NPTEL ONLINE CERTIFICATION COURSES

Blockchain and its applications

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Lecture 27: State Machine Replication as Distributed Consensus

CONCEPTS COVERED

- State Machine Replication as a Consensus
- Synchronous vs Asynchronous Consensus with Crash Faults

KEYWORDS

- **Crash Fault Tolerance**
- **Paxos**

State Machine Replication as Consensus

- There is a natural reason to use state machine replication-based consensus over permissioned blockchains
    - The network is closed, the nodes know each other, so state replication is possible among the known nodes
    - Avoid the overhead of mining - do not need to spend anything (like power, time, bitcoin) other than message passing
    - However, consensus is still required - machines can be faulty or behave maliciously

State Machine Replication as Consensus

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  - T er, so s odes
  - A pend a essage I
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But, we need a bit redesign !

State Machine Replication as Consensus

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But, we need a bit redesign !

Crypto is the saver

Crypto + Distributed Consensus = Consensus for Permissioned Blockchain

State Machine Replication as Consensus

- Classical Distributed Consensus Algorithms (**Paxos**, **RAFT**, **Byzantine Agreement**) are based on State Machine Replication
  - Let us (re)visit those algorithms

Faults in a Distributed Systems

- **Crash Faults**: The node stops operating – hardware or software faults
  - In an asynchronous system: You do not know whether messages have been delayed or the node is not responding
  - Rely on majority voting – progress as and when you have received the confirmation from the majority
  - Propagation of the consensus information – nodes on a slow network will receive it eventually

Faults in a Distributed Systems

- **Byzantine Faults:** Nodes misbehave – send different information to different peers (partition the network)
    - More difficult to handle
    - More suitable for blockchains

Asynchronous Consensus with Crash Faults

- Remember the **FLP Impossibility**
  - Give priority to safety over liveness

- Guarantees the followings --
  - **Validity**: If all correct process proposes the same value v, then any correct process decides v
  - **Agreement:** No two correct processes decide differently
  - **Termination**: Every correct process eventually decides

Asynchronous Consensus with Crash Faults

- Guarantees the followings --
  - **Validity**: If all correct process proposes the same value v, then any correct process decides v **(Unlikely to happen in PoW)**
  - **Agreement:** No two correct processes decide differently **(Safety – Not in PoW)**
  - **Termination**: Every correct process eventually decides **(Liveness – Priority in PoW)**

CFT Consensus

- CFT Consensus
  - **Paxos** (Proposed by Lamport, the most fundamental CFT) -- used in DynamoDB
  - **RAFT** (Much simpler than Paxos) -- Used in Fabric Transaction Ordering

CFT Consensus

We'll see how Paxos works

- CFT Consensus
  - **Paxos** (Proposed by Lamport, the most fundamental CFT) -- used in DynamoDB
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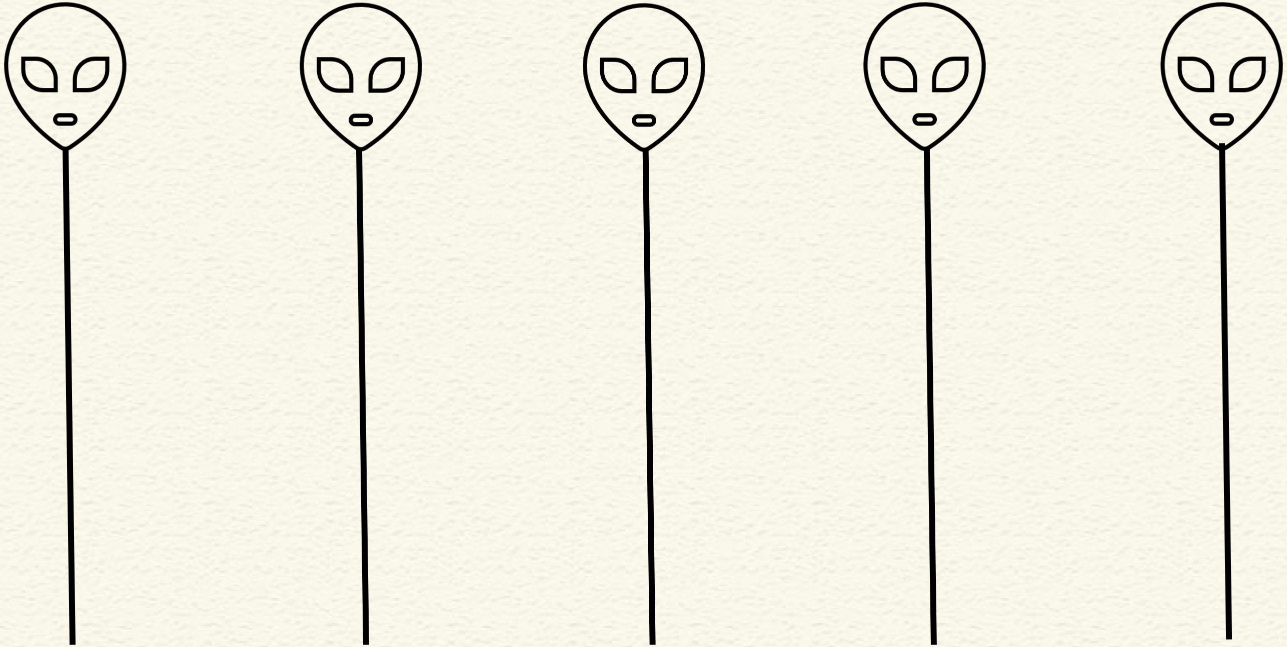
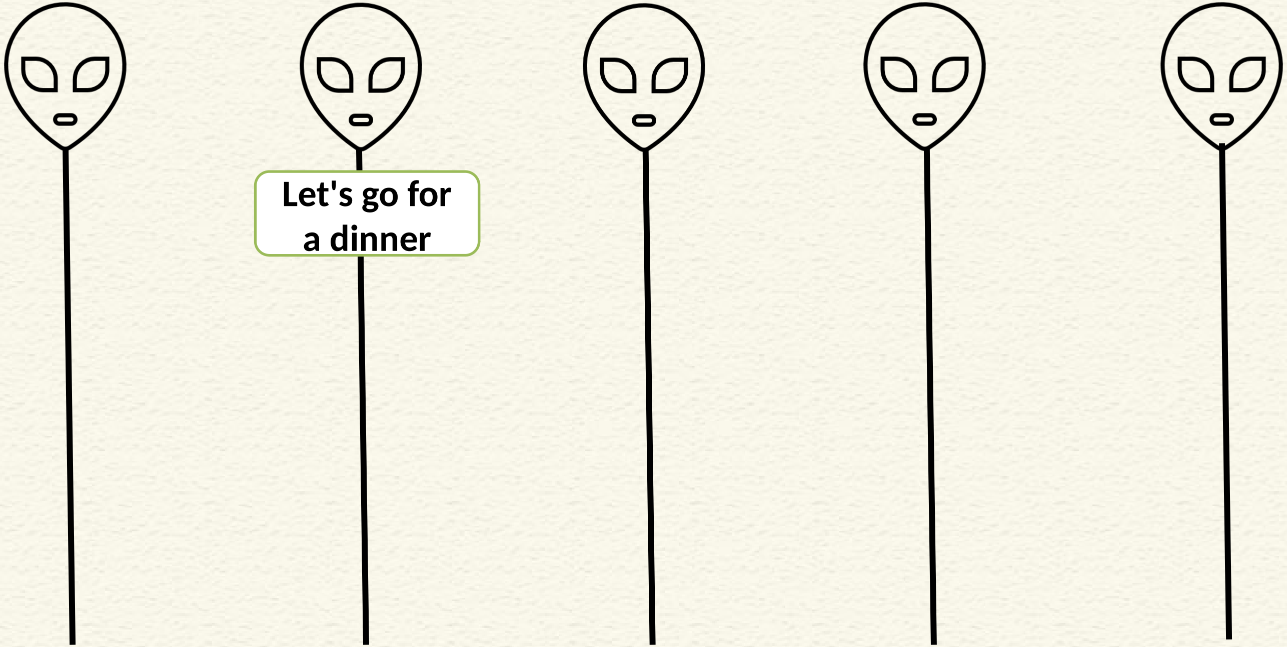
CFT in a Synchronous System



