Systèmes Distribués

Master MIAGE 1

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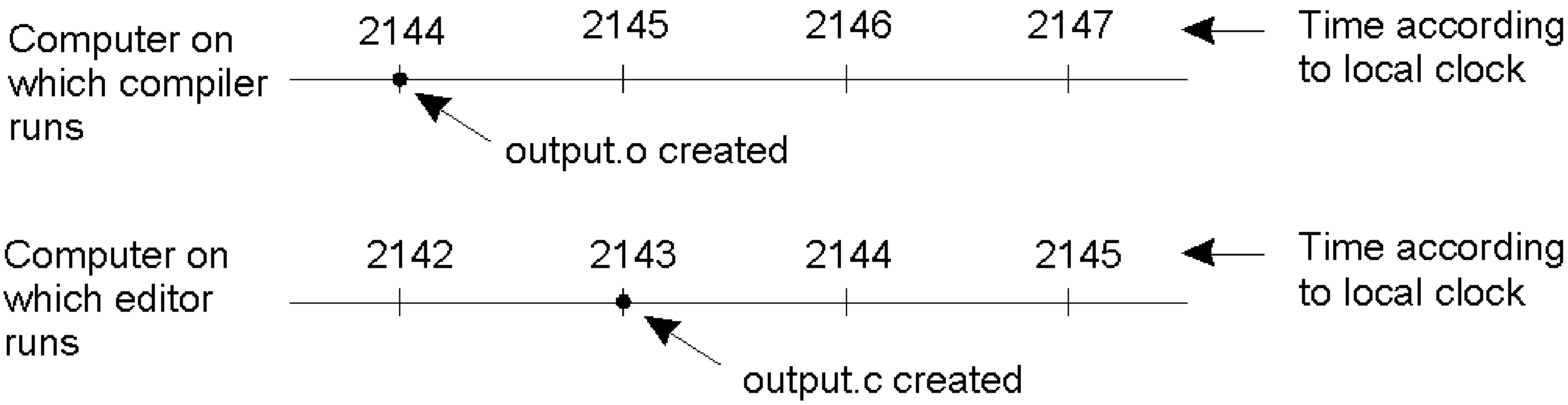
CM - Séance 5

Synchronisation

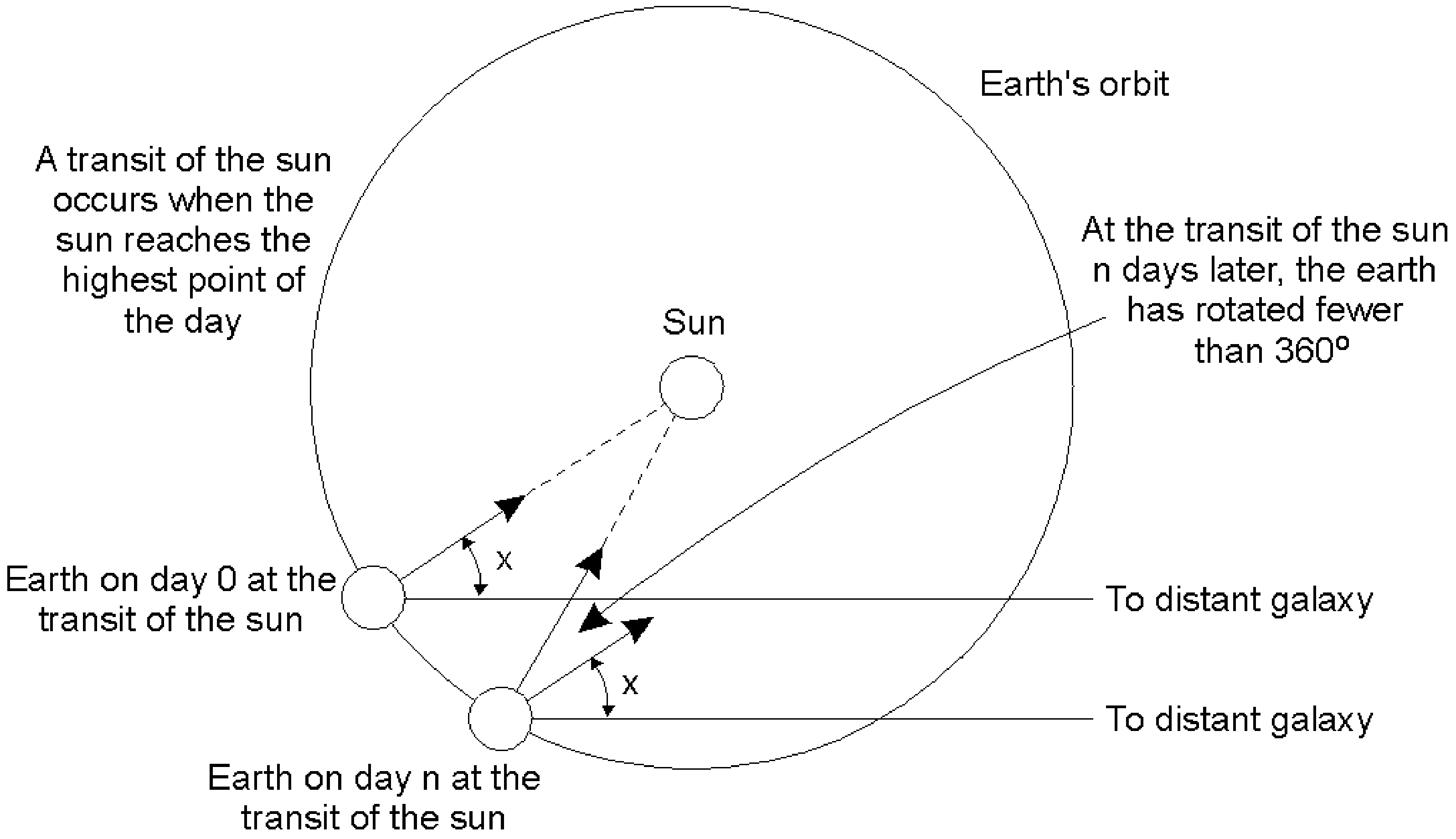
(chapitre 6)

Clock Synchronization


Computer on which compiler runs
2144
2145
2146
2147
Time according to local clock
output.o created
Computer on which editor runs
2142
2143
2144
2145
Time according to local clock
output.c created

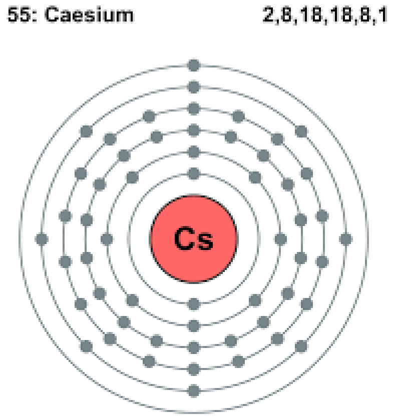
When each machine has its own clock, an event that occurred after another event may nevertheless be assigned an earlier time.

Physical Clocks (1)

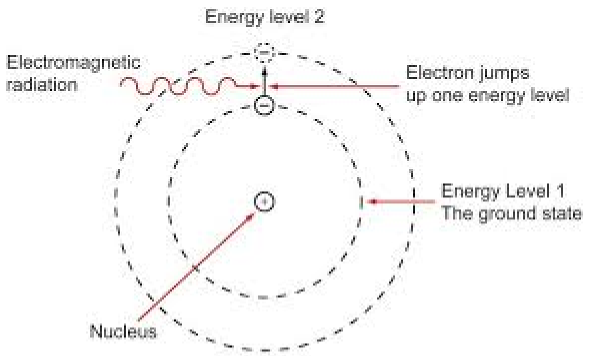

Earth's orbit
A transit of the sun occurs when the sun reaches the highest point of the day
Sun
At the transit of the sun n days later, the earth has rotated fewer than 360º
x
Earth on day 0 at the transit of the sun
To distant galaxy
x
To distant galaxy
Earth on day n at the transit of the sun

Computation of the mean solar day.

