Congestion Control in ATM Networks: Recent Results and Open Problems

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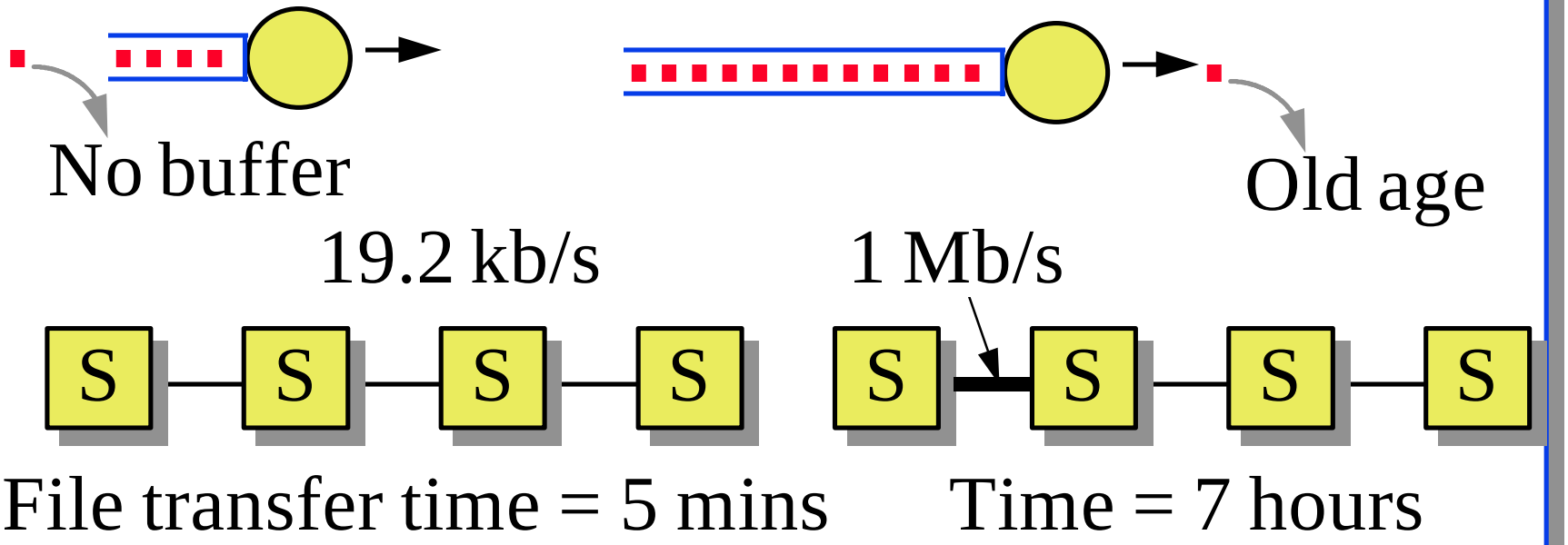
- Why worry about congestion in high speed networks?
- Seven congestion management functions in ATM
- Single bit feedback vs explicit rate
- Current ATM forum rules for data traffic

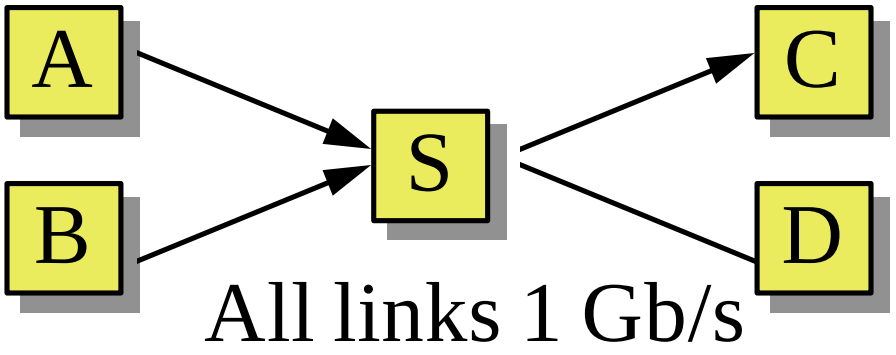
Why Worry About Congestion?

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.





Conclusions:

