CSE 444: Database Internals

Lecture 24

Two-Phase Commit (2PC)

References

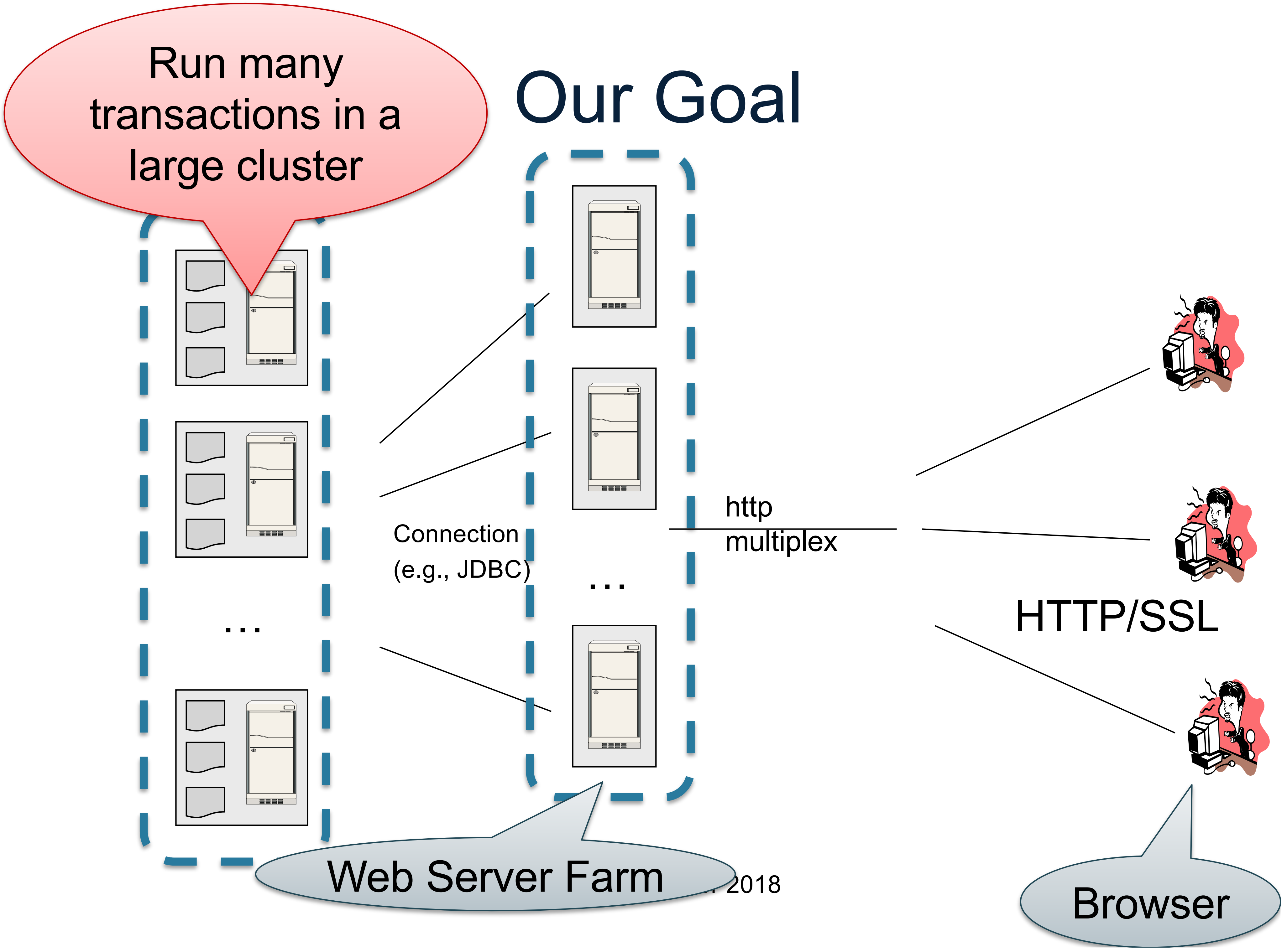
- Ullman book: Section 20.5
- Ramakrishnan book: Chapter 22

We are Learning about **Scaling DBMSs**

- Scaling the execution of a query
  - Parallel DBMS
  - MapReduce
  - Spark

- Scaling transactions
  - Distributed transactions
  - Replication
  - Scaling with NoSQL and NewSQL

Our Goal


Run many transactions in a large cluster
…
Connection (e.g., JDBC)
…
http multiplex
HTTP/SSL
Web Server Farm
Browser

Transaction Scaling Challenges

- Distribution
  - There is a limit on transactions/sec on one server
  - Need to partition the database across multiple servers
  - If a transaction touches one machine, life is good!
  - If a transaction touches multiple machines, ACID becomes extremely expensive! Need two-phase commit
- Replication
  - Replication can help to increase throughput and lower latency
  - Create multiple copies of each database partition
  - Spread queries across these replicas
  - Easy for reads but writes, once again, become expensive!