Horloges Atomiques



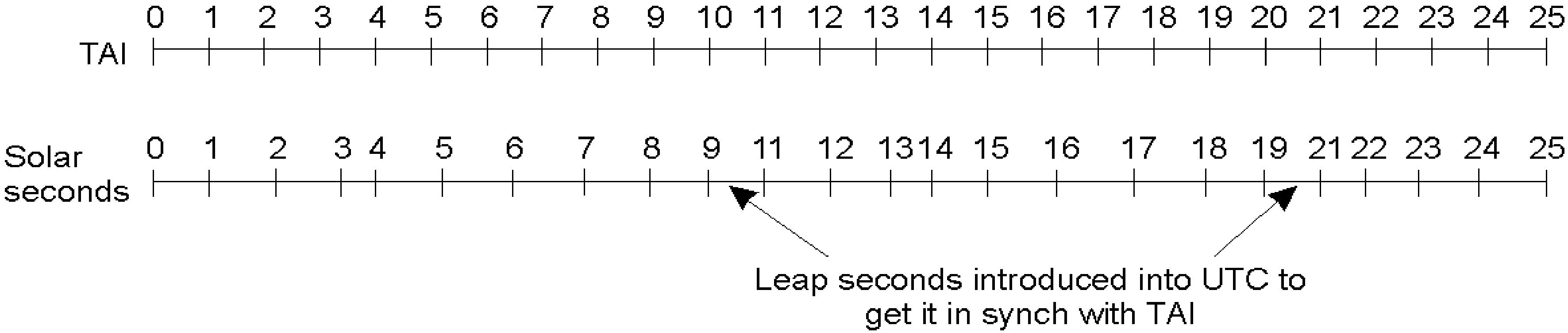
- ^{133}Cs (le seul isotope stable du césium)
- 1 s = 9 192 631 770 périodes de la radiation correspondant à la transition entre les deux niveaux hyperfins de l’état fondamental de l’atome de césium 133


Energy level 2
Electromagnetic radiation
Electron jumps up one energy level
Energy Level 1 The ground state
Nucleus

- Exactitude de 2×10^{-14} (soit une seconde sur 1 600 000 ans)
- Bureau International de l’Heure (BIH) de Paris

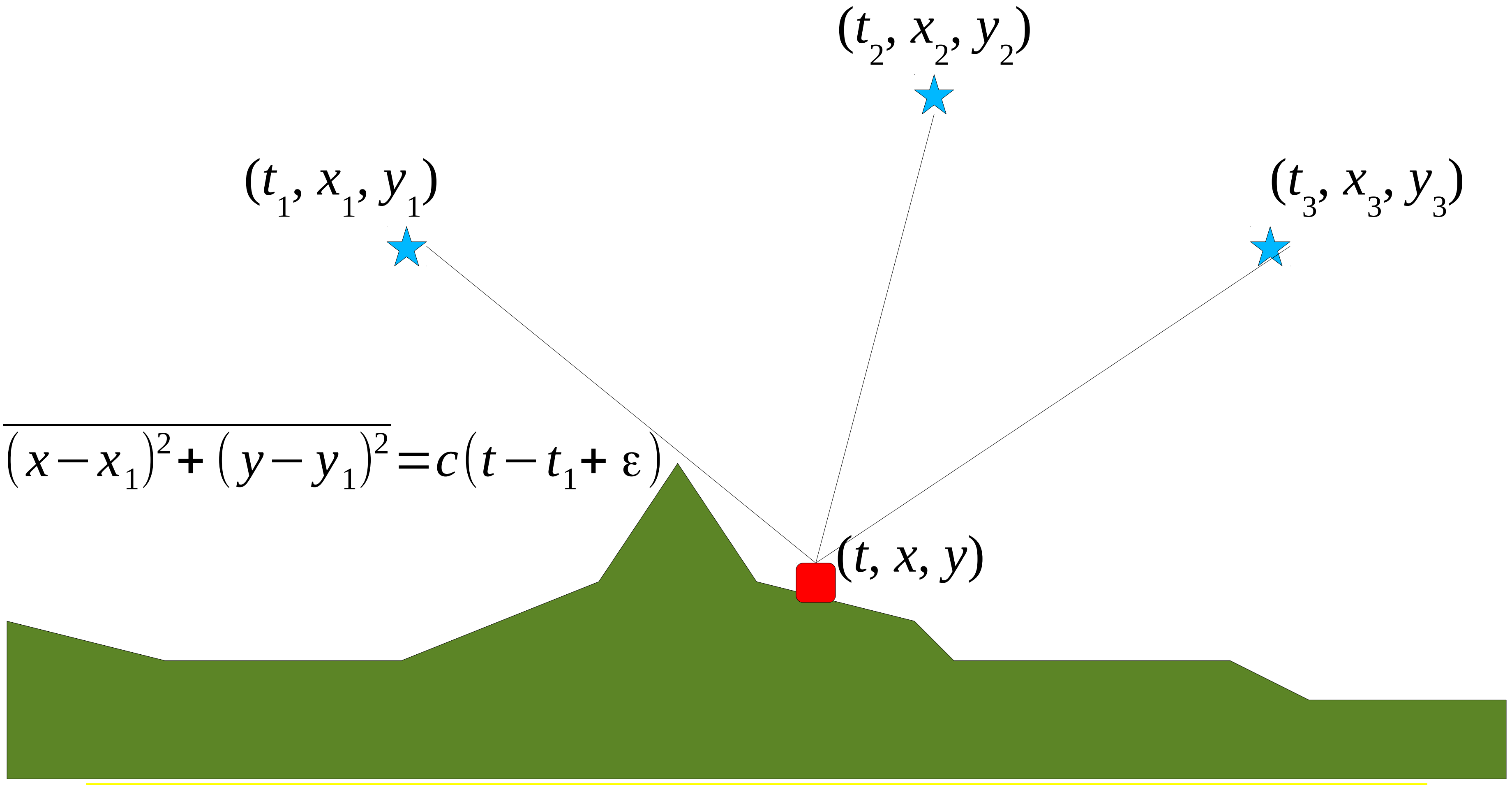
Physical Clocks (3)

Temps atomique international (TAI)



