EECS 591
Distributed Systems

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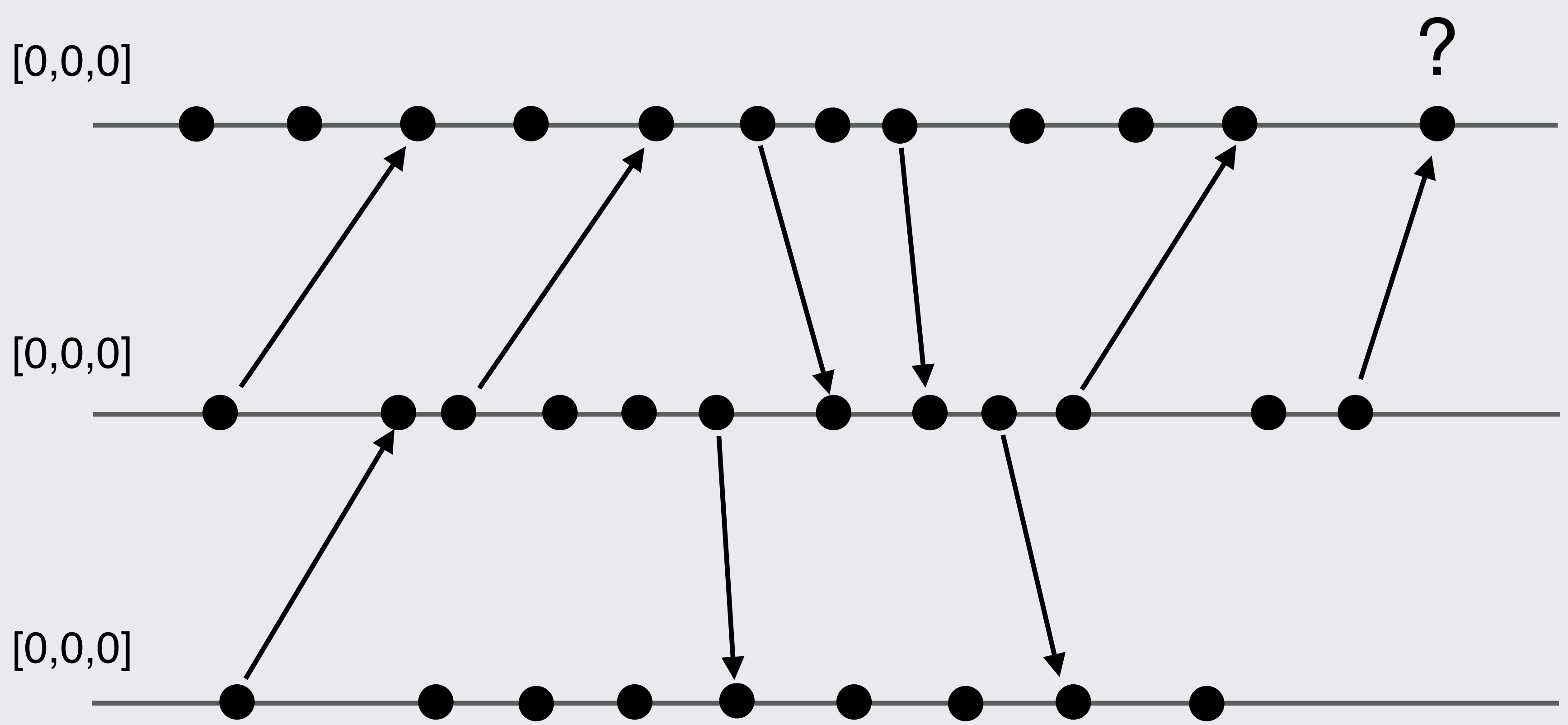
Fall 2021

