Distributed Systems: Randomized Consensus

Randomized Consensus Protocols

Why? Because of FLP

There is No ① deterministic, ② fault tolerant Consensus Protocol (Agreement, Validity, Termination) in the asynchronous model.

Partial Synchrony:

There is ~~No~~ deterministic, fault tolerant Consensus Protocol (Agreement, Validity, Termination) in the ~~asynchronous model.~~

Today's goal: Relax a different constraint

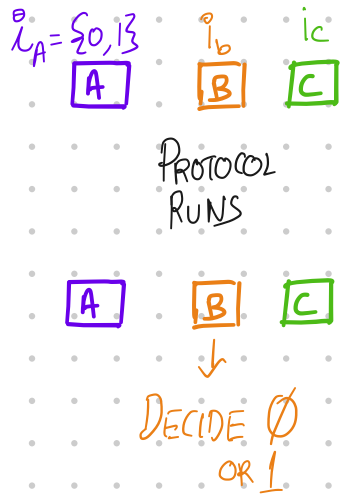
There is ? ~~No deterministic~~ RANDOMIZED, fault tolerant Consensus Protocol (Agreement, Validity, Termination) in the asynchronous model.

Why?

- Revisit binary consensus; Binary consensus → RSM
- May remove some assumptions about deployment — How To Set Timeouts
- Intellectually interesting
- From people here :)

Ben-Or Consensus

- Binary Consensus



- Agreement: If process p decides v and process q decides v' then $v = v'$
- Termination: Eventually some process p decides.
- Validity: The decided value v must have been some processes input
  - If all inputs are ∅ then protocol decides ∅

    ∅ ∅ ∅ ⇒ Decide ∅
  - If all inputs are 1 then protocol decides 1

    1 1 1 ⇒ Decide 1

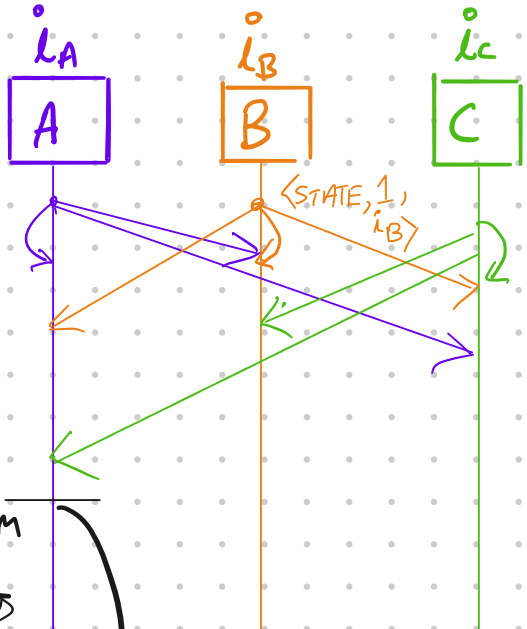
$\phi \quad 1 \quad \phi \Rightarrow$ Decide ϕ } Both are OK!
$\phi \quad 1 \phi \Rightarrow$ Decide 1 }

Ben-Or: Binary consensus with
- Agreement
- Validity
- Termination w/ probability 1

Core Techniques
- Quorum Intersection
- Random Coin Flips To Break Conflicts
  - ↳ Think back to Paxos discussion re: termination with competing proposers Section 2.4

