Fault Tolerant Consensus – Wrapup I

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1. Synchronous network model
2. Stopping failures
3. EIGStop
4. Side by side
5. Byzantine agreement with authentication

Synchronous network model

- All these algorithms are still based on the synchronous network model
- Even the simple stopping failure cannot be deterministically solved in the asynchronous network model

- FLP – Fischer, Lynch and Patterson

  Impossibility of Asynchronous Distributed Consensus with a Single Faulty Process

- Solutions for the asynchronous model use randomisation, failure detectors (partially synchronous model)

Stopping failures model

- Much simplified version of the Byzantine agreement
- A failed process can only stop sending messages, forever
  (no intermittent failures, recovery not considered)

- No possibility to send confusing messages
  (i.e. different messages to different directions)

- The problem can be solved for any $F \leq N - 1$ ☺
  (not only when $3F \leq N - 1$)

The Stopping agreement conditions – vs ~~Byz~~

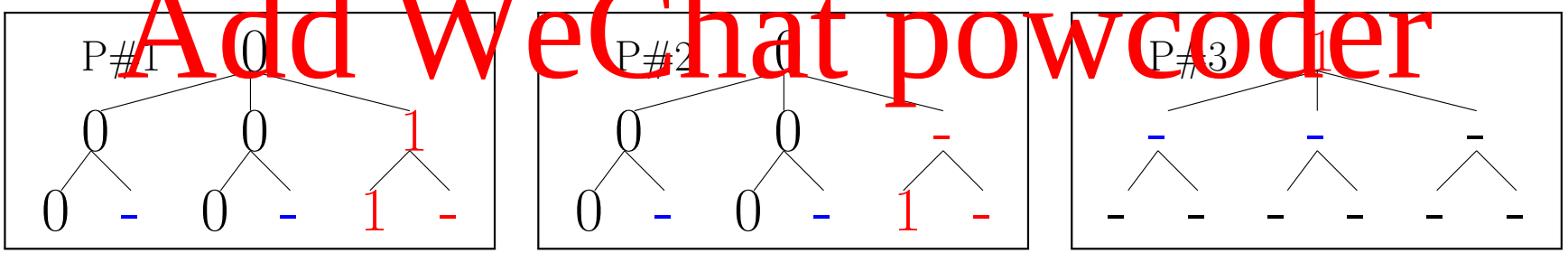
- Termination: all non-faulty processes eventually decide
- Agreement: no two ~~non-faulty~~ processes ever decide on different values
- Validity: if all ~~non-faulty~~ processes start with the same initial value $v \in V$, then v is the only one possible decision value
- If the processes start with different initial values, then the final decision could be any of these (as long as it is consistent)

EIGStop

- EIG tree as in the EIGByz, $F + 1$ messaging rounds
  - recall: F can be as high as $N - 1$ (not at most $(N - 1)/3$)
- Top-down val()'s as in the EIGByz, i.e. via messaging
- No bottom-up newval() attributes
- Final decision: set W of all non-null val()'s in EIG tree
  - all values at all levels! not just leaves
  - nulls discarded! not assumed v_0
- If W is singleton, $W = \{v\}$, then the decision is v
- Otherwise, if W is mixed, $W = \{0, 1\}$, then the decision is v_0
  - no voting! no tie breaking

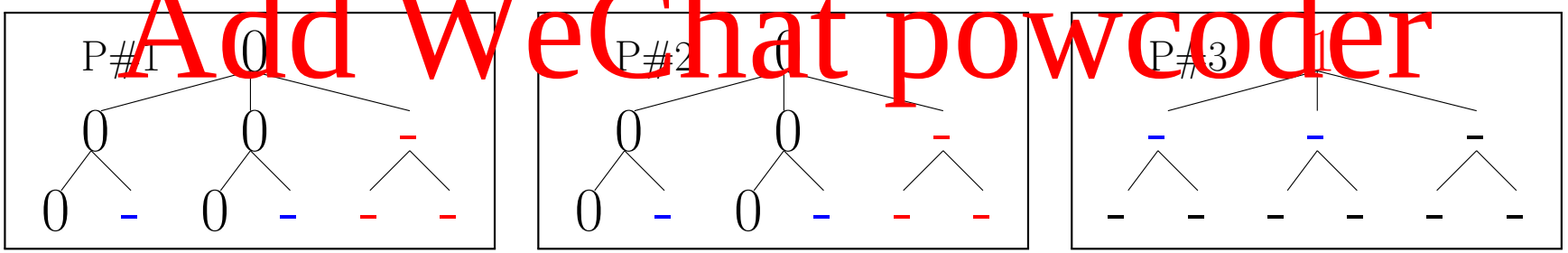
EIGStop example – assuming $v_0 = 1$; nulls as -

