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# **ERICA+: Extensions to the ERICA Switch Algorithm**

**Raj Jain, Shiv Kalyanaraman, Rohit Goyal,**

**Sonia Fahmy, Fang Lu**

The Ohio State University

Dept of Computer and Information Science

Columbus, OH 43210-1277

Contact: Jain@cis.ohio-state.edu

<http://www.cis.ohio-state.edu/~Jain/>



ERICA under VBR

Scheduling of multiple classes

ERICA with full utilization

- q Features
- q New Algorithm
- q Simulation Results

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# Current Switch Algorithm: ERICA

ERICA = Explicit Rate Indication for Congestion  
Avoidance

Monitor:

Overload = Input rate/Target Rate

Fair Share = Available rate/# of active VCs

This VC's Share = CCR/Overload

ER = Max(Fair Share, This VC's Share)

ER in Cell = Min(ER in Cell, ER)

ER in Cell = Min{ER in Cell, Max(Available rate/#  
of active VCs , CCR/Overload) }

Use BECN option when appropriate

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# ERICA under VBR

With VBR, the available bandwidth (AB) changes dynamically.

Need:

- q An algorithm for setting explicit rates as changes
- q A scheduling algorithm for multiple classes

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# Innovation 1: Allocation

Monitor VBR usage

ABR capacity = Target Rate - VBR input rate

Overload factor = ABR input rate/ABR capacity

This VC's share = VC's CCR/overload factor

Fair share = ABR capacity/Number of active ABR VCs

RR = Max{Fair share, This VC's share}

NOTE:

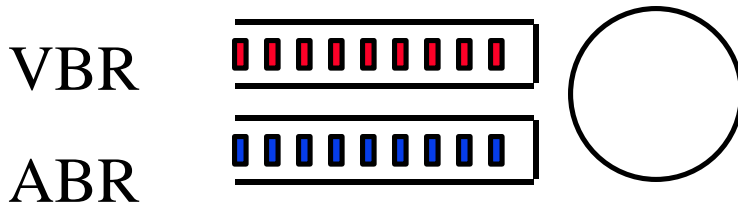
q ABR capacity = Target Util.  $\times$  Link Rate - VBR output rate  
and not

ABR capacity = Target Util.  $\times$  (Link Rate - VBR output rate)  
 $\Rightarrow$  Target utilization applies to total link load

q VBR Output rate < Target utilization

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# Scheduling



Allows any desired allocation:

$V_{\text{frac}}$  = Fraction reserved for VBR

$A_{\text{frac}}$  = Fraction reserved for ABR

Guarantees non-starvation.

All classes can have a guaranteed minimum.

No capacity is wasted.

Capacity not used by one is used by the other class

Scheduling decision is made per cell or per group of cells

Keep scores for both (or n) classes

The class with higher score is serviced next

Complete pseudo-code in the contribution

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# Scheduling Variables

$A_{\text{frac}}$  = Minimum Fraction desired for ABR

$V_{\text{frac}}$  = Maximum Fraction desired for VBR

( $A_{\text{frac}}$  ABR cells are transmitted for every  $V_{\text{frac}}$  VBR cells)

$A_{\text{credit}}$  = Current credit for ABR traffic

$V_{\text{credit}}$  = Current credit for VBR traffic

(In general, the traffic with higher credit is serviced next.)

$A_{\text{queue}}$  = Number cells in the ABR queue

$V_{\text{queue}}$  = Number cells in the VBR queue

$A_{\text{count}}$  = Number of ABR cells served

$V_{\text{count}}$  = Number of VBR cells served

The complete pseudo-code is in the original contribution text.

