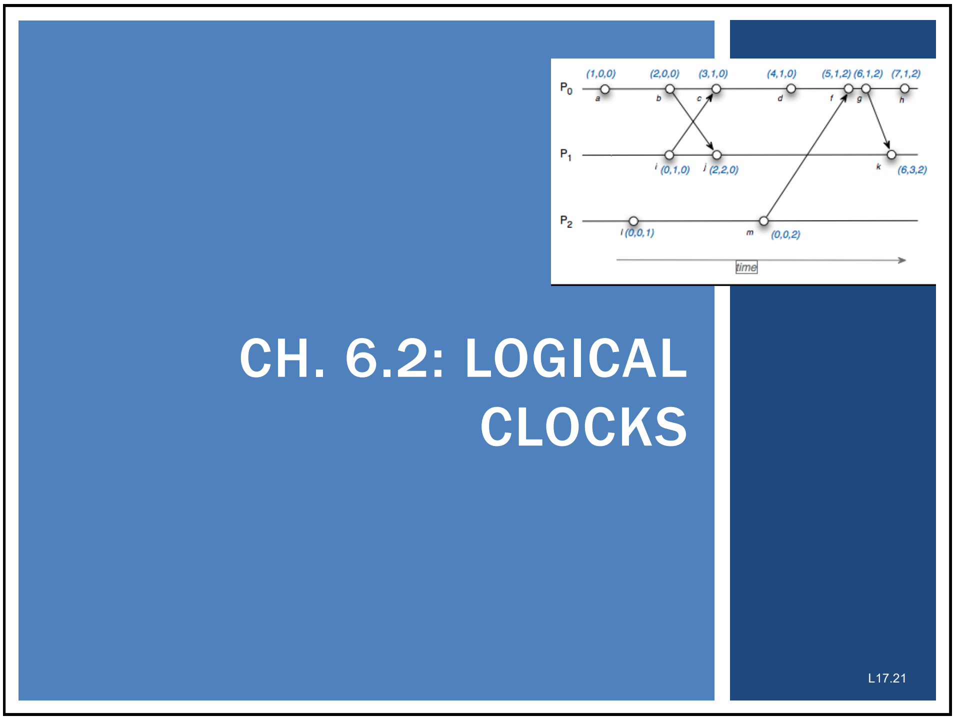


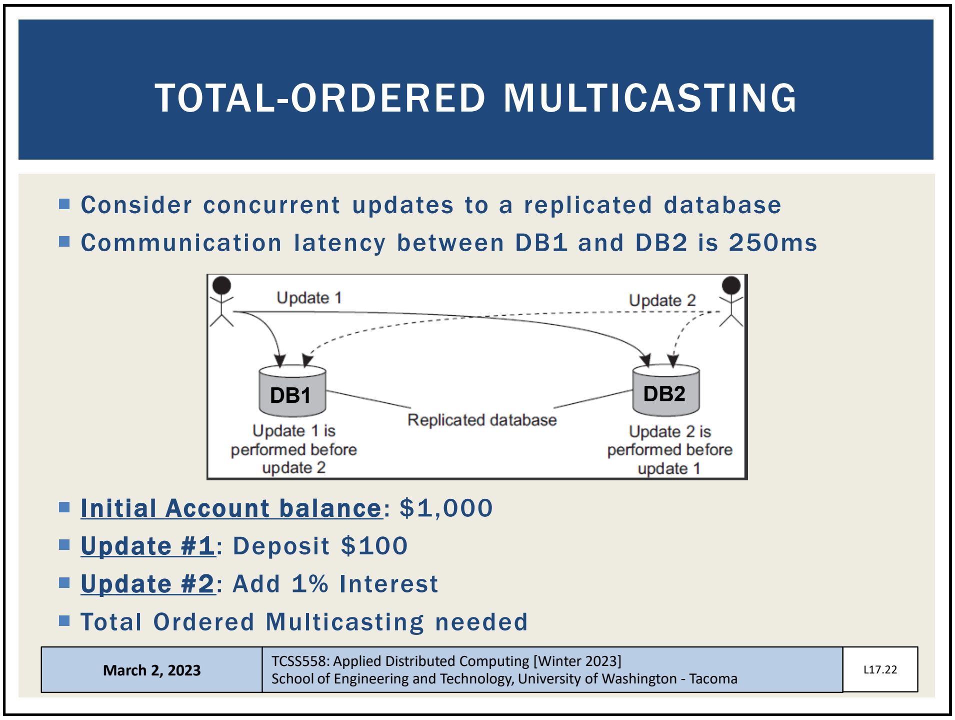
CHAPTER 6 - COORDINATION

- 6.1 Clock Synchronization
  - Physical clocks
  - Clock synchronization algorithms
- 6.2 Logical clocks
  - Lamport clocks
  - Vector clocks
- 6.3 Mutual exclusion
- 6.4 Election algorithms
- 6.6 Distributed event matching *(light)*
- 6.7 Gossip-based coordination *(light)*



CH. 6.2: LOGICAL CLOCKS

L17.21



TOTAL-ORDERED MULTICASTING

- Consider concurrent updates to a replicated database
- Communication latency between DB1 and DB2 is 250ms

Update 1
Update 2
DB1
DB2
Replicated database
Update 1 is performed before update 2
Update 2 is performed before update 1

- **Initial Account balance**: $1,000
- **Update #1**: Deposit $100
- **Update #2**: Add 1% Interest
- Total Ordered Multicasting needed

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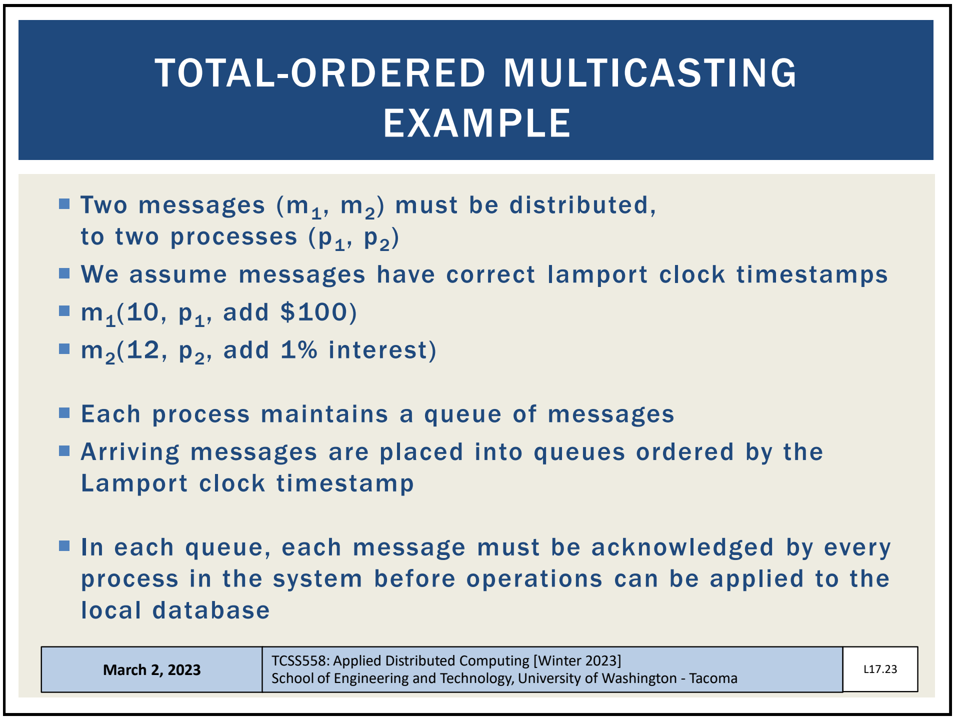

TOTAL-ORDERED MULTICASTING EXAMPLE

- Two messages (m_1, m_2) must be distributed, to two processes (p_1, p_2)
- We assume messages have correct lamport clock timestamps
- m_1(10, p_1, add $100)
- m_2(12, p_2, add 1% interest)

- Each process maintains a queue of messages
- Arriving messages are placed into queues ordered by the Lamport clock timestamp

- In each queue, each message must be acknowledged by every process in the system before operations can be applied to the local database

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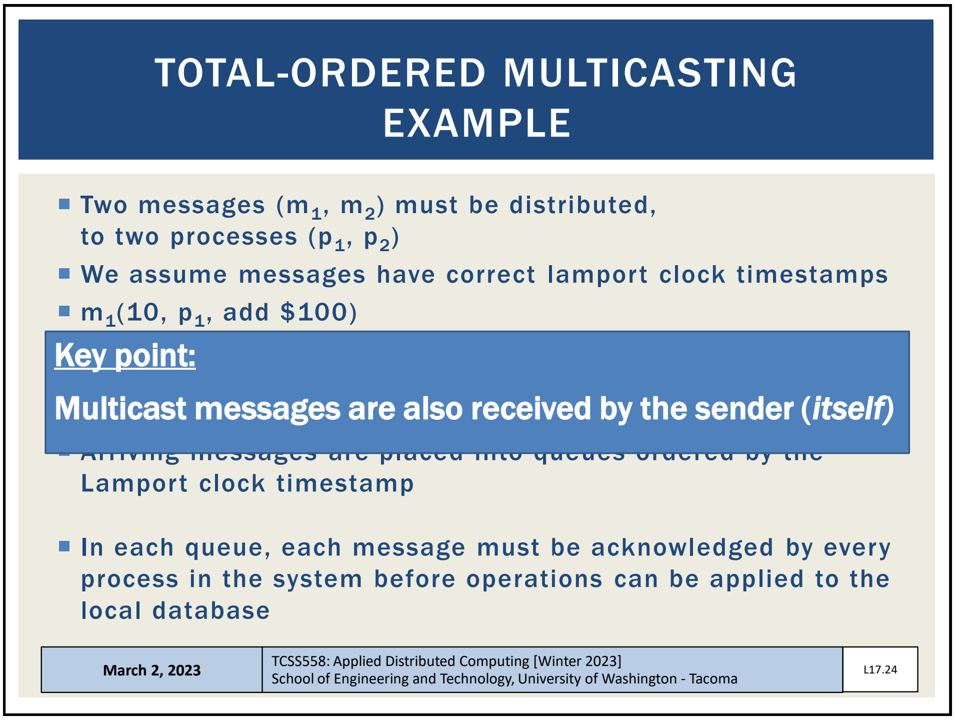

TOTAL-ORDERED MULTICASTING EXAMPLE

- Two messages (m_1, m_2) must be distributed, to two processes (p_1, p_2)
- We assume messages have correct lamport clock timestamps
- m_1(10, p_1, add $100)

Key point:

Multicast messages are also received by the sender (*itself*)

- Arriving messages are placed into queues ordered by the Lamport clock timestamp

- In each queue, each message must be acknowledged by every process in the system before operations can be applied to the local database