Round 1

Round ↓ ⟨State, 1, i_A⟩

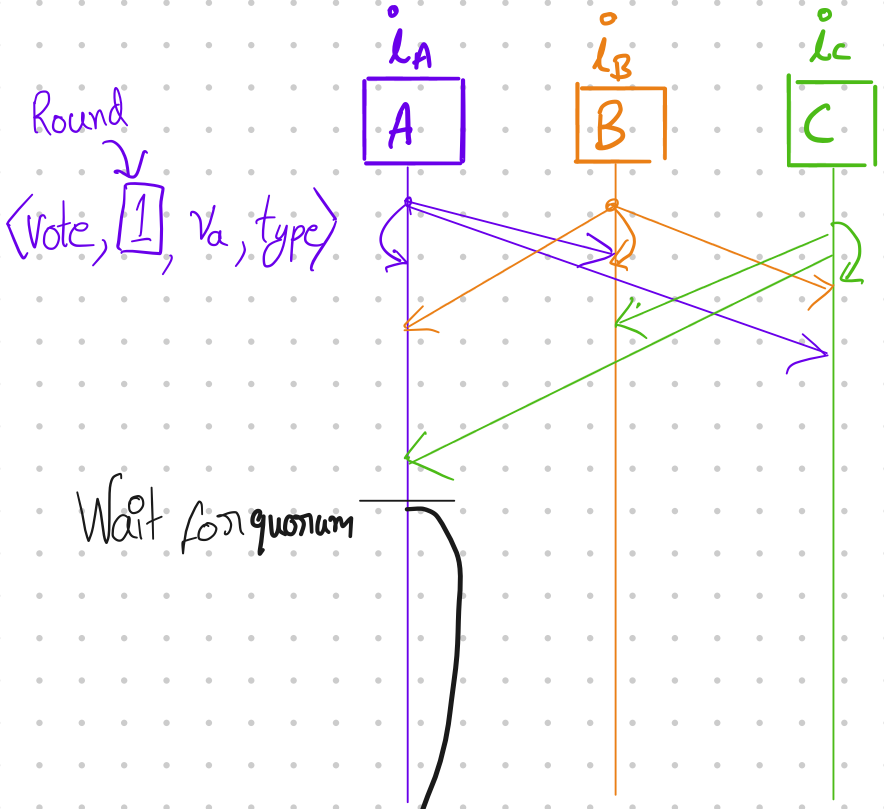


Paper Uses Messages Of Type 1 (1, r, ...) & Type 2 (2, r, ...)

Going to use type 1 ≡ State, type 2 ≡ vote

→ Cases

- Quorum has the same value v
  - vote value $v_a = v$ type = D
- Else
  - vote value $v_a = ?$ type = L



→ Cases

① One ⟨vote, 1, v, D⟩ message } Some node saw evidence that a majority had the same value v

$i_A = v$

② $\geq f+1$ $\langle vote, 1, v, D \rangle$ message

A quorum saw that a majority had the same value v

Decide v

[Note, this also means for all future rounds $i_A = v$]

③ No message of type D

i_A = Randomly choose $\emptyset$ & 1

Go to Round 2

- State
- Vote

...

Why does it work

- What happens if $i_A = i_B = i_C = \emptyset$ (or 1) at round R?

Dec. $\emptyset$

- What happens if a quorum has the same input, e.g., $i_A = i_B = 1$?

1 or ?

- Claim: If node A decides in round R, then other nodes decide in round R+1. Why?

$\geq f+1$ <vote, R, v, D> messages — A quorum saw that a majority had the same value v

Decide v

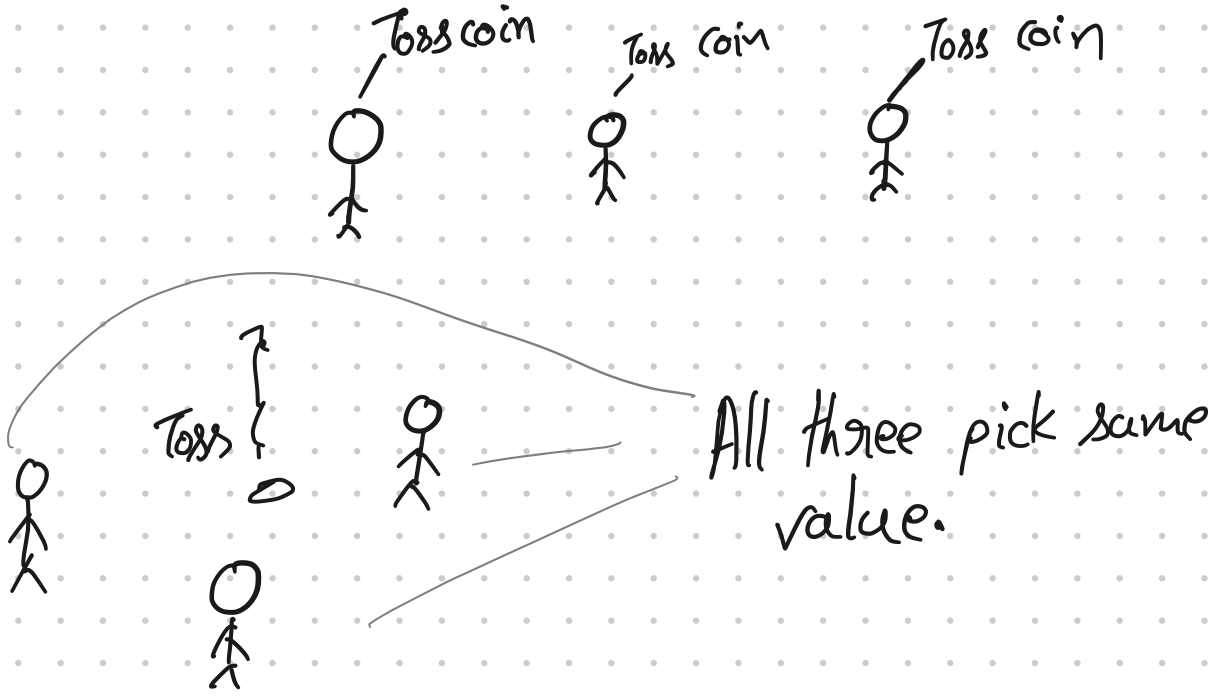
[Note, this also means for all future rounds $i_A = v$]

