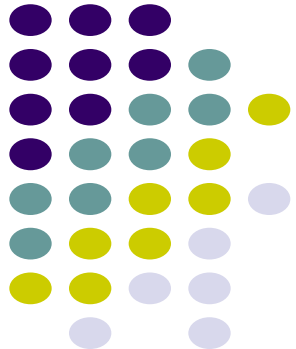
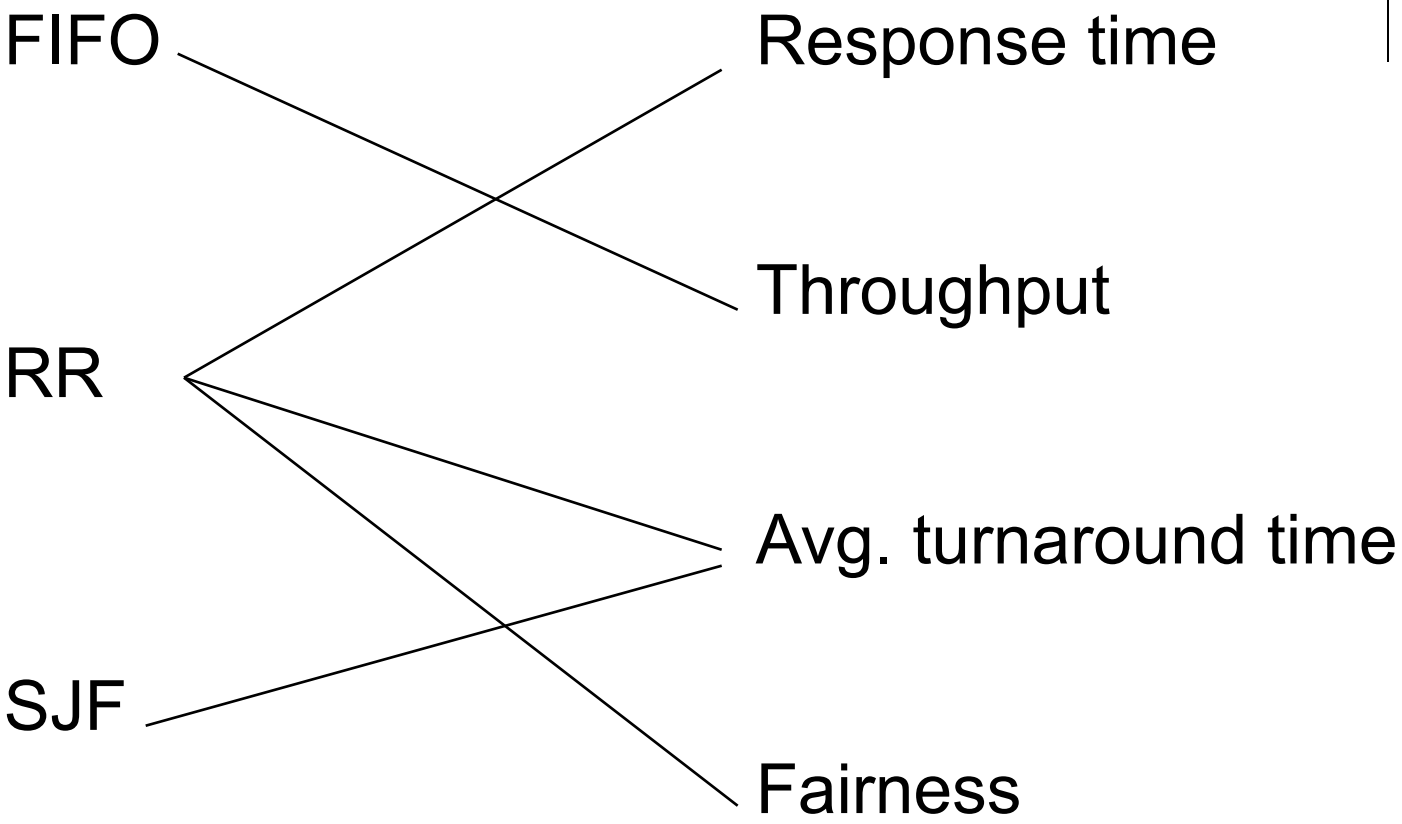
More Scheduling and Interprocess communication

ECE 469, Feb 20

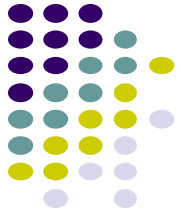
Aravind Machiry



Recap: Scheduling Policies Advantages



Priority Scheduling

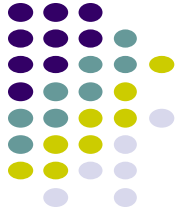


- To accommodate the spirits of SJF/RR/FIFO
- The method
  - Assign each process a *priority*
  - Run the process with highest priority in ready queue first
    - Use FIFO for processes with equal priority
  - Adjust priority dynamically
    - To deal with *all* issues: e.g. aging, I/O wait raises priority

Priority Scheduling

- Who sets the priorities
  - Internally by OS
    - I/O to computation ratio (can be dynamic)
    - Memory requirement (can be dynamic)
    - Time constraints (e.g. real-time systems)
  - Externally by users/sysadm
    - Importance
    - Funds paid for
    - Being nice
- Dynamically adjusting priority is tricky

Priority Scheduling



- Advantages
  - Flexibility.

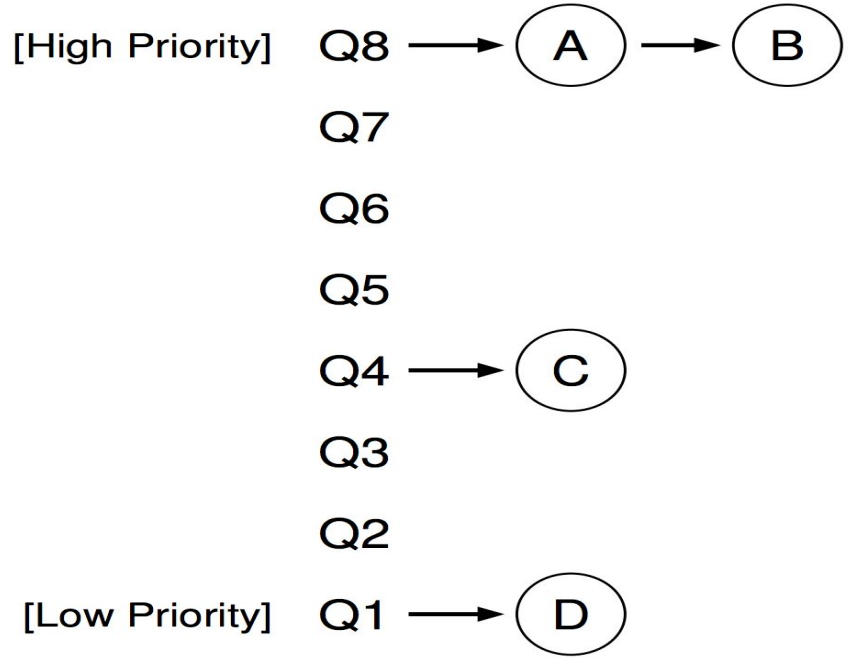
- Disadvantages
  - Starvation: A low priority process might never get to run.

Multiple Queue Scheduling

- Maintain multiple queues of different priorities.
  - Background queue vs Foreground queue

- Prefer jobs in higher priority queues.

Multiple Queue Scheduling



Multiple Queue Scheduling

- Challenges:
  - How to assign process to queues?
  - How to schedule processes within a queue?
  - How to switch between queues?

Multiple Queue Scheduling

- How to assign processes to queues?
  - Based on User:
    - Sysadmin vs Regular user
  - Based on Type:
    - Foreground vs. background.

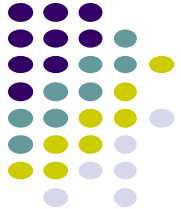
Multiple Queue Scheduling

- How to schedule processes within a queue?
  - All queues have same scheduling policy.
  - Scheduling policy varies with queues:
    - Foreground queue - Need to be responsive:
      - Round Robin
    - Background queue - Shorter turnaround time:
      - SJF

Multiple Queue Scheduling

- How to switch between queues?
  - Fixed priority preemptive scheduling (high-pri queue trumps other)
  - Time-slice between queues

Multiple Queue Scheduling



- Pros:

Multiple Queue Scheduling

- Pros:
  - Low scheduling overhead
    - Jobs do not move across queues

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- Cons:

Multiple Queue Scheduling

- Pros:
  - Low scheduling overhead
    - Jobs do not move across queues

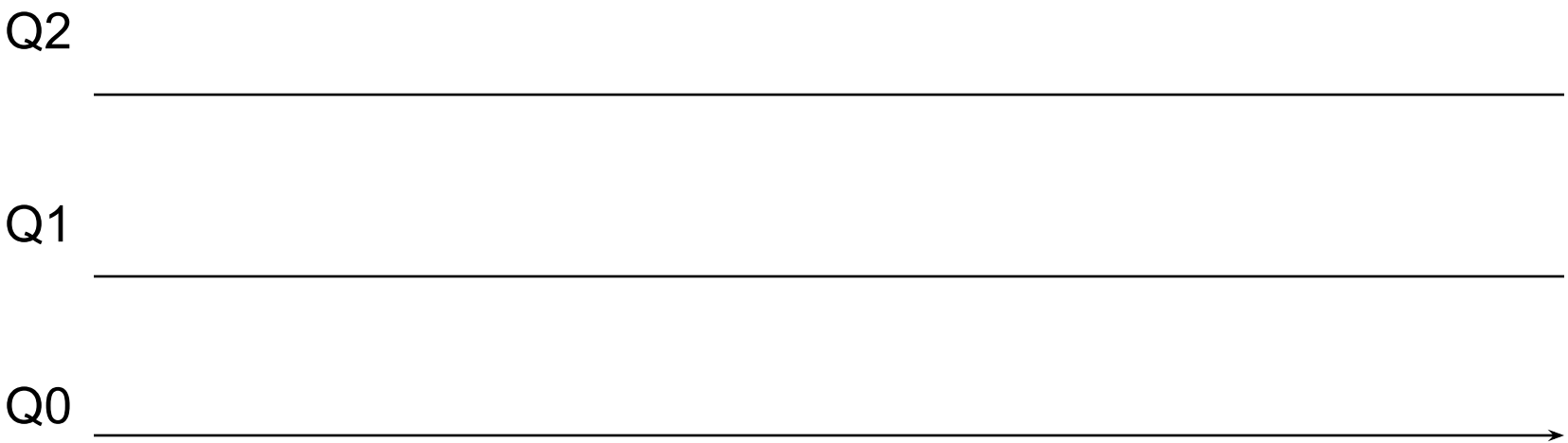
- Cons:
  - Processes permanently assigned to one queue – not flexible
    - Program behavior may change
    - E.g. can switch between I/O bound and CPU bound
    - Need some learning/adaptation at runtime

  - Starvation cannot be easily handled
    - Need some learning/adaptation at runtime

Multilevel Feedback Queue (MLFQ)

- Problem: how to change priority?
- Jobs start at highest priority queue
- Feedback
  - Priority Decreases: If a job uses up an entire time slice while running, its priority is reduced (i.e., it moves down one queue).
  - Priority Unchanged: If a job gives up the CPU before the time slice is up, it stays at the same priority level.
  - Priority Increases: After a long time period, move all the jobs in the system to the topmost queue (aging)

Multilevel Feedback Queue (MLFQ)



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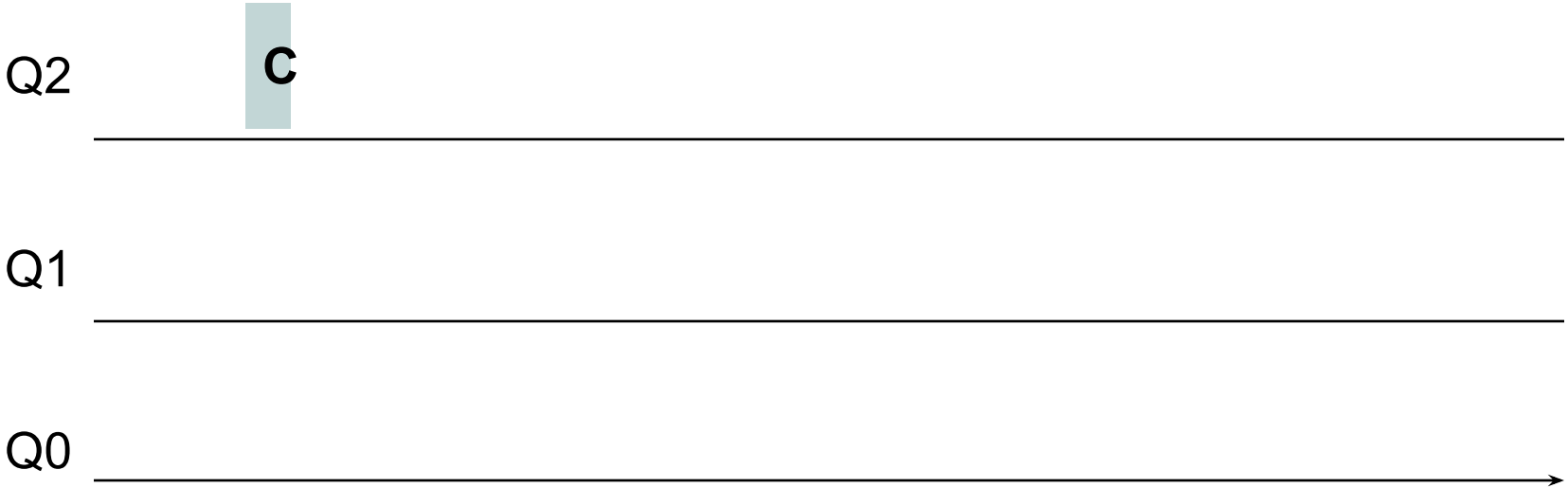

