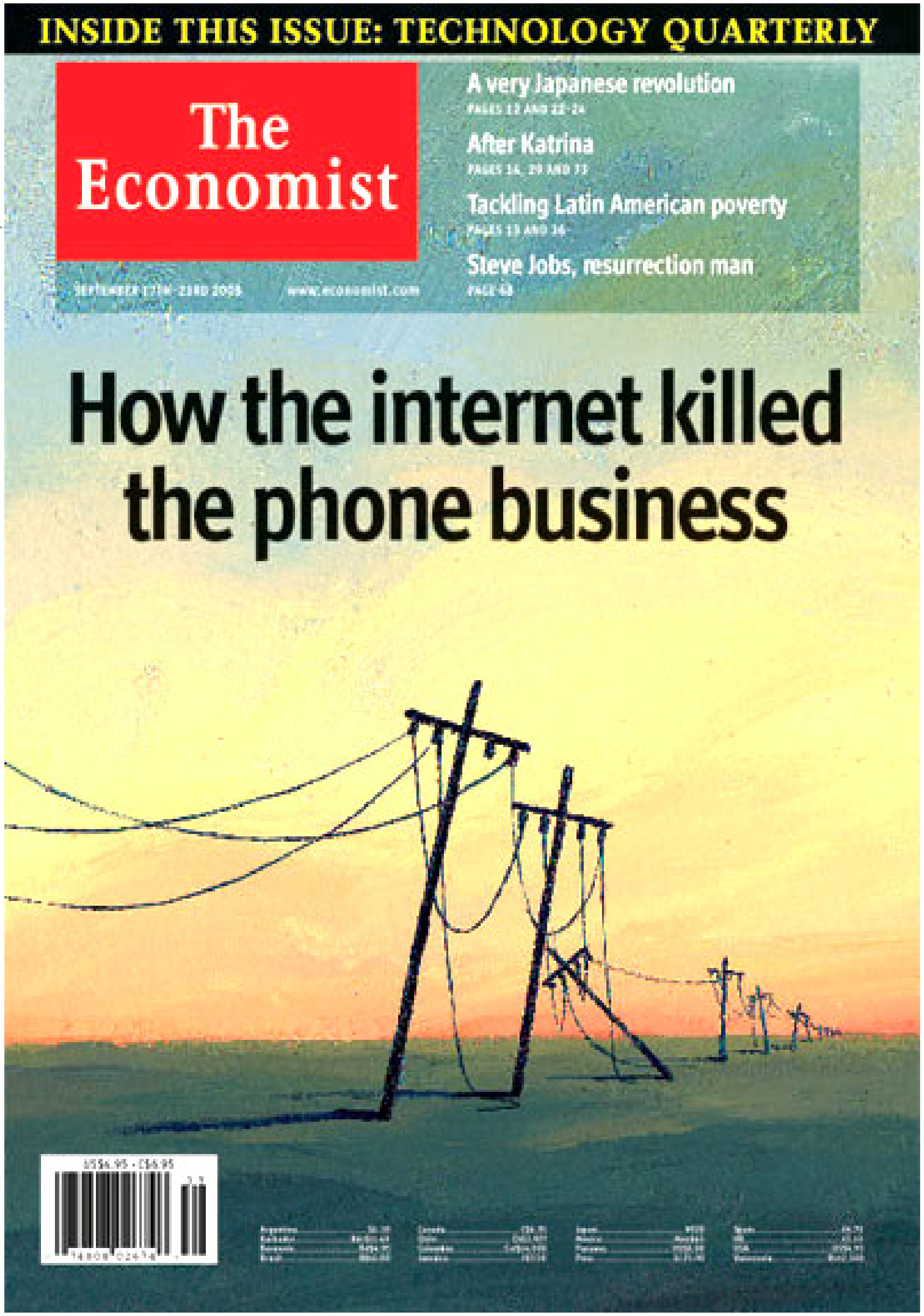
Energy efficient rate control mechanism for multimedia delivery over wireless Internet

Sudipta Mahapatra, Ph. D
Associate Professor
Department of E & ECE
IIT Kharagpur
Sudipta@ece.iitkgp.ernet.in

M. Harikrishna
harikrishna.mallisetty@gmail.com

Amareswararao K.
k.amareswararao@gmail.com



THE Internet touched our lives in terms of

- ✓How we communicate
- ✓How we promote our products
- ✓How we teach our children
- ✓How we invest our time

Growth…..50 million

Radio……... 40 years
TV …………15 years
Internet …..5 years

[Economist, September 2005]

Outline

- Wireless Internet (WI) and Multimedia Delivery
- Major Challenges
- Need for Loss Differentiation
- RCM-BR Protocol
- Simulation study
- Conclusion

Wireless Internet (WI)

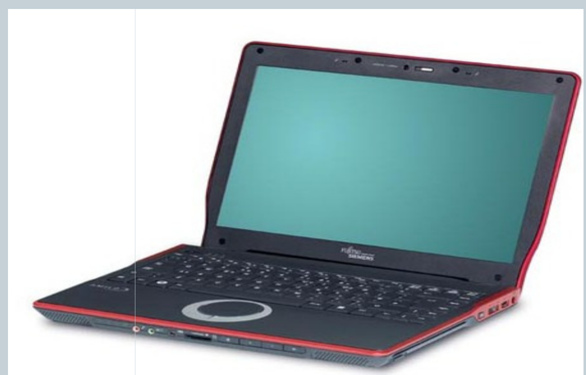
A service granting access to the World Wide Web or Internet via Wireless Networks. It consists of

- ✓ **Fixed internet hosts.**
- ✓ **Mobile nodes.**
- ✓ **Connectors like access points in between.**