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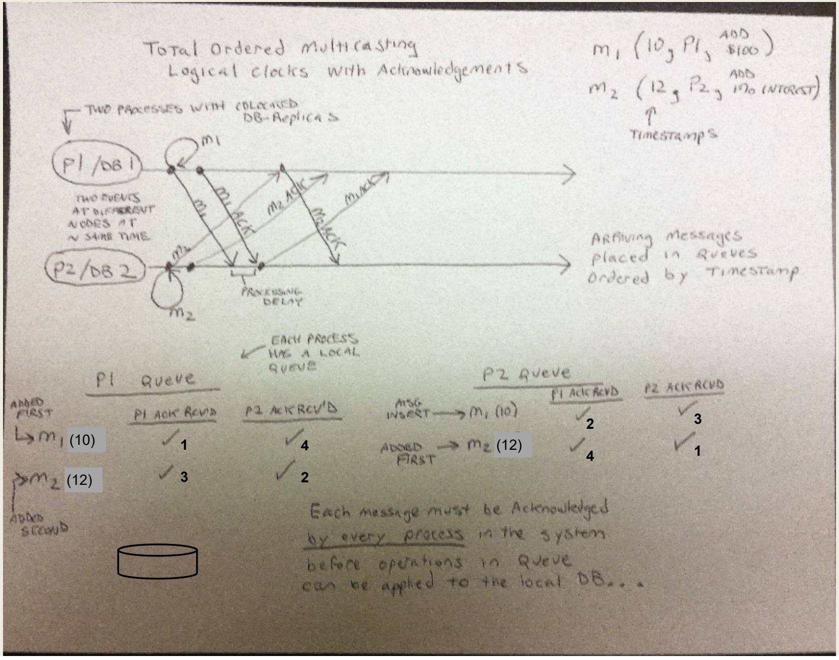
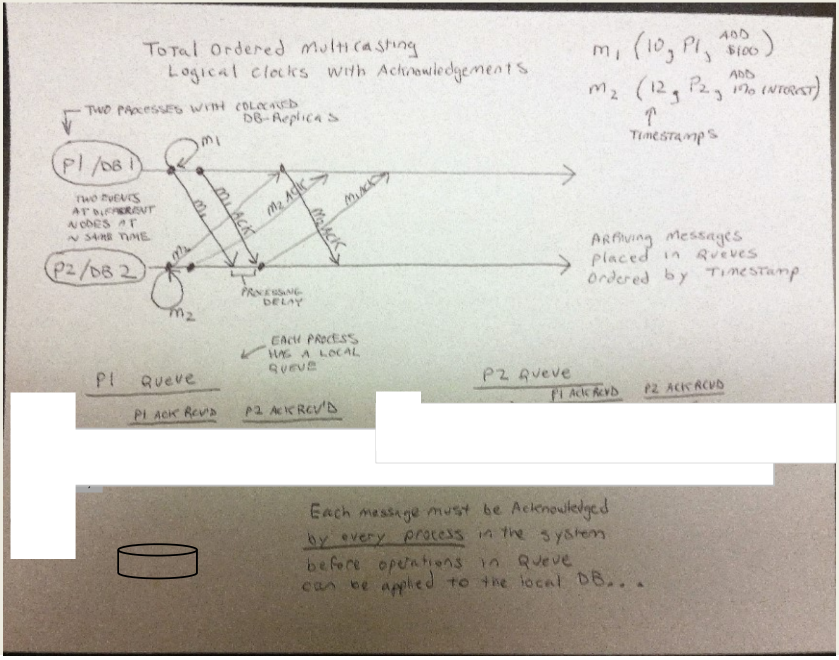
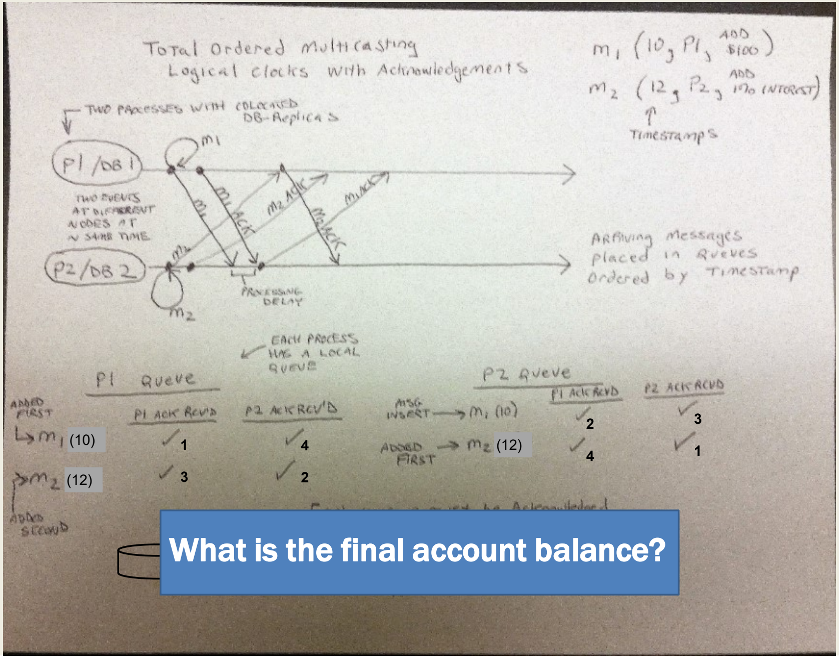
TOTAL-ORDERED MULTICASTING EXAMPLE


Total Ordered Multicasting
Logical clocks with Acknowledgements
m1 (10, P1, ADD $100)
m2 (12, P2, ADD 1% INTEREST)
Timestamps
TWO PROCESSES WITH COLOCATED DB-Replicas
P1 / DB 1
P2 / DB 2
TWO EVENTS AT DIFFERENT NODES AT ~ SAME TIME
m1
m2
m1 ACK
m2 ACK
PROCESSING DELAY
Arriving messages placed in Queues Ordered by Timestamp
EACH PROCESS HAS A LOCAL QUEUE
P1 Queue
P1 ACK RCV'D
P2 ACK RCV'D
ADDED FIRST
m1 (10) ✓1 ✓4
m2 (12) ✓3 ✓2
ADDED SECOND
P2 Queue
P1 ACK RCVD
P2 ACK RCVD
MSG INSERT → m1 (10) ✓2 ✓3
ADDED FIRST → m2 (12) ✓4 ✓1
Each message must be Acknowledged by every process in the system before operations in Queue can be applied to the local DB...

TOTAL-ORDERED MULTICASTING EXAMPLE


Total Ordered Multicasting
Logical clocks with Acknowledgements
m1 (10, P1, ADD $100)
m2 (12, P2, ADD 1% INTEREST)
Timestamps
TWO PROCESSES WITH COLOCATED DB-Replicas
P1 / DB 1
P2 / DB 2
TWO EVENTS AT DIFFERENT NODES AT ~ SAME TIME
m1
m2
m1 ACK
m2 ACK
PROCESSING DELAY
Arriving messages placed in Queues Ordered by Timestamp
EACH PROCESS HAS A LOCAL QUEUE
P1 Queue
P1 ACK RCV'D
P2 ACK RCV'D
P2 Queue
P1 ACK RCVD
P2 ACK RCVD
Each message must be Acknowledged by every process in the system before operations in Queue can be applied to the local DB...

TOTAL-ORDERED MULTICASTING EXAMPLE


Total Ordered Multicasting
Logical clocks with Acknowledgements
m1 (10, P1, ADD $100)
m2 (12, P2, ADD 1% INTEREST)
Timestamps
TWO PROCESSES WITH COLOCATED DB-Replicas
P1 /DB 1
P2/DB 2
m1
m2
TWO EVENTS AT DIFFERENT NODES AT ~ SAME TIME
m1
m1 ACK
m2 ACK
m2 ACK
m1 ACK
m2
PROCESSING DELAY
Arriving messages placed in Queues Ordered by Timestamp
EACH PROCESS HAS A LOCAL QUEUE
P1 Queue
ADDED FIRST
m1 (10)
m2 (12)
ADDED SECOND
P1 ACK RCV'D
1
3
P2 ACK RCV'D
4
2
P2 Queue
MSG INSERT → m1 (10)
ADDED FIRST → m2 (12)
P1 ACK RCVD
2
4
P2 ACK RCVD
3
1

What is the final account balance?

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TOTAL-ORDERED MULTICASTING - 2

- Each message timestamped with local logical clock of sender
- **Multicast messages are also received by the sender (*itself*)**
- Assumptions:
  - Messages from same sender received in order they were sent
  - No messages are lost
- When messages arrive they are placed in local queue ordered by timestamp
- Receiver ***multicasts*** acknowledgement of message receipt to other processes
  - Time stamp of message receipt is lower the acknowledgement
- This process ***replicates*** queues across sites
- Messages delivered to application (database) only when message at the head of the queue has been acknowledged by ***every*** process in the system

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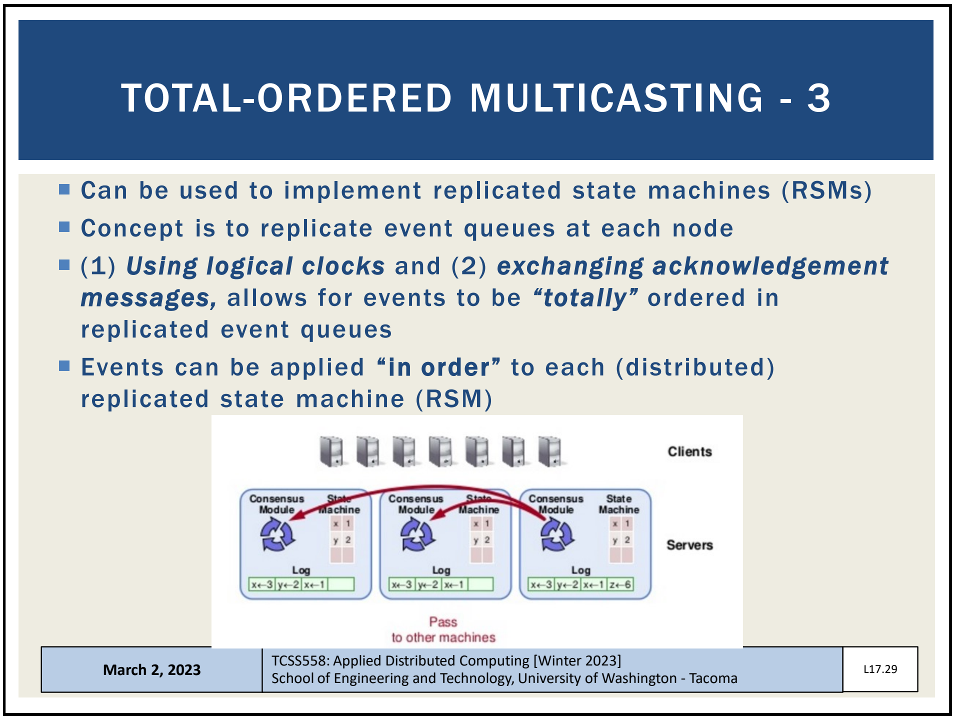
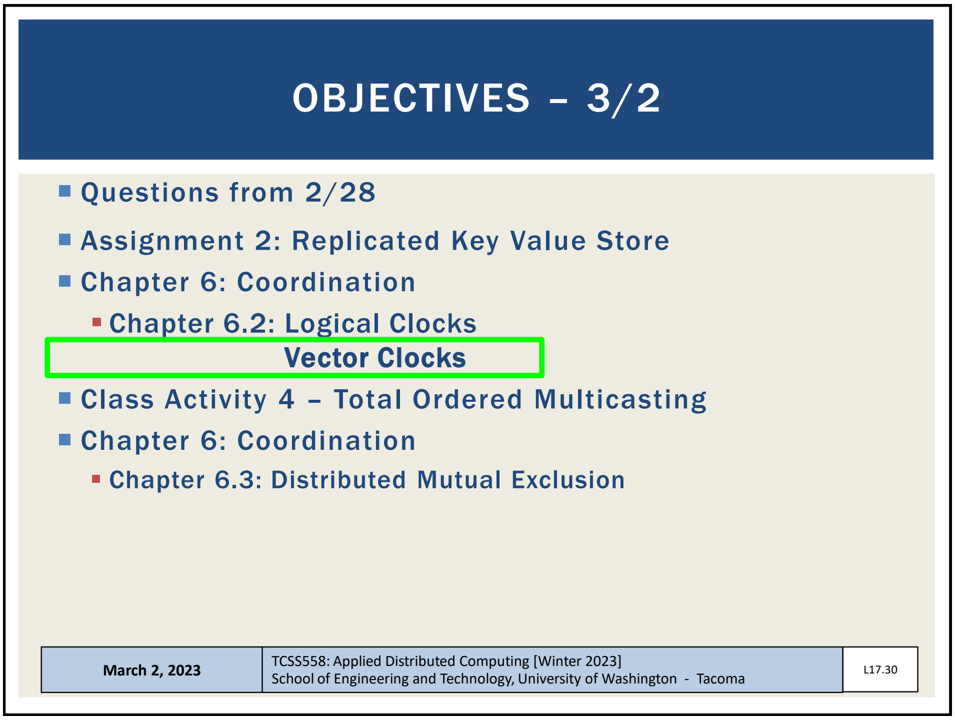


TOTAL-ORDERED MULTICASTING - 3

- Can be used to implement replicated state machines (RSMs)
- Concept is to replicate event queues at each node
- (1) ***Using logical clocks*** and (2) ***exchanging acknowledgement messages***, allows for events to be ***"totally"*** ordered in replicated event queues
- Events can be applied **"in order"** to each (distributed) replicated state machine (RSM)

Clients
Servers
Consensus Module
State Machine
x 1
y 2
Log
x←3 y←2 x←1
x←3 y←2 x←1 z←6
Pass
to other machines



OBJECTIVES – 3/2

- Questions from 2/28
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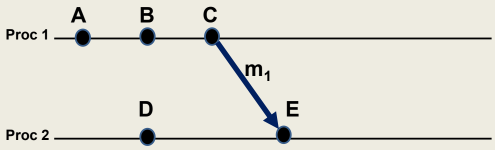
VECTOR CLOCKS

- Lamport clocks don't help to determine causal ordering of messages
- Vector clocks capture causal histories and can be used as an alternative
- But what is causality? …

WHAT IS CAUSALITY?



- Having a causal relationship between two events (A and E) indicates that event E results from the occurrence of event A.
- When one event results from another, there is a causal relationship between the two events.
- This is also referred to as cause and effect.

