Clock Synchronization

Computer on which compiler runs — 2144 2145 2146 2147 ← Time according to local clock

output.o created

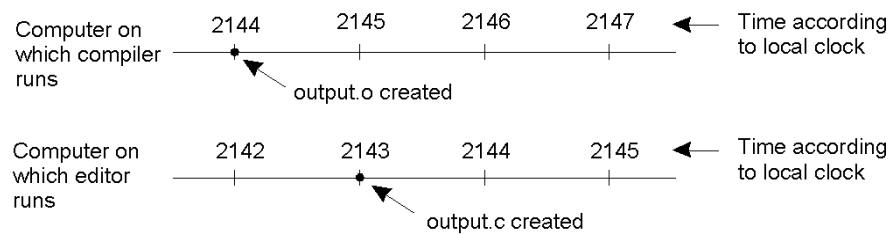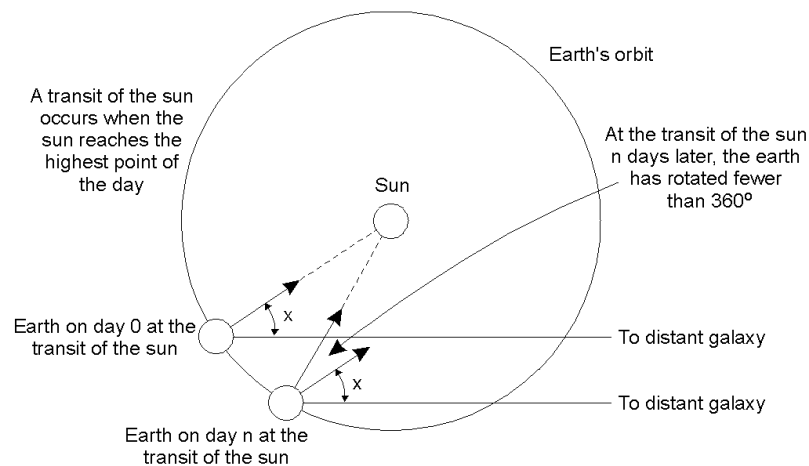Computer on which editor runs — 2142 2143 2144 2145 ← Time according to local clock
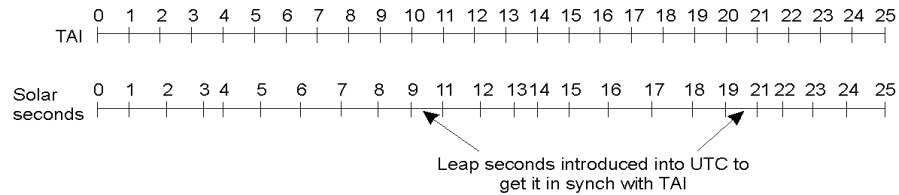
output.c created

When each machine has its own clock, an event that occurred after another event may nevertheless be assigned an earlier time.
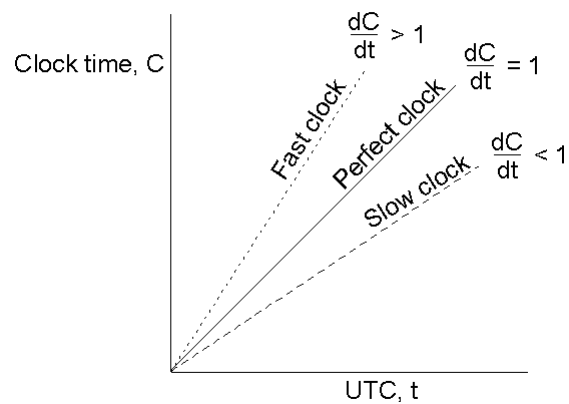
Physical Clocks (1)

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 360°

Earth on day 0 at the transit of the sun

x

To distant galaxy

x

To distant galaxy

Earth on day n at the transit of the sun

Computation of the mean solar day.