Vector clocks



Client's estimation and precision

Client's best guess: $Q(x) = T + D(1+2\rho) - min \cdot \rho$

Maximum error: $e = D(1+2\rho) - min$

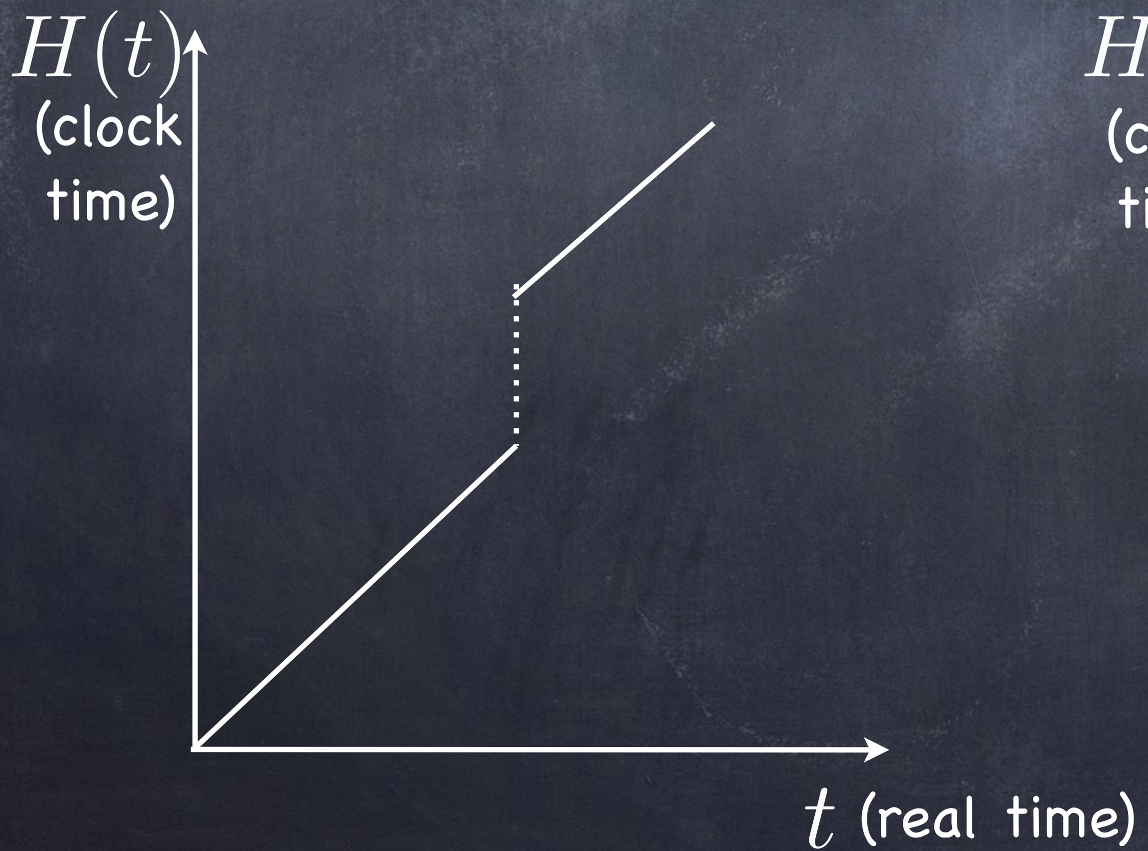
You can keep trying, until you achieve the required precision

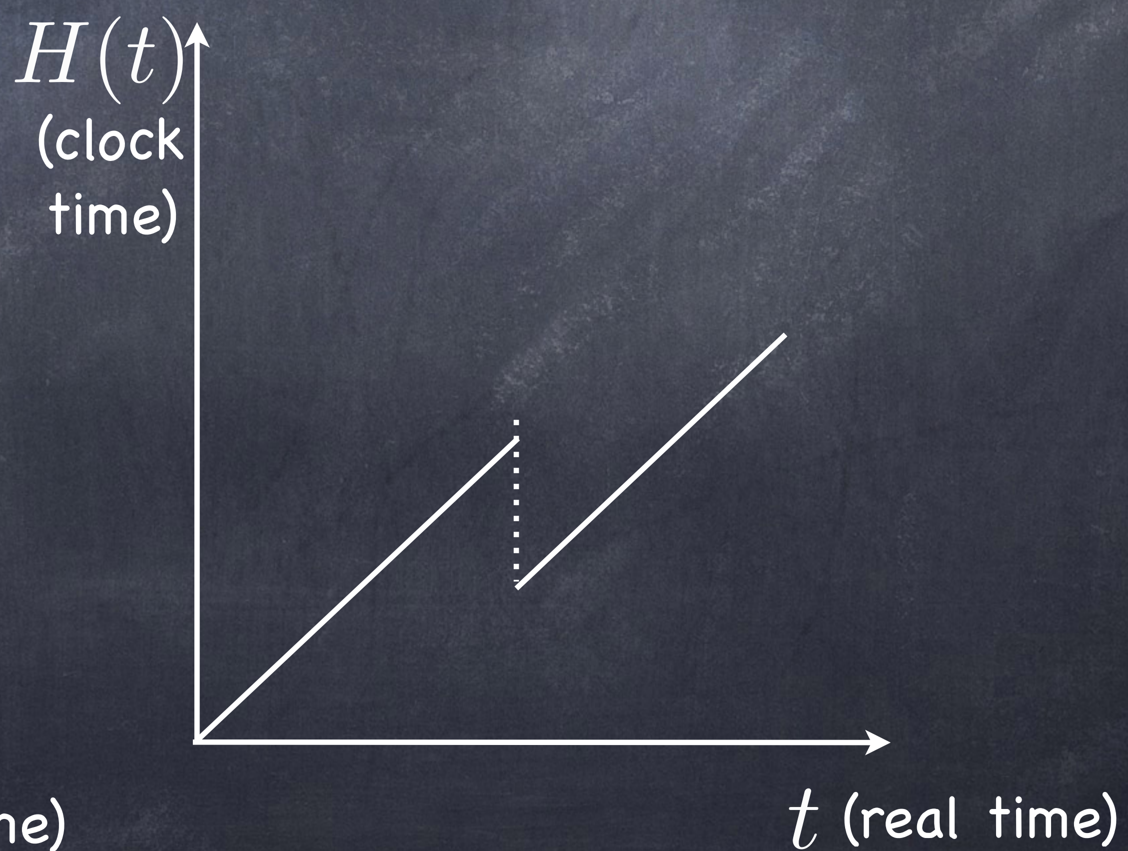
(if that precision is reasonable)

Adjusting the clock

After synchronizing:

- If client simply sets $P(x) = Q(x)$, it could create time discontinuities.

