CONSENSUS AND FAILURE DETECTION

FLP: Impossibility of Consensus

- Consensus is impossible
  - … in asynchronous system
  - … with crash-stop failures
- Adversary argument:
  - Any protocol cannot block
  - Delay delivery of critical message
  - Force system to reconfigure
  - Deliver message now it's no longer critical
  - Continue ad infinitum

FLP: Impossibility of Consensus

- Consensus is impossible
  - … in asynchronous system
  - … with crash-stop failures
- Adversary argument:
  - Relies on only one failure (message loss)
    - …which never actually happens!
  - *Key point: protocol cannot distinguish failure from delay*

FLP: Impossibility of Consensus

- Suppose we knew *exactly* one failure
- If N processes, then every process broadcasts its input (true or false) to every other process
- Each process: Make decision after receiving N-1 broadcasts

Properties of Failure Detectors

- Completeness: detection of every crash
  - **Strong completeness:** Eventually, every process that crashes is permanently suspected by every correct process
  - **Weak completeness:** Eventually, every process that crashes is permanently suspected by some correct process

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Properties of Failure Detectors

- Accuracy: does it make mistakes?
  - **Strong accuracy:** No process suspected before it crashes.
  - **Weak accuracy:** Some correct process is never suspected
  - **Eventual strong accuracy:** there is a time after which correct processes are not suspected by any correct process
  - **Eventual weak accuracy:** there is a time after which some correct process is not suspected by any correct process

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A sampling of failure detectors

Completeness	Accuracy			
	Strong	Weak	Eventually Strong	Eventually Weak
Strong	*Perfect* $\mathcal{P}$	*Strong* $\mathcal{S}$	*Eventually Perfect* $\Diamond\mathcal{P}$	*Eventually Strong* $\Diamond\mathcal{S}$
Weak	$\mathcal{D}$	*Weak* $\mathcal{W}$	$\Diamond\mathcal{D}$	*Eventually Weak* $\Diamond\mathcal{W}$

Perfect Detector

- Named *Perfect,* written $\mathcal{P}$
- Strong completeness and strong accuracy
- Immediately detects all failures
- Never makes mistakes

Eventually Weak Detector

- Eventually Weak: ◊W: "diamond-W"
- Weak Completeness: There is a time after which every process that crashes is suspected by *some* correct process
  - If it crashes, "we eventually, accurately detect the crash"
- Eventually Weak Accuracy: There is a time after which *some* correct process is never suspected by any correct process
  - Think: "we can eventually agree upon a leader."
  - Failure detectors are unreliable, but mistakes are recognized

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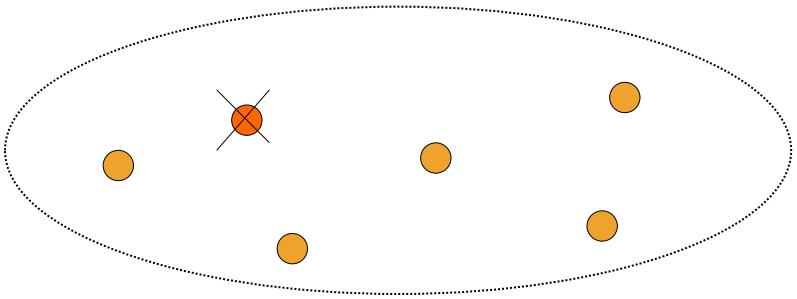
From Weak Completeness to Strong Completeness



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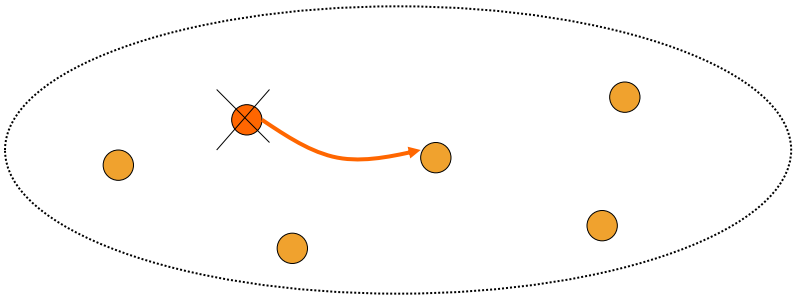
From Weak Completeness to Strong Completeness