Physical Clocks (2)

```
           0  1  2  3  4  5  6  7  8  9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25
   TAI    ├──┼──┼──┼──┼──┼──┼──┼──┼──┼──┼──┼──┼──┼──┼──┼──┼──┼──┼──┼──┼──┼──┼──┼──┼──┤

           0  1  2  3 4  5   6   7   8  9  11  12  1314 15   16   17   18  19 2122 23 24 25
 Solar    ├──┼──┼──┼─┼──┼───┼───┼───┼──┼──▼──┼───┼──┼──┼───┼───┼───┼──┼──▼──┼──┼──┼──┤
 seconds
```

Leap seconds introduced into UTC to
get it in synch with TAI

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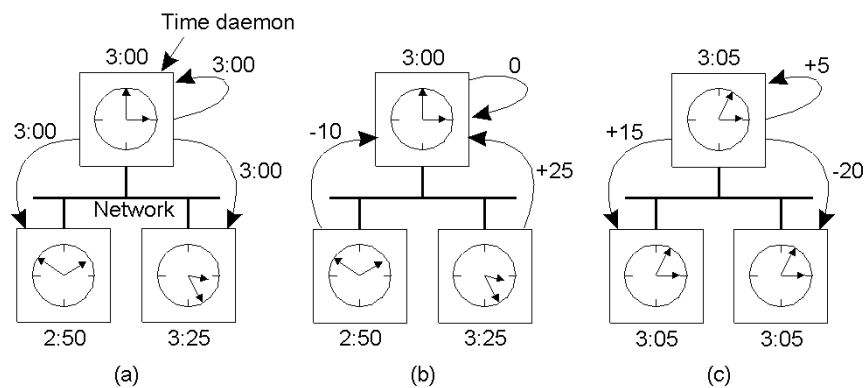
Clock Synchronization Algorithms

Clock time, C

$\frac{dC}{dt} > 1$

$\frac{dC}{dt} = 1$

$\frac{dC}{dt} < 1$

Fast clock

Perfect clock

Slow clock

UTC, t

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

Cristian's Algorithm
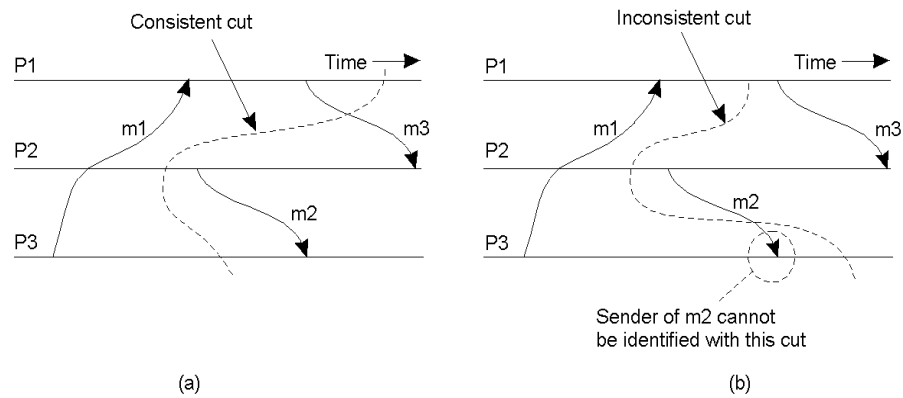
Both T_0 and T_1 are measured with the same clock
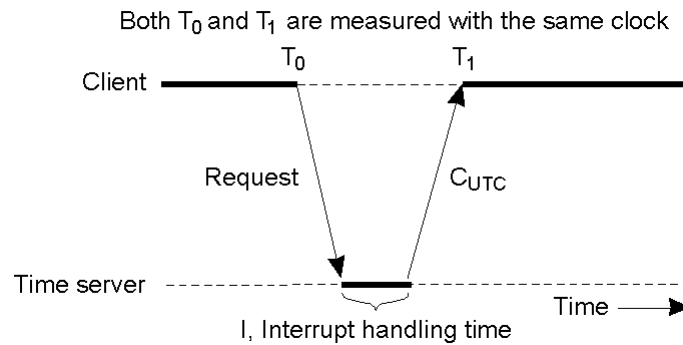
Getting the current time from a time server.