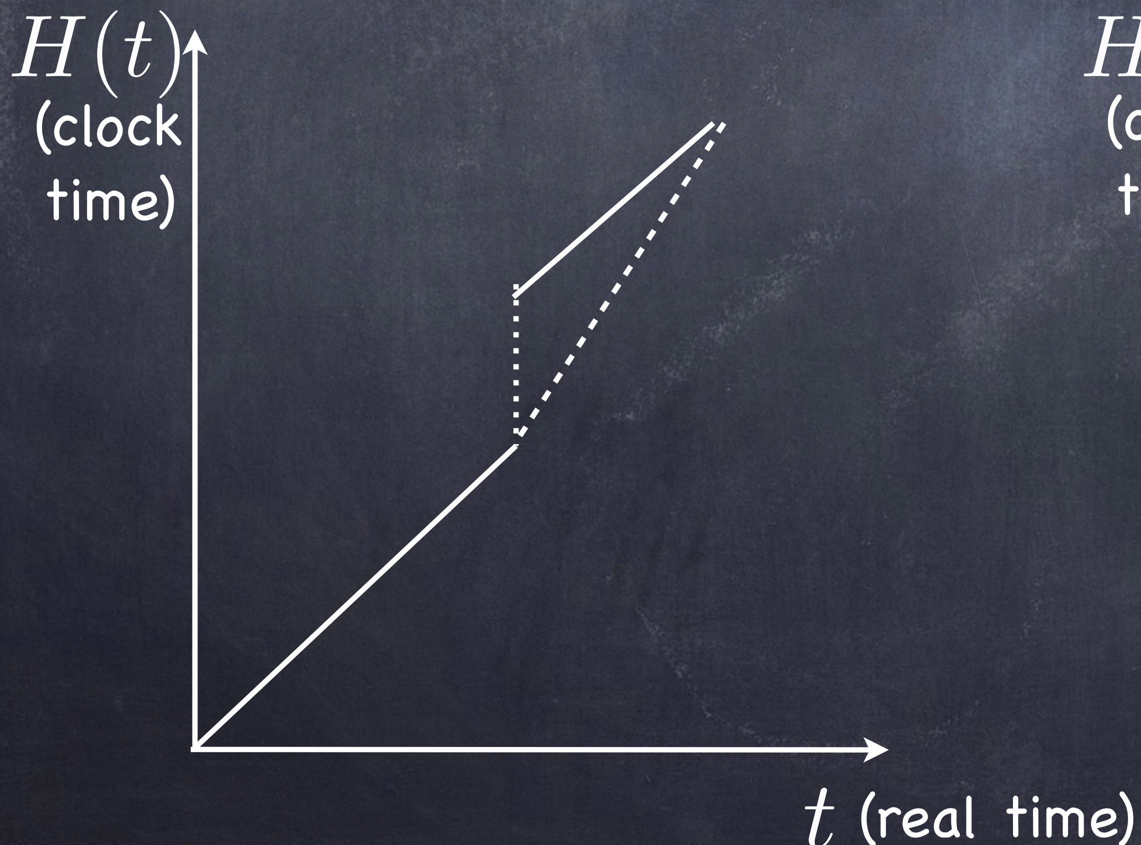


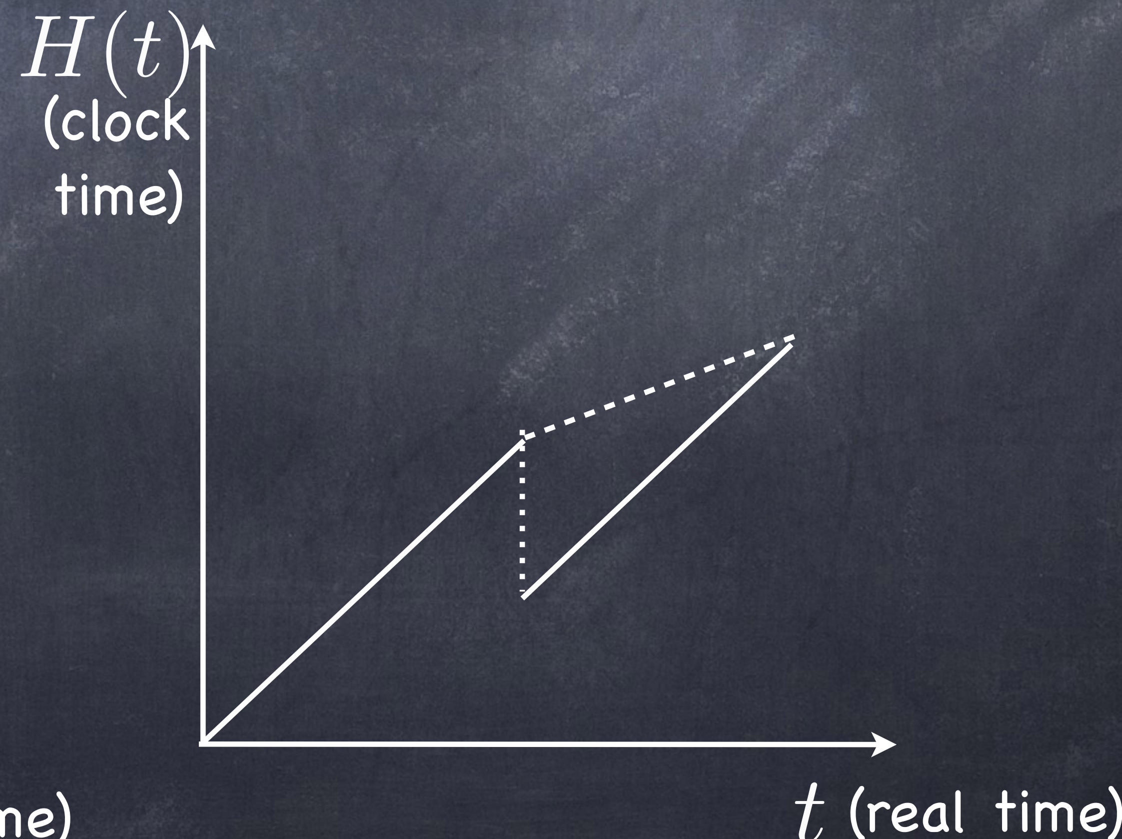


Adjusting the clock

Logical clock $C(t) = H(t) + A(t)$

Hardware clock   Adjustment function





Network Time Protocol

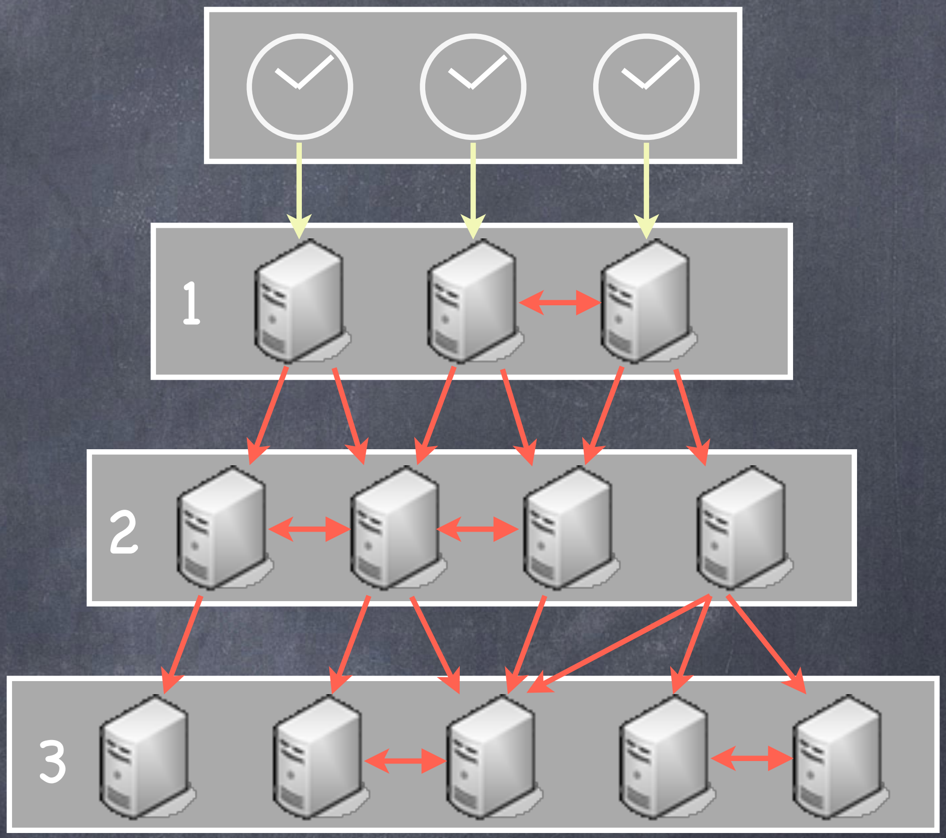
- The oldest distributed protocol still running on the Internet
- Hierarchical architecture
