

High speed computer networks

Congestion control

Sosina M.
Addis Ababa institute of technology (AAiT)
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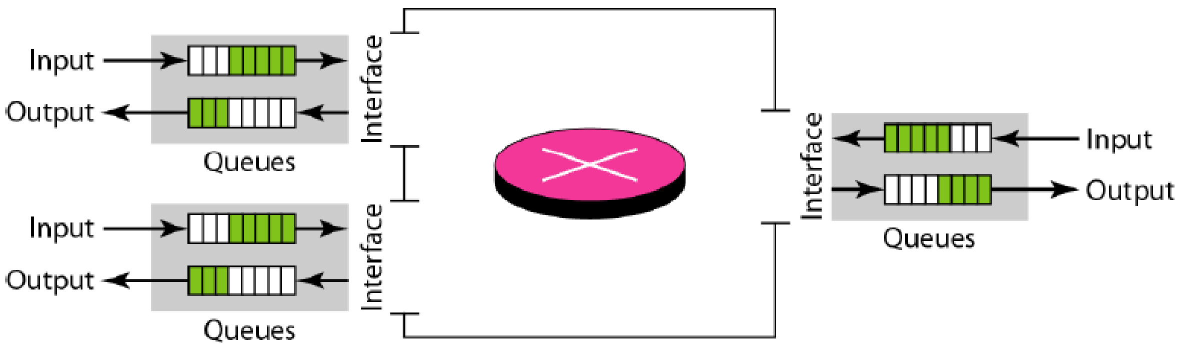
Congestion

- Congestion occurs when the load on the network is greater than the capacity
  - The number of packets sent to the network > the number packet the network can handle
- ***Congestion control*** – a mechanism to control the congestion and keep the load below the capacity

Effect of congestion

- Consider a queueing situation at a single packet switch or router
  - Two fixed or variable size buffers associated to each port