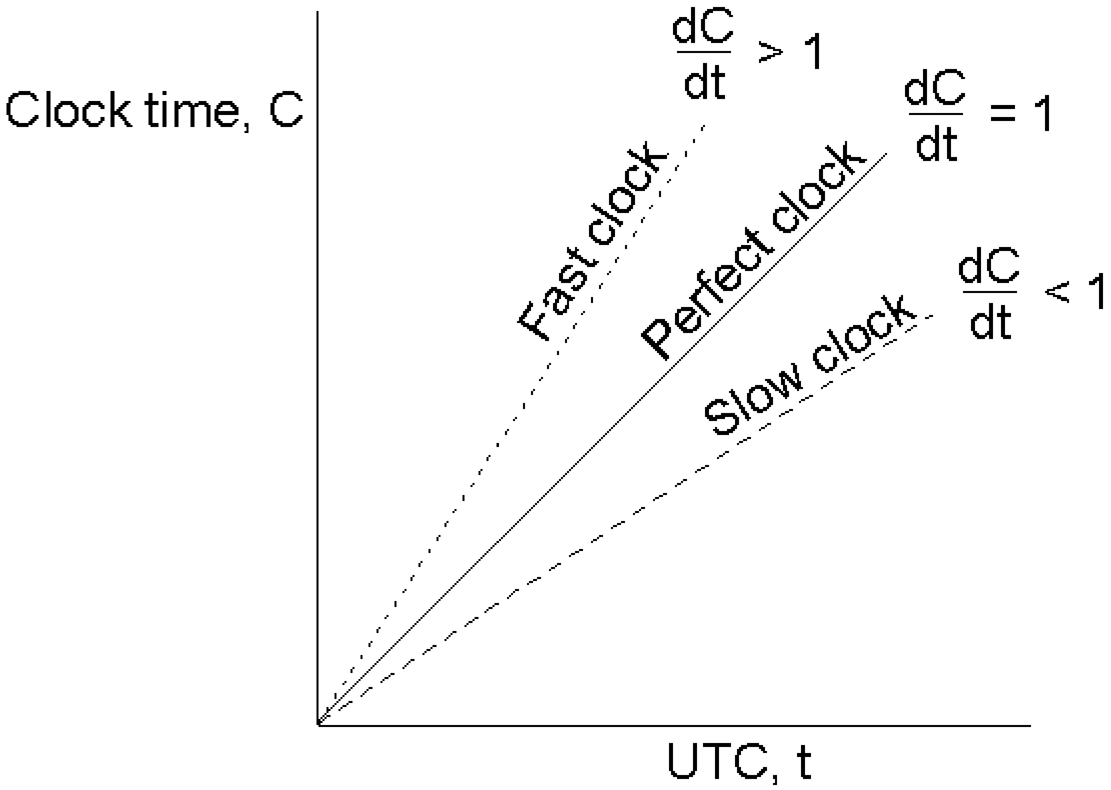
TAI seconds are of constant length, unlike solar seconds. Leap seconds are introduced when necessary to keep in phase with the sun.

Global Positioning System



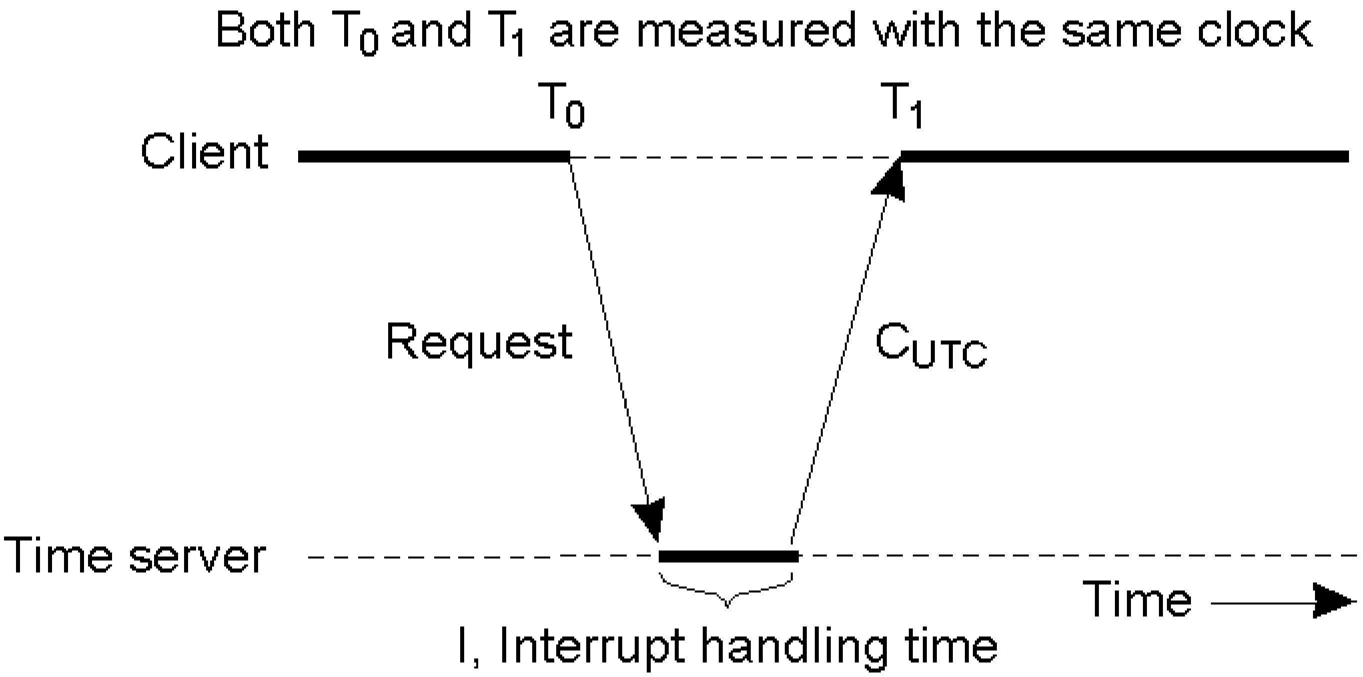
$$\sqrt{(x-x_1)^2+(y-y_1)^2}=c(t-t_1+\varepsilon)$$

Clock Synchronization Algorithms



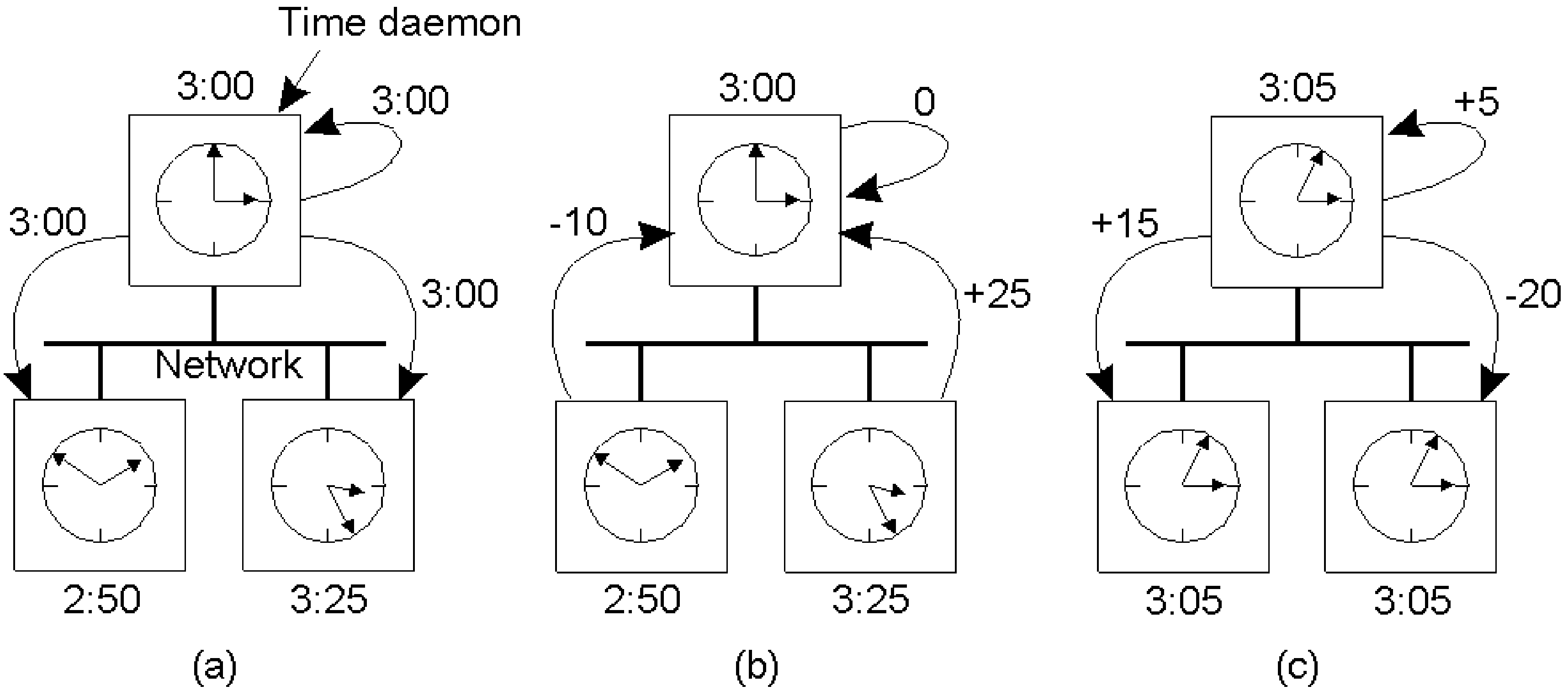
The relation between clock time and UTC when clocks tick at different rates.