- Latency-tolerant, jitter-tolerant, fault-tolerant.. very tolerant!

Hierarchical structure

Each level is called a "stratum"

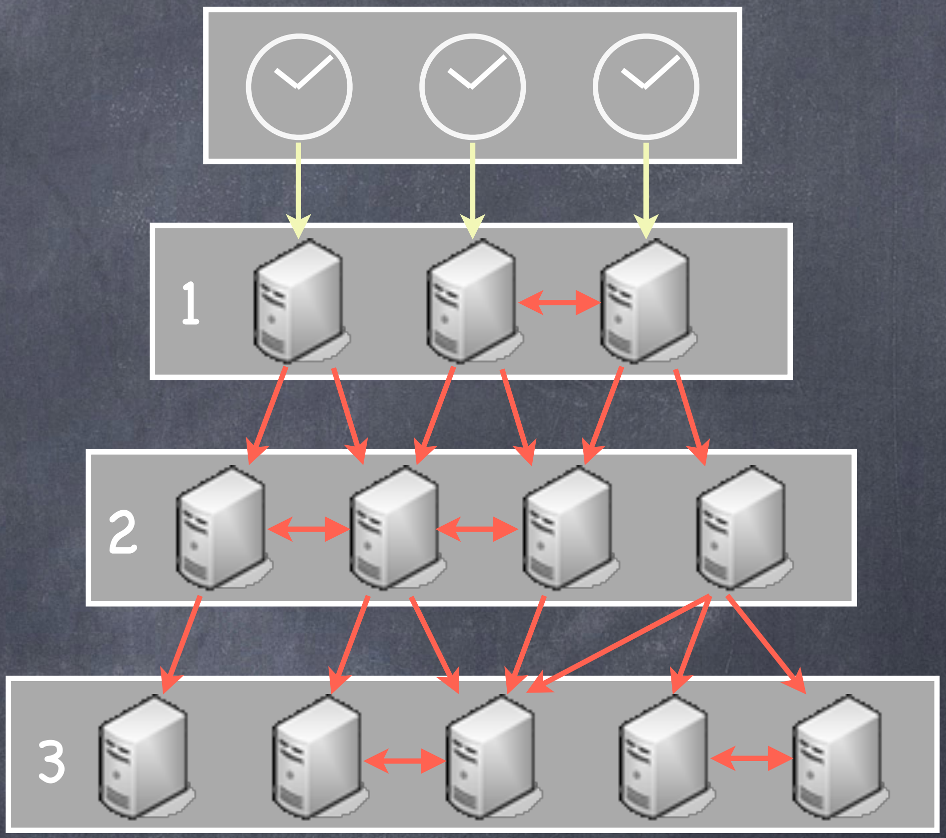
- Stratum 0: atomic clocks
- Stratum 1: time servers with direct connections to stratum 0
- Stratum 2: Use stratum 1 as time sources and work as server to stratum 3
- etc....