CFT in a Synchronous System



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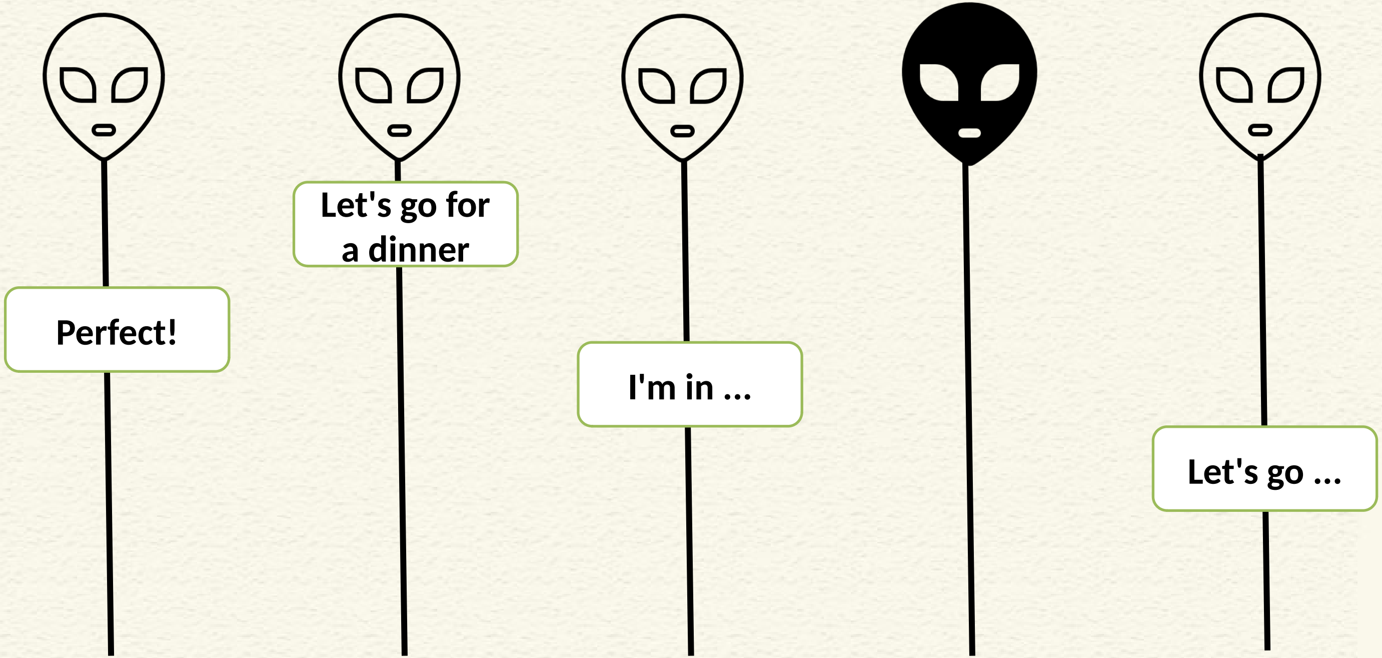