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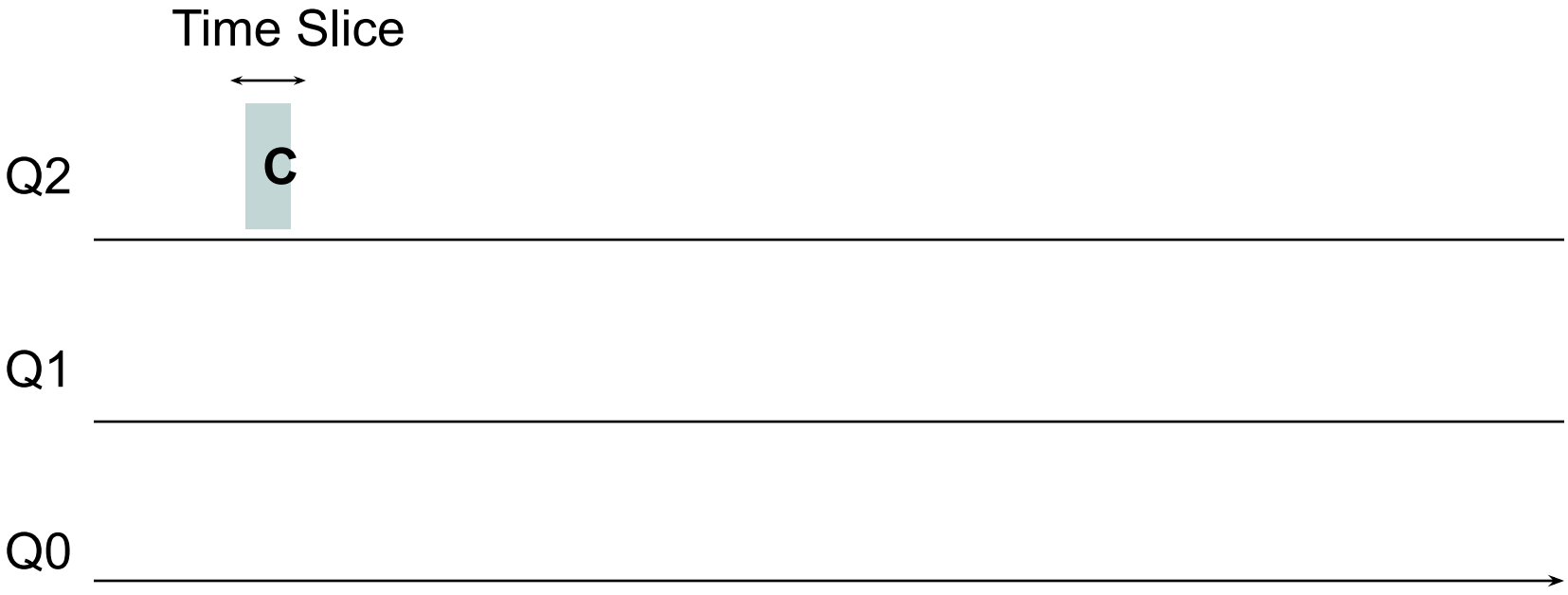

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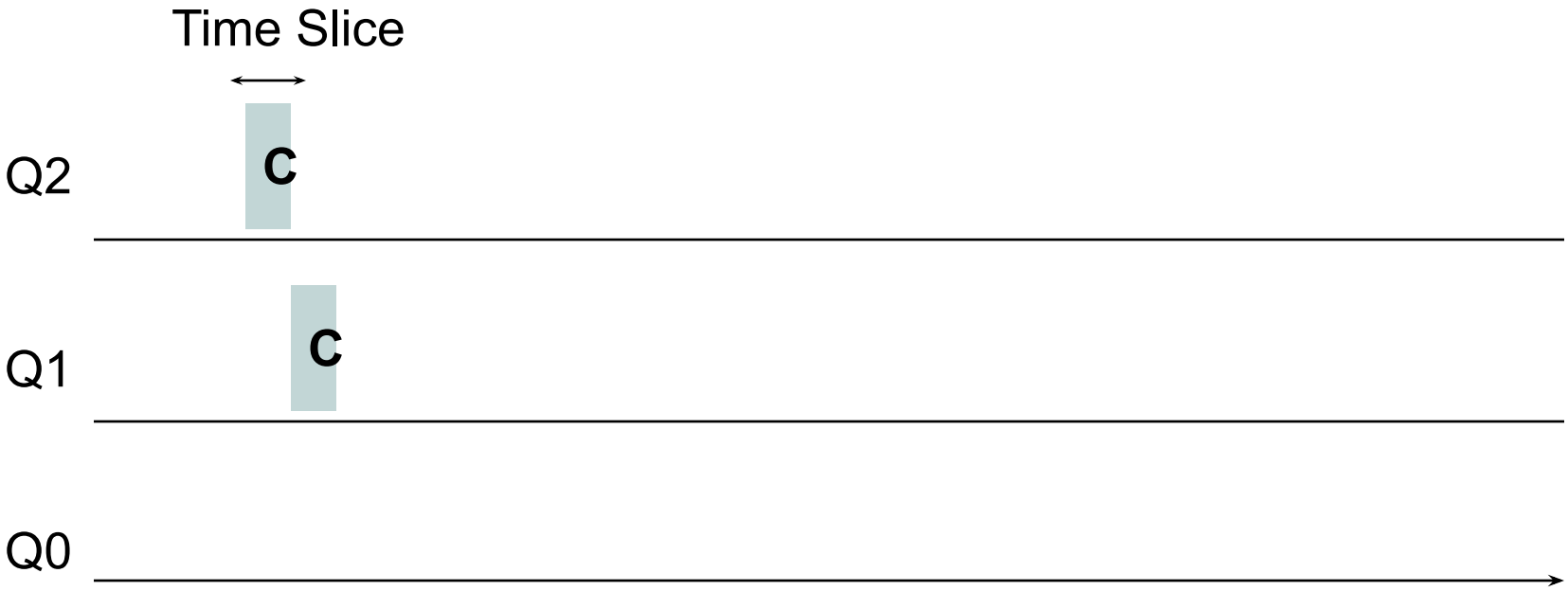

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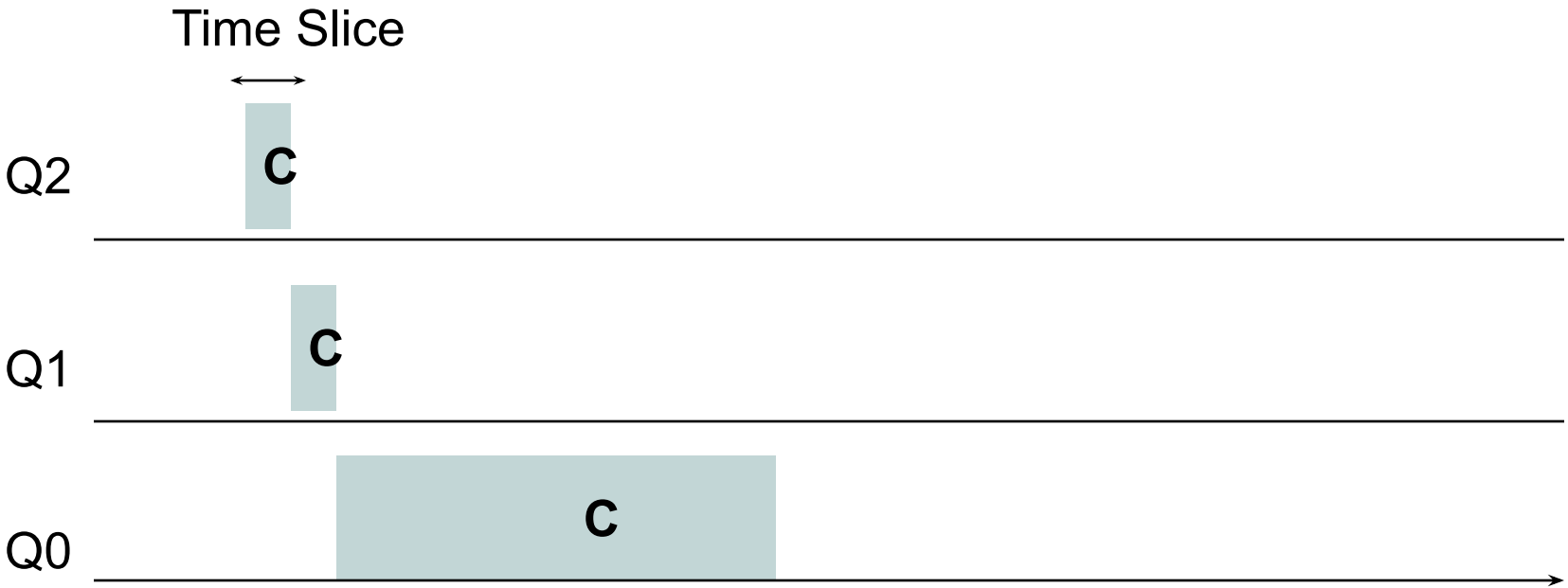
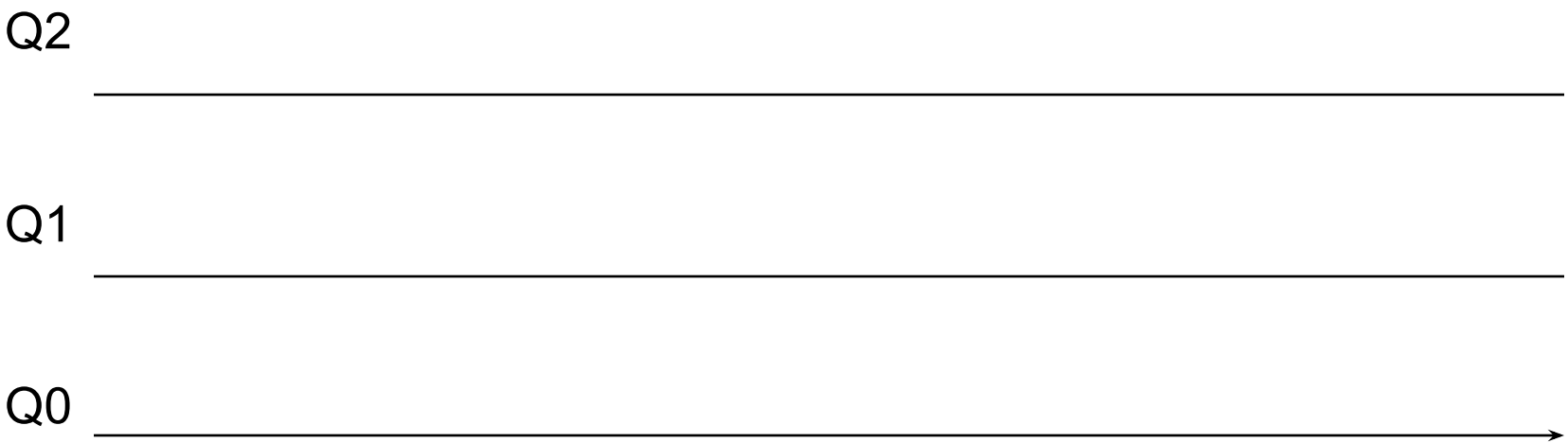