Accuracy is loosely coupled with stratum level



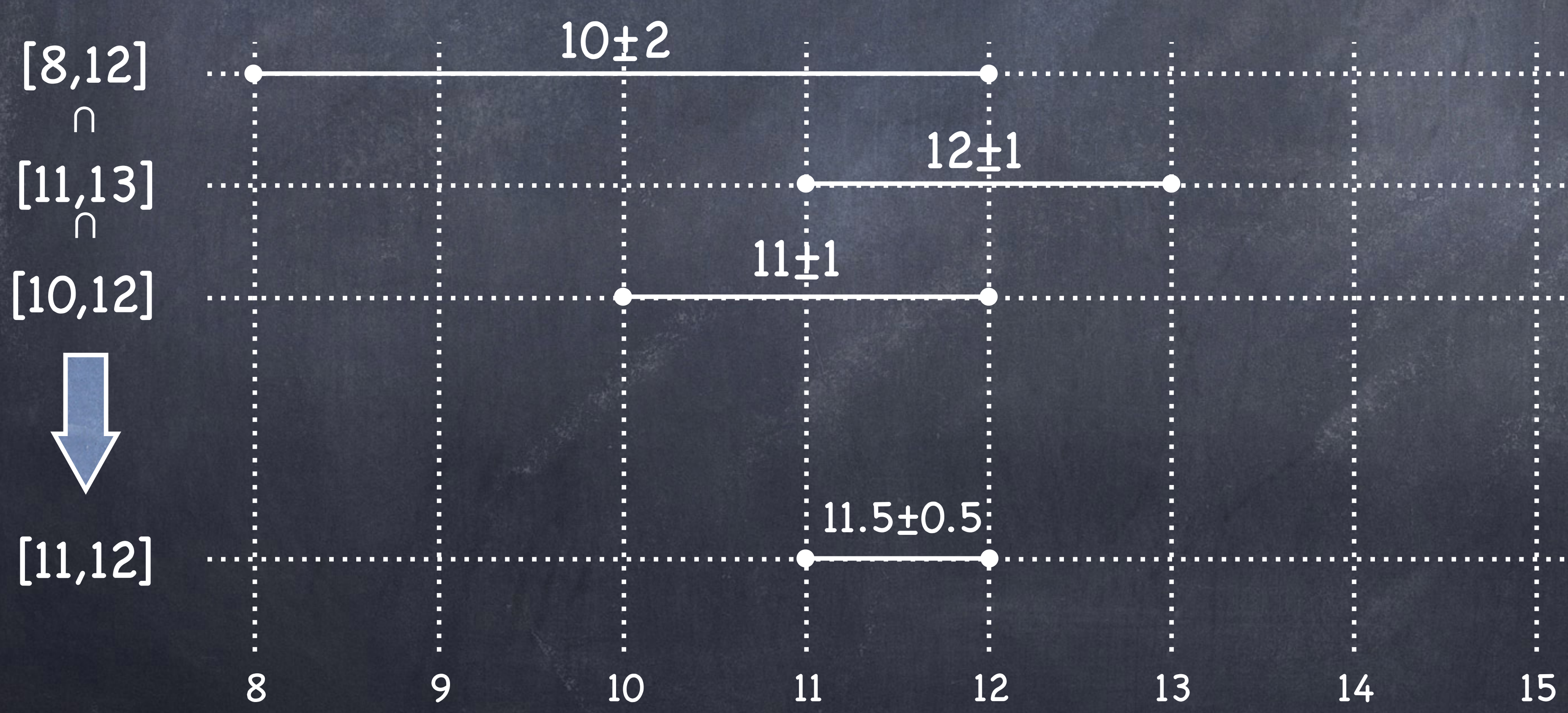
Very tolerant. How?

- Tolerance to jitter, latency, faults: **redundancy**
- Each machine sends NTP requests to many other servers on the same or the previous stratum
- The synchronization protocol between two machines is similar to Cristian's algorithm
- Each response defines an interval $[T_1, T_2]$
- How to **combine** those intervals?



Marzullo's algorithm

- Given M source intervals, find the largest interval that is contained in the largest number of source intervals