Weak Completeness: Failed node is detected by **some** correct process

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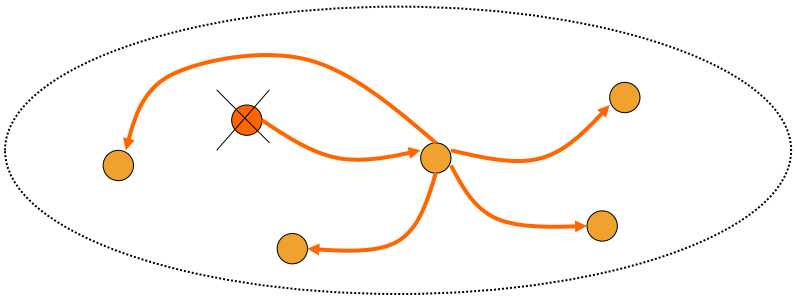
From Weak Completeness to Strong Completeness



Strong Completeness: Initial detector notifies the other correct nodes

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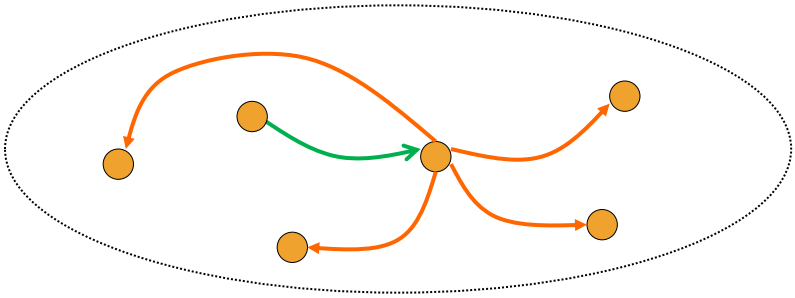
From Weak Completeness to Strong Completeness



Accuracy: "Failed" node eventually notifies correct processes of their mistake

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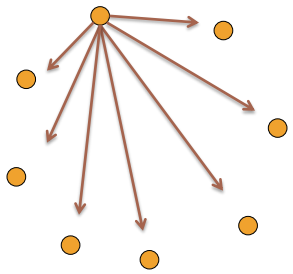
Consensus with Eventually Strong Detector

- Round i (repeat until final value):
  - Coordinator is process (i mod N)
  - Broadcast to all processes for their value
  - Wait for majority to respond (assume < N/2 fails)



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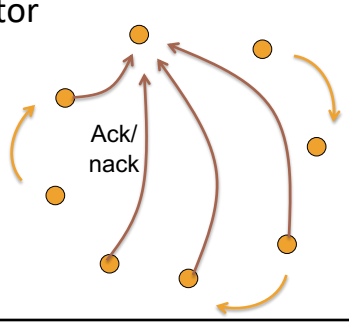
Consensus with Eventually Strong Detector

- Round i:
  - Each correct process may ack with its value…
  - …or believe coordinator has failed, i += 1
  - …must still send nack for termination of coordinator



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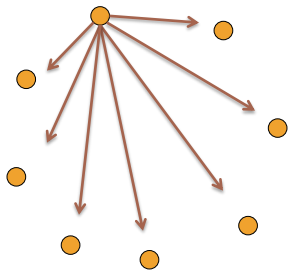
Consensus with Eventually Strong Detector

- Termination:
  - Eventual weak accuracy: *Some* coordinator will *eventually* be seen correct by all correct processes
  - With majority vote, broadcast final value



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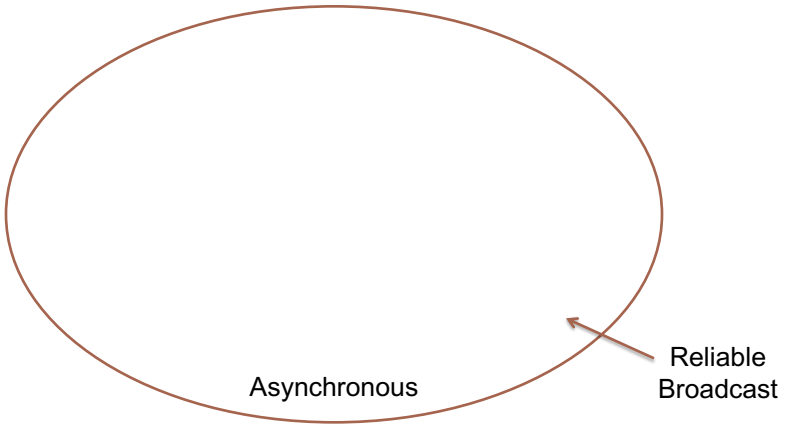
Power of Failure Detectors