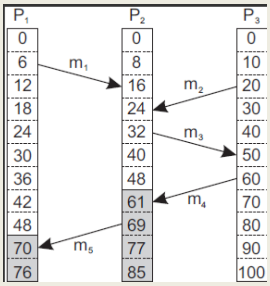
CAUSALITY - 2

- **Disclaimer:**
- Without knowing actual information contained in messages, it is not possible to state with certainty that there is a causal relationship or perhaps a conflict

- Lamport/Vector clocks can help us suggest possible causality
- But we never know for sure…

CAUSALITY - 3

- Consider the messages:



P_1	P_2	P_3
0	0	0
6	8	10
12	16	20
18	24	30
24	32	40
30	40	50
36	48	60
42	61	70
48	69	80
70	77	90
76	85	100

- P2 receives m1, and subsequently sends m3
- **Causality:** Sending m3 ***may*** depend on what's contained in m1
- P2 receives m2, receiving m2 is ***not*** related to receiving m1
- ***Is sending m3 causally dependent on receiving m2?***

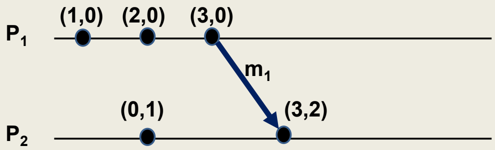
VECTOR CLOCKS

- Vector clocks help keep track of **causal history**
- If two local events happened at process P, then the causal history H(p2) of event p2 is {p1,p2}

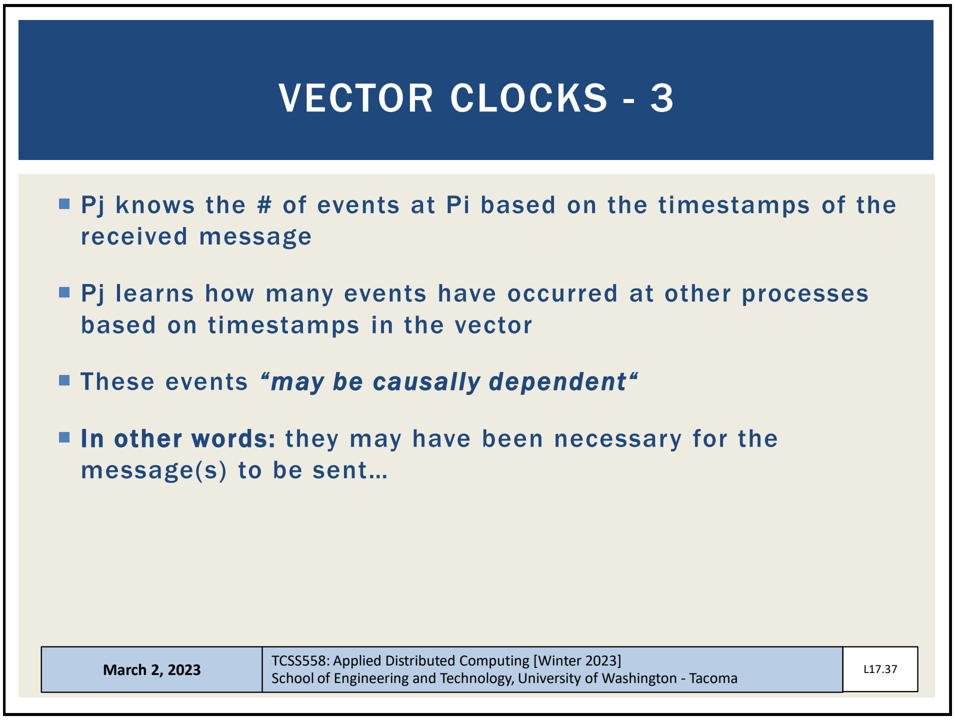
- P sends messages to Q (*event p3*)
- Q previously performed event q1
- Q records arrival of message as q2
- Causal histories merged at Q H(q2)= {p1,p2,p3,q1,q2}

- Fortunately, can simply store history of last event, as a vector clock → H(q2) = (3,2)
- Each entry corresponds to the last event at the process

VECTOR CLOCKS - 2



- Each process maintains a vector clock which
  - Captures number of events at the local process (e.g. logical clock)
  - Captures number of events at all other processes
- Causality is captured by:
  - For each event at Pi, the vector clock (VC_i) is incremented
  - The msg is timestamped with VC_i; and sending the msg is recorded as a new event at P_i
  - P_j adjusts its VC_j choosing the **max** of: the message timestamp –or- the local vector clock (VC_j)



VECTOR CLOCKS - 3

- Pj knows the # of events at Pi based on the timestamps of the received message
- Pj learns how many events have occurred at other processes based on timestamps in the vector
- These events ***"may be causally dependent"***
- **In other words:** they may have been necessary for the message(s) to be sent…

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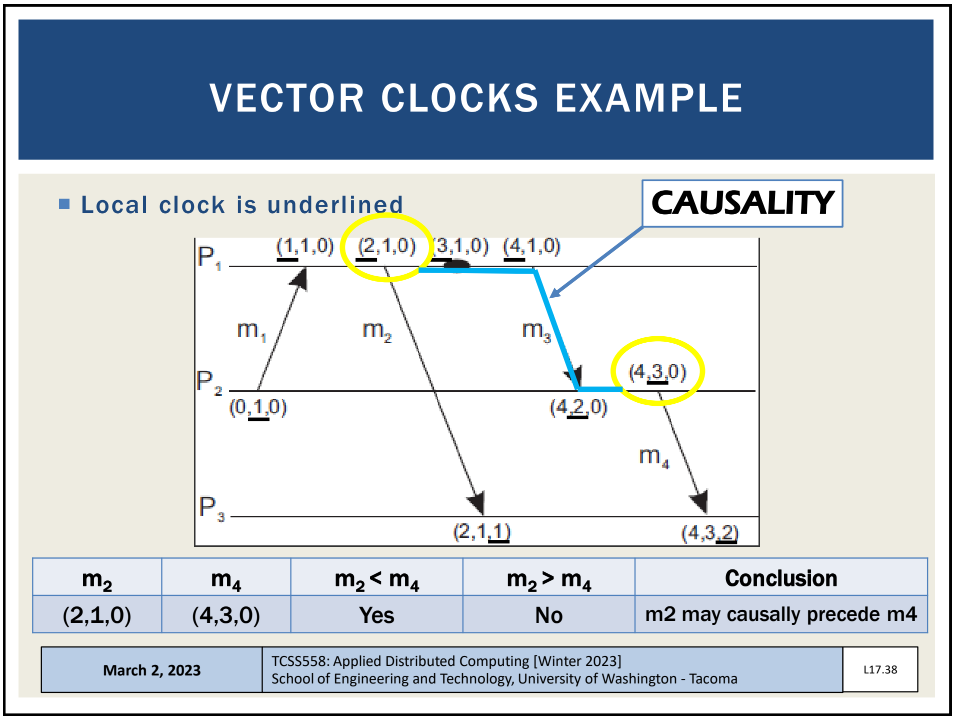

VECTOR CLOCKS EXAMPLE

- Local clock is underlined

m_2	m_4	$m_2 < m_4$	$m_2 > m_4$	Conclusion
(2,1,0)	(4,3,0)	Yes	No	m2 may causally precede m4

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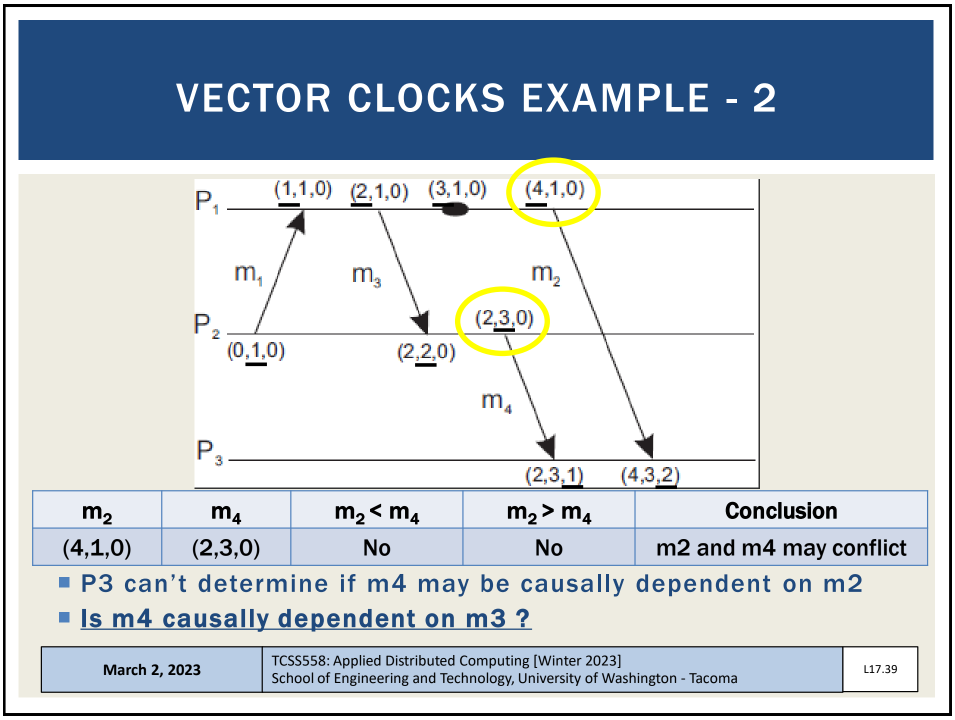
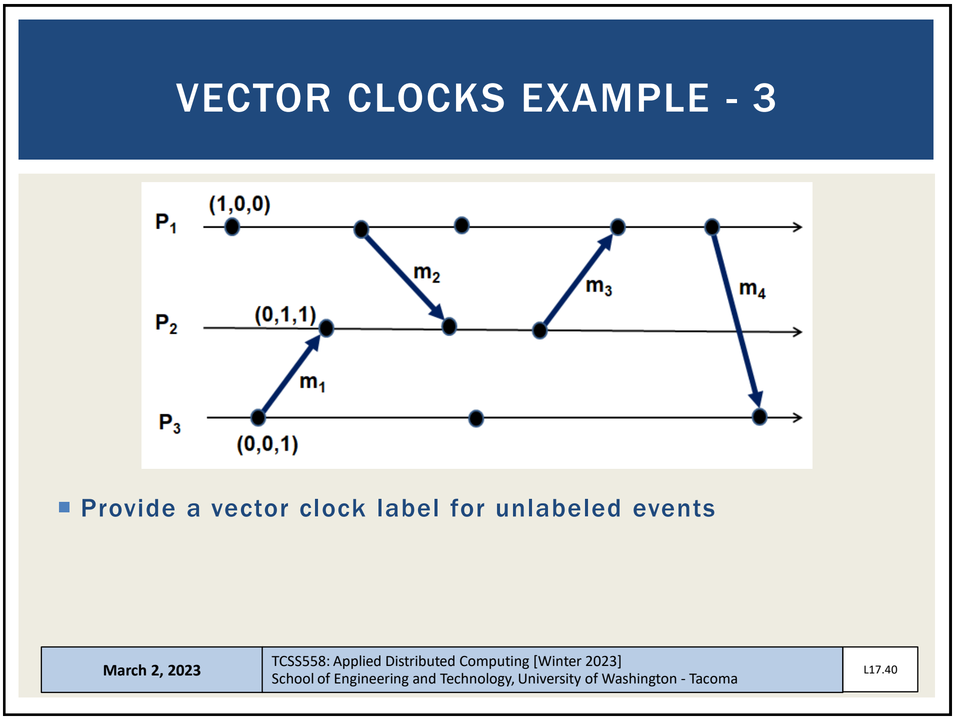


VECTOR CLOCKS EXAMPLE - 2

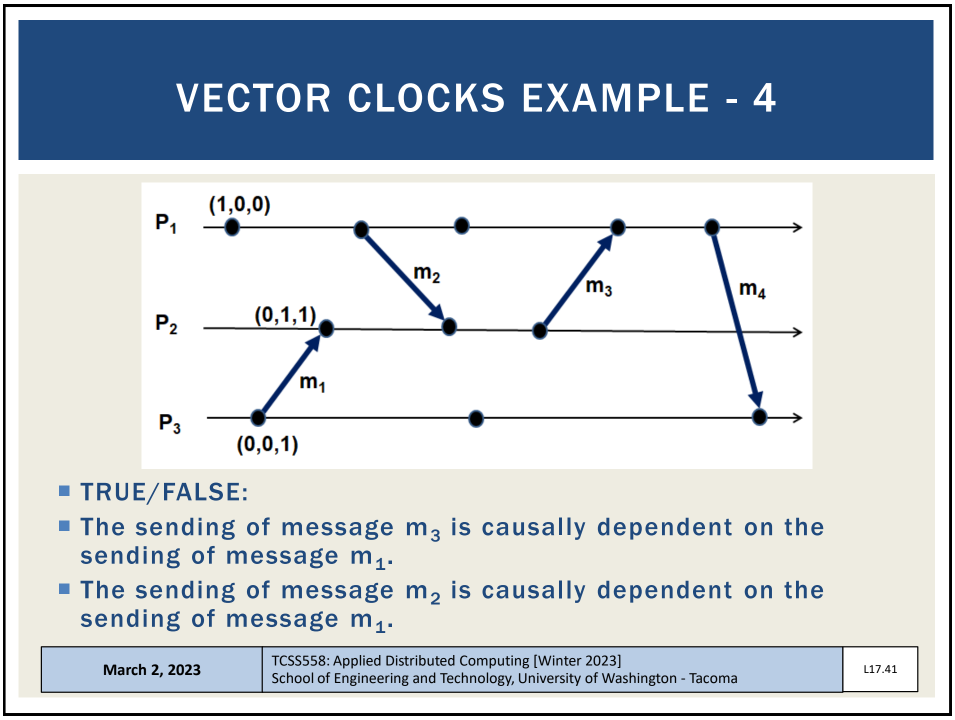
m_2	m_4	$m_2 < m_4$	$m_2 > m_4$	Conclusion
(4,1,0)	(2,3,0)	No	No	m2 and m4 may conflict

- P3 can't determine if m4 may be causally dependent on m2
- **Is m4 causally dependent on m3 ?**



VECTOR CLOCKS EXAMPLE - 3

- Provide a vector clock label for unlabeled events



VECTOR CLOCKS EXAMPLE - 4

- TRUE/FALSE:
- The sending of message m_3 is causally dependent on the sending of message m_1.
- The sending of message m_2 is causally dependent on the sending of message m_1.