MLFQ: Long job and short jobs in between



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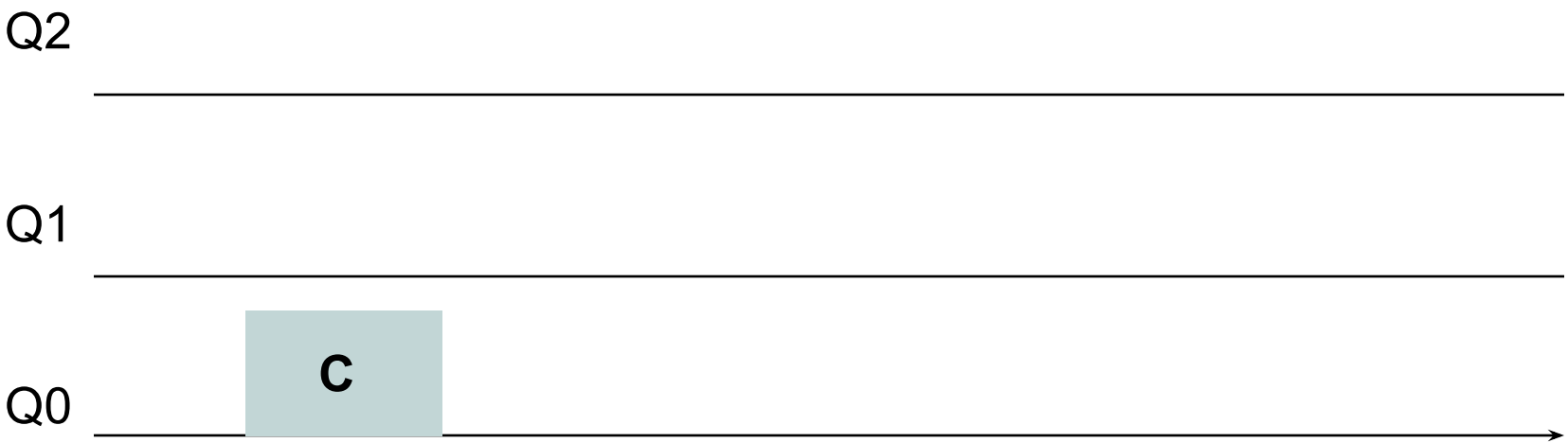

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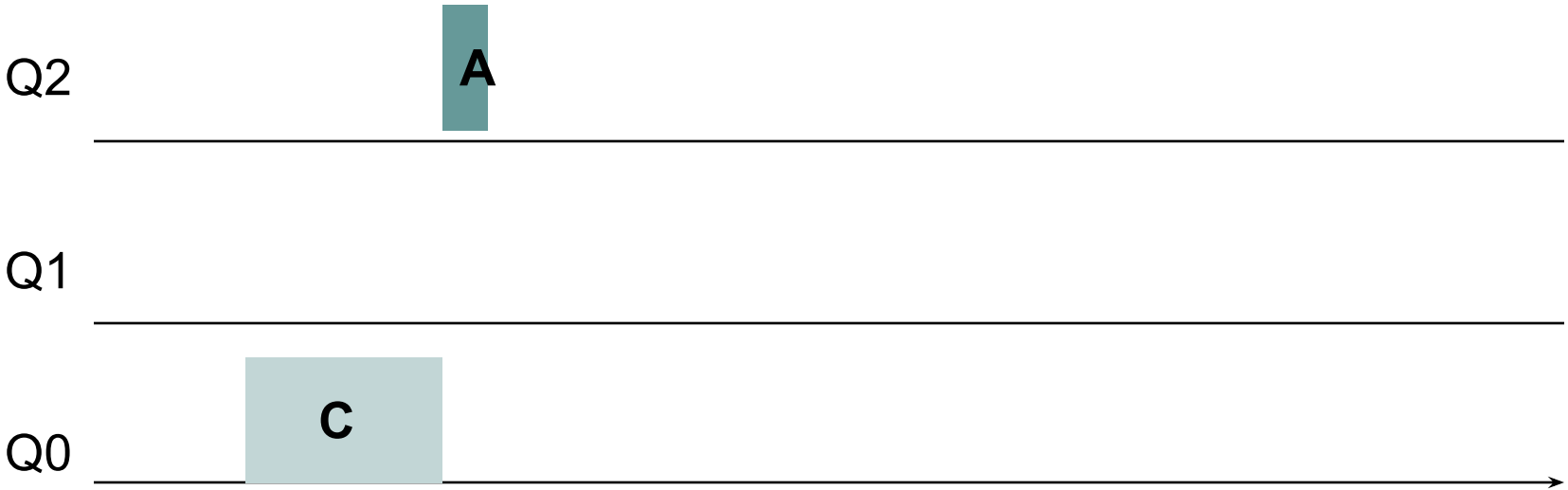

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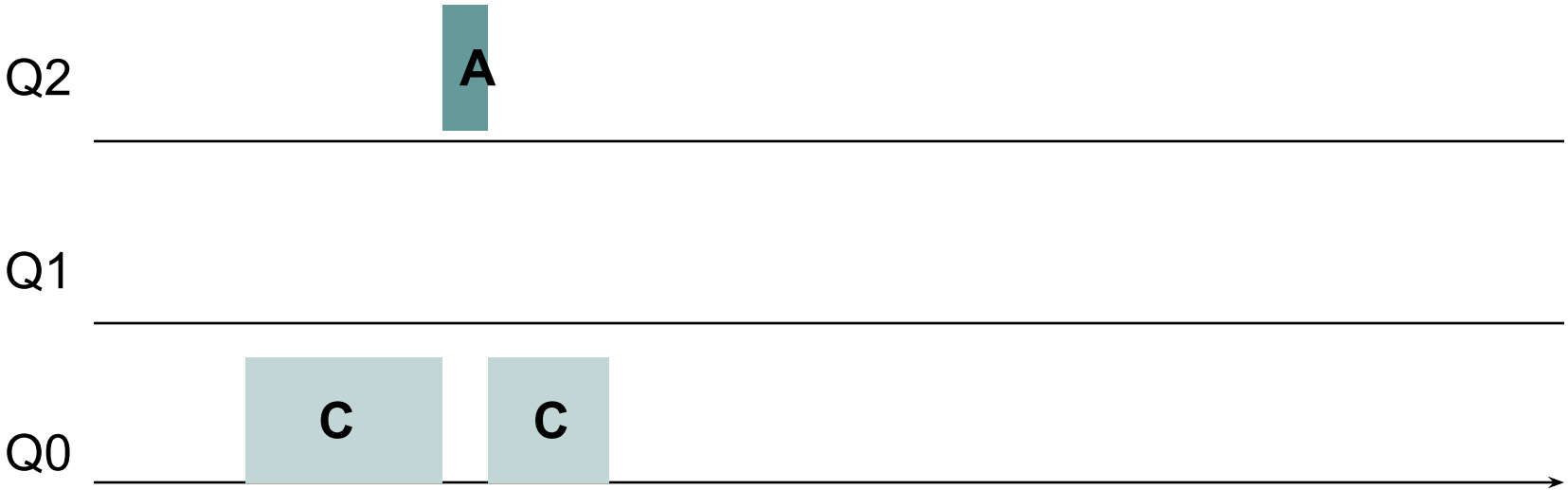

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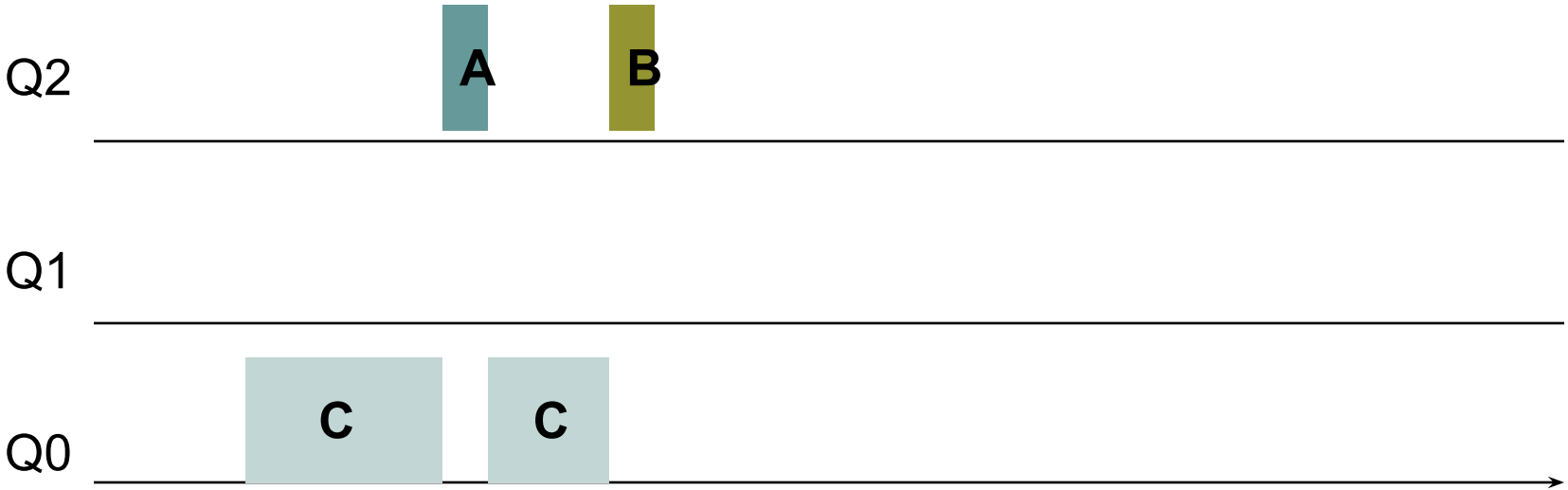

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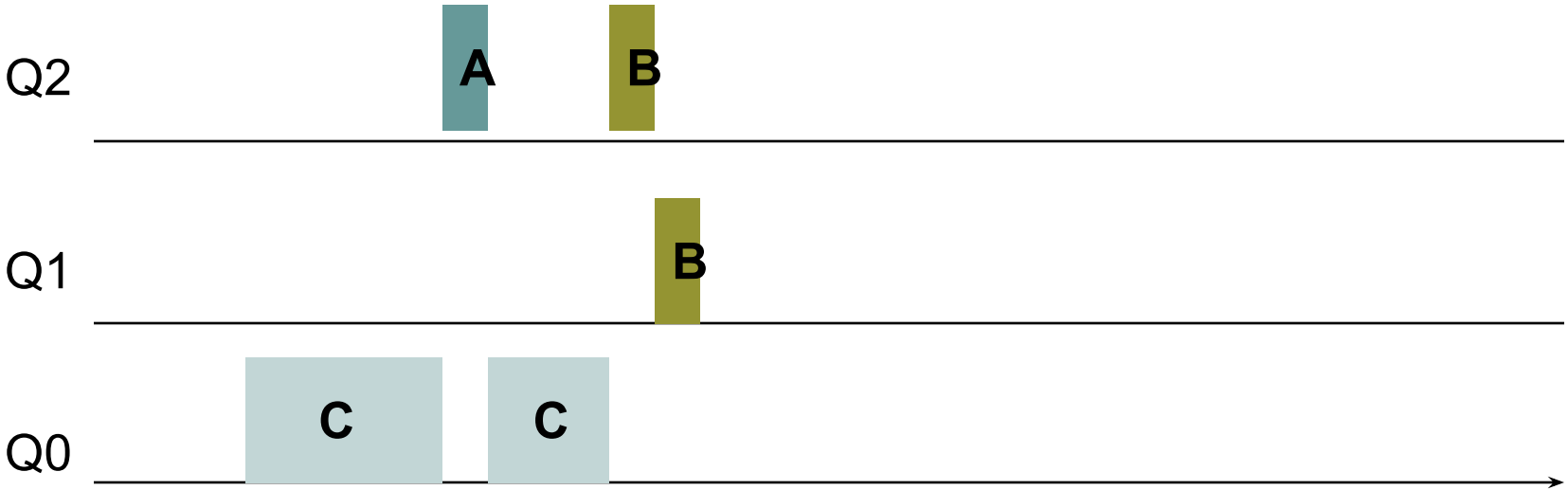

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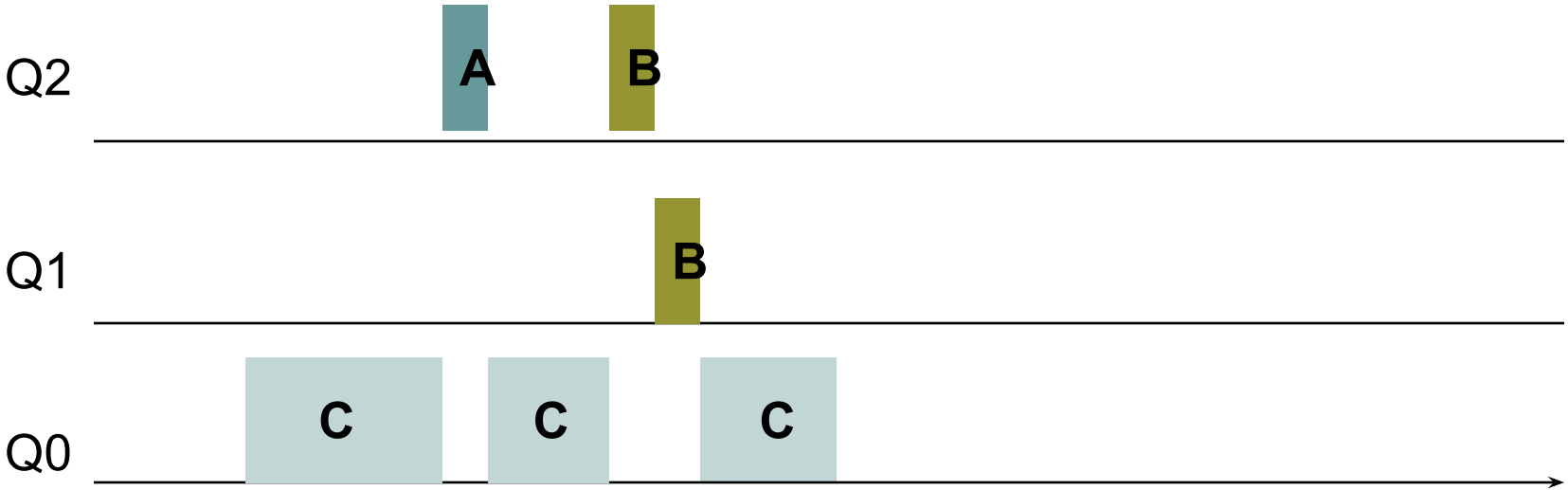