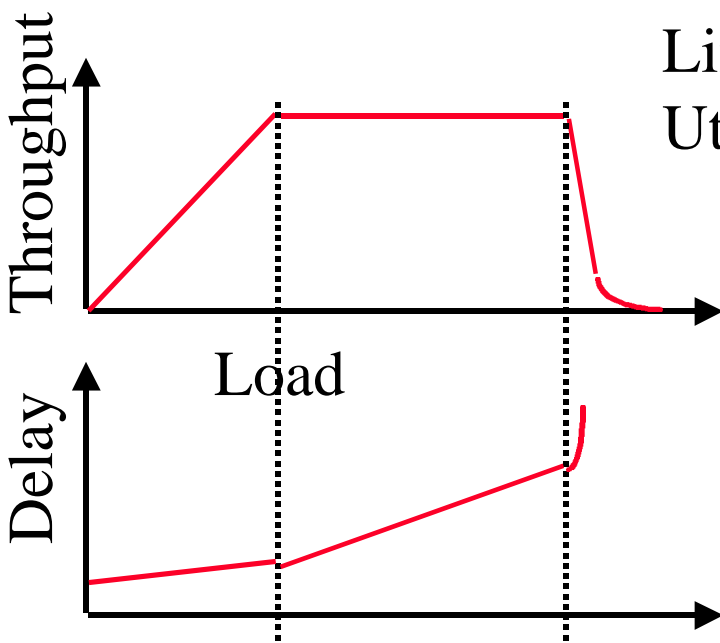
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# Congestion Avoidance

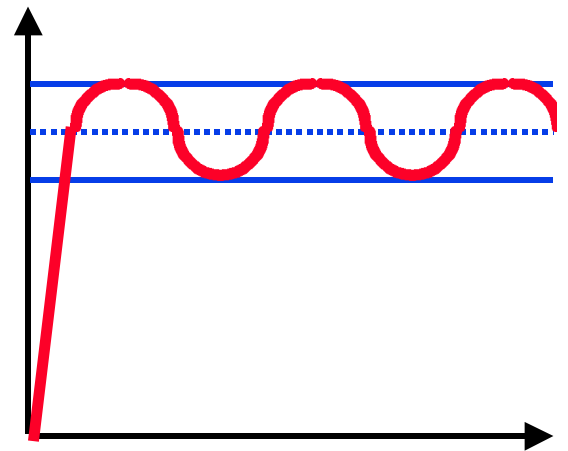
High throughput, Low delay

Small queues

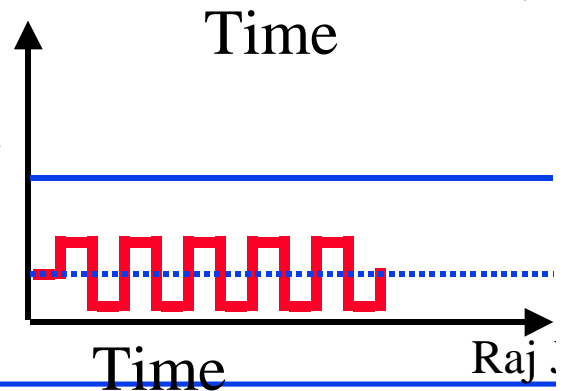
Bounded oscillations  $\Rightarrow$  Good for Video traffic



Link  
Utilization



Queue  
Length  
5



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# Issues with Current Congestion Avoidance Schemes

Link utilization is 90% or below

May not be acceptable for high-cost WAN links.

Queue length is close to 1.

