CS144
An Introduction to Computer Networks

Packet Switching

Useful queue properties

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Queues with Random Arrival Processes

Usually, arrival processes are complicated, so we often model them using random processes.

The study of queues with random arrival processes is called Queueing Theory.

Queues with random arrival processes have some interesting properties.

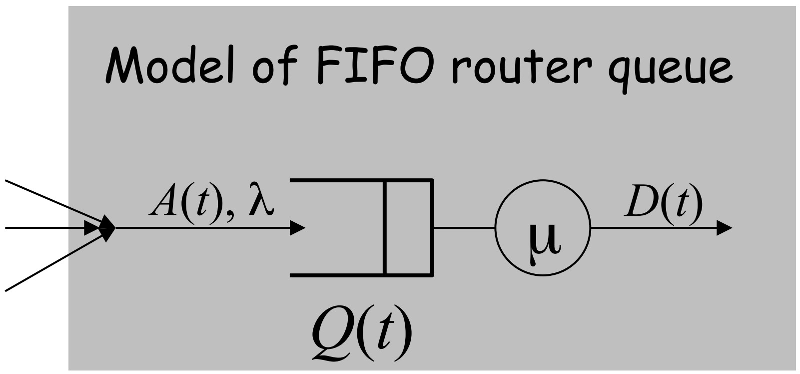
Outline

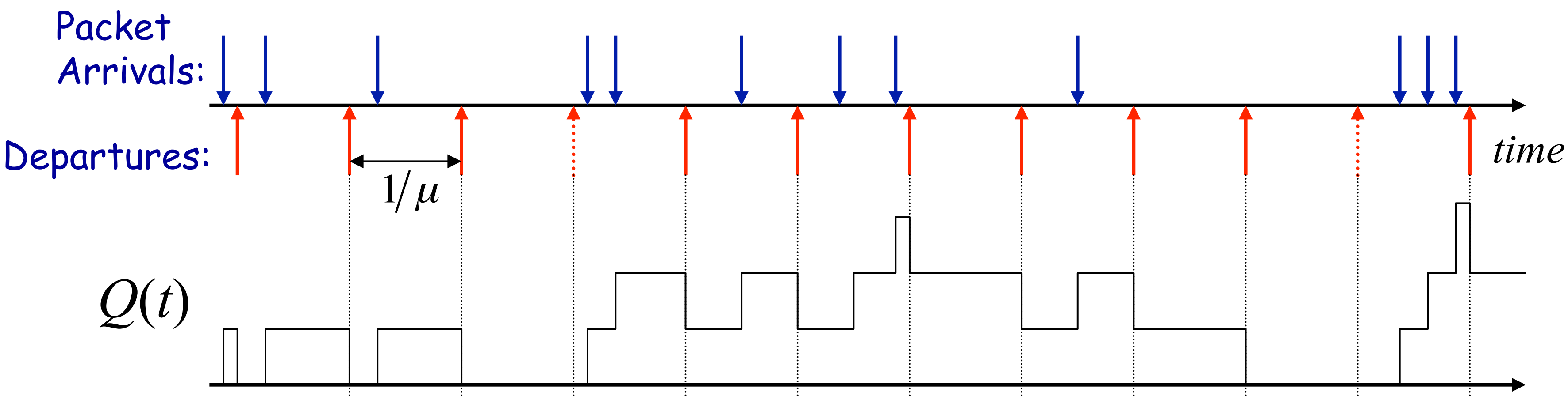
1. Burstiness increases delay.
2. Determinism minimizes delay.
3. Little's Result.
4. The M/M/1 queue.