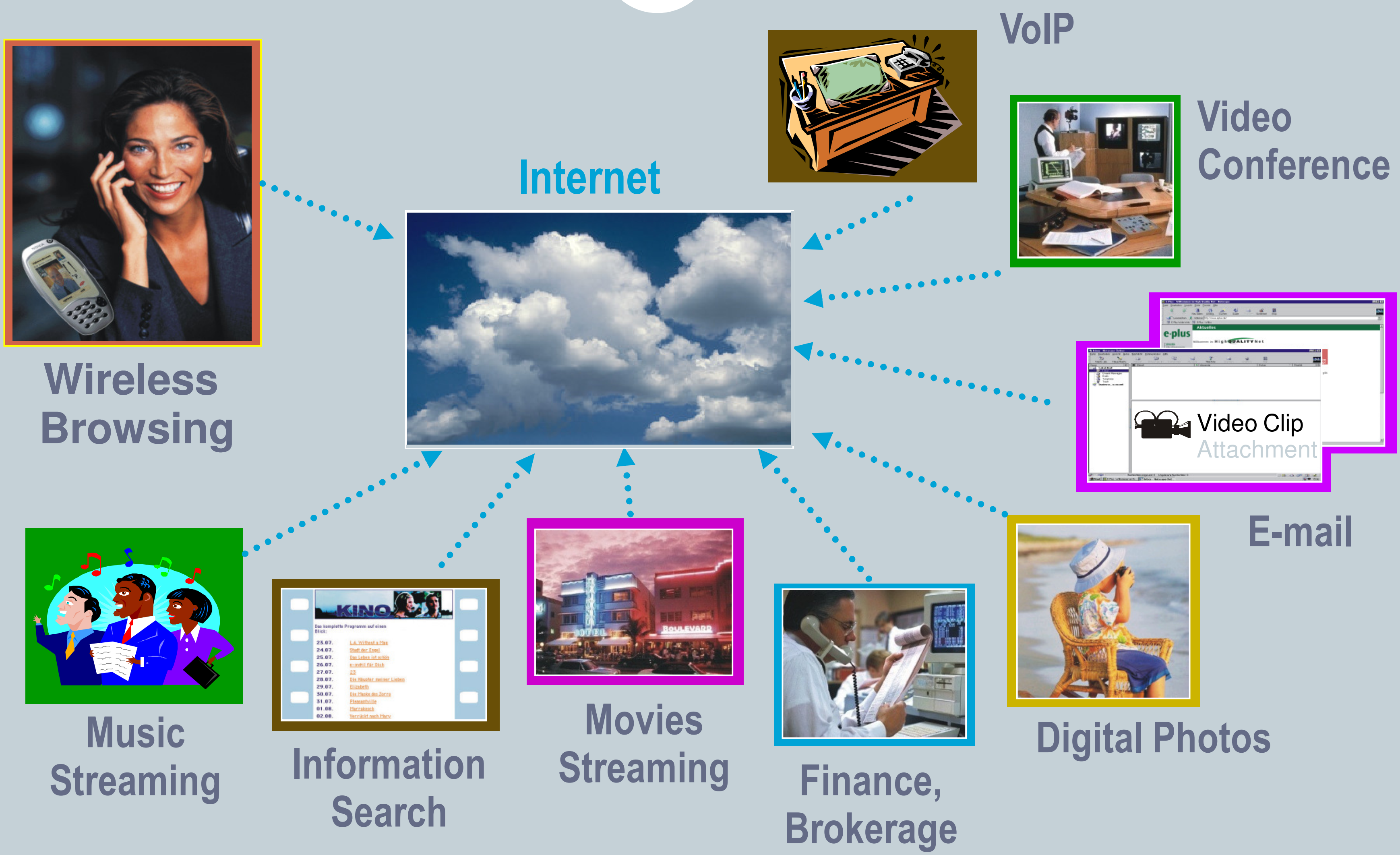
They host information resources as well as application software for providing network services.

They have wireless access card to access Internet. Ex. Wi-Fi card

To provide wireless Access to the devices



Multimedia over IP Networks



MM Networking Applications

Classes of MM applications:

1) Streaming stored audio and video

2) Streaming live audio and video

3) Real-time interactive audio and video

Fundamental characteristics:

- Typically **delay sensitive**
  - End-to-end delay
  - Jitter – Delay variation
- But **loss tolerant**: infrequent losses cause minor glitches
- Normal data can tolerate delay tolerant, but not loss

Why Is Real-Time Transport Hard?

Internet is a best-effort network . . .

Congestion	Insufficient rate to communicate
Packet loss	Impairs perceptual quality
Delay	Impairs interactivity of services; Telephony: one way delay < 150 ms [ITU-T Rec. G.114]
Delay jitter	Obstructs continuous media playout

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Challenges in Multimedia Delivery over Wireless Internet

- Different QoS requirements for different types of media.
- High packet loss rate and bit error rate.
- Bandwidth limitation and fluctuation.
- Low performance in traditional transport protocols.
- Heterogeneity among users and networks.
- Limited battery life.

Ref: Qian Zhang, Fan Yang, Wenwu Zhu,"Cross-layer Qos Support for Multimedia delivery over Wireless Internet",EURASIP Journal on Applied signal processing 2005,pp207-219.