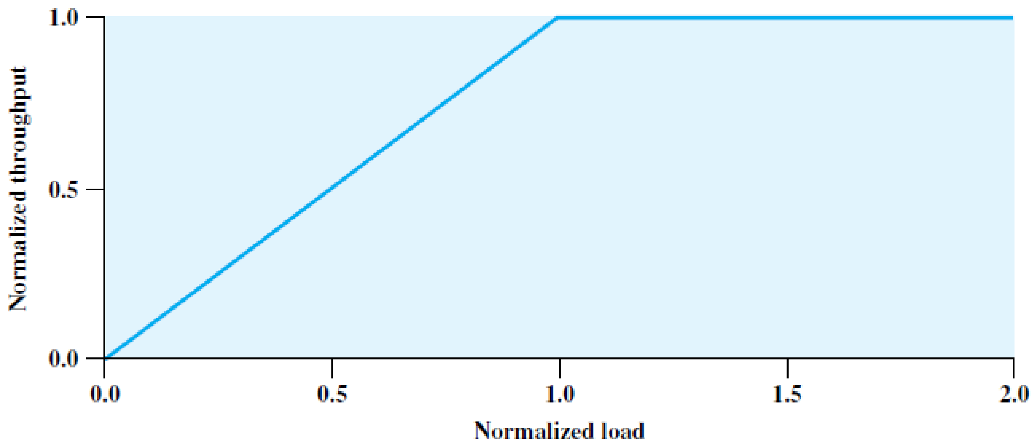


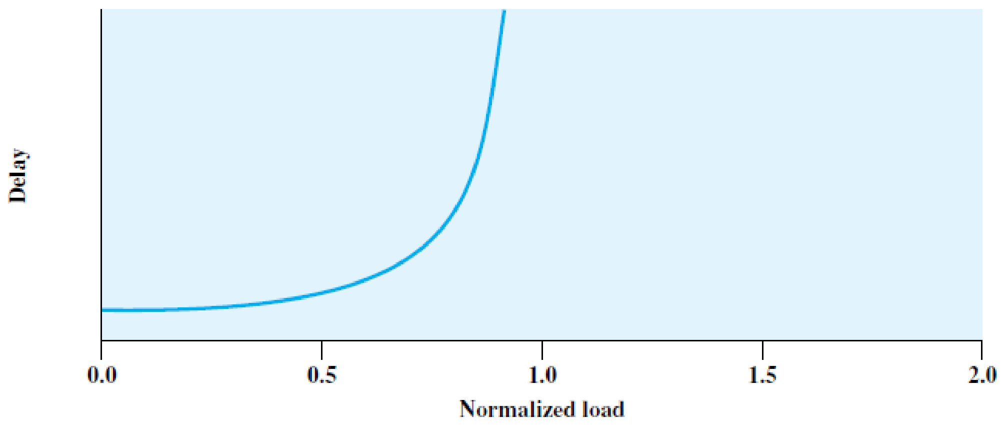
Arriving packet

- ✓ Wait at the end of the input queue
- ✓ Processed – route decision
- ✓ Wait in the output queue

Network performance

- **Performance measures**
  - Throughput
  - Delay
- ***Ideal performance***
  - Number of packets delivered to destination vs. the number of packets transmitted by the source





Network performance

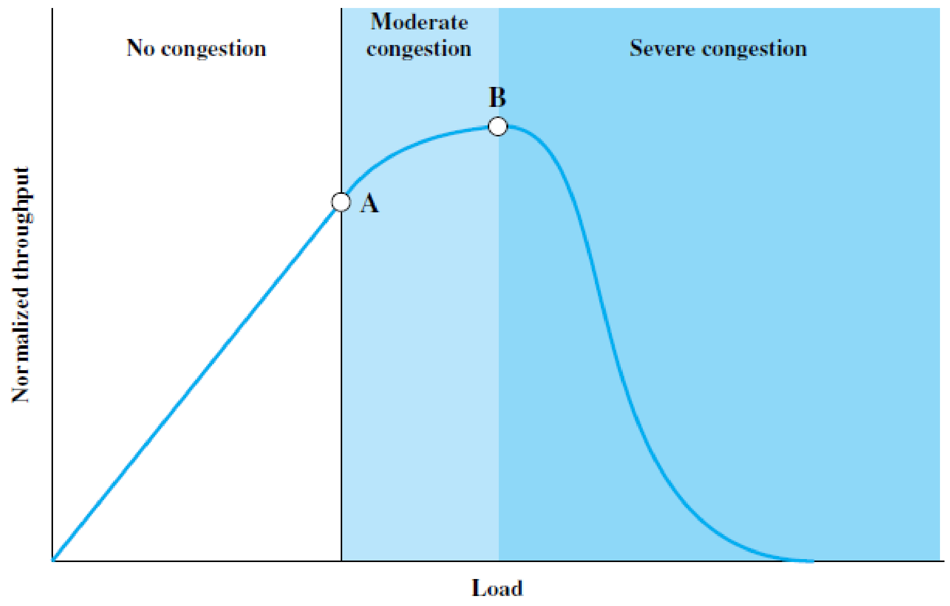
- Ideal case assumptions
  - Infinite buffers
  - No overhead related to congestion control

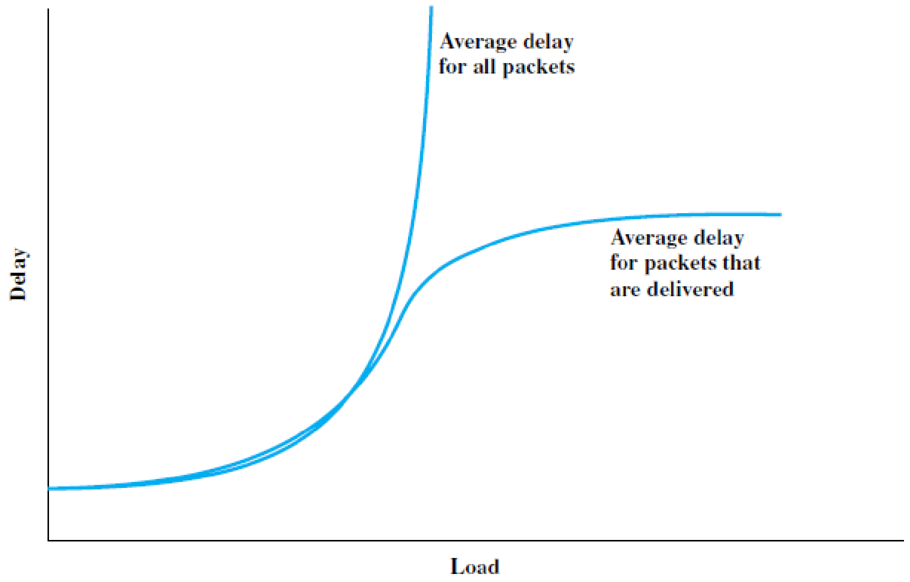
- ***Practical performance***
  - ***Delay versus load***
    - ✓ The Load is much less than the capacity → minimum delay
      - *Minimum delay = propagation delay + processing delay*
    - ✓ The load reaches the network capacity → delay increases sharply
      - *Delay= minimum delay + queueing delay (for all routes in the path)*
    - ✓ The load is greater than the capacity →becomes infinite
      - When the buffers at a node become full, the node discard packets