Not good if bandwidth becomes available suddenly

You can't use BECN to ask sources to increase

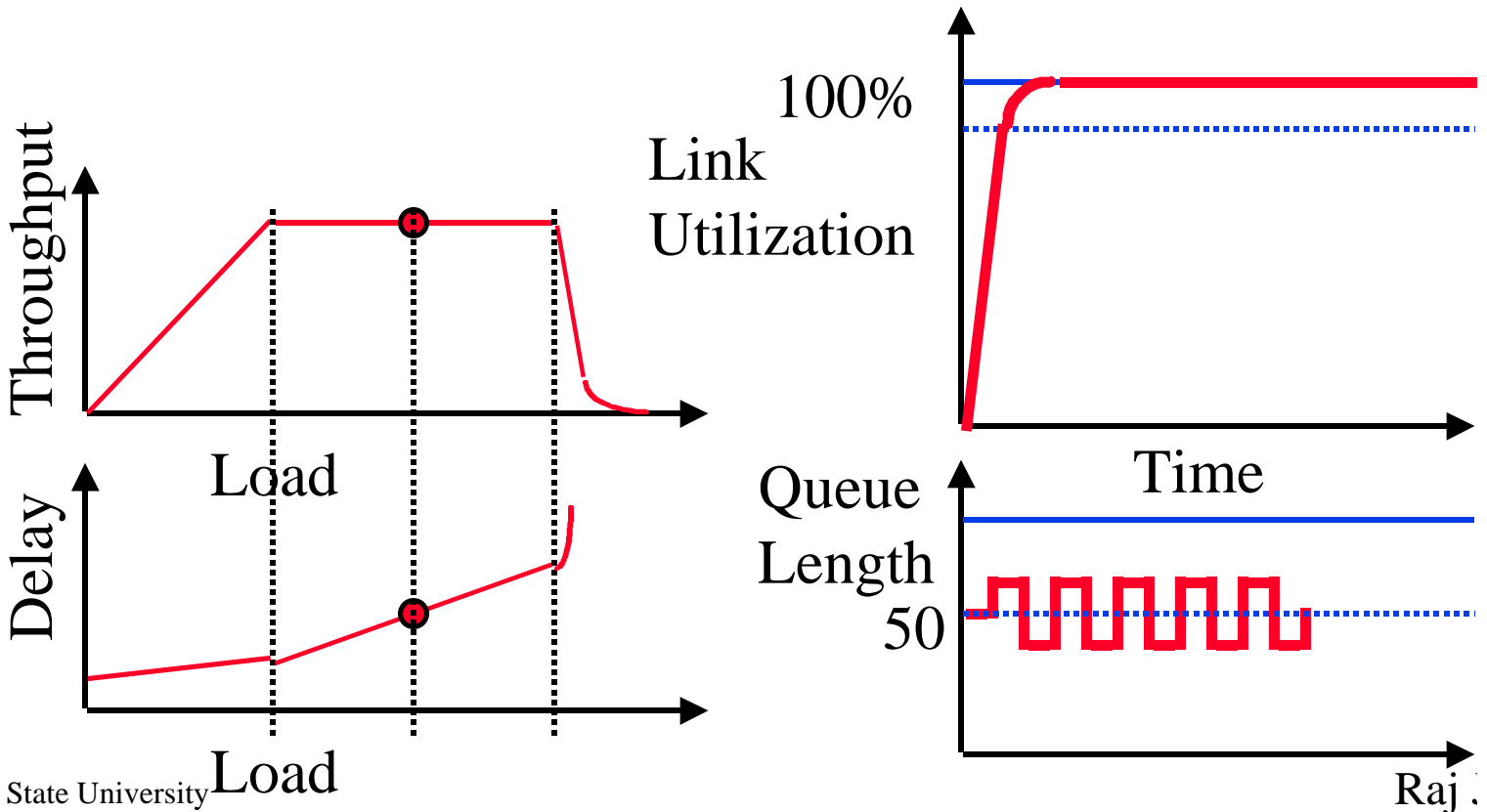
Low rate sources may have long inter-RM cell times

# Features of the New Scheme

Allows operation at any point between the knee and the cliff

The queue length can be set to any desired value.

Allows utilization to be 100%



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# Features (Continued)

Compatible with current ATM Forum TM agreements

No changes to source operation required

No changes to destination operation required

No changes to RM cell format required

Follows all switch requirements

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## Innovation 2

Target utilization is dynamically changed.

