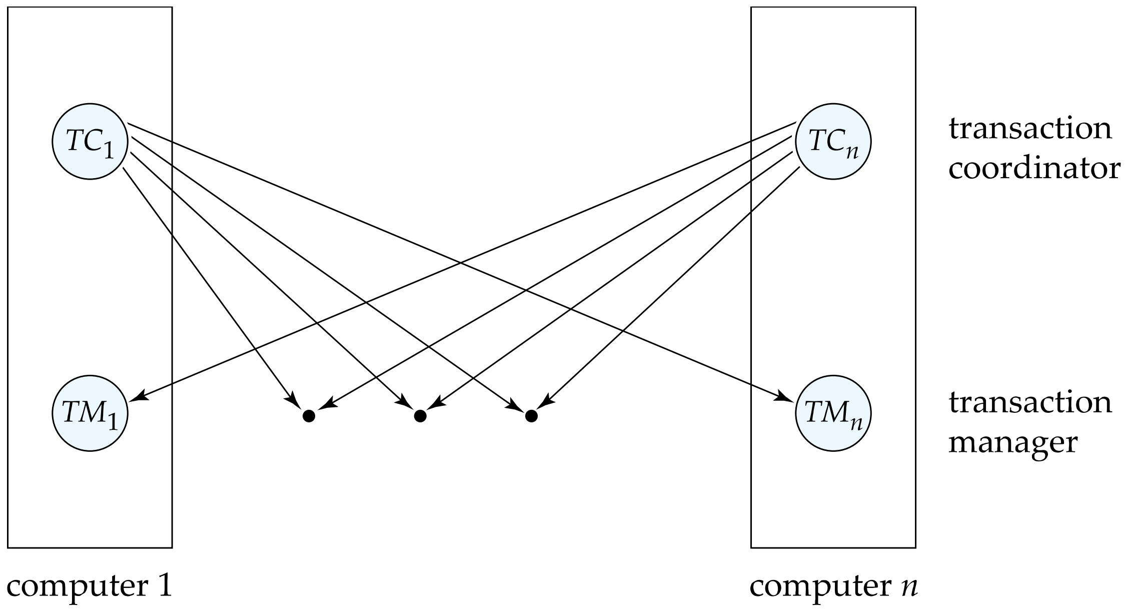
Distributed Transactions

- **Local transactions**
  - Access/update data at only one database
- **Global transactions**
  - Access/update data at more than one database
- Key issue: how to ensure ACID properties for transactions in a system with global transactions spanning multiple database

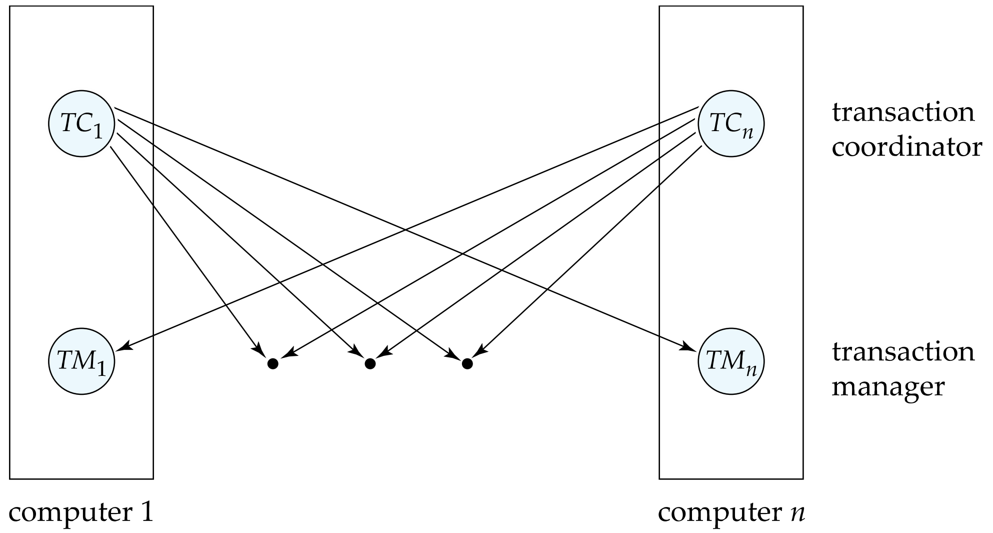
Distributed Transactions

- Transaction may access data at several sites.
  - Each site has a local **transaction manager**
  - Each site has a **transaction coordinator**
    - Global transactions submitted to any transaction coordinator



Distributed Transactions

- Each transaction coordinator is responsible for:
  - Starting the execution of transactions that originate at the site.
  - Distributing subtransactions at appropriate sites for execution.
  - Coordinating the termination of each transaction that originates at the site
    - transaction must be committed at all sites or aborted at all sites.
- Each local transaction manager responsible for:
  - Maintaining a log for recovery purposes
  - Coordinating the execution and commit/abort of the transactions executing at that site.