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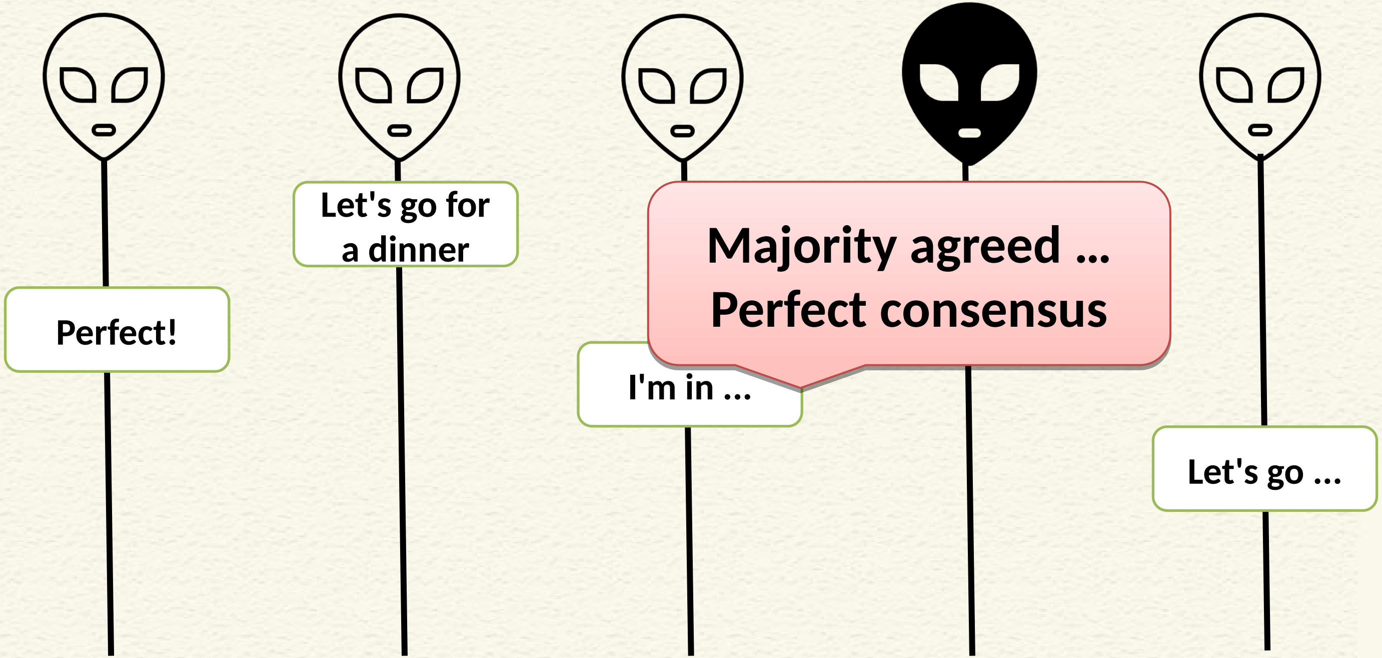
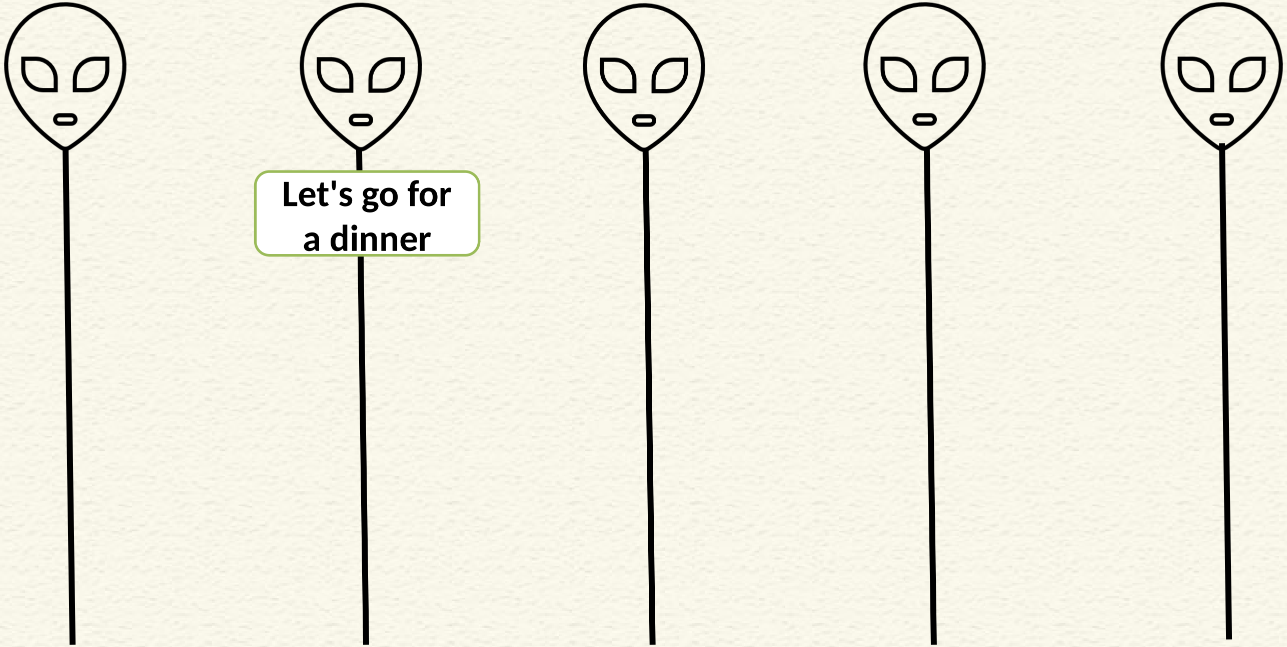


CFT in an Asynchronous System



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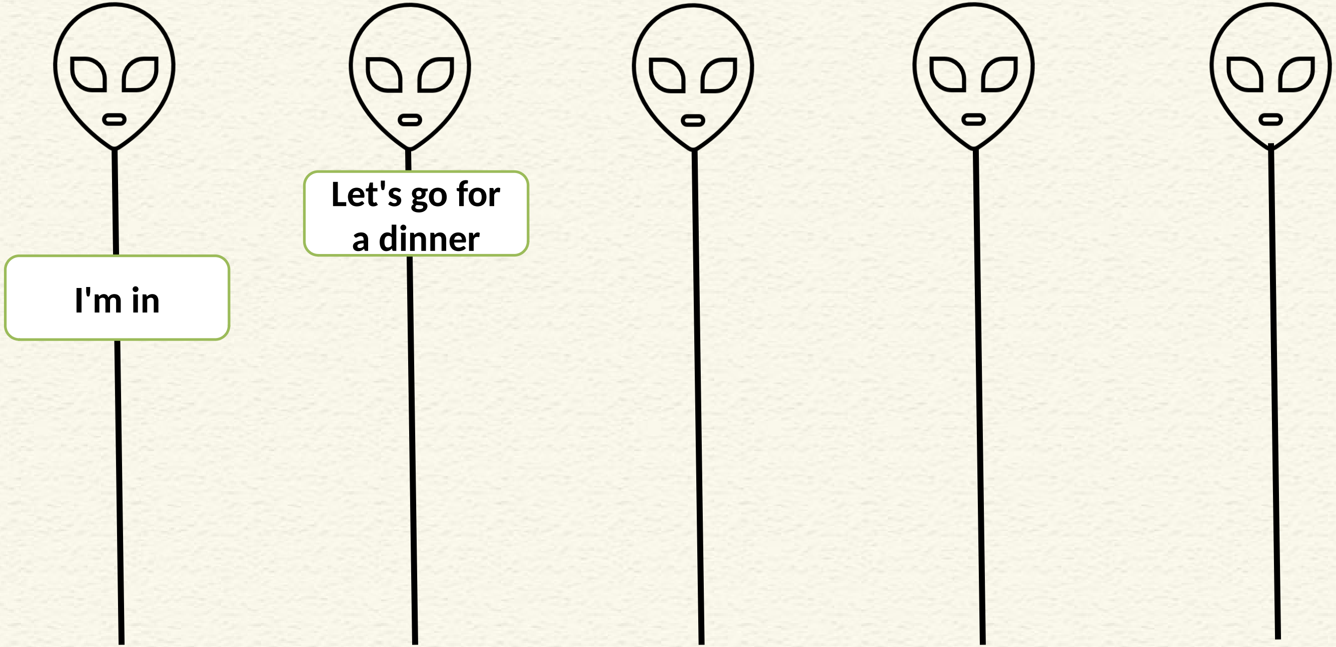

