6.033 Spring 2019

Lecture #18

- **Distributed transactions**
  - **Multi-site atomicity**
  - **Two-phase commit**

goal: build reliable systems from unreliable components

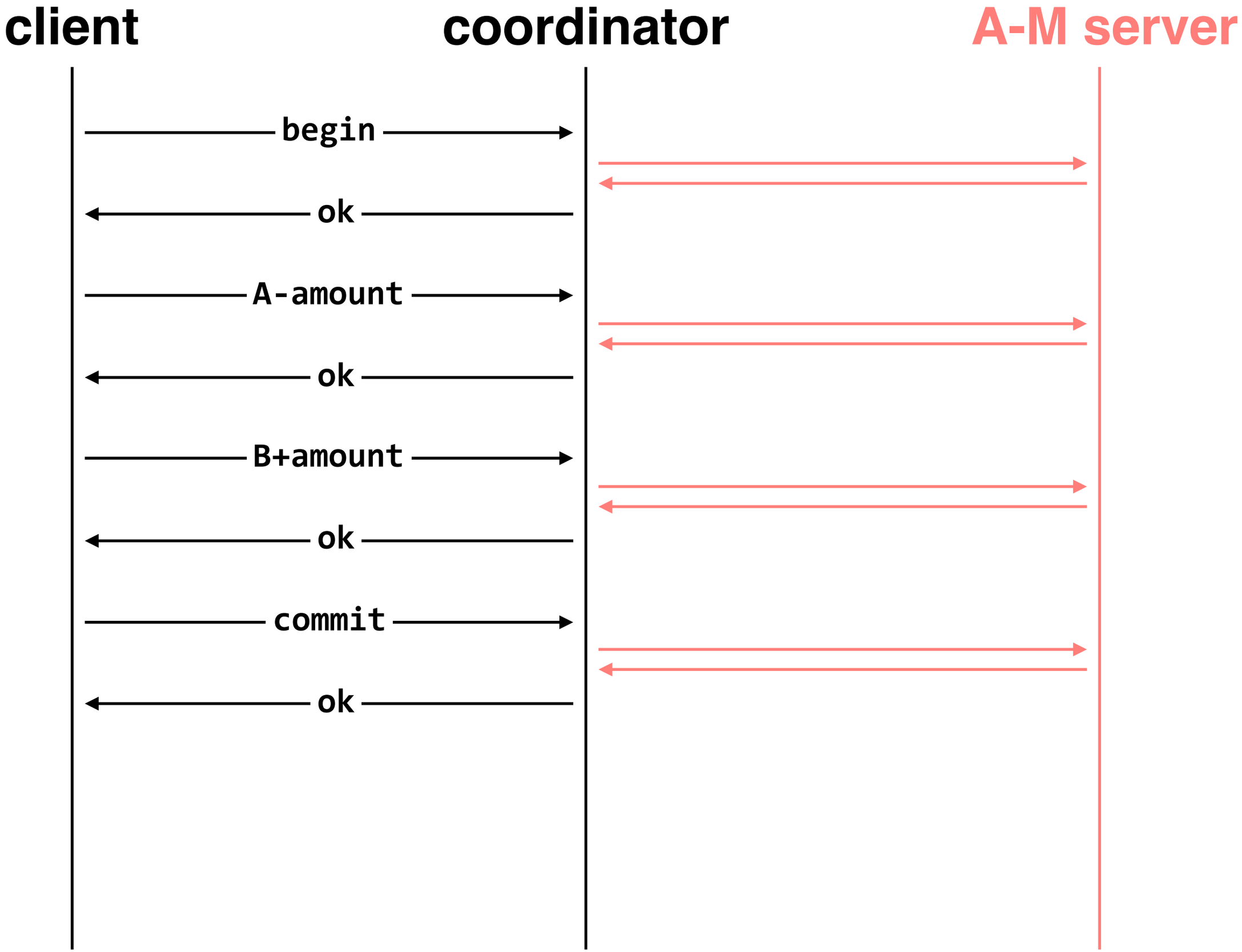
the abstraction that makes that easier is

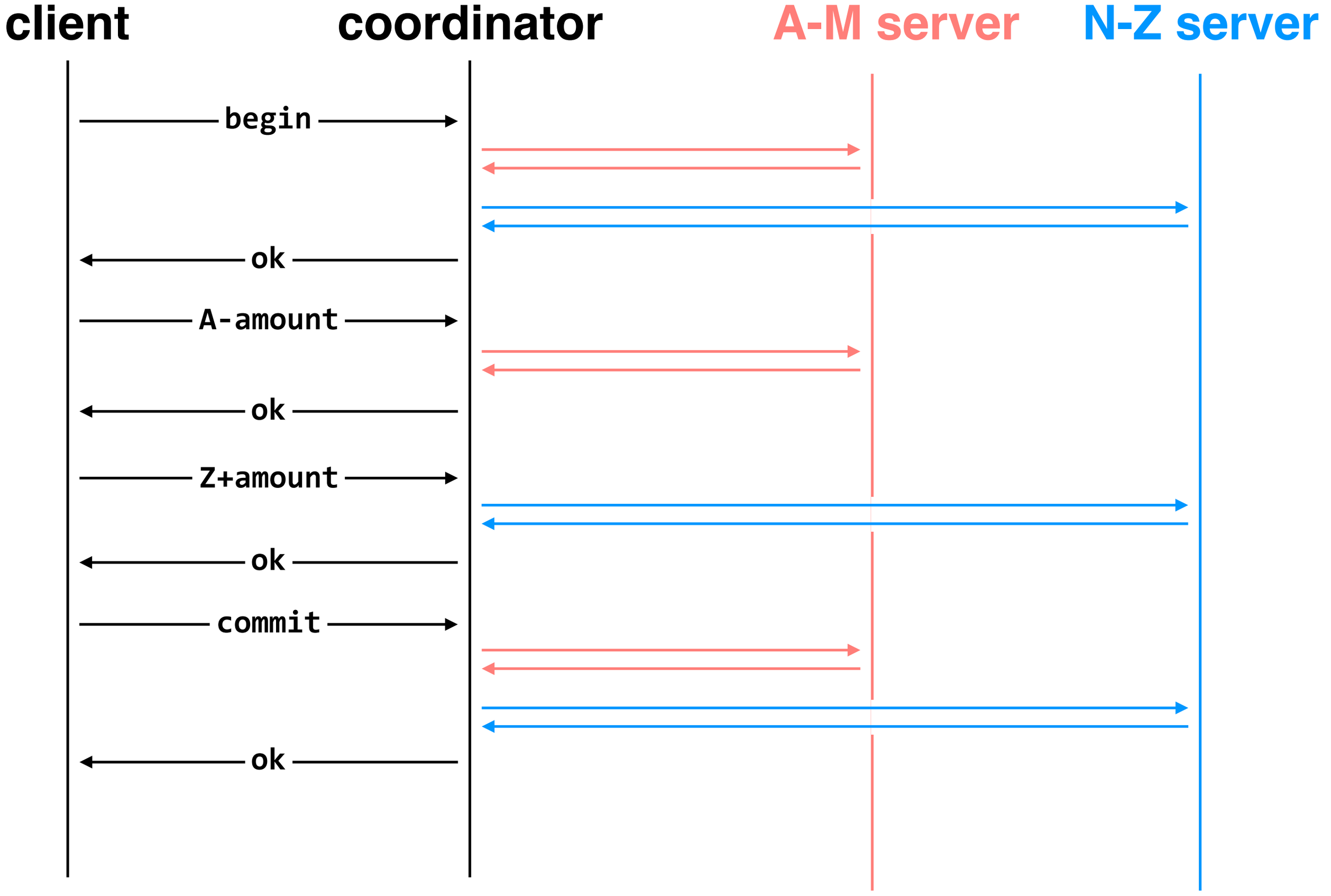
transactions, which provide **atomicity** and **isolation**, while not hindering **performance**