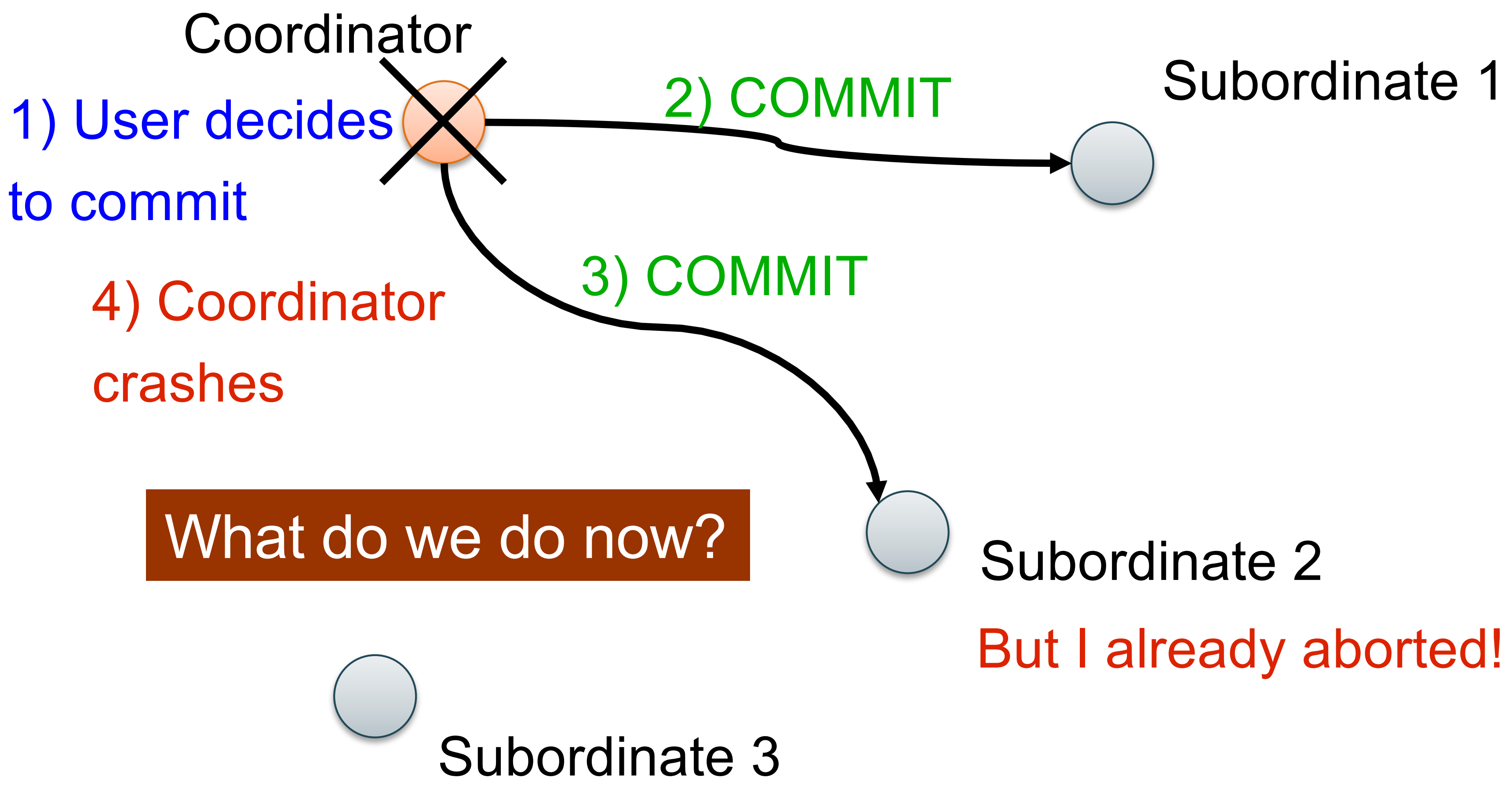
Distributed Transactions

- Concurrency control
- Failure recovery
  - Transaction must be committed at all sites or at none of the sites!
    - No matter what failures occur and when they occur
  - Two-phase commit protocol (2PC)

Distributed Concurrency Control

- In theory, different techniques are possible
  - Pessimistic, optimistic, locking, timestamps
- In practice, distributed two-phase locking
  - Simultaneously hold locks at all sites involved
- Deadlock detection techniques
  - Global wait-for graph (not very practical)
  - Timeouts
- If deadlock: abort least costly local transaction

