Queuing

CEE 320
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Fundamentals of Queuing Theory

- **Microscopic traffic flow**
  - **Different analysis than theory of traffic flow**
  - **Intervals between vehicles is important**
  - **Rate of arrivals is important**

Queuing Terminology – think McDonalds

- **Customers requiring service are generated over time by an *input source***
- **These customers enter the *queuing system* and join a *queue***
- **At certain times, a member of the queue is selected for service by some rule known as the *queue discipline*.**
- **The required service is then performed for the customer by the *service mechanism*, after which the customer leaves the queuing system.**

Non-traffic queuing examples

- **Single channel/server**
  - **Wendy's, ATM**
  - **Fast-food drive through**
- **Multiple channel/server (one arrival channel)**
  - **Bank teller**
  - **Airport check-in counter**
  - **Burger King**
- **Multiple channel/server (multiple arrival channels)**
  - **Grocery/retail store (Publix, Lowe's, Wal-Mart)**
  - **McDonald's**

Demand Population/ Arrival Pattern

- Equal time headways
  - Based on uniform distribution
- Exponentially distributed time headways
  - Based on Poisson distribution

Queue Disciplines

- **Refers to the order in which members of the queue are selected for service**
  - **FIFO – first-in first-out**
    - **First customer to arrive is first to depart**
  - **LIFO – last-in first-out**
    - **Last customer into queue is first to leave**
  - **SIRO – service in random order**
  - **Priority**
    - **Customers get served in order of priority (highest to lowest)**

Service Mechanism/ Departure Pattern

- Time elapsed from start to finish of service

- Again, potential patterns:
  - Equal time headways
    - Based on uniform distribution
  - Exponentially distributed time headways
    - Based on Poisson distribution

Number of Servers/Departure Channels

- **Single channel/server**
  - **One server for all queued customers**
- **Multiple channel/server**
  - **Finite number of “identical” servers operating in a parallel configuration**
- **Infinite-server**
  - **A server for every customer**
    - **Don’t we wish!**

Examples of different queue disciplines (non-traffic)

- FIFO
  - Bank teller line, Wendy's
- LIFO
  - Elevator
  - Cafeteria trays

Examples of different queue disciplines (non-traffic)

- **Priority**
  - **Sinking ship – women and children first**
  - **Hospital waiting room – most injured first**
  - **Getting bumped by “more important” people (fancy restaurant)**

Traffic Queuing Examples

- **Left-turn bay length**
- **Number of approach lanes at a signal controlled intersection**
- **Number of toll plaza booths**
- **Number of border crossing booths**
- **Narrow bridge**

Examples of different queue disciplines (traffic)

- FIFO
  - Traffic signal
- LIFO
  - Elevator

Parallel, Serial Queue Systems

- **Parallel**
  - **Toll booths**
  - **Retail store checkout**
  - **Some fast food restaurants**
- **Serial**
  - **Opening night of a movie**
    - **Ticket line, line to get into theater, line for snacks**