Cristian's Algorithm


Both T_0 and T_1 are measured with the same clock
T_0
T_1
Client
Request
C_{UTC}
Time server
Time
I, Interrupt handling time

Getting the current time from a time server.

The Berkeley Algorithm



a) The time daemon asks all the other machines for their clock values

b) The machines answer

c) The time daemon tells everyone how to adjust their clock

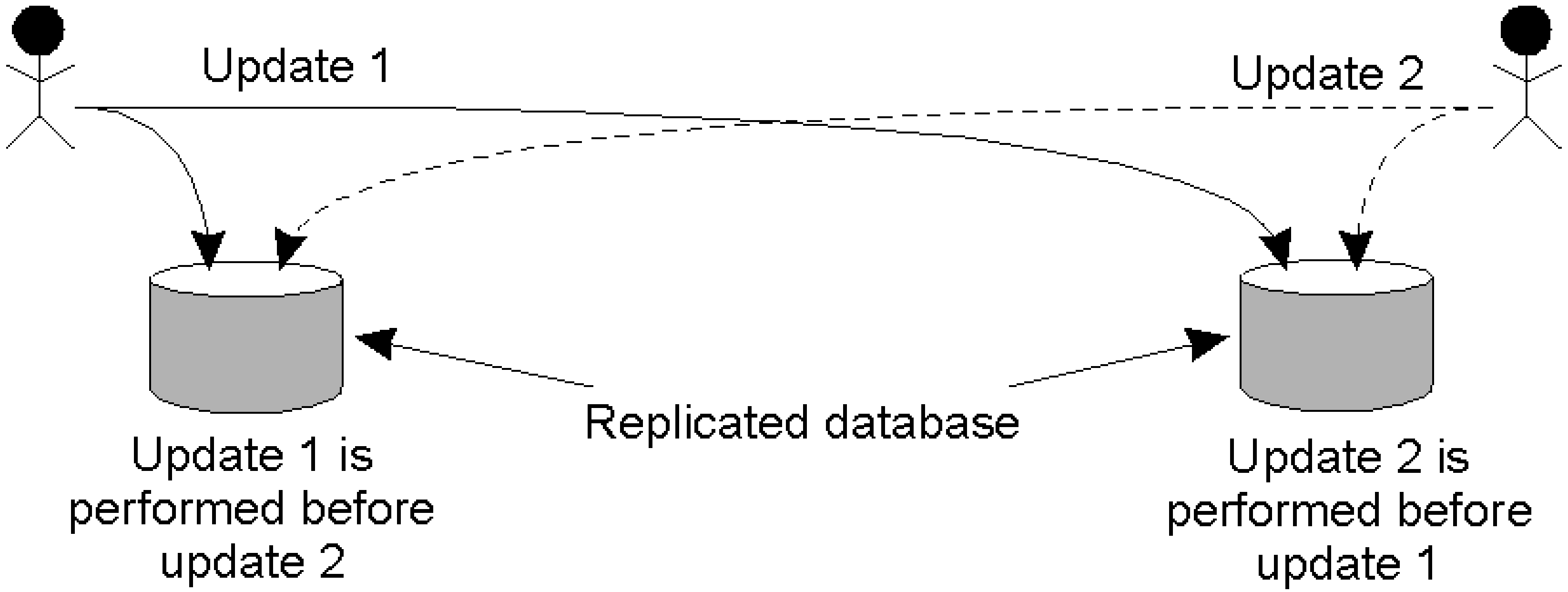
NTP

- Network Time Protocol (RFC 958 → RFC 5905)
- High-accuracy time synchronization for computers across the net
- In Unix : ntpd – NTP daemon, adjusts its own computer time
- Each daemon can be client, server, or peer for other daemons:
  - As client it queries reference time from one or more servers
  - As server it makes its own time available as reference time
  - As peer it compares its system time to other peers until all the peers finally agree about the "true" time to synchronize to
- Hierarchical time synchronization structure (strata)
- A daemon's stratum is the stratum of its time source + 1
- Radio clocks have a stratum number of 0