- Process #1 : init 0; decision $v_0 = 1$
- Process #2 : init 0; decision $v_0 = 1$
- Process #3 : init 1; no decision; fails after sending one 1st round message, to #1



EIGStop example – assuming $v_0 = 1$; nulls as -

- Process #1 : init 0; decision 0
- Process #2 : init 0; decision 0
- Process #3 : init 1; no decision; fails before sending any 1st round message



EIGStop example – assuming $v_0 = 1$; nulls as -

- WHAT IF scenario – NOT supported by this EIGStop protocol

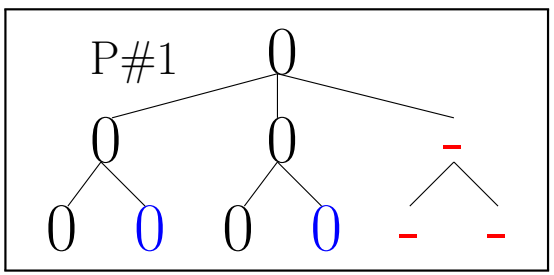
  What if P#3 fails before sending any 1st round out-message but would be allowed to recover and decide

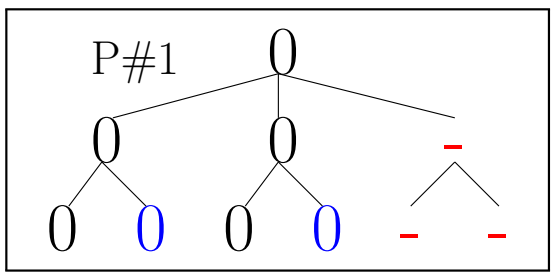
- NO agreement

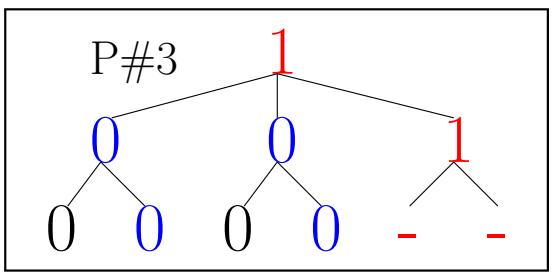
- Process #1 : init 0; decision 0

- Process #2 : init 0; decision 0

- Process #3 : init 1 ; decision $v_0 = 1$







OptEIGStop

- Each process sends out only two messages
- First: its initial choice, to all the processes
- Second: a different value, to all the processes
  - The first time it learns about a different value
  - Arbitrary choice, if there are more

EIGStop vs EIGByz vs 3PC – assuming $v_0 = 0$

- X indicates a faulty process, which fails from start, before sending any 1st round message

Initial	EIGStop	EIGByz	3PC
0 0 0 0	0	0	0
0 0 0 1	0	0	0
0 0 1 1	0	0	0
0 1 1 1	0	1	0
1 1 1 1	1	1	1
0 0 0 X	0	0	0
0 0 1 X	0	0	0
0 1 1 X	0	0	0
1 1 1 X	1	1	0

EIGStop vs EIGByz vs 3PC – assuming $v_0 = 1$

- X indicates a faulty process, which fails from start, before sending any 1st round message

Initial	EIGStop	EIGByz	3PC
0 0 0 0	0	0	0
0 0 0 1	1	0	0
0 0 1 1	1	1	0
0 1 1 1	1	1	0
1 1 1 1	1	1	1
0 0 0 X	0	0	0
0 0 1 X	1	1	0
0 1 1 X	1	1	0
1 1 1 X	1	1	0

Complexity

- EIGStop
  - Rounds: $f+1$
  - Messages: $\mathcal{O}((f+1)n^2)$ messages
  - OptEIGStop messages: $\mathcal{O}(2n^2)$ messages
- EIGByz – Additional requirement: $n > 3f$
  - Rounds: $f+1$
  - Messages: $\mathcal{O}((f+1)n^f)$ messages
- 3PC:
  - Rounds: $\mathcal{O}(f+1)$
  - Messages: $\mathcal{O}(fn)$ messages

Byzantine agreement with authentication

- Assume that each process digitally signs its messages in a total safe way, e.g. based on a reliable unbreakable PKI/DSA...
- Is this reasonable?
- Problem with certificate weaknesses: What if a powerful Byzantine faulty process is able to forge such signatures?
- Problem with authority: What if the certification authority itself is hacked or even turns into a Byzantine process?
- Anyway, assuming that such digital signatures are totally safe, Byzantine faulty nodes are not able to wreak much more havoc than a stopped process
- EIGStop can be adapted to solve the (slightly different) Byzantine agreement with authentication
- Faster/better/more general algorithms possible...