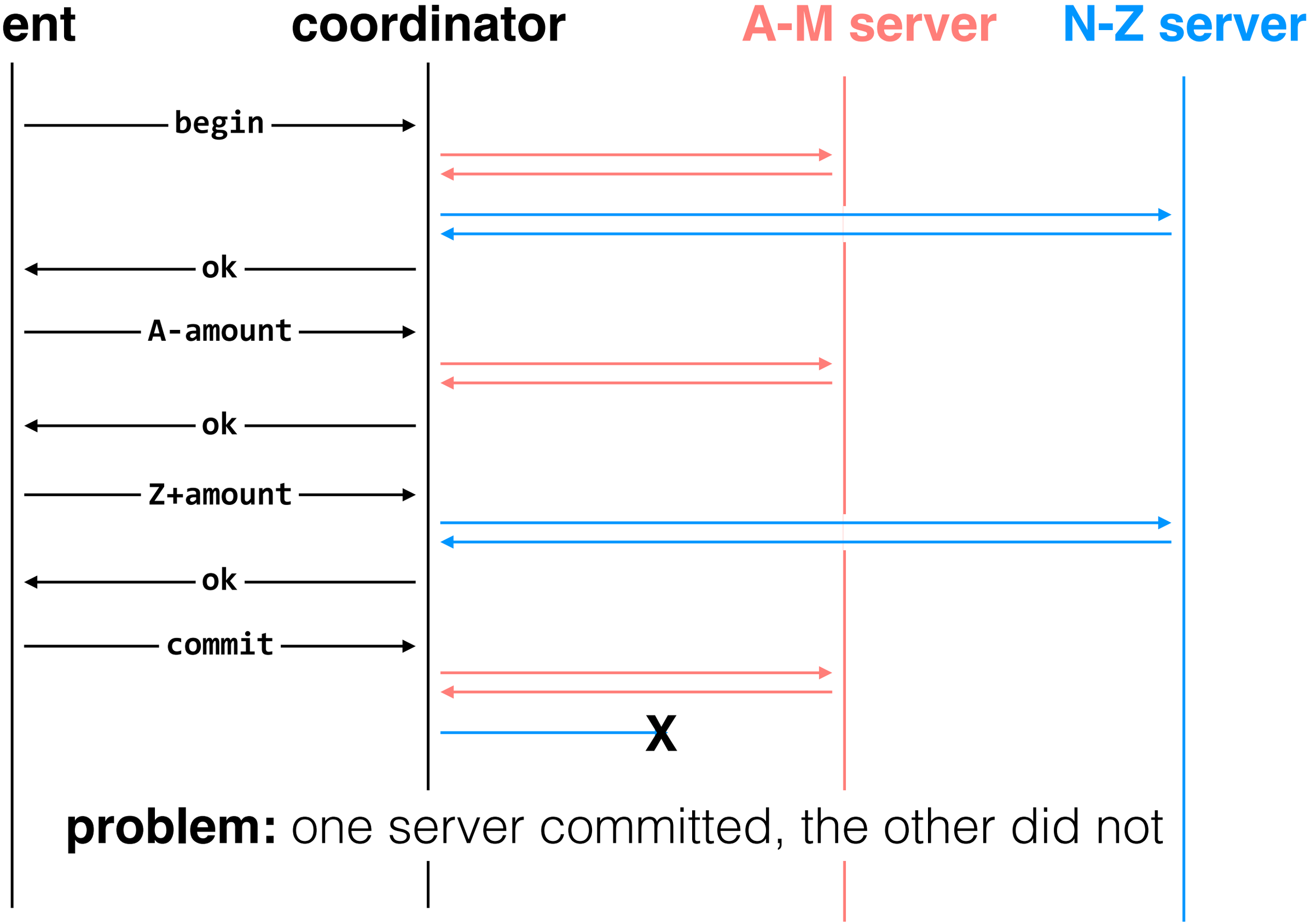
atomicity ⟶ **shadow copies** (simple, poor performance) or **logs** (better performance, a bit more complex)

isolation ⟶ **two-phase locking**

eventually, we also want transaction-based systems to be **distributed**: to run across multiple machines


client
coordinator
A-M server
begin
ok
A-amount
ok
B+amount
ok
commit
ok


client
coordinator
A-M server
N-Z server
begin
ok
A-amount
ok
Z+amount
ok
commit
ok



problem: one server committed, the other did not

goal: develop a protocol that can provide **multi-site atomicity** in the face of all sorts of failures

(message loss, message reordering, worker failure, coordinator failure)