Audio & Video Quality Requirements

Medium	Application	Degree of symmetry	Typical data rates	Key performance parameters and target values			
				One-way Delay	Delay variation	Information loss	Other
Audio	Conversational voice	Two-way	4-13 kb/s	< 150 ms preferred* < 400 ms limit*	< 1 ms	< 3% packet loss ratio (PLR)	
Audio	Voice messaging	Primarily one-way	4-13 kb/s	< 1 s for playback < 2 s for record	< 1 ms	< 3% PLR	
Audio	High quality streaming audio	Primarily one-way	32-128 kb/s	< 10 s	< 1 ms	< 1% PLR	
Video	Videophone	Two-way	32-384 kb/s	< 150 ms preferred < 400 ms limit		< 1% PLR	Lip-synch < 80 ms
Video	One-way	One-way	32-384 kb/s	< 10 s		< 1% PLR	

* Assumes adequate echo control

Ref: INTERNET-DRAFT Strategies for Streaming Media Using TFRC Jan 2008

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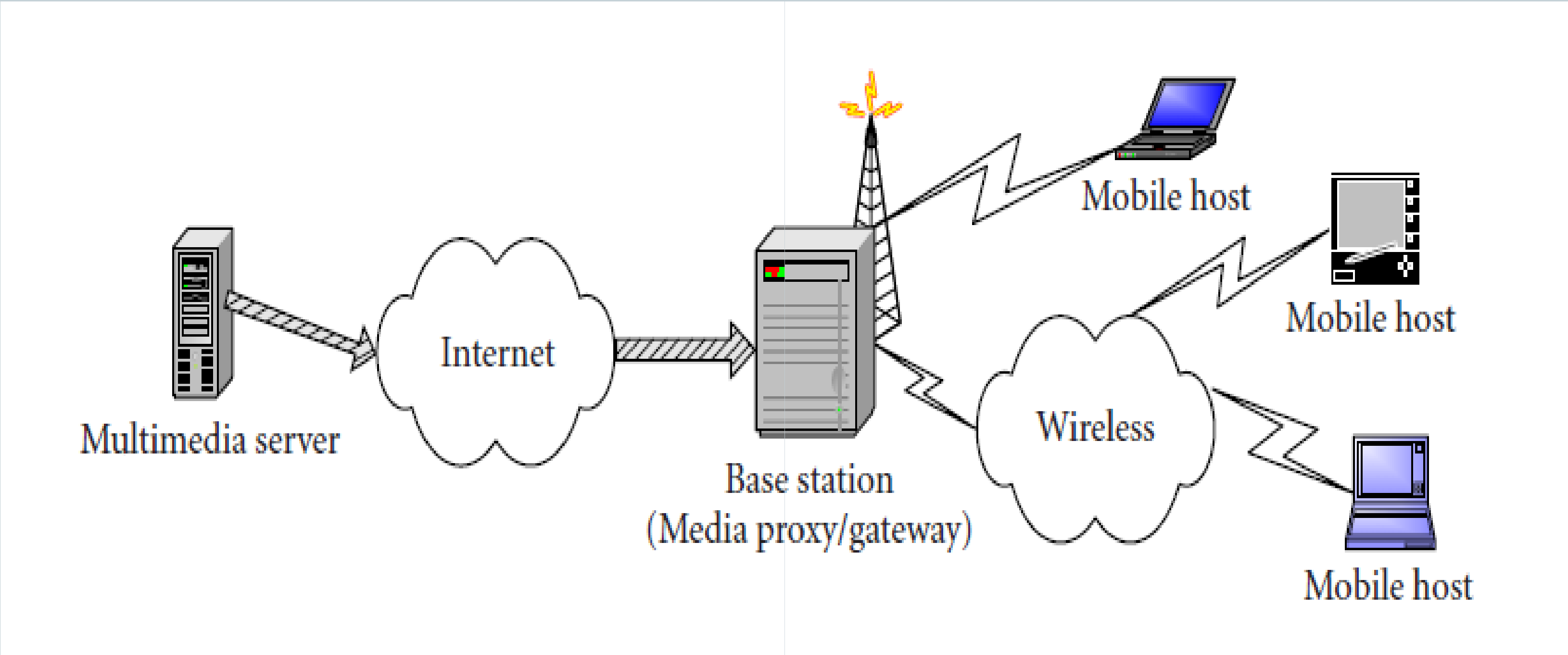
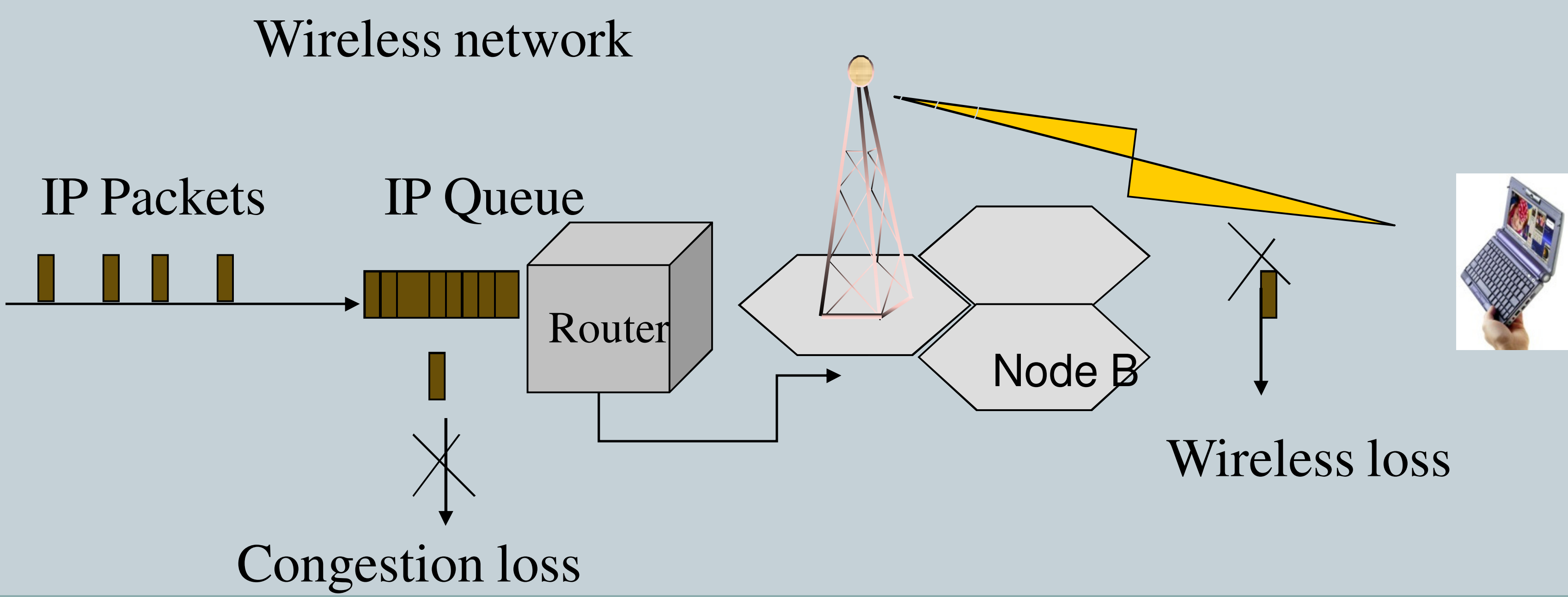
Wireless Multimedia Streaming Architecture