Network performance

- *Throughput versus load*
  - The load is below the capacity of the network →throughput=load
  - Moderate condition →throughput increases at a rate slower than the rate of increase in the offered load
    - The load is unlikely to spread uniformly through the network (some nodes may experience severe congestion and may need to discard packets)
    - As the load increases, the network will attempt to balance the load by routing packets through the area of lower congestion →routing message exchange
  - Throughput drops with increased offered load
    - Packet discarding
    - Retransmission

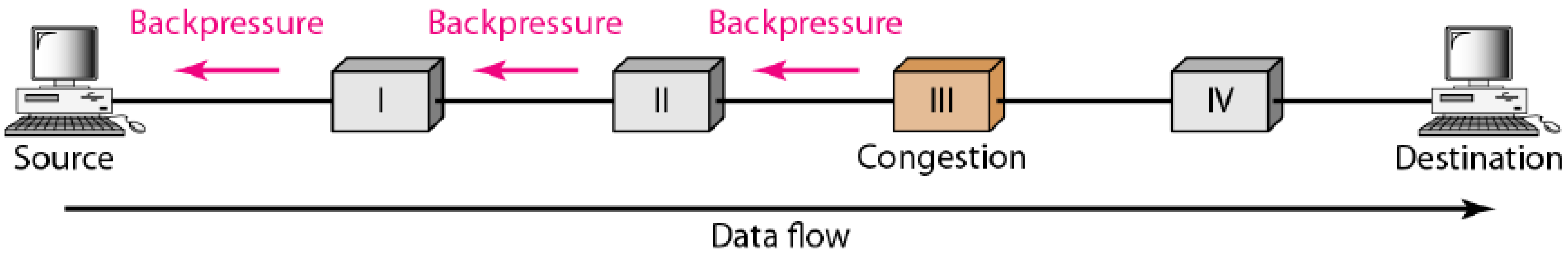
Network performance





Congestion control

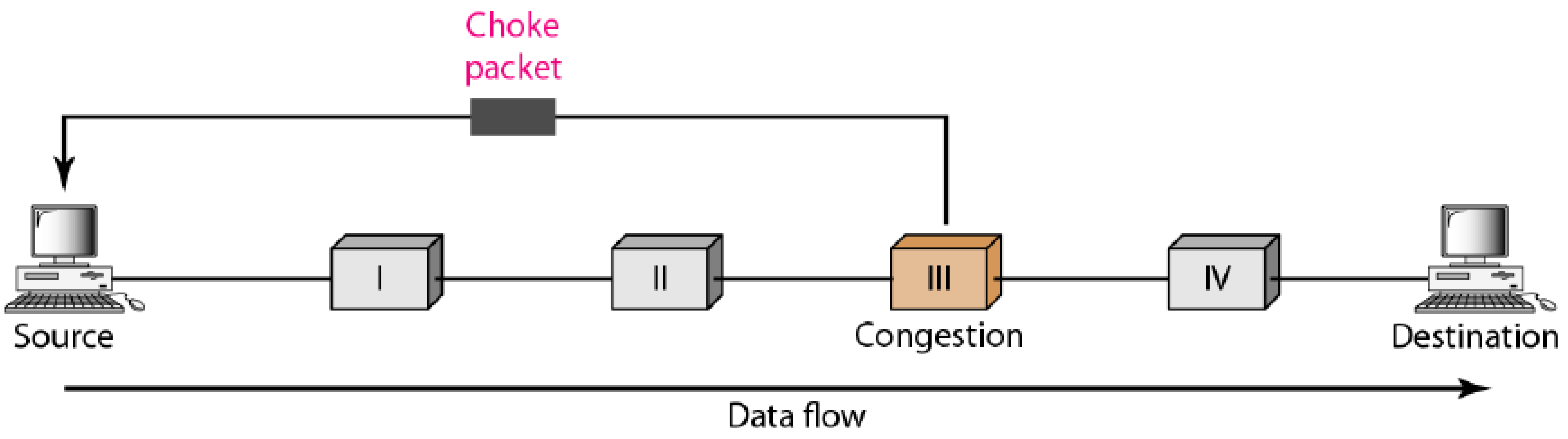
- ❑ ***Backpressure***
  - a node to node congestion control
  - Starts with a node and propagates
    - ✓ Congested node stops receiving data from the immediate upstream node or nodes
    - ✓ Upstream node/nodes become congested →reject data from their upstream node/nodes