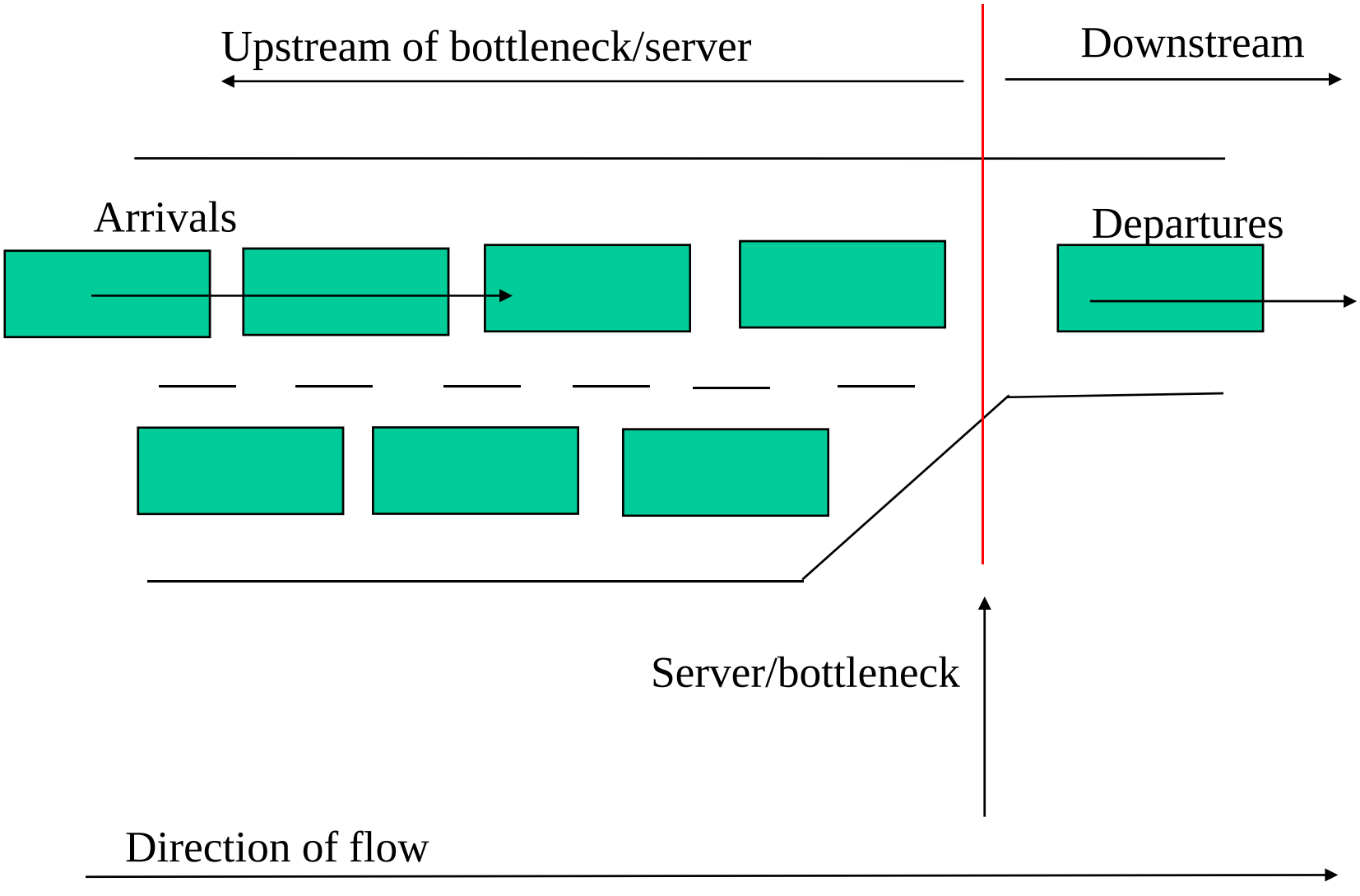
Queuing Model Notation

- **Arrival pattern/departure pattern/# of departure channels**
- **alpha/alpha / #**
- **D for uniform, deterministic**
- **M for exponential, stochastic**
- **e.g., D/D/1, M/M/2**

