• In-network resource management
• Queue management schemes
• Traffic differentiation
Internet of Problems

How do we **route** (and address) scalably, while dealing with issues of policy and economy?

How do we **transport** data scalably, while dealing with varying application demands?

How do we **adapt** new applications and technologies to an inflexible architecture?

- BGP
- TCP, in-network resource management
problem: TCP reacts to drops, and packets aren’t dropped until queues are full
Queue Management

given a queue, when do we drop packets?

1. droptail

drop packets only when the queue is full. simple, but leads to high delays and synchronizes flows.

2. RED

drop packets before the queue is full
As the average queue size increases, the drop probability never drops below \( p_{\text{min}} \). However, it always increases as the queue size approaches \( q_{\text{max}} \).
Queue Management

given a queue, when do we drop (or mark) packets?

1. droptail

drop packets only when the queue is full. simple, but leads to high delays and synchronizes flows.

2. RED (drops) / ECN (marks)

drop (or mark) packets before the queue is full: with increasing probability as the queue grows. prevents queue lengths from oscillating, decreases delay, flows don’t synchronize, but complex and hard to pick parameters
what if we want to give latency guarantees to certain types of traffic?
(or at least try to prioritize latency-sensitive traffic)
Delay-based Scheduling

how could we give latency guarantees for some traffic?

1. priority queueing

put latency-sensitive traffic in its own queue and serve that queue first. does not prevent the latency-sensitive traffic from “starving out” the other traffic (in other queues).
what if we want to allocate different amounts of bandwidth to different types of traffic?
Bandwidth-based Scheduling

how can we allocate a specific amount of network bandwidth to some traffic?

1. **round-robin**
   
can’t handle variable packet sizes (and in its most basic form doesn’t allow us to weight traffic differently)

2. **weighted round-robin**
   
can set weights and deal with variable packet sizes
Weighted Round Robin

in each round:

for each queue q:
    q.norm = q.weight / q.mean_packet_size

min = min of q.norm’s over all flows

for each queue q:
    q.n_packets = q.norm / min
    send q.n_packets from queue q
Bandwidth-based Scheduling
how can we allocate a specific amount of network bandwidth to some traffic?

1. **round-robin**
   can’t handle variable packet sizes (and in its most basic form doesn’t allow us to weight traffic differently)

2. **weighted round-robin**
   can set weights and deal with variable packet sizes, but needs to know mean packet sizes

3. **deficit round-robin**
in each round:
  for each queue q:
    q.credit += q.quantum
    while q.credit >= size of next packet p:
      q.credit -= size of p
      send p
Bandwidth-based Scheduling

how can we allocate a specific amount of network bandwidth to some traffic?

1. **round-robin**
   
can’t handle variable packet sizes (and in its most basic form doesn’t allow us to weight traffic differently)

2. **weighted round-robin**
   
can set weights and deal with variable packet sizes, but needs to know mean packet sizes

3. **deficit round-robin**
   
doesn’t need mean packet sizes. near-perfect fairness and low packet processing overhead
Delay-based Scheduling

how could we give latency guarantees for some traffic?

1. priority queueing

put latency-sensitive traffic in its own queue and serve that queue first. does not prevent the latency-sensitive traffic from “starving out” the other traffic (in other queues).

can solve this problem by doing something similar to bandwidth-based scheduling across the two queues.
In-network Resource Management

Queue Management
- switches can signal congestion before queues are full
  - DropTail
  - RED
  - ECN

Delay-based Scheduling
- switches can prioritize latency-sensitive traffic
  - Priority Queueing

Bandwidth-based Scheduling
- switches can enforce (weighted) fairness among different types of traffic
  - Round-robin
  - Weighted Round-robin
  - Deficit Round-robin

in-network resource management: a good idea?
• Active **queue management schemes**, such as RED or ECN, drop or mark packets before a queue is full, in hopes of getting TCP senders to react earlier to congestion. They are difficult to get to work on the Internet-at-large, but the ideas can be useful in other types of networks.

• **Traffic differentiation** requires a scheduling discipline, such as *weighted round robin* or *deficit round robin*. The goal of these schemes is to give weighted fairness in the face of variable packet sizes while having low processing overhead.

• Both of these are examples of **in-network resource management**