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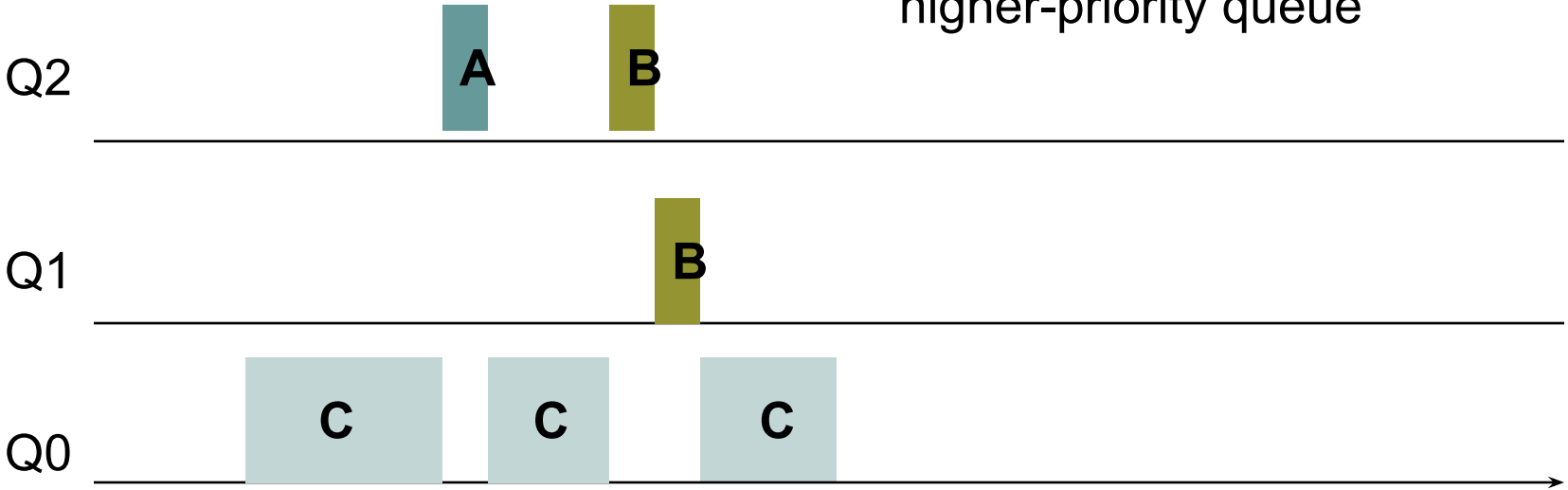
Leave I/O bound and interactive processes in higher-priority queue



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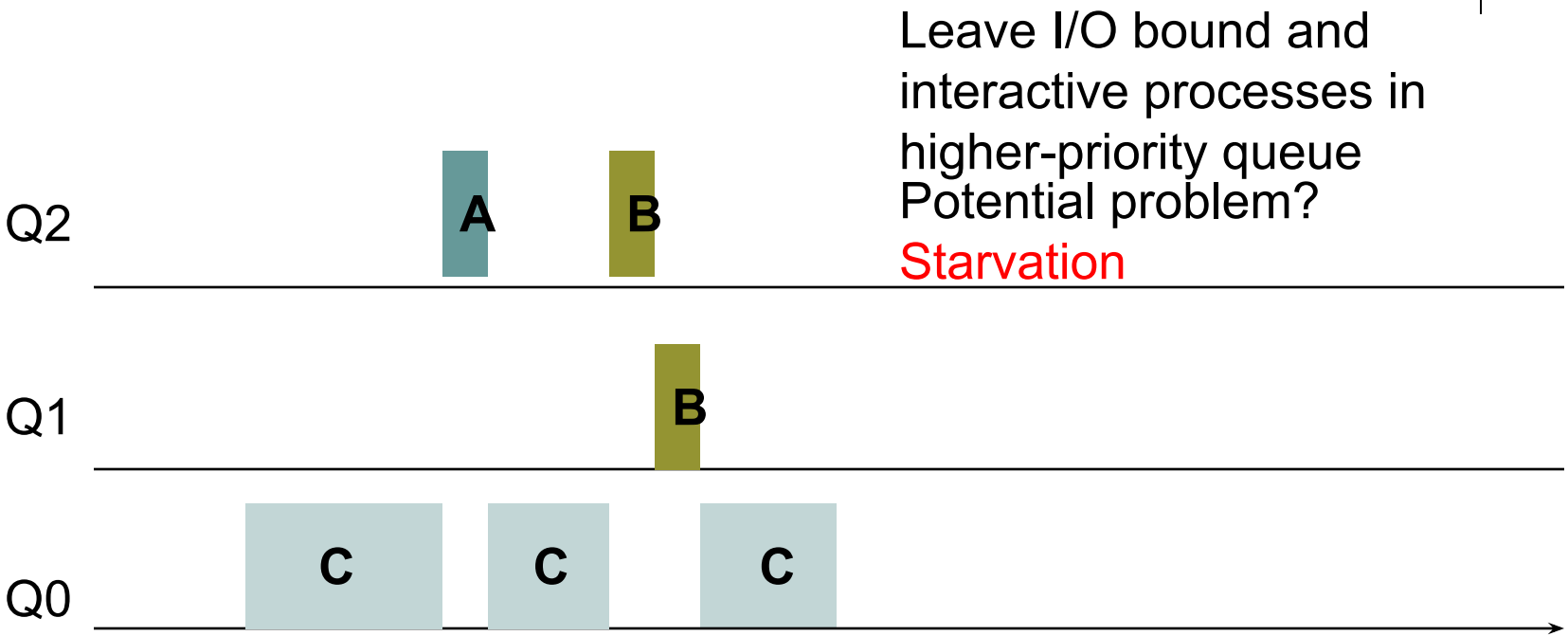
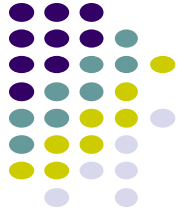


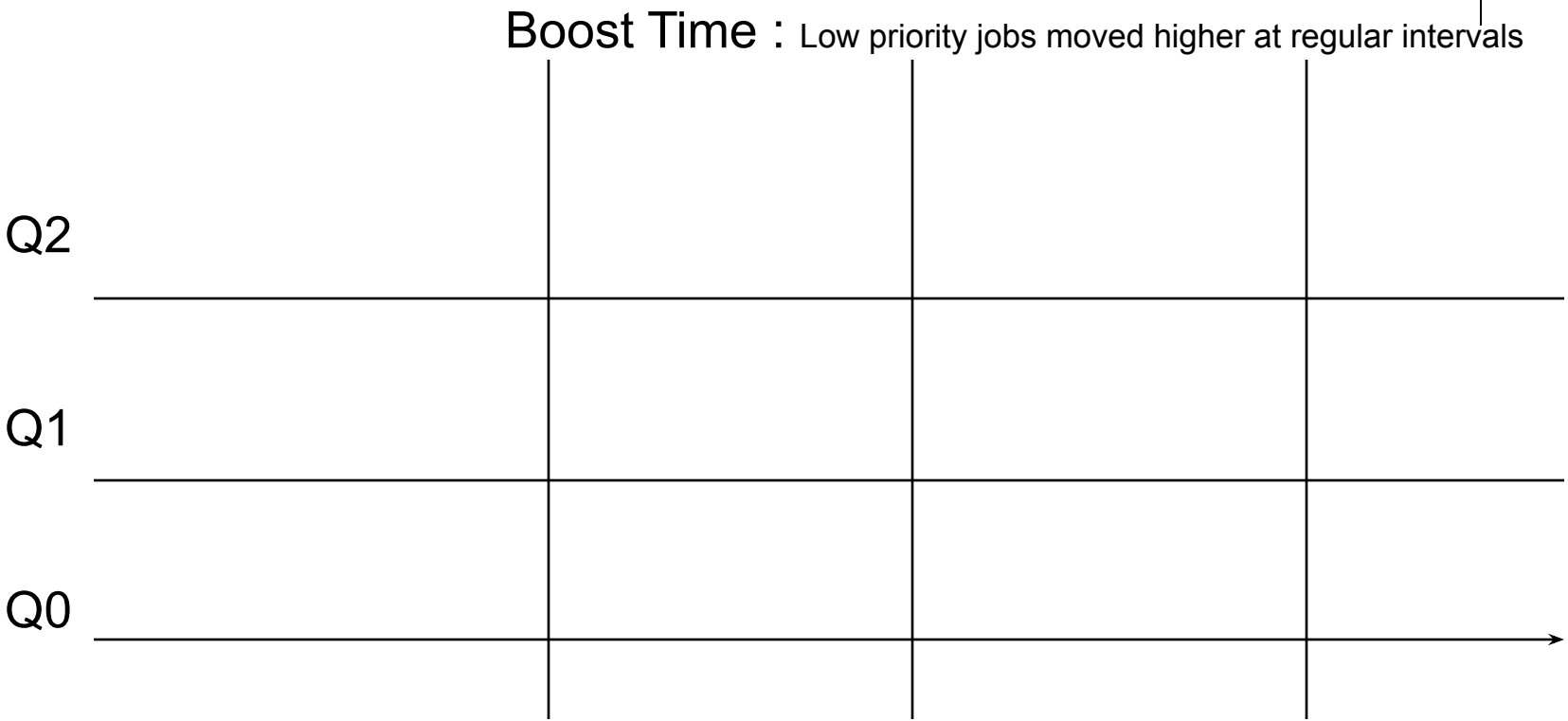
Leave I/O bound and interactive processes in higher-priority queue

Potential problem?

Starvation

MLFQ: Long job and short jobs in between + boost





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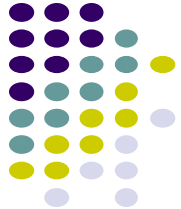

