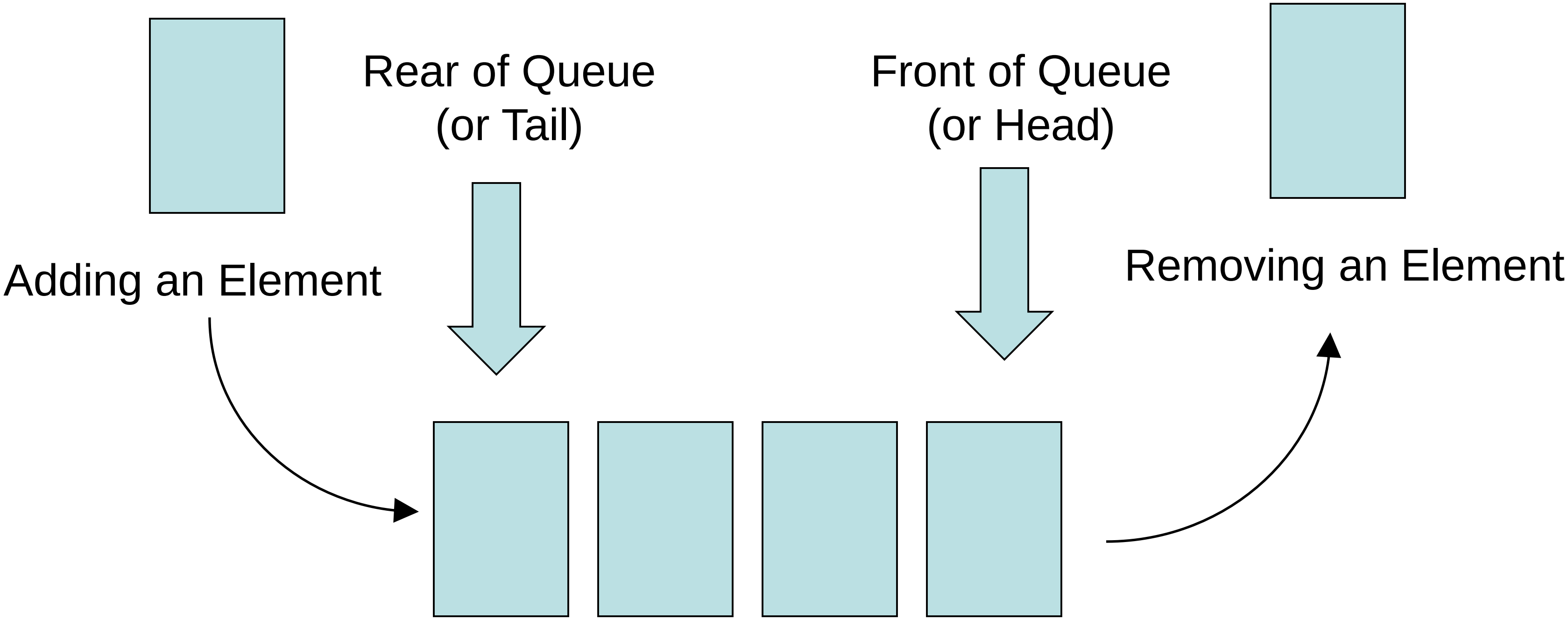
Queues

- Queue Concept
- Queue Design Considerations
- Queues in Java Collections APIs
- Queue Applications
- Reading L&C 5.1-5.8, 9.3

Queue Abstract Data Type

- A *queue* is a linear collection where the elements are added to one end and removed from the other end
- The processing is *first in, first out (FIFO)*
- The first element put on the queue is the first element removed from the queue
- Think of a line of people waiting for a bus (The British call that “queuing up”)

A Conceptual View of a Queue



Rear of Queue
(or Tail)

Front of Queue
(or Head)

Adding an Element

Removing an Element

Queue Terminology

- We *enqueue* an element on a queue to add one
- We *dequeue* an element off a queue to remove one
- We can also examine the *first* element without removing it
- We can determine if a queue is *empty* or not and how many elements it contains (its *size*)
- The L&C QueueADT interface supports the above operations and some typical class operations such as `toString()`

Queue Design Considerations

- Although a queue can be empty, there is no concept for it being full. An implementation must be designed to manage storage space
- For `first` and `dequeue` operation on an empty queue, this implementation will throw an exception
- Other implementations could return a value `null` that is equivalent to “nothing to return”

The java.util.Queue Interface

- The java.util.Queue interface is in the Java Collections API (extends Collection)
- However, it is only an interface and you must use an implementing class
- LinkedList is the most commonly used implementing class
- For a queue of *type* objects:

```
Queue<type> myQueue = new LinkedList<type>();
```