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

Economic Reasons

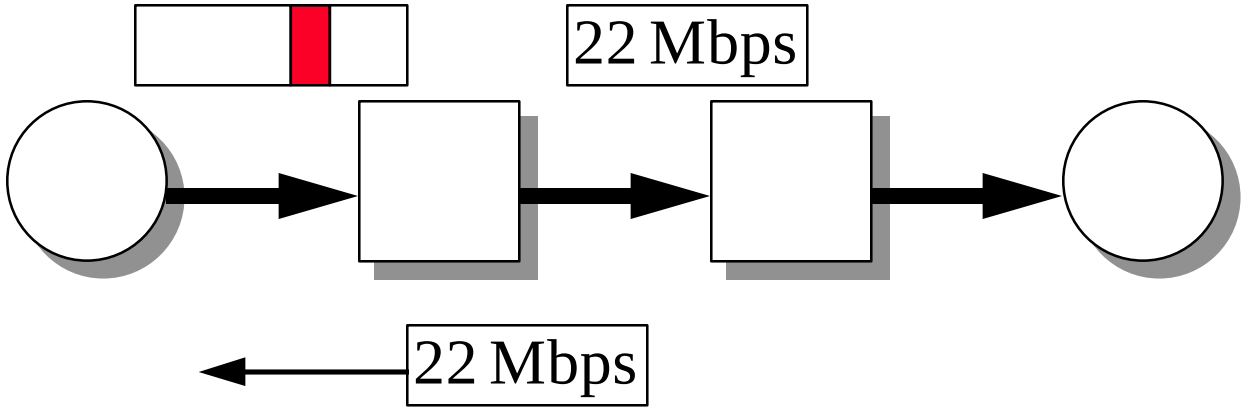
- Network is a shared resource
  Because it is expensive and needed occasionally
  (Like airplanes, emergency rooms)
- Most costs are fixed.
  Cost for fiber, switches, laying fiber and maintaining them does not depend upon usage
  $\Rightarrow$ Underutilization is expensive
- But overutilization leads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

Traffic Management Functions

- Connection Admission Control (CAC):
  Verify that the requested bandwidth and quality of service (QoS) can 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
- Priority Control:
  Cell Loss Priority (CLP) = 1 cells may be dropped
- Selective Cell Discarding: Frame Discard

Traffic Management Fns (Cont)

- Feedback Controls: Network tells the source to increase or decrease its load.
  - Explicit forward congestion indication (EFCI)
  - Explicit rate (ER)
  - Backward explicit congestion notification (BECN)

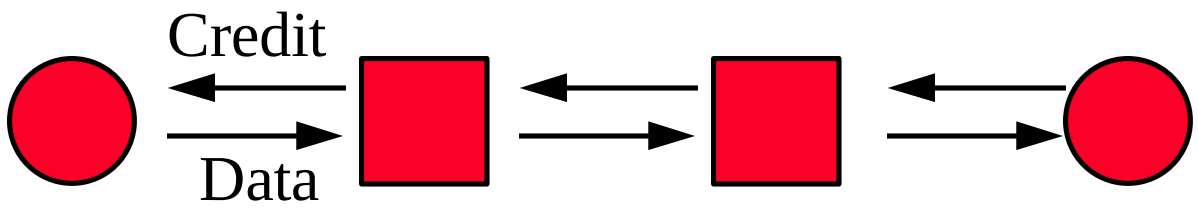


Classes of Service

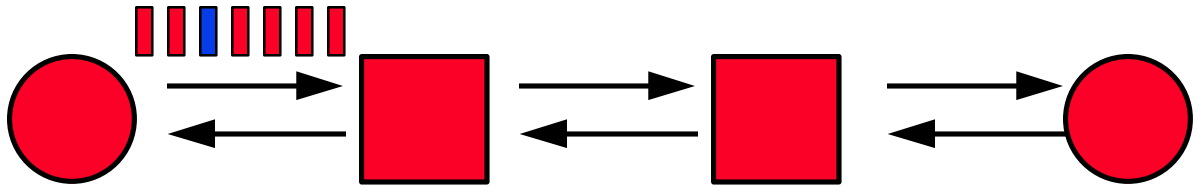
- ABR (Available bit rate): Follows feedback instructions. Network gives maximum throughput with minimum loss.
- UBR (Unspecified bit rate): User sends whenever it wants. No feedback mechanism. No guarantee. Cells may be dropped during congestion.
- CBR (Constant bit rate): User declares required rate. Throughput, delay and delay variation guaranteed.
- VBR (Variable bit rate): User declares 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. Mean delay guaranteed.

Two Leading Approaches

- Credit Based: Hop-by-hop per-VC window
  - Static: Full round-trip worth of credit per VC
  - Adaptive: Credits depend upon activity



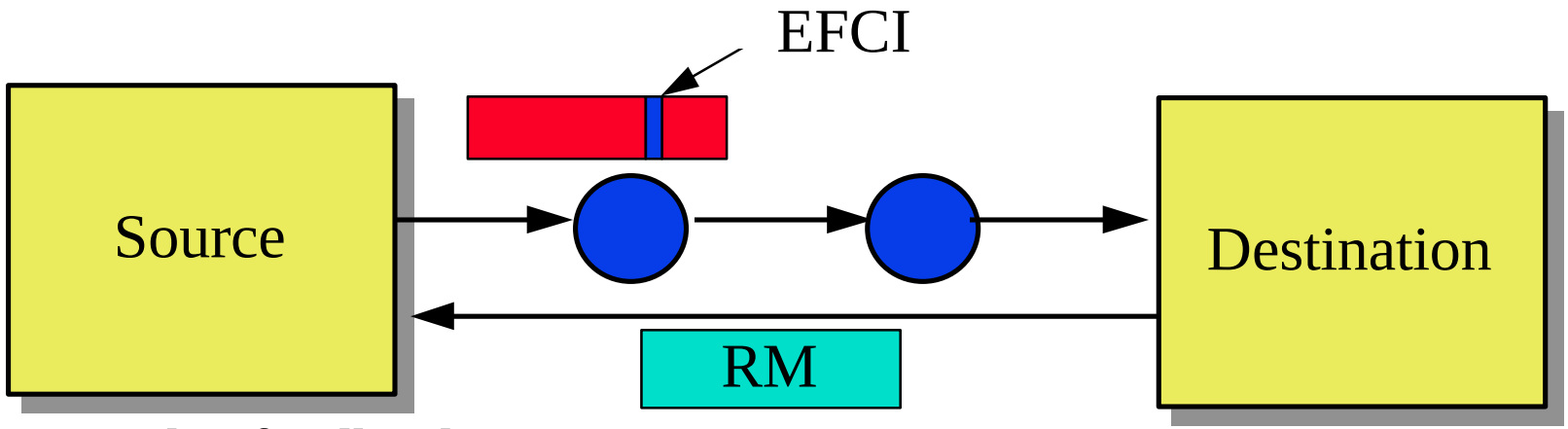
- Rate Based: End-to-end rate control
  - Binary: Feedback via congestion bit in cells
  - Explicit: Feedback via resource mgmt cells