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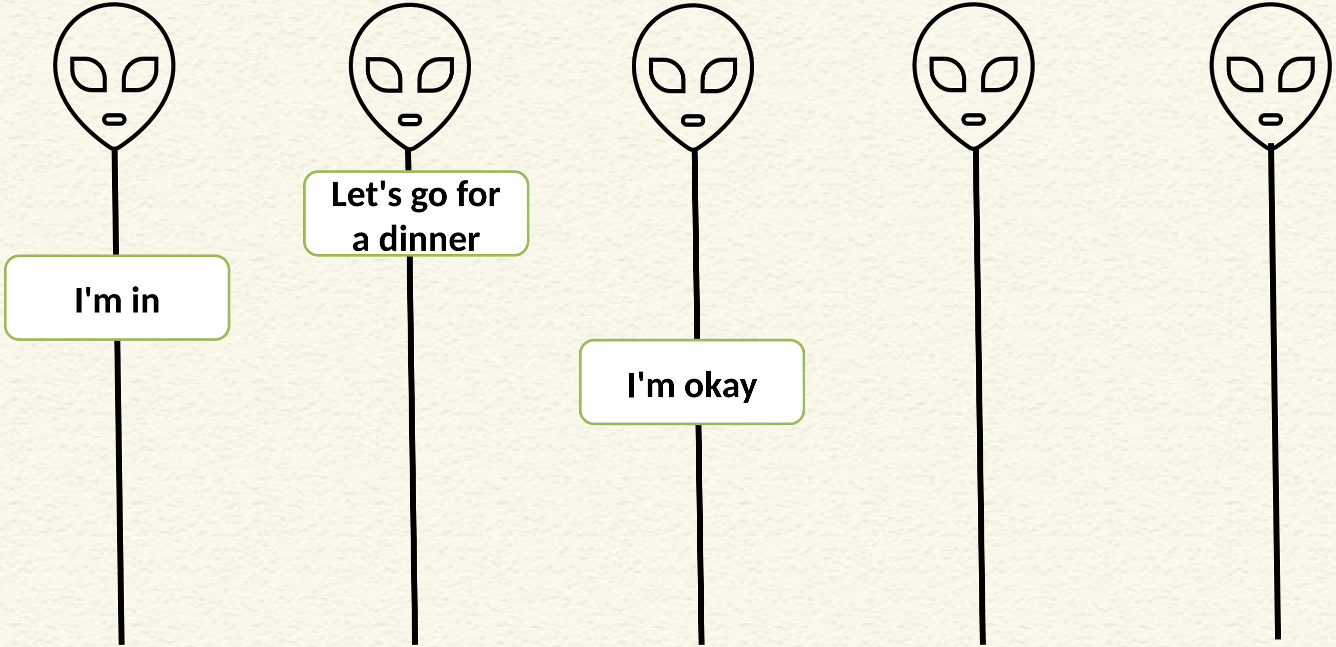

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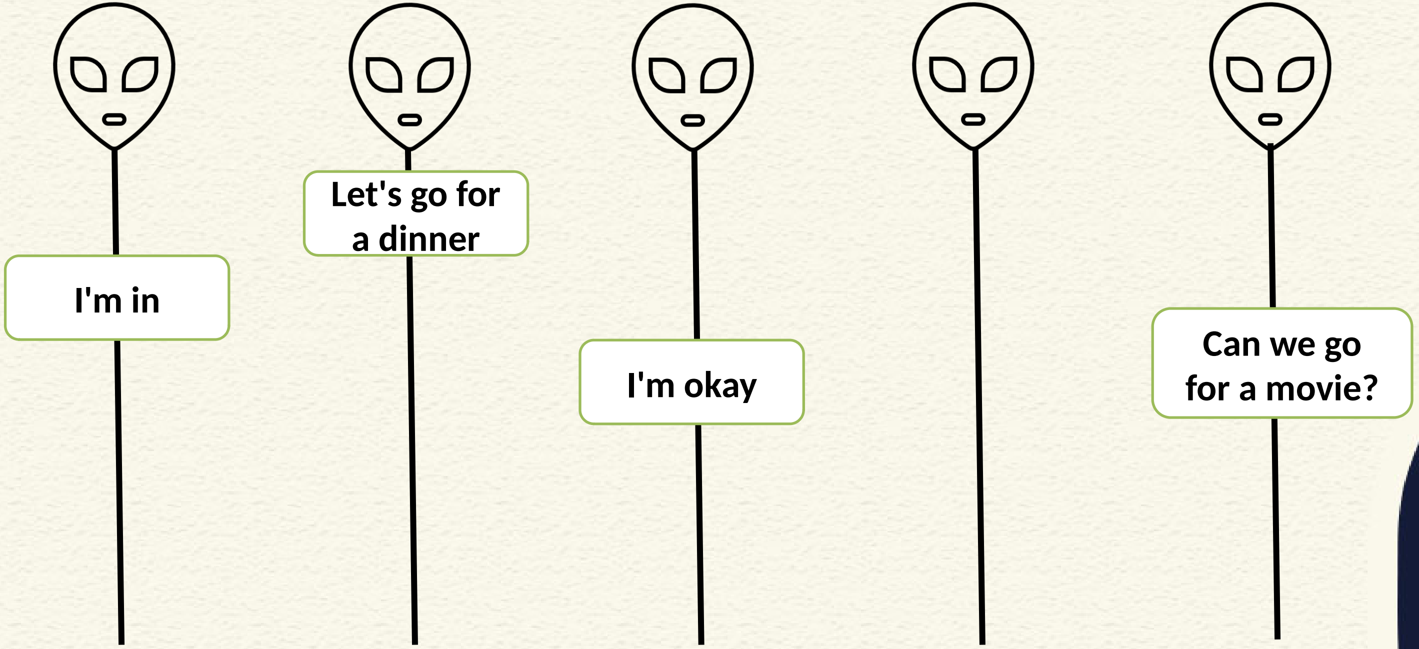