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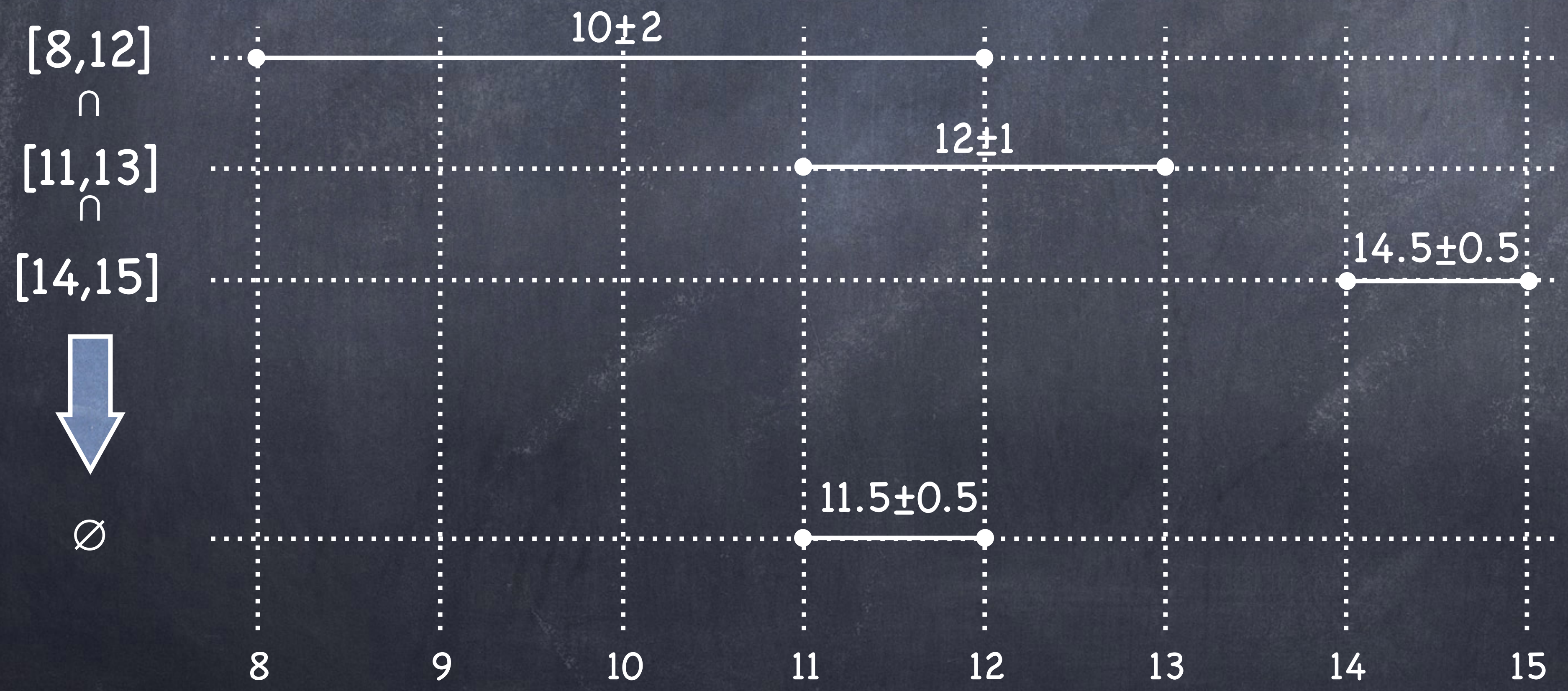
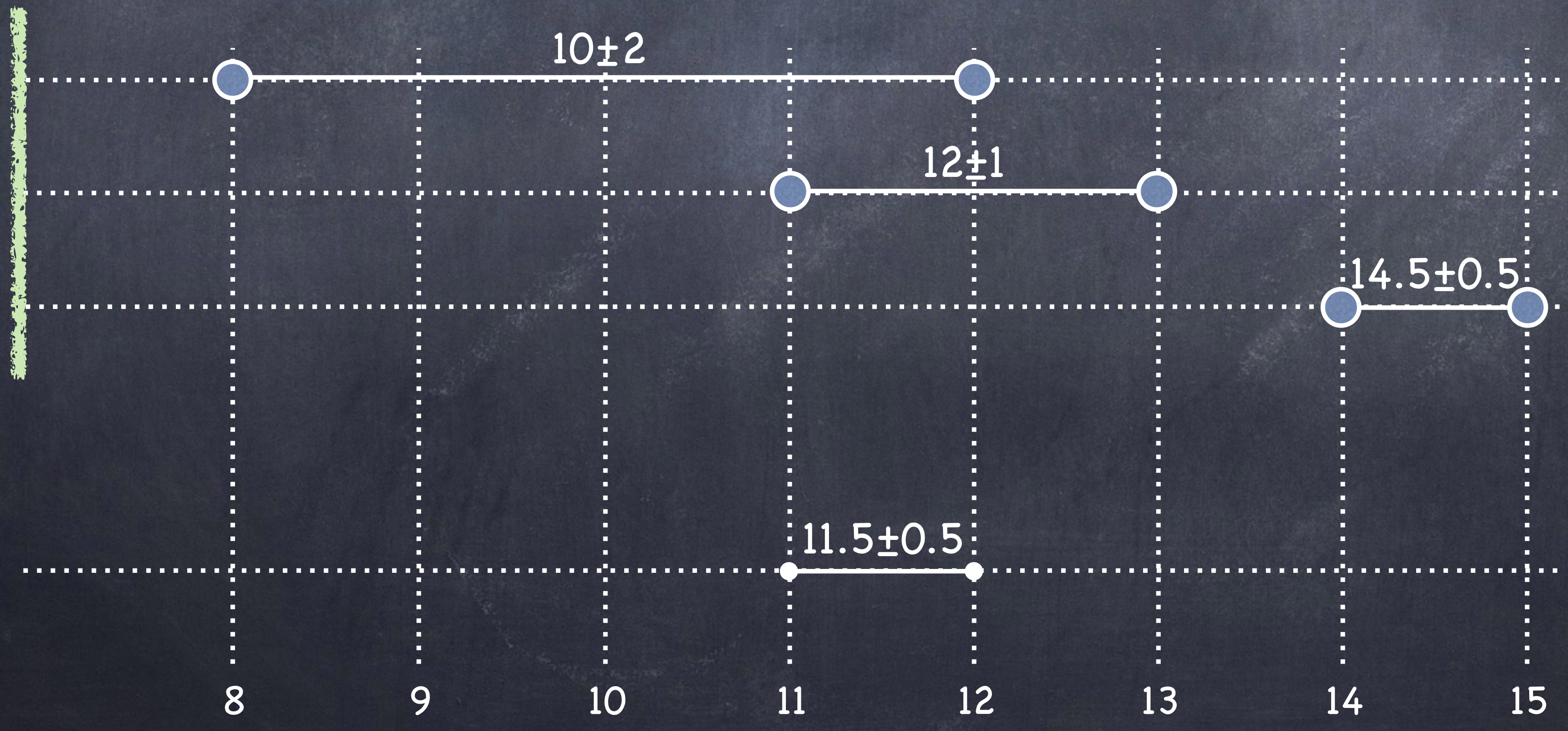


