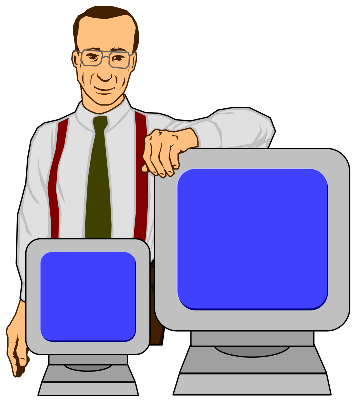
ATM Traffic Management



One Megabit memory, One Megabyte disk, One Mbps link, One MIP processor, one dollar each.....

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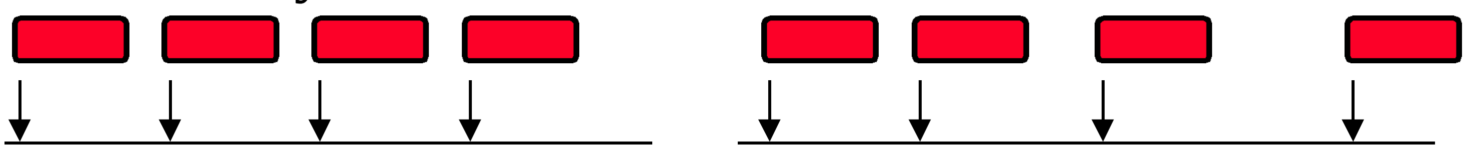
ATM Networks: Overview

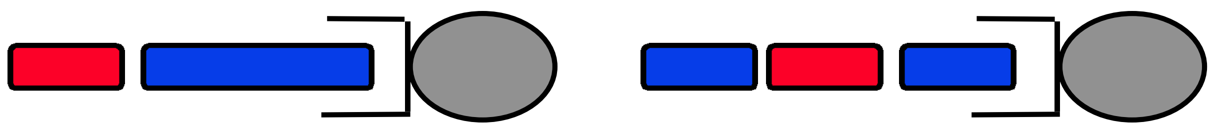
- STM = Synchronous Transfer Mode,
  ATM = Asynchronous Transfer Mode



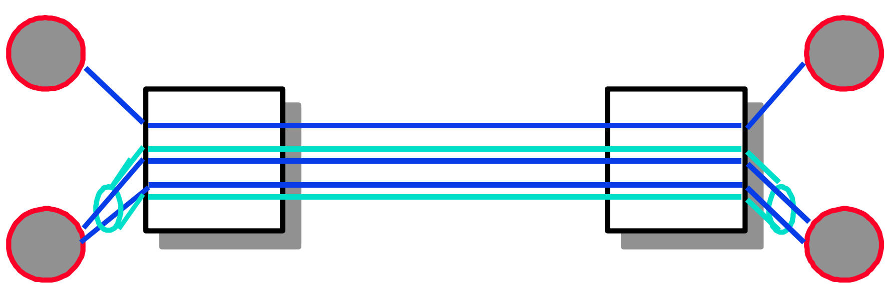
Allows any-speed and even variable rate connection

Broadband = Rate greater than primary rate (1.5 Mbps)

- ATM = Short fixed size 53-byte cells



- Connection oriented ⇒ Virtual Channels (VC)



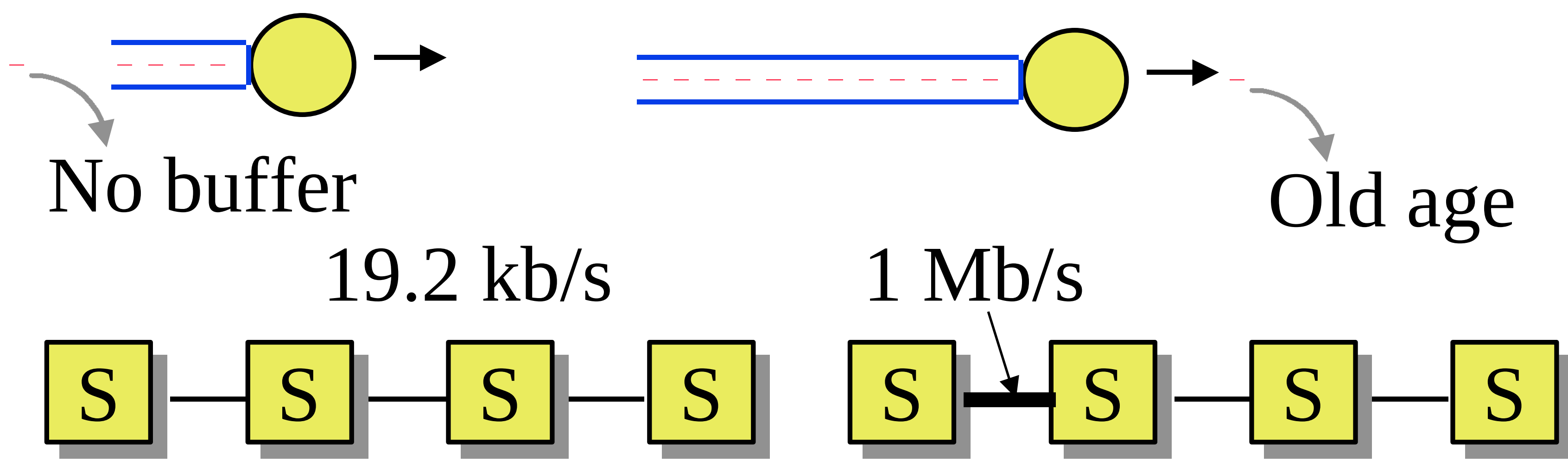
- Why worry about congestion?
- Congestion schemes for ATM
- Rate vs Credit: Key issues
- Explicit Rate-based Control
- ABR Traffic Management

Why Worry About Congestion?

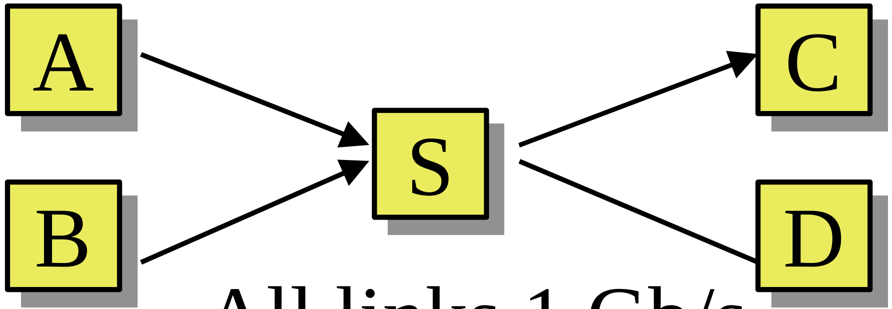
Q: Will the congestion problem be solved when:

- Memory becomes cheap (infinite memory)?
- Links become cheap (very high speed links)?
- Processors become cheap?

A: None of the above.



