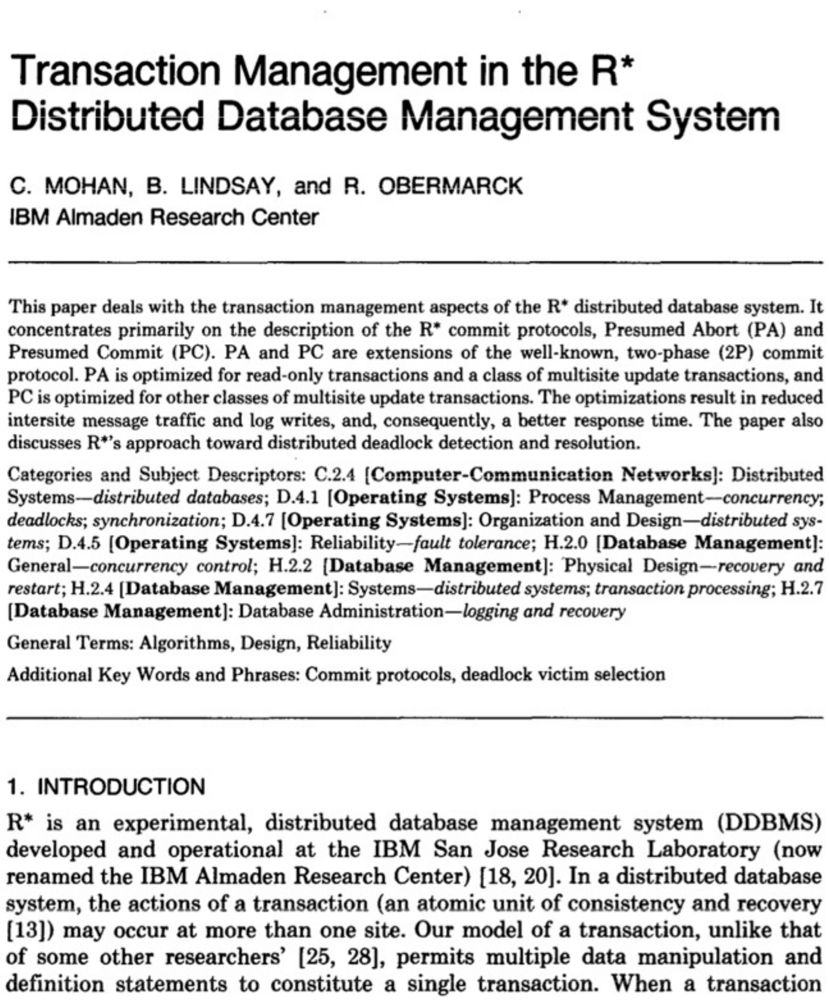
WISCONSIN
UNIVERSITY OF WISCONSIN–MADISON

CS 764: Topics in Database Management Systems

Lecture 20: Two-Phase Commit (2PC)

Xiangyao Yu
11/14/2022

Today’s Paper: Distributed Transactions in R*



Transaction Management in the R* Distributed Database Management System

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IBM Almaden Research Center

This paper deals with the transaction management aspects of the R* distributed database system. It concentrates primarily on the description of the R* commit protocols, Presumed Abort (PA) and Presumed Commit (PC). PA and PC are extensions of the well-known, two-phase (2P) commit protocol. PA is optimized for read-only transactions and a class of multisite update transactions, and PC is optimized for other classes of multisite update transactions. The optimizations result in reduced intersite message traffic and log writes, and, consequently, a better response time. The paper also discusses R*’s approach toward distributed deadlock detection and resolution.

Categories and Subject Descriptors: C.2.4 [**Computer-Communication Networks**]: Distributed Systems—*distributed databases*; D.4.1 [**Operating Systems**]: Process Management—*concurrency; deadlocks; synchronization*; D.4.7 [**Operating Systems**]: Organization and Design—*distributed systems*; D.4.5 [**Operating Systems**]: Reliability—*fault tolerance*; H.2.0 [**Database Management**]: General—*concurrency control*; H.2.2 [**Database Management**]: Physical Design—*recovery and restart*; H.2.4 [**Database Management**]: Systems—*distributed systems; transaction processing*; H.2.7 [**Database Management**]: Database Administration—*logging and recovery*

General Terms: Algorithms, Design, Reliability

Additional Key Words and Phrases: Commit protocols, deadlock victim selection

1. INTRODUCTION

R* is an experimental, distributed database management system (DDBMS) developed and operational at the IBM San Jose Research Laboratory (now renamed the IBM Almaden Research Center) [18, 20]. In a distributed database system, the actions of a transaction (an atomic unit of consistency and recovery [13]) may occur at more than one site. Our model of a transaction, unlike that of some other researchers’ [25, 28], permits multiple data manipulation and definition statements to constitute a single transaction. When a transaction

ACM Trans. Database Syst. 1986.

Announcement

Updated schedule for future lectures

Next lecture: Cornus (optimized 2PC in cloud)

Last lecture: GPU databases

Agenda

Two-phase commit

Presumed abort (PA)

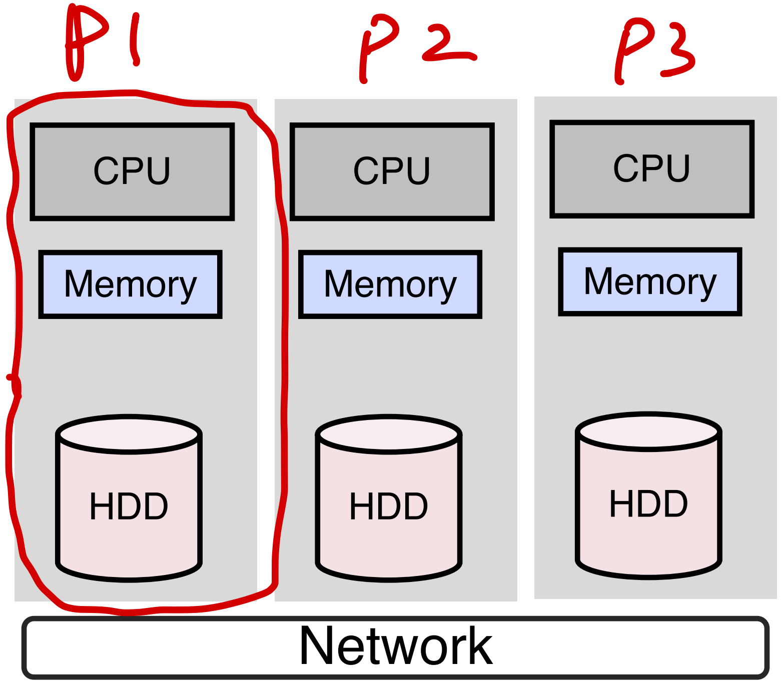
Presumed Commit (PC)

Distributed Transactions

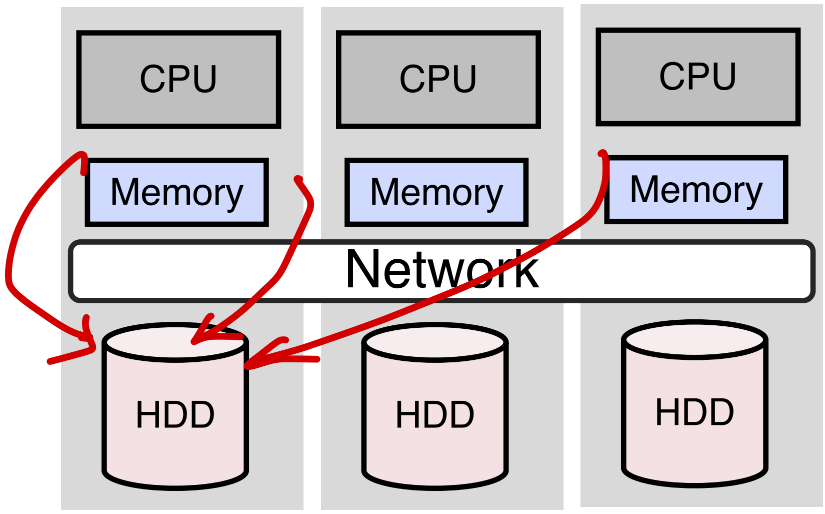
Architectures: shared-nothing vs. shared-disk

Data is partitioned and stored in each server

A distributed transaction accesses data across multiple partitions



Shared Nothing



Shared Disk

Distributed Transactions

Architectures: shared-nothing vs. shared-disk

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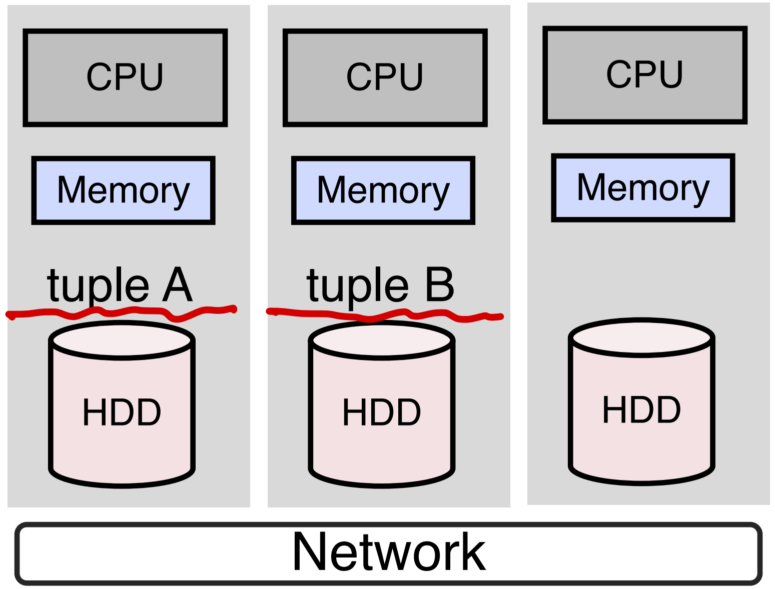
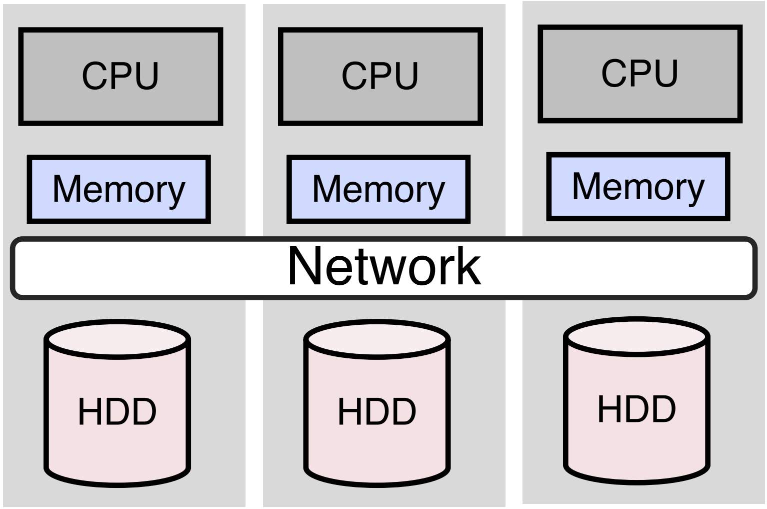


Shared Nothing

Transaction T:
write(A)
write(B)

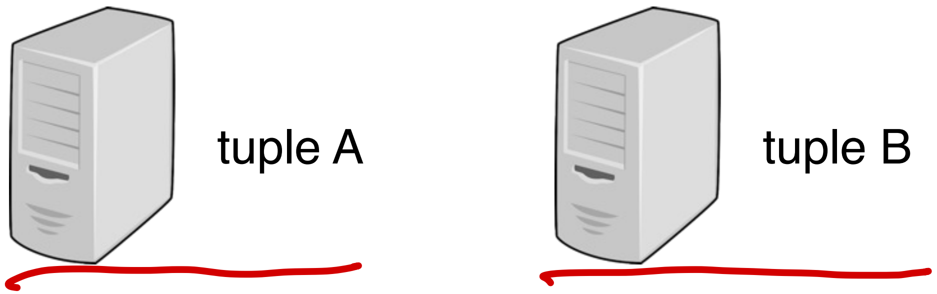


Shared Disk

Atomic Commit Protocol (ACP)