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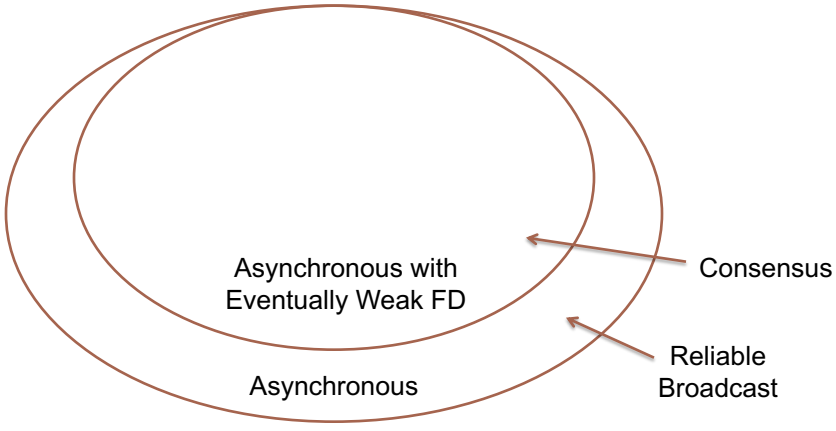
Power of Failure Detectors



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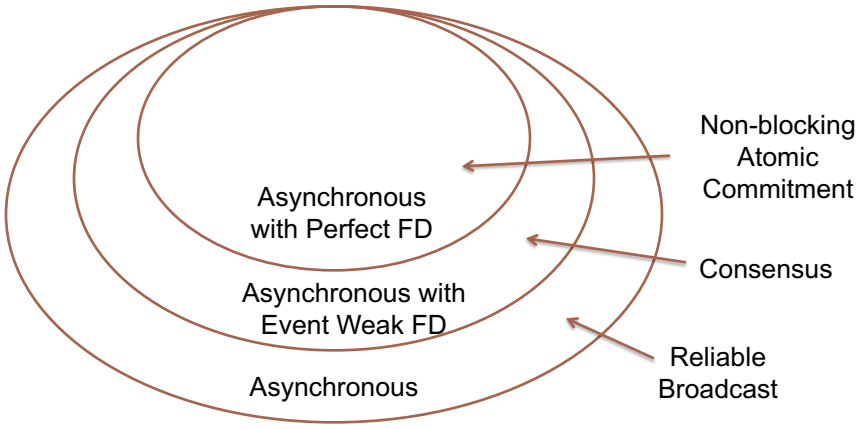
Power of Failure Detectors



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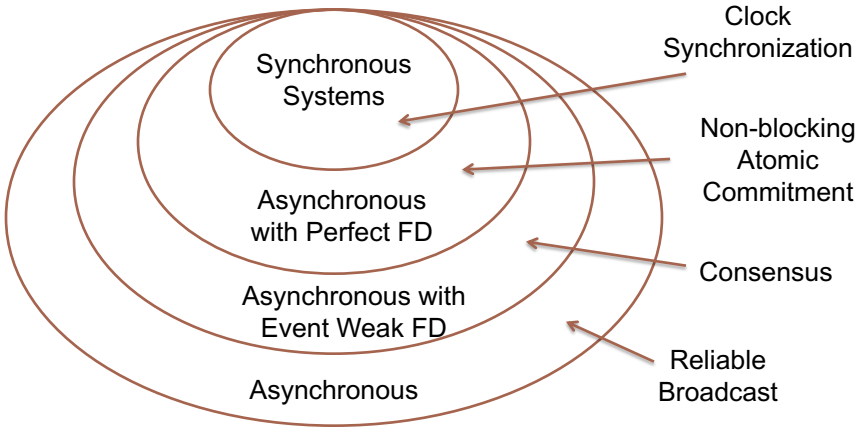
Power of Failure Detectors



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How to Proceed?

- Approximate ◊W with sufficiently long timeouts
  - Problem: latency
- Use probabilistic protocols
  - Solve consensus with high probability
- Change problem e.g. to group membership
  - Process group approach, false positives ok
- Accept consensus protocol that terminates with high probability
  - Paxos algorithm

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