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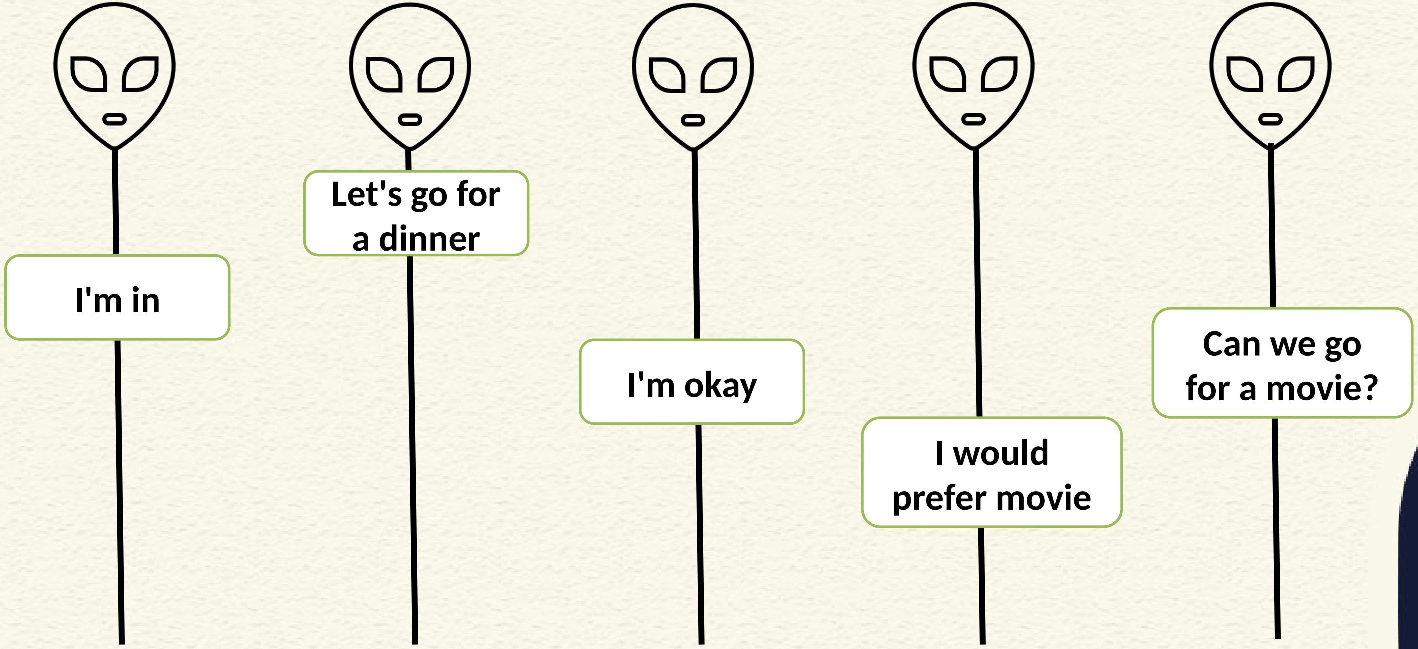


I'm in

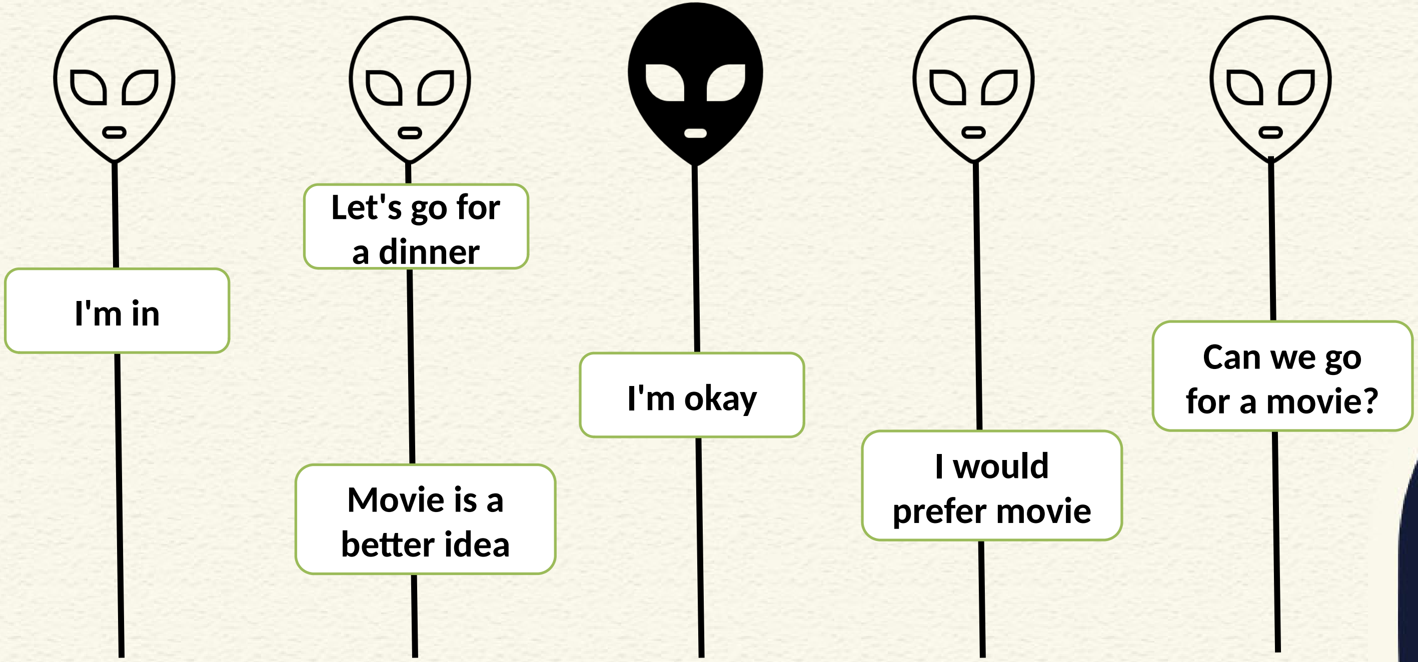
Let's go for a dinner

I'm okay

I would prefer movie

Can we go for a movie?