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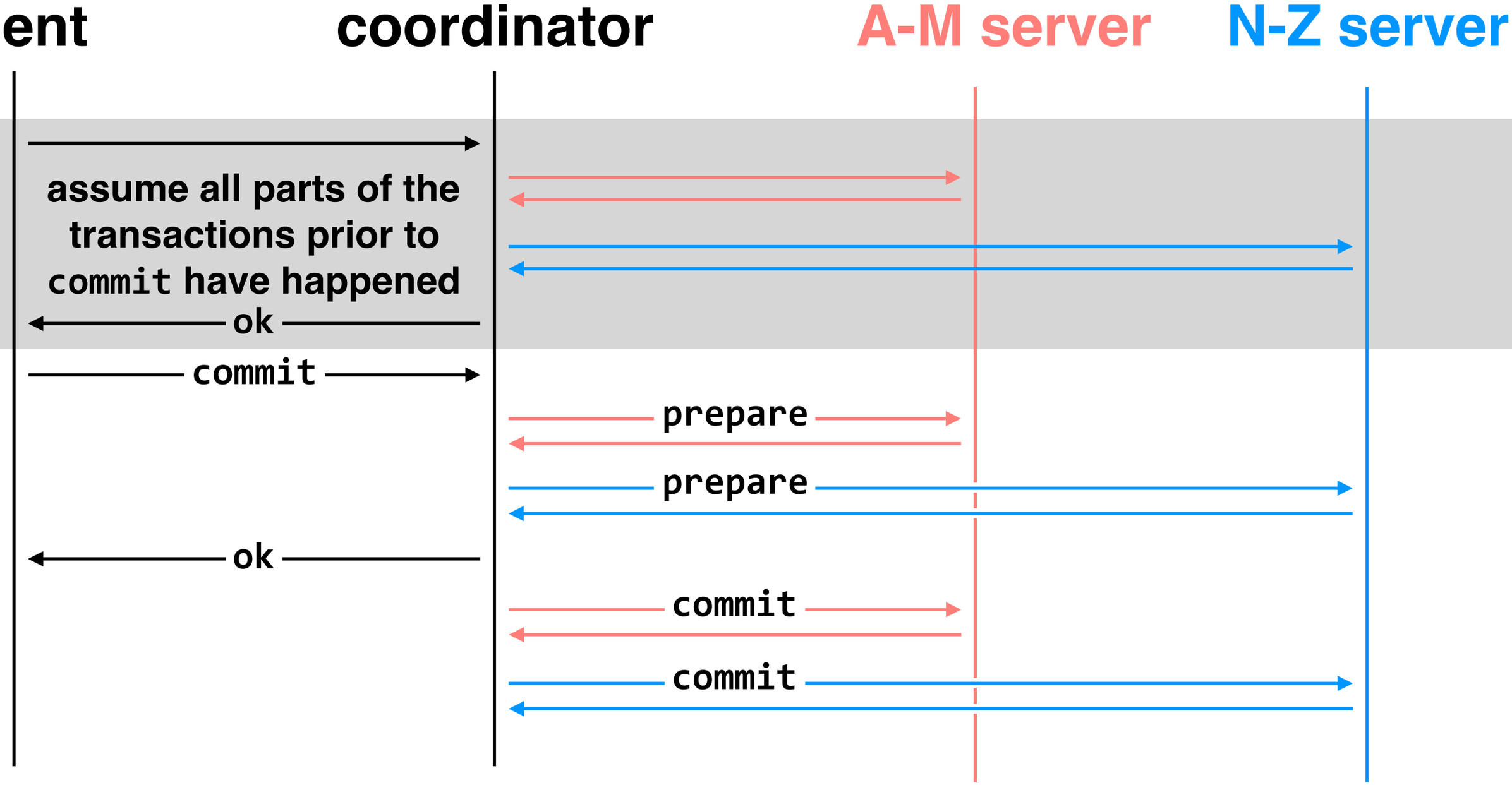
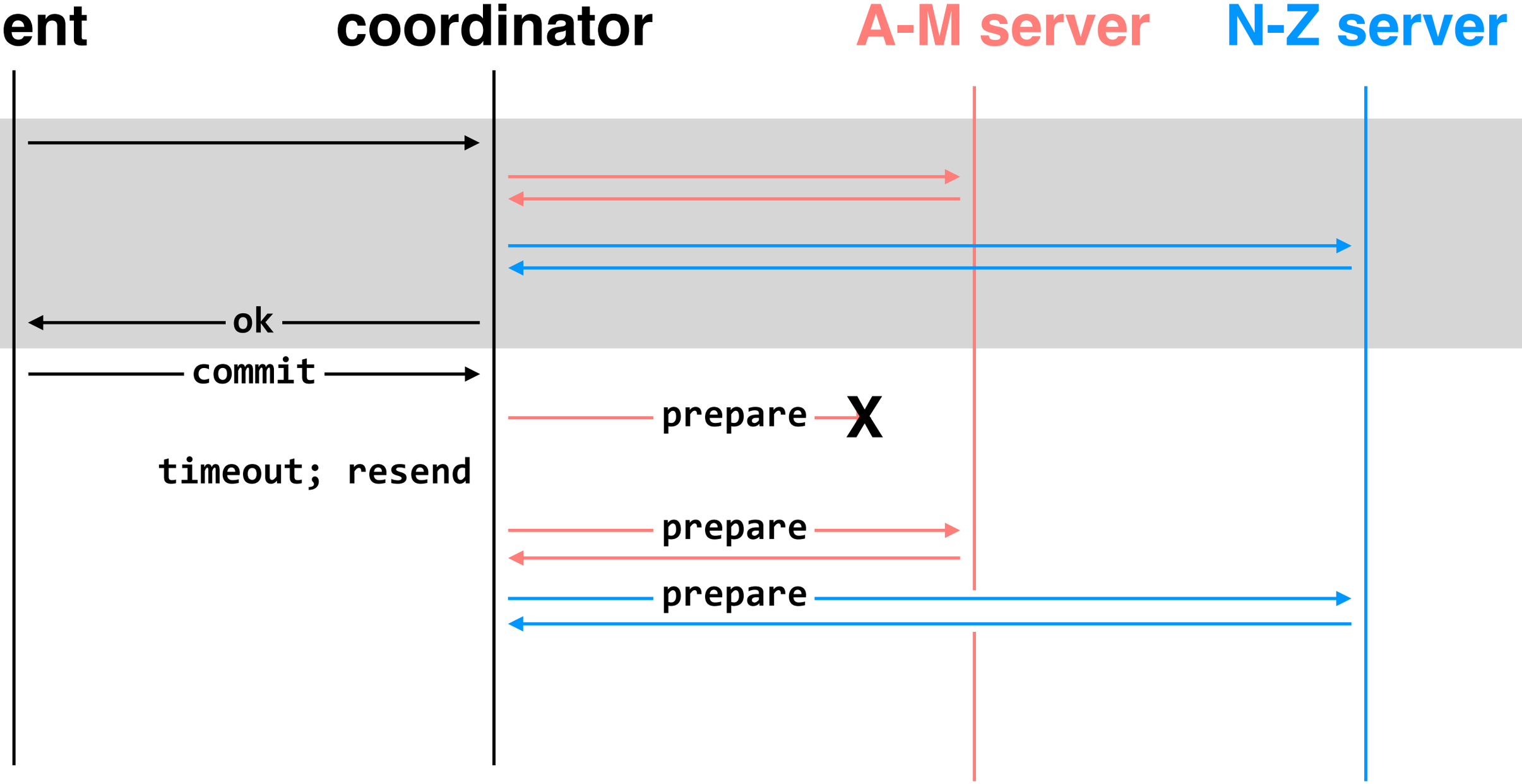
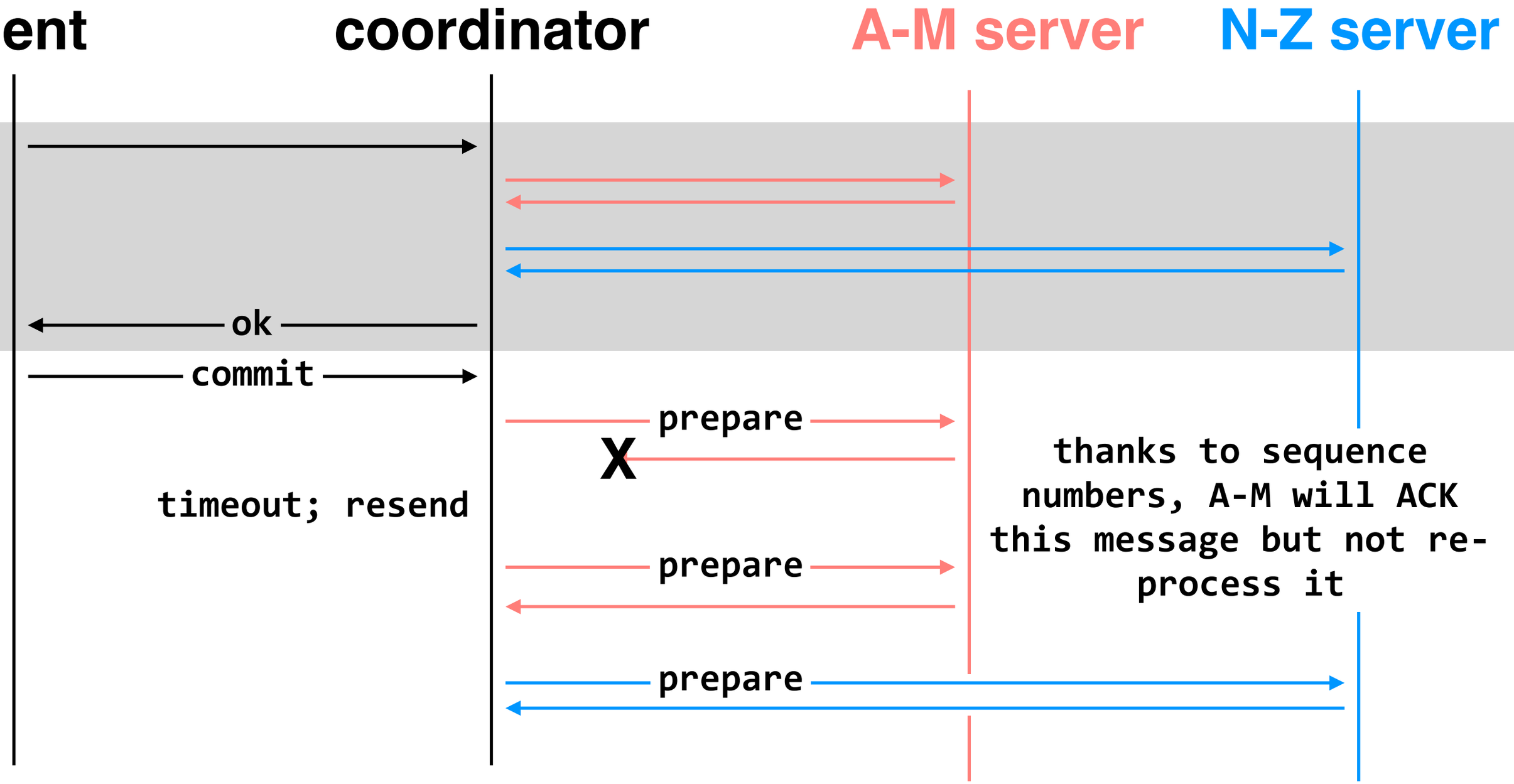
message failures solved with reliable transport protocol (sequence numbers + ACKs)