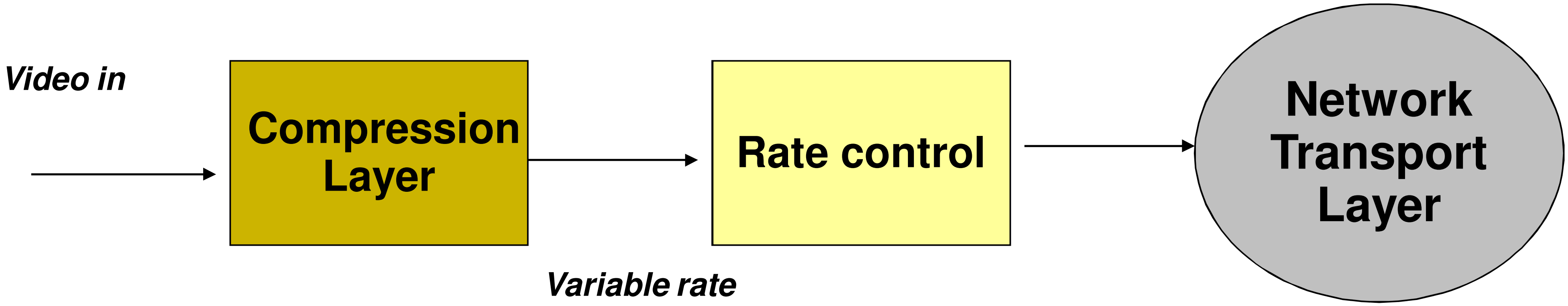
Ref: Qian Zhang, Fan Yang, Wenwu Zhu,"Cross-layer Qos Support for Multimedia delivery over Wireless Internet",EURASIP Journal on Applied signal processing 2005,pp207-219.

Problems: Wireless Losses

- Problem: Two types of losses in wireless Networks
  - Packet drops due to congestion
  - Packet drops due to bad channel conditions



Need For Rate Control



"Multimedia traffic transport requires rate control deployment to protect the shared Internet from unfairness and further congestion collapse."

Ref: O. B. Akan and I. F. Akyildiz, "ARC: the analytical rate control scheme for real-time traffic in wireless networks," *IEEE/ACM Transactions on Networking*, vol. 12, no. 4, pp. 634–644, 2004

Desired TCP Behavior in Wireless Internet

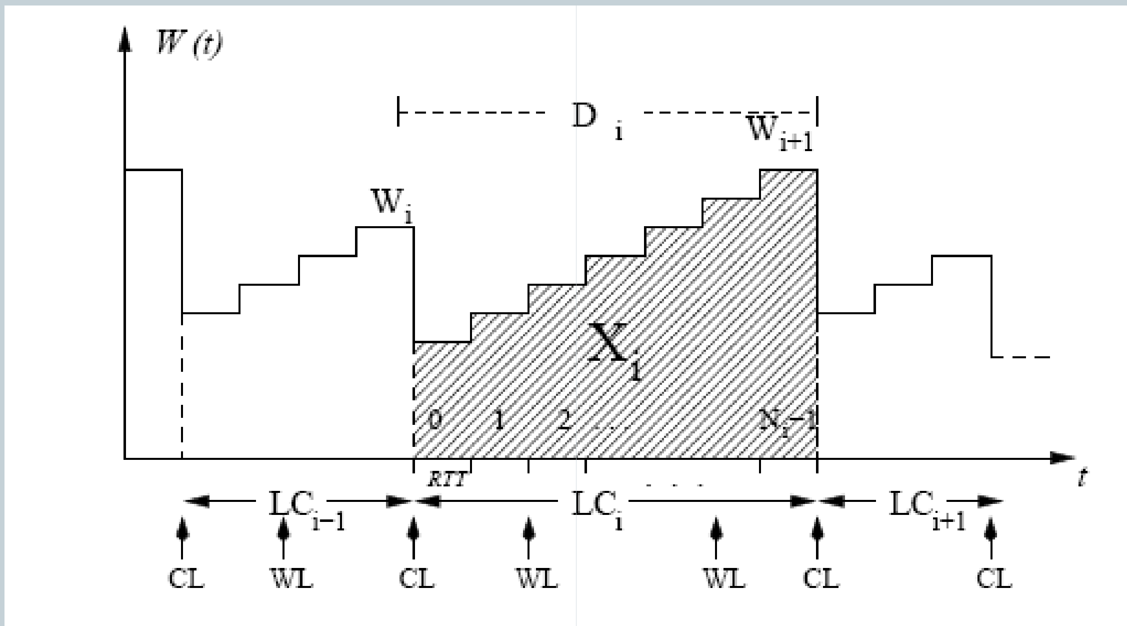


Fig:1 Steady state desired behavior of a TCP source in wireless link

Equation Based Rate Control

"Equation based rate control has lower variation in throughput over time compared with TCP. That's why it is more suitable for applications where smooth sending rate is required".