System Failure Modes

- Failures unique to distributed systems:
  - Failure of a site.
  - Loss of massages
    - Handled by network transmission control protocols such as TCP-IP
  - Failure of a communication link
    - Handled by network protocols, by routing messages via alternative links
  - **Network partition**
    - A network is said to be **partitioned** when it has been split into two or more subsystems that lack any connection between them
      - Note: a subsystem may consist of a single node
- Network partitioning and site failures are generally indistinguishable.

Commit Protocols

- Commit protocols are used to ensure atomicity across sites
  - a transaction which executes at multiple sites must either be committed at all the sites, or aborted at all the sites.
    - cannot have transaction committed at one site and aborted at another
- The *two-phase commit* (2PC) protocol is widely used
- *Three-phase commit* (3PC) protocol avoids some drawbacks of 2PC, but is more complex
- *Consensus protocols* solve a more general problem, but can be used for atomic commit
  - More on these later in the chapter
- The protocols we study all assume **fail-stop** model – failed sites simply stop working, and do not cause any other harm, such as sending incorrect messages to other sites.
  - Protocols that can tolerate some number of malicious sites discussed in bibliographic notes online

Two Phase Commit Protocol (2PC)

- Execution of the protocol is initiated by the coordinator after the last step of the transaction has been reached.
- The protocol involves all the local sites at which the transaction executed
- Protocol has two phases
- Let *T* be a transaction initiated at site S_i, and let the transaction coordinator at S_i be C_i

Phase 1: Obtaining a Decision

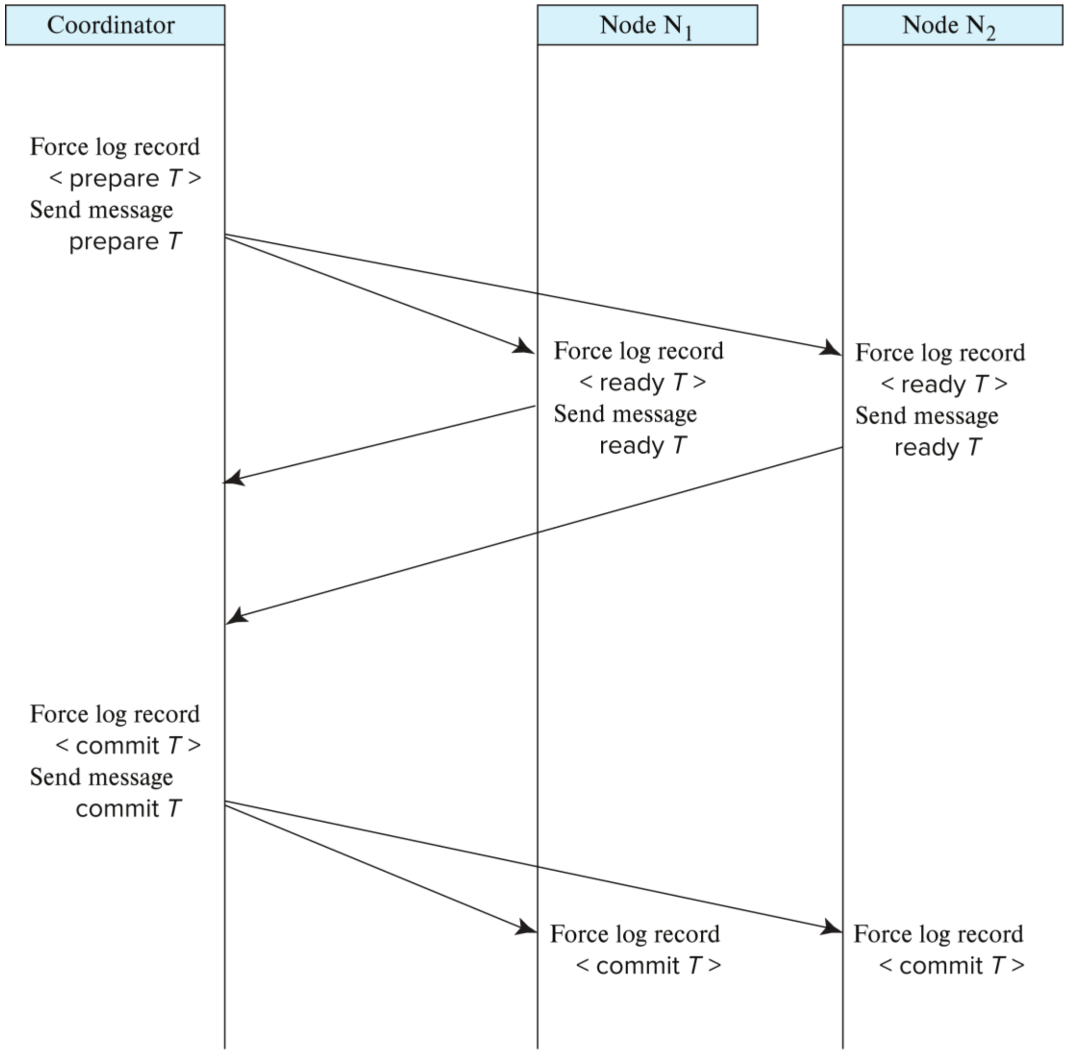
- Coordinator asks all participants to *prepare* to commit transaction T_i.
  - C_i adds the records <**prepare** *T*> to the log and forces log to stable storage
  - sends **prepare** *T* messages to all sites at which *T* executed
- Upon receiving message, transaction manager at site determines if it can commit the transaction
  - if not, add a record <**no** *T*> to the log and send **abort** *T* message to C_i
  - if the transaction can be committed, then:
    - add the record <**ready** *T*> to the log
    - force *all records* for *T* to stable storage
    - send **ready** *T* message to C_i