  - Can be applied only to virtual circuit networks
  - Implemented in X.25

Choke packet

- A packet is sent by a node to the source to inform it of congestion
  - A warning is sent from the router to the source station directly
  - Example - ICMP



Signaling

- ***Implicit signaling***
  - Congestion → delay occurs and packets are discarded
  - If the source is able to detect increased delays and packet discard
    - Implicit congestion notification
  - Congestion control is the responsibility of end systems
  - An effective congestion control technique in ***connectionless configuration***
  - Can be also used in connection-oriented networks (e.g., frame relay)

Signaling

- **Explicit signaling**
  - The node that experience congestion can explicitly send a signal to the source or destination
  - The signal is included in the packets that carry data
  - **Backward** – Notifies the source
  - **Forward** – sent in direction of the congestion (warn destination)
    - ✓ In some scheme, the end system, that received the signal, echoes the signal back to the source

Explicit signaling

- Explicit signaling approaches can be categorized
  - Binary
    - ✓ A bit is set in a data packet
  - Credit based
    - ✓ Indicate how many packets the source may transmit
  - Rate based
    - ✓ Provide an explicitly data rate limit

Traffic management

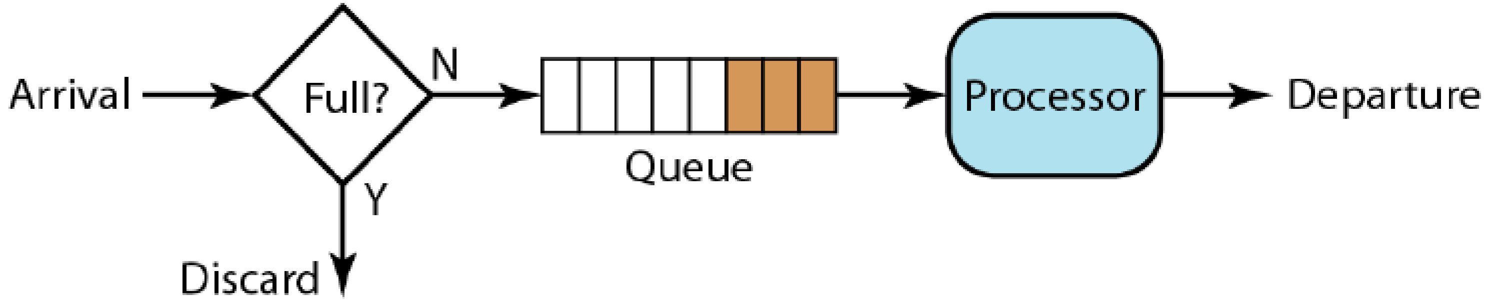
- When a node is saturated and must discard packets, it can apply some simple rule
  - Such as discard the most recent arrival
- Other consideration
  - **Fairness**
    - Last in first discard may not be fair
    - An example of technique that may promote fairness
      - A node can maintain a separate queue for each logical connection (or source –destination pair)
      - If all of the queue buffers are of equal length →the queues with higher traffic load will suffer discards more often

Traffic management: considerations

- **Quality of service**
  - ✓ Treating different traffic flows differently – based on the application requirements
  - ✓ E.g., a node might transmit higher-priority packets a head of lower-priority packets in the same queue
  - ✓ Or a node might maintain different queues for different QoS levels and gives preferential treatments to the higher levels
- **Reservations**
  - ✓ When a logical connection is established
    - The network and the user enter ***into a traffic contract which specifies a data rate and other characteristics of the traffic flow***
    - Excess traffic is either discarded or handled on a best-effort basis