File transfer time = 5 mins   Time = 7 hours



All links 1 Gb/s

Conclusions:

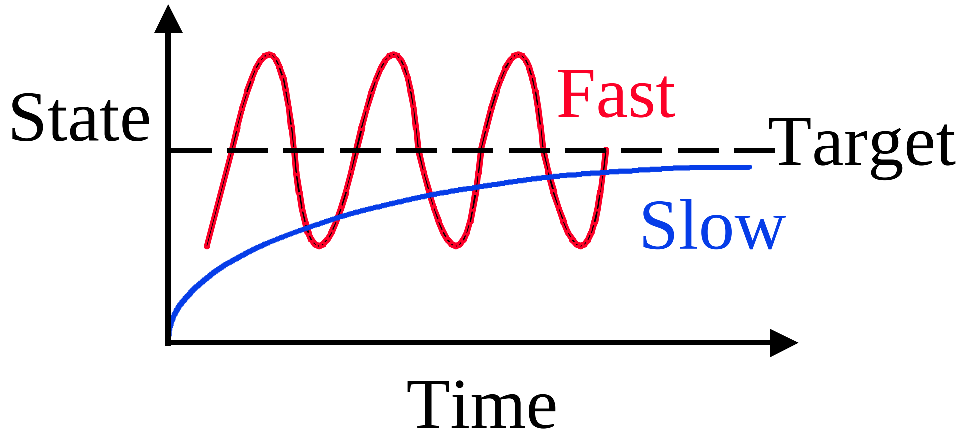
- Congestion is a dynamic problem. Static solutions are not sufficient
- Bandwidth explosion
  $\Rightarrow$ More unbalanced networks
- Buffer shortage is a symptom not the cause.

Economic Reasons

- Network is a shared resource
  Because it is expensive and needed occasionally
  (Like airplanes, emergency rooms)
- Most costs are fixed.
  Cost for fiber, switches, laying fiber and maintaining them does not depend upon usage
  $\Rightarrow$ Underutilization is expensive
- But overutilization leads to user dissatisfaction.
- Need a way to keep the network maximally utilized

One Scheme or Many?

- Fundamental principle of control theory:



- Control faster than feedback ⇒ Instability
  Control slower than feedback ⇒ non-responsiveness
  Ideal: Control rate ≈ Feedback rate
- Lesson: No scheme can cure a congestion lasting less than its feedback delay.

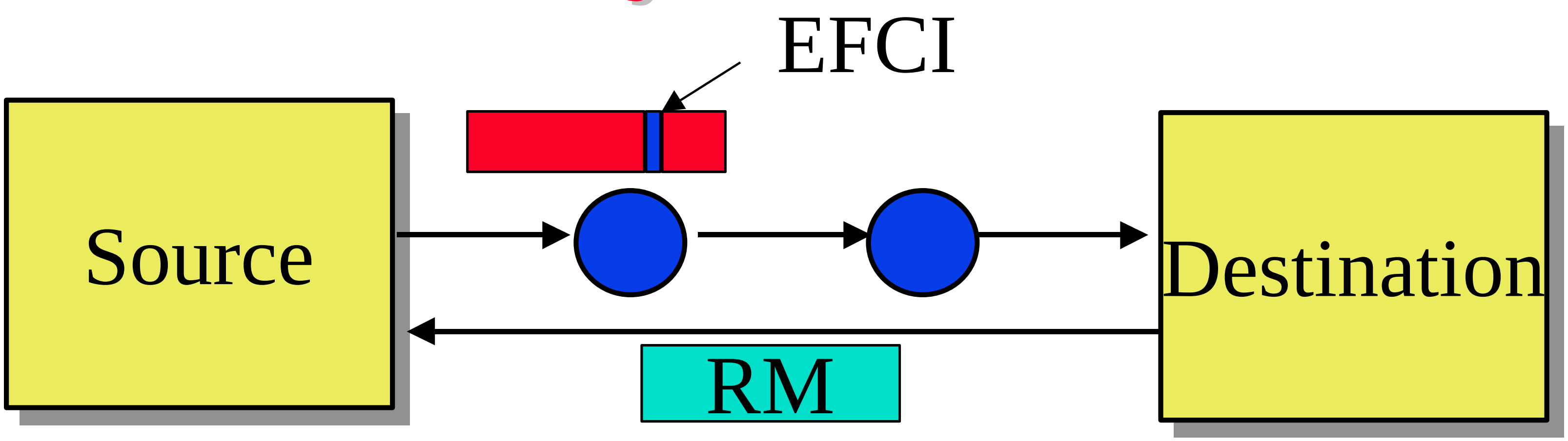
Classes of Service

- CBR (Constant bit rate): User dec8 Tcres required rate. Throughput, delay and delay variation guaranteed.
- VBR (Variable bit rate): User dec8ares average and max rate.
  - rt-VBR (Real-time variable bit rate): Conferencing. Max delay and delay variation guaranteed.
  - nrt-VBR (non-real time variable bit rate): Stored video.
- ABR (Available bit rate): Follows feedback instructions. Network gives maximum throughput with minimum loss.
- UBR (Unspecified bit rate): User sends whenever it wants. No feedback mechanism. No guarantee. Cells may be dropped during congestion.

Traffic Management Functions

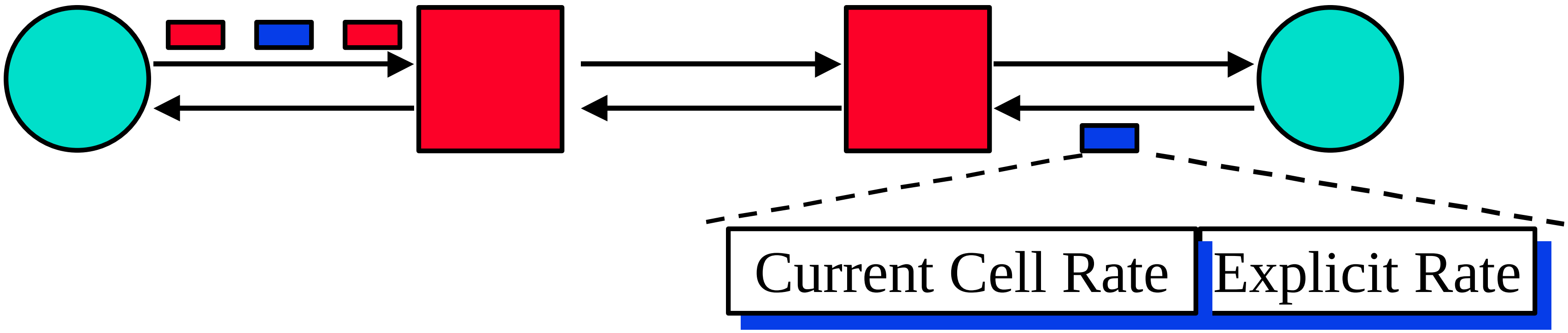
- Connection Admission Control (CAC):
  Can requested bandwidth and quality of service be supported?
- Traffic Shaping: Limit burst length. Space-out cells.
- Usage Parameter Control (UPC):
  Monitor and control traffic at the network entrance.
- Network Resource Management:
  Scheduling, Queueing, virtual path resource reservation
- Selective cell discard:
  Cell Loss Priority (CLP) = 1 cells may be dropped
  Cells of non-complient connections may be dropped
- Frame Discarding
- Feedback Controls: Network tells the source to increase or decrease its load.