Two-Phase Commit: Motivation

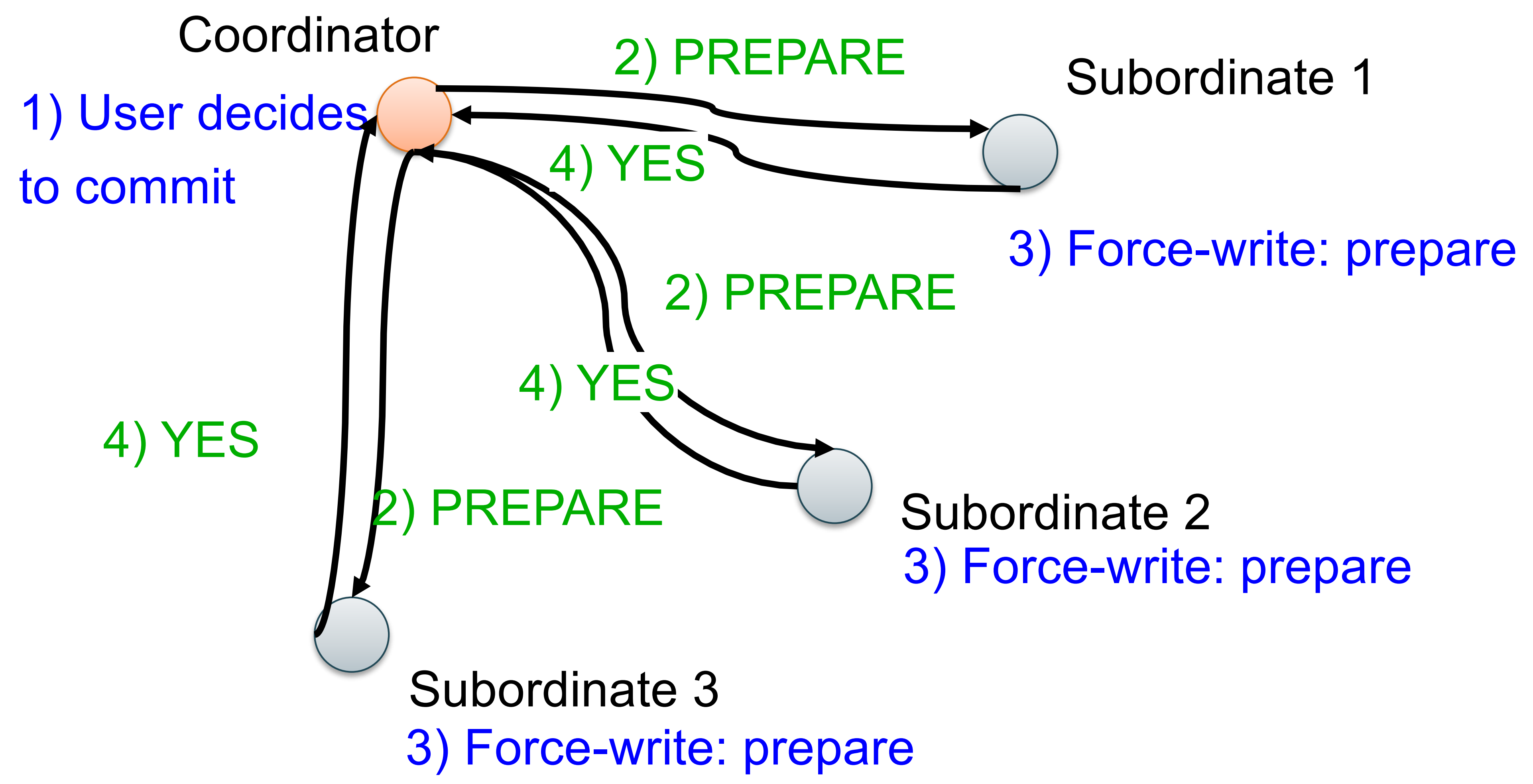


Two-Phase Commit Protocol

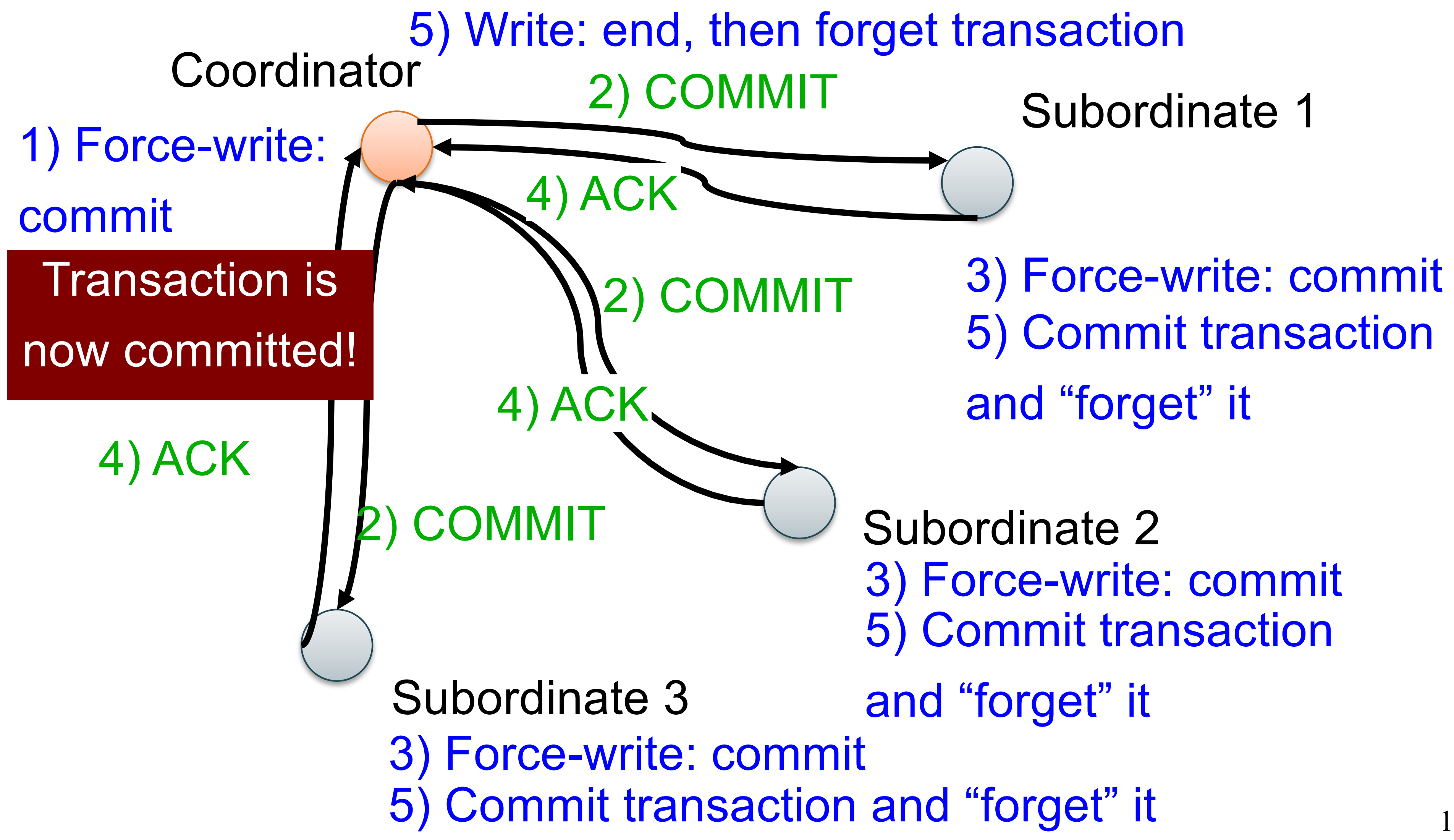
- One coordinator and many subordinates
  - Phase 1: prepare
    - All subordinates must flush tail of write-ahead log to disk before ack
    - Must ensure that if coordinator decides to commit, they can commit!
  - Phase 2: commit or abort
  - Log records for 2PC include transaction and coordinator ids
  - Coordinator also logs ids of all subordinates

- Principle
  - Whenever a process makes a decision: vote yes/no or commit/abort
  - Or whenever a subordinate wants to respond to a message: ack
  - First force-write a log record (to make sure it survives a failure)
  - Only then send message about decision