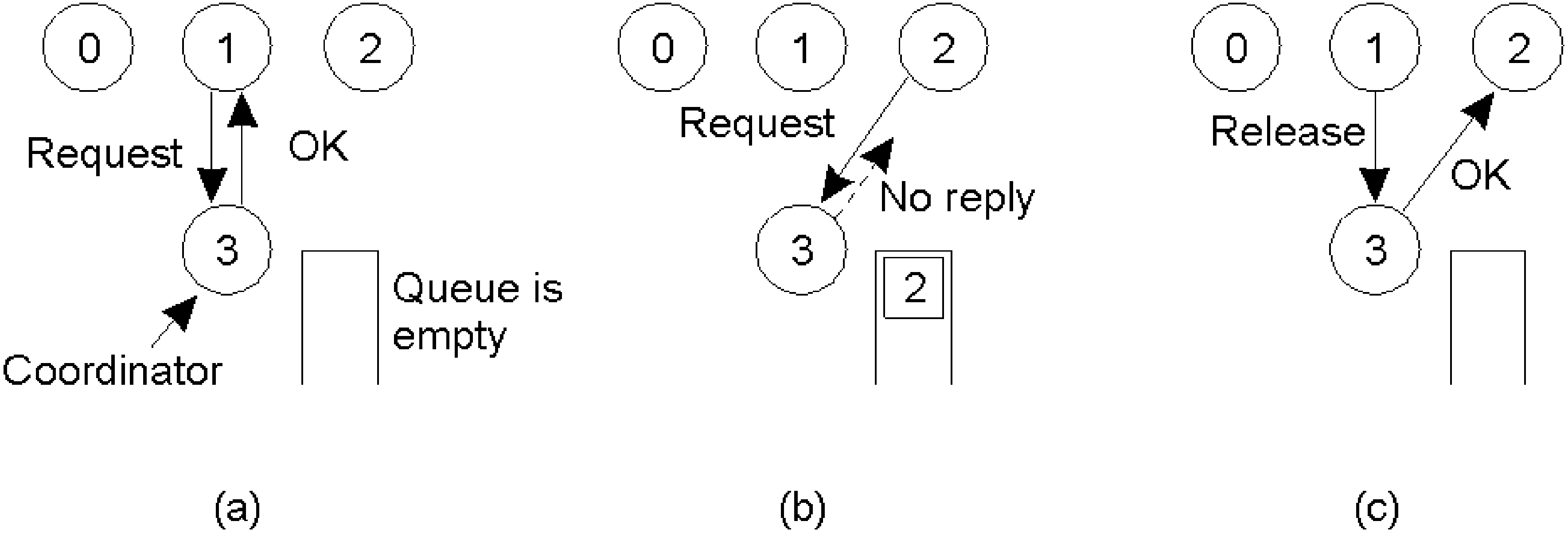
Lamport's Logical Clocks

- Relation →
  - If a and b are events in the same thread and a comes before b, then a → b
  - If a is the sending of a message by a thread and b is the receipt of the same message by a different thread, then a → b
- Clock Condition: for any events, a and b,
  - If a → b then C(a) < C(b)
- Implementation
  - Each thread increments its clock between any two successive events
  - A massage contains C(a) as its timestamp; upon receiving it, the receiving thread sets its clock to max{clock, C(a) + 1}

Lamport Timestamps


Update 1
Update 2
Replicated database
Update 1 is performed before update 2
Update 2 is performed before update 1

Mutual Exclusion: A Centralized Algorithm



a) Process 1 asks the coordinator for permission to enter a critical region. Permission is granted

b) Process 2 then asks permission to enter the same critical region. The coordinator does not reply.

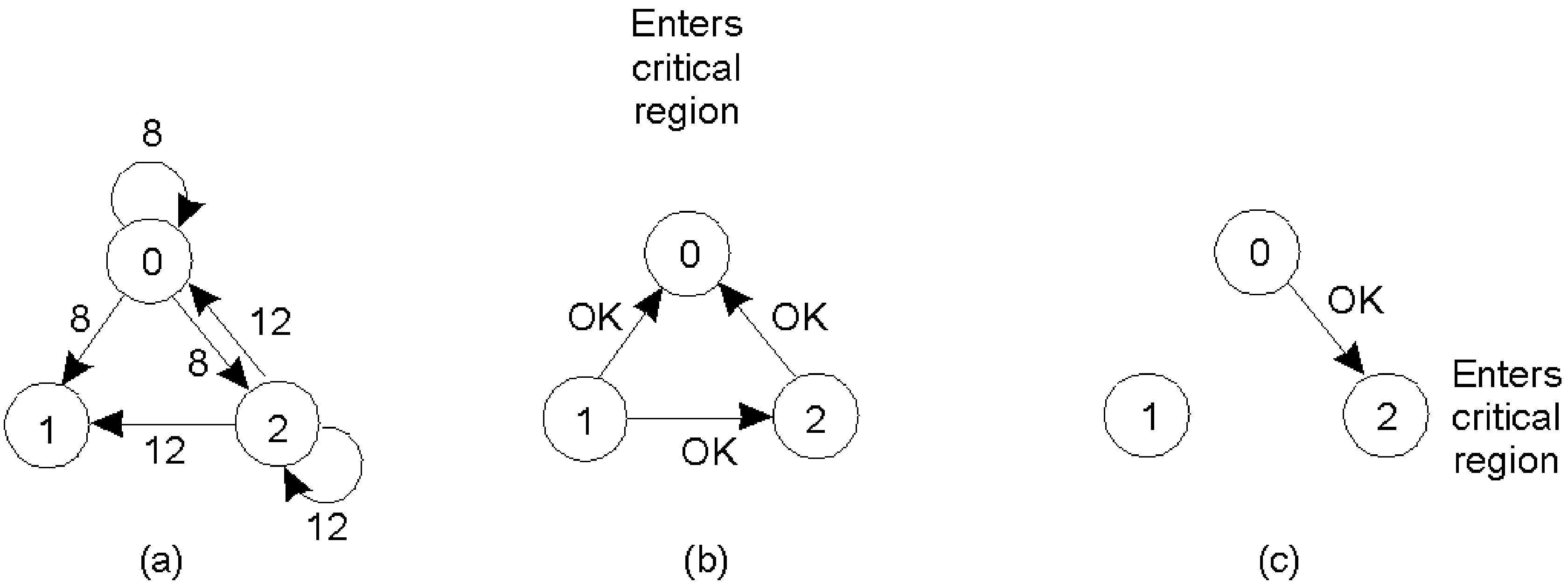
c) When process 1 exits the critical region, it tells the coordinator, when then replies to 2

A Decentralized Algorithm

- For each resource, *n* coordinators
- Access granted with *m* > *n*/2 authorizations
- Let *p* = prob that a coordinator resets in Δ*t*,
- P[k] = *k* coordinators reset

$$P[k] = \binom{m}{k} p^k (1-p)^{m-k}$$

A Distributed Algorithm

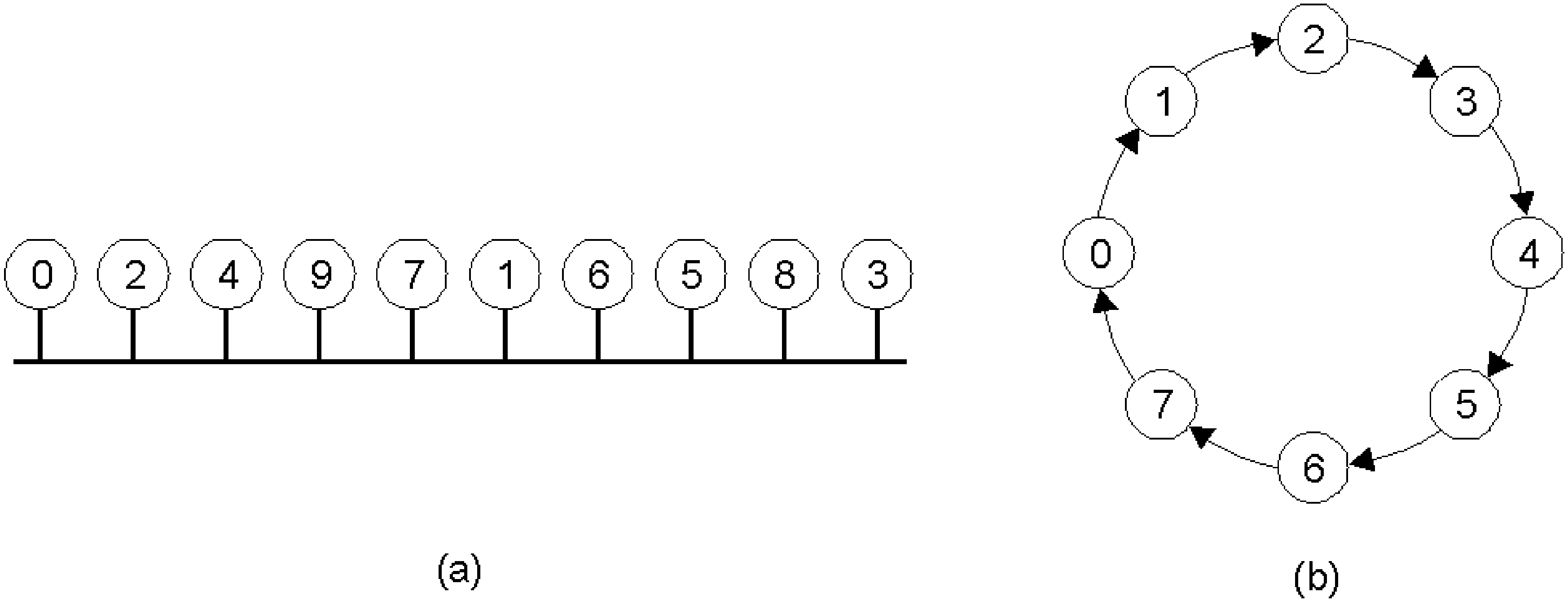


a) Two processes want to enter the same critical region at the same moment.

b) Process 0 has the lowest timestamp, so it wins.

c) When process 0 is done, it sends an OK also, so 2 can now enter the critical region.