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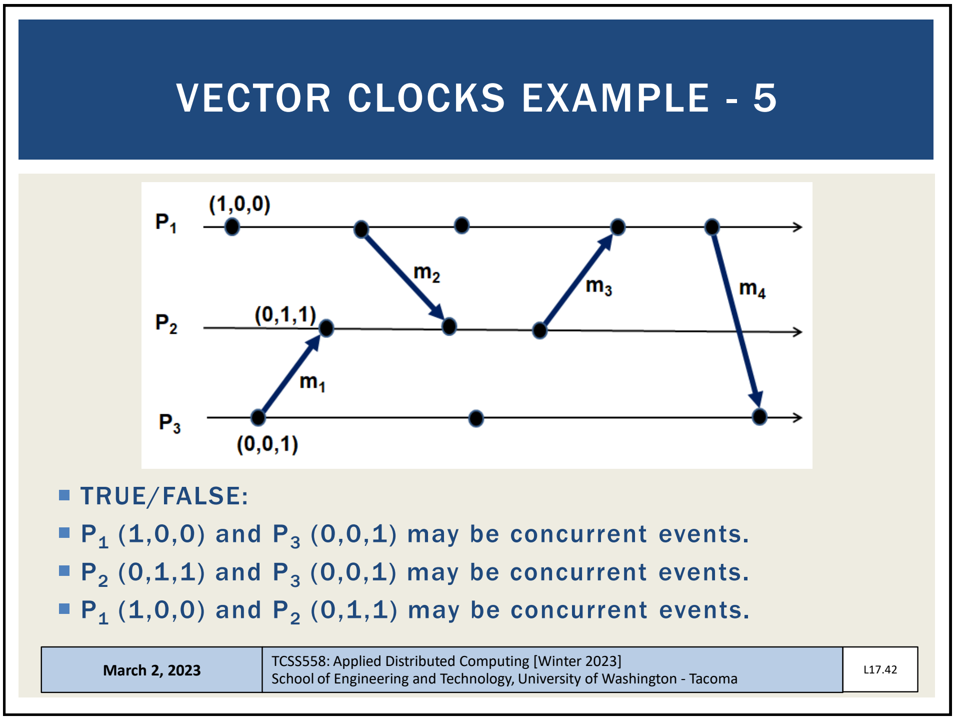

VECTOR CLOCKS EXAMPLE - 5

- TRUE/FALSE:
- P_1 (1,0,0) and P_3 (0,0,1) may be concurrent events.
- P_2 (0,1,1) and P_3 (0,0,1) may be concurrent events.
- P_1 (1,0,0) and P_2 (0,1,1) may be concurrent events.

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WE WILL RETURN AT 2:40 PM

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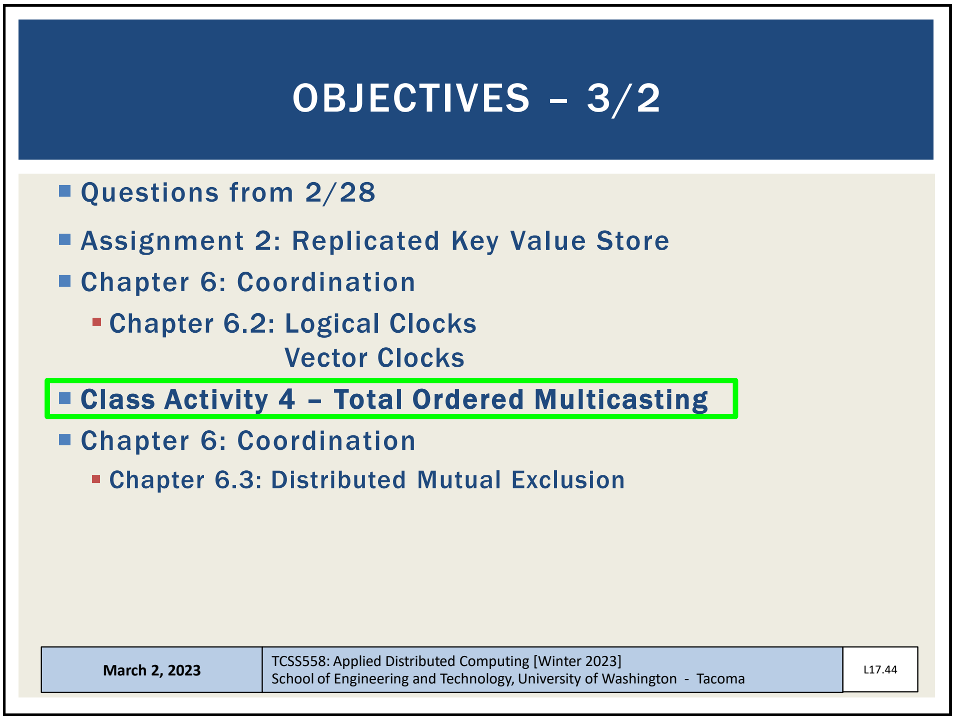

OBJECTIVES – 3/2

- Questions from 2/28
- Assignment 2: Replicated Key Value Store
- Chapter 6: Coordination
  - Chapter 6.2: Logical Clocks
    Vector Clocks
- **Class Activity 4 – Total Ordered Multicasting**
- Chapter 6: Coordination
  - Chapter 6.3: Distributed Mutual Exclusion

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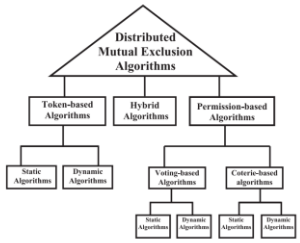
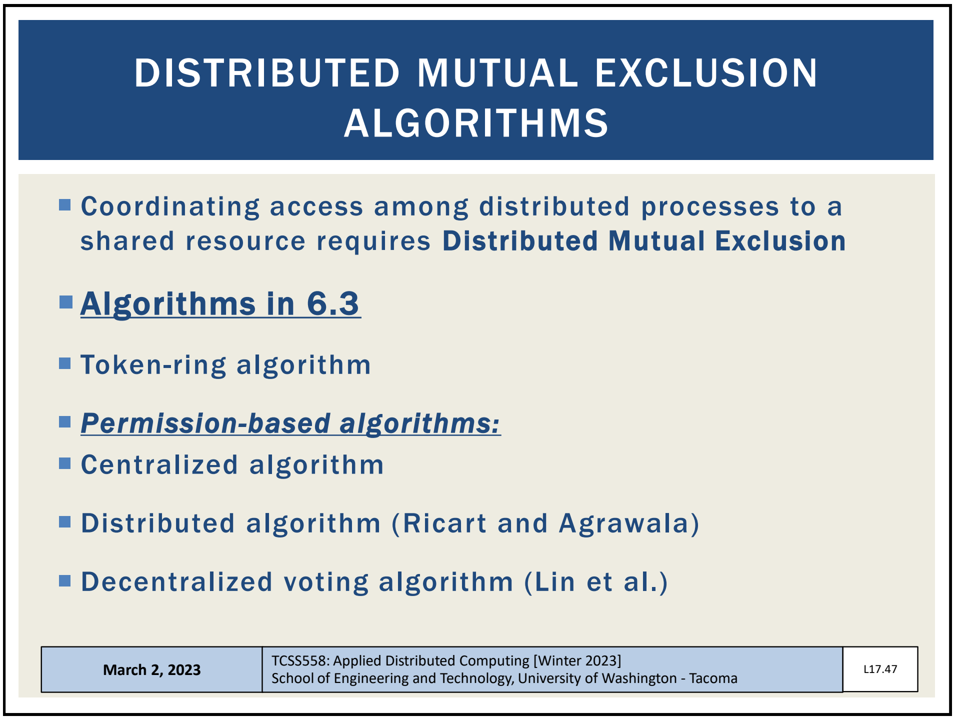
OBJECTIVES – 3/2

- Questions from 2/28
- Assignment 2: Replicated Key Value Store
- Chapter 6: Coordination
  - Chapter 6.2: Logical Clocks
    Vector Clocks
- Class Activity 4 – Total Ordered Multicasting
- Chapter 6: Coordination
  - **Chapter 6.3: Distributed Mutual Exclusion**

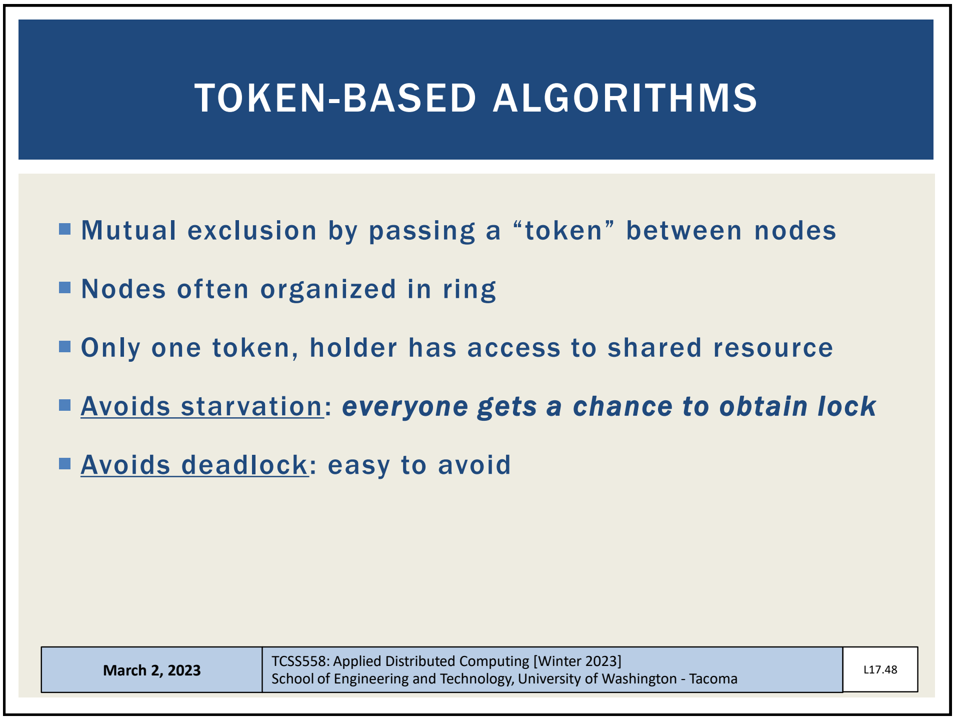


CH. 6.3: DISTRIBUTED MUTUAL EXCLUSION



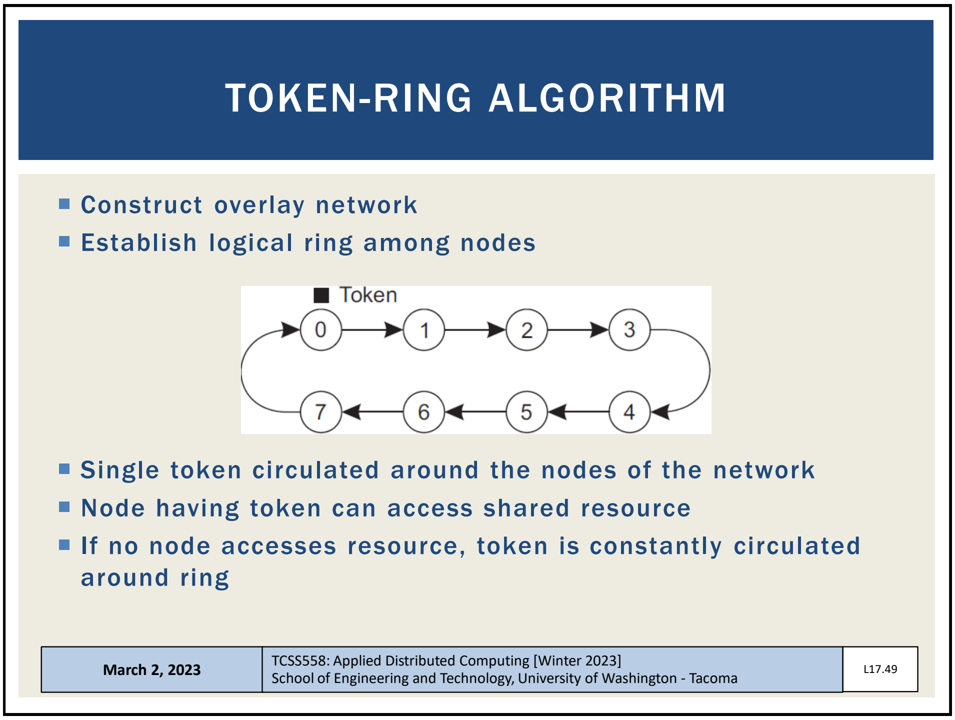
DISTRIBUTED MUTUAL EXCLUSION ALGORITHMS

- Coordinating access among distributed processes to a shared resource requires **Distributed Mutual Exclusion**
- **Algorithms in 6.3**
- Token-ring algorithm
- ***Permission-based algorithms:***
- Centralized algorithm
- Distributed algorithm (Ricart and Agrawala)
- Decentralized voting algorithm (Lin et al.)