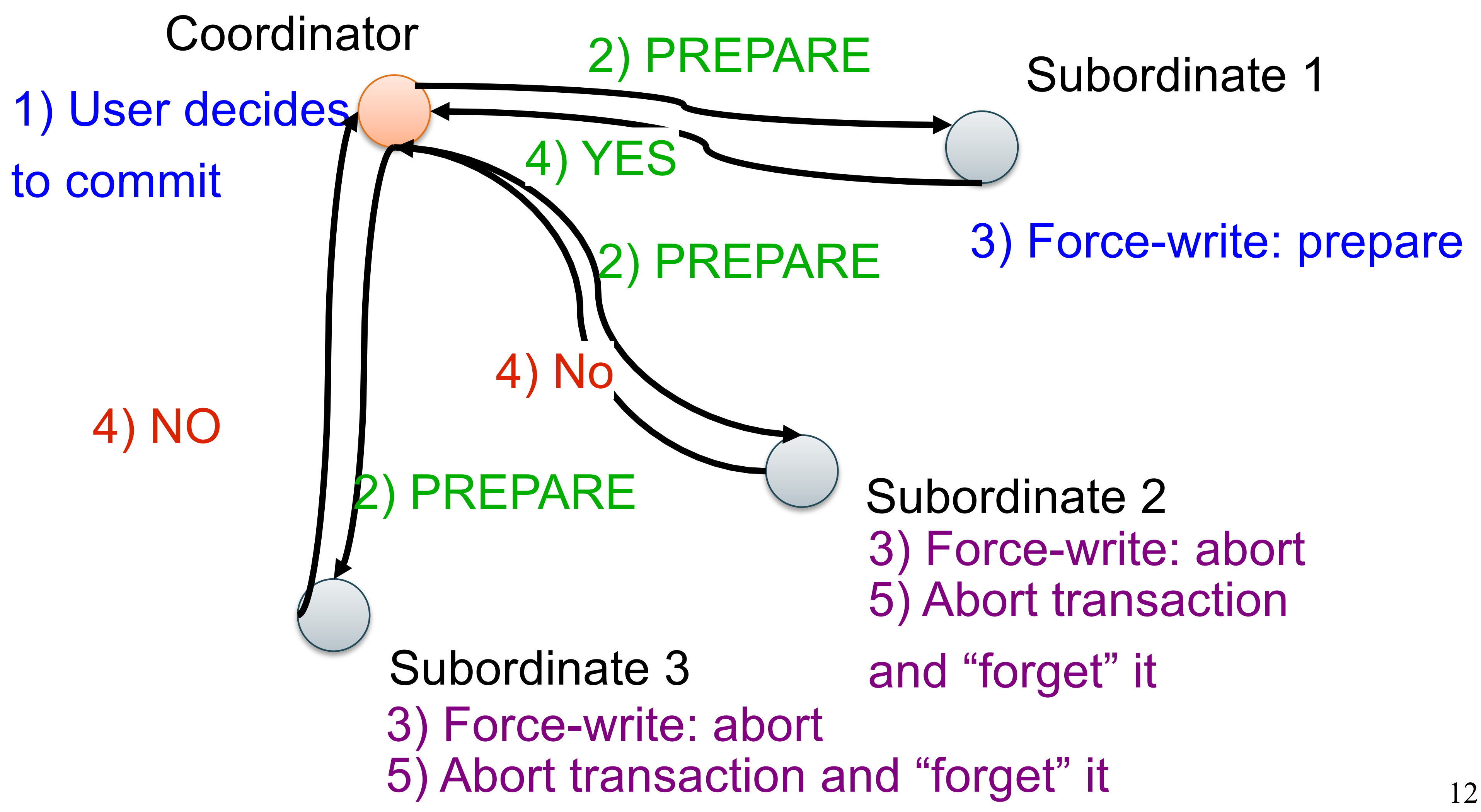
2PC: Phase 1, Prepare



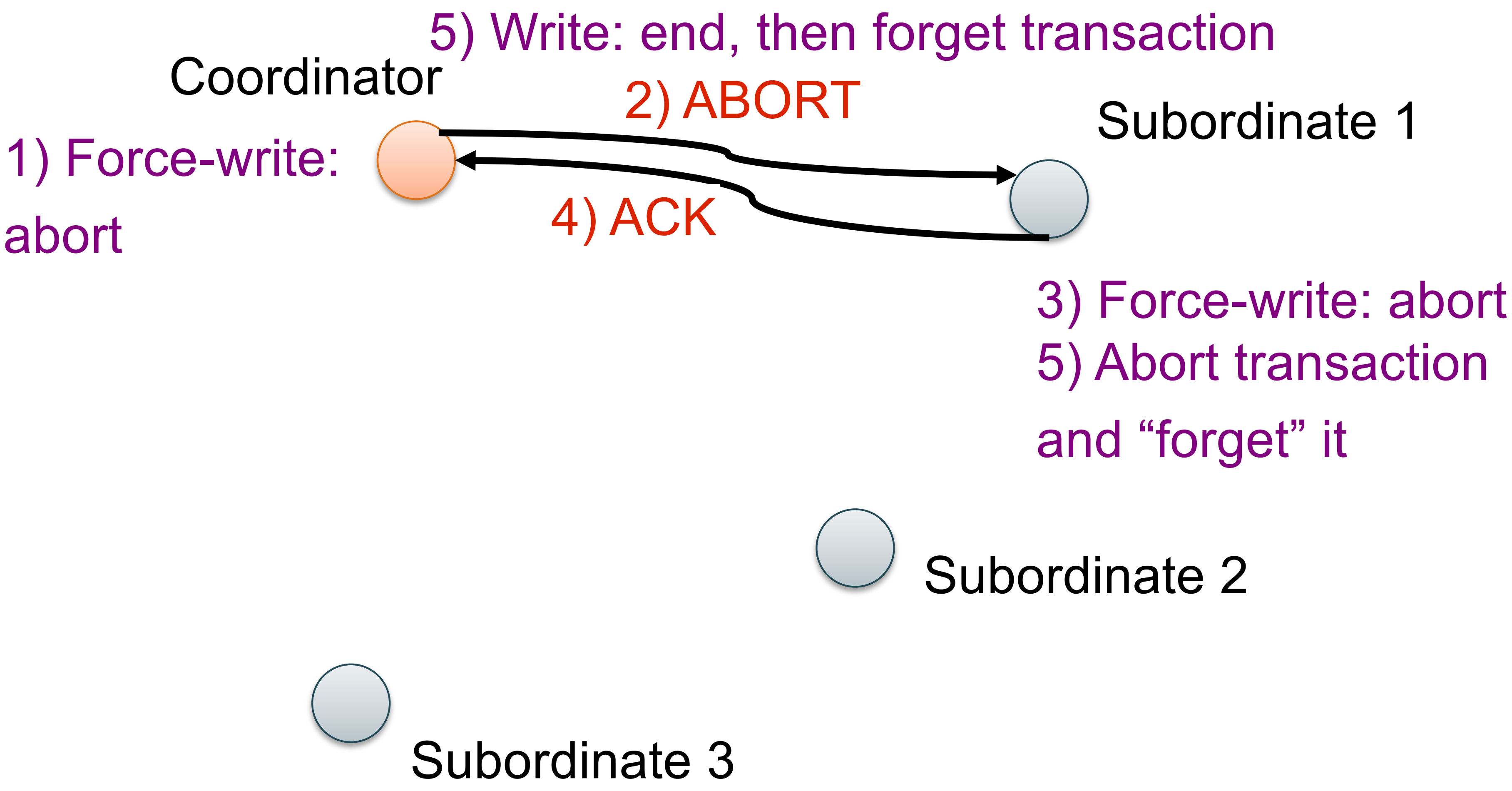
2PC: Phase 2, Commit



2PC with Abort

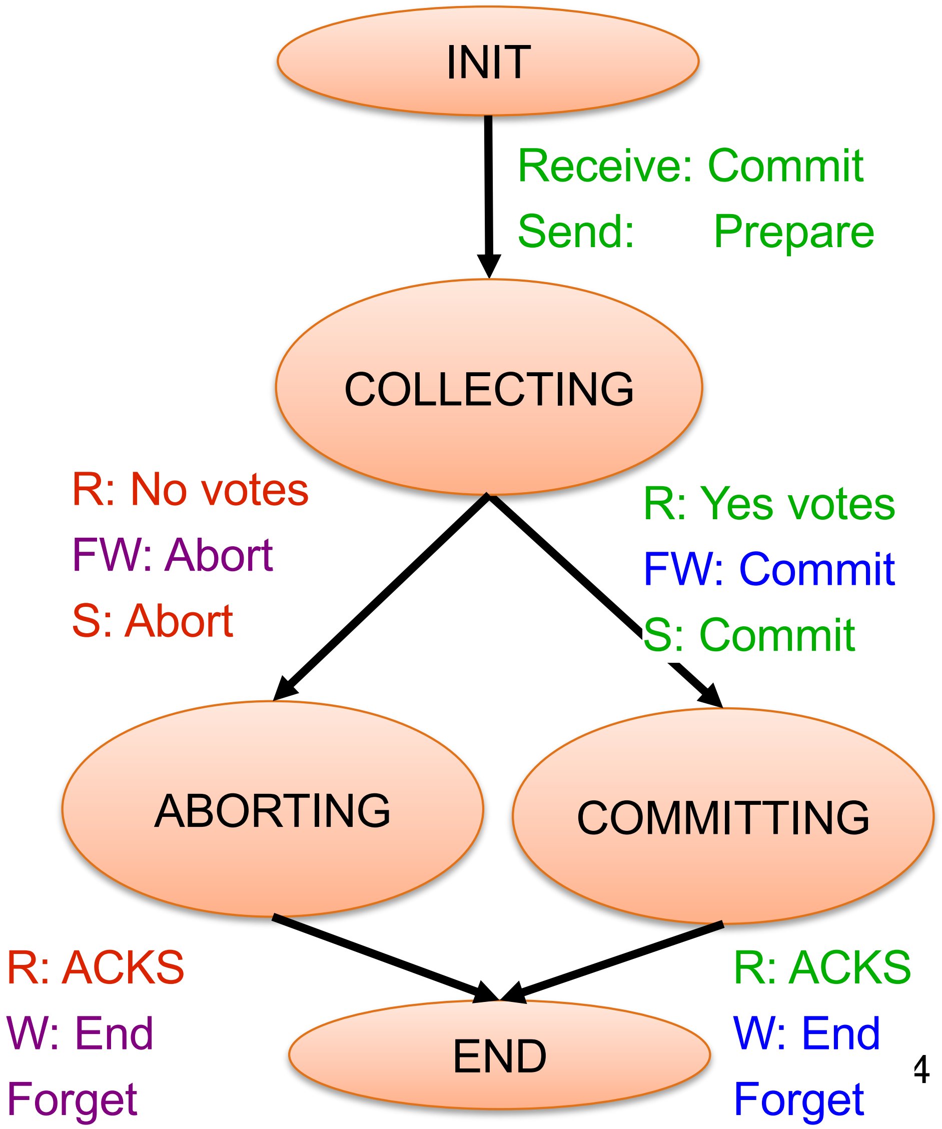


2PC with Abort



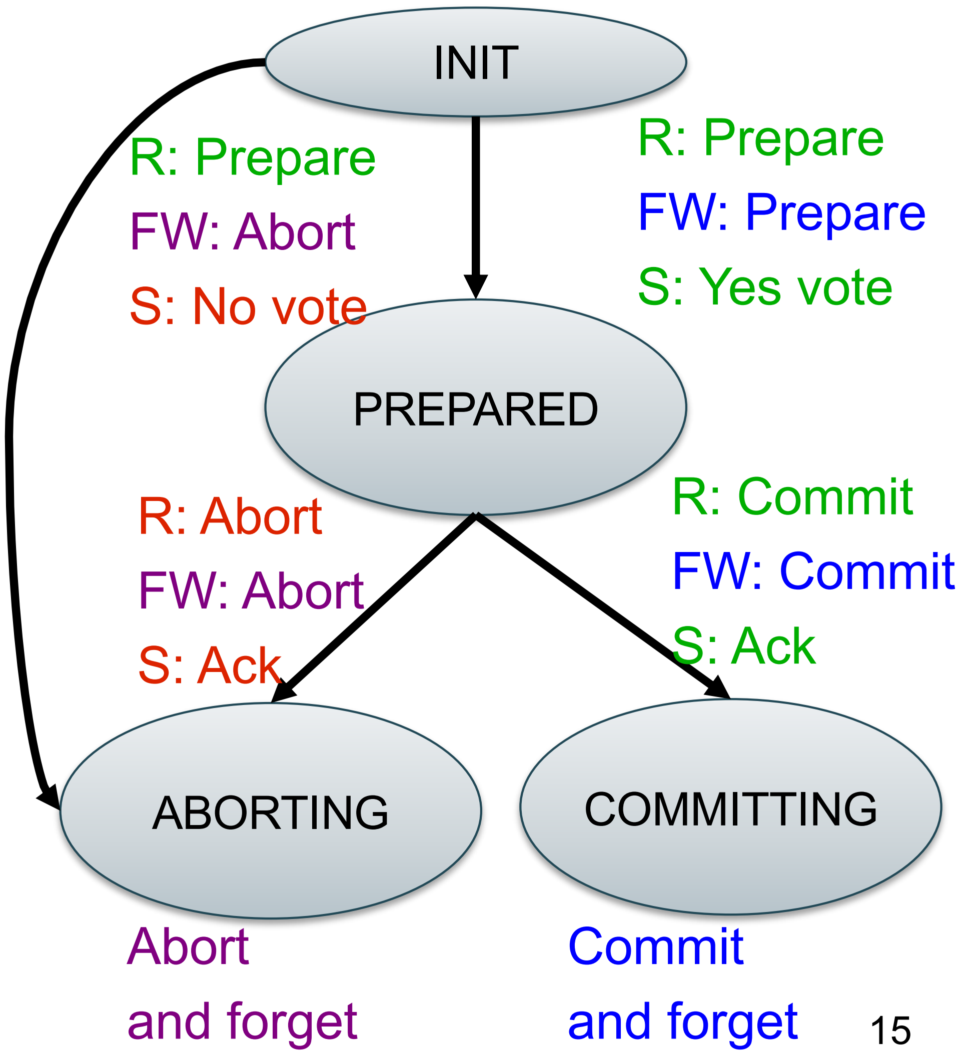
Coordinator State Machine

- All states involve waiting for messages



Subordinate State Machine

- INIT and PREPARED involve waiting



Handling Site Failures