A Token Ring Algorithm



a) An unordered group of processes on a network.

b) A logical ring constructed in software.

Comparison

Algorithm	Messages per entry/exit	Delay before entry (in message times)	Problems
Centralized	3	2	Coordinator crash
Distributed	2 (n – 1)	2 (n – 1)	Crash of any process
Token ring	1 to ∞	0 to n – 1	Lost token, process crash

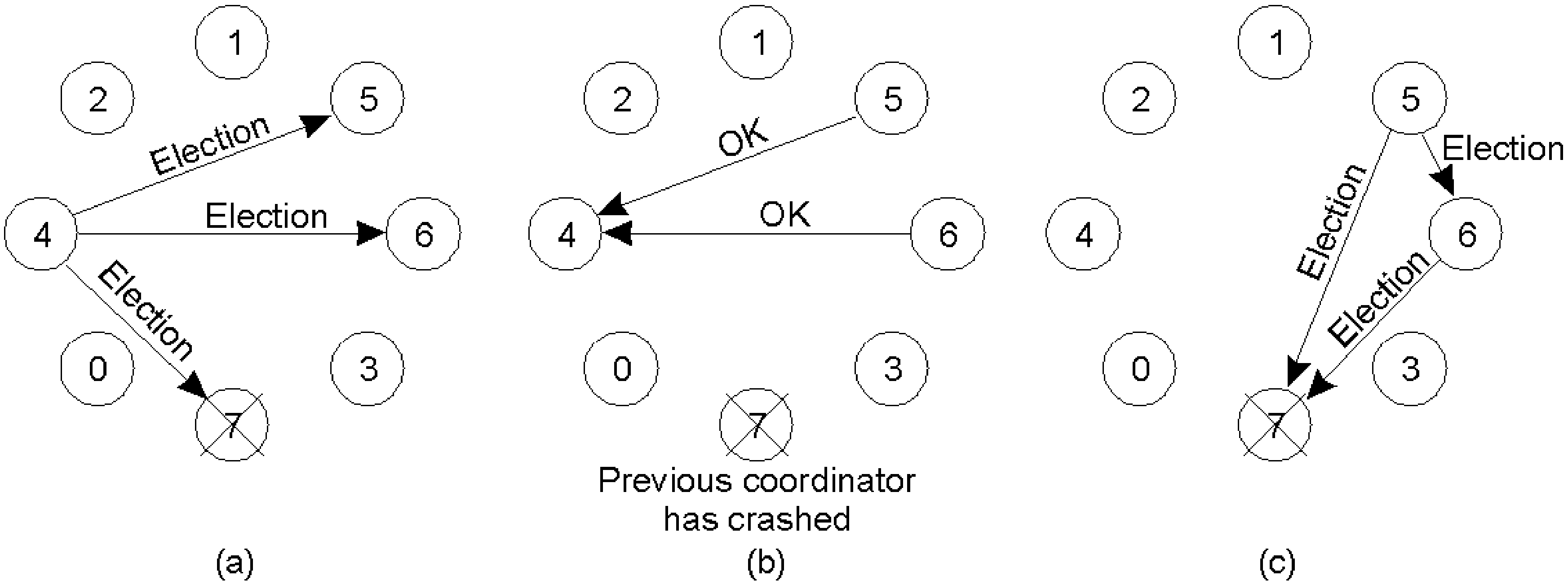
A comparison of three mutual exclusion algorithms.

Election Algorithms

- How is coordinator to be selected dynamically?
- N.B.: in some systems, chosen by hand (e.g., file server) → single point of failure

- Questions:
  - Centralized or decentralized?
  - Which one is more robust?

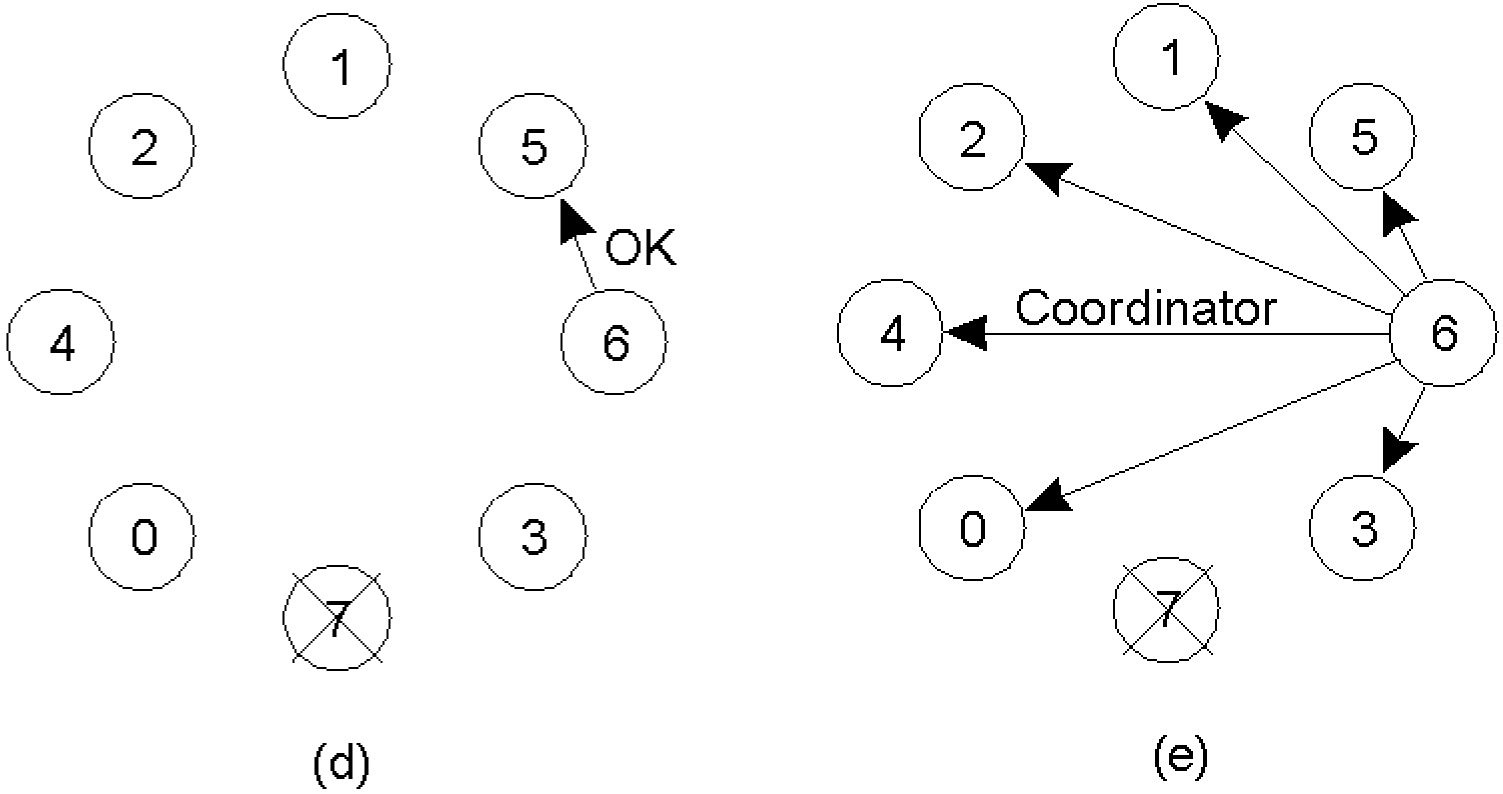
The Bully Algorithm (1)