Atomic commit protocol: all partitions reach the same commit or abort decision of a transaction

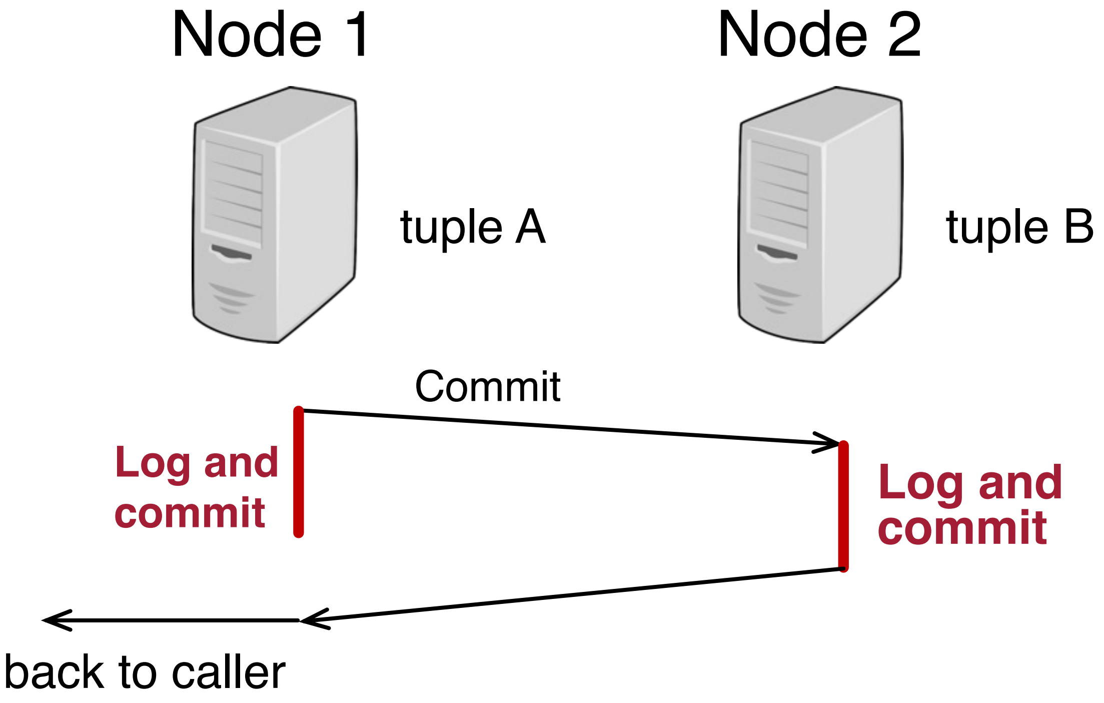
Example:



Transaction T:
write(A)
write(B)

The two updates must commit or abort atomically

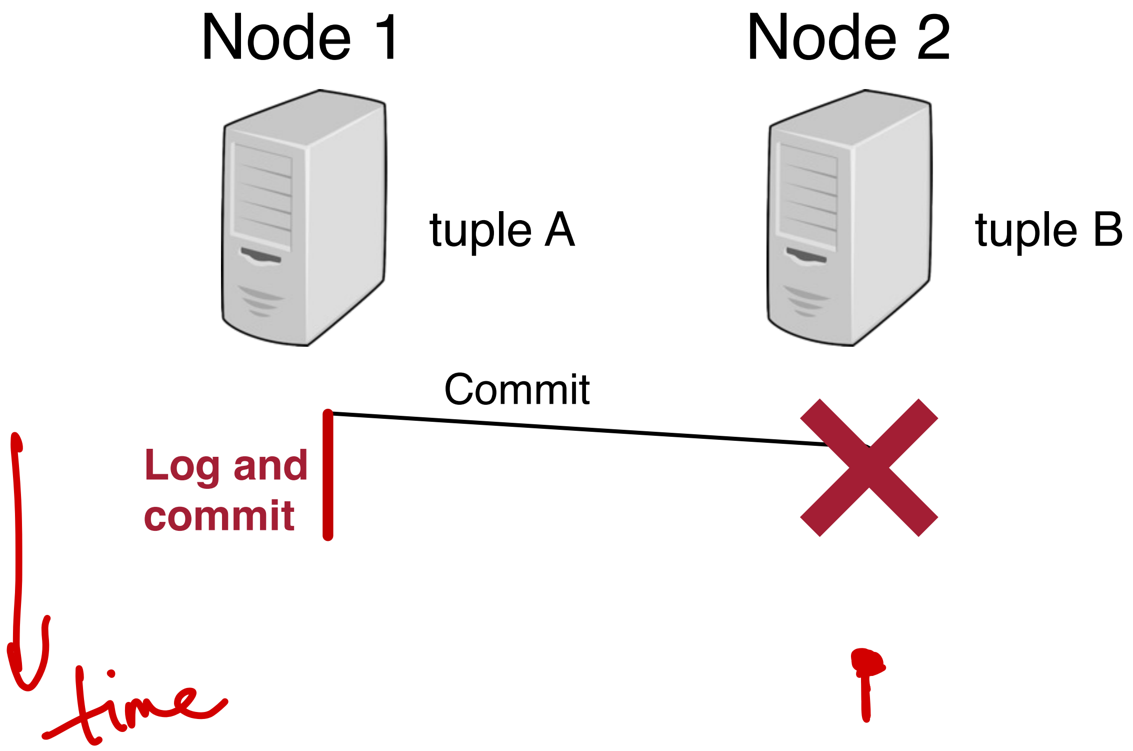
The Challenge of Atomic Commit



Transaction T:
write(A)
write(B)

A naïve approach: all nodes log and commit independently

The Challenge of Atomic Commit



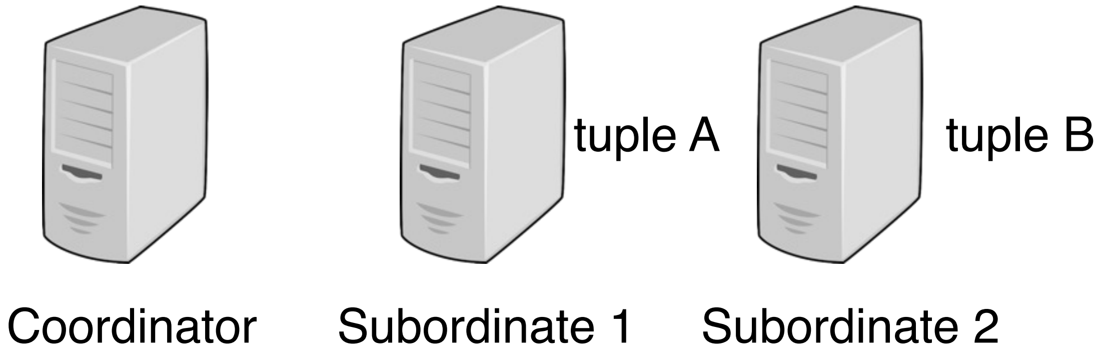
Transaction T:
write(A)
write(B)

A naïve approach: all nodes log and commit independently

Node 2 crashes before logging

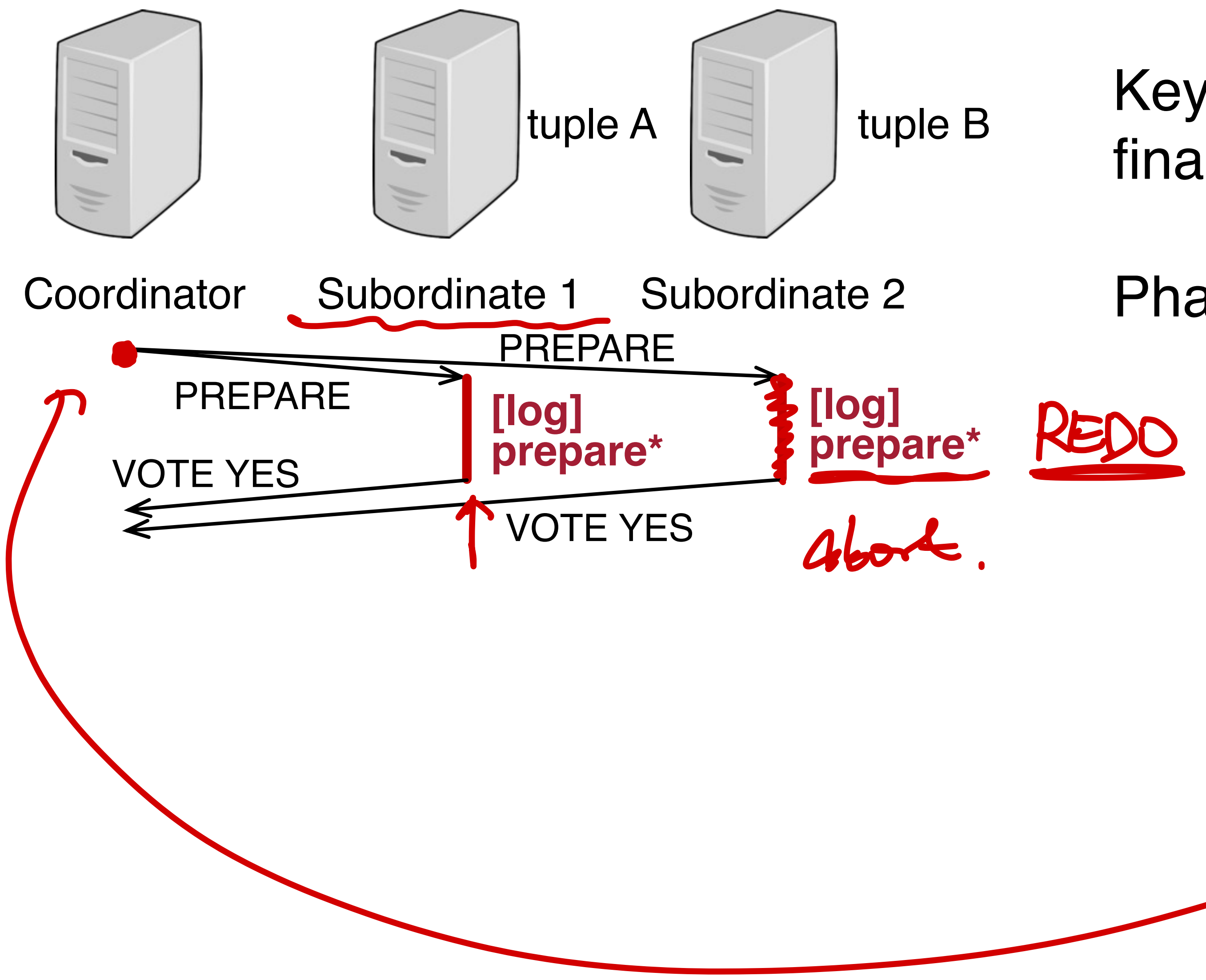
- Transaction T commits in node 1 but not in node 2

Two-Phase Commit (2PC)



