Classical Consensus

Possible Timing Models

Asynchronous

- A sent message will *eventually* be delivered

Synchronous

- Guarantees on the time of delivers
- e.g. message sent at time t, will be delivered at time t+x

Eventually Synchronous

- A mix between both, where there is a *known upper bound* on the delivered time which is *variable*.

Possible Fault Models

Up to **f out of N processes can fail**

- Typically f < N/2, f < N/3

Honest nodes

- Remain available and do not behave byzantine

Availability failure

- A node might suddenly crash/Internet connectivity drop

Byzantine failure

- Malicious failure of an adversary

Broadcast Models

Consistent Broadcast

- A corrupted sender implies that not every party might terminate/deliver a request.

Reliable Broadcast

- Sender emits value v
- Termination: if sender honest, correct party outputs v
- Reliability: every correct party outputs v
- Consistency: two distinct parties output v1, v2 and v1=v2

https://lpd.epfl.ch/site/_media/education/sdc_byzconsensus.pdf

PBFT, Paxos, RAFT, et al.

Leader election

- Every node can become eventually a leader (e.g. round-robin)

Safety

- The output is guaranteed to be consistent, even under an unstable network and malicious leader
- Although asynchronous eventually synchronous

Liveness

- If no progress, new leader elected
- If network stable and honest leader then liveness

Known Impossibility Results

Fischer, Lynch, Patterson (1985)

- FLP result
- In a fully asynchronous system, there is no deterministic consensus solution that tolerates one or more failures
- No algorithm can always reach consensus in bounded time.

Implication

- Timing assumptions are required for every protocol
- Randomness is crucial

Given any protocol

Is the impossibility result respected?

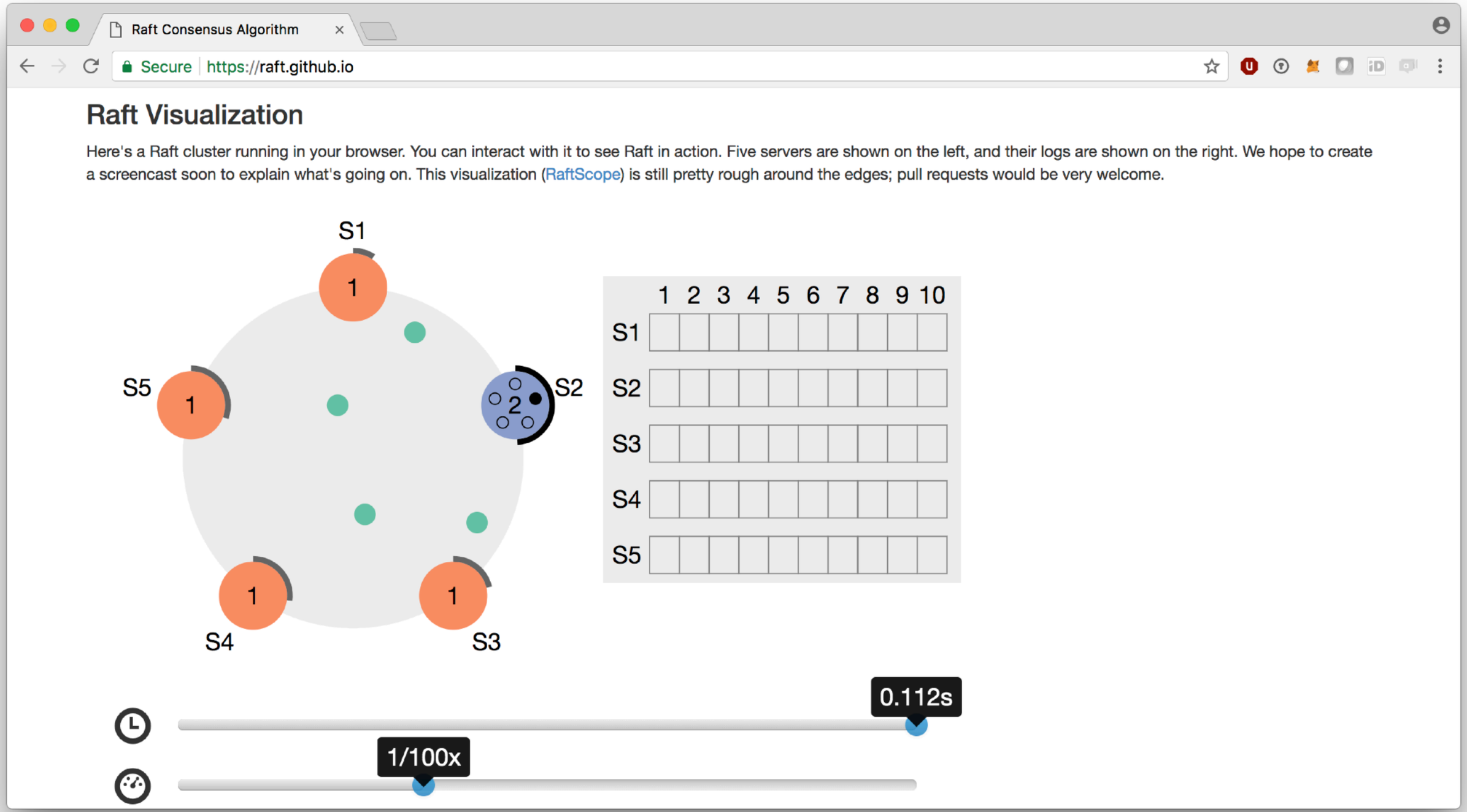
What's the message complexity/number of rounds?

How many nodes are allowed to fail?

Where does the randomness come from?

Can an adversary manipulate the randomness/become leader?

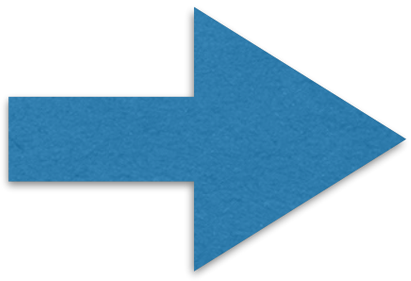
RAFT



http://thesecretlivesofdata.com/raft/ https://raft.github.io/

How does this relate to Bitcoin?

- No need for a final consensus output
- Block/transaction reward as incentive to participate
- **The participating nodes do not need to be known upfront!**



Fundamentally different to the results of years of research