  Transaction is now in ready state at the site

Phase 2: Recording the Decision

- *T* can be committed of C_i received a **ready** *T* message from all the participating sites: otherwise *T* must be aborted.
- Coordinator adds a decision record, <**commit** *T*> or <a**bort** *T*>, to the log and forces record onto stable storage. Once the record stable storage it is irrevocable (even if failures occur)
- Coordinator sends a message to each participant informing it of the decision (commit or abort)
- Participants take appropriate action locally.

Two-Phase Commit Protocol


Coordinator
Node N_1
Node N_2
Force log record < prepare T >
Send message prepare T
Force log record < ready T >
Send message ready T
Force log record < ready T >
Send message ready T
Force log record < commit T >
Send message commit T
Force log record < commit T >
Force log record < commit T >

Handling of Failures - Site Failure

When site S_k recovers, it examines its log to determine the fate of transactions active at the time of the failure.

- Log contain <**commit** *T*> record: site executes **redo** (*T*)
- Log contains <**abort** *T*> record: site executes **undo** (*T*)
- Log contains <**ready** *T*> record: site must consult C_i to determine the fate of *T*.
  - If *T* committed, **redo** (*T*)
  - If *T* aborted, **undo** (*T*)
- The log contains no control records concerning *T* implies that S_k failed before responding to the **prepare** *T* message from C_i
  - since the failure of S_k precludes the sending of such a response C_i must abort *T*
  - S_k must execute **undo** (*T*)

Handling of Failures- Coordinator Failure

- If coordinator fails while the commit protocol for *T* is executing then participating sites must decide on *T*' s fate:
  1. If an active site contains a <**commit** *T*> record in its log, then *T* must be committed.
  2. If an active site contains an <**abort** *T*> record in its log, then *T* must be aborted.
  3. If some active participating site does not contain a <**ready** *T*> record in its log, then the failed coordinator C_i cannot have decided to commit *T*. Can therefore abort *T*.
  4. If none of the above cases holds, then all active sites must have a <**ready** *T*> record in their logs, but no additional control records (such as <**abort** *T*> of <**commit** *T*>). In this case active sites must wait for C_i to recover, to find decision.
- **Blocking problem**: active sites may have to wait for failed coordinator to recover.

Handling of Failures - Network Partition

- If the coordinator and all its participants remain in one partition, the failure has no effect on the commit protocol.
- If the coordinator and its participants belong to several partitions:
  - Sites that are not in the partition containing the coordinator think the coordinator has failed, and execute the protocol to deal with failure of the coordinator.
    - No harm results, but sites may still have to wait for decision from coordinator.
- The coordinator and the sites are in the same partition as the coordinator think that the sites in the other partition have failed, and follow the usual commit protocol.
    - Again, no harm results