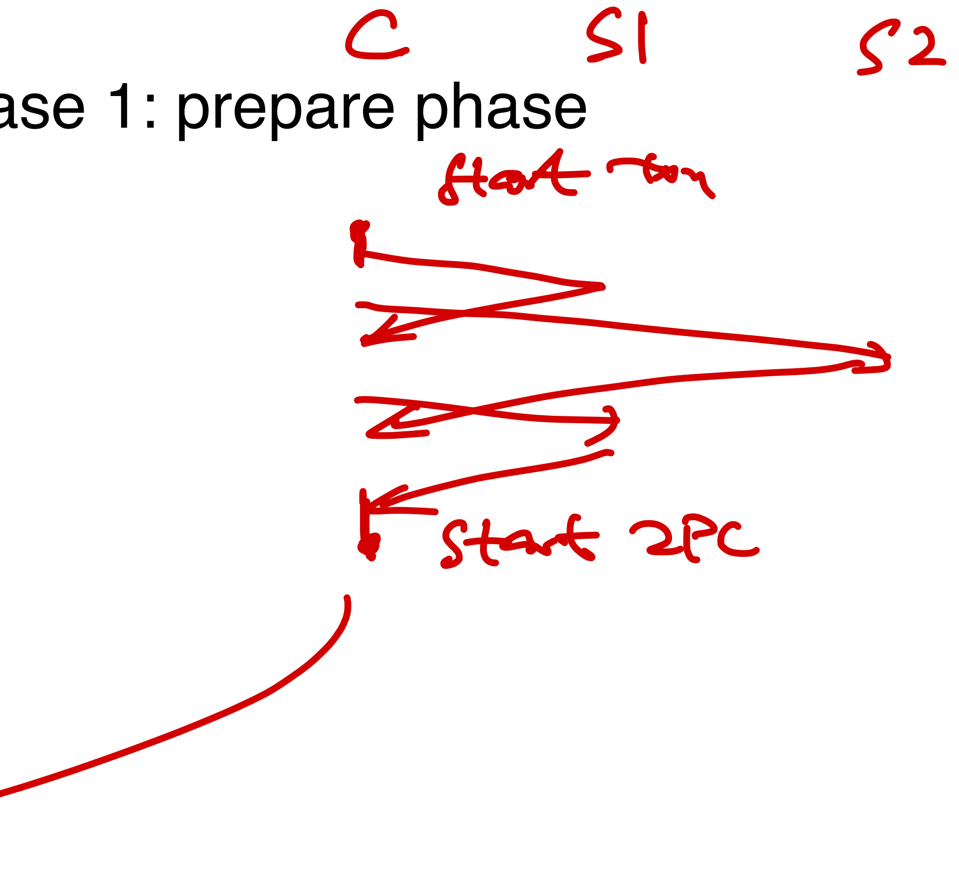
Key idea: let the coordinator log the final commit/abort decision

Two-Phase Commit (2PC)

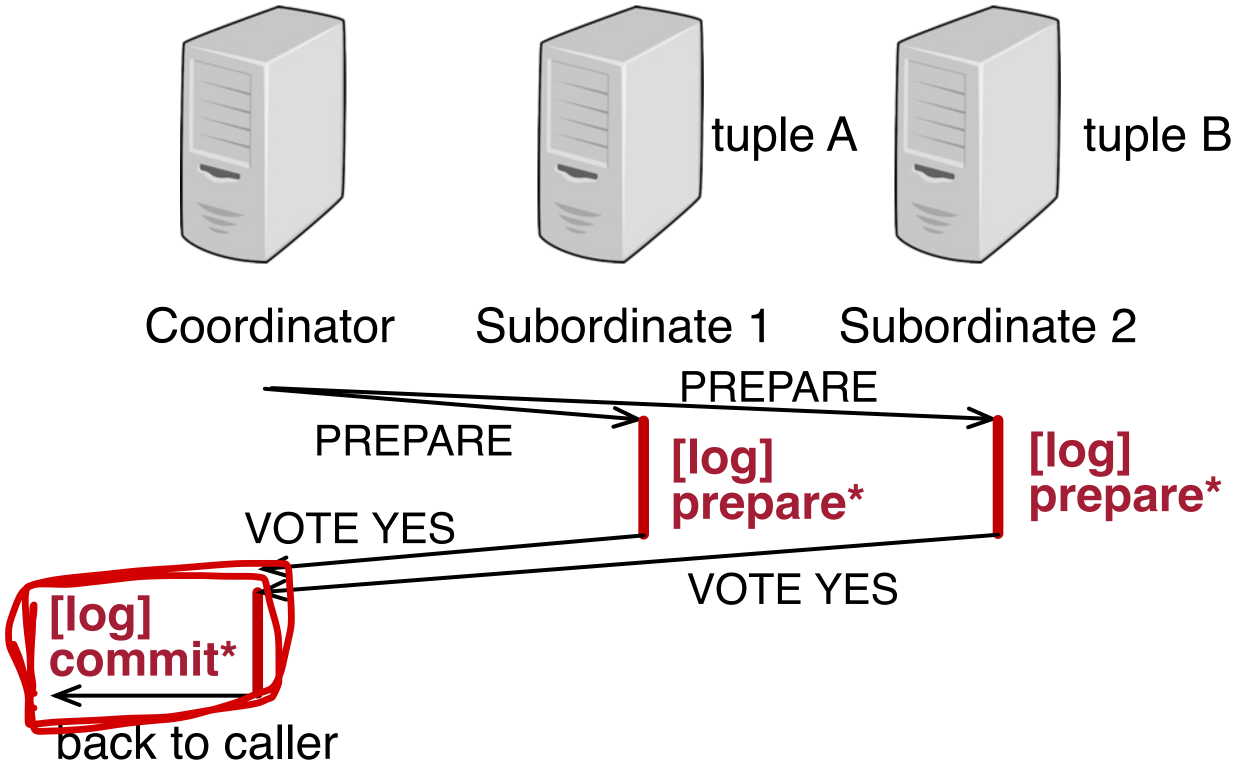


Key idea: let the coordinator log the final commit/abort decision

Phase 1: prepare phase



Two-Phase Commit (2PC)

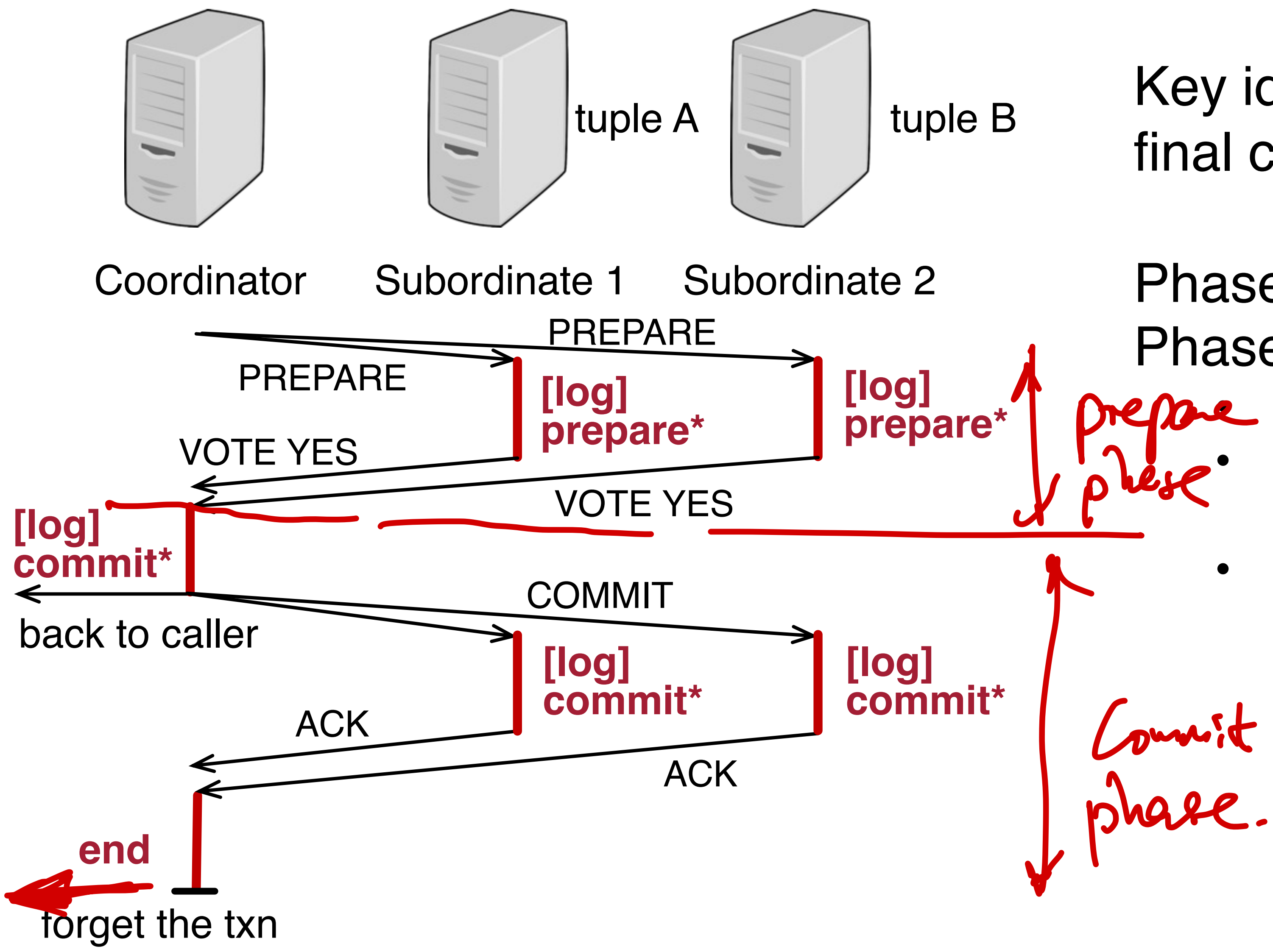


Key idea: let the coordinator log the final commit/abort decision

Phase 1: prepare phase
Phase 2: commit phase

- Coordinator logs the decision

Two-Phase Commit (2PC)



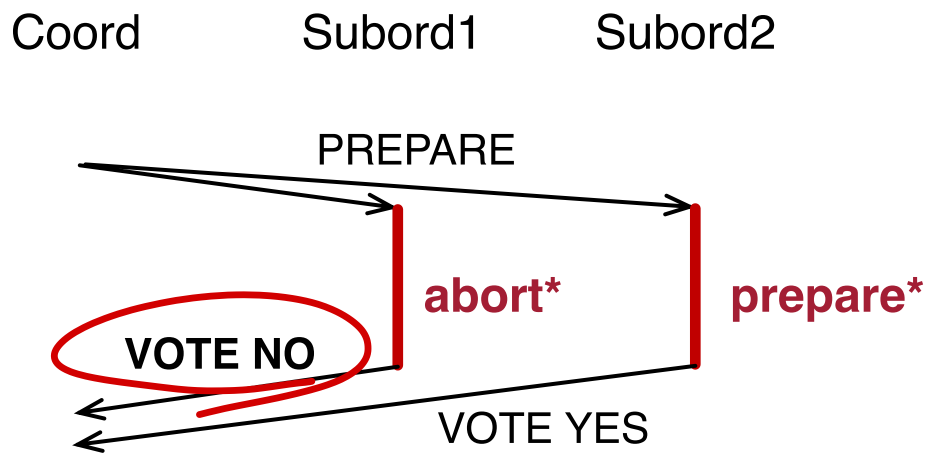
Key idea: let the coordinator log the final commit/abort decision

Phase 1: prepare phase

Phase 2: commit phase

- Coordinator logs the decision
- Coordinator sends the decision to subordinates
- Coordinator forgets the transaction after receiving ACKs