TOKEN-BASED ALGORITHMS

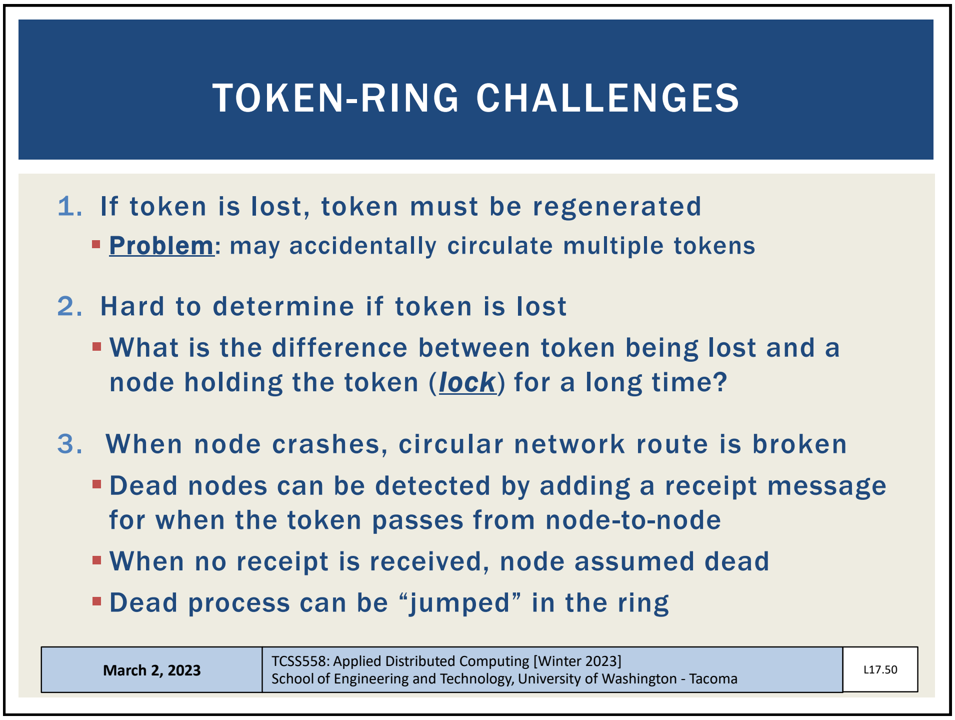
- Mutual exclusion by passing a “token” between nodes
- Nodes often organized in ring
- Only one token, holder has access to shared resource
- Avoids starvation: ***everyone gets a chance to obtain lock***
- Avoids deadlock: easy to avoid



TOKEN-RING ALGORITHM

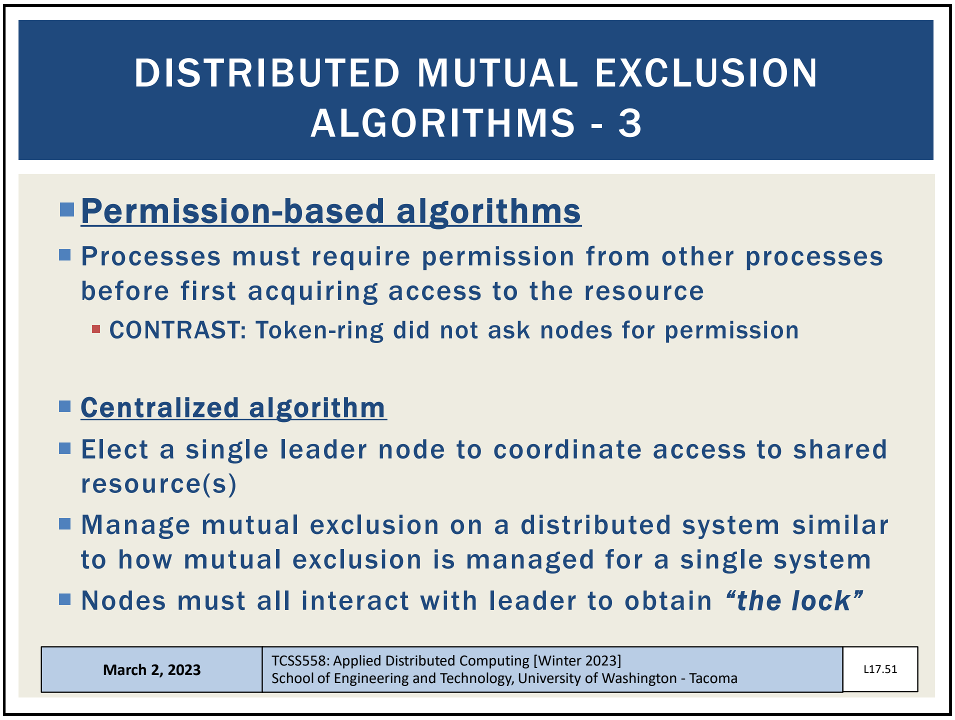
- Construct overlay network
- Establish logical ring among nodes

- Single token circulated around the nodes of the network
- Node having token can access shared resource
- If no node accesses resource, token is constantly circulated around ring



TOKEN-RING CHALLENGES

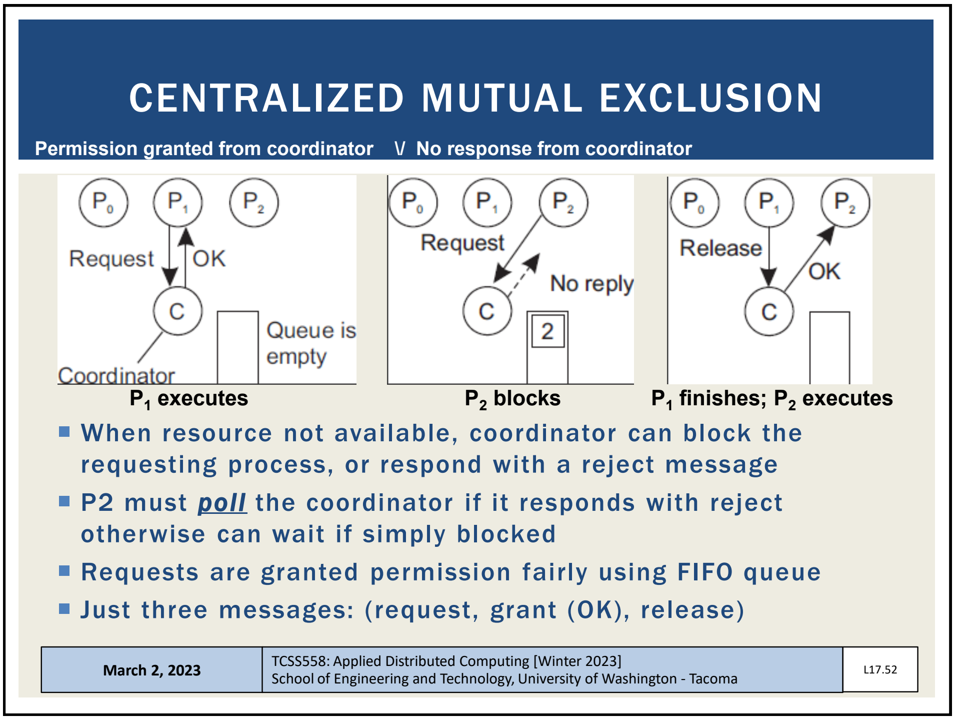
1. If token is lost, token must be regenerated
   - **Problem**: may accidentally circulate multiple tokens
2. Hard to determine if token is lost
   - What is the difference between token being lost and a node holding the token (***lock***) for a long time?
3. When node crashes, circular network route is broken
   - Dead nodes can be detected by adding a receipt message for when the token passes from node-to-node
   - When no receipt is received, node assumed dead
   - Dead process can be "jumped" in the ring



DISTRIBUTED MUTUAL EXCLUSION ALGORITHMS - 3

- **Permission-based algorithms**
- Processes must require permission from other processes before first acquiring access to the resource
  - CONTRAST: Token-ring did not ask nodes for permission

- **Centralized algorithm**
- Elect a single leader node to coordinate access to shared resource(s)
- Manage mutual exclusion on a distributed system similar to how mutual exclusion is managed for a single system
- Nodes must all interact with leader to obtain ***"the lock"***

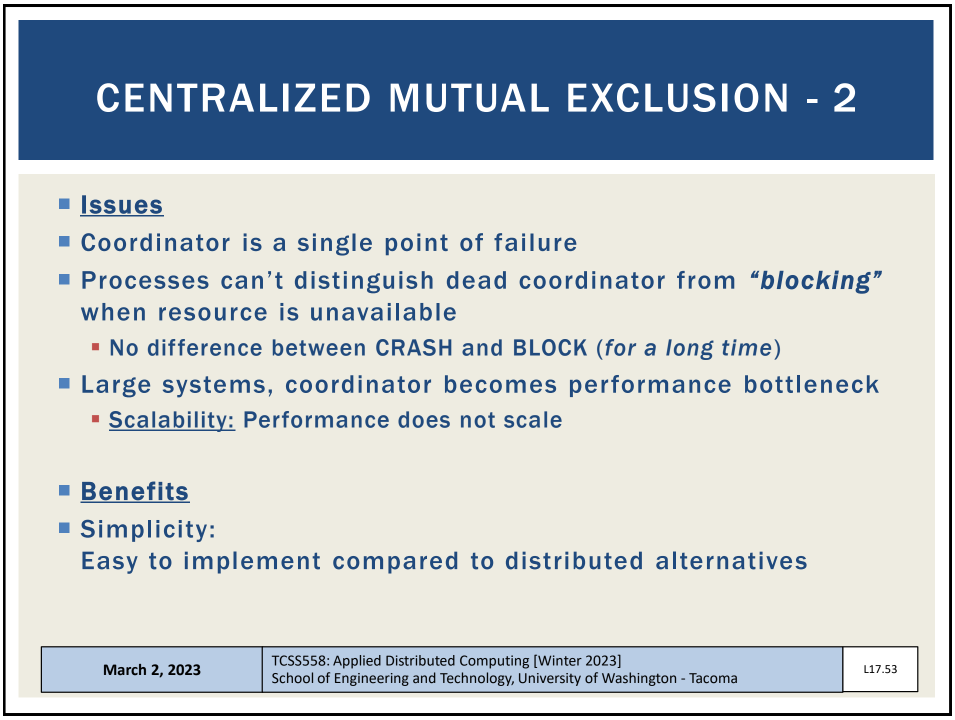


CENTRALIZED MUTUAL EXCLUSION

Permission granted from coordinator V No response from coordinator

P_1 executes **P_2 blocks** **P_1 finishes; P_2 executes**

- When resource not available, coordinator can block the requesting process, or respond with a reject message
- P2 must ***poll*** the coordinator if it responds with reject otherwise can wait if simply blocked
- Requests are granted permission fairly using FIFO queue
- Just three messages: (request, grant (OK), release)



CENTRALIZED MUTUAL EXCLUSION - 2

- **Issues**
- Coordinator is a single point of failure
- Processes can't distinguish dead coordinator from ***"blocking"*** when resource is unavailable
  - No difference between CRASH and BLOCK (*for a long time*)
- Large systems, coordinator becomes performance bottleneck
  - Scalability: Performance does not scale

- **Benefits**
- Simplicity:
  Easy to implement compared to distributed alternatives

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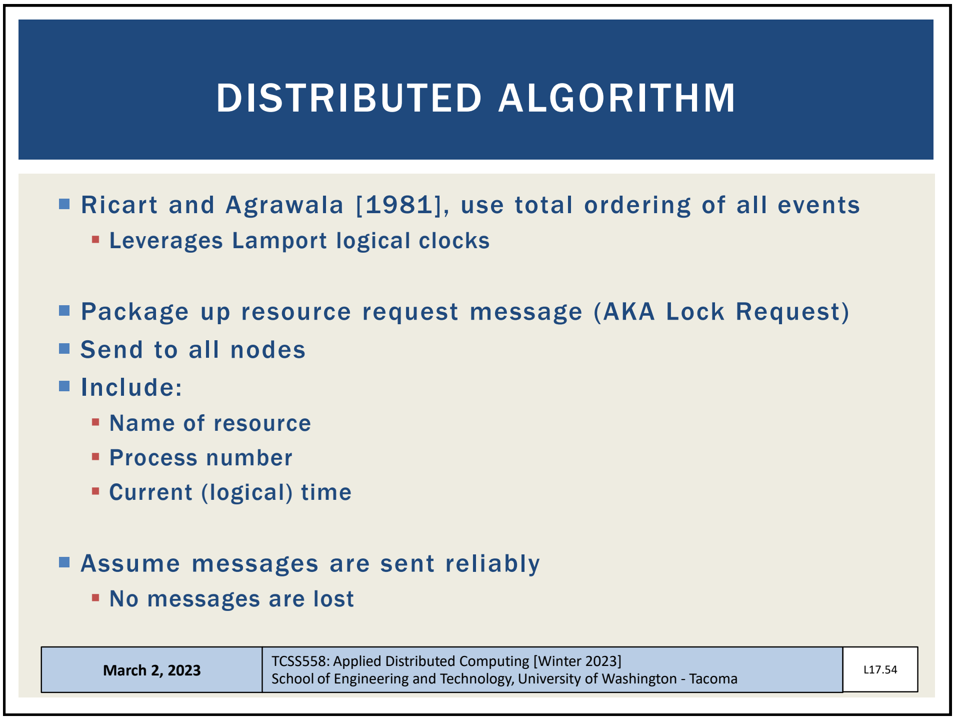

DISTRIBUTED ALGORITHM

- Ricart and Agrawala [1981], use total ordering of all events
  - Leverages Lamport logical clocks