During steady state: Target utilization = 100%

During overload the target may be low, e.g., 80%

During underload the target may be high, e.g., 110%

Available Bandwidth =  $\text{fn}(\text{Unused bandwidth, Queue length, queue length goal})$

Unused bandwidth = Link Rate - VBR output rate

Rest is similar to ERICA

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## Innovation 3

Since available bandwidth (AB) varies dynamically, a queue of 30 may be too big when AB is 1 Mbps but too little when AB is 100 Mbps.

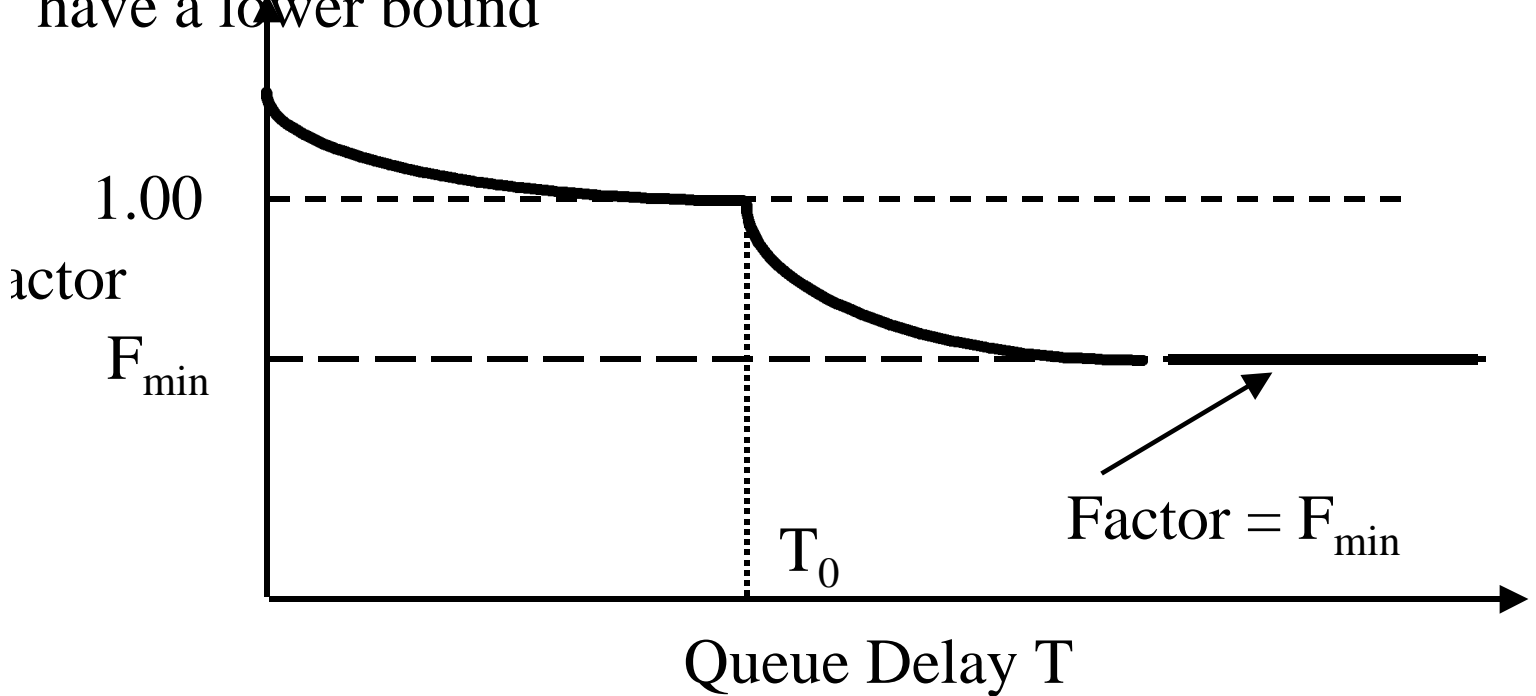
Use queue delay instead of queue length

Queue Delay = Queue length / Available bandwidth

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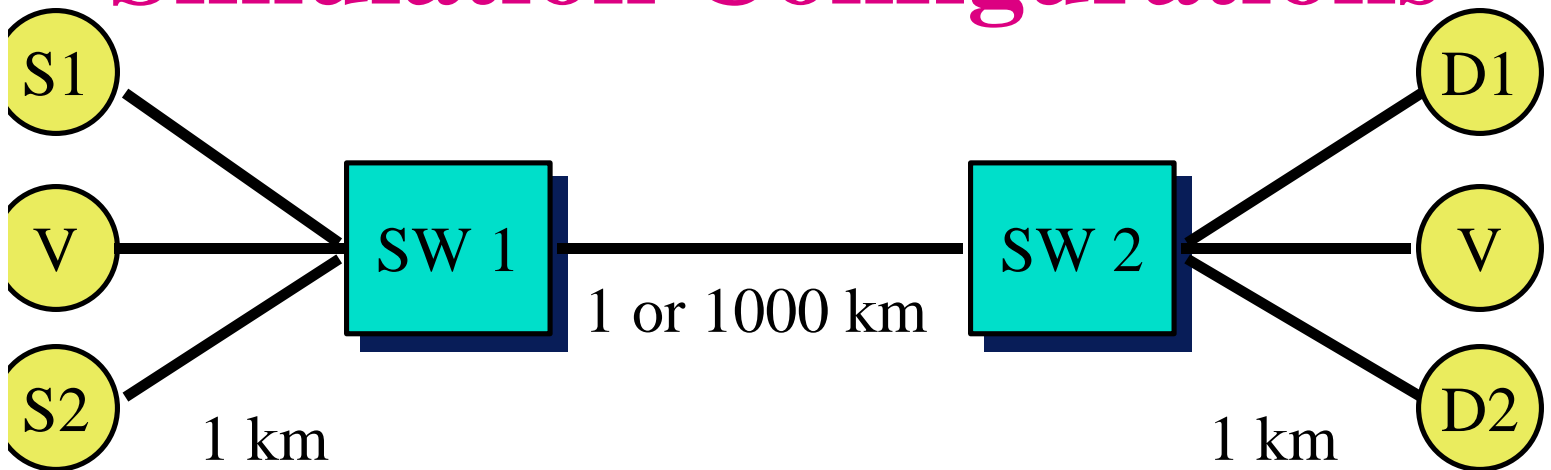
# Innovation 4

The function should be monotonically non-increasing and have a lower bound



$$\text{Available Bandwidth} = \text{Unused Bandwidth} \times \text{Factor}$$

# Simulation Configurations



All links 155.52 Mbps

One or Two ABR sources

With/without VBR background traffic

LAN or WAN

The VBR source turns on/off

q Every 4 ms (LAN) starts at  $t = 2$  ms

q Every 20 ms (WAN) starts at  $t = 12$  ms

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# Simulation Parameters

Source: Standard group #7

$N_{rm} = 32$

$AIRF = 1 \Rightarrow AIR = PCR/N_{rm} \Rightarrow ACR$  is not limited by AI

$RDF = 512$  cells

$\{TDF, PNI\} = \{1/8, 0\} \Rightarrow$  Rule 5 on

$CIF = 512$  (LAN), 8192(WAN)

$\Rightarrow$  High ICR  $\Rightarrow$  Rule 5 not triggered

$RTT = 10$  times the actual propagation delay

$\Rightarrow$  High XRM  $\Rightarrow$  Rule 6 not triggered

$XDF = 1/2$

Traffic: Unidirectional

Switch:

Averaging interval =  $\min\{30 \text{ cells}, 200 \mu\text{s}\}$

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# Simulation Results

ERICA+ provides 100% utilization

No overflow or underflow of queues

ERICA+ converges fast

Queue length stays at the desired value

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# Summary



ERICA with VBR and a general scheduling algorithm

ERICA+ provides 100% utilization

Allows operation at any point between the knee and the cliff.

100% throughput with any desired queue length possible.

Provides quick response to transients

High starts possible in LAN environments