The Berkeley Algorithm
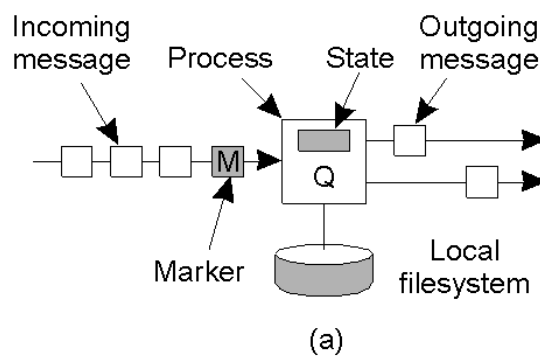
a) The time daemon asks all the other machines for their clock values
b) The machines answer
c) The time daemon tells everyone how to adjust their clock

Global State (1)

Consistent cut

P1   Time

m1   m3

P2

m2

P3

Inconsistent cut

P1   Time

m1   m3

P2

m2

P3

Sender of m2 cannot
be identified with this cut

(a)   (b)

    a)   A consistent cut
    b)   An inconsistent cut

Global State (2)

Incoming
message   Process   State   Outgoing
message

M   Q

Marker   Local
filesystem

(a)

    a)   Organization of a process and channels for a distributed
        snapshot

Global State (3)

(b)	(c)	(d)

Recorded state
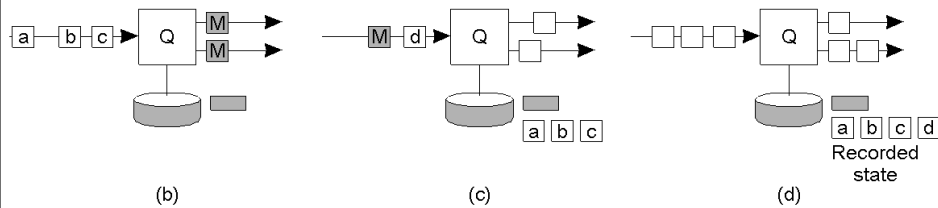
b) Process Q receives a marker for the first time and records its local state
c) Q records all incoming message
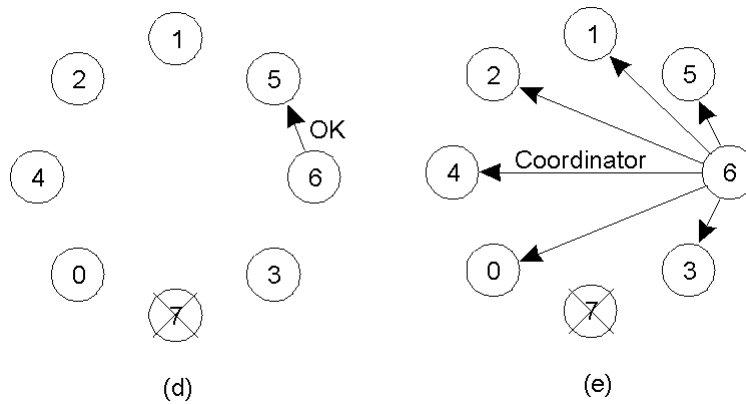d) *Q receives a marker for its incoming channel and finishes recording the state of the incoming channel*

The Bully Algorithm (1)

(a)	(b)	(c)