Initial Binary Rate-based Scheme



- *We invented DECbit scheme (1986). Implemented in many standards since 1986.*
- *Forward explicit congestion notification (FECN) in Frame relay*
- Explicit forward congestion indicator (EFCI) set to 0 at source. Congested switches set EFCI to 1
- Every *n*th cell, destination sends an resource management (RM) cell to the source indicating increase amount or decrease factor

The Explicit Rate Scheme

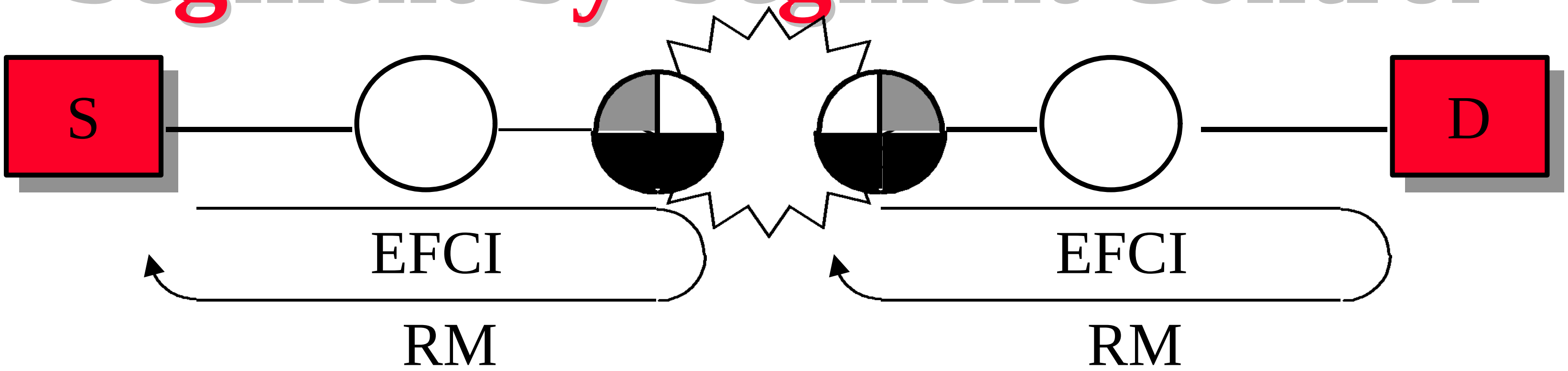


- Sources send one RM cell every n cells
- The RM cells contain "Explicit rate"
- Destination returns the RM cell to the source
- The switches adjust the rate down
- Source adjusts to the specified rate

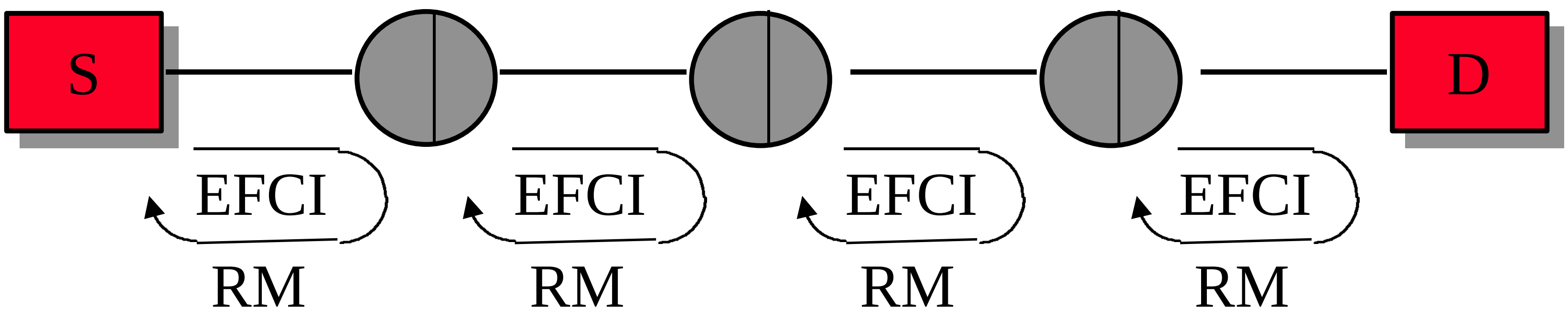
ERICA Switch Algorithm

- Each manufacturer will have its own explicit rate switch algorithm
- Explicit Rate Indication for Congestion Avoidance (ERICA) is the most thoroughly analyzed algorithm among disclosed algorithms
- Shown to be efficient, fair, fast transient response, able to handle bursty TCP traffic
- ERICA+ allows low delay even at 100% utilization and provides stability in the presence of high frequency VBR background traffic
- Being implemented by several vendors