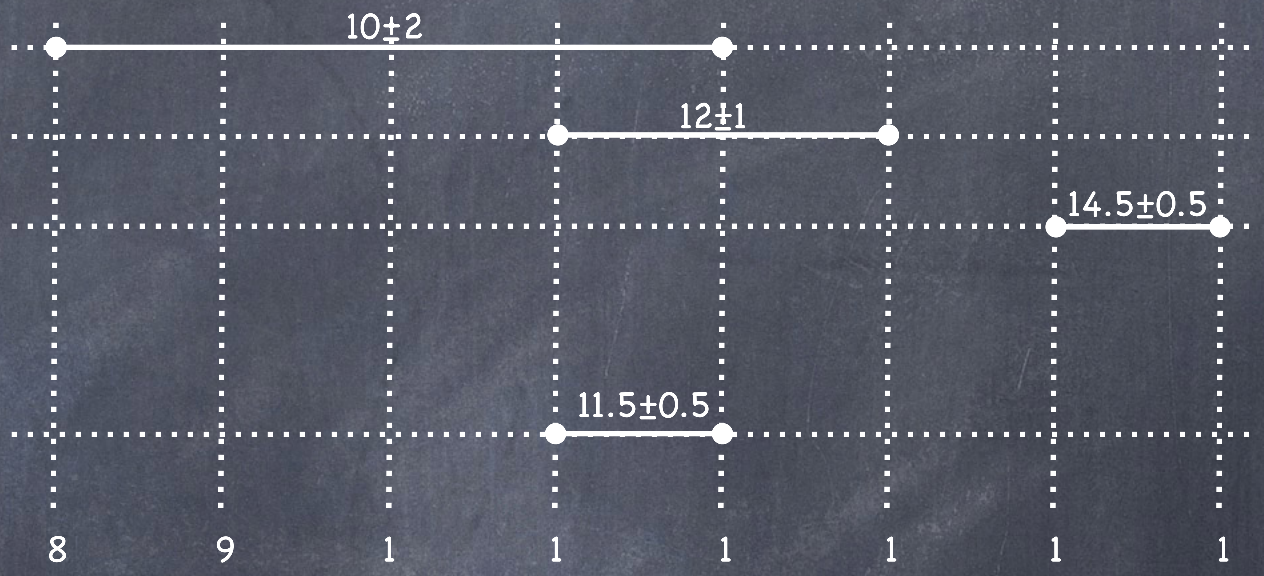
The intuition

- Visit the endpoints left-to-right
- Count how many source intervals are active at each time
  - Increase count at starting points, decrease at ending points



Preprocessing

- For each source interval [T_1,T_2], create 2 tuples of the form <time, type>:
  - <T_1,+1> (start of interval)
  - <T_2,-1> (end of interval)
- Sort all tuples according to time



Example:

Source intervals: [8,12], [11,13], [14,15]

Tuples: <8,+1> <12,-1> <11,+1> <13,-1> <14, +1> <15, -1>

Sorted: <8,+1> <11,+1> <12,-1> <13,-1> <14, +1> <15, -1>

The algorithm

```
best=0, count=0
for all tuples<time[i],type[i]> {
        count = count + type[i]

        if(count>best) {
              best=count
              beststart=time[i]
              bestend=time[i+1]
        }
}
return [beststart, bestend]
```