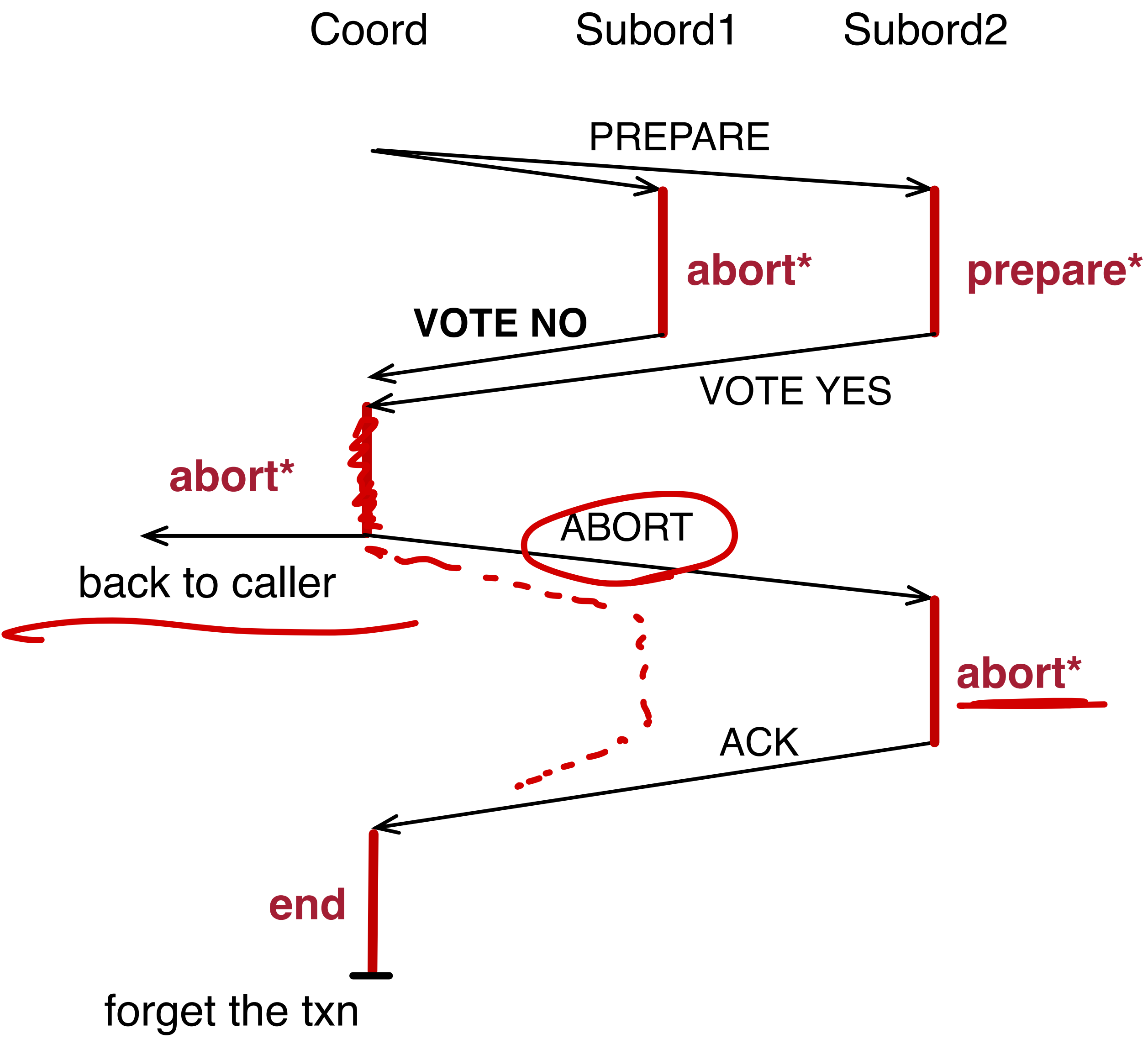
2PC – Abort Example



Subordinate returns VOTE NO if the transaction is aborted

- Subordinate can release locks and forget the transaction

2PC – Abort Example

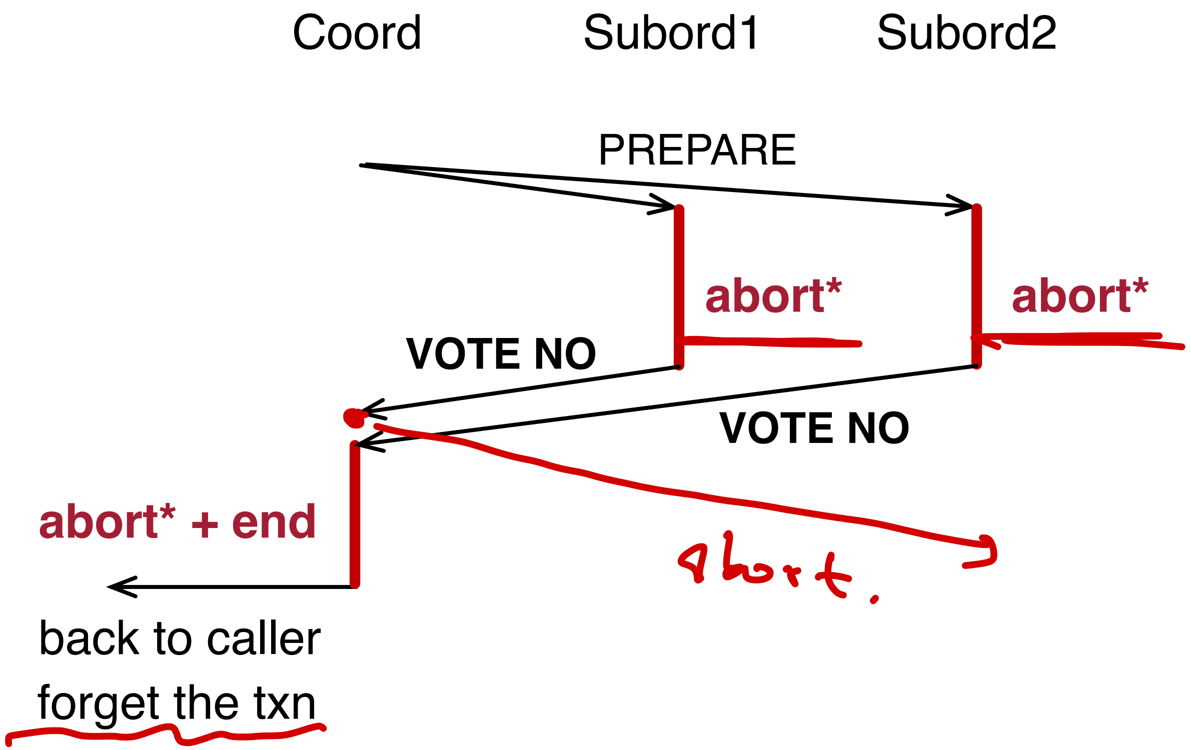


Subordinate returns VOTE NO if the transaction is aborted

- Subordinate can release locks and forget the transaction

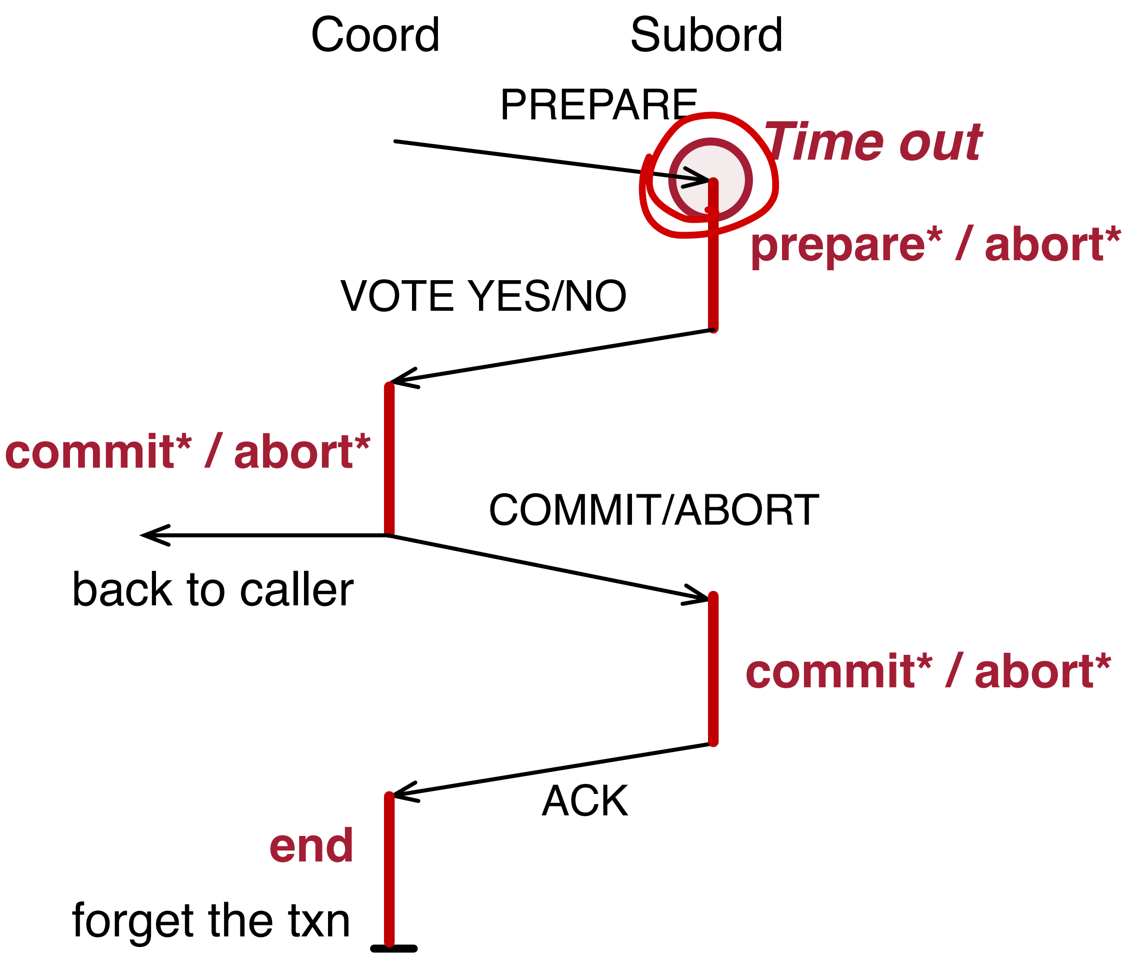
Skip the commit phase for aborted subordinates