- Approach 1: no site failure detection
  - Can only do retrying & blocking
- Approach 2: timeouts
  - Since unilateral abort is ok,
  - Subordinate can timeout in init state
  - Coordinator can timeout in collecting state
  - Prepared state is still blocking
- 2PC is a blocking protocol

Site Failure Handling Principles

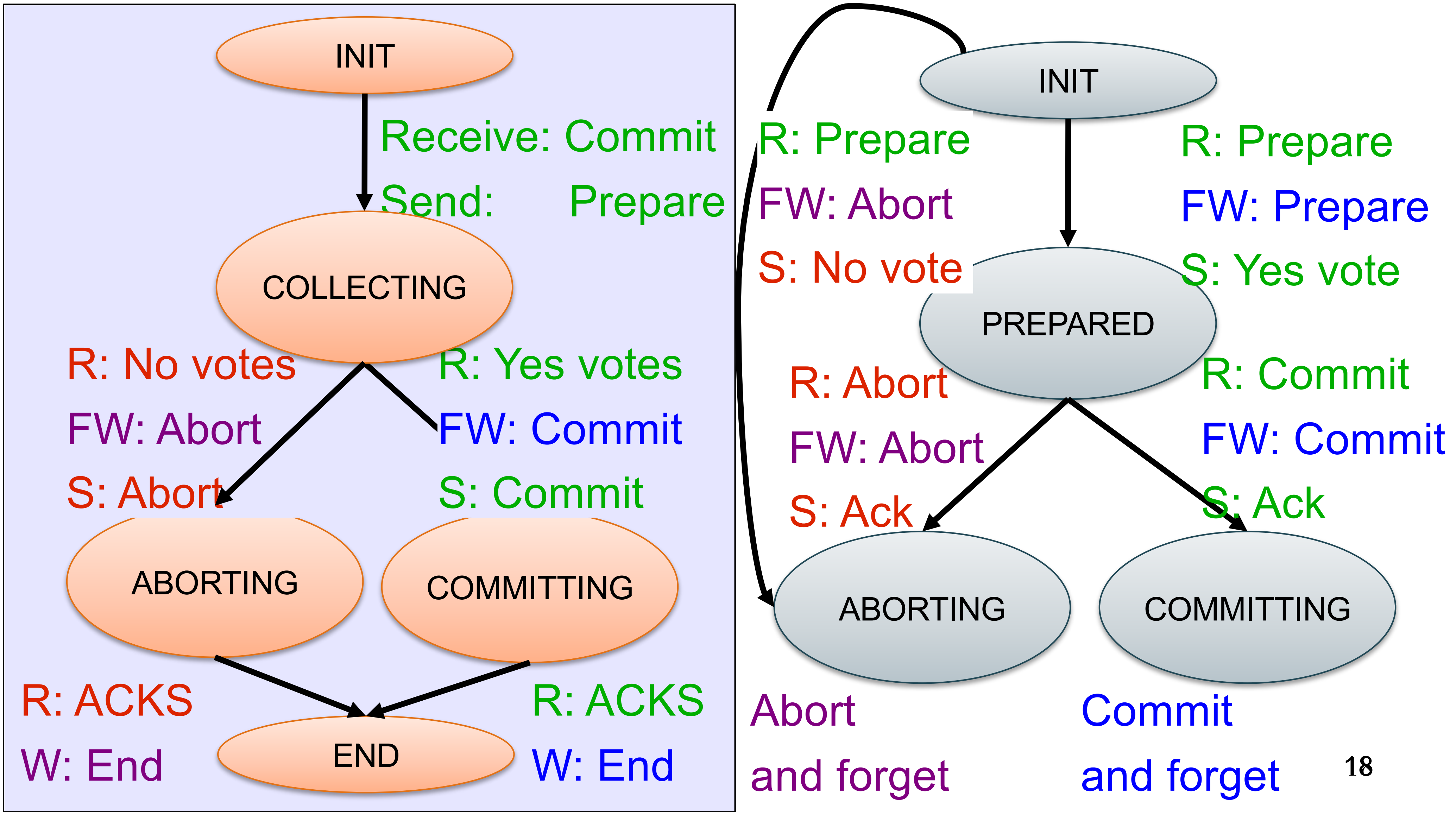
- Retry mechanism
  - In prepared state, periodically query coordinator
  - In committing/aborting state, periodically resend messages to subordinates

- If doesn't know anything about transaction respond “abort” to inquiry messages about fate of transaction

- If there are no log records for a transaction after a crash then abort transaction and “forget” it

Site Failure Scenarios

Examples on the board (please take notes)