CFT in an Asynchronous System



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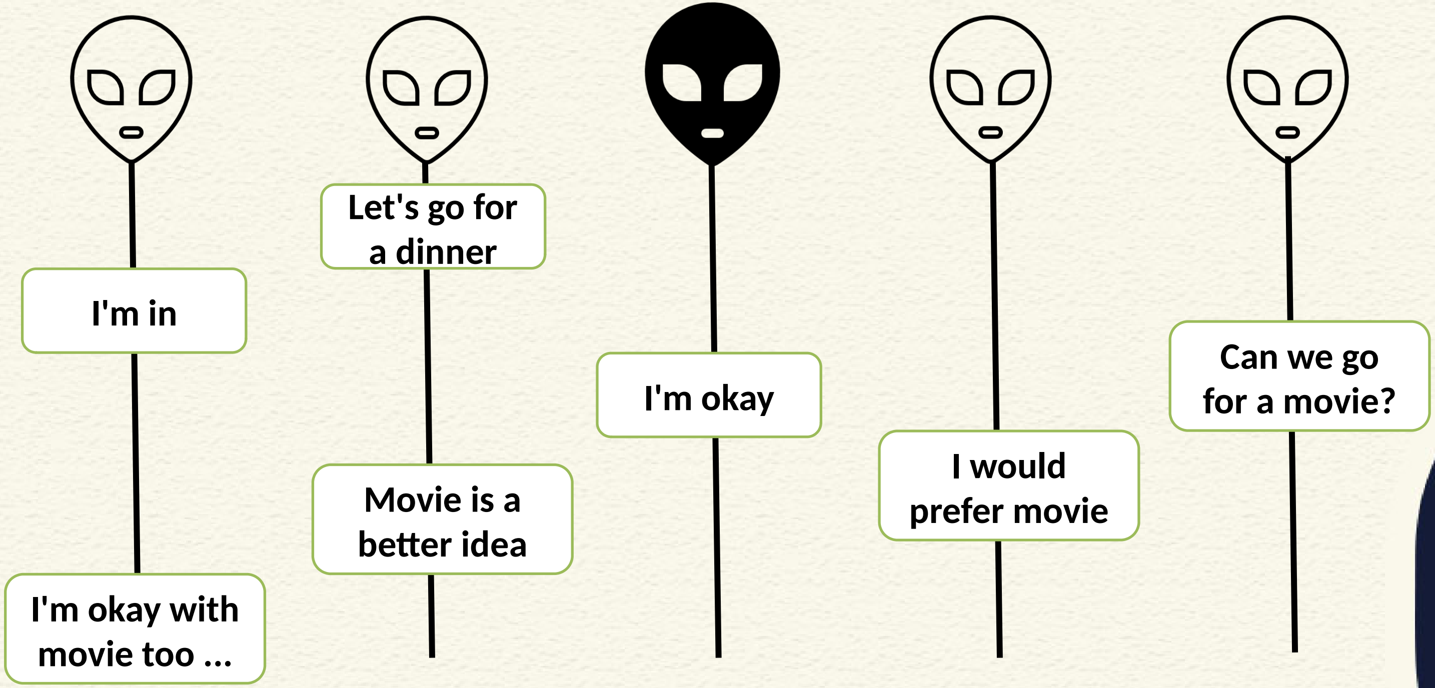


I'm in

I'm okay with movie too ...

Let's go for a dinner

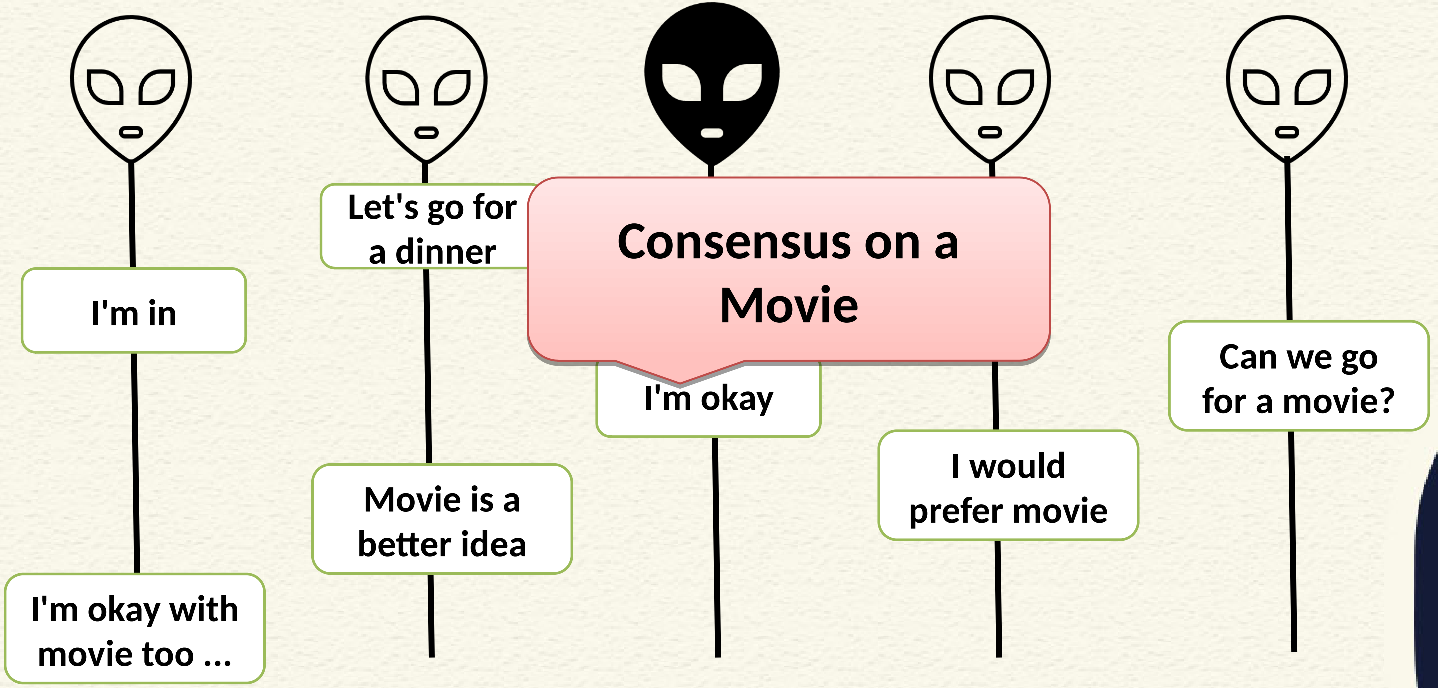
Movie is a better idea

I'm okay

I would prefer movie

Can we go for a movie?