The bully election algorithm

- Process 4 holds an election
- Process 5 and 6 respond, telling 4 to stop
- Now 5 and 6 each hold an election

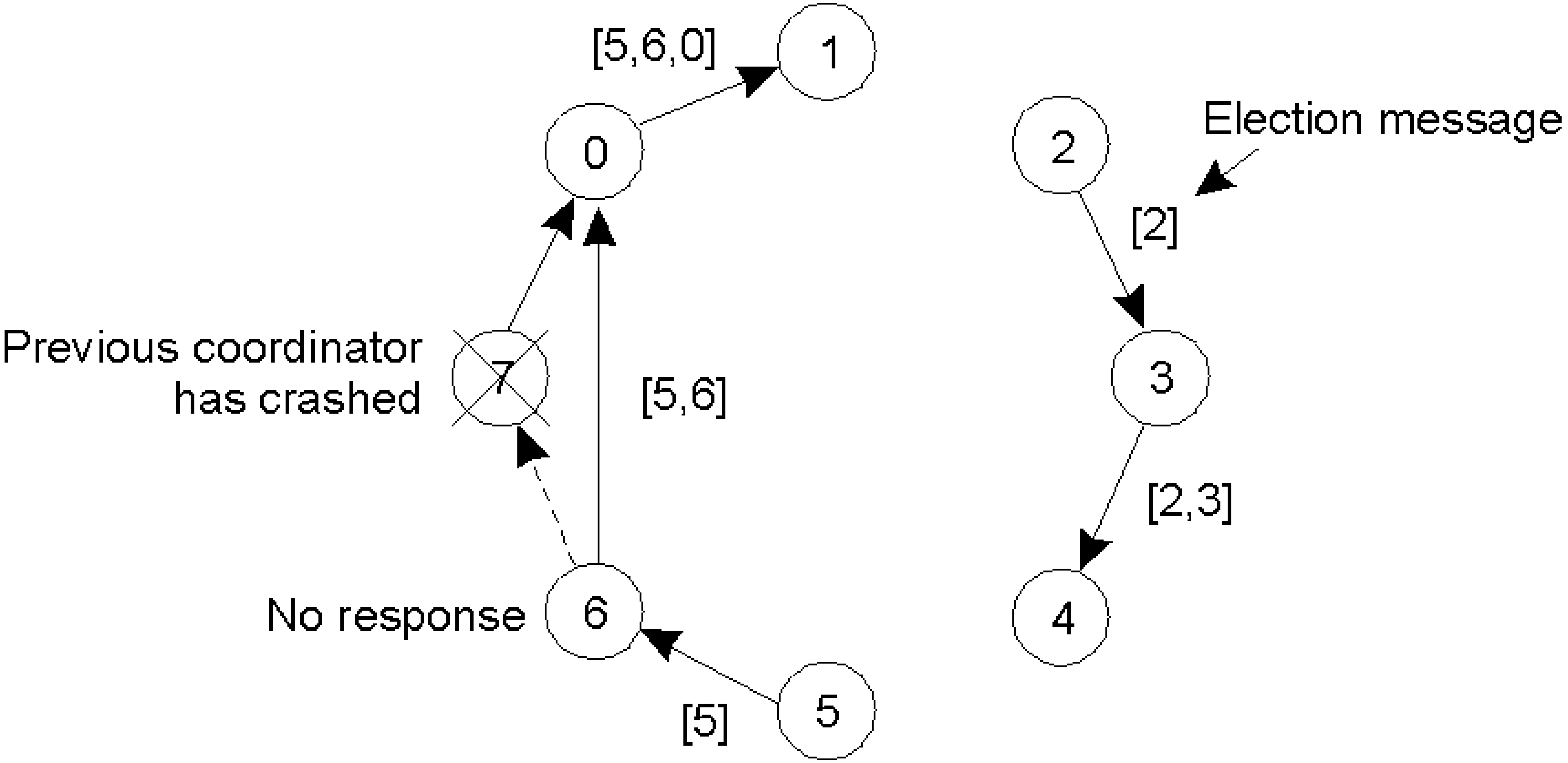
The Bully Algorithm (2)



a) Process 6 tells 5 to stop

b) Process 6 wins and tells everyone

A Ring Algorithm



Superpeer Election

- How can we select superpeers such that:
  - Normal nodes have low-latency access to them
  - Superpeers are evenly distributed
  - There is a predefined fraction of superpeers
  - Each superpeer does not serve more than a fixed number of normal nodes

Superpeer Election in DHTs

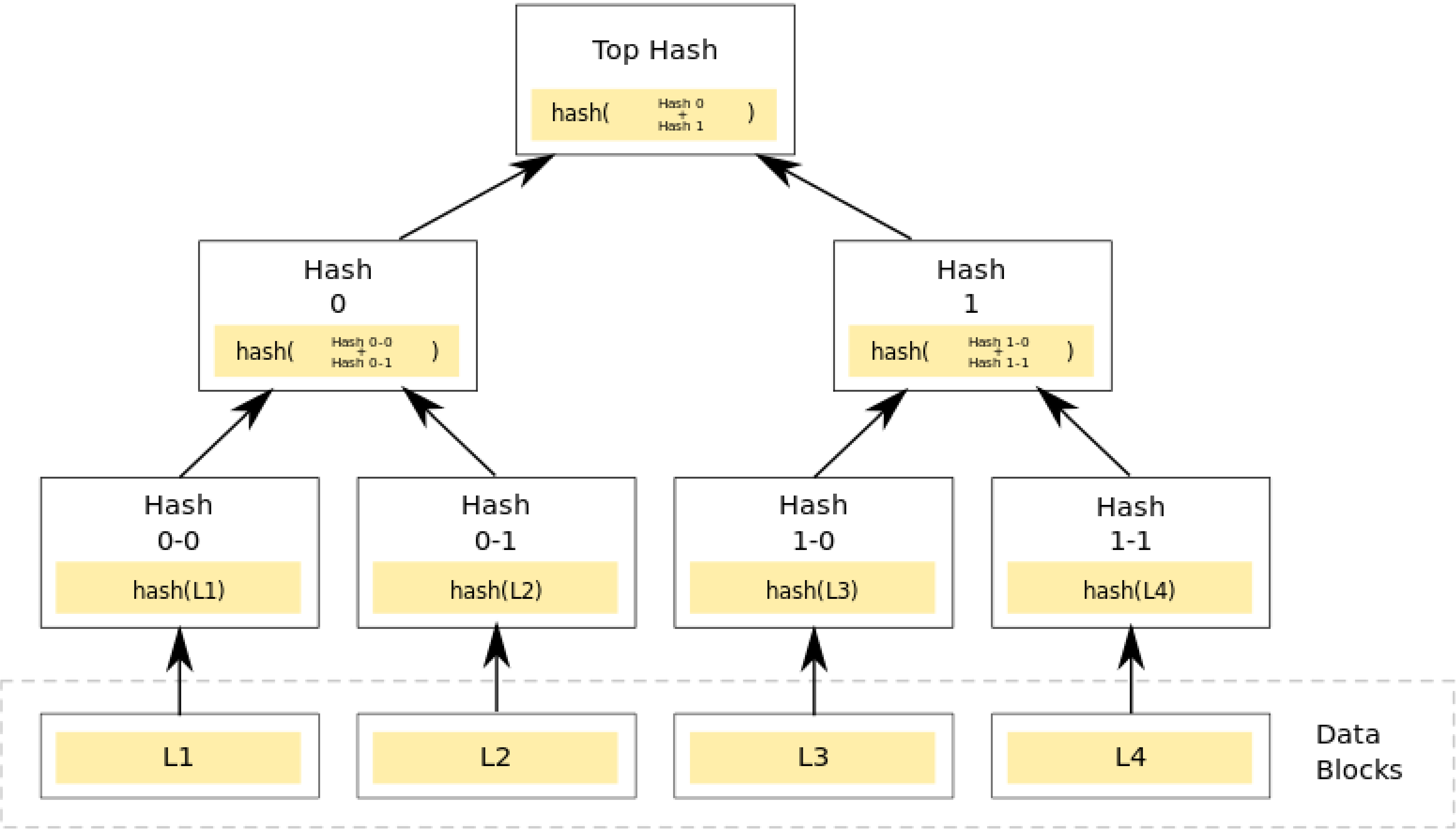
- Reserve a fixed part of ID space for superpeers
- S = desired number of superpeers
- m = bit-length of keys
- Reserve $k = \lceil \log_2 S \rceil$ bits for superpeers