Segment-by-Segment Control

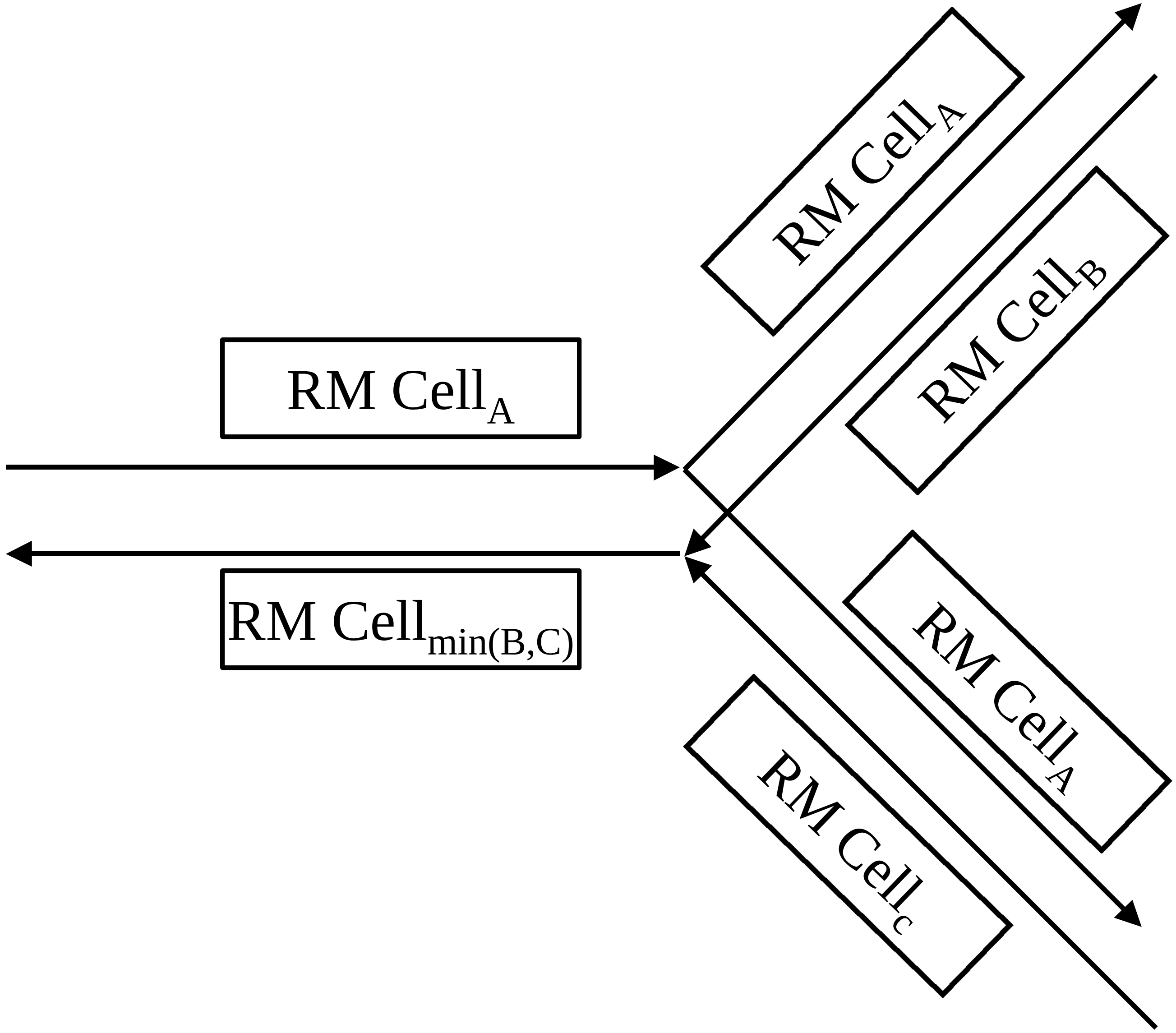


- Virtual source/virtual destinations follow all notification/control rules
- Can be hop-by-hop



- Virtual dest/sources maintain per-VC queues.

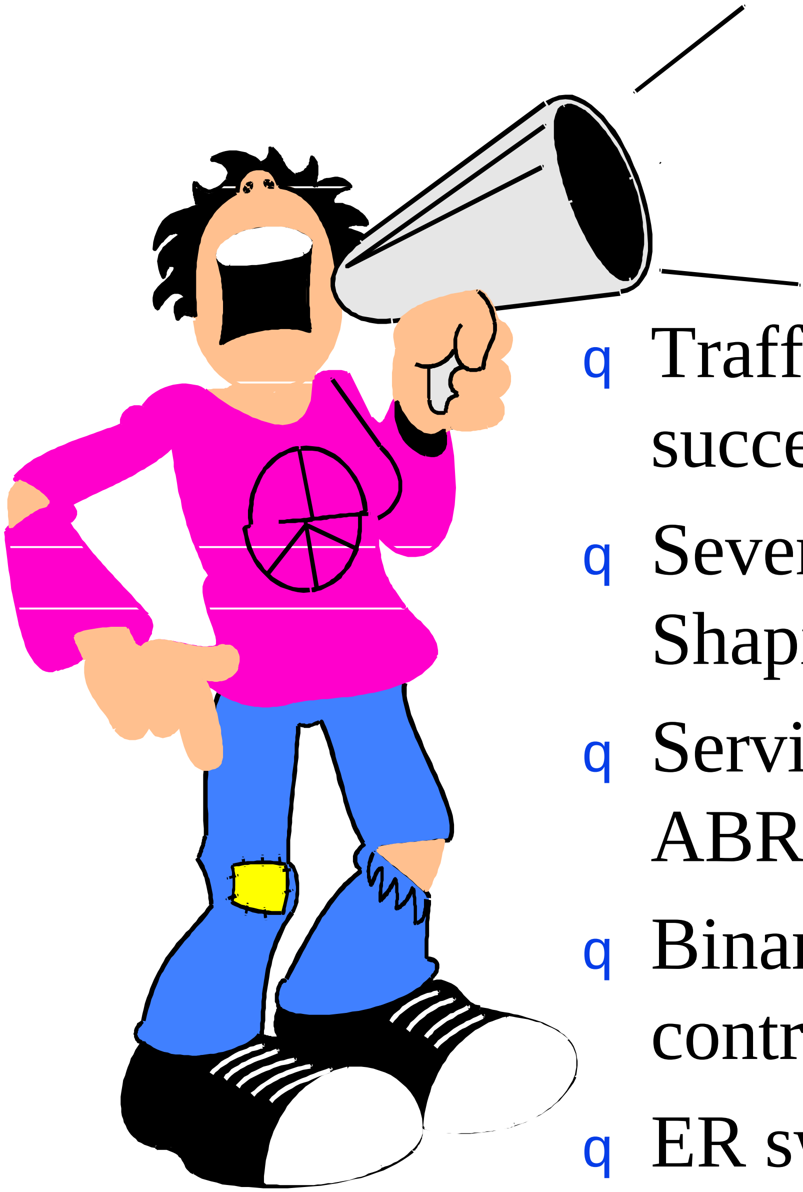
Multicast



Outstanding Issues

- Bursty sources: Client server, transactions, WWW
- Effect of parameters: Optimal parameter values
- Priority service for RM cells
- Multicast
- Connection admission control (CAC)
- TCP/IP over UBR
- Non-conforming sources
- Optimal Source Strategy: Parameter + Out-of-rate cells
- Virtual Source/destination
- Implicit feedback schemes: Heterogeneous Networks

Congestion: Summary



- Traffic Management is key to success of ATM
- Several different methods: CAC, Shaping, UPC, Scheduling, ...
- Service categories:CBR, VBR, ABR, UBR
- Binary feedback too slow for rate control. Especially for satellites.
- ER switches provide much better performance than EFCI.