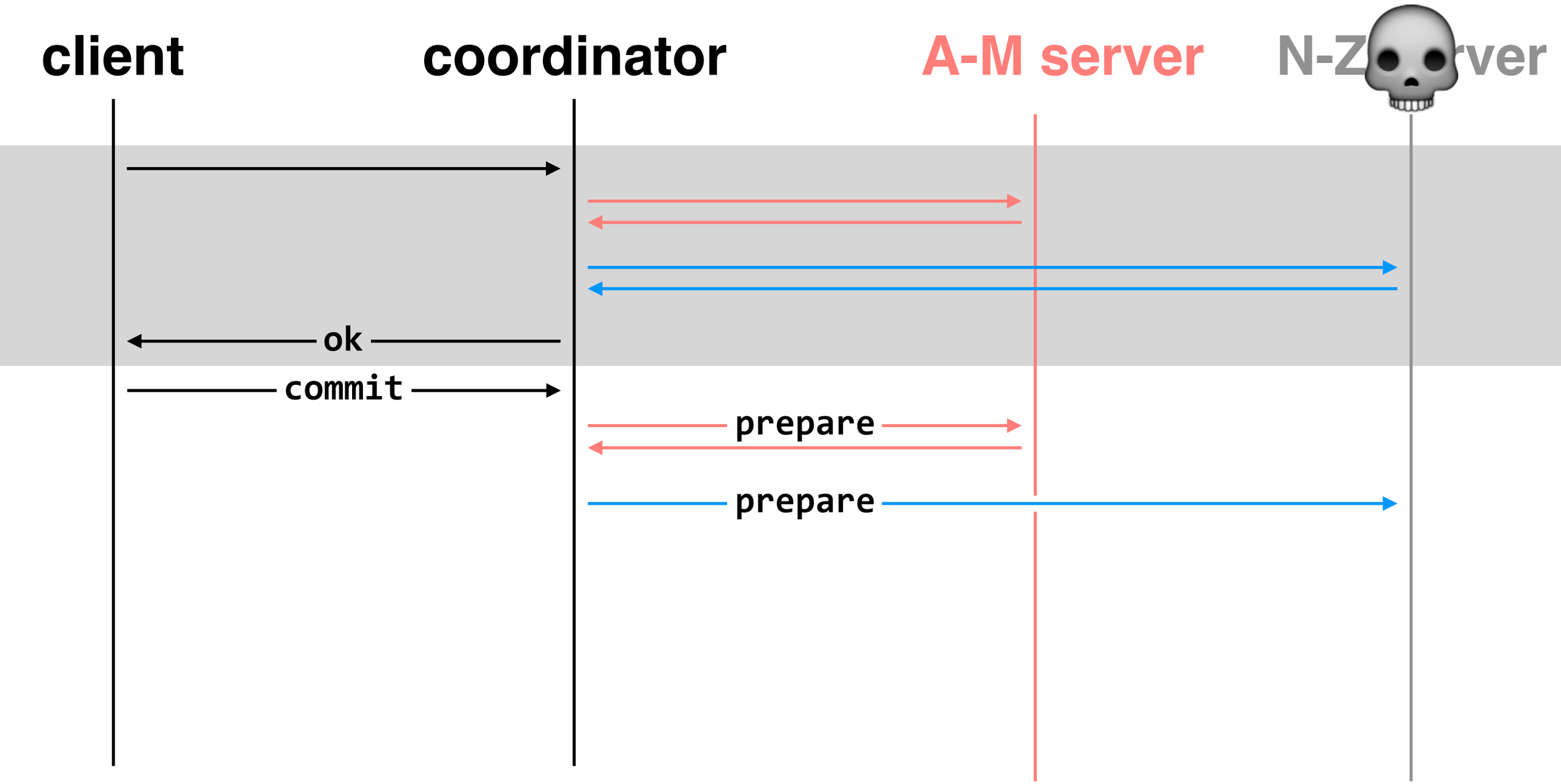
two-phase commit: nodes agree that they're ready to commit before committing