- Package up resource request message (AKA Lock Request)
- Send to all nodes
- Include:
  - Name of resource
  - Process number
  - Current (logical) time

- Assume messages are sent reliably
  - No messages are lost

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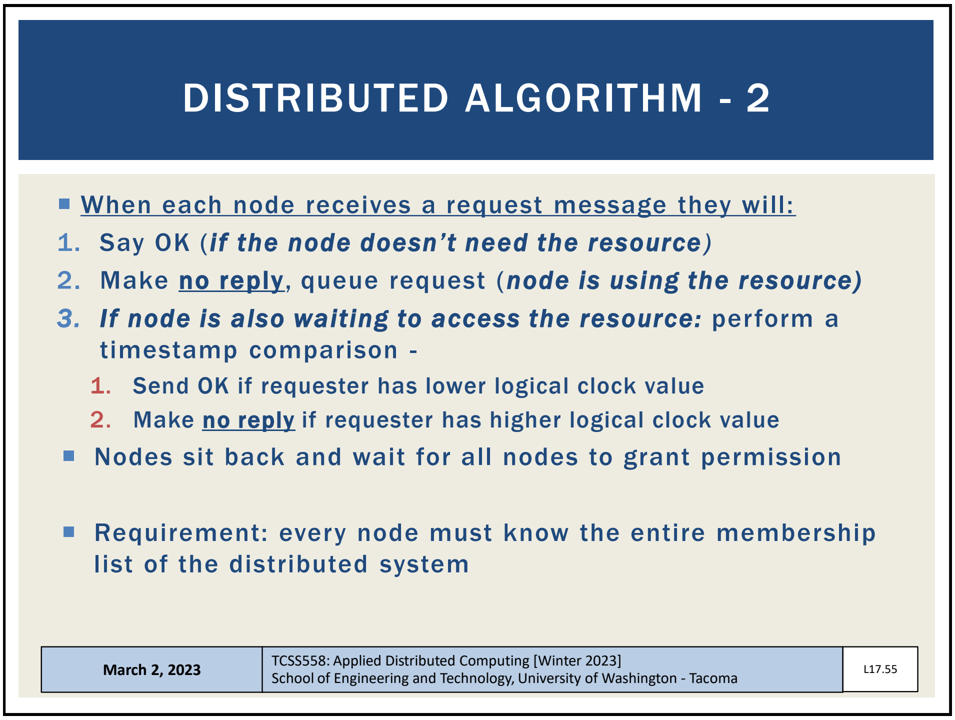

DISTRIBUTED ALGORITHM - 2

- When each node receives a request message they will:

1. Say OK (*if the node doesn't need the resource*)
2. Make **no reply**, queue request (***node is using the resource)***
3. ***If node is also waiting to access the resource:*** perform a timestamp comparison -
    1. Send OK if requester has lower logical clock value
    2. Make **no reply** if requester has higher logical clock value

- Nodes sit back and wait for all nodes to grant permission

- Requirement: every node must know the entire membership list of the distributed system

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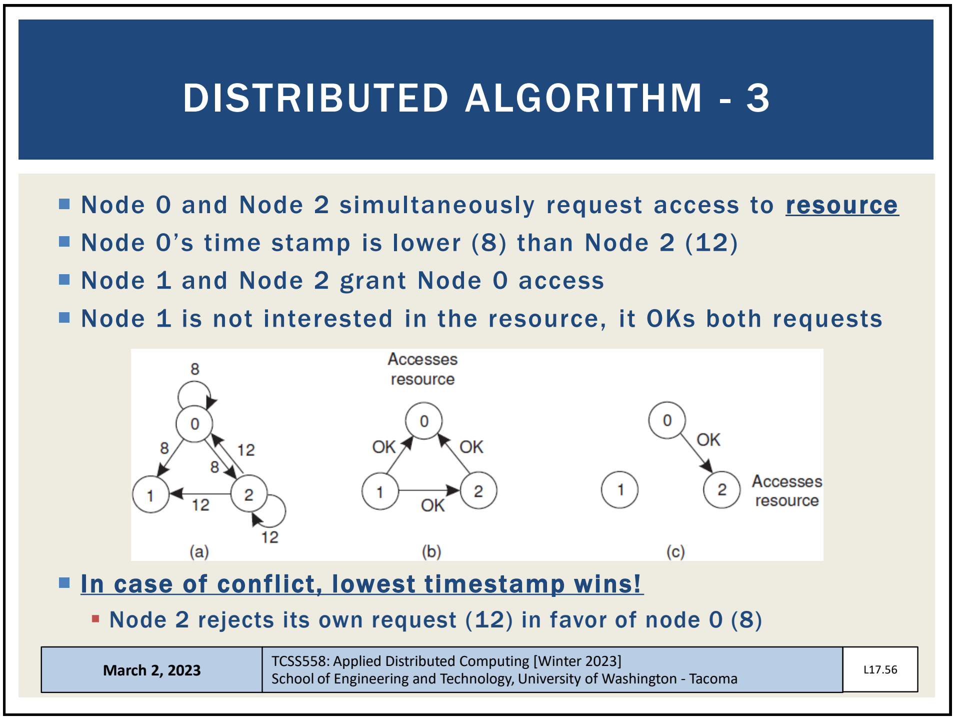

DISTRIBUTED ALGORITHM - 3

- Node 0 and Node 2 simultaneously request access to **resource**
- Node 0's time stamp is lower (8) than Node 2 (12)
- Node 1 and Node 2 grant Node 0 access
- Node 1 is not interested in the resource, it OKs both requests

- **In case of conflict, lowest timestamp wins!**
    - Node 2 rejects its own request (12) in favor of node 0 (8)

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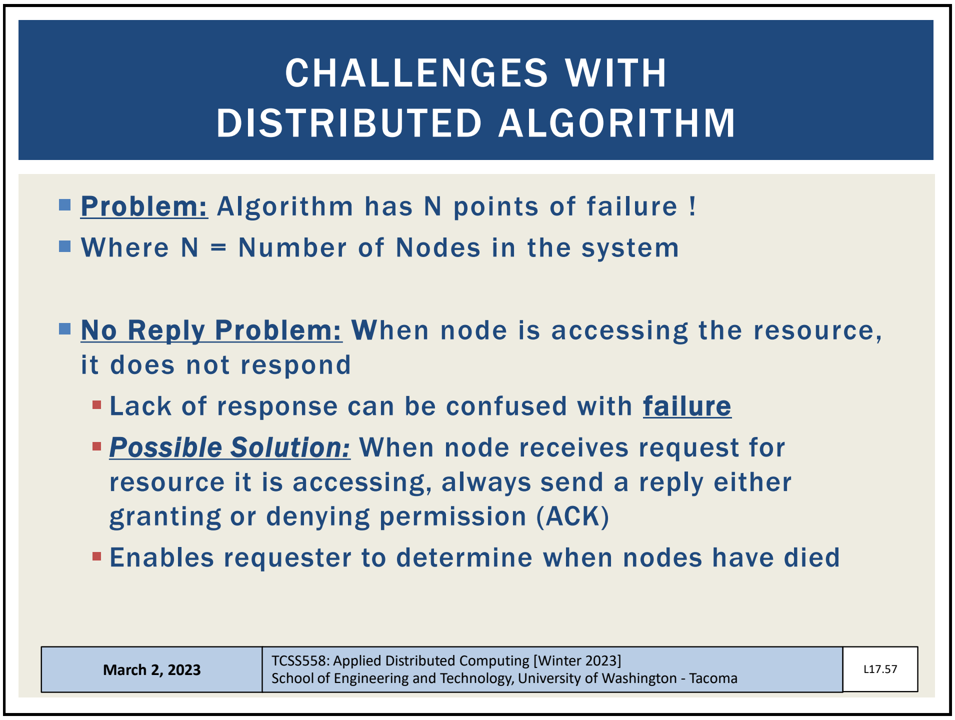

CHALLENGES WITH DISTRIBUTED ALGORITHM

- **Problem:** Algorithm has N points of failure !
- Where N = Number of Nodes in the system

- **No Reply Problem:** When node is accessing the resource, it does not respond
  - Lack of response can be confused with **failure**
  - ***Possible Solution:*** When node receives request for resource it is accessing, always send a reply either granting or denying permission (ACK)
  - Enables requester to determine when nodes have died

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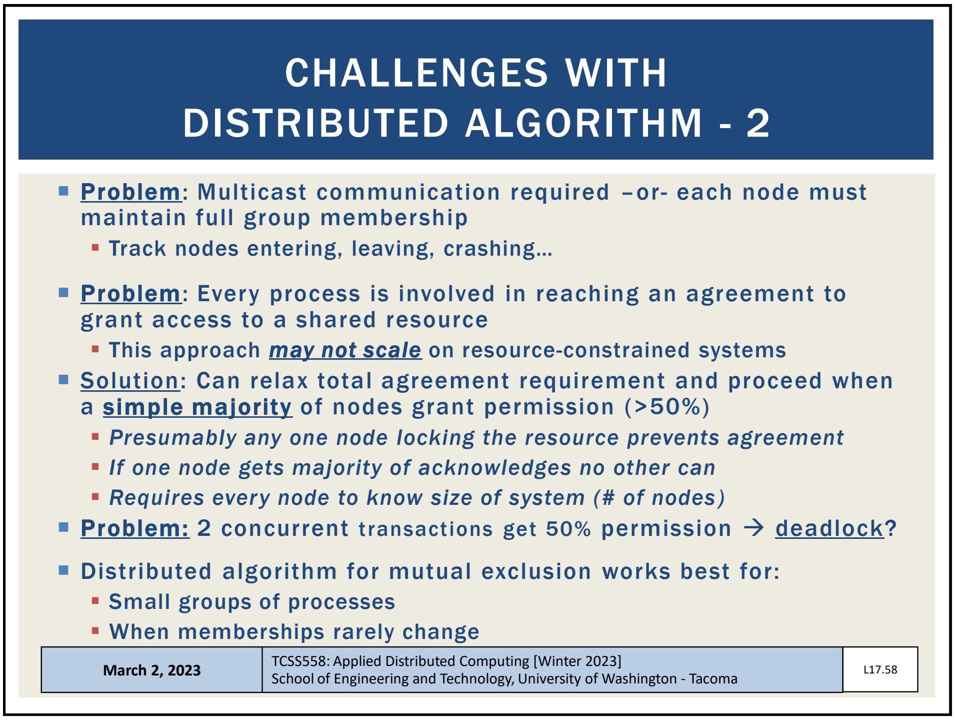

CHALLENGES WITH DISTRIBUTED ALGORITHM - 2

- **Problem**: Multicast communication required –or- each node must maintain full group membership
  - Track nodes entering, leaving, crashing…
- **Problem**: Every process is involved in reaching an agreement to grant access to a shared resource
  - This approach ***may not scale*** on resource-constrained systems
- **Solution**: Can relax total agreement requirement and proceed when a **simple majority** of nodes grant permission (>50%)
  - *Presumably any one node locking the resource prevents agreement*
  - *If one node gets majority of acknowledges no other can*
  - *Requires every node to know size of system (# of nodes)*
- **Problem:** 2 concurrent transactions get 50% permission → **deadlock**?
- Distributed algorithm for mutual exclusion works best for:
  - Small groups of processes
  - When memberships rarely change