Ref: RFC 3448 bis

Existing Schemes

- TFRC [2000]

$$T = \frac{s}{RTT\sqrt{\frac{2p}{3}} + t_{RTO}\left(3\sqrt{\frac{3p}{8}}\right)p\left(1+32p^2\right)}$$

- ARC [2004]

$$T = \frac{s}{4.RTT}\left(3+\sqrt{25+24\left(\frac{1-\omega}{\pi-\omega}\right)}\right)$$

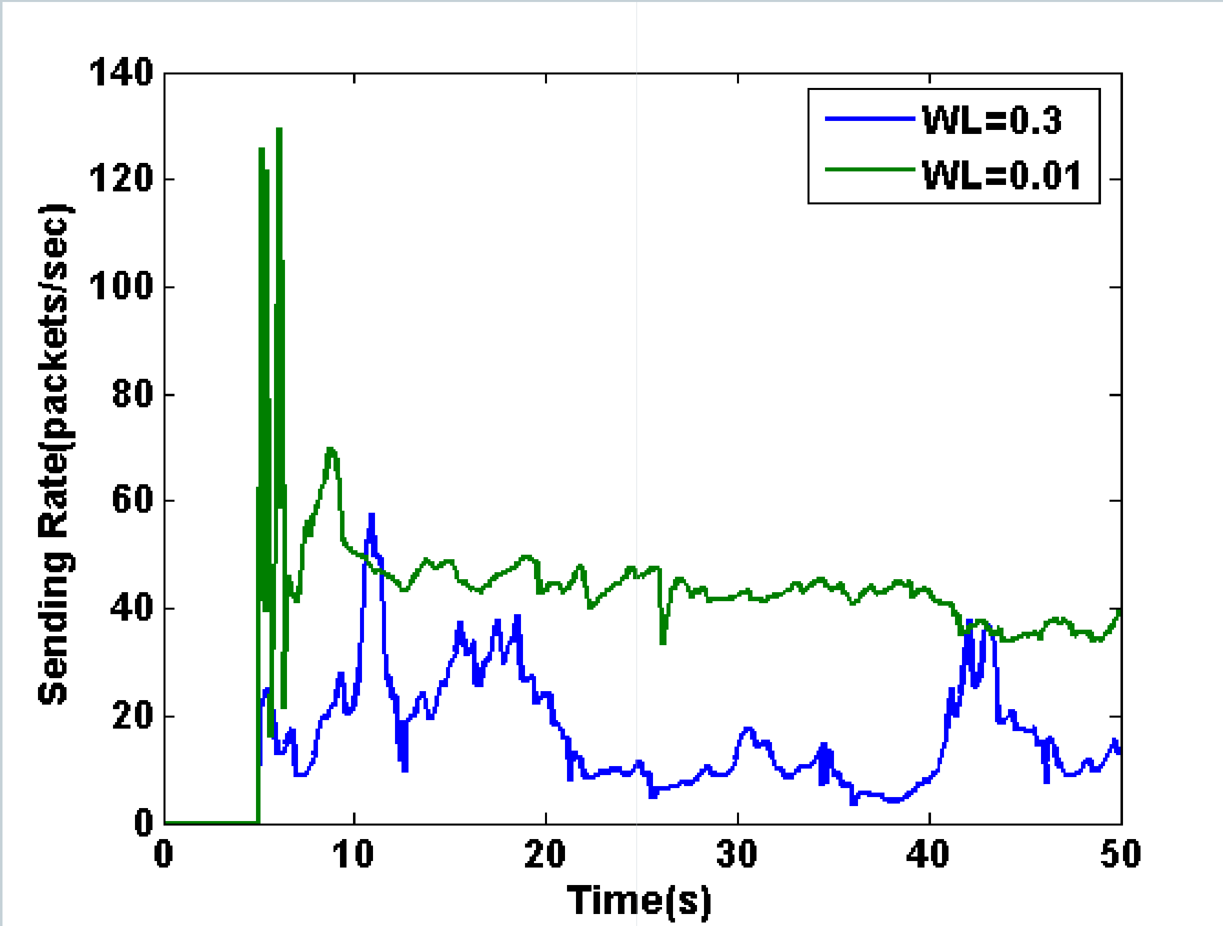
- TFRC-JR[2007]

- Some Other Schemes:

RCS[2001], WMSTFP[2003], WLED[2006], DCCP[2006],

Equation Based Rate control in Cellular Networks[2009];

TFRC Rate Variation



Energy potential

- Congestion losses
  - Burst congestion loses
  - Transient congestion losses
- Wireless losses
  - Transient/Random losses
  - Burst wireless losses