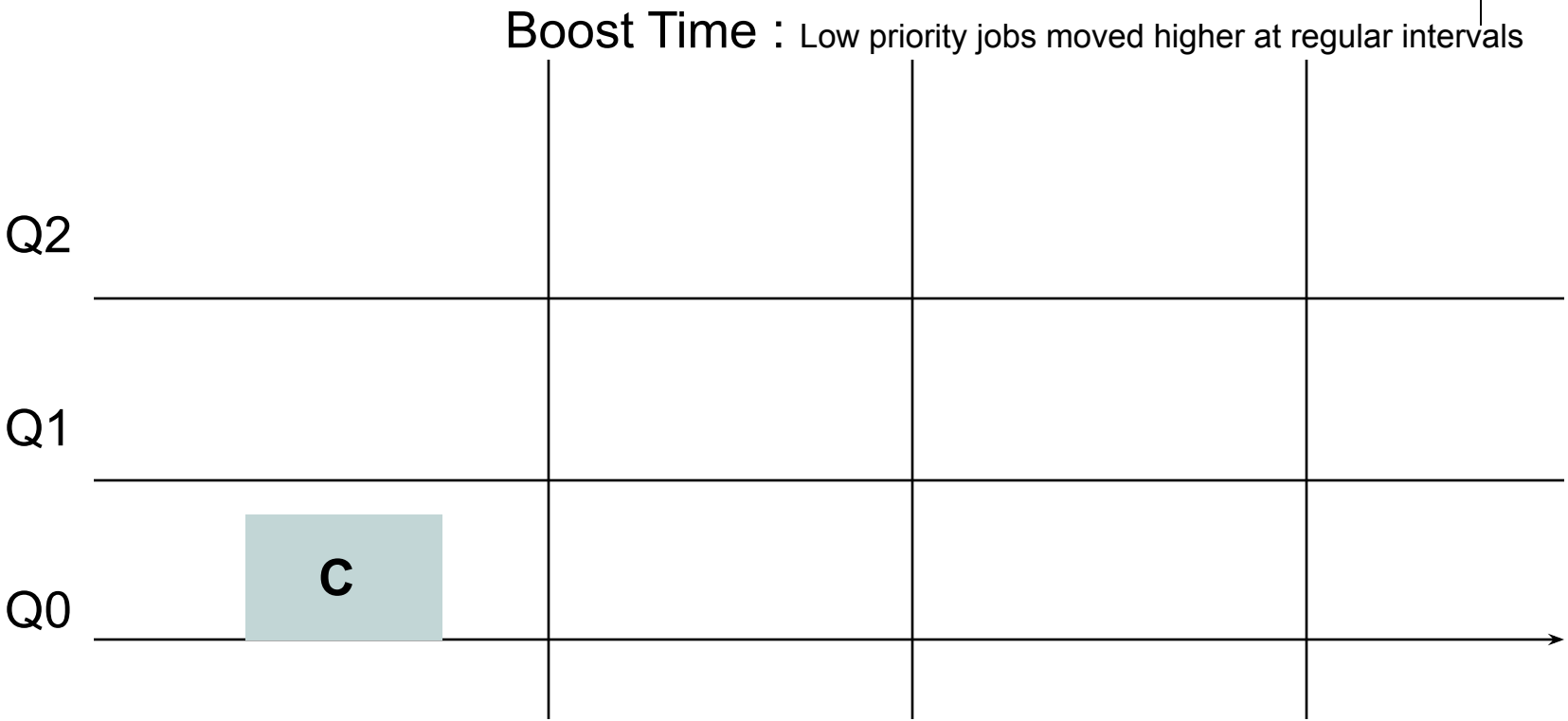

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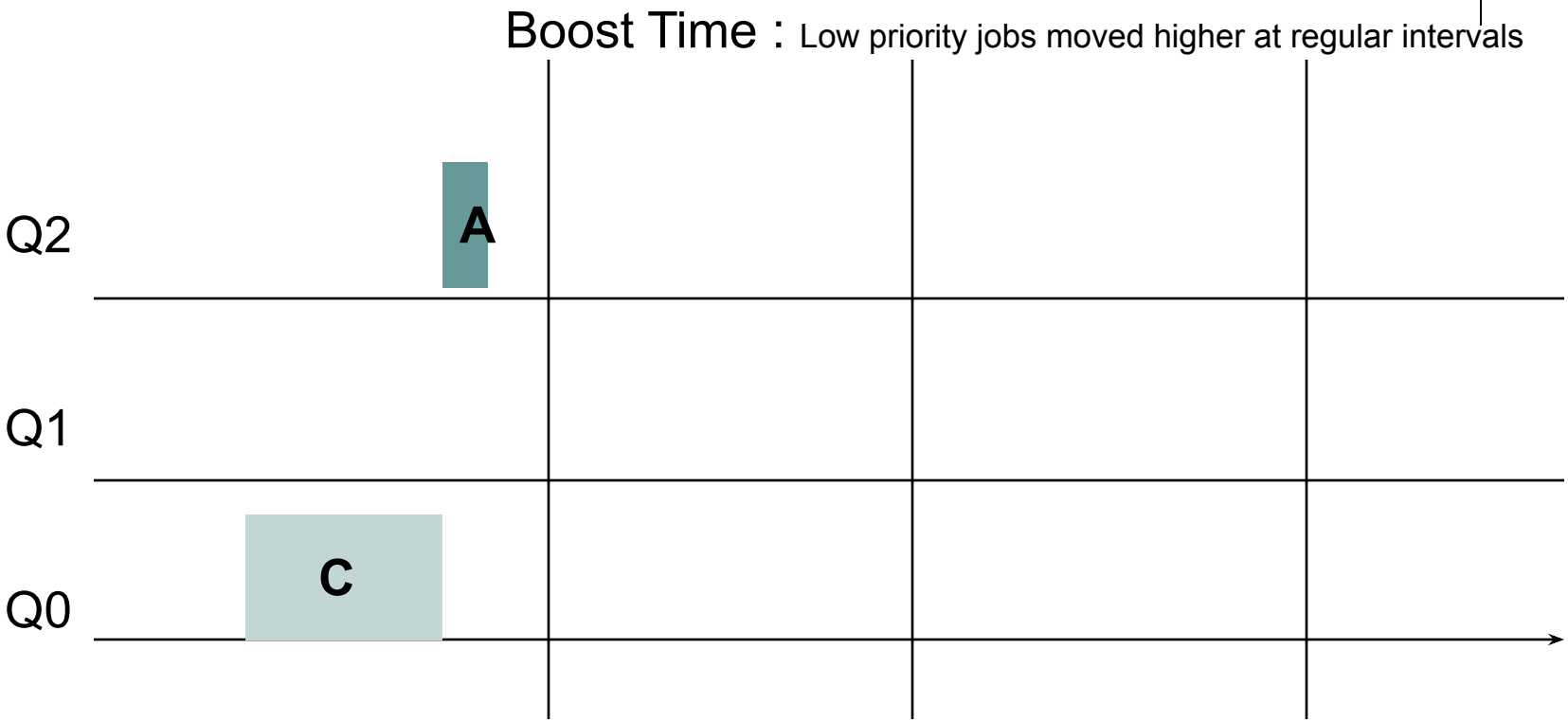

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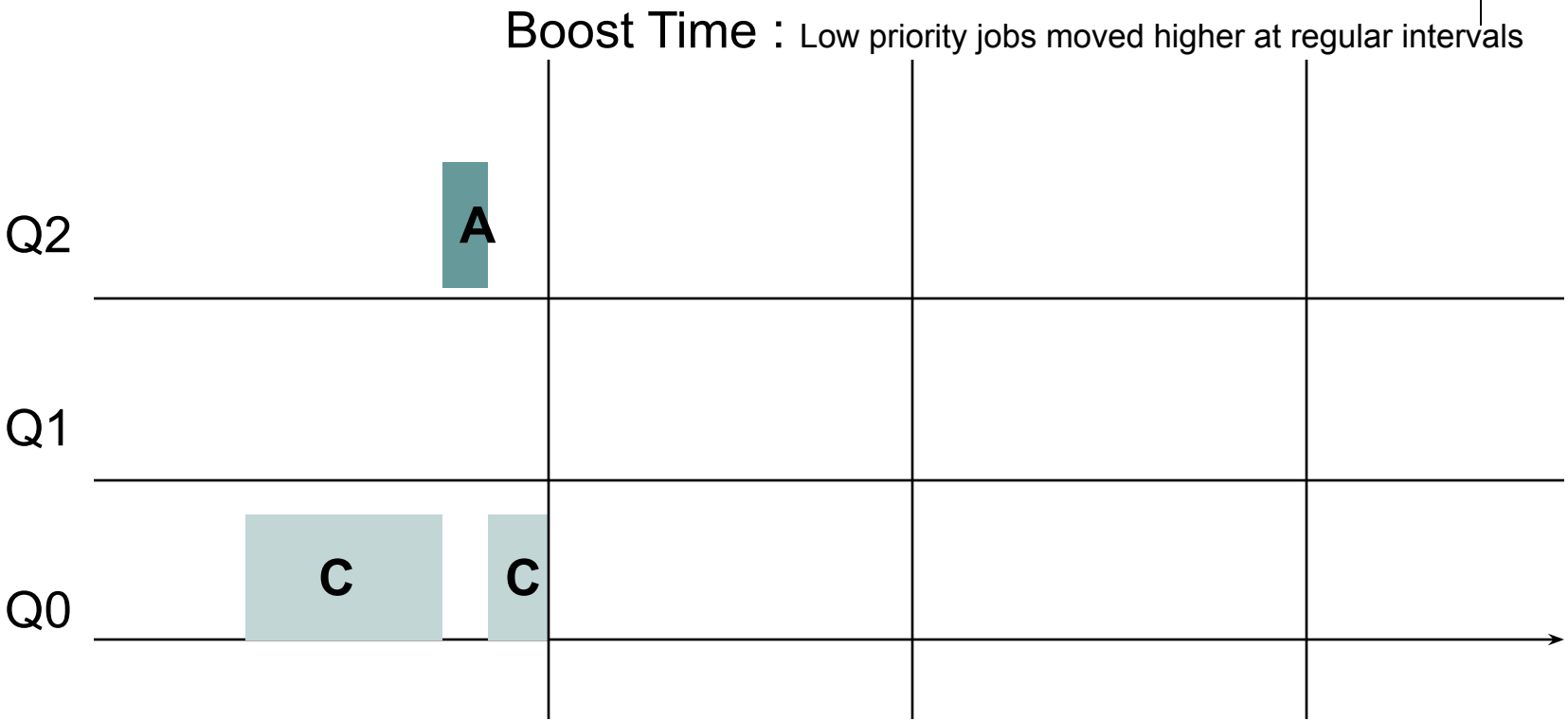

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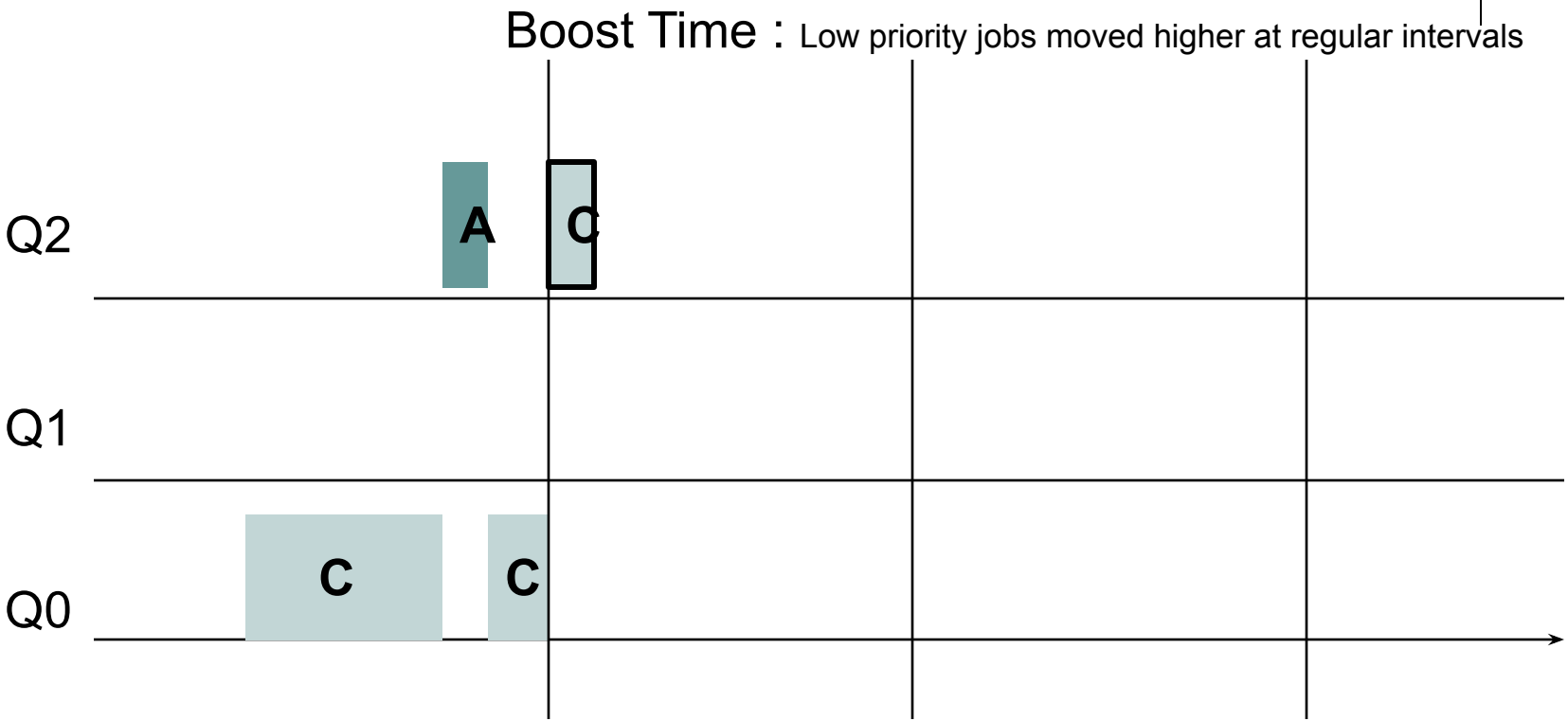