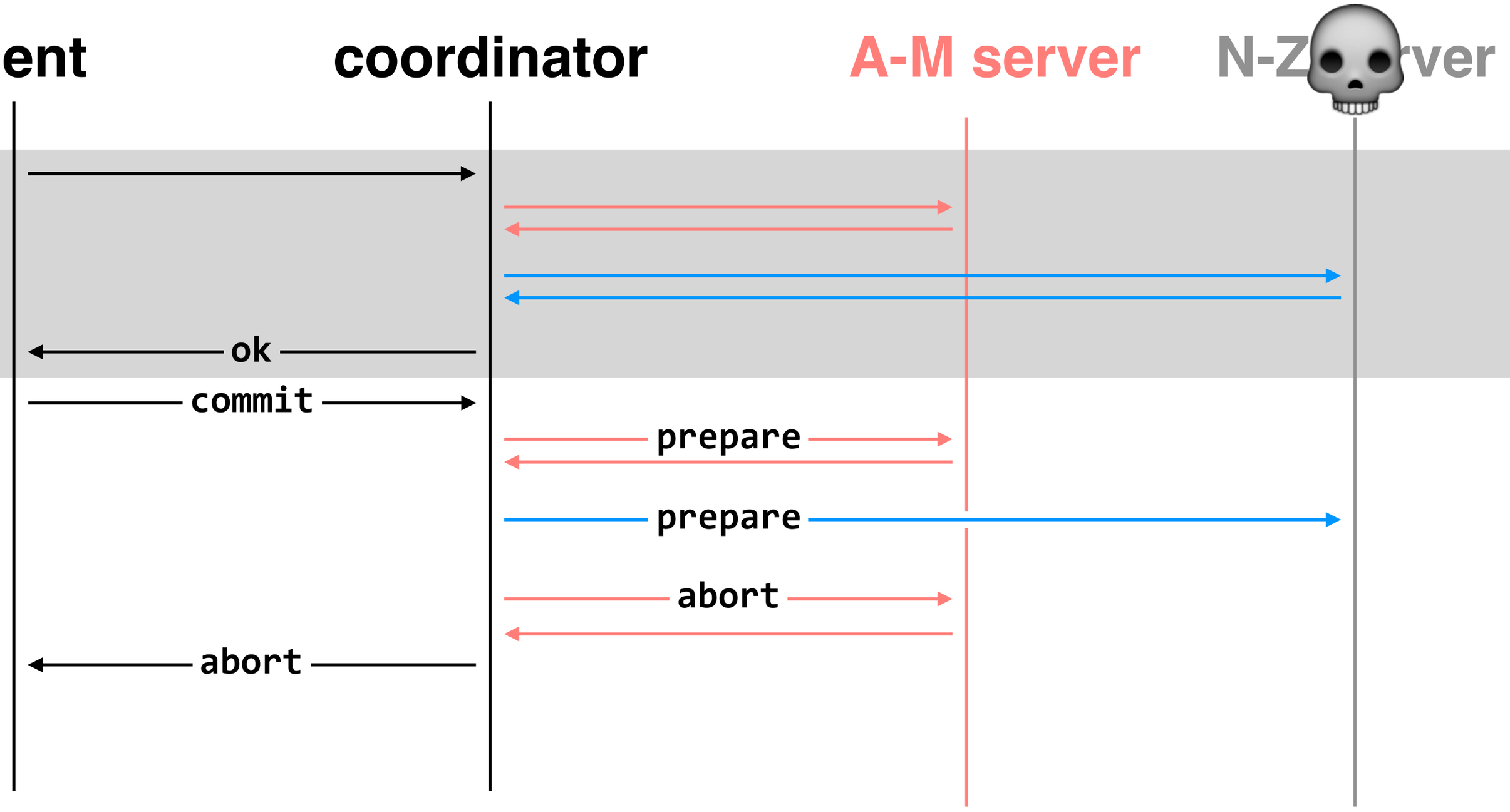
failure: lost `prepare`



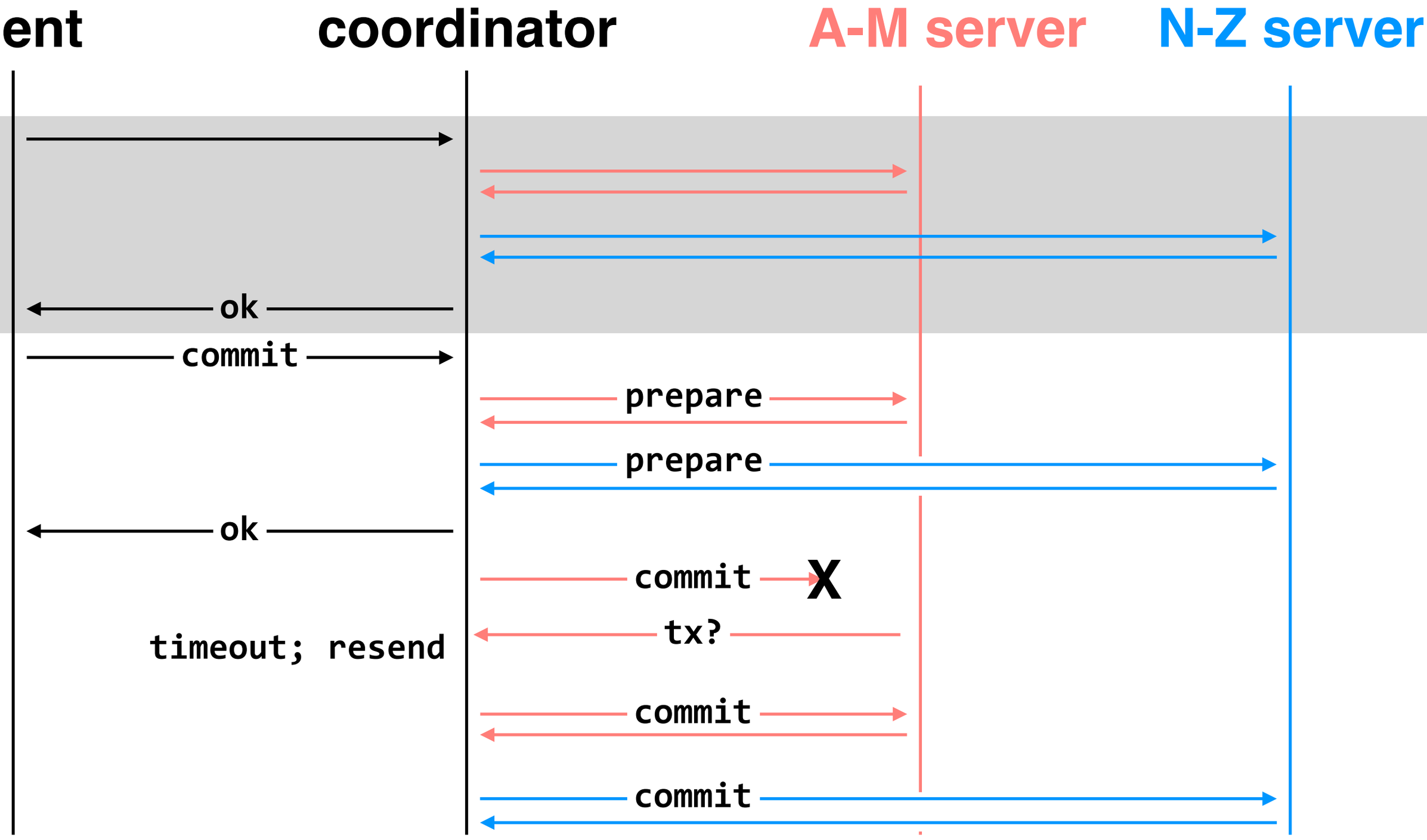
failure: lost ACK for `prepare`



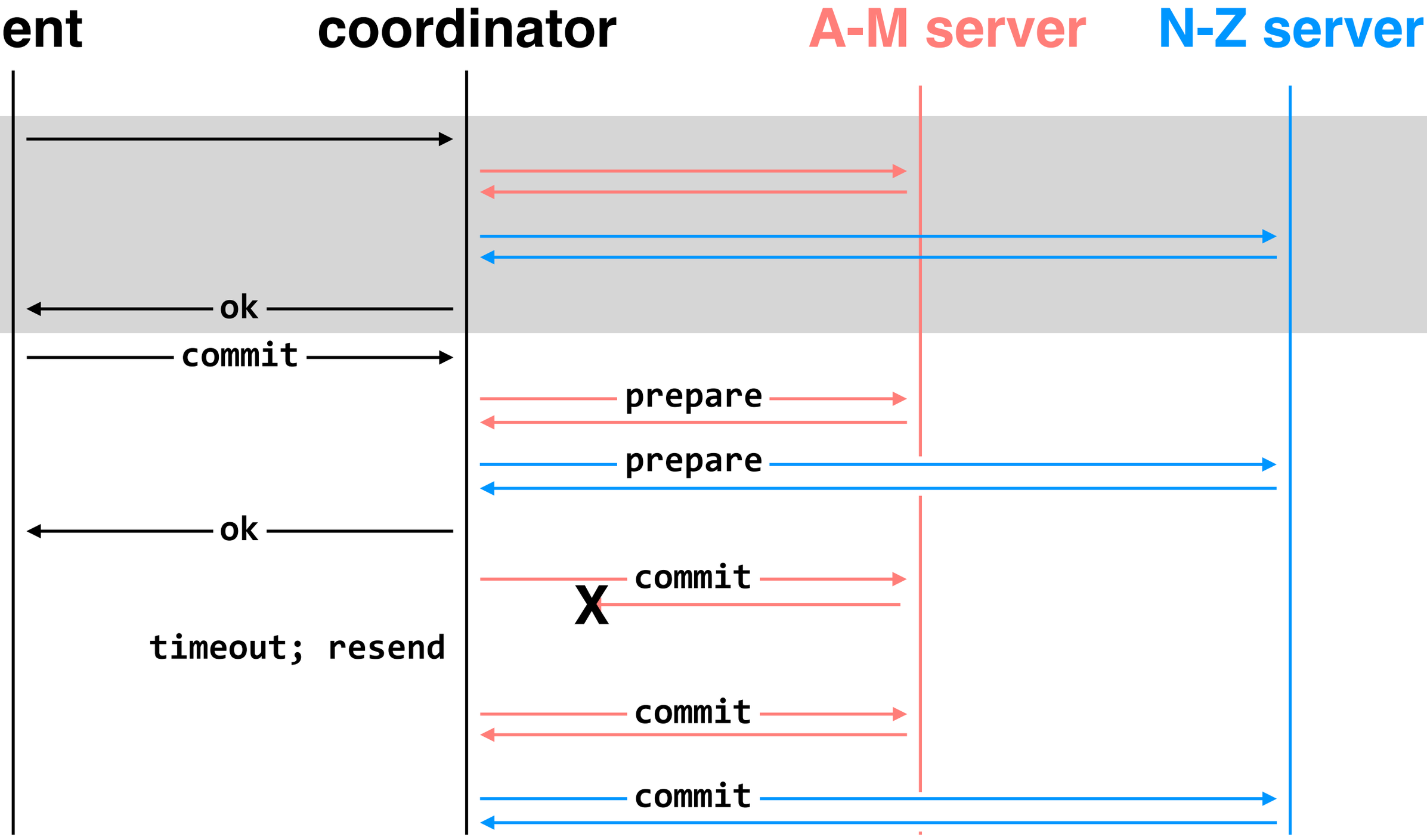
failure: worker failure while preparing



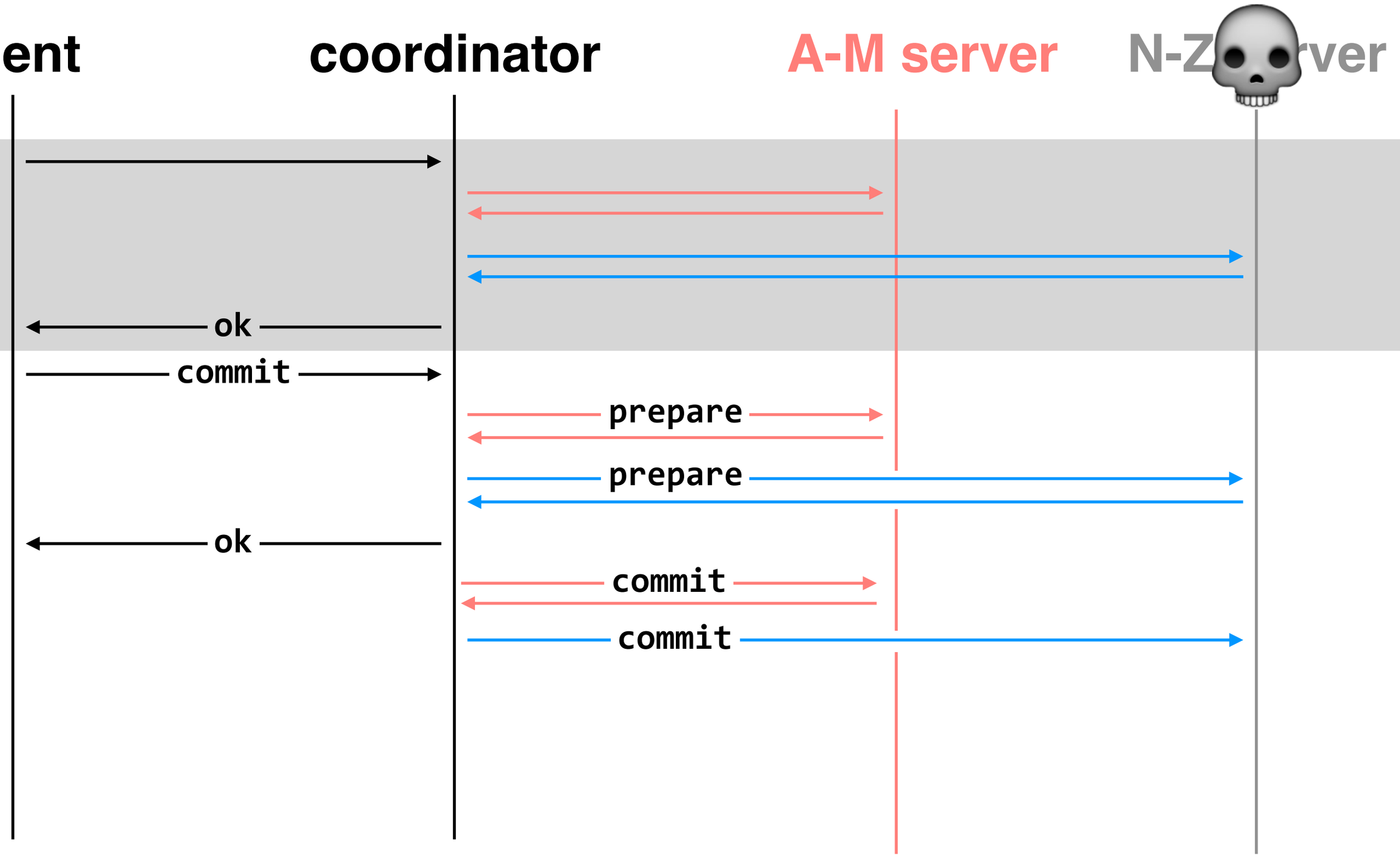
failure: worker failure while preparing