CFT in an Asynchronous System



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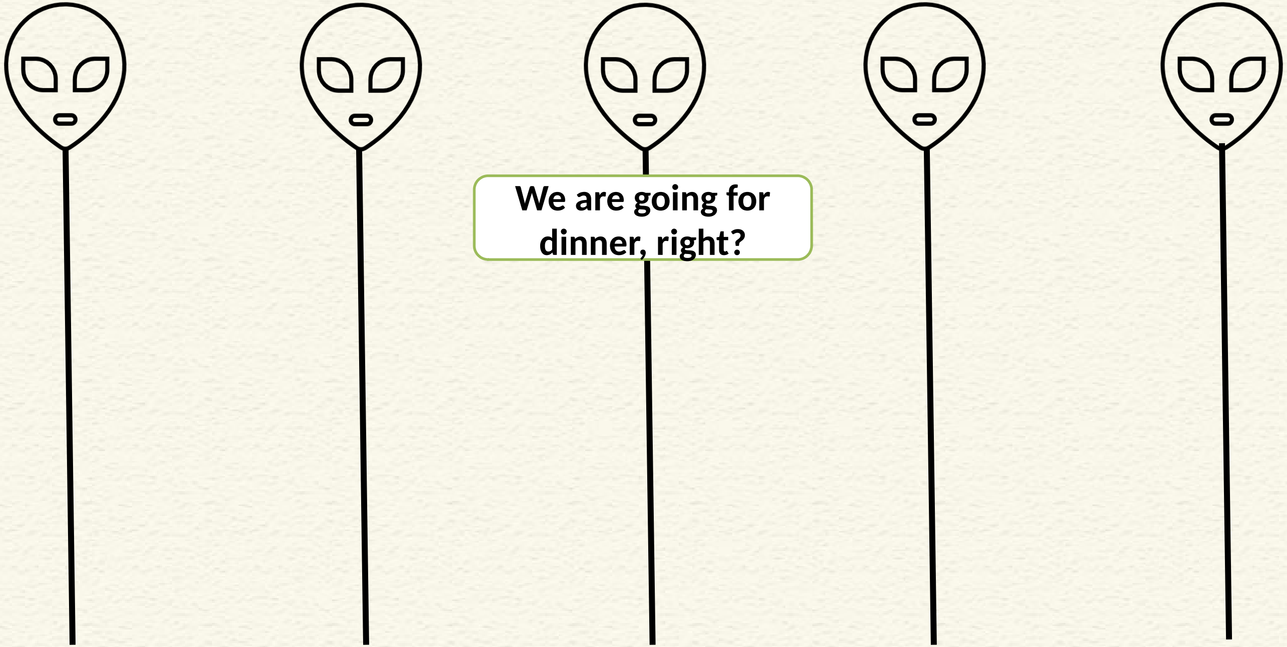
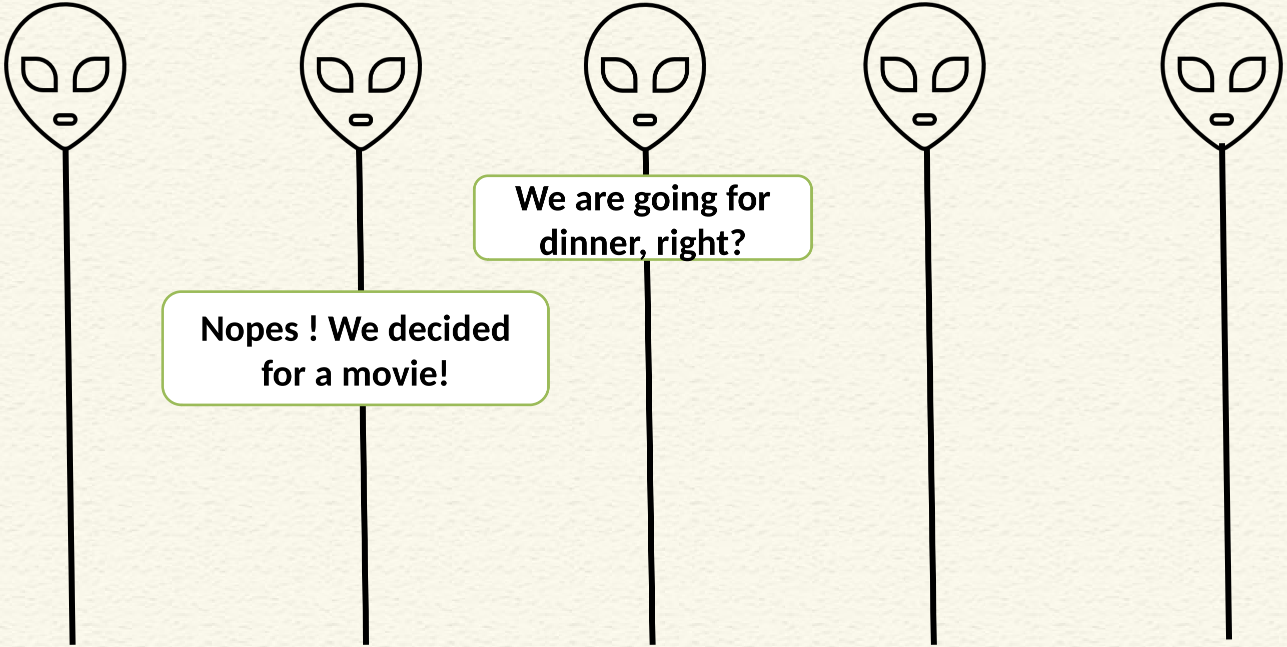
Consensus on a Movie

CFT in an Asynchronous System



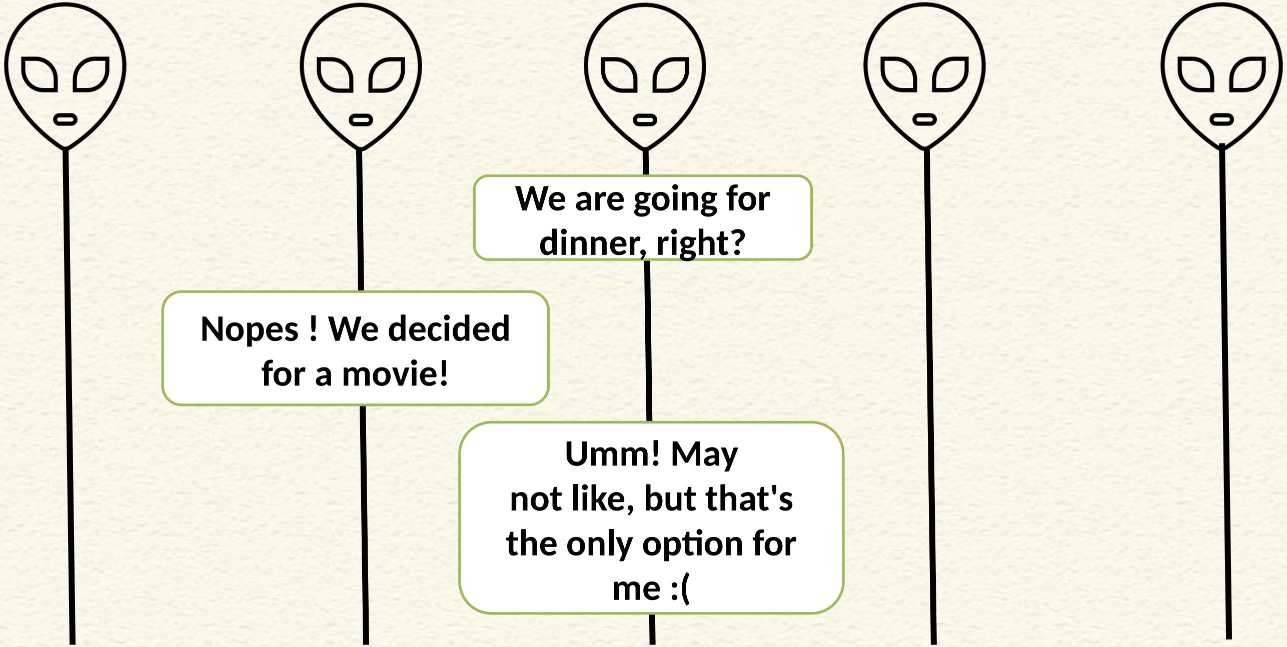
We are going for dinner, right?