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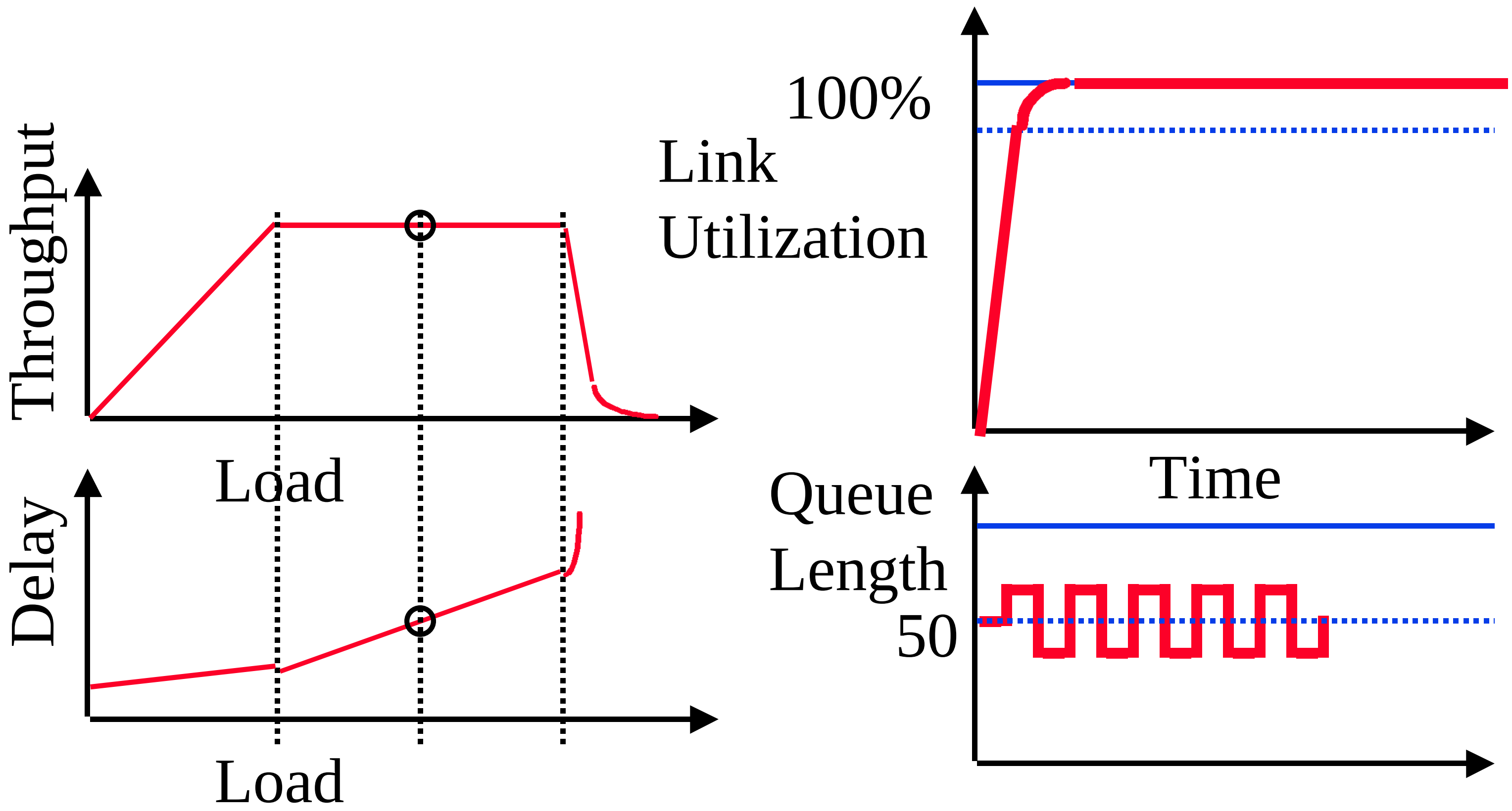
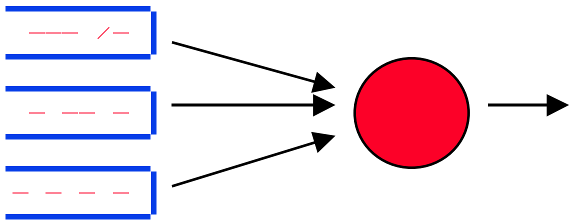
ERICA+: Full Utilization

- Allows operation at any point between the knee and the cliff
- The queue time can be set to any desired value.
- Allows utilization to be 100%



Fair Queueing

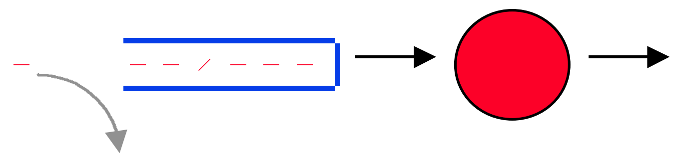
- Goal: Isolation of flows.
- Round Robin:



- Problem: Flows with large packets get more bandwidth.
- Bit-by-bit Round Robin
- Fair Queueing: Compute end-times of packets under bit-by-bit round robin.
- Weighted Fair Queueing: Different flows are allowed different bandwidth.

Selective Cell Discarding

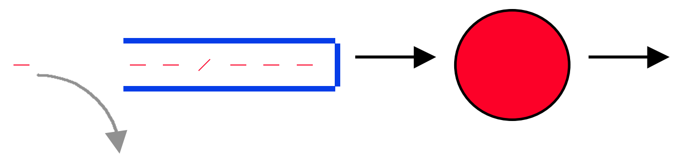
- **Goal**: Discard cells of VCs not following contract
- **Normal Discard**: CLP=1 cells are discarded if buffer is full.



- **Selective Cell Discard**: May discard CLP =1 or CLP =0 cells of non-complient VCs.

Early Packet Discard

- **Goal**: To minimize packet loss rate
- **Normal Discard**: Cells are discarded if buffer is full.



  Problem: Unfair to late-comers.

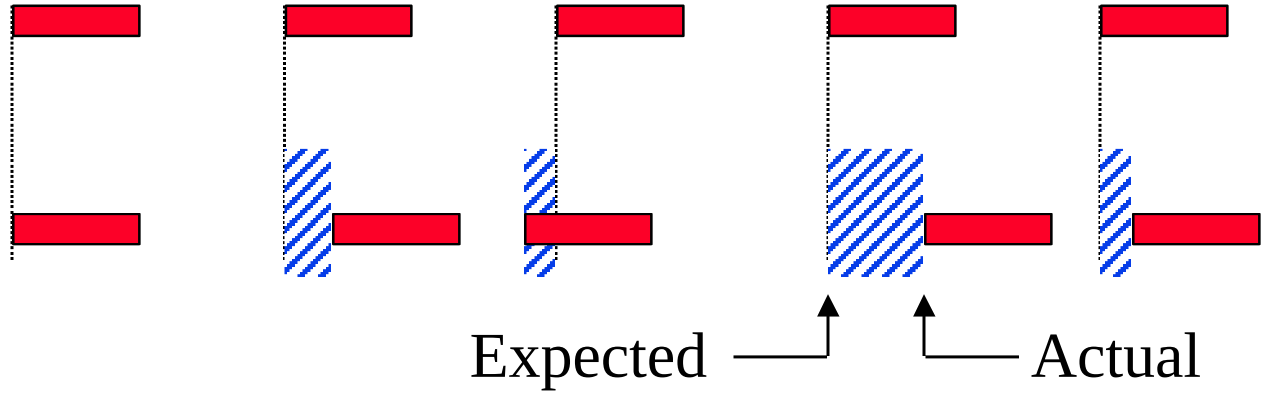
- **Random Discard**: Randomly select a cell in the queue and discard it.
  Problem: Need to look inside the queues.
- **Early Packet Discard**: When a queue threshold exceeds,
  - First cell of the next arriving packet is discarded.
  - Drop all cells of discarded packets.