HIDE

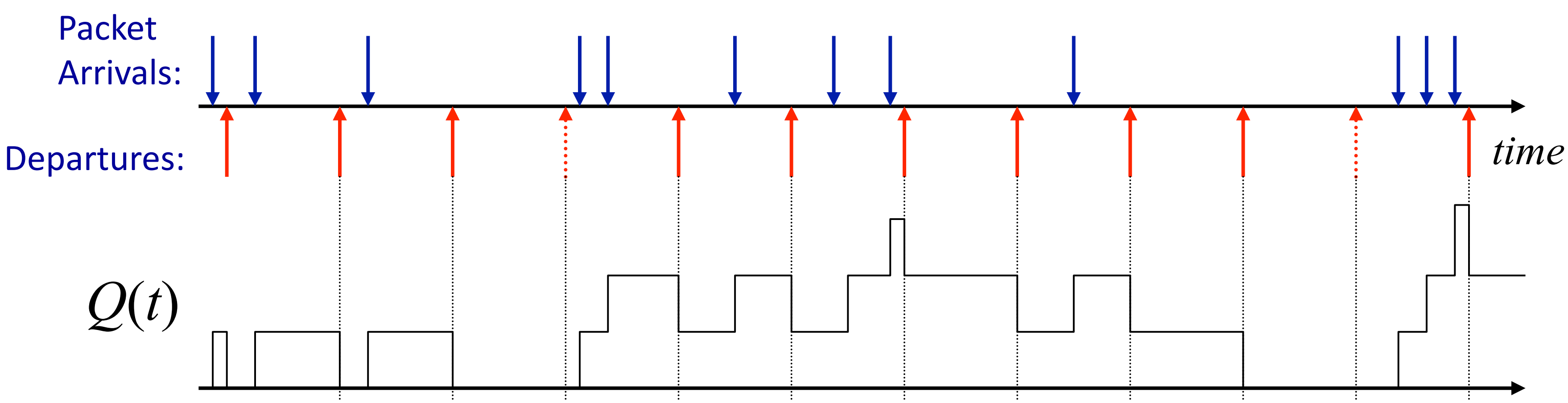
Time evolution of a queue

Packets



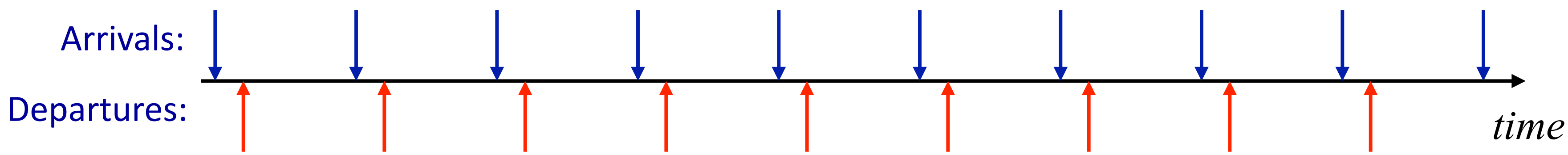


Time evolution of a queue



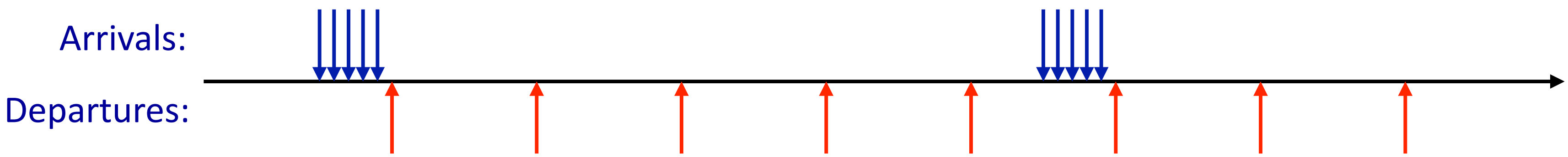
Queue Property #1
"Burstiness increases delay"

Example 1: Periodic single arrivals



Queue Property #1
"Burstiness increases delay"