CFT in an Asynchronous System



We are going for dinner, right?
Nopes ! We decided for a movie!

CFT in an Asynchronous System

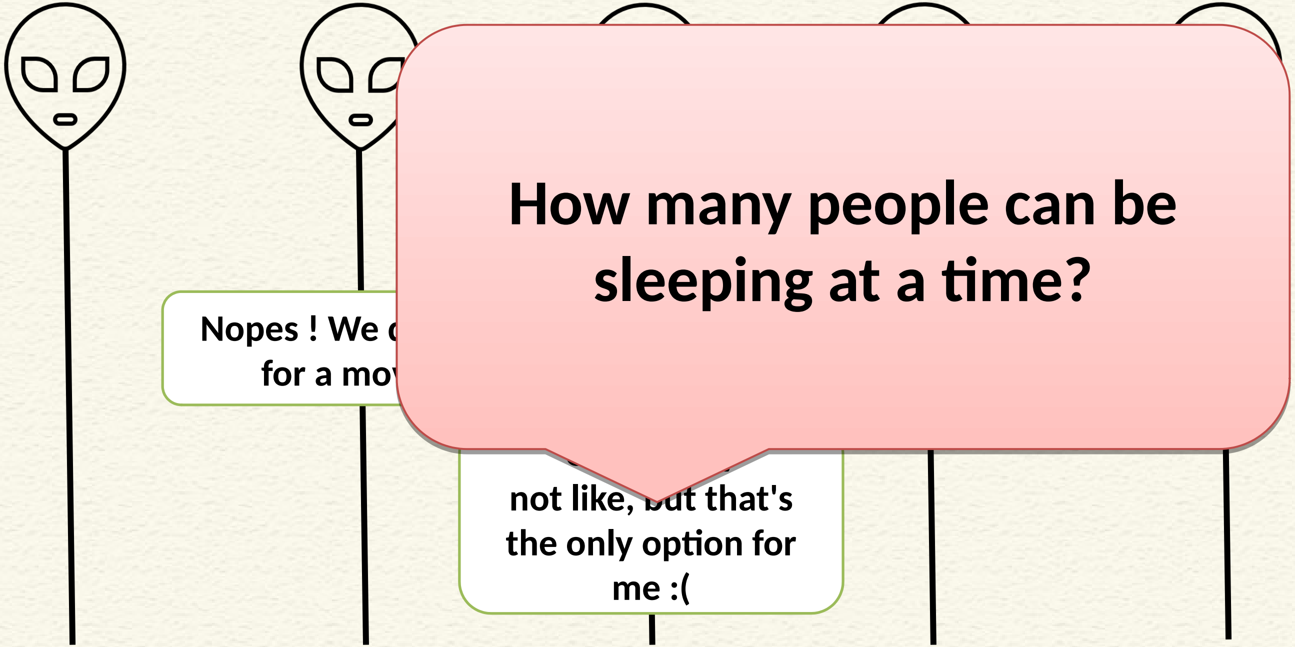


We are going for dinner, right?

Nopes ! We decided for a movie!

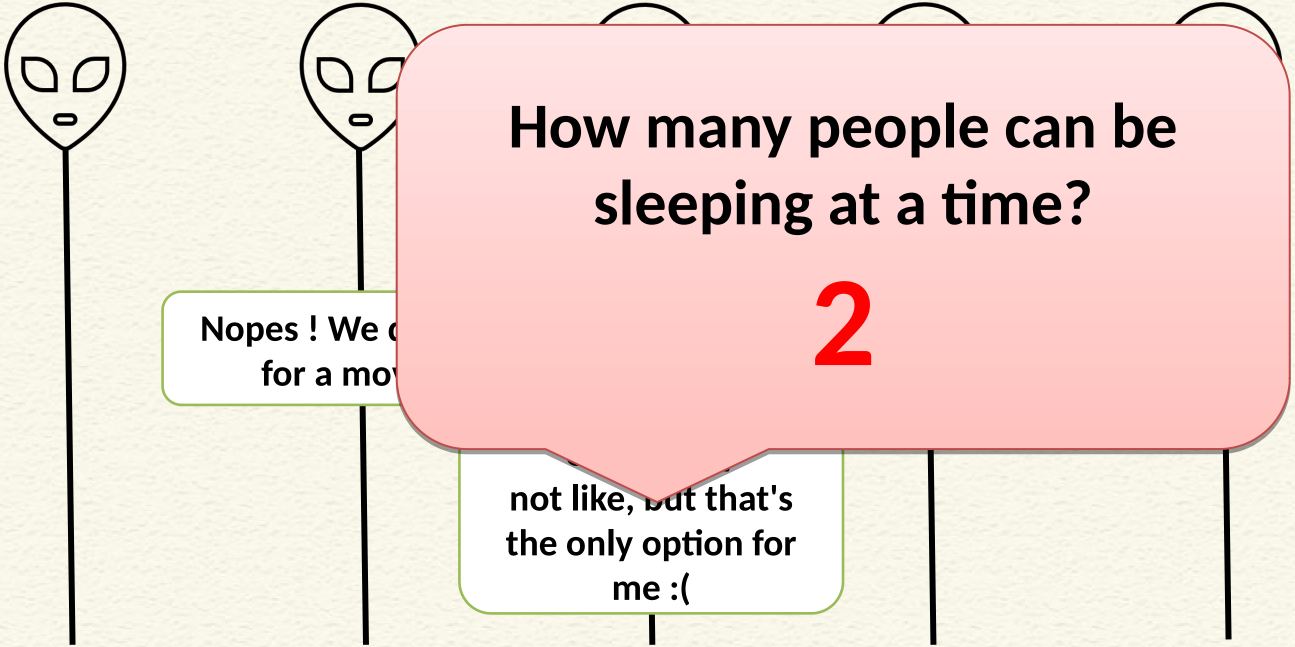
Umm! May not like, but that's the only option for me :(

CFT in an Asynchronous System



How many people can be sleeping at a time?

CFT in an Asynchronous System



How many people can be sleeping at a time?

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Asynchronous CFT

- If there are F faulty nodes (crash fault), we need atleast 2F+1 nodes to reach consensus

- **Paxos:** A family of distributed algorithms to reach consensus in an asynchronous CFT

What is Paxos?

- We'll discuss vanilla Paxos
- Proposed by Lamport in 1989
- Received a lot of criticism about its proof of correctness
- Accepted in ACM Transactions on Computer Systems in 1998, titled *"The Part-time Parliament"*
- Lamport received the Turing award in 2013

Conclusion

- Consensus is harder on asynchronous environment
- For asynchronous CFT, we need 2F+1 nodes with F crash faults only
- Let's explore Paxos in the next class

Thank you