Optimization: Common Coin

③ No message of type D

i_A = Randomly choose 0 & 1

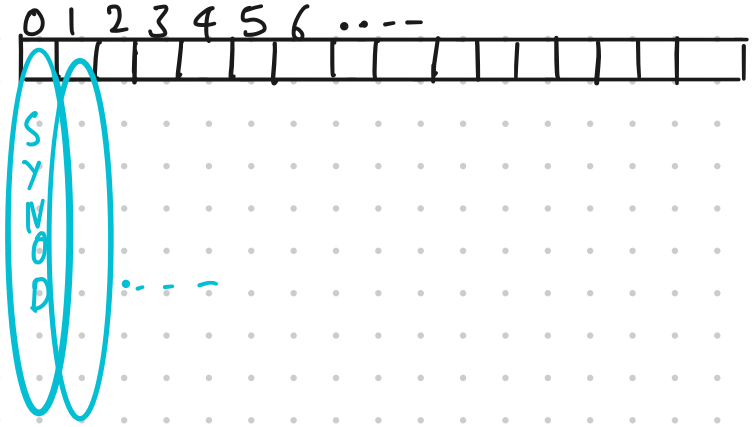
Remember: Want to get all nodes to propose the same value



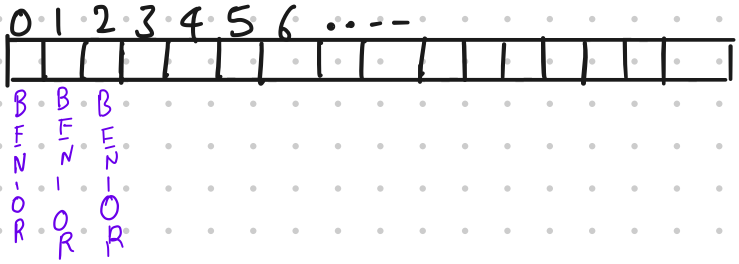
How?

Using Ben-Or In An RSM

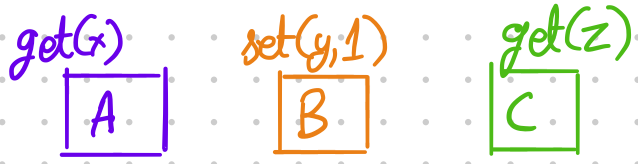
- Kind of saw this when building multipaxos



- Similar approach



Unique challenge: Binary consensus → Arbitrary commands



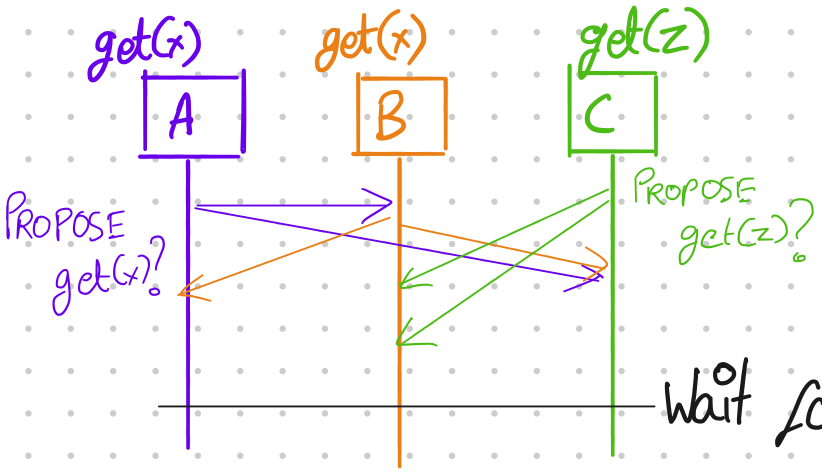
What do A, B & C use as input to Ben-Or?

Possibilities — Leader chooses command?

↳ That is what we did for multi-paxos.