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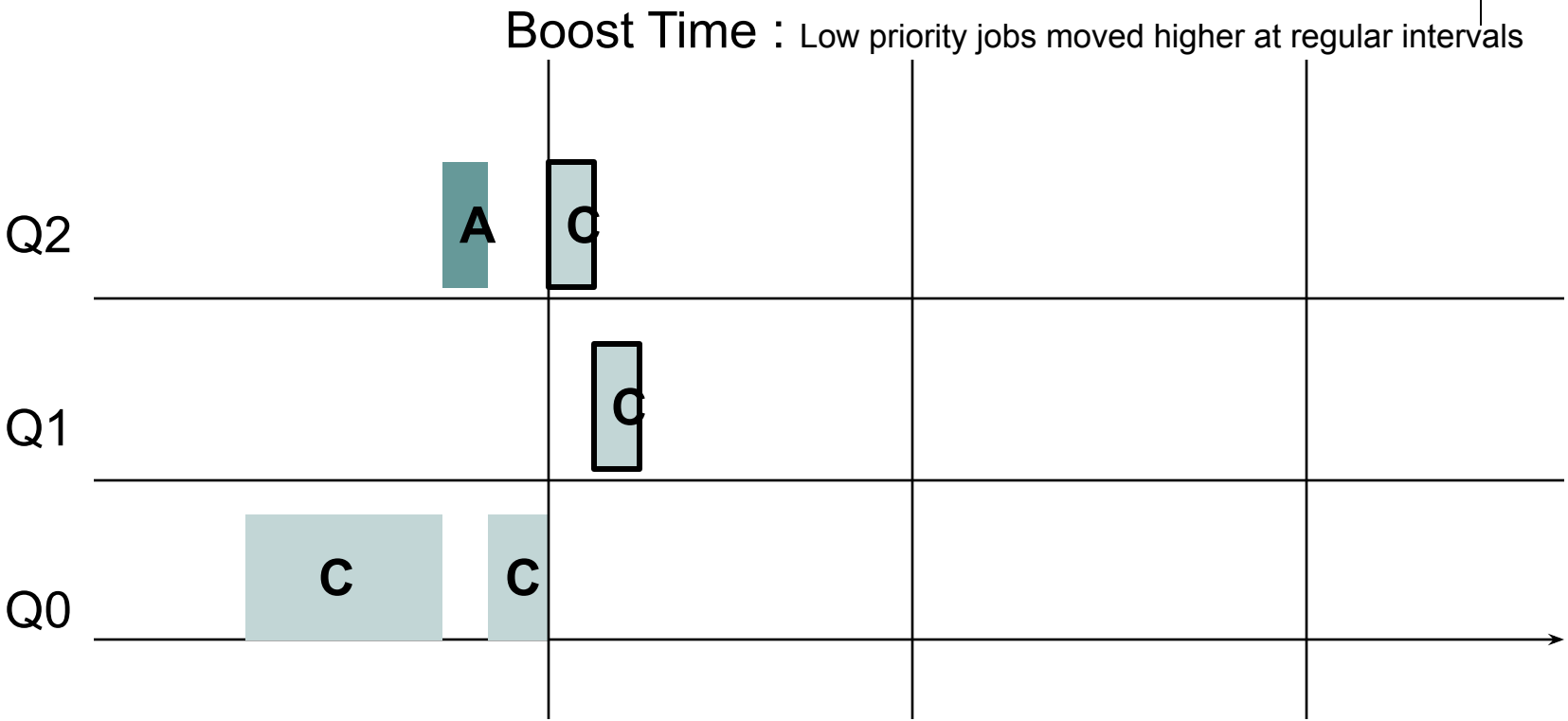

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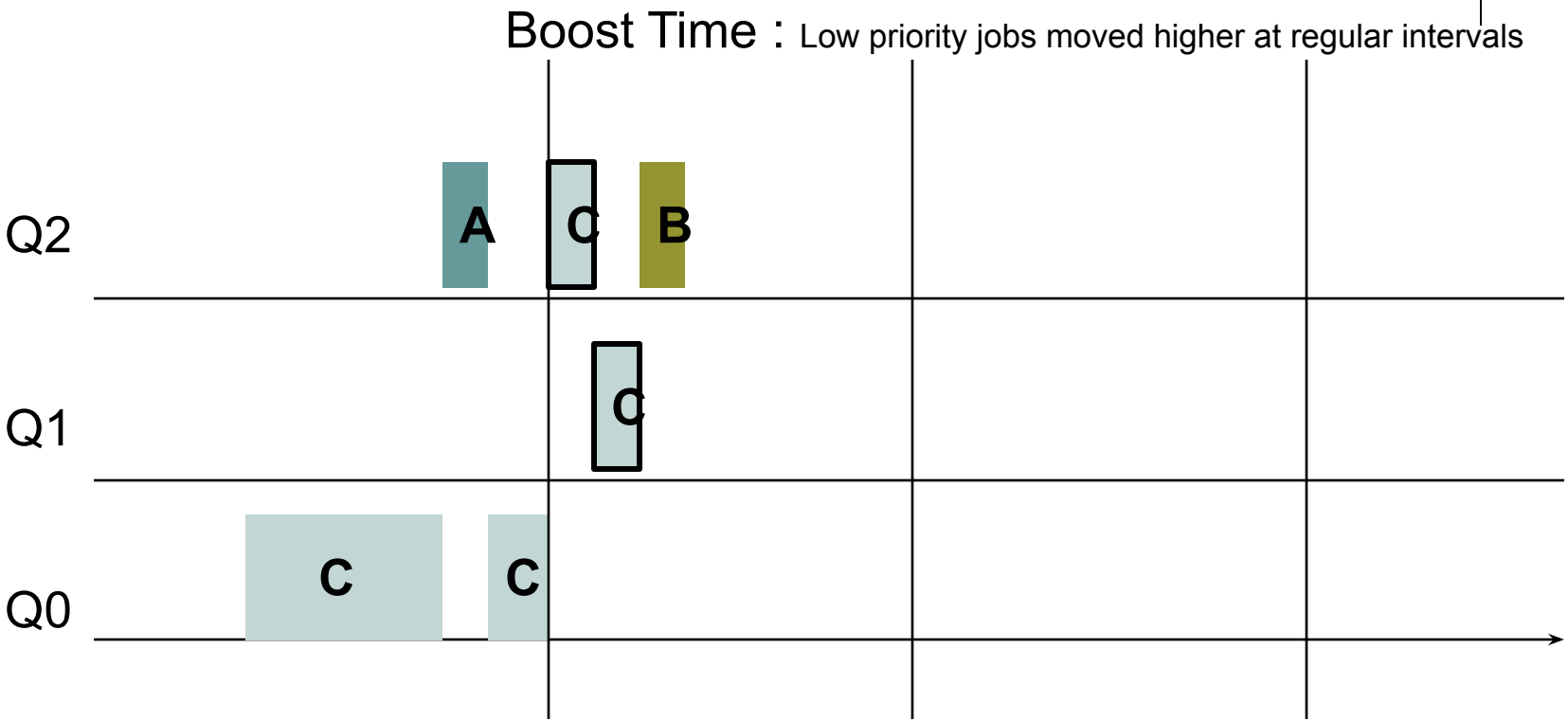

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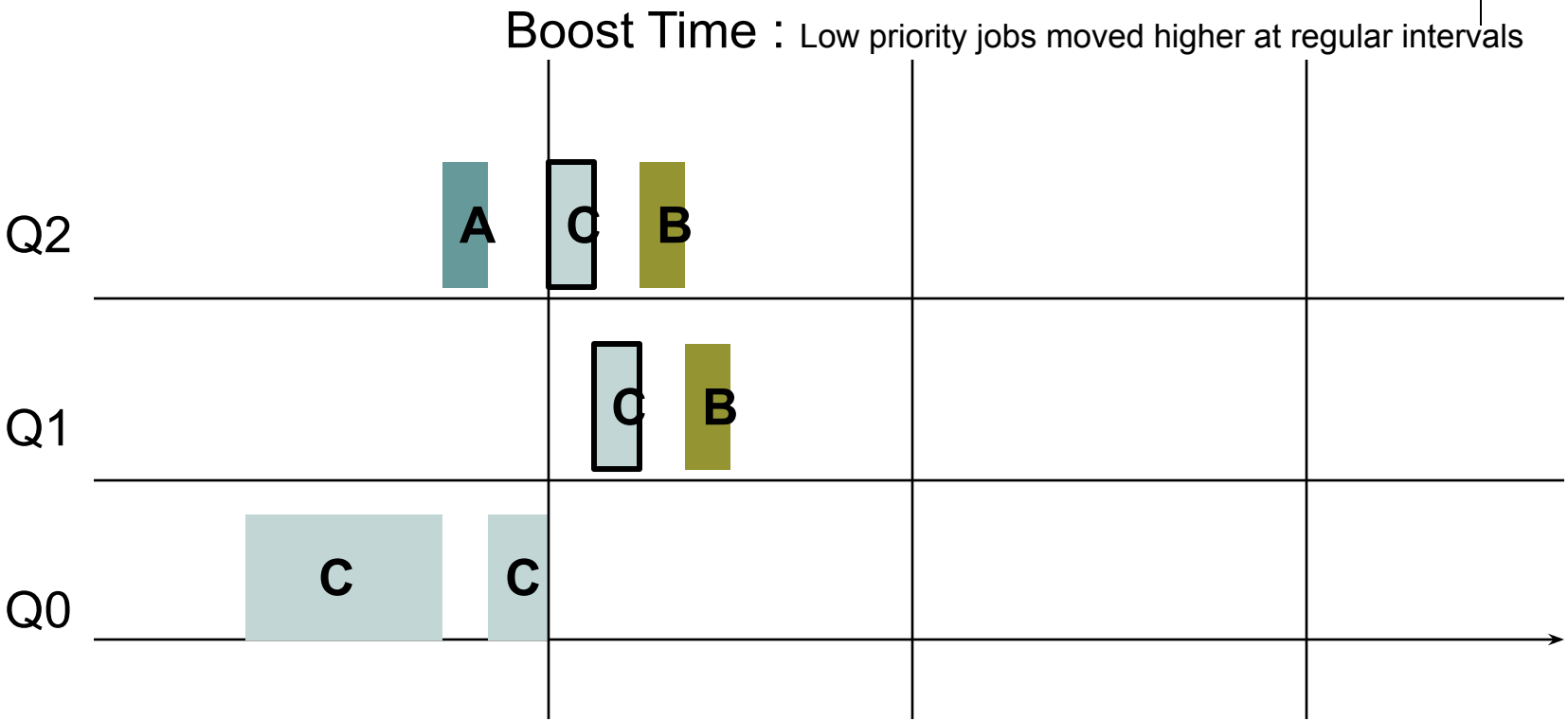