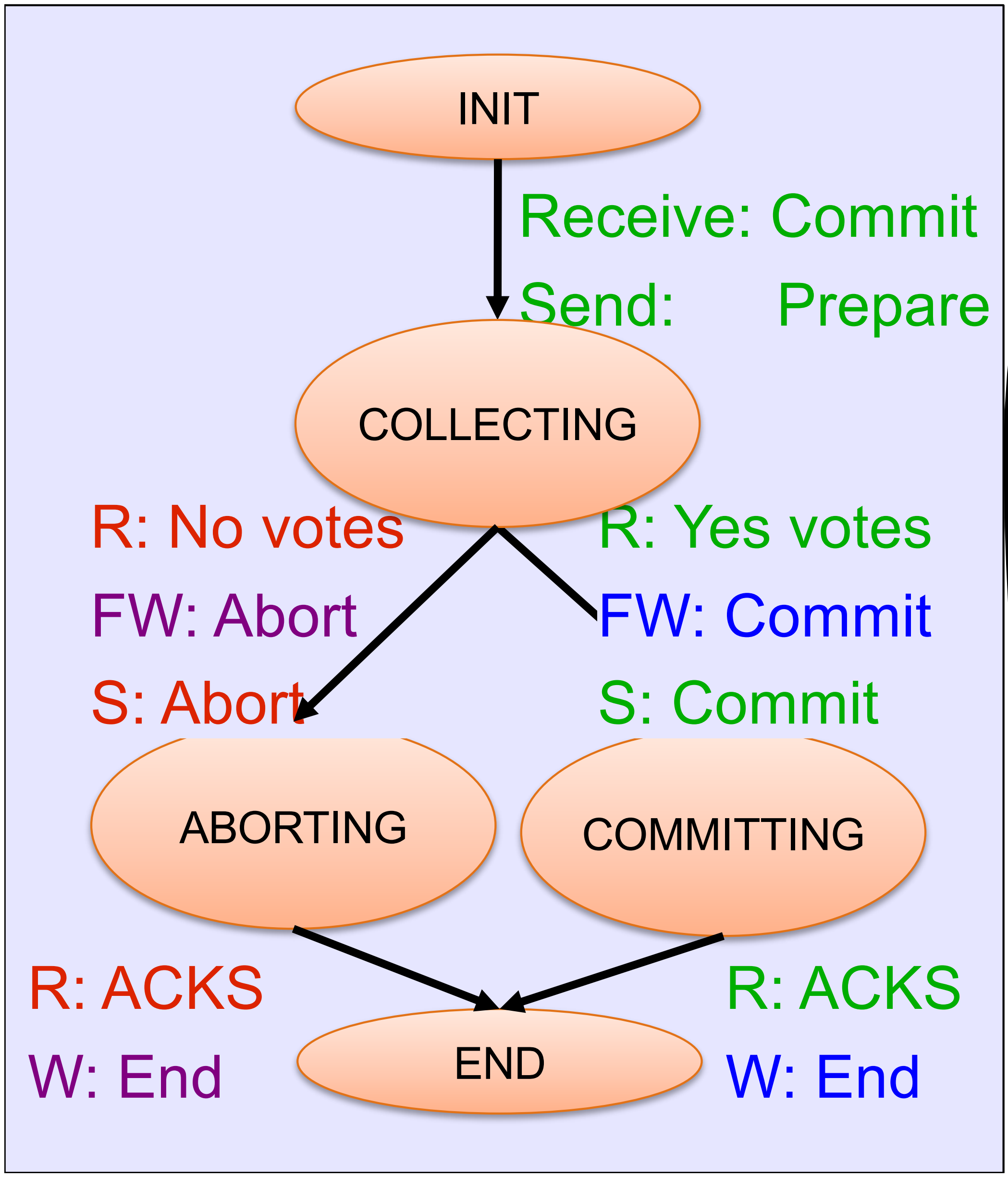
Observations

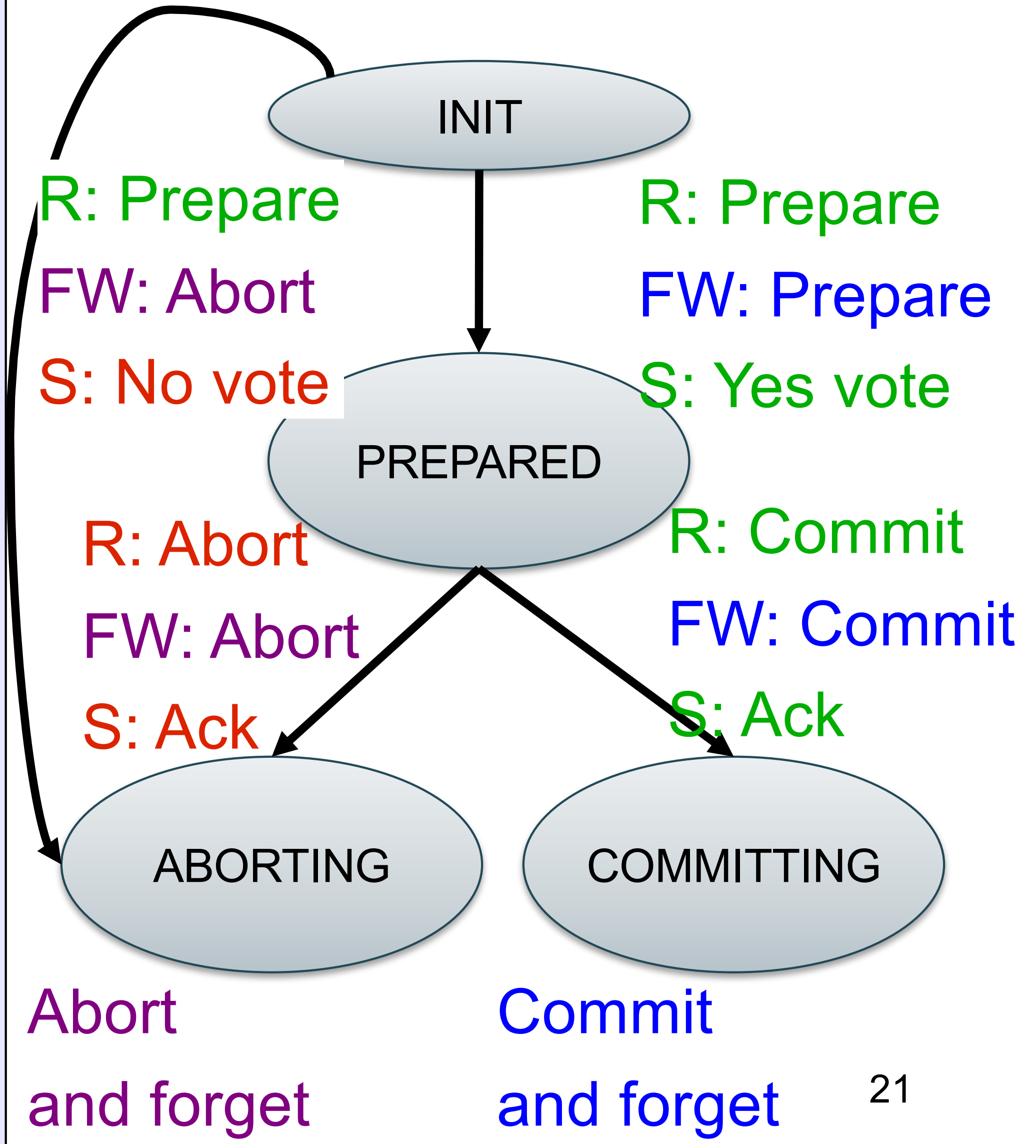
- Coordinator keeps transaction in transactions table until it receives all acks
  - To ensure subordinates know to commit or abort
  - So acks enable coordinator to “forget” about transaction
- After crash, if recovery process finds no log records for a transaction, the transaction is presumed to have aborted
- Read-only subtransactions: no changes ever need to be undone nor redone