In case of burst wireless losses

$$\text{nlost} \propto \text{rate}$$

$$\text{energy wastage} \propto \text{nlost}$$

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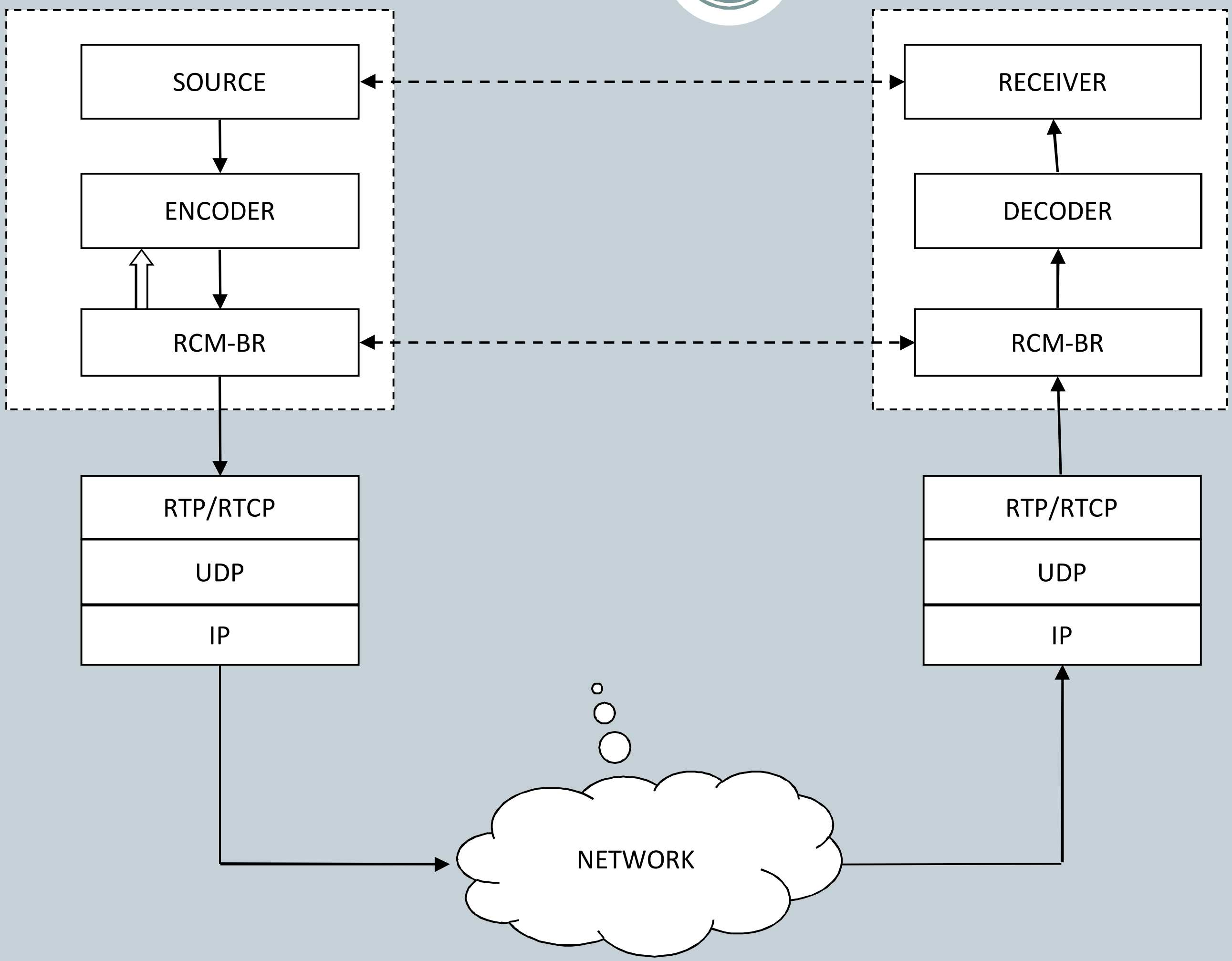
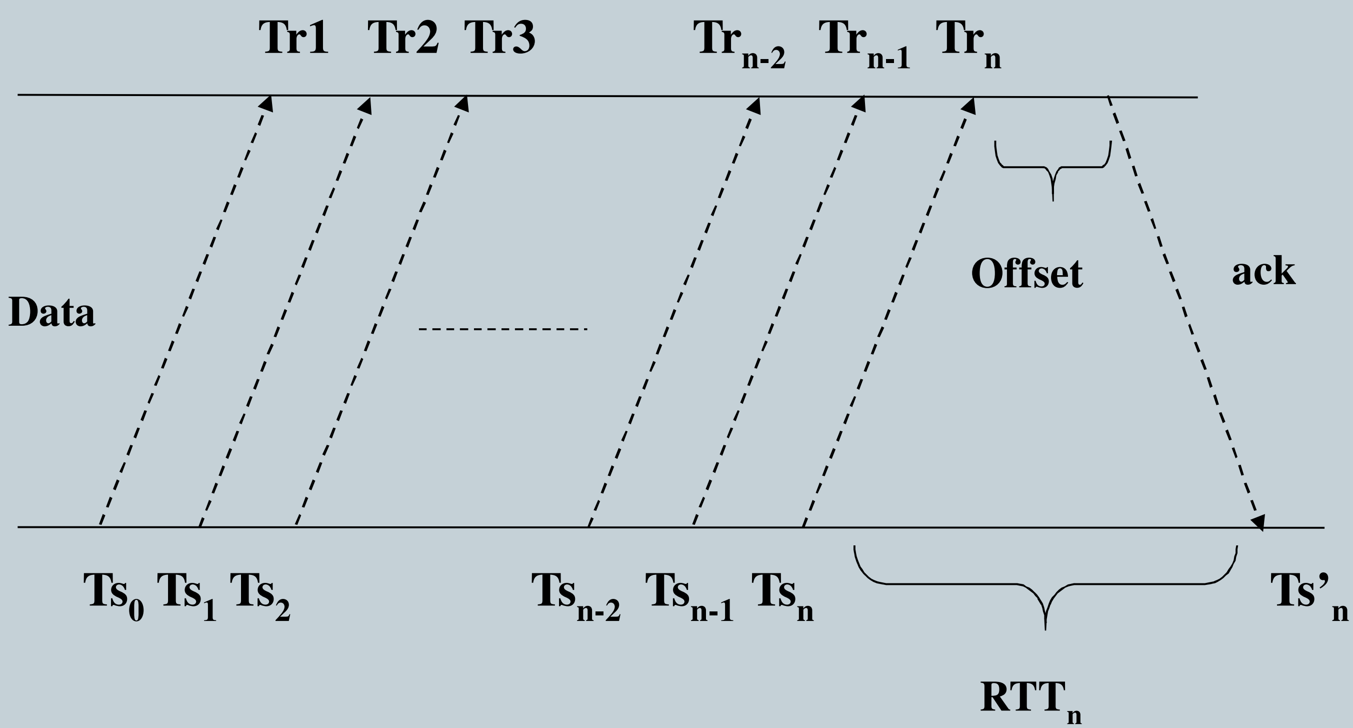
RCM-BR protocol overview

- Estimate RTT
- Differentiate wireless and congestion losses
- Detect burst wireless loss
- Estimate loss probability
- Estimate available B.W.
- Adjust the rate