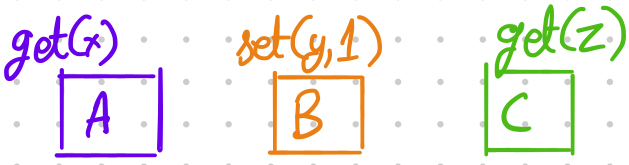
PAXIA

- USE A PROTOCOL TO CHOOSE ONE (OR TWO) PROPOSALS
  - ↳ Be wary: Why isn't this just consensus?



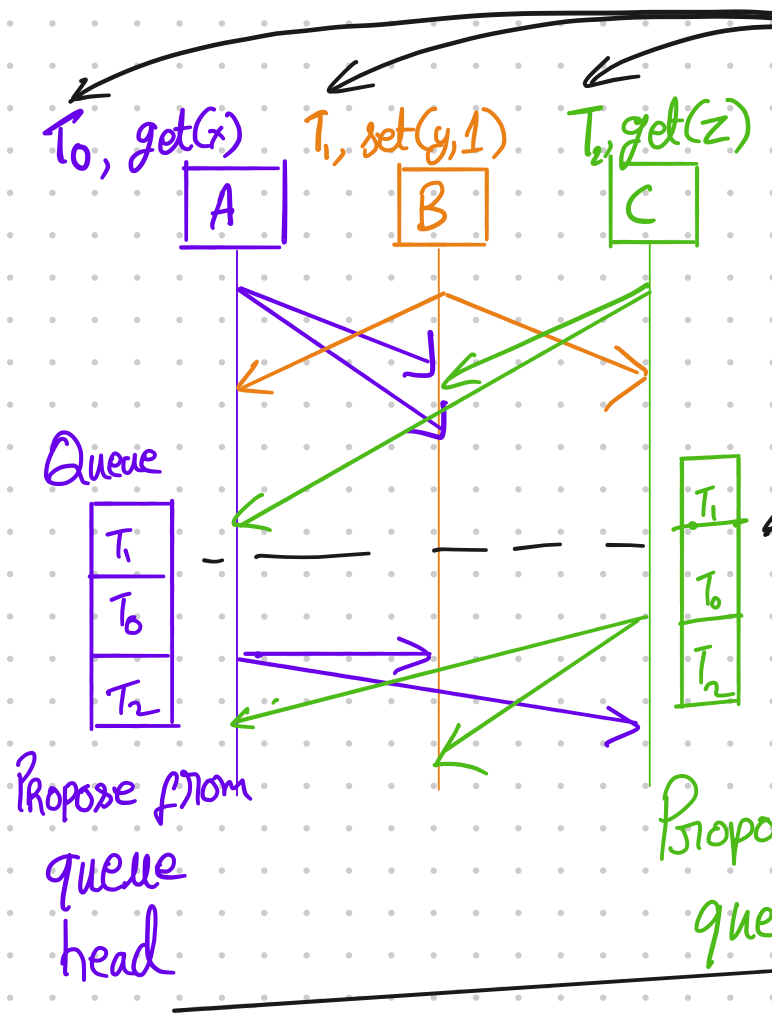
Wait for n-f (quorum)

- If quorum has some command
  - Ben Or input [for round 0] = C [or COMMON COMMAND]
- Else - Ben Or input = ⊥



How to deal with this situation?

Purpose of timestamps?



Priority queue with a consistent ordering

- Any node (A) that sees the same command C from a quorum enters Ben-Or with C.
- Other nodes use ⊥

What to do with coin toss?

Remember:

③ No message of type D

i_A = Randomly choose 0 & 1

Want coin to randomly choose b/w
c & ⊥

But, getting to this stage ⇒

(a) Some command c was agreed as a proposal by a quorum of nodes.

Why?

(b) ≥1 node did not see a quorum support the command c

Why?

Might not know c?

Errata: Any node arriving at coin toss can recover c

Implementing Rabia

- Might be instructive to see what an implementation looks like
  - ↳ Will make one available later this week

Old Lab 4 { (in Elixir, using the framework you used for labs)
→ Might help further explore ideas

Prep for next week — BFT

- On faults (remember discussion about failure models last week)

→ Fail-stop / Crash

→ Fail-recover / Crash-recover

Assumptions?

What if the assumptions do not hold?

Why would they not hold?

Effects?

- Raft (midterm question)

- Rubia

BFT

What can we do with no assumptions about the behavior of faulty (failed) nodes.

Note, we are still making assumptions about the FAILURE MODEL

↳ # of nodes failed

(often at a cost)