Presumed Abort Protocol

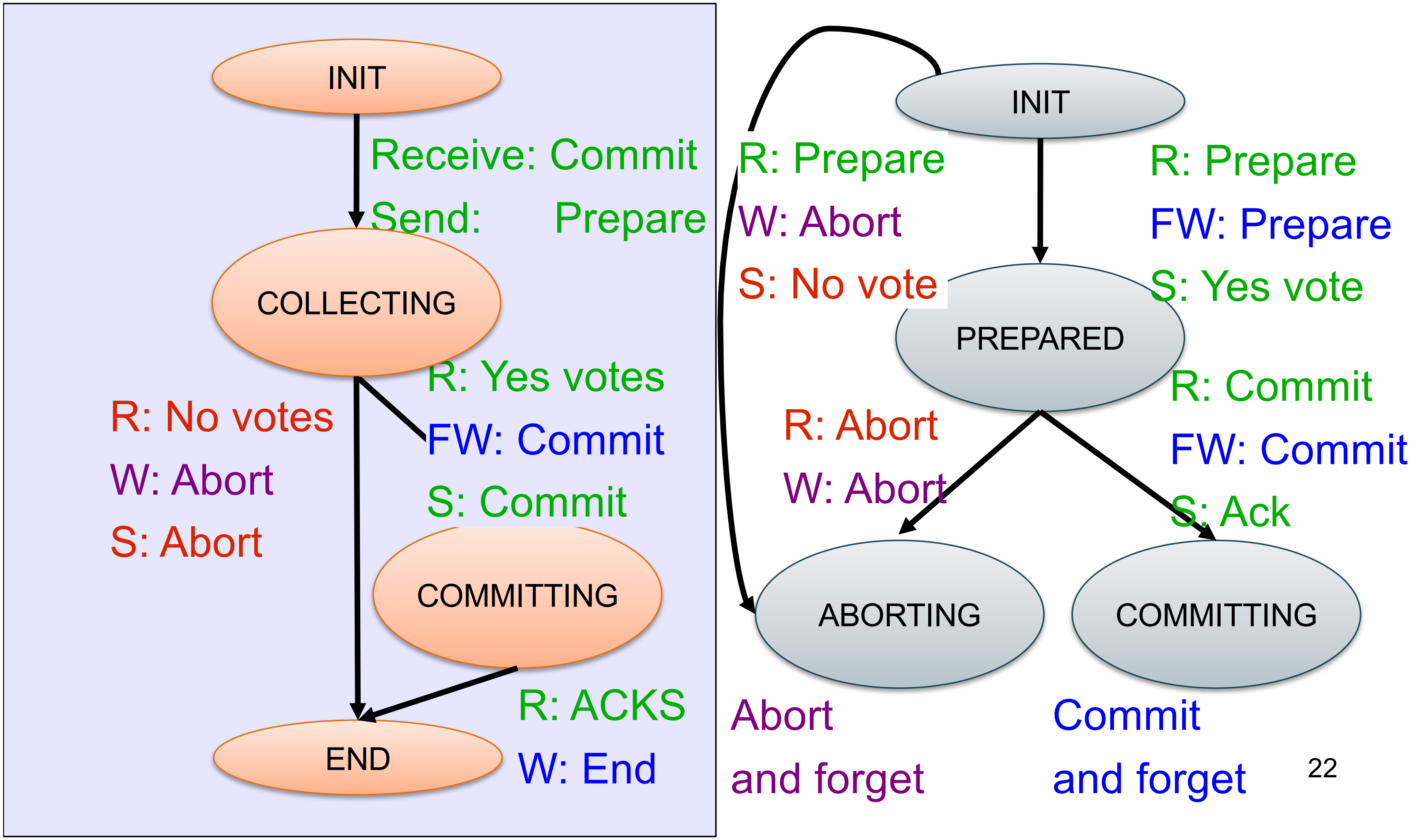
- Optimization goals
  - Fewer messages and fewer force-writes
- Principle
  - If nothing known about a transaction, assume ABORT
- Aborting transactions need no force-writing
- Avoid log records for read-only transactions
  - Reply with a READ vote instead of YES vote
- Optimizes read-only transactions

2PC State Machines (repeat)





Presumed Abort State Machines


INIT
Receive: Commit
Send: Prepare
COLLECTING
R: Yes votes
FW: Commit
S: Commit
R: No votes
W: Abort
S: Abort
COMMITTING
R: ACKS
W: End
END
INIT
R: Prepare
W: Abort
S: No vote
R: Prepare
FW: Prepare
S: Yes vote
PREPARED
R: Abort
W: Abort
R: Commit
FW: Commit
S: Ack
ABORTING
COMMITTING
Abort
and forget
Commit
and forget