The java.util.Queue Interface

- The names of the methods are different
- Enqueue is done using:

```
boolean offer(T element) // returns false if full
```

- Dequeue is done using either:

```
T poll()    // returns null value if empty
T remove()  // throws an exception if empty
```

- Peek is done using either:

```
T peek()    // returns null value if empty
T element() // throws an exception if empty
```

Applications for a Queue

- A queue can be used as an underlying mechanism for many common applications
  - Cycling through a set of elements in order
  - Simulation of client-server operations
  - Radix Sort
  - Scheduling processes in an operating system such as printer queues

Cycling through Code Keys

- The Caesar cipher is simple letter shifting
- Each letter is treated as its number 0-25 in the alphabet and each letter is encoded as:

  cipher value = (letter value + constant) % 26
- The message is decoded letter by letter:

  letter value = (cipher value – constant) % 26

  if (letter value < 0) letter value += 26
- Using the constant 7, the word “queue” would be coded as “xblbl”
- Note: the word’s “pattern” is recognizable

Cycling through Code Keys

- The Caesar cipher is easy to solve because there are only 26 possible “keys” to try
- It can be made harder by cycling through a key set of values such as 3, 1, 7, 4, 2, 5
- We put that sequence of numbers in a queue
- As we encode each letter, we dequeue a number for the constant and re-enqueue it - cycling through the entire key set as many times as needed for the message length

Cycling through Code Keys

- Using that queue of numbers as the constant values, the word “queue” becomes “tvlyg”
- Note: the word’s “pattern” is not recognizable
- If we are encoding a message containing the entire Unicode character set, we can omit the modulo 26 operator as in the text book code
- See L&C, Listing 5.1

Ticket Counter Simulation

- See L&C Listing 5.2 and 5.3
- The simulation in this example sets up a queue with each customer arriving at regular 15 second intervals
- This is not a very meaningful analysis because it doesn’t take into account the typical variations in arrival rates
- E.G. One customer every 15 seconds could mean 8 customers arriving at one time and then 2 minutes with no arriving customers

Ticket Counter Simulation

- Textbook code always gives same values:

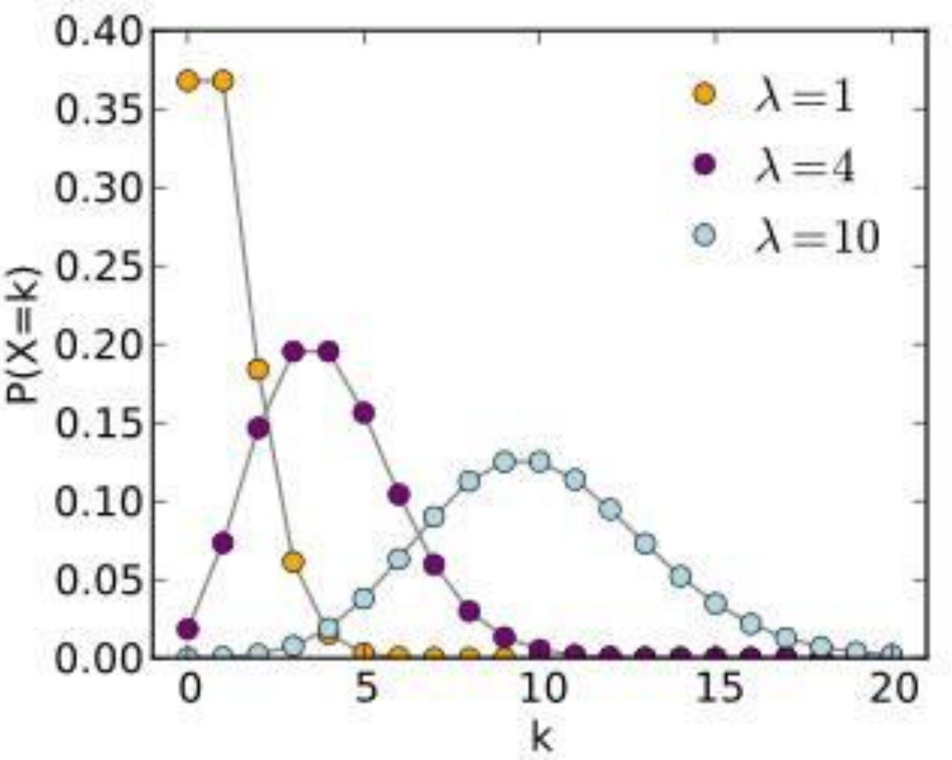
cashiers	time
1	5317
2	2325
3	1332
4	840
5	547
6	355
7	219
8	120
9	120
10	120