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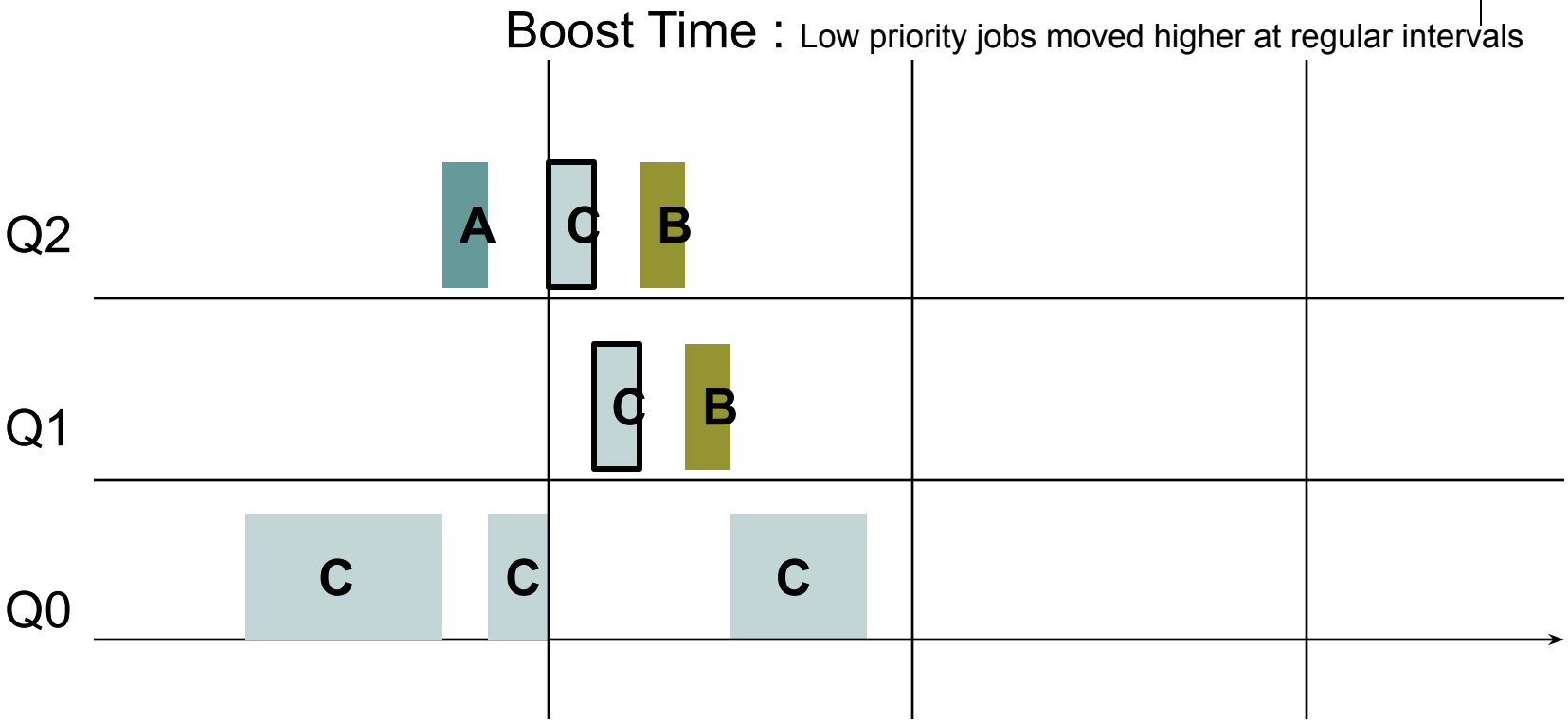
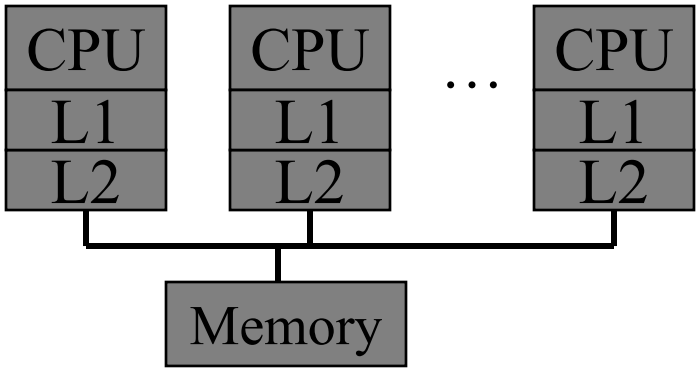
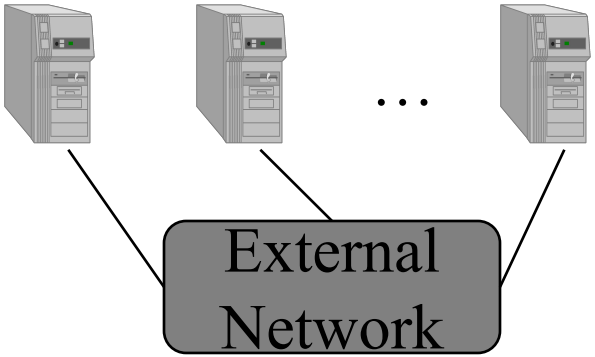


Multiprocessor and Cluster





Multiprocessor architecture
- L2 cache coherence
- A single “image” OS

Cluster/Multicomputer
- Distributed memory
- An OS on each box

Multiprocessor/Cluster Scheduling

- New design issue: process/thread inter-dependence
  - Threads of the same process may synchronize
  - Processes of the same job may send/recv messages

Multiprocessor/Cluster Scheduling: Example approach

- Gang scheduling (coscheduling)

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Multiprocessor/Cluster Scheduling: Example approach

- Gang scheduling (coscheduling)
  - Related process and threads run at the same time.
  - Threads of same process will run at same time on multiprocessor.
  - Processes of same application run at the same time on cluster.

Multiprocessor/Cluster Scheduling: Example approach

- Dedicated processor assignment
  - Threads will be running on specific processors to completion
  - Pros / cons?
    - Good for reducing cache misses
    - Bad for load balance / fairness

CPU scheduling: Final Thoughts

- Mechanism is easy, policy is hard
  - Jobs have diverse characteristics
  - 4 performance metrics
  - Don’t know about future

- Hard to analyze even when narrowing down metric/job nature

True/False

- “A CPU scheduling algorithm that minimizes avg turnaround time cannot lead to starvation.”

- “Among all CPU scheduling algorithms, Round Robin always gives the worse average turnaround time.”

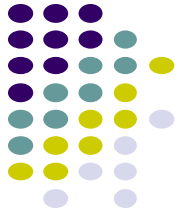
Scheduling Algorithms in OSes

Operating System	Preemption	Algorithm
Windows 3.1x	None	Cooperative Scheduler
Windows 95Windows 95, 98Windows 95, 98, Me	Half	Preemptive for 32-bit processes, Cooperative Scheduler for 16-bit processes
Windows NT (2000, XP, Vista, 7, and Server)	Yes	Multilevel feedback queue
Mac OS pre-9	None	Cooperative Scheduler
Mac OS 9	Some	Preemptive for MP tasks, Cooperative Scheduler for processes and threads
Mac OS X	Yes	Multilevel feedback queue
Linux pre-2.6	Yes	Multilevel feedback queue
Linux 2.6-2.6.23	Yes	O(1) scheduler
Linux post-2.6.23	Yes	Completely Fair Scheduler
Solaris	Yes	Multilevel feedback queue
NetBSD	Yes	Multilevel feedback queue
FreeBSD	Yes	Multilevel feedback queue

Process

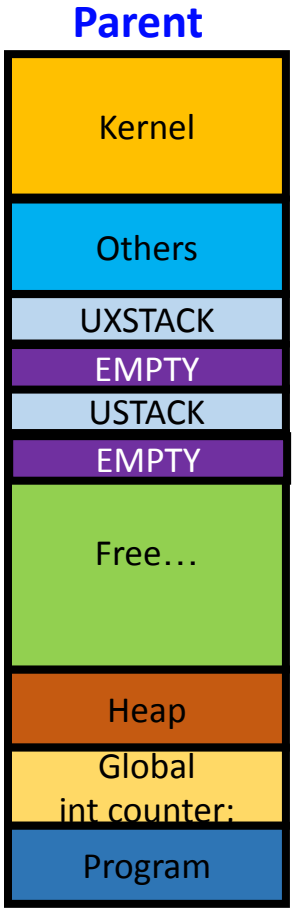
- A process contains everything needed for execution
  - An address space (defining all the code and data pages)
  - OS resources (e.g., open files) and accounting information
  - Execution state (PC (program counter), SP (stack pointer), regs, etc.)

Web Server Example



- How does a web server handle 1 request?
- A web server needs to handle many concurrent requests
- Solution 1:
  - Have the parent process fork as many processes as needed
  - Processes communicate with each other via inter-process communication

Multiple Processes



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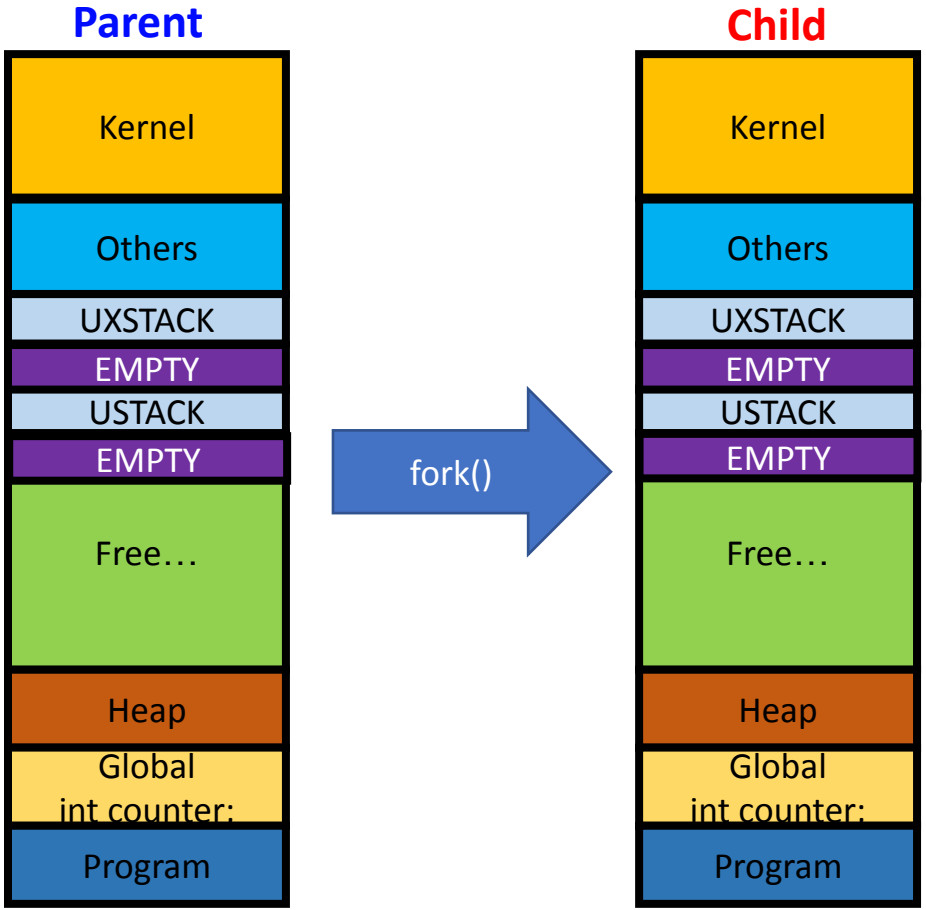

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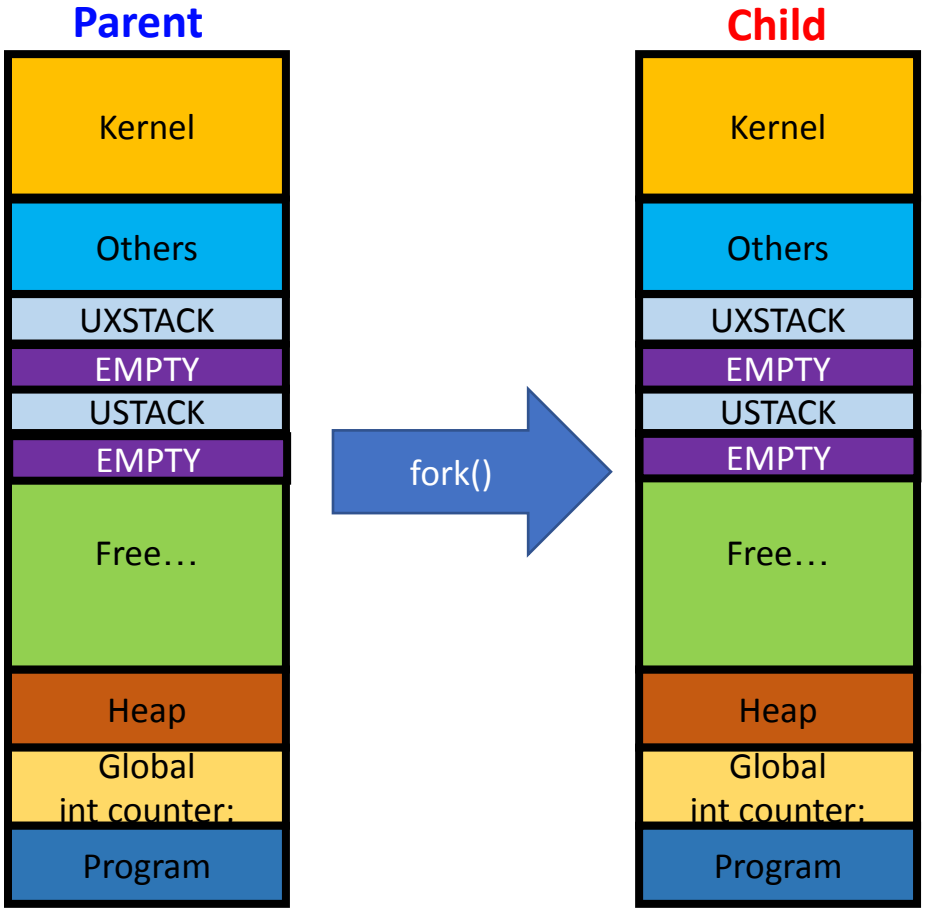
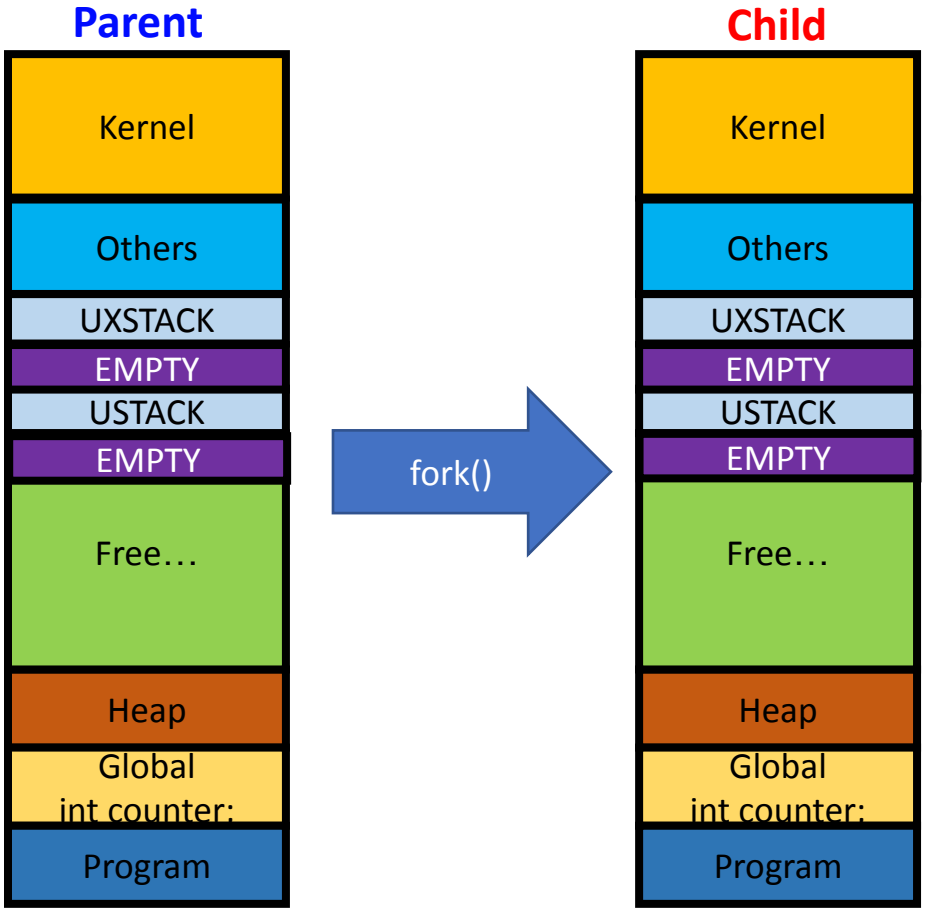