failure: lost `commit` message



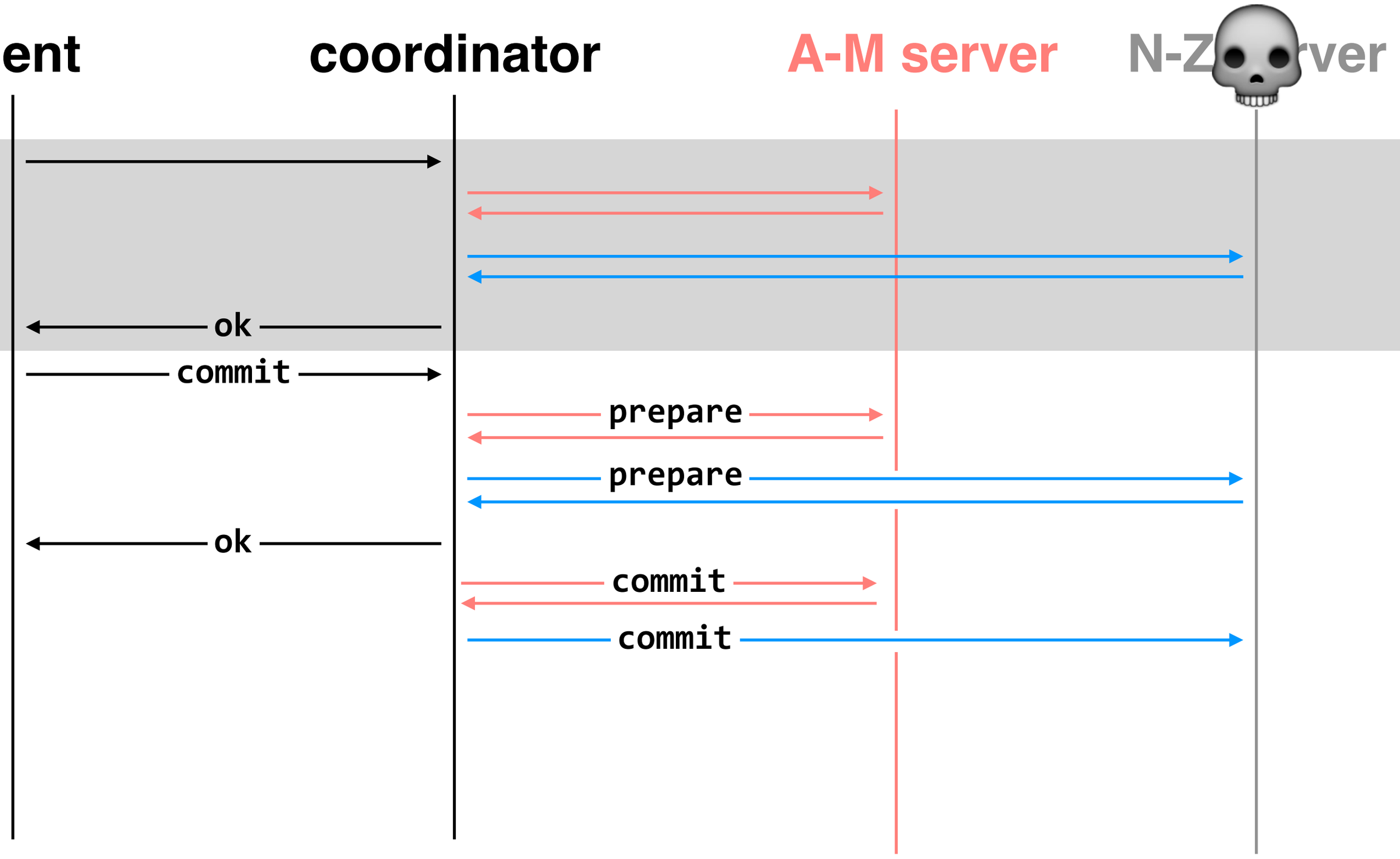
failure: lost `ACK` for `commit` message



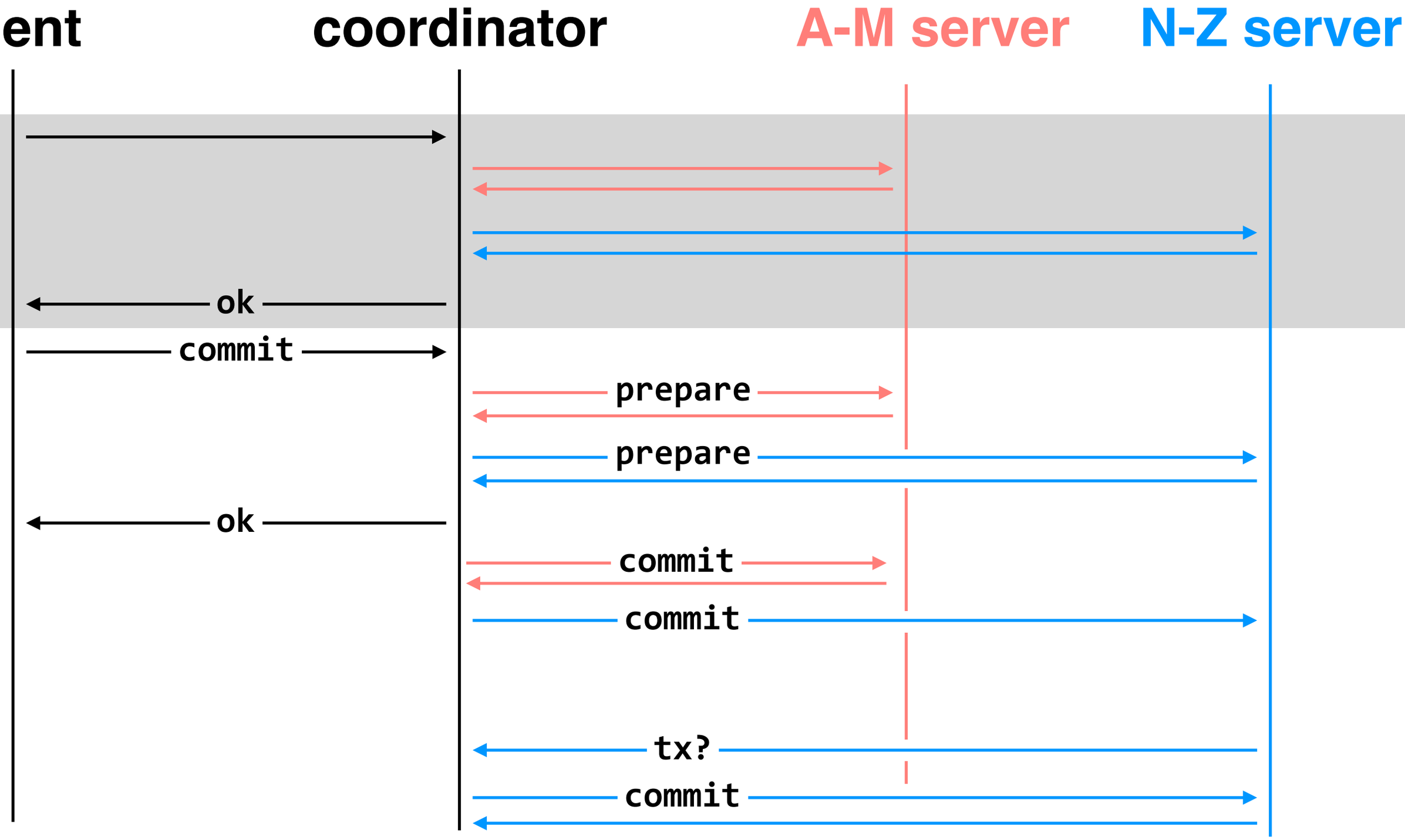
failure: worker failure during commit

if workers fail after the commit point, we **cannot abort** the transaction. workers must be able to recover into a prepared state