Cell Delay Variation

- Cell Transfer Delay (CTD): First bit out to last bit in
- Cell Delay Variation (CDV) = CTD_{max} - CTD_{min}
  - Peak-to-peak CDV
  - Instantaneous CDV

Instantaneous CDV

- I-CDV= Actual-Expected arrival time
- Expected = Emission + Nominal delay
- Cell Delay Variation Window (CDV-W)
  CDV-W = |I-CDV(Max)| + |I-CDV(Min)|
- Cells arriving outside window are considered lost
- Large CDV ⇒ Large buffers ⇒ Higher cost



Generic Flow Control (GFC)

- ATM header format designed from DQDB cell headers. The first byte in DQDB is access control for contention.
- Some countries wanted to keep this in ATM for compatibility and others saw no use for it.
- Compromise ⇒ One half of the octet was reserved for "Generic Flow Control" to be defined at some future point.
- British Telecom adapted multiservice flow control (MSFC) from Orwell ring and proposed to use it for GFC

Fast Resource Management

- User requests to send a burst.
- Network reserves the resources and grants the request
- User sends the bursts
- If network rejects, ???

ERICA Features

- Measured overload/load at switch
- Small queue lengths during steady state
- Fast response due to optimistic design
- Parameters: Few, insensitive, easy
- Insensitive to source not using their allocated rates
- Several options: Backward Explicit Congestion Notification
- Simplified switch algorithm
- Optimized all steps. Eliminated unncessary steps. Eliminated many parameters

ERICA+: Switch Algorithm

- Target cell rate = Target Utilization × Link Capacity
- Target Utilization
  = fn(Current load, Queue length, Queue drain time goal)
- Rest is similar to ERICA
- Features:
  - Queue length is bounded during overload
  - No queue underflow ⇒ Switches keep ABR cells waiting to be transmitted as soon as the bandwidth becomes available.
  - 100% Utilization even with VBR

Control Mechanisms

- nrt-VBR: Open-Loop + Optional closed loop component
  - Traffic shaping, CLP
  - EFCI optional
    ⇒ No switch or end-system behavior specified
- UBR: Local policy. CLP=0 or 1. Not subject to CAC.
- ABR:
  - CLP=1 data cells not allowed.
  - No EFCI in RM cells
  - All parameters are negotiated independently for the two directions
  - MCR=0 not subject to CAC due to load

Rate Representation

Reserved	Nonzero	Exponent	Mantissa
1	1	5	9 ← Size in bits

- Rate in cells/second = $[2^e(1+m/512)]*nz$
- Example:

  0-1-01010-0 1100 1010 = $2^{18}(1+202/512)$

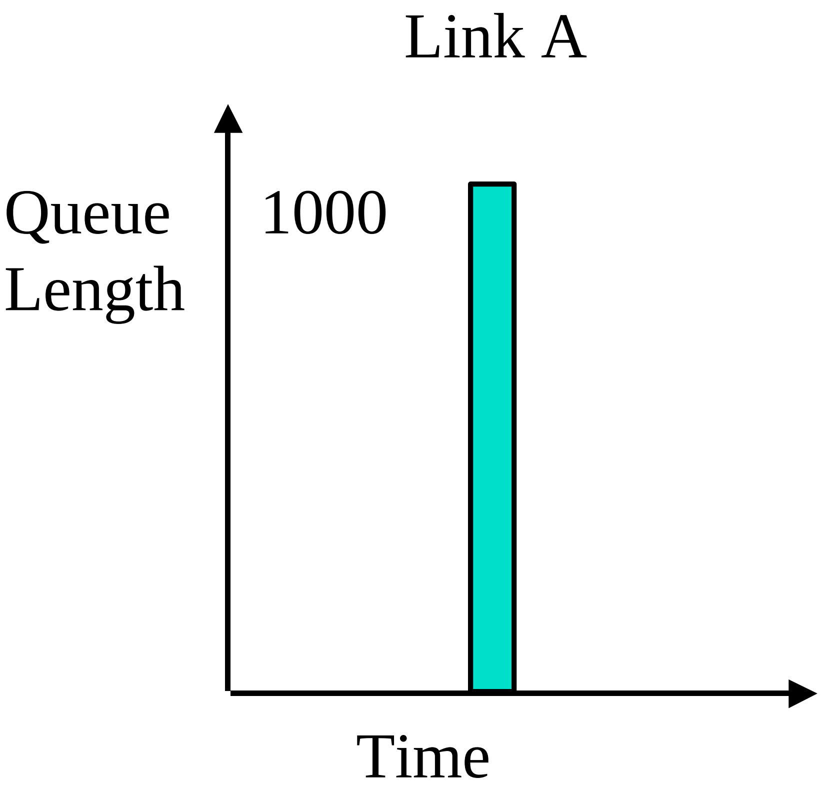
  = 262144×1.394523

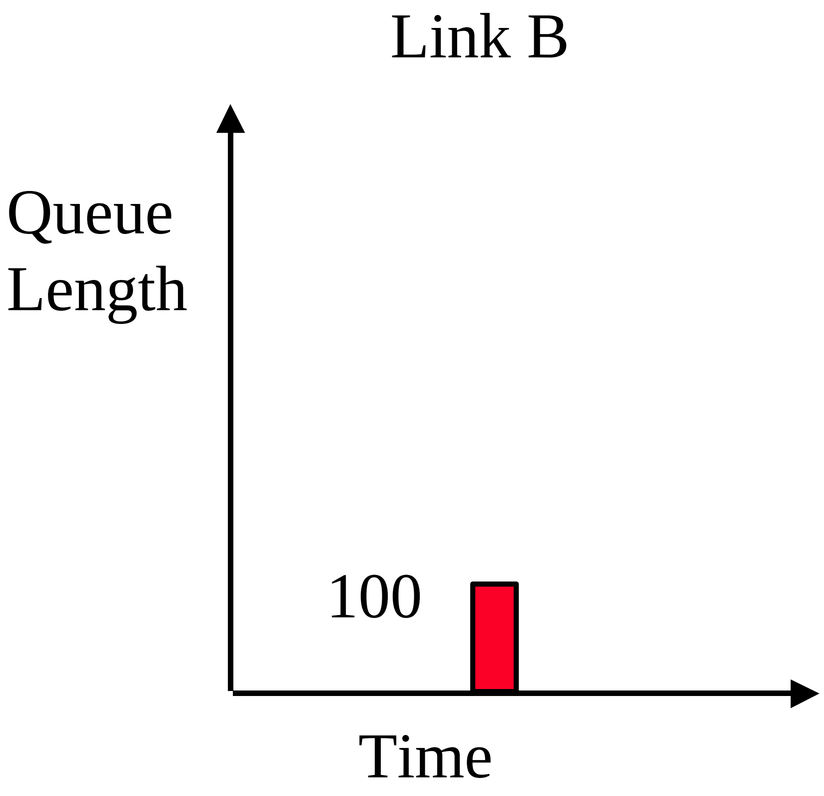
  = 365,566 cells/sec = 155 Mbps

OSU Congestion Principles

- Input rate (and not queue length) is the load measure
- Congestion avoidance (and not congestion control) should be the goal
- Transient performance (and not the steady state performance) is more important