Credit vs Rate Debate: Issues

- Per-VC queueing $\Rightarrow$ Switch complexity
  Nonscalable
- Switch vs end-system complexity
- Zero cell loss
- Isolation and misbehaving users
- Buffer requirements: Full round-trip per VC
- Ramp-up time
- Switch design flexibility:
  Explicit rate $\Rightarrow$ Different goals in switches

Initial Binary Rate-based Scheme

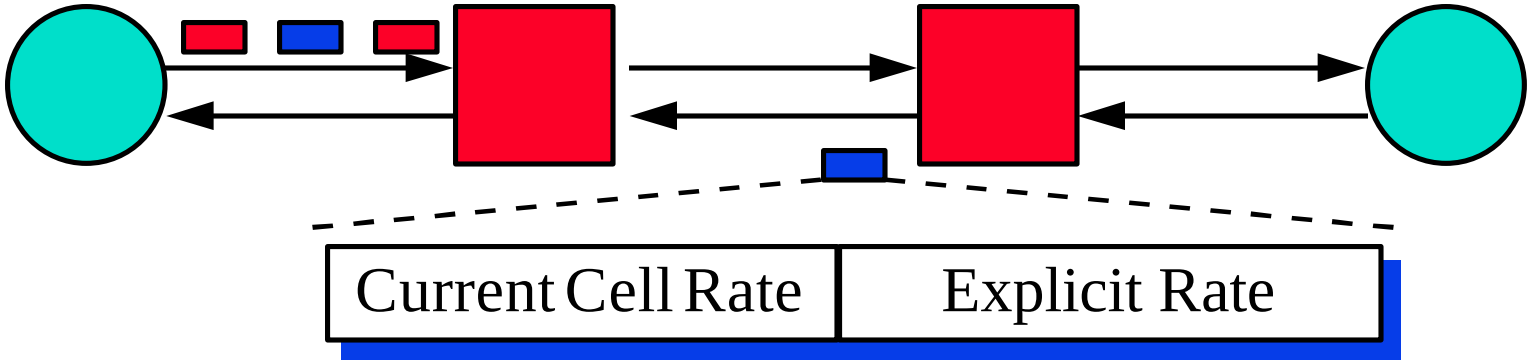


- One-bit feedback
  (Concept originated by the DECbit scheme)
- Explicit forward congestion indicator (EFCI) set to 0 at source
- Congested switches set EFCI to 1
- Every *n*th cell, destination sends a resource management (RM) cell to the source indicating increase amount or decrease factor

Binary Vs Explicit Rate

- Binary (Bit) was designed for window control
  One bit indicates only up or down
  $\Rightarrow$ Takes several round-trips
  $\Rightarrow$ Long queue length = ΔRate $\times$ ΔTime
  $\Rightarrow$ Time is critical with rate control
- Longer-distance networks
  $\Rightarrow$ Can't afford too many round-trips
- Bit was designed for connectionless networks
  With connection-oriented networks
  $\Rightarrow$ Switches know cells of a flow

The Explicit Rate Scheme



- Every Nrm cells, the sources send a control cell
- The switches measure load over a period
- The destination returns the cell to the source
- The switches specify explicit rate in cell
- The source adjusts the transmission rate

ERICA Switch Algorithm

- Explicit Rate Indication for Congestion Avoidance
- Set target rate, say, at 95% of link bandwidth
- Monitor input rate and number of active VCs *k*
  Overload = Input rate/Target rate
- This VC's Share = VC's Current Cell Rate/Overload
- Fairshare = Target rate/ *k*
- ER = ***Max(***Fairshare, This VC's share)
- ER in Cell = Min(ER in Cell, ER)

- Ref: R. Jain, et al, "A Simple Switch Algorithm," AF-TM 95-0179R1, February 1995.

ERICA Features

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

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.
- Explicit rate needs to be carefully examined.

Our ATM Forum Contributions

All contributions are available on-line at
http://www.cis.ohio-state.edu/~jain/

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