- Routing to superpeers: send message for key p
- to node responsible for p & $\underbrace{11...11}_{k}00...00$

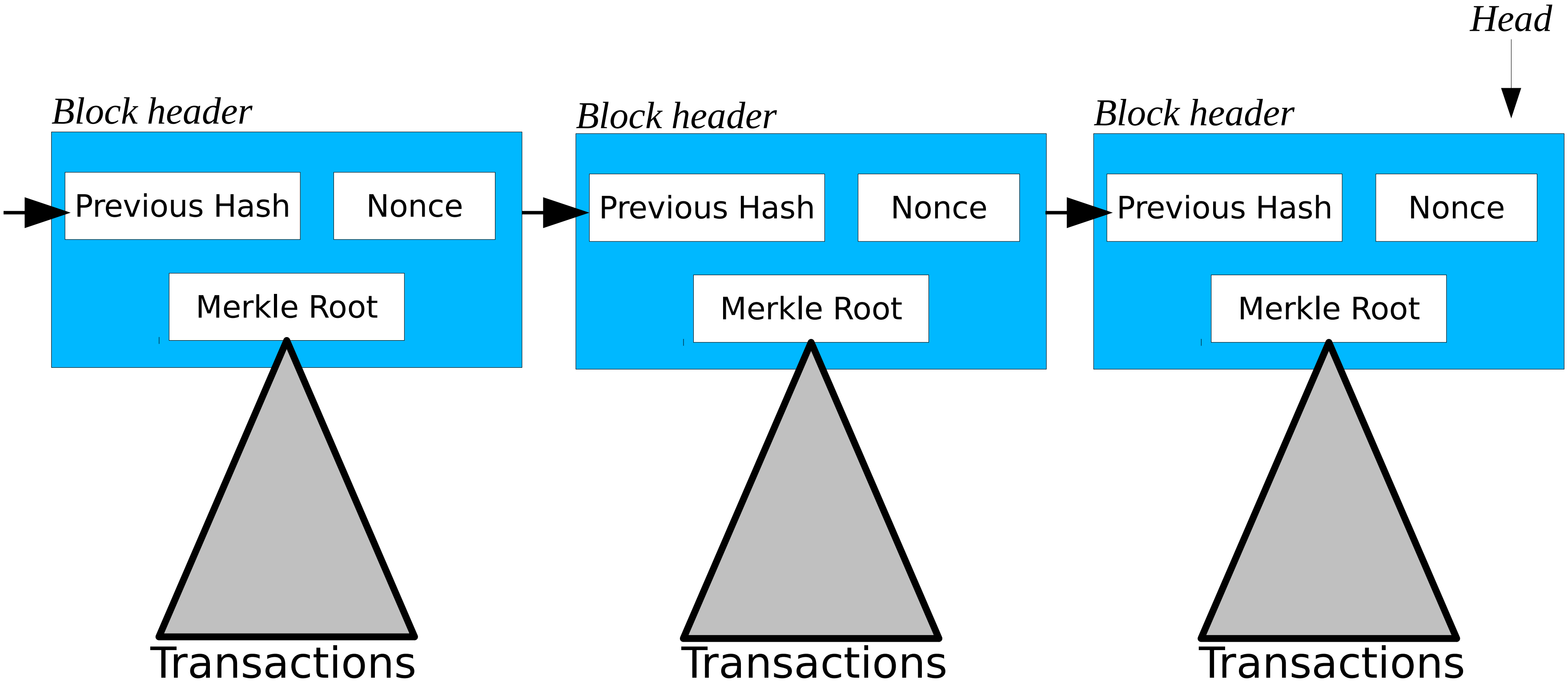
Bitcoin

- Bitcoin is the first fully decentralized cryptocurrency.
- The security properties of Bitcoin rely on blockchain technology, which is an open ledger containing all current and historical transactions in the system.
- The header of each block in a blockchain contains a Merkle root of the latest transactions, the hash value of the previous block header, and a nonce.
- Bitcoin relies on the SHA-2 cryptographic algorithm, in particular the sha256 32-bit hash function

Merkle Tree


Top Hash
hash(Hash 0 + Hash 1)
Hash 0
hash(Hash 0-0 + Hash 0-1)
Hash 1
hash(Hash 1-0 + Hash 1-1)
Hash 0-0
hash(L1)
Hash 0-1
hash(L2)
Hash 1-0
hash(L3)
Hash 1-1
hash(L4)
L1
L2
L3
L4
Data Blocks

Blockchain


Head
Block header
Previous Hash
Nonce
Merkle Root
Transactions
Block header
Previous Hash
Nonce
Merkle Root
Transactions
Block header
Previous Hash
Nonce
Merkle Root
Transactions

Mining Process

- Mining is the process of generating nonces, which are proofs of work (PoWs) derived from solving cryptographic puzzles.
- A miner must find a valid nonce as a PoW satisfying sha256(sha256(blkhdr)) < *t*, where
  - blkhdr refers to all data in a block header
  - *t* is a 256-bit number specified by the Bitcoin protocol, so it is more difficult to find a valid nonce given a smaller *t*.
  - The value of t is automatically adjusted by the Bitcoin system to keep the average duration of each round 10 minutes.
- When a miner finds a valid nonce and generates a new block, this block is broadcast to every node in the Bitcoin network.
- All nodes receiving it regard it as the new head of the blockchain.

Forks

- If two miners build and broadcast two different valid blocks, a node may consider the block first received as the new head.
- Because of different network latencies, more than two heads can exist at the same time. This situation is called a **fork**.
- By appending a subsequent block to only one branch in the fork, the branch is defined as valid, while all others are invalidated.
- The PoW uses the one-CPU-one-vote principle to solve the problem of majority decision making representation.
- The majority decision is represented by the longest chain, which has the greatest PoW effort invested in it.
- If a majority of CPU power is controlled by honest nodes, the honest chain will grow the fastest and outpace any other chain.

Merci de votre attention