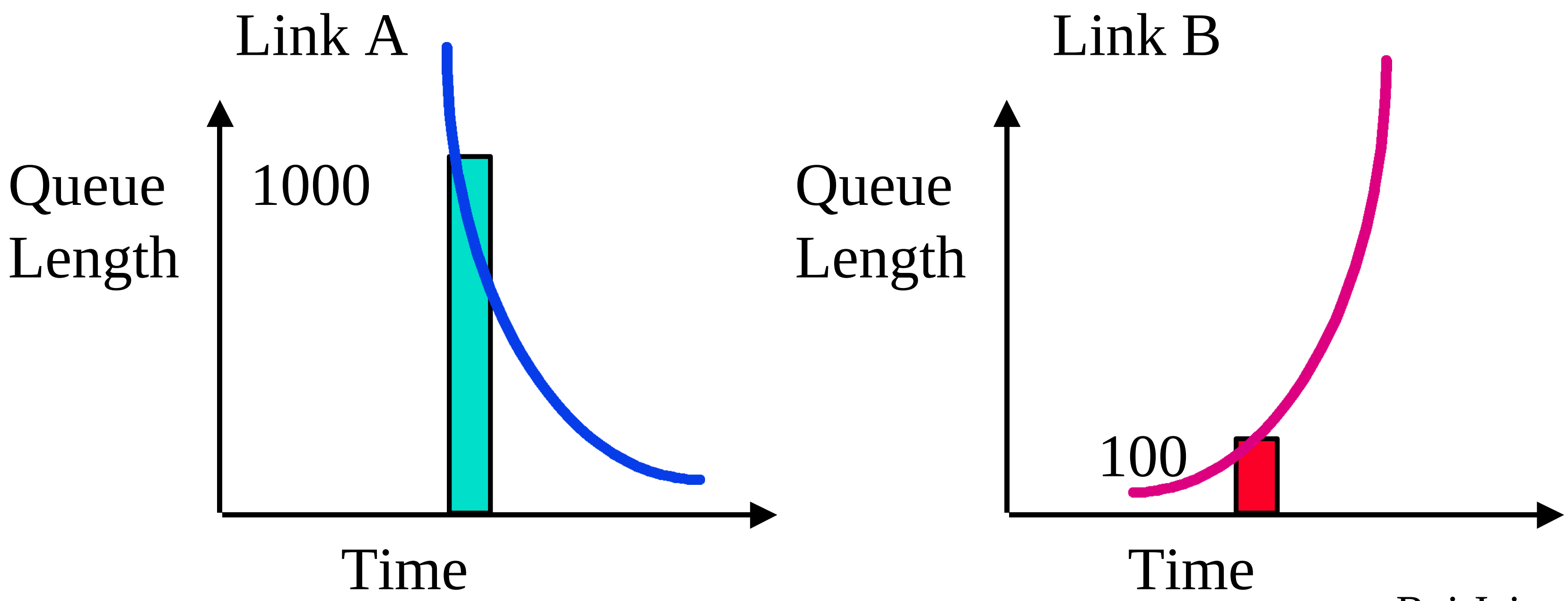
Which Link is More Overloaded?





Answer: It Depends!

- Link Speed: OC-12 or T1?
- Control: Rate or Window?
  Q = Window, dQ/dt = Rate
- For Rate Control: Monitor input rate