Ticket Counter Simulation

- A more sophisticated simulation would use probability distributions for the arrival rate and for the processing time
  - With an average serving time that sets a maximum capacity for handling customers based on the number of servers
  - And an average arrival time with parameters for the distribution of arrivals over time
- A statistical analysis is more important for an ice cream shop next to a movie theater (during a movie versus as a movie lets out)

Ticket Counter Simulation

- Poisson Distribution is commonly used for estimating arrival times in simulations
  - Lambda is the average number of arrivals per time interval
  - P(X=k) is the probability that k is the number of arrivals during this time interval



Ticket Counter Simulation

- Replacement for textbook code in listing 5.3:

```
 /** load customer queue
     improved to use random Poisson arrival times*/
Poisson myDist = new Poisson(lambda);
for (int count=0; count < NUM_INTERVALS / lambda; count++)
{
   int numberOfCustomers = myDist.getValue();
   for (int i = 0; i < numberOfCustomers; i++)
        customerQueue.offer(new Customer(count*15*lambda));
}
```

- Introduces random arrival times based on the Poisson distribution for each time interval

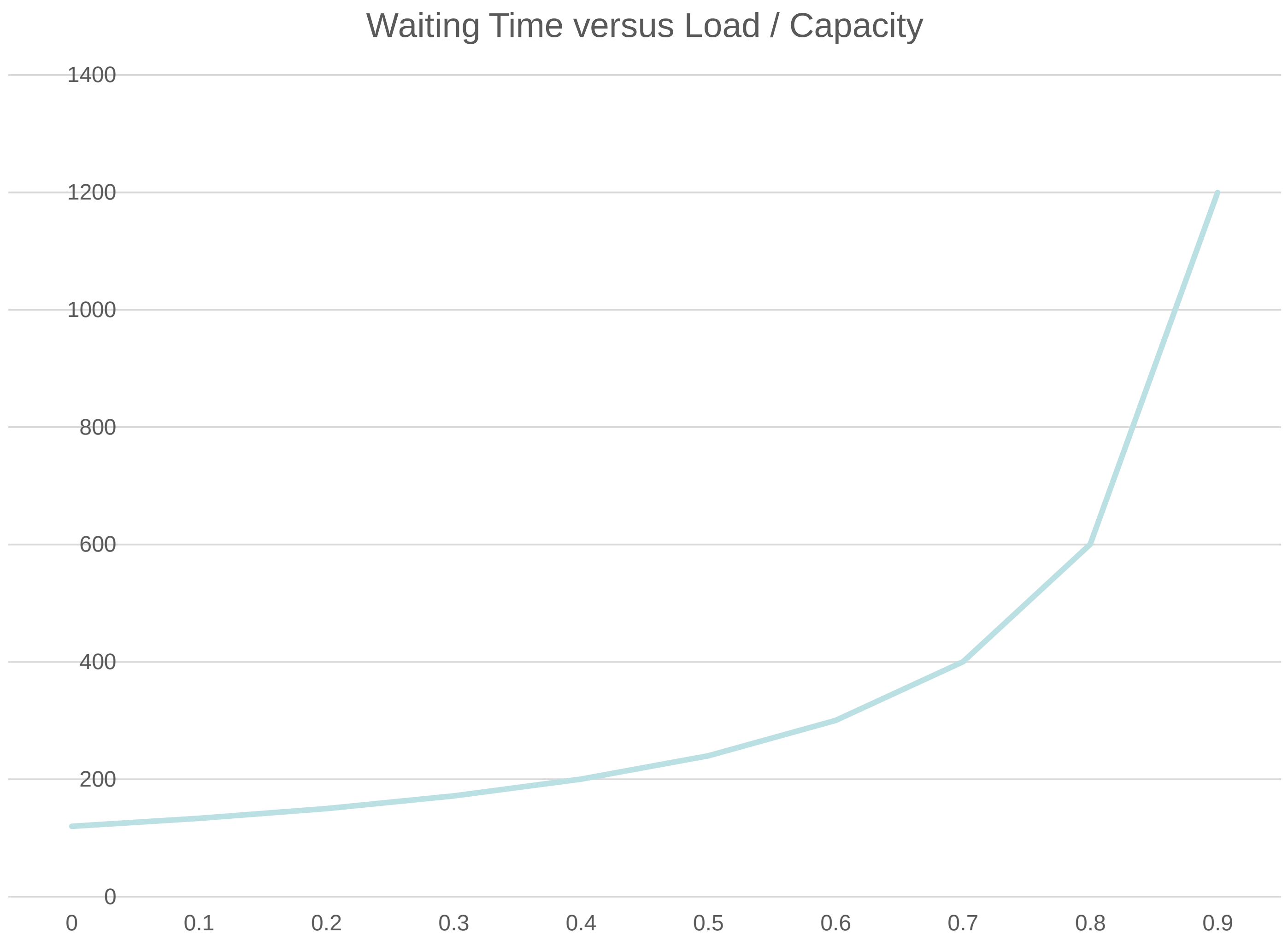
Ticket Counter Simulation

- For a Markov/Markov/1 (M/M/1) process (one queue and one server), the expected waiting time can be calculated in closed form