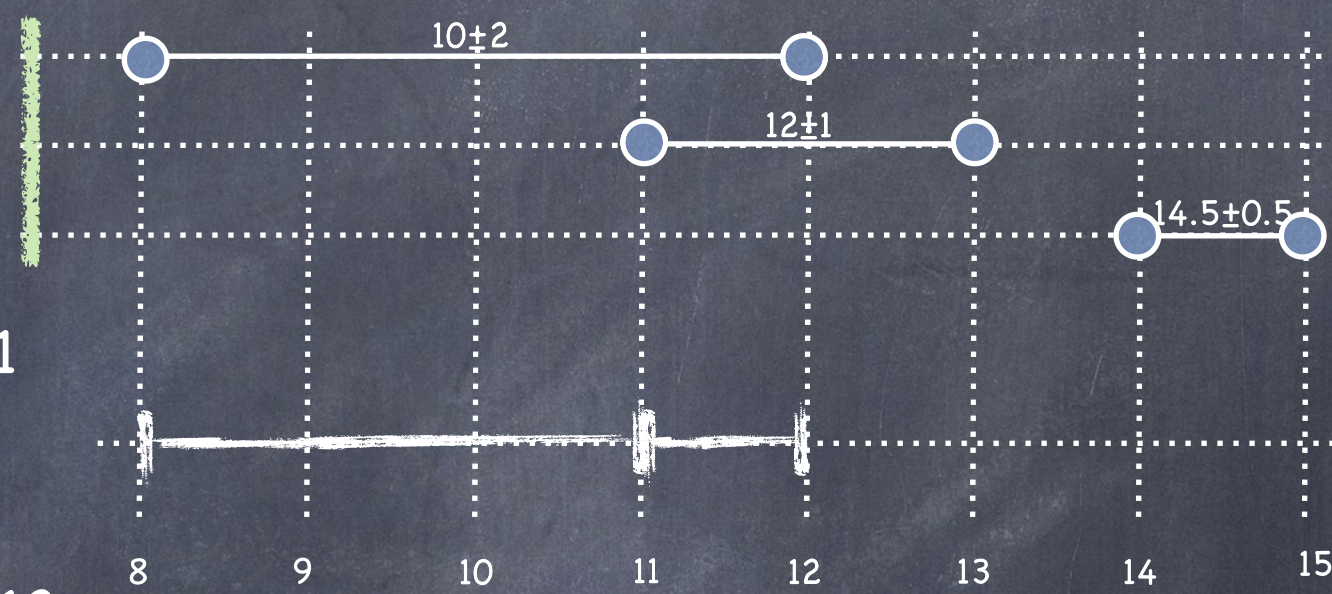
Notes:

- *count*: numbers of “active” intervals
- *best*: best numbers of “active” intervals we have seen

- *count=count+type[i]* : if it’s a startpoint (type=+1), increase count, else decrease it
- *if(count>best)* : if this is the highest number of active intervals we have seen, let the best interval be [time[i], time[i+1]]
  - If the next point is a startpoint, it will replace this best interval
  - If the next point is an endpoint, it will end this best interval

The algorithm at work

Sorted: <8,+1> <11,+1> <12,-1> <13,-1> <14, +1> <15, -1>



Init: best=0, count=0

<8,+1> : count = count + (+1) = 1
Is count>best? Yes
best=1, beststart=8, bestend=11

<11,+1> : count = count + (+1) = 2
Is count>best? Yes
best=2, beststart=11, bestend=12

<12,-1> : count = count + (-1) = 1
Is count>best? No

<13,-1> : count = count + (-1) = 0
Is count>best? No

<14, +1> : count = count + (+1) = 1
Is count>best? No

<15, -1 : count = count + (-1) = 0
Is count>best? No

return [11,12]

NTP timestamps

How to represent time?
"Wednesday September 9th 2020, 16:15:00" ?
"20200909161500EDT" ?

NTP: 64-bit UTC timestamp

32 bits	32 bits
offset in seconds	sub-second precision

offset = #seconds since January 1, 1900

Wraps around every 2^{32} seconds = 136 years
First wrap-around: 2036

Solution: 128-bit timestamp. "Enough to provide unambiguous time representation until the universe goes dim"

ADMINISTRIVIA

- Start forming groups for research project (3 students per group)
    - Take a look at future content in part 1
    - I have uploaded a list of papers we will read in part 2
    - Start thinking about what you want to do
- Homework assignment #1 will be released soon

Atomic Commit

-Do you take each other?
  -I do.
  -I do.
-I now pronounce you atomically committed.

Slides by

Lorenzo Alvisi

EVIL LORENZO!

1. Evil Lorenzo Speaks French
2. And was born in Corsica
3. Went to Dartmouth instead of Cornell
4. Rides a Ducati instead of a Moto Guzzi
5. Still listens opera, but doesn't care for Puccini
5. Evil Lorenzo thinks that 2f+1 is good enough

Properties

Property: a predicate evaluated over a run of the program (also called a **trace**)

Example:
"every message that is received was previously sent"

Not everything you may want to say about a program is a property:
"the program sends an average of 50 messages in a run"

SAFETY PROPERTIES

- "nothing bad happens"
  - only one process can be in the critical section at any time
  - messages that are delivered are delivered in causal order
  - Windows never crashes
- A safety property is "prefix closed":
  - if it holds in a run, it holds in every prefix

LIVENESS PROPERTIES

- "something good eventually happens"
  - a process that wishes to enter the critical section eventually does so
  - some message is eventually delivered
  - Windows eventually boots
- Every run can be extended to satisfy a liveness property
  - if it doesn't hold in a run, that doesn't mean it may not hold eventually

Safety or Liveness?

Whenever process A wants to enter the critical section, then all other processes get to enter at most once before A gets to enter	Safety
This program terminates	Liveness
If this program eventually sends a message, it will be a well-formed HTTP request	Safety

A REALLY COOL THEOREM

Every property is a conjunction of a safety property and a liveness property

(Alpern & Schneider)

Atomic commit: the objective

Preserve data consistency for distributed transactions in the presence of failures

MODEL

- For each distributed transaction T:
  - one coordinator
  - a set of participants
- Coordinator knows participants; participants don't necessarily know each other
- Each process has access to a Distributed Transaction Log (DT Log) on stable storage

THE SETUP

- Each process p_i has an input value $vote_i$

$$vote_i \in \{Yes, No\}$$

- Each process p_i has an output value $decision_i$

$$decision_i \in \{Commit, Abort\}$$