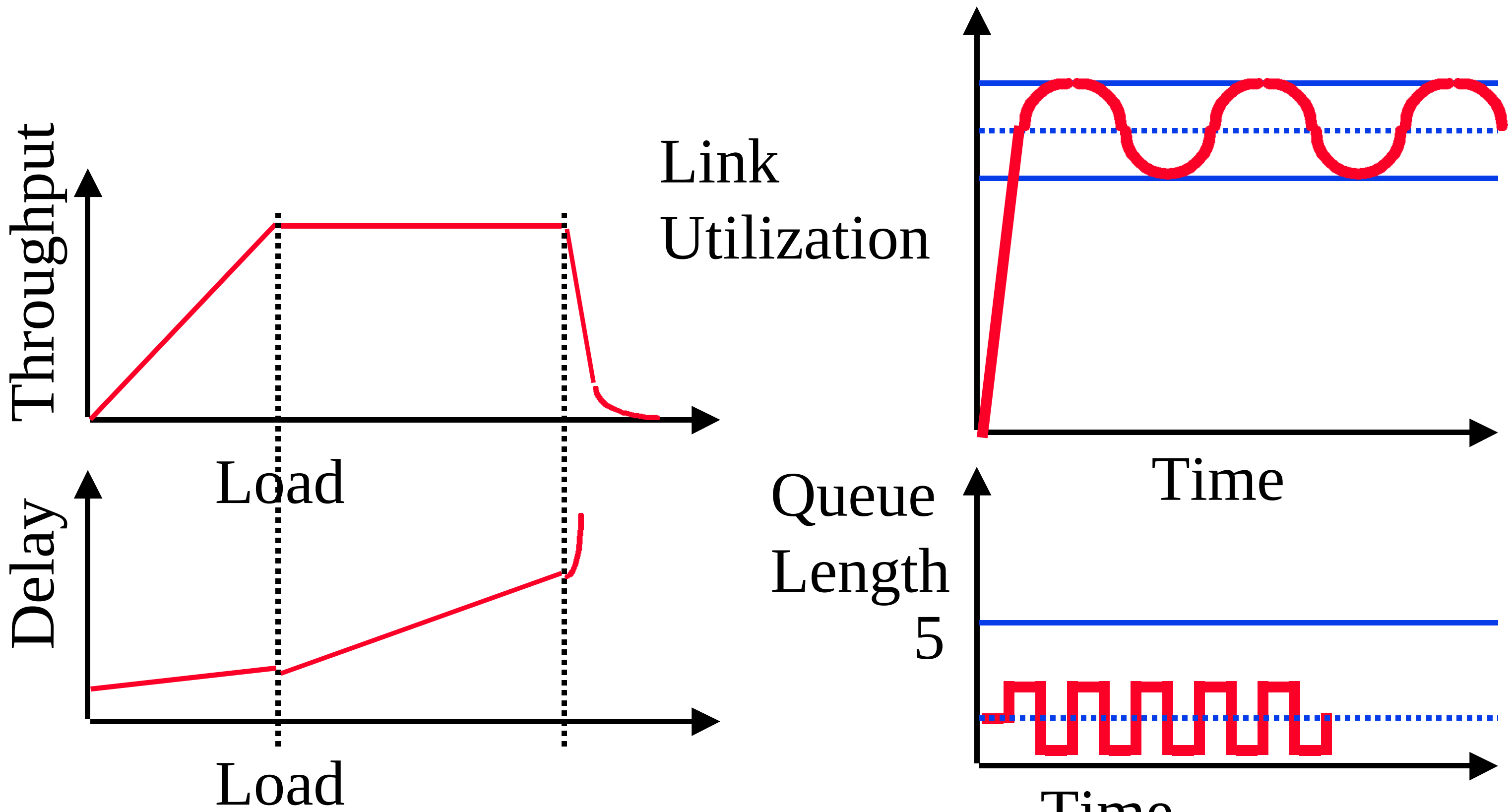


Conclusions I

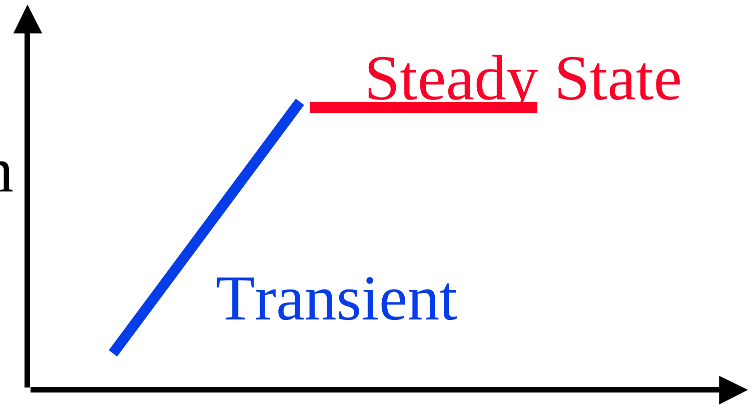
+ Instantaneous queue length is not a good indicator of load for a rate controlled system.
  Q(t) = Q(t-1) + Input rate(t) - Service rate(t)
+ Using queue length as the load indicator in a rate controlled system leads to unnecessary oscillations.
+ Input rate monitoring not only correctly tells whether the system is overloaded, it also tells by what factor.
+ Queue = n is not a good goal. Input rate=service rate is.

Congestion Avoidance

- High throughput, Low delay
- Small queues
- Bounded oscillations ⇒ Good for Video traffic



Why Worry About Transients?

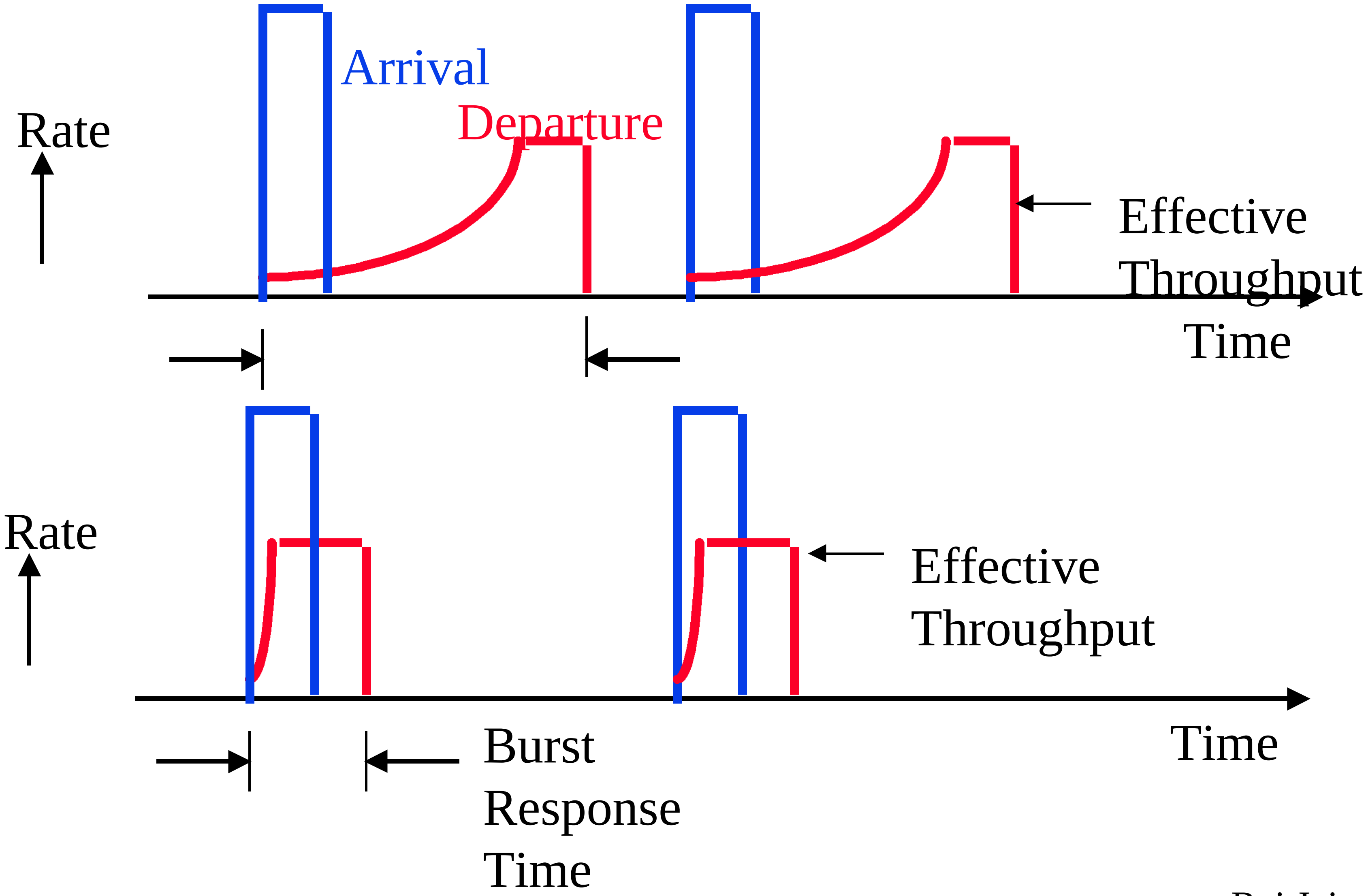


On most networks:

- There are no infinite sources.
- Sources come and go
- VCs may stay but are mostly inactive
- Traffic is highly bursty

⇒ Networks are operating in the transient region, most of the time.

Burst Performance



Legacy LANs vs ATM

- Today's LANs have a very fast transient response. Can get to the peak rate within a few microseconds
- On ATM LANs:
  Wait for connection setup and then...
  Everytime, a burst arrives, take several milliseconds to ramp up
- Q: Given 100 Mbps Switched Ethernet and 155 Mbps ATM at the same price, which one would you buy?

Quiz

T F Please check True/False

1. ❑ ❑ Congestion is not a problem in high-speed networks
2. ❑ ❑ User parameter control (UPC) allows a user to set its parameters
3. ❑ ❑ CDVT measures the cell delay variation caused by the network
4. ❑ ❑ ABR users do not have to specify CDVT
5. ❑ ❑ GCRA allows a network to determine conforming and non-conforming cells
6. ❑ ❑ All non-conforming cells are dropped at the source
7. ❑ ❑ Credit based scheme requires per-VC queueing
8. ❑ ❑ EFCI is better than explicit rate for high-speed networks
9. ❑ ❑ VSVD allows a network operator to use proprietary control scheme inside its networks.

Thank You!