2PC – All Subordinates Abort



Skip the second phase entirely if the transaction aborts at all the subordinates

2PC – Failures

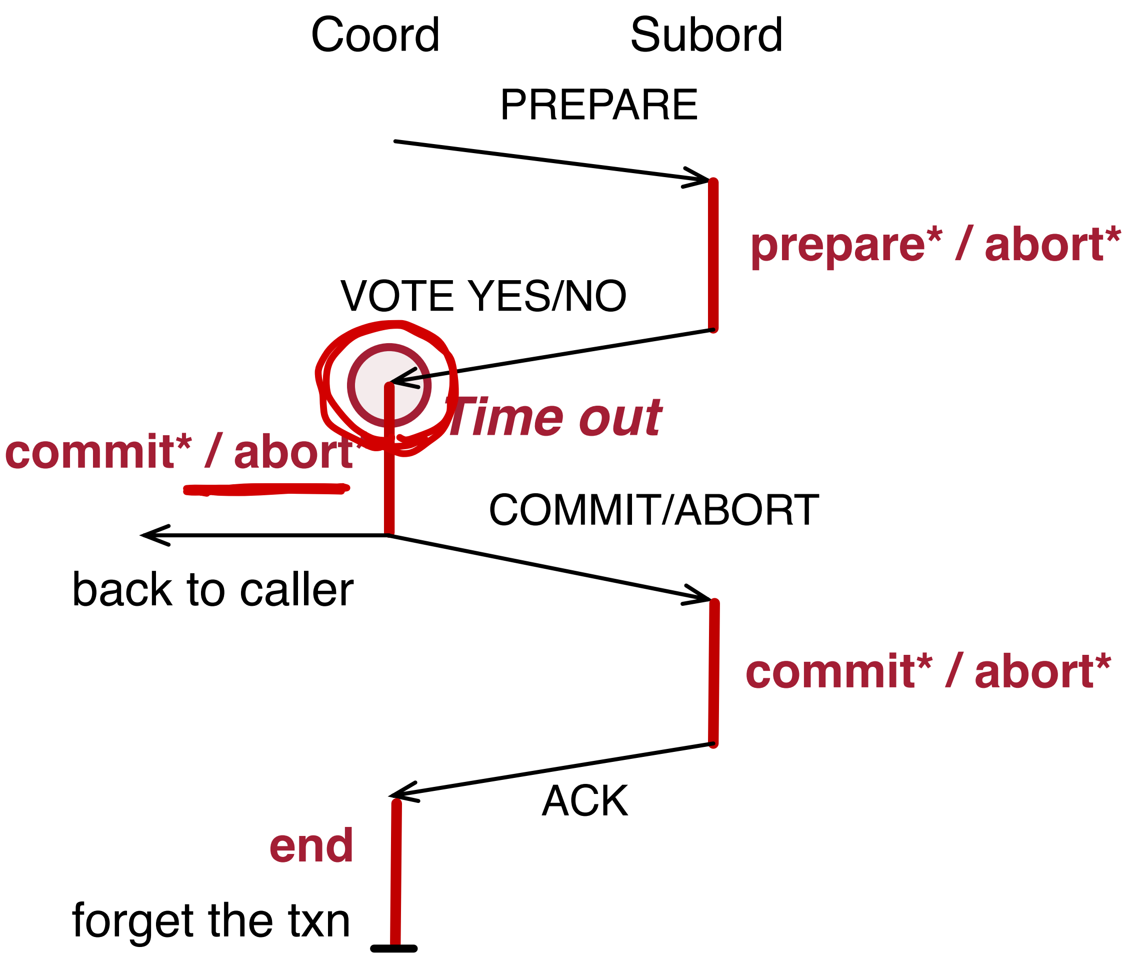


Use timeout to detect failures

Subordinate timeout

- Waiting for PREPARE: self abort

2PC – Failures

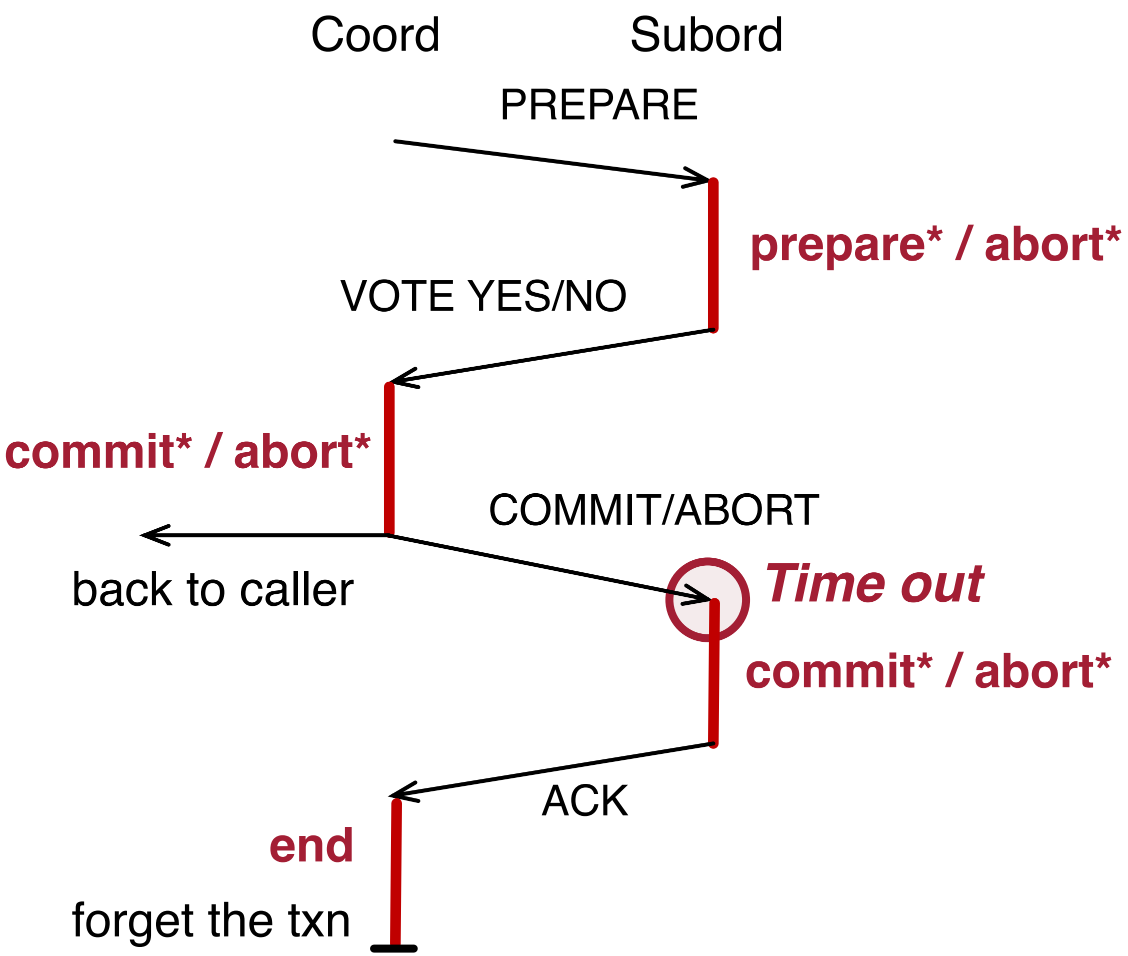


Use timeout to detect failures

Coordinator timeout

- Waiting for vote: self abort

2PC – Failures

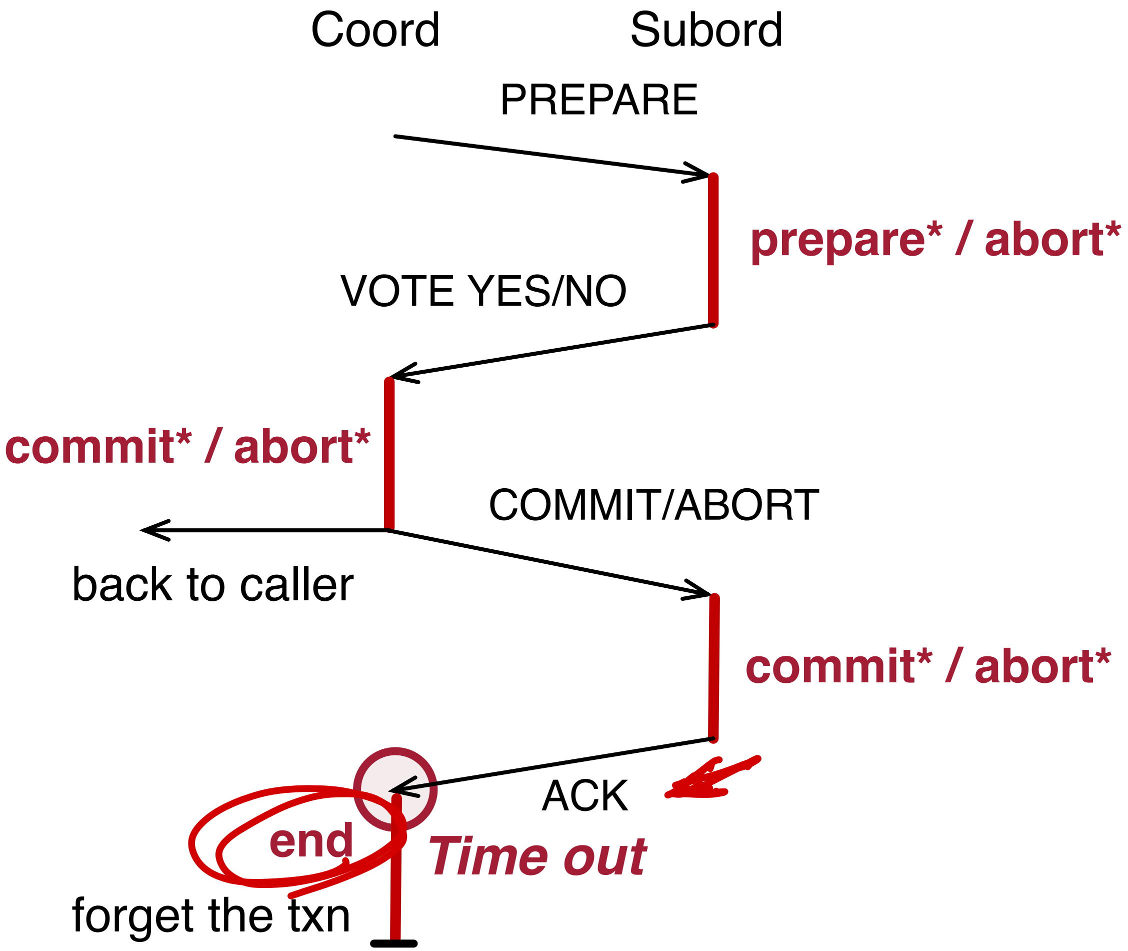


Use timeout to detect failures

Subordinate timeout

- Waiting for decision: contact coordinator or peer subordinates (**may block until the coordinator recovers**)

2PC – Failures

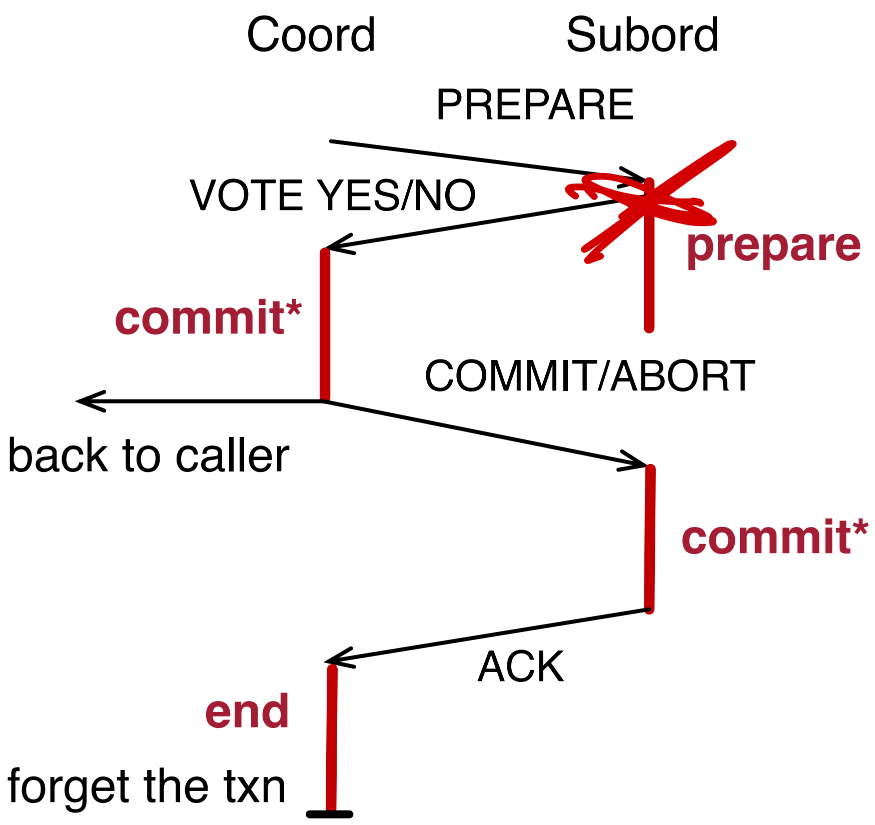


Use timeout to detect failures

Coordinator timeout

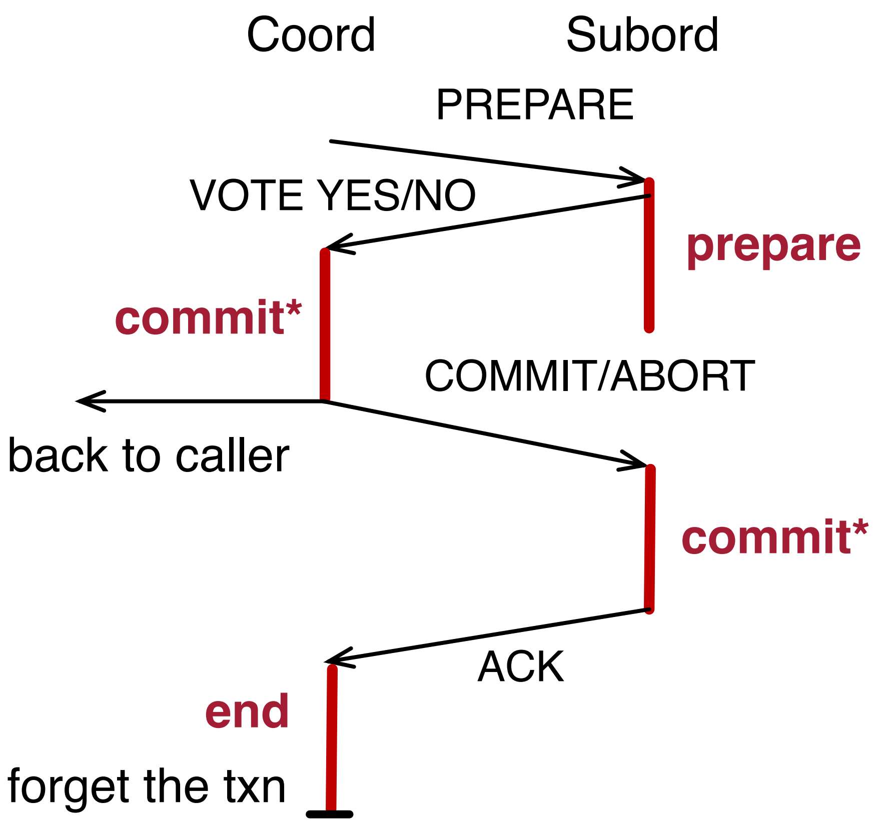
- Waiting for ACK: contact subordinates

2PC – Alternative Designs?