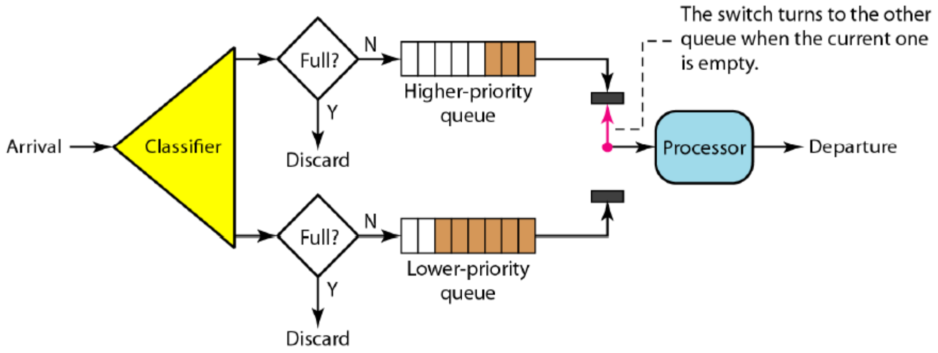
Techniques to improve QoS

- Techniques that can be used to improve the quality of service
  - Scheduling techniques that are designed to improve the QoS
    - ✓ **FIFO queueing**



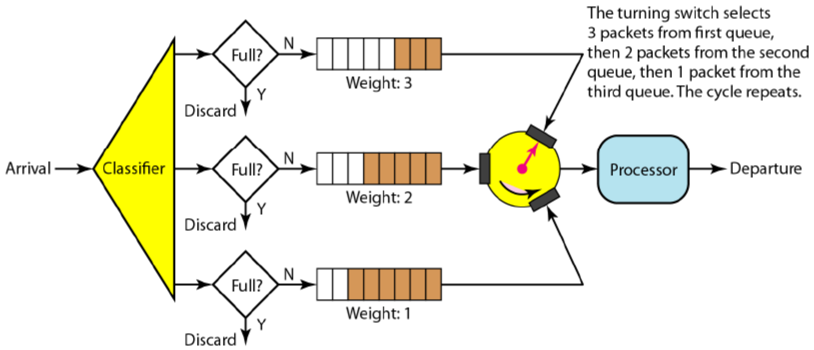
Scheduling

- **Priority queueing**
  - Packets are first assigned to a priority class
  - Each priority class has its own queue
  - The packets in the highest-priority queue are processed first
  - Packets in the lowest-priority queue are processed last



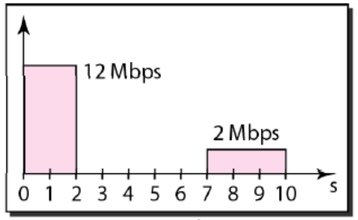
Scheduling

- **Weighted fair queueing**
  - Packets are assigned to different classes and queues
  - The queues are weighted based on the priority of the queues
  - The system process packets in a round-robin fashion with the number of packets selected from each queue ***based on the corresponding weight***

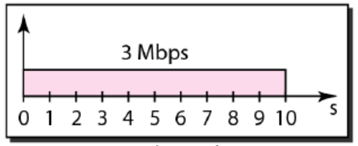


Traffic shaping

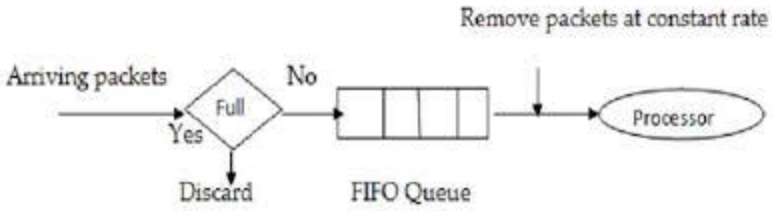
- A mechanism to control the amount and the rate of the traffic sent to the network
- **Leaky bucket**
  - Bursty chunks are stored in the bucket and sent out at an average rate
  - Example – a simple FIFO queue
    - ✓ fixed-size packets –the process removes a fixed number of packets from the queue
    - ✓ Variable length packet – the output rate must be based on the number of bytes