Previous coordinator has crashed
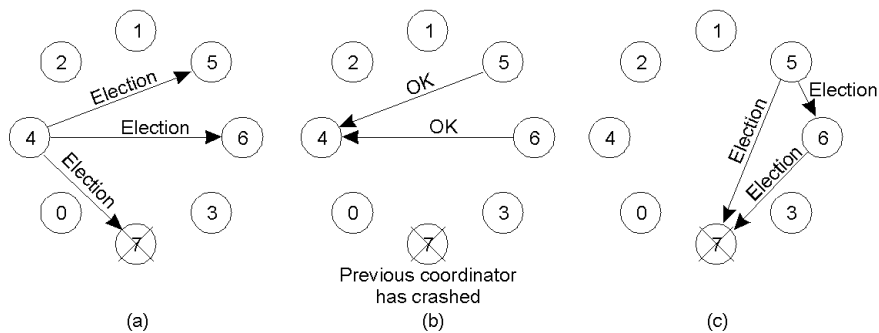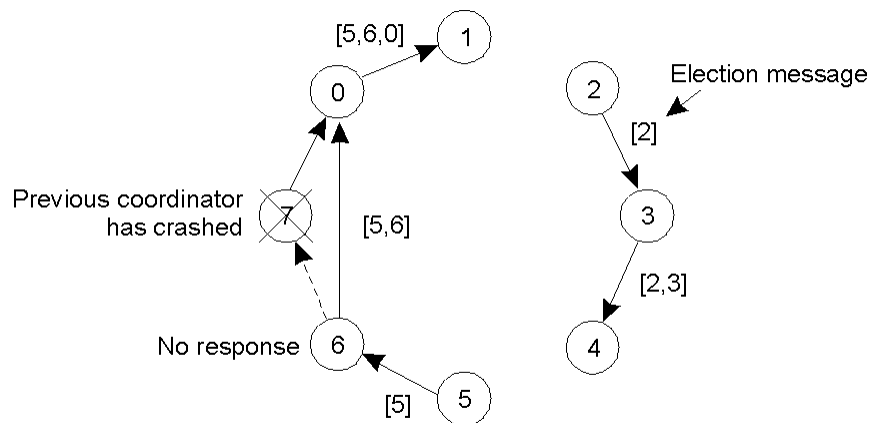
The bully election algorithm
- Process 4 holds an election
- Process 5 and 6 respond, telling 4 to stop
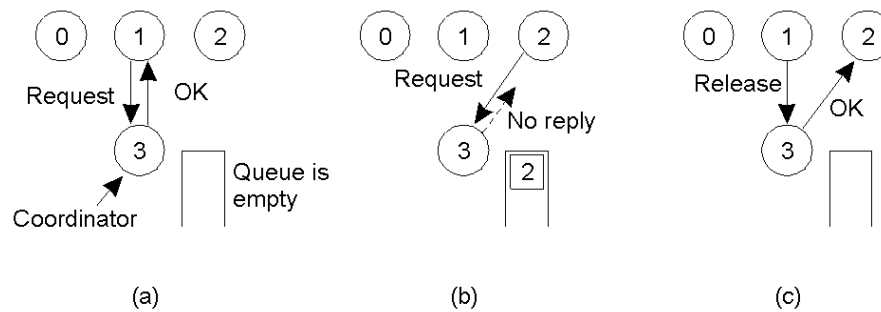- Now 5 and 6 each hold an election

Global State (3)

d) Process 6 tells 5 to stop
e) Process 6 wins and tells everyone

A Ring Algorithm

Election algorithm using a ring.

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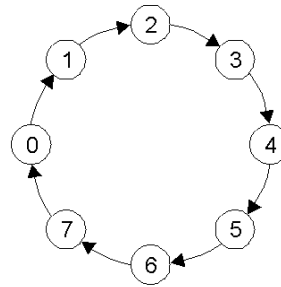
A Distributed Algorithm
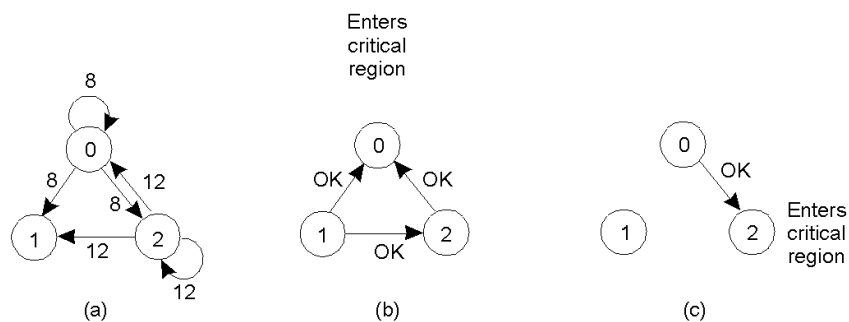
a) Two processes want to enter the same critical region at the same moment.

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 Toke Ring Algorithm
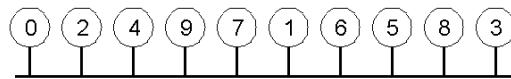
(a)

(b)

a)   An unordered group of processes on a network.
b)   A logical ring constructed in software.