workers write **PREPARE** records once prepared. the recovery process — reading through the log — will indicate which transactions are prepared but not committed



failure: worker failure during commit



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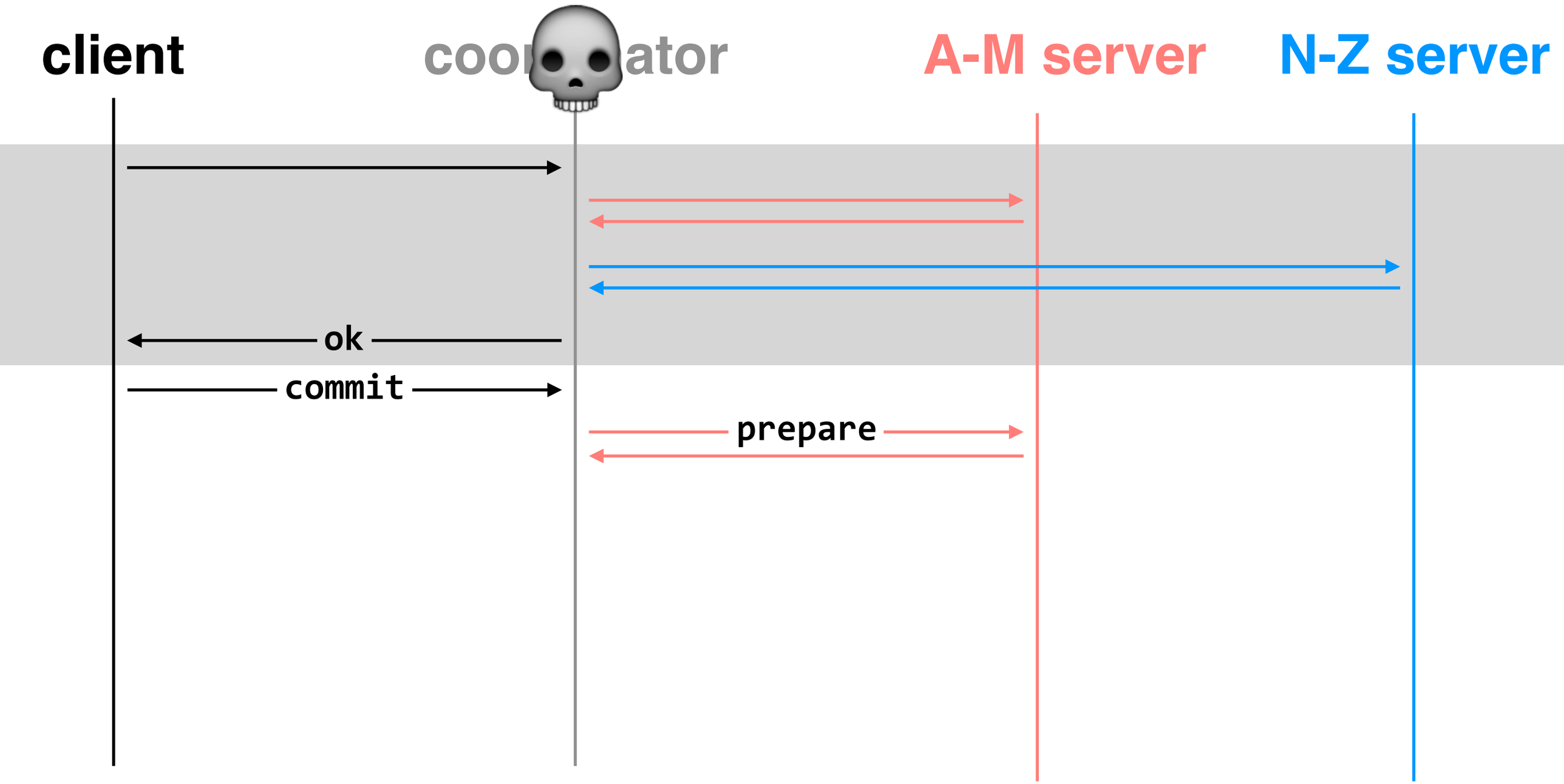
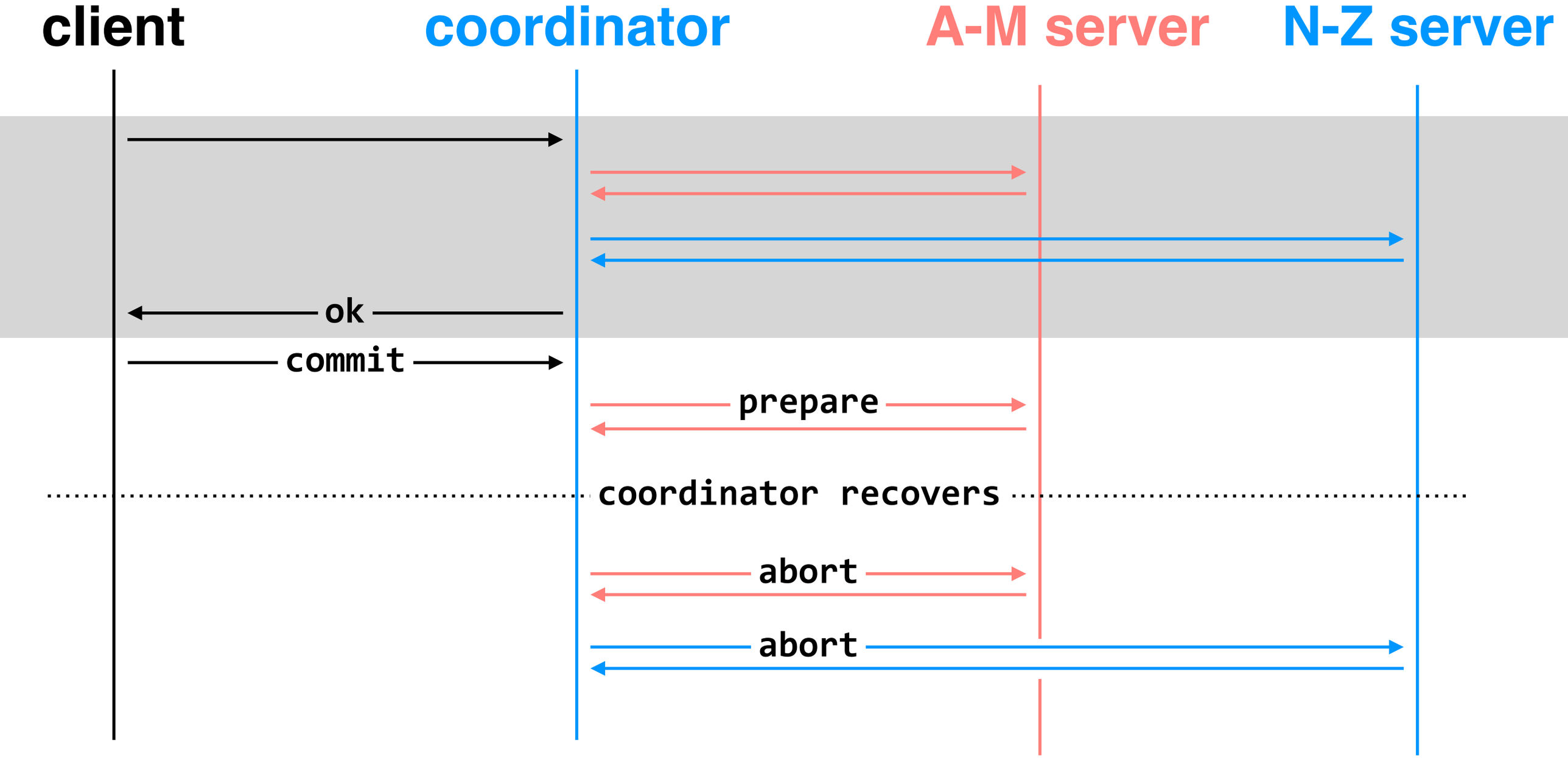
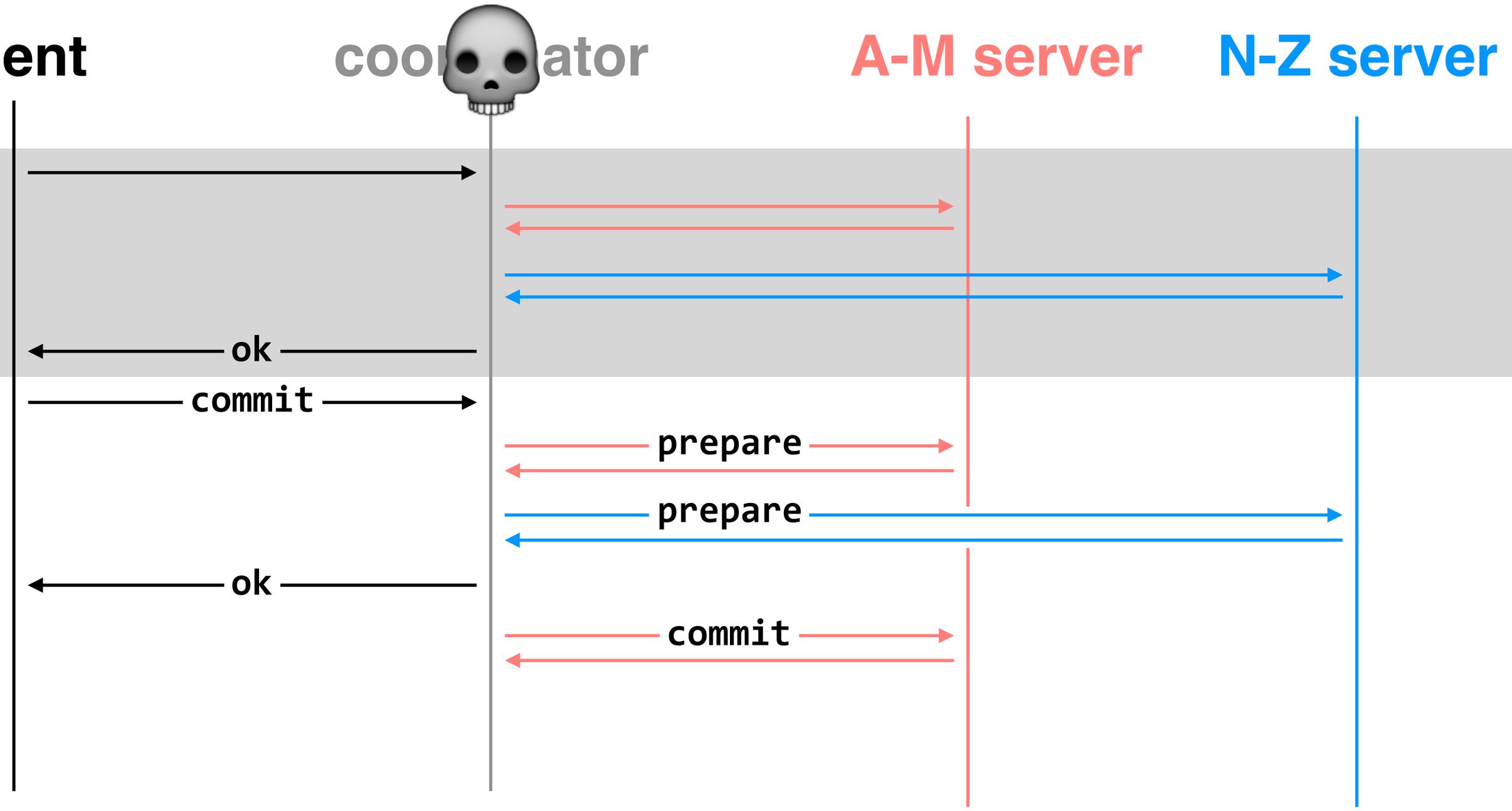