The Protocol Structure



Estimating RTT



Adaptive Loss Differentiation

- Infers the cause of loss: The threshold is a function of the minimum RTT, and current sample RTT so that it may automatically adapt itself to current congestion level.

$$T > \bar{T} + T_{dev} \cdot \left(2.\left(\frac{T_p}{T}\right)^K - 1 \right)$$

$$\bar{T} = \frac{7}{8}\bar{T} + \frac{1}{8}T$$

$$T_{dev} = \frac{3}{4}T_{dev} + \frac{1}{4}\left|T - \bar{T}\right|$$

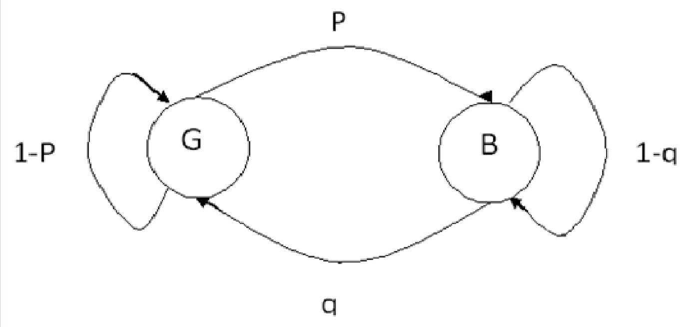
Estimating loss probabilities

- Wireless loss

$$A=\begin{bmatrix} 1\text{-}p & p \\ q & 1\text{-}q \end{bmatrix}$$

$$p = \mathrm{P}(q_t = B|q_{t-1} = G);$$

$$q = \mathrm{P}(q_t = G|q_{t-1} = B);$$



$$\pi_B = \frac{p}{p+q} \qquad \pi_G = \frac{q}{p+q}$$

$$p_E = (1-P_G)\,\pi_G + (1-P_B)\,\pi_B;$$

- Congestion loss

$$p_c = (1-\mathrm{Pr})\,\pi_r + (1-P_l)\,\pi_l;$$

- Total loss

$$\Pi = 1\text{-}(1\text{-}p_E)(1\text{-}p_c)$$

Accuracy of Classification

Type of algorithm	C/C	W/W	C/W	W/C
Spike	100%	0%	100%	0%
Zig-Zag	85%	60%	40%	15%
Adaptive LDA	82.5%	85.38%	14.62%	17.5%
SVM	88%	84%	16%	12%

Detecting burst wireless loss

burst-thrust function

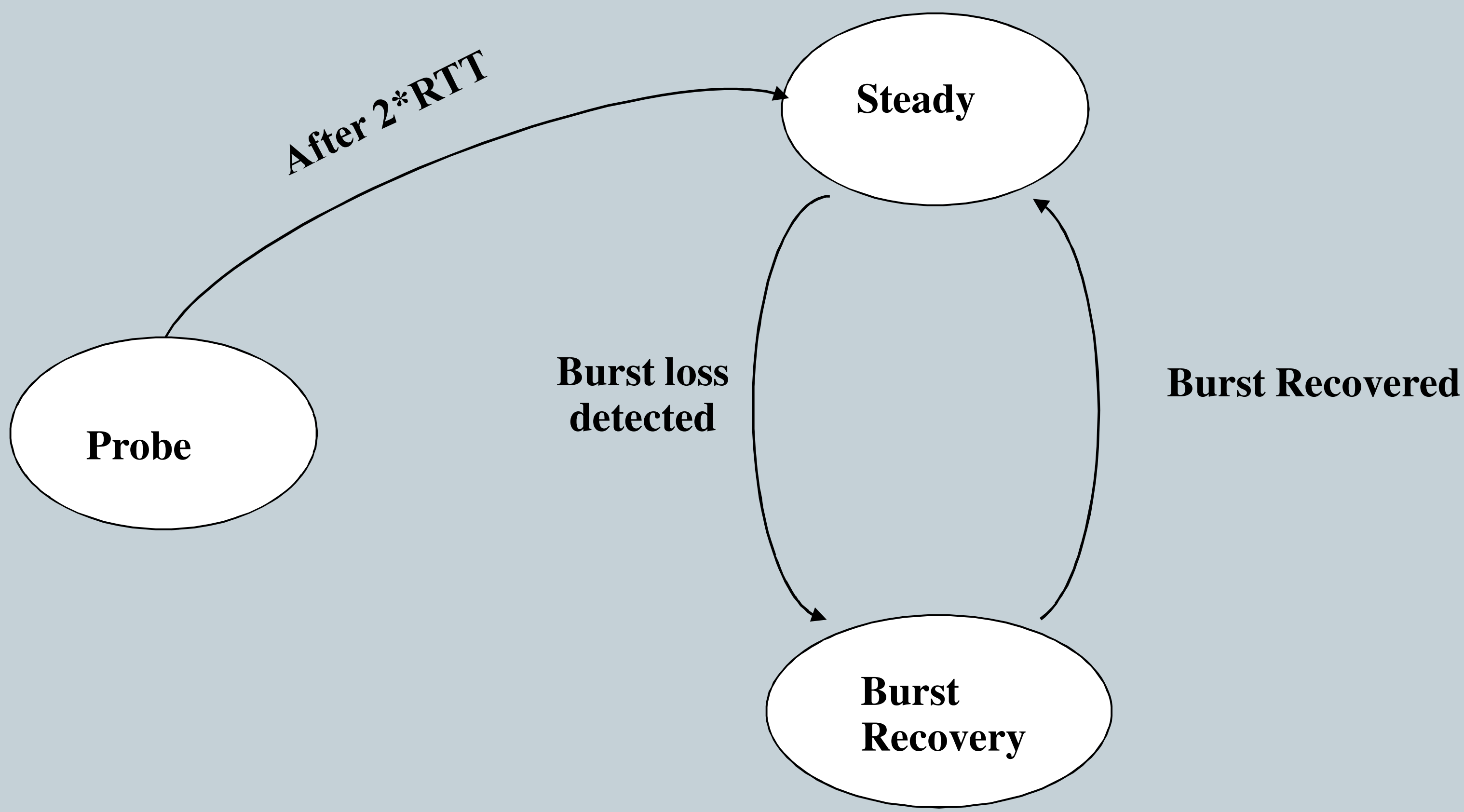
$$g(k) = \begin{cases} 1, k \leq \theta \\ \sqrt{k-\theta}, k > \theta \end{cases}$$