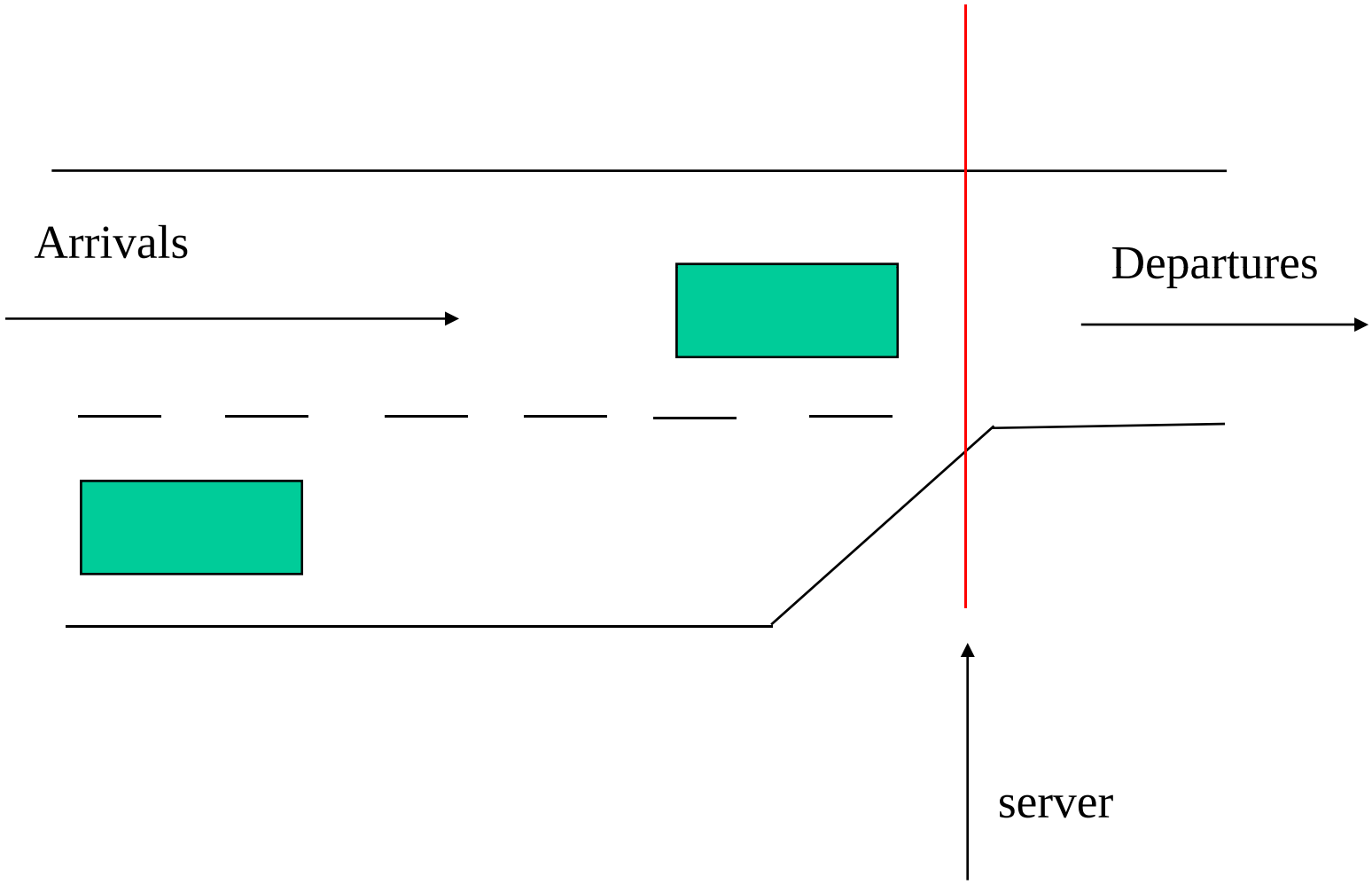
Statistics of Interest

- Average queue length
- Average number in system
- Maximum queue length
- Average waiting time in queue
- Average time in system

Activated


Upstream of bottleneck/server
Downstream
Arrivals
Departures
Server/bottleneck
Direction of flow