Subordinate returns vote to coordinator before logging prepare?

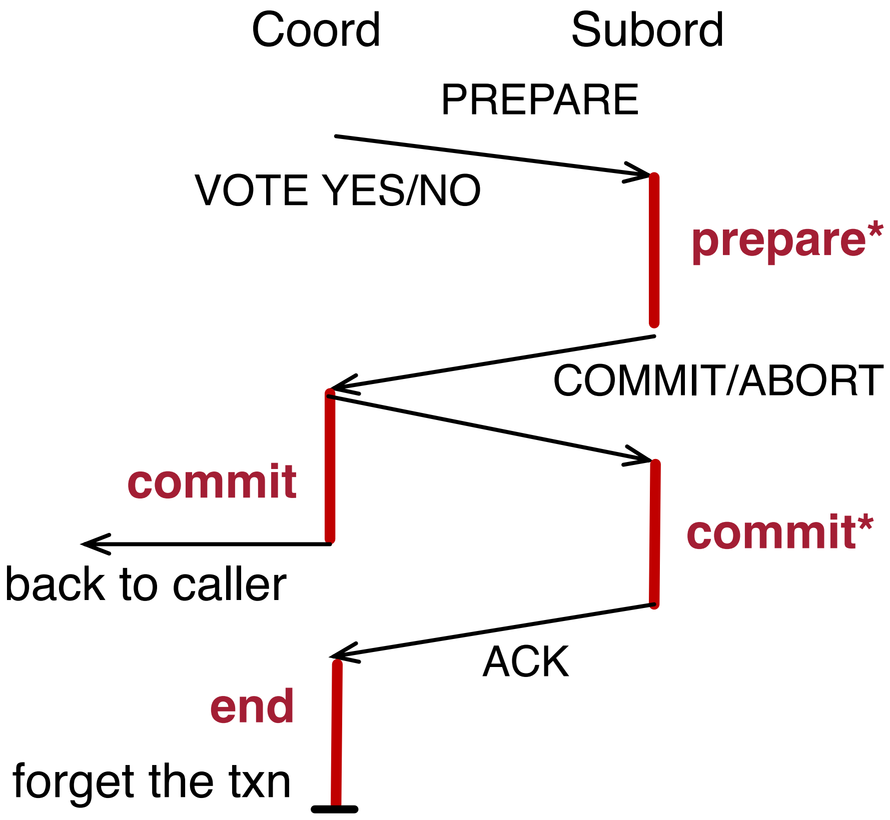
2PC – Alternative Designs?



Subordinate returns vote to coordinator before logging prepare?

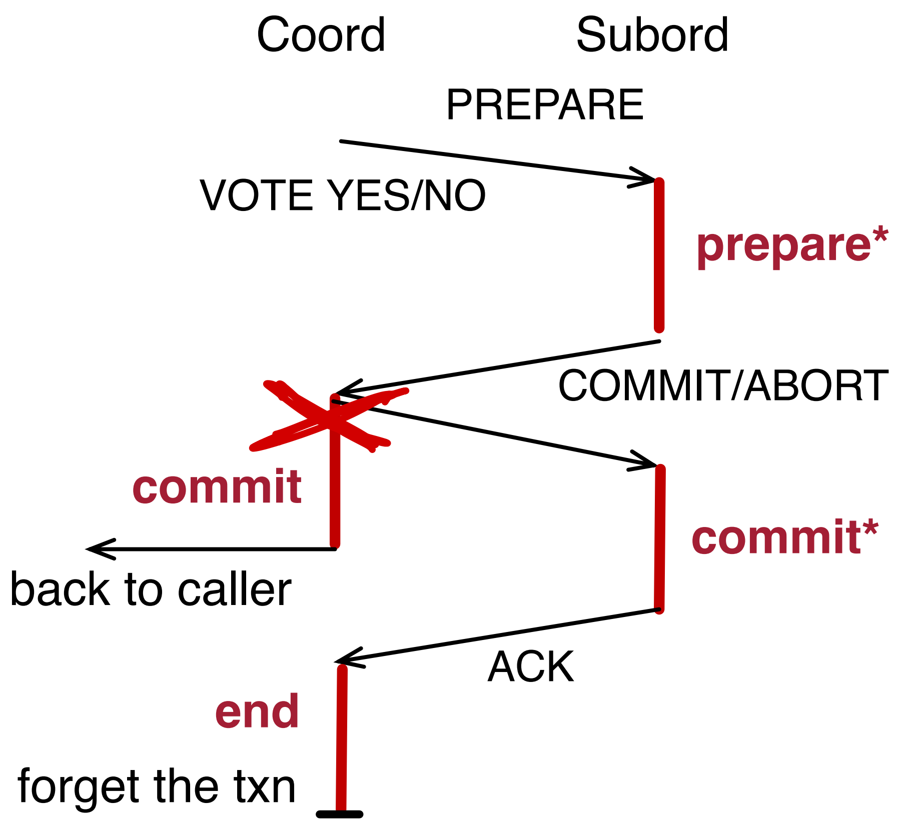
Problem: subordinate may crash before the log record is written to disk. The log record is thus lost but the coordinator already committed the transaction

2PC – Alternative Designs?



Coordinator sends decision to subordinates before logging the decision?

2PC – Alternative Designs?



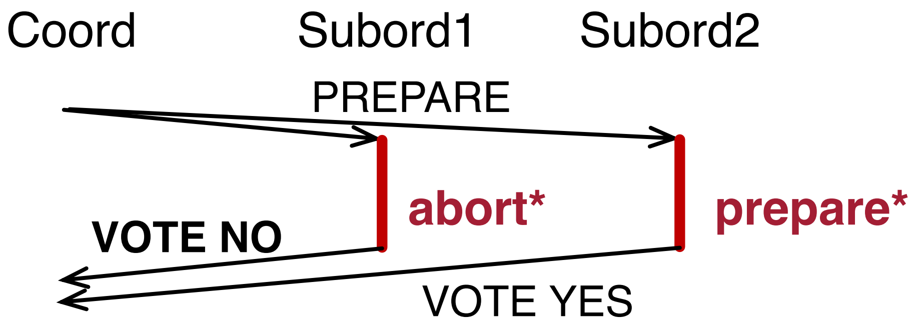
Coordinator sends decision to subordinates before logging the decision?

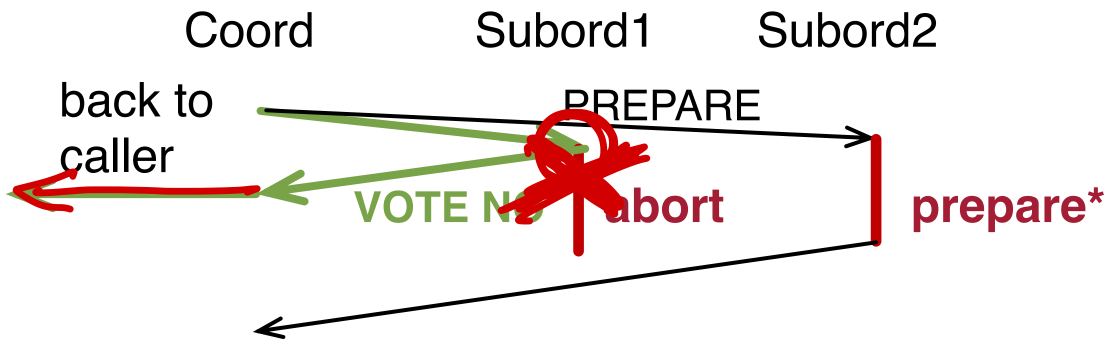
Problem: coordinator crashes before logging the decision and decides to abort after restart

Optimization 1: Presumed Abort (PA)

Observation: It is safe for a coordinator to “forget” a transaction immediately after it makes the decision to abort it and to write an abort record