Bursty data



Fixed-rate data



Traffic shaping

- **Token bucket**
  - Allows idle hosts to accumulated credit for the future in form of token
  - Algorithm
    - ✓ A variable is used to count the token
    - ✓ The counter is incremented every t second and decremented whenever a packet is sent
    - ✓ When the counter reaches zero, no further packet is sent out

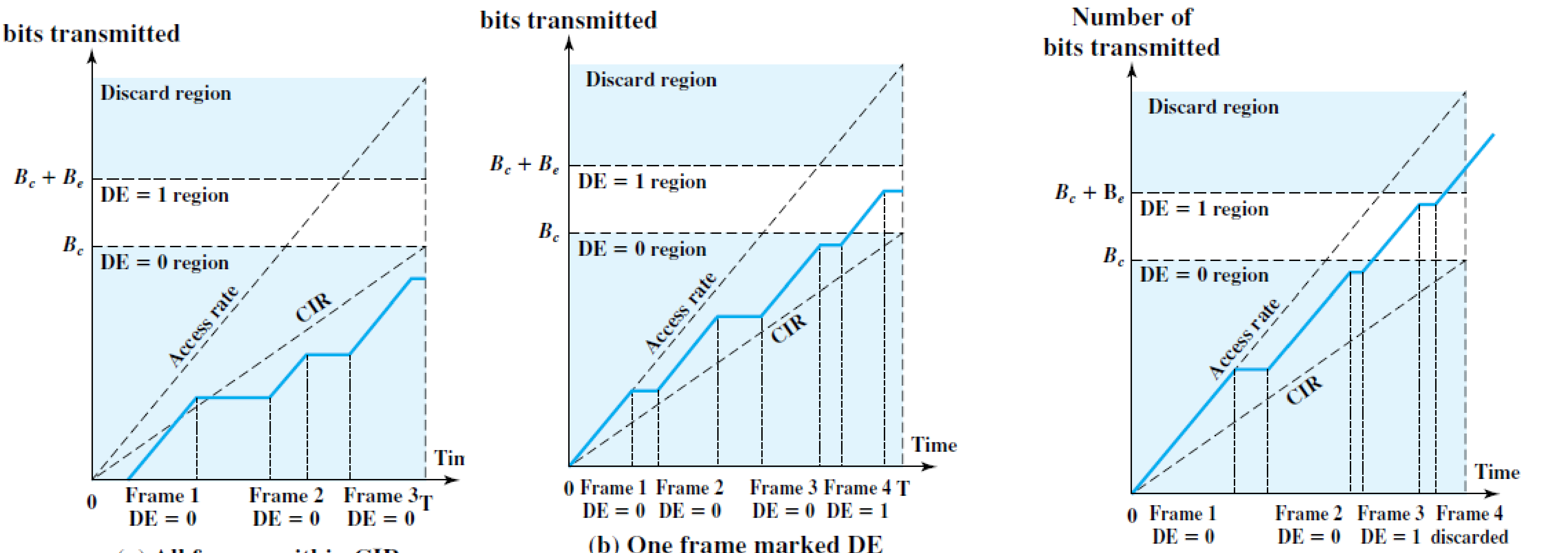
Frame relay congestion control

Technique	Type	Function	Key Elements
Discard control	Discard strategy	Provides guidance to network concerning which frames to discard	DE bit
Backward explicit Congestion Notification	Congestion avoidance	Provides guidance to end systems about congestion in network	BECN bit or CLLM message
Forward explicit Congestion Notification	Congestion avoidance	Provides guidance to end systems about congestion in network	FECN bit
Implicit congestion notification	Congestion recovery	End system infers congestion from frame loss	Sequence numbers in higher-layer PDU

Frame relay traffic management

- Committed information rate (CIR)
  - The rate the network agrees to support
- Any data transmitted in excess of the CIR are vulnerable to discard in the event of congestion
- Two additional parameters
  - Committed burst size(Bc) – the maximum amount data that the network agrees to transfer over a measurement interval T
  - Excess burst size (Be) – the maximum amount of data in excess of Bc that the network will attempt to transfer

Frame relay traffic management



(a) All frames within CIR

(b) One frame marked DE

(c) One frame marked DE; one frame discarded