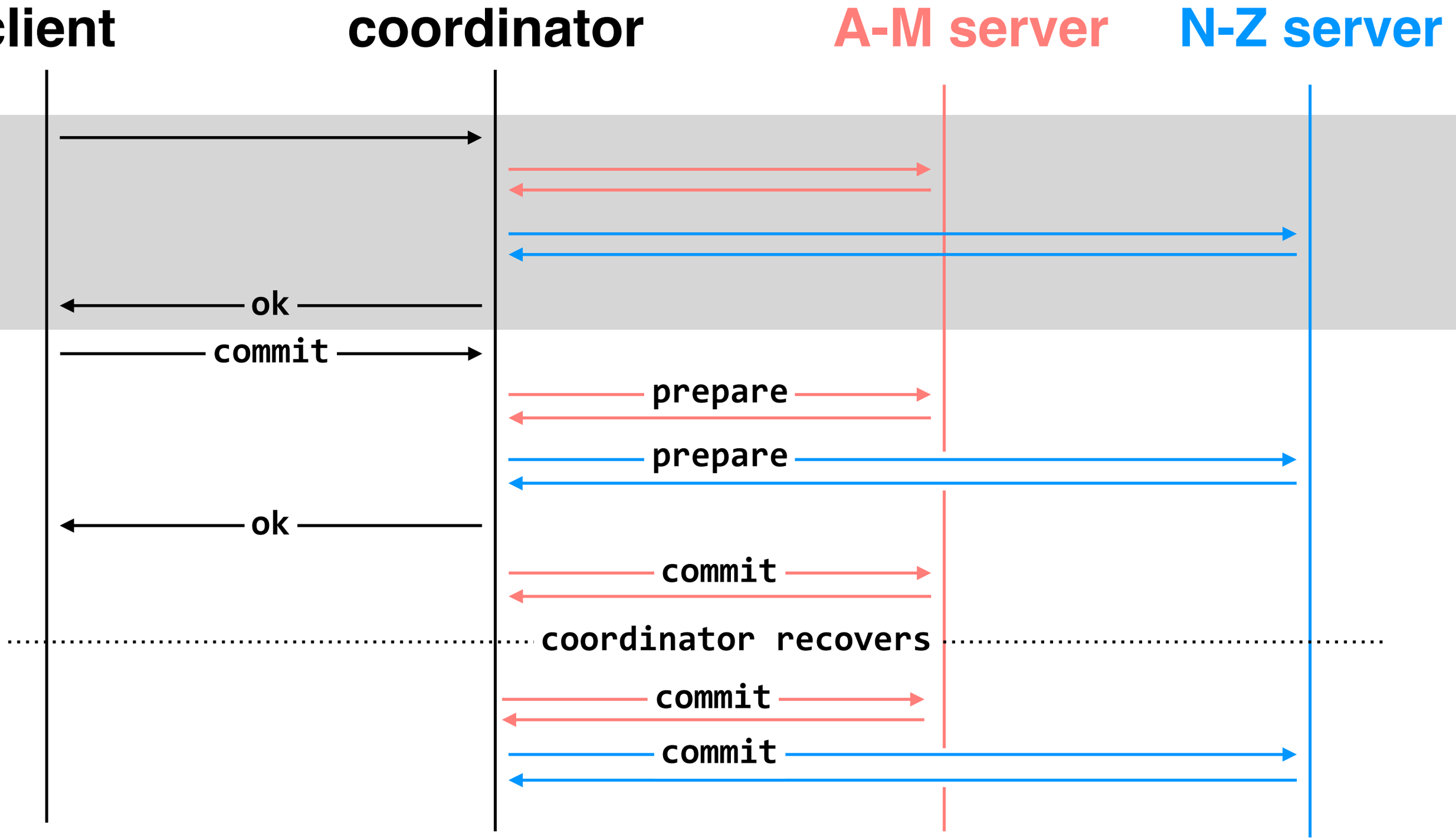
failure: coordinator failure during prepare



failure: coordinator failure during prepare



failure: coordinator failure during commit



failure: coordinator failure during commit

problem: in our example, when workers fail, some of the data (e.g., accounts A-M) is completely unavailable

solution: replicate data

but! how will we keep multiple copies of the data **consistent**? what type of consistency do we want?

- **Two-phase commit** allows us to achieve **multi-site atomicity**: transactions remain atomic even when they require communication with multiple machine.

- In two-phase commit, failures prior to the commit point can be aborted. If workers (or the coordinator) fail after the commit point, they **recover into the prepared state**, and complete the transaction.

- Our remaining issue deals with availability and replication: we will replicate data across sites to improve availability, but must deal with keeping multiple copies of the data **consistent**.