PA: Aborted Transaction



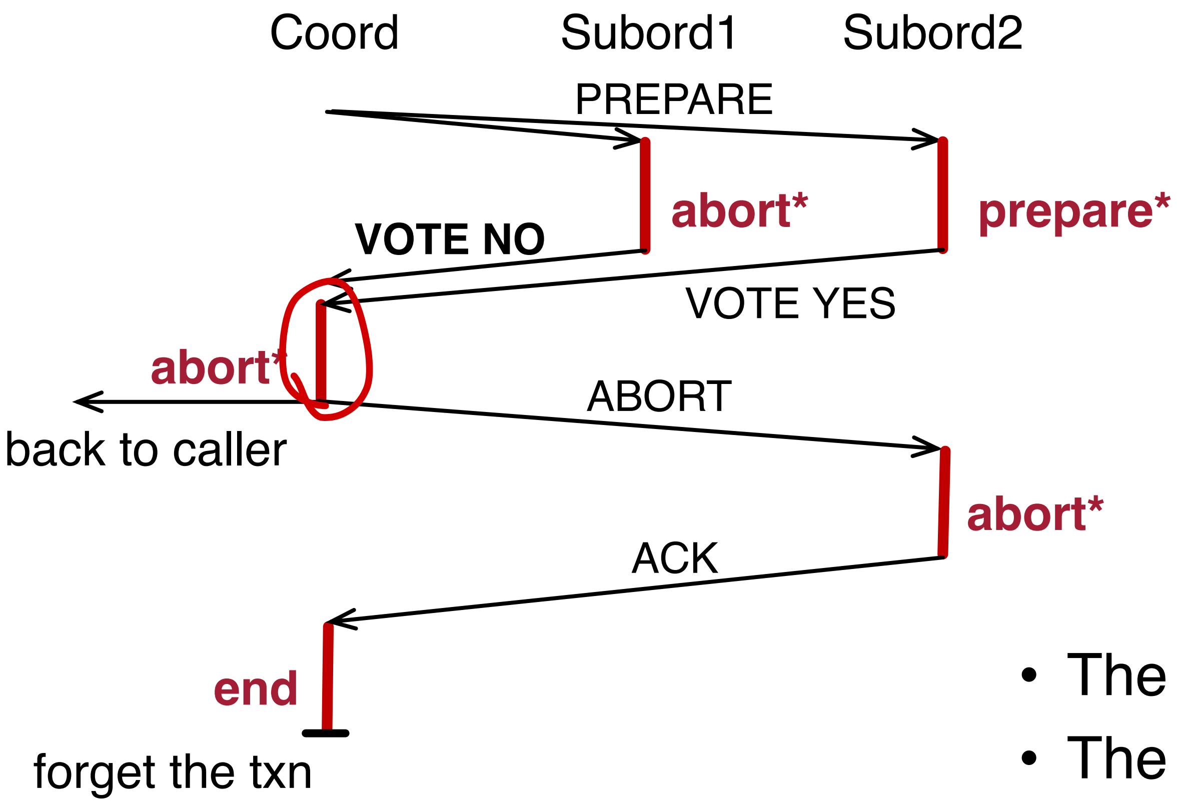


Presumed Abort

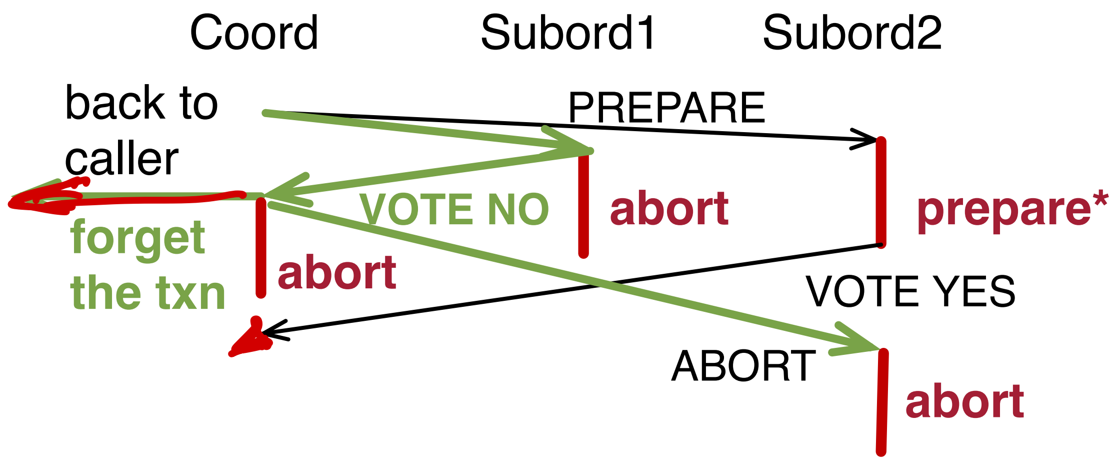
- The abort record is not forced in subordinate

Standard 2PC

PA: Aborted Transaction



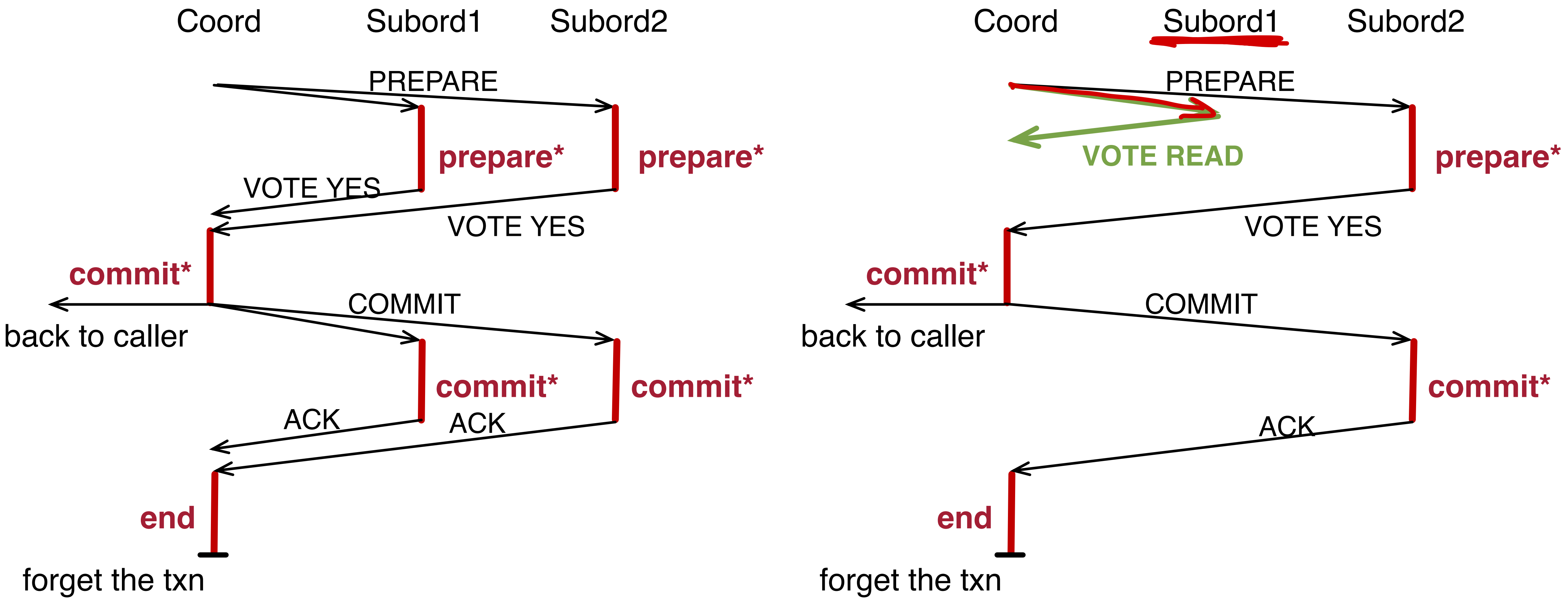
Standard 2PC



Presumed Abort

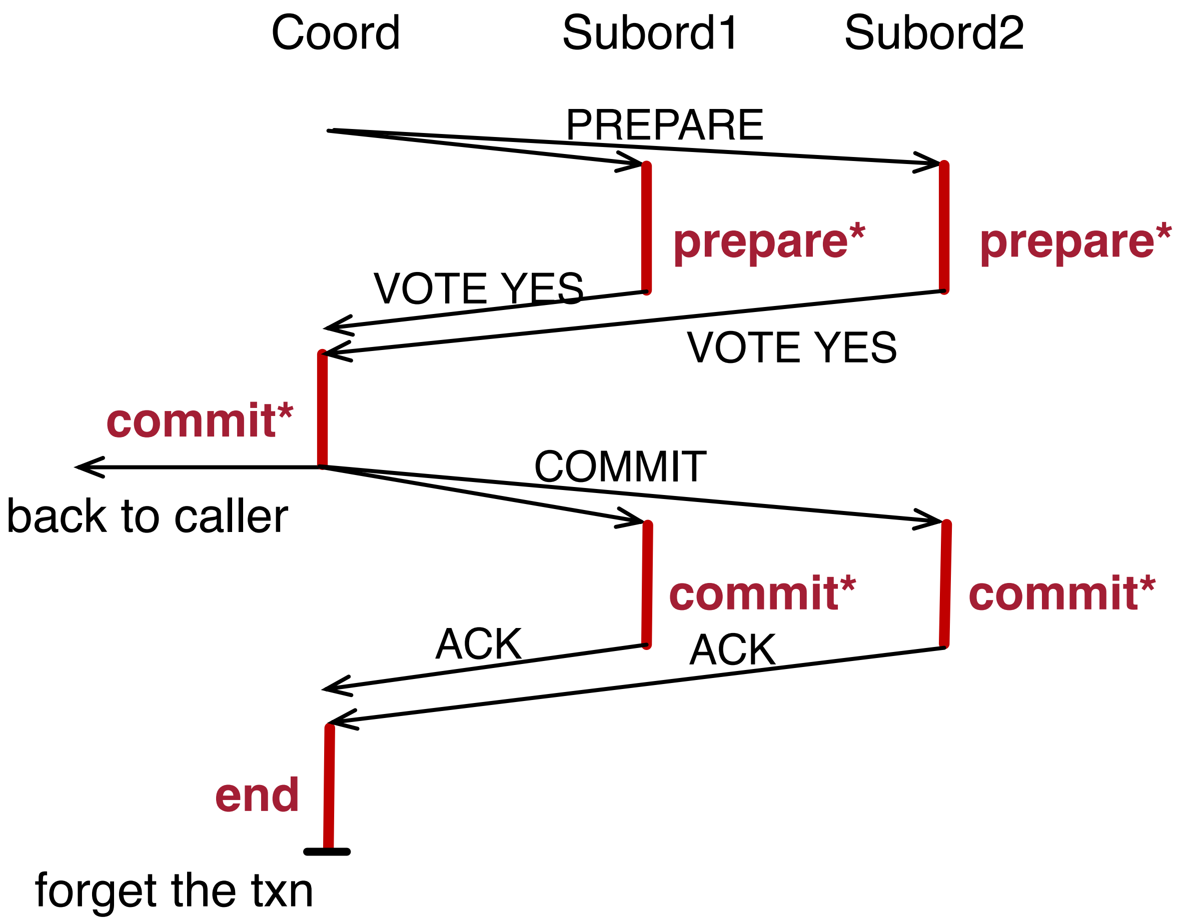
- The abort record is not forced in subordinate
- The abort record is not forced in coordinator
- Coordinator forgets the transaction early
- No ACK for aborts
- **Behavior of committed transactions unchanged**

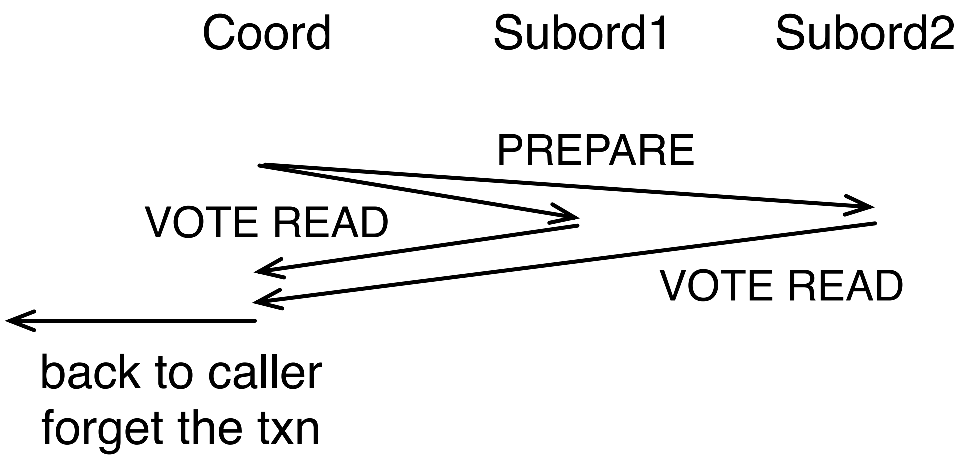
PA: Partially Readonly Transactions



Readonly subordinate does not log in prepare phase and skips commit phase

PA: Completely Readonly Transactions



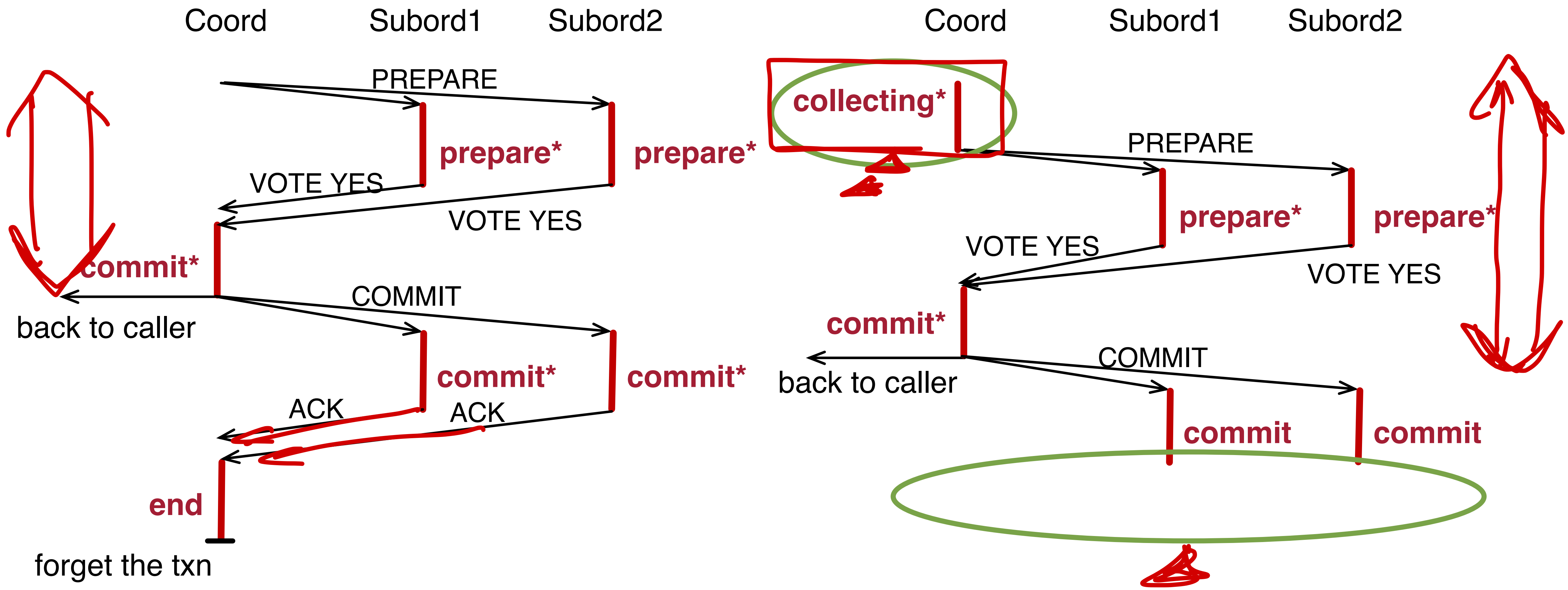


Completely readonly transactions skip the commit phase entirely

Optimization 2: Presumed Commit (PC)

Since most transactions are expected to commit, can we make commits cheaper by eliminating the ACKs for COMMITS?