Not Activated



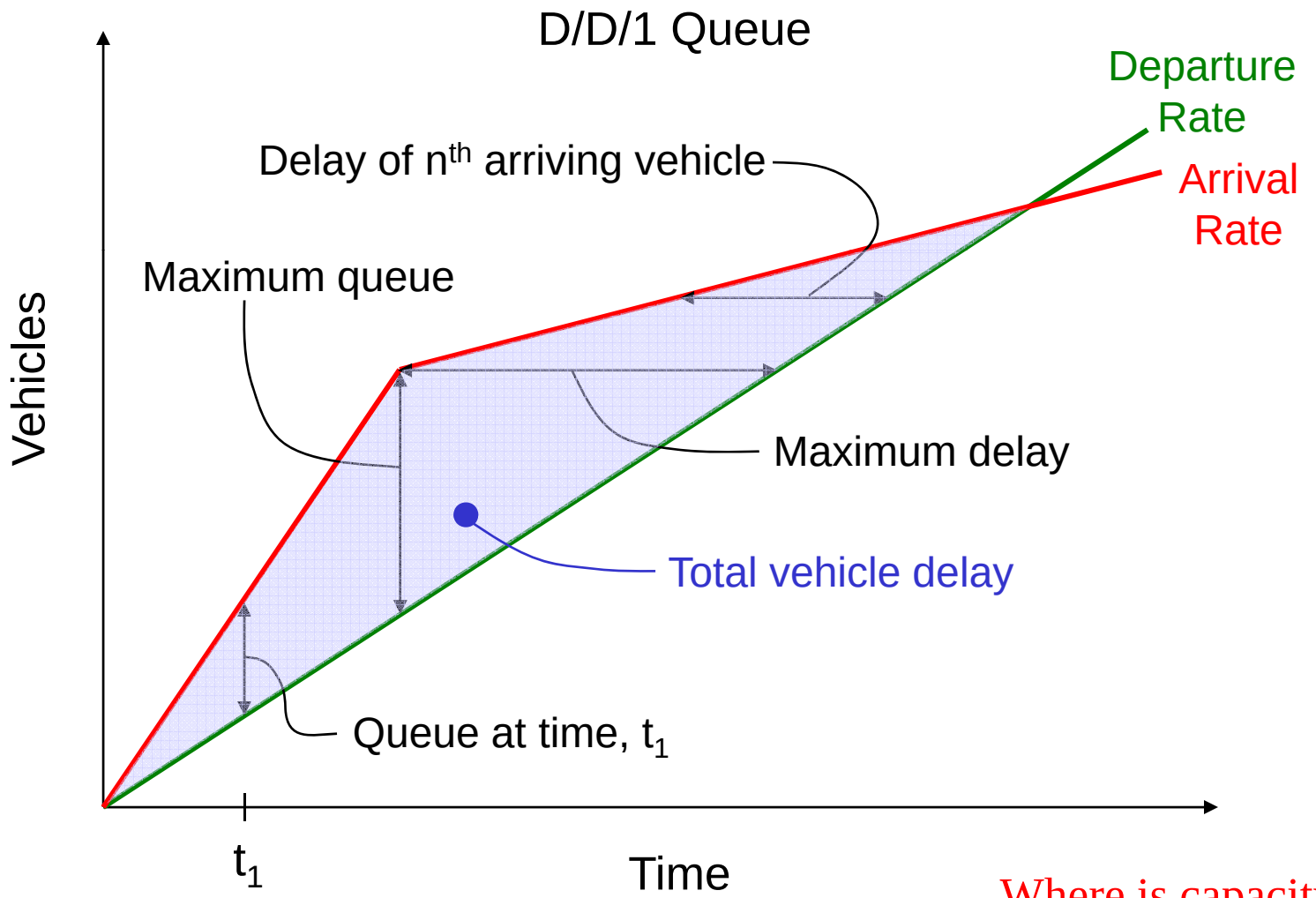
Flow Analysis

- **Bottleneck active**
  - **Service rate is capacity**
  - **Downstream flow is determined by bottleneck service rate**
  - **Arrival rate > departure rate**
  - **Queue present**

Flow Analysis

- **Bottle neck not active**
  - **Arrival rate < departure rate**
  - **No queue present**
  - **Service rate = arrival rate**
  - **Downstream flow equals upstream flow**

Queue Analysis – Graphical



Where is capacity?