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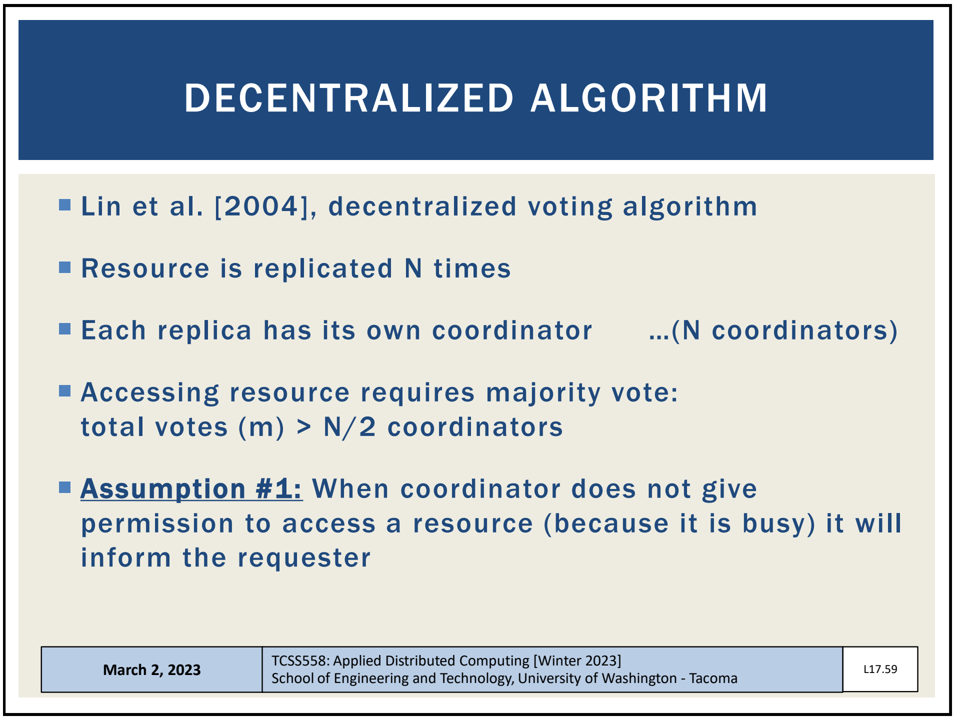
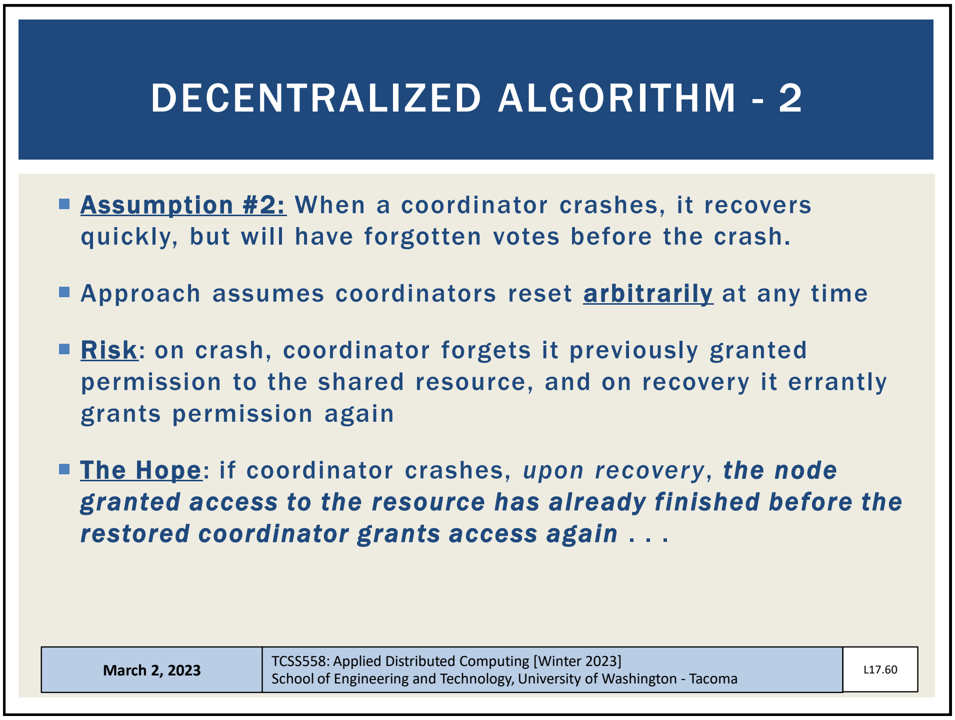


DECENTRALIZED ALGORITHM

- Lin et al. [2004], decentralized voting algorithm
- Resource is replicated N times
- Each replica has its own coordinator …(N coordinators)
- Accessing resource requires majority vote:
  total votes (m) > N/2 coordinators
- **Assumption #1:** When coordinator does not give permission to access a resource (because it is busy) it will inform the requester



DECENTRALIZED ALGORITHM - 2

- **Assumption #2:** When a coordinator crashes, it recovers quickly, but will have forgotten votes before the crash.
- Approach assumes coordinators reset **arbitrarily** at any time
- **Risk**: on crash, coordinator forgets it previously granted permission to the shared resource, and on recovery it errantly grants permission again
- **The Hope**: if coordinator crashes, *upon recovery*, ***the node granted access to the resource has already finished before the restored coordinator grants access again . . .***

DECENTRALIZED ALGORITHM - 3

- With 99.167% coordinator availability (30 sec downtime/hour) chance of violating correctness **is so low** it can be neglected in comparison to other types of failure
- Leverages fact that a new node must obtain a majority vote to access resource, ***which requires time***

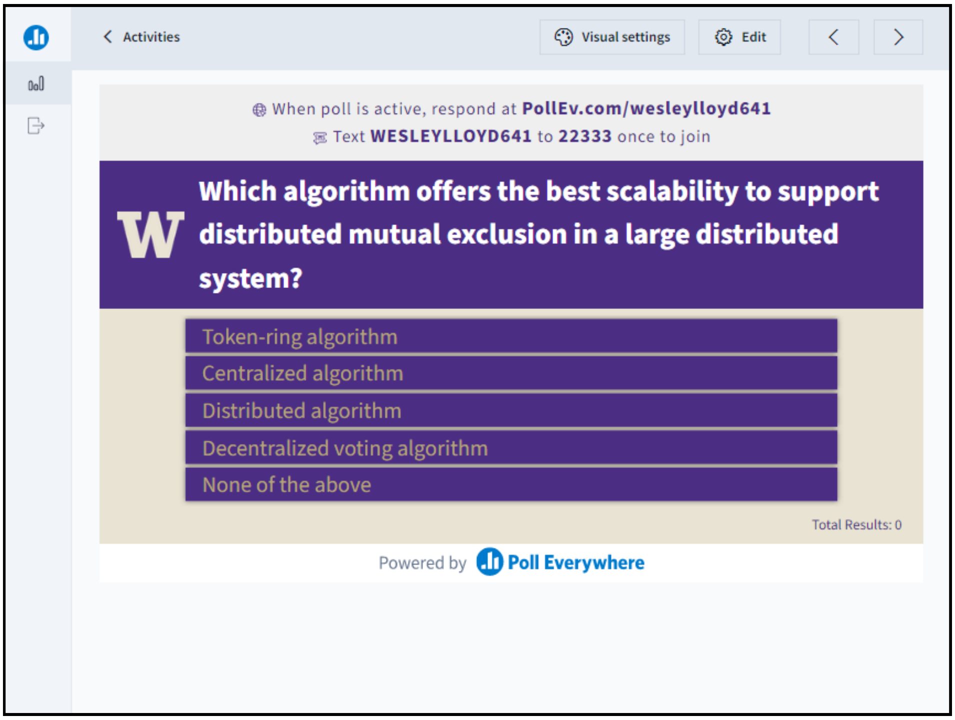
N	m	p	Violation
8	5	3 sec/hour	$< 10^{-15}$
8	6	3 sec/hour	$< 10^{-18}$
16	9	3 sec/hour	$< 10^{-27}$
16	12	3 sec/hour	$< 10^{-36}$
32	17	3 sec/hour	$< 10^{-52}$
32	24	3 sec/hour	$< 10^{-73}$

N	m	p	Violation
8	5	30 sec/hour	$< 10^{-10}$
8	6	30 sec/hour	$< 10^{-11}$
16	9	30 sec/hour	$< 10^{-18}$
16	12	30 sec/hour	$< 10^{-24}$
32	17	30 sec/hour	$< 10^{-35}$
32	24	30 sec/hour	$< 10^{-49}$

N = number of resource replicas, m = required “majority” vote
p=seconds per hour coordinator is offline

DECENTRALIZED ALGORITHM - 4

- **Back-off Polling Approach for *permission-denied:***
- If permission to access a resource is denied via majority vote, process can poll to gain access again with a ***random*** delay (***known as back-off***)
- Node waits for a random amount, retries…
- If too many nodes compete to gain access to a resource, majority vote can lead to low resource utilization
  - ***No one can achieve majority vote to obtain access to the shared resource***
  - *Mimics elections where with too many candidates, where no one candidate can get >50% of the total vote*
- Problem Solution detailed in [Lin et al. 2014]



When poll is active, respond at **PollEv.com/wesleylloyd641**
Text **WESLEYLLOYD641** to **22333** once to join

Which algorithm offers the best scalability to support distributed mutual exclusion in a large distributed system?

- Token-ring algorithm
- Centralized algorithm
- Distributed algorithm
- Decentralized voting algorithm
- None of the above

Total Results: 0

Powered by Poll Everywhere

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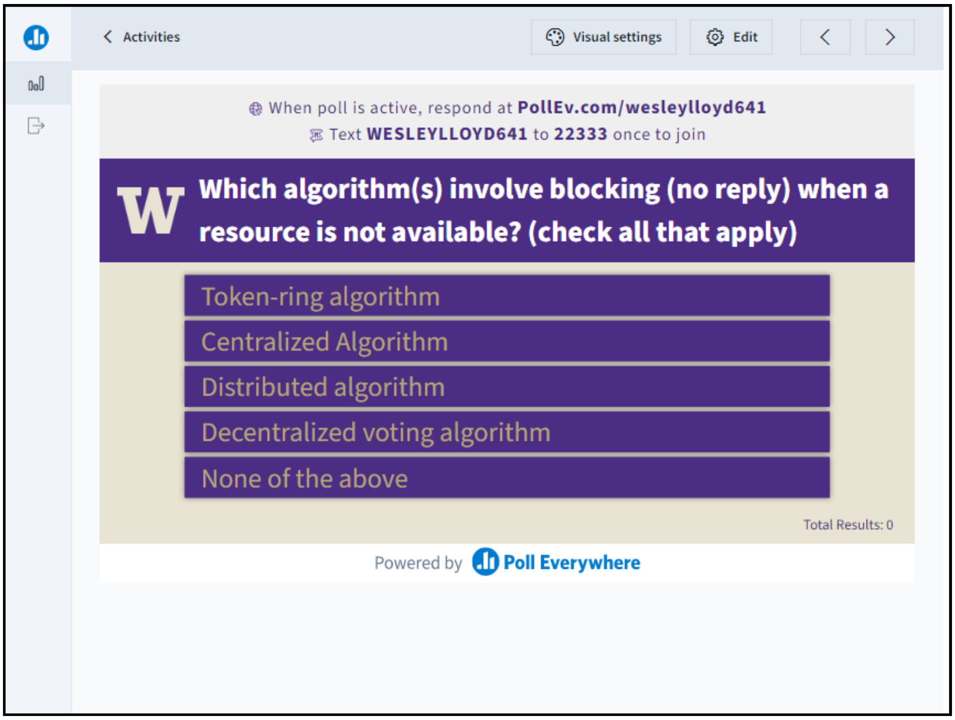

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Which algorithm(s) involve blocking (no reply) when a resource is not available? (check all that apply)

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- Distributed algorithm
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- None of the above

Total Results: 0

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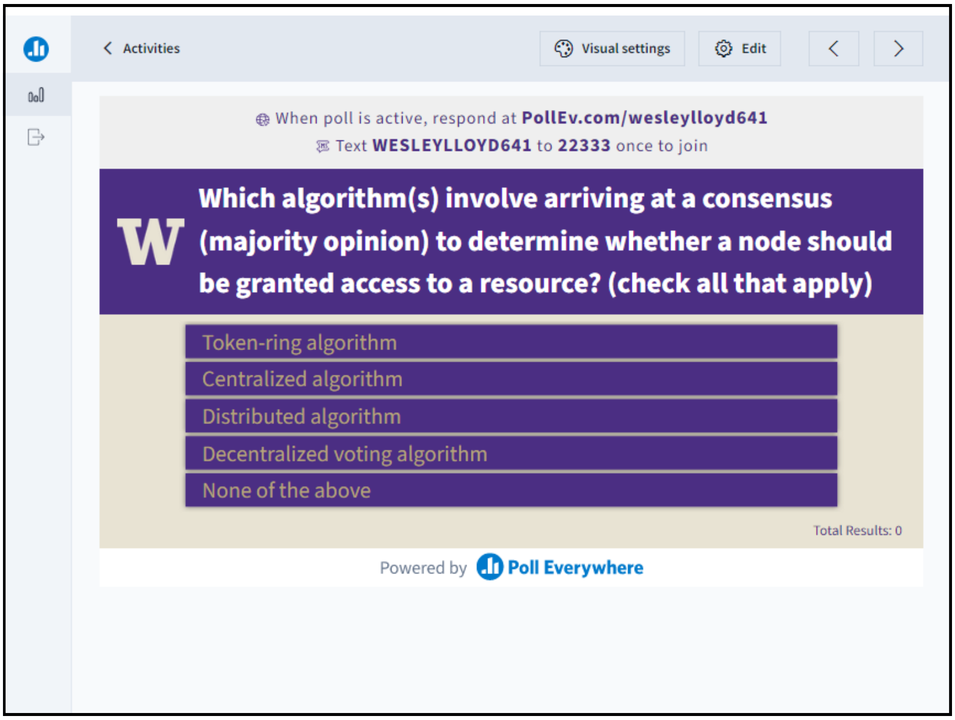

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Which algorithm(s) involve arriving at a consensus (majority opinion) to determine whether a node should be granted access to a resource? (check all that apply)