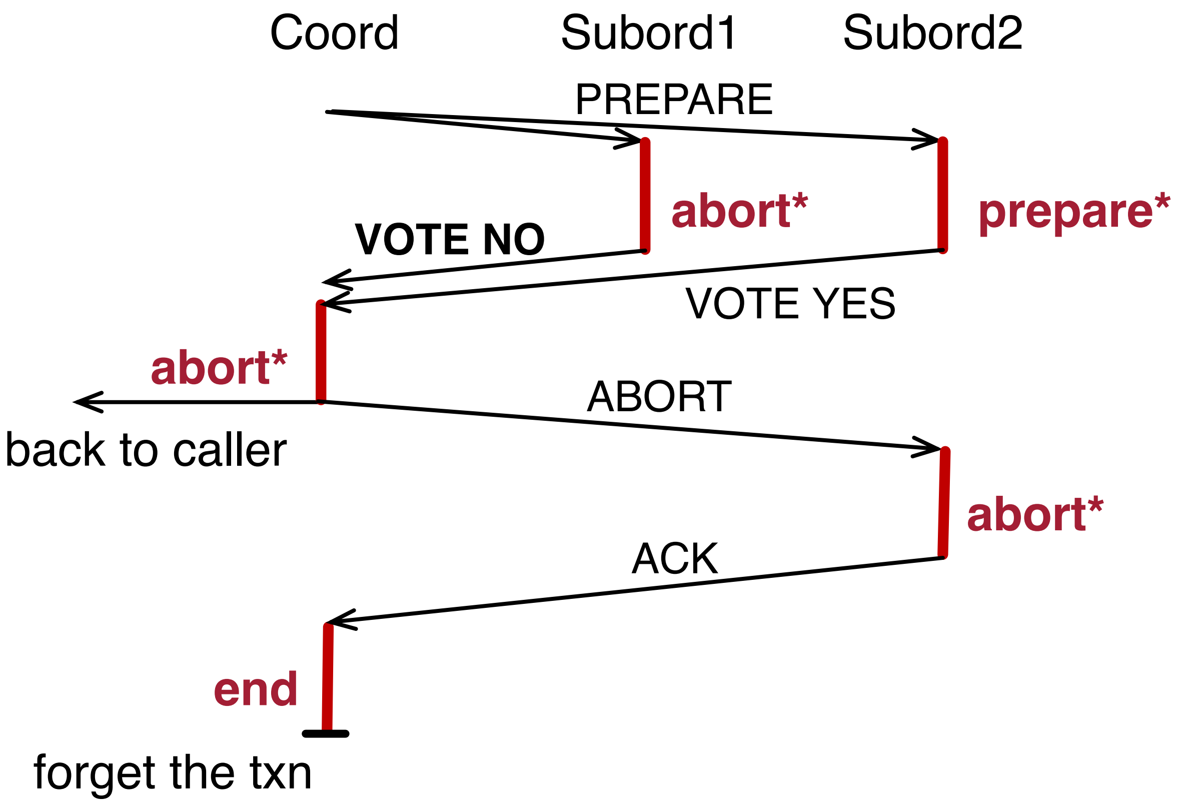
PC: Committed Transaction

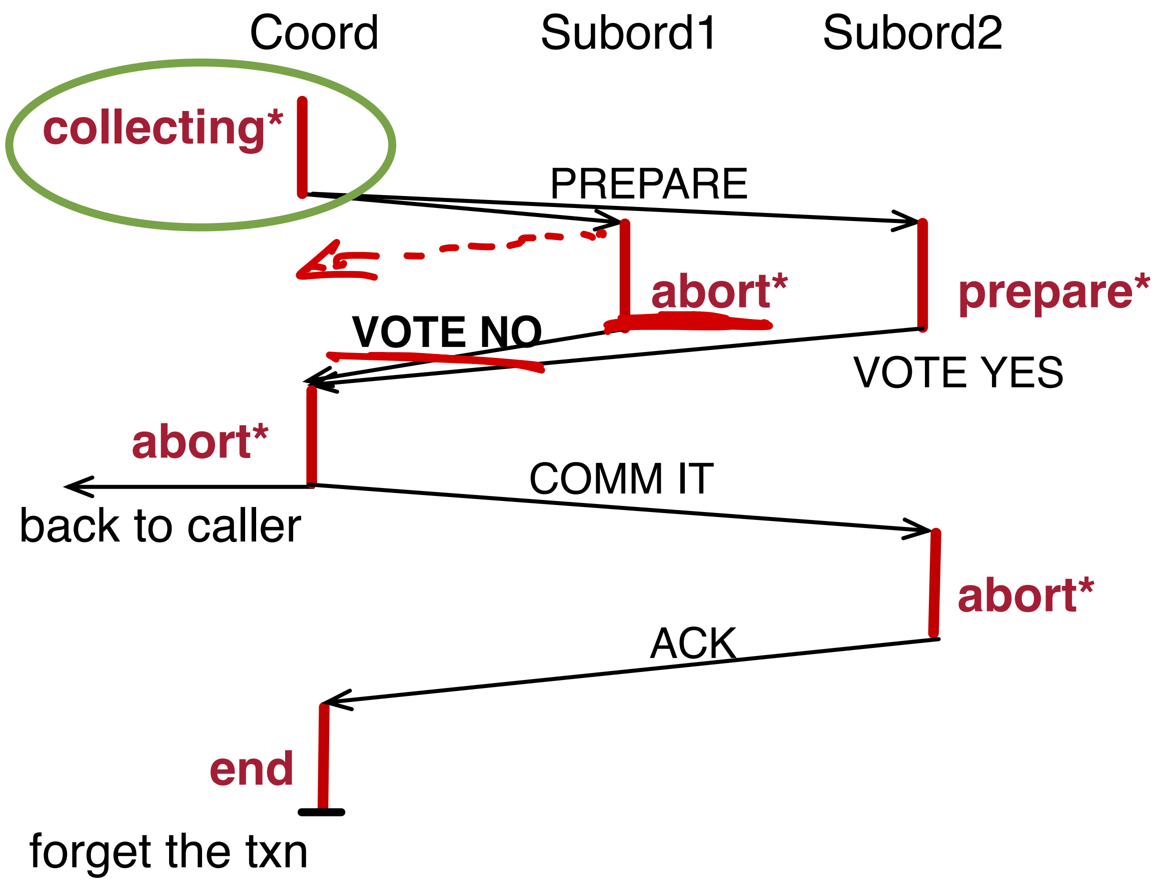


Need to force log **collecting** due to potential abort of coordinator

No need to send ACK for COMMITS

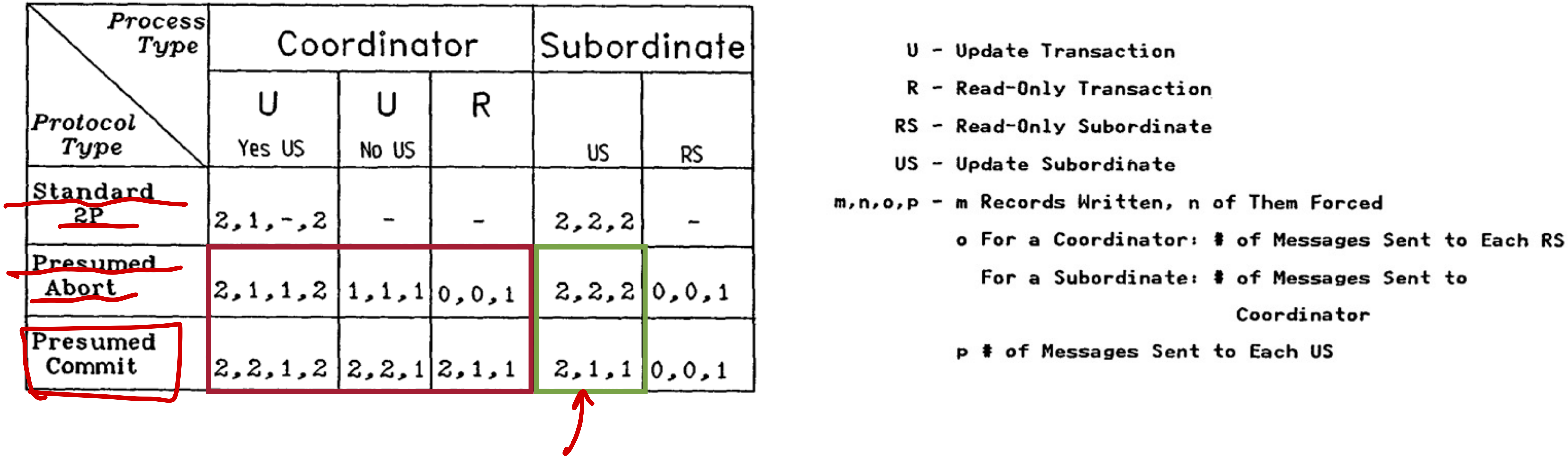
PC: Aborted Transaction





Abort behavior is similar to standard 2PC but requires logging **collecting**

Summary



Process Type / Protocol Type	Coordinator			Subordinate	
	U Yes US	U No US	R	US	RS
Standard 2P	2,1,-,2	-	-	2,2,2	-
Presumed Abort	2,1,1,2	1,1,1	0,0,1	2,2,2	0,0,1
Presumed Commit	2,2,1,2	2,2,1	2,1,1	2,1,1	0,0,1

U - Update Transaction

R - Read-Only Transaction

RS - Read-Only Subordinate

US - Update Subordinate

m,n,o,p - m Records Written, n of Them Forced

o For a Coordinator: # of Messages Sent to Each RS

For a Subordinate: # of Messages Sent to Coordinator

p # of Messages Sent to Each US

Presumed Abort (PA) is better than standard 2PC (widely used in practice)

Presumed Commit (PC) is worse than PA in most cases

Conclusions

Distributed transaction requires an atomic commit protocol

Two-phase commit (2PC) is the most widely used atomic commit protocol

- Standard 2PC
- Optimization 1: presumed abort (PA) — most commonly used in practice
- Optimization 2: presumed commit (PC)

Q/A – Two Phase Commit

More performant alternatives to 2PC?

Transactions in today's distributed DBMS?

2PC in replicated and non-replicated data systems?

Distributed deadlocks possible in shared-nothing database?

Is coordinator a single point of failure?

What if a long-running txn fails before reaching commit or abort?

Cope with message lost during network transmission?

2PC vs. Paxos?

Next Lecture

Zhihan Guo, et al., Cornus: Atomic Commit for a Cloud DBMS with Storage Disaggregation. arXiv 2102.10185 (to appear in VLDB), 2022