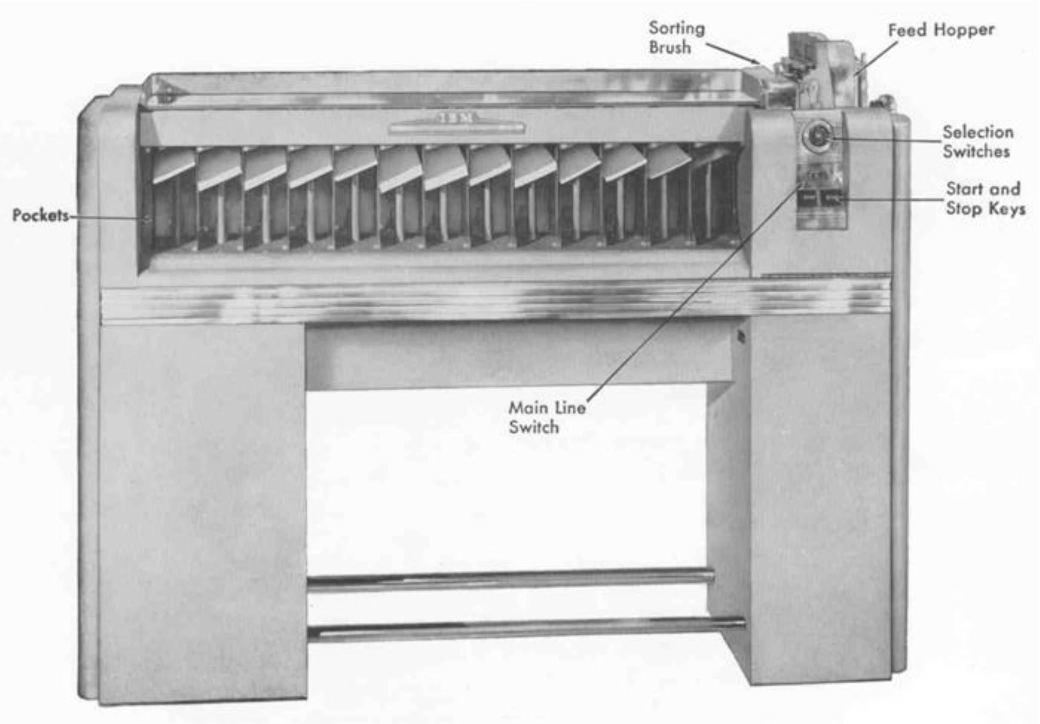
Waiting Time = Service Time / (1 – load/capacity)

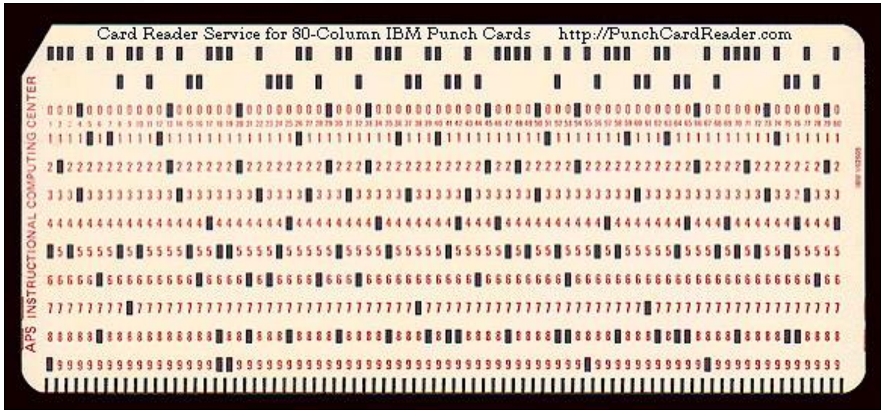
- This produces a graph of waiting time versus load/capacity with infinite waiting time at load equal to 100% or more of capacity

Ticket Counter Simulation



Radix Sort - IBM Card Sorter





Radix Sort - Algorithm

- See L&C Listing 9.3
- Like the old IBM punched card sorters