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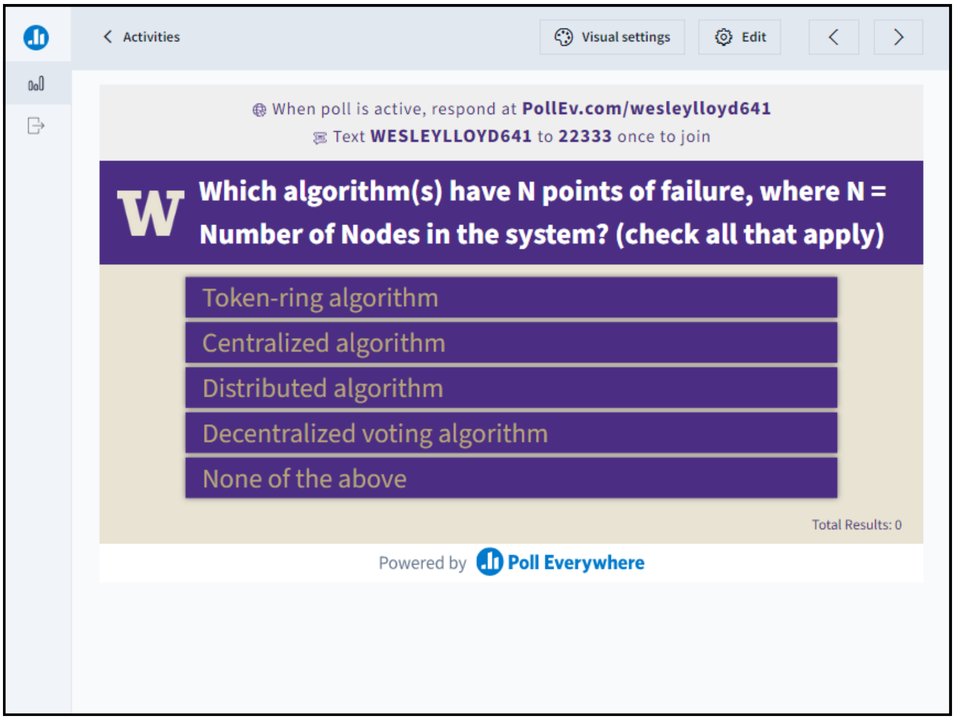

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Which algorithm(s) have N points of failure, where N = Number of Nodes in the system? (check all that apply)

- Token-ring algorithm
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- Distributed algorithm
- Decentralized voting algorithm
- None of the above

Total Results: 0

Powered by Poll Everywhere

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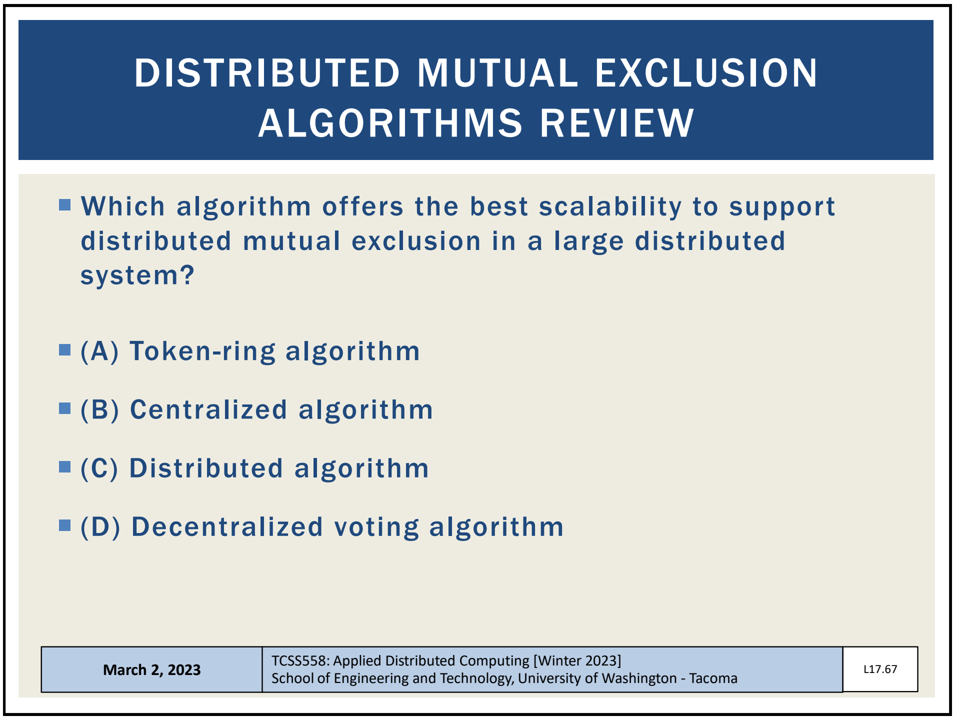

DISTRIBUTED MUTUAL EXCLUSION ALGORITHMS REVIEW

- Which algorithm offers the best scalability to support distributed mutual exclusion in a large distributed system?
- (A) Token-ring algorithm
- (B) Centralized algorithm
- (C) Distributed algorithm
- (D) Decentralized voting algorithm

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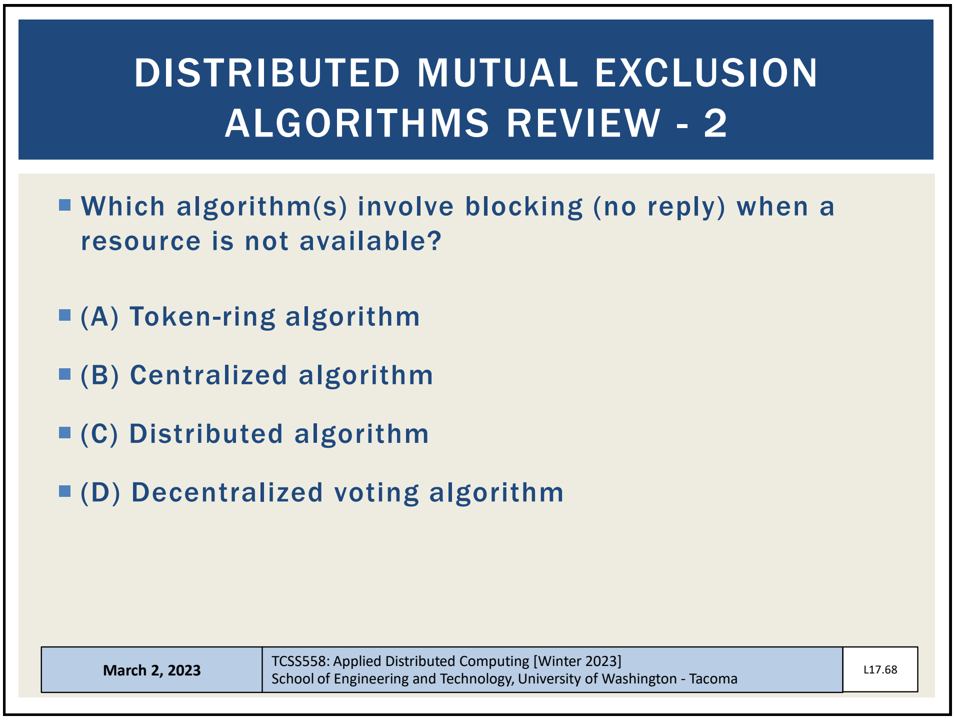

DISTRIBUTED MUTUAL EXCLUSION ALGORITHMS REVIEW - 2

- Which algorithm(s) involve blocking (no reply) when a resource is not available?
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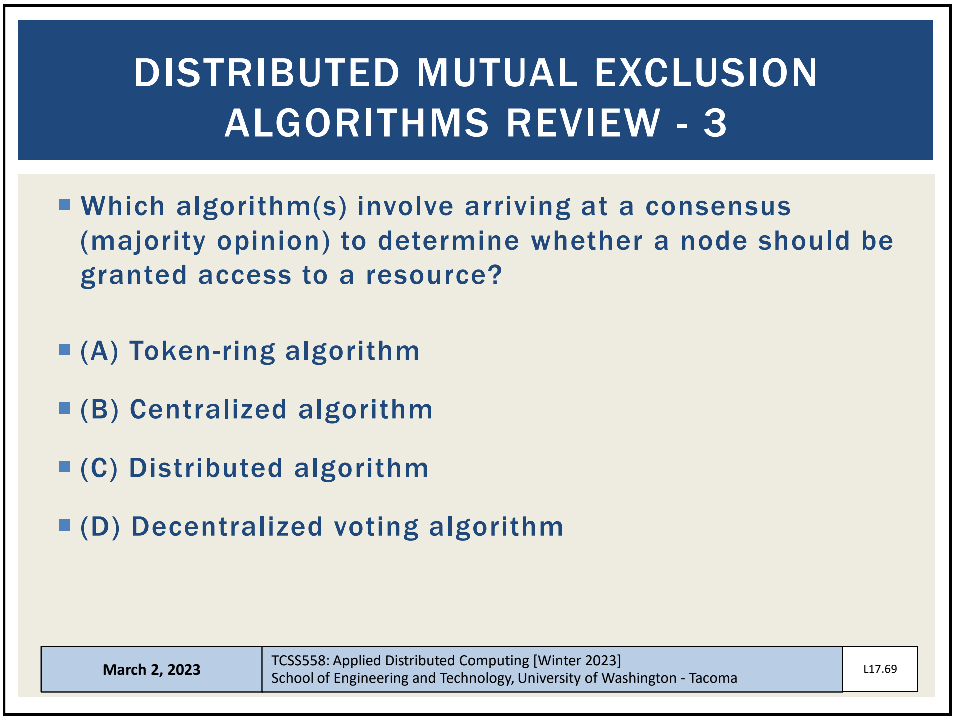

DISTRIBUTED MUTUAL EXCLUSION ALGORITHMS REVIEW - 3

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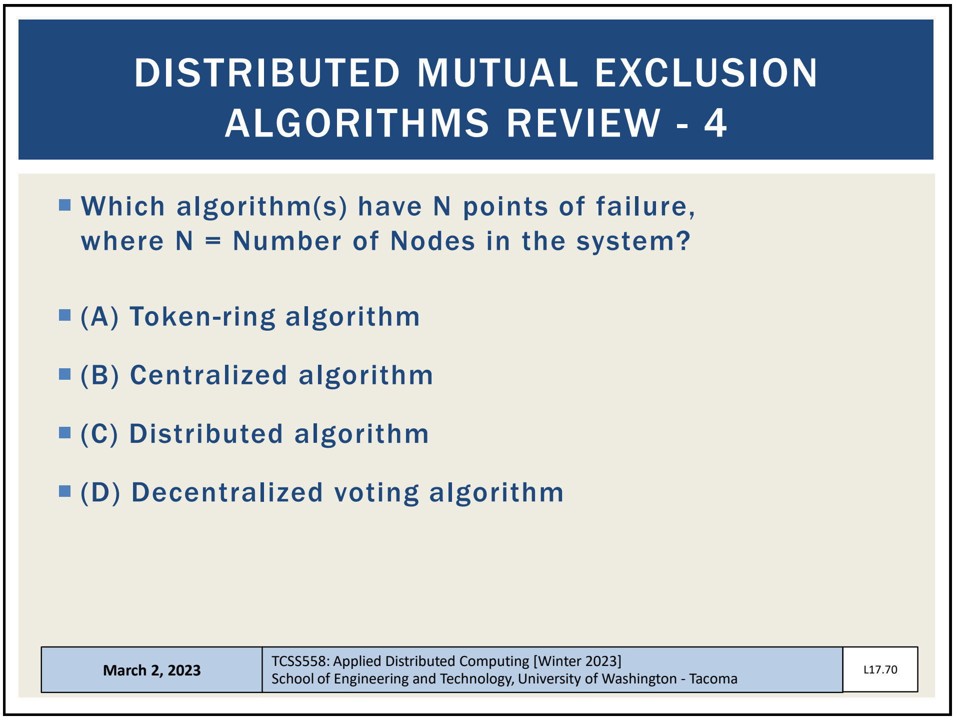

DISTRIBUTED MUTUAL EXCLUSION ALGORITHMS REVIEW - 4

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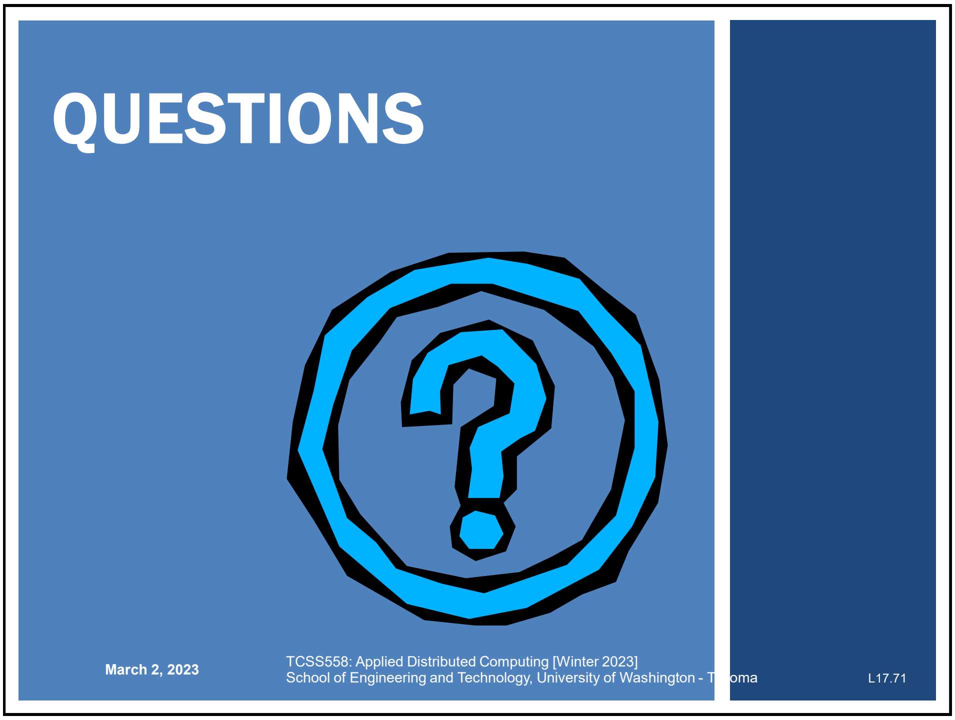

QUESTIONS

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