Where, θ=max(4, previous rate*rtt/2)

k is the no .of packets lost due to wireless loss

g(k)>1 $\Rightarrow$ Burst wireless loss

Finite state machine model of RCM-BR source



Algorithm

Probe()

While(t<=RTT)

    Send PROBE_PACKET with S_{target}

End;

Estimate initial rate

end;

STEADY( )

Calculate RTT;

Calculate g(wlost)

If (g(wlost)=1)

Calculate π, ω;

Calculate T;

Rf=(now-lastchange)/RTT

If(T>rate_)

*rate=rate+Rf * (1- π) *T;*

else

*rate=a * T+(1-a) *rate;*

else

*rate=(1-w)*rate*

burst recovery()

end;

Where R_f is the rate change factor that detects how many times the sending rate is changed with respect to RTT . 'now' represent the current time and 'last change' represents the last time when the rate was changed.

Burst recovery()

calculate g(k)

if (g(k)>1)

    rate=(1-w)*rate;

else

    rate=prev_g(k)*rate

    steady()

end;

Probe period

- Initially sender sends probe packets with target rate till RTT.
  - Low priority dummy packets
- Receiver sends acks to received probe packets
- At 2*RTT, sender sets initial transmission rate

$$S_{init} = \frac{\max\{1, n_{ack}\}}{RTT}$$

Steady period

calculate RTT

Calculate g(k)

If Burst wireless loss is not detected

Calculate *Π,ω*

Estimate available B.W

$$T = \frac{s}{4.RTT}\left(3 + \sqrt{25 + 24\left(\frac{1-\omega}{\pi-\omega}\right)}\right)$$

Rf=(now-lastchange)/RTT

If(T>rate)

*rate=rate+Rf * (1- π) *T;*

else

*rate=a * T+(1-a) *rate*

Burst recovery


```
calculate g(k)
if (g(k)>1)
   rate=max(minrate,(1-w)*rate);
else
   rate=prevg(k)*rate
```

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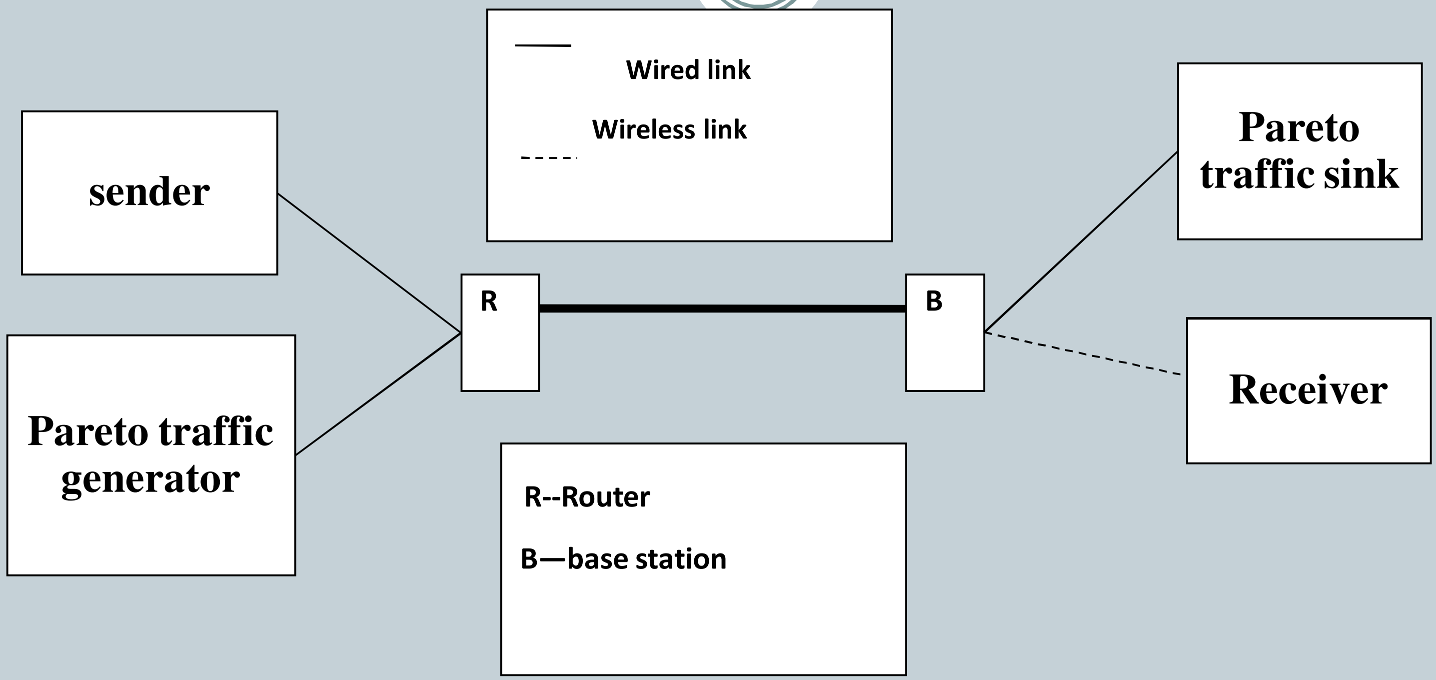
Simulation model (NS-2)