Example 2: Periodic burst arrivals

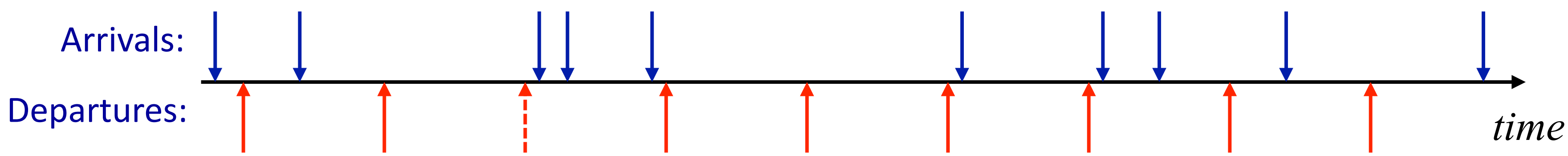


In general, burstiness increases delay

Queue Property #2

"Determinism minimizes delay"

Example 3: Random arrivals

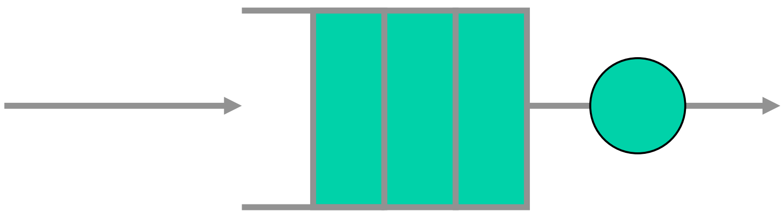


In general, determinism minimizes delay.

i.e. random arrivals wait longer on average than simple periodic arrivals.

HIDE

Queue Property #3
"Little's Result"



$$L = \lambda d$$

Where:

L is the average number of customers in the system (the number in the queue + the number in service),

λ is the arrival rate, in customers per second, and

d is the average time that a customer waits in the system (time in queue + time in service).

Result holds so long as no customers are lost/dropped.

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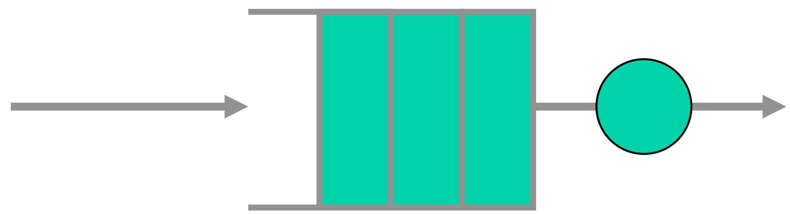
Queue Property #3
"Little's Result"



The Poisson process

An arrival process is Poisson if:

1. Pr{k arrivals in an interval of t seconds} is

$$P_k(t) = \frac{(\lambda t)^k}{k!} e^{-\lambda t}$$

2. $E\left[\text{number of arrivals in interval } t\right] = \lambda t$
3. Successive interarrival times are independent (i.e. not bursty).

Why the Poisson process?

Models aggregation of many independent random events, e.g.

- Arrival of new phone calls to a telephone switch
- Decay of many independent nuclear particles
- “Shot noise” in an electrical circuit

It makes the math easy.

Be warned

1. Network traffic is very bursty!
2. Packet arrivals are not Poisson.
3. But it models quite well the arrival of new flows.

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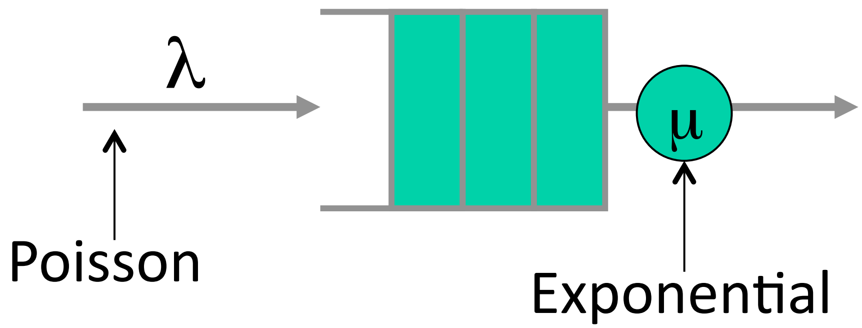
M/M/1 Queue



Summary

Queue properties

- Burstiness increases delay
- Little's result: $L = \lambda d$

Packet arrivals are *not* Poisson

…but some events are, such as web requests and new flow arrivals.

An M/M/1 queue is a simple queue model.