Fork() creates new process by copying memory space

Process creates a new PRIVATE memory space

Multiple Processes



Fork() creates new process by copying memory space

Pr

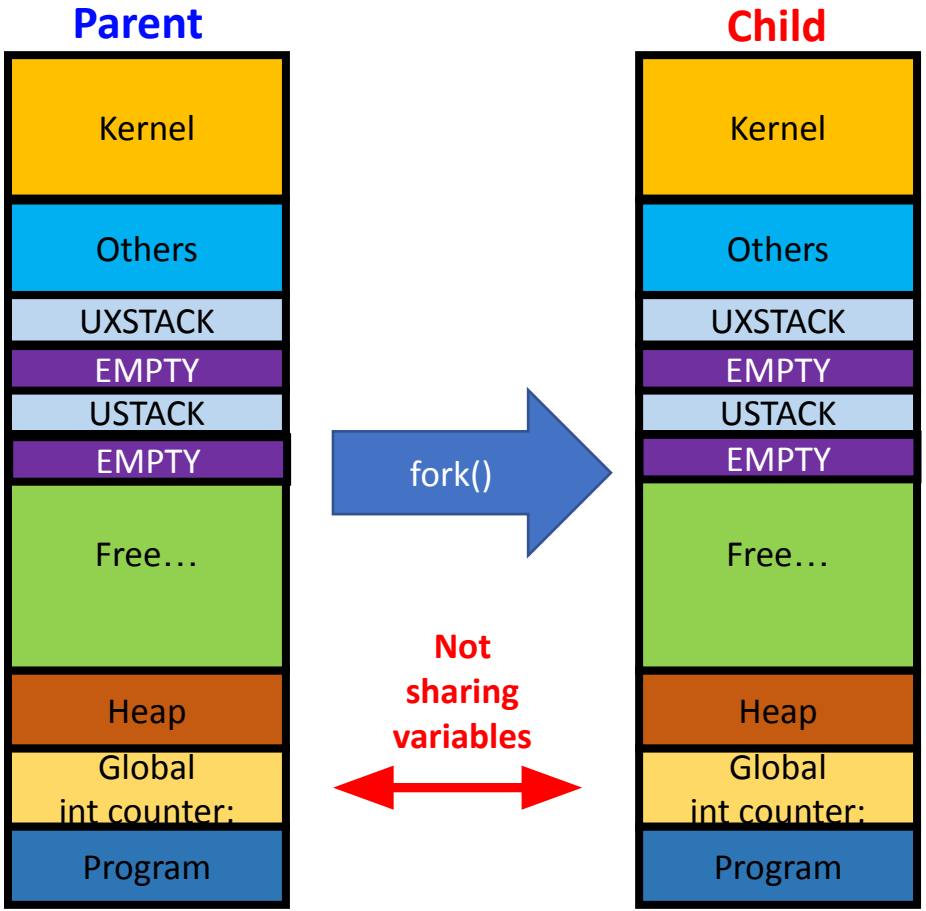
```c
#include <stdio.h>
#include <unistd.h>

int counter;
volatile int value = 1;

void countup() {
    for(int i=0; i<1000000; ++i) {
        counter += value;
    }
}

int main() {
    pid_t pid = fork();
    countup();
    printf("%s: %d\n", pid ? "Parent" : " Child", counter);
}
```

Multiple Processes



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```

```
Parent: 1000000
 Child: 1000000
```

All these processes may need to communicate

- How can two processes communicate?

How do Process communicate?

- At process creation time
  - Parents get one chance to pass everything at fork()

All these processes may need to communicate

- How can two processes communicate?
  - Different machine?

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- How can two processes communicate?
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    - Over network

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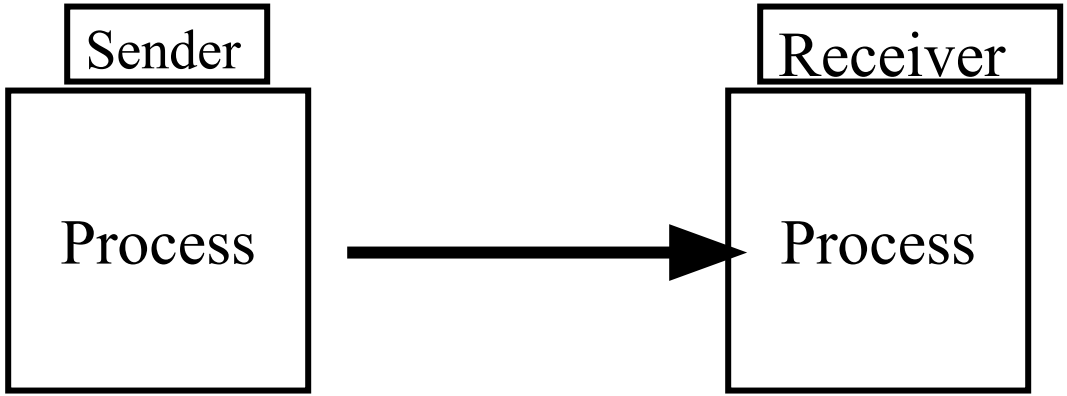
      - Shared Memory
      - Message boxes

Inter process communication (IPC)

IPC with Messages and MailBoxes

- Messages provide for communication without shared data
  - One process or the other owns the data, (guaranteed) never two at the same time
  - Think about USPS

IPC with Messages and MailBoxes

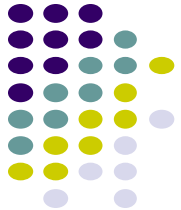


Why Messages?

- Many types of applications fit into the model of processing a sequential flow of information

- Communication across address spaces – no side effects
  - Less error-prone? (commonly believed, but not necessarily true!)
  - They might have been written by different programmers who aren't familiar with code
  - They might not trust each other
  - They may be running on different machines!
  - Examples?

Message Passing API

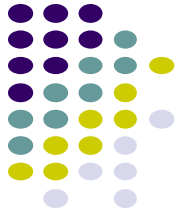


- Generic API
  - send(mailbox, msg)
  - recv(mailbox, msg)

- What is a mailbox?
  - A *buffer* where messages are stored between the time they are sent and the time when they are received

- What should “msg” be?
  - Fixed size msgs
  - Variable sized msgs: need to specify sizes

Implementation Options with Buffering



- When should send() return?

- When should recv() return?

Send

- *Fully Synchronous*
  - Will not return until **data is received** by the receiving process

Send

- *Fully Synchronous*
  - Will not return until **data is received** by the receiving process

- *Synchronous*
  - Will not return until data is **received by the mailbox**
  - Block on full buffer

Send

- *Fully Synchronous*
  - Will not return until **data is received** by the receiving process
- *Synchronous*
  - Will not return until data is **received by the mailbox**
  - Block on full buffer
- *Asynchronous*
  - **Return immediately**
  - Completion
    - Require the application to check status (application polls)
    - Notify the application (OS sends interrupt)

Receive

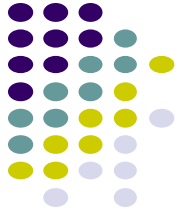
- *Synchronous*
  - Return data if there is a message
  - **Block on empty buffer**

Receive

- *Synchronous*
  - Return data if there is a message
  - **Block on empty buffer**

- *Asynchronous*
  - Return data if there is a message
  - Return **status if there is no message** (probe)

Implementing Mailboxes



- What is the conceptual problem for OS implementation here?
  - Assume sender and receiver are on the same machine

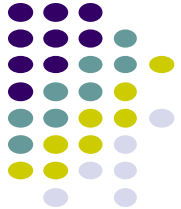
Implementing Mailboxes

- What is the conceptual problem for OS implementation here?
  - Assume sender and receiver are on the same machine:
    - Buffering
    - Managing mailboxes:
      - between a pair or processes?
      - One for each process?
    - Process Termination

Buffering

- No buffering
  - Sender must wait until the receiver receives the message
  - Rendezvous on each message
- Bounded buffer
  - Finite size
  - Sender blocks when the buffer is full
  - Receiver blocks when the buffer is empty
  - Using lock/condition variable (or semaphore)

Direct Communication



- Each process must name the sending or receiving process
- A communication link
  - is set up between the pair of processes
  - is associated with exactly two processes
  - exactly one link between each pair of processes

P: send(process Q, msg)

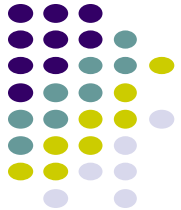
Q: recv(process P, msg)

Producer-Consumer with Message passing

```
Producer(){
  while (1) {
    …
    produce item
    …
    send( consumer, item);
  }
}
```

```
Consumer(){
  while (1) {
    recv( producer, item );
    …
    consume item
    …
  }
}
```

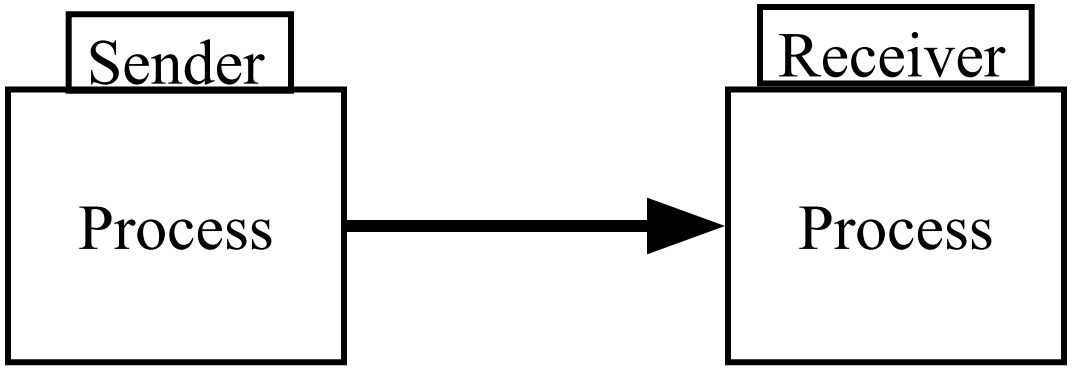
Indirect Communication



- Use a “mailbox” or “ports” to allow many-to-many communication
  - Mailbox typically owned by the OS
    - Requires open/close a mailbox before allowed to use it
- A “link”
  - is set up among processes only if they have a shared mailbox
  - Can be associated with more than two processes

```
P: open (mailbox); send( mailbox, msg);
   close(mailbox)
Q: open (mailbox); recv( mailbox, msg );
   close(mailbox)
```

Process Termination



- S has terminated
  - Problem: R may be blocked forever
  - Solution: R pings S once a while
- R has terminated
  - Problem: S runs out buffer and will be blocked forever
  - Solution: S checks on R occasionally

IPC Big Debate: Message passing v/s Shared memory

- Two programming models are equally powerful
- But result in very different-looking programming styles

- Do you think shared-data or message-passing is easier to work with?
  - Programming? Debugging?

- What about concurrent programming across machines?
  - Message passing is more natural
  - Shared memory can still be simulated in software
    - Distributed Shared Memory (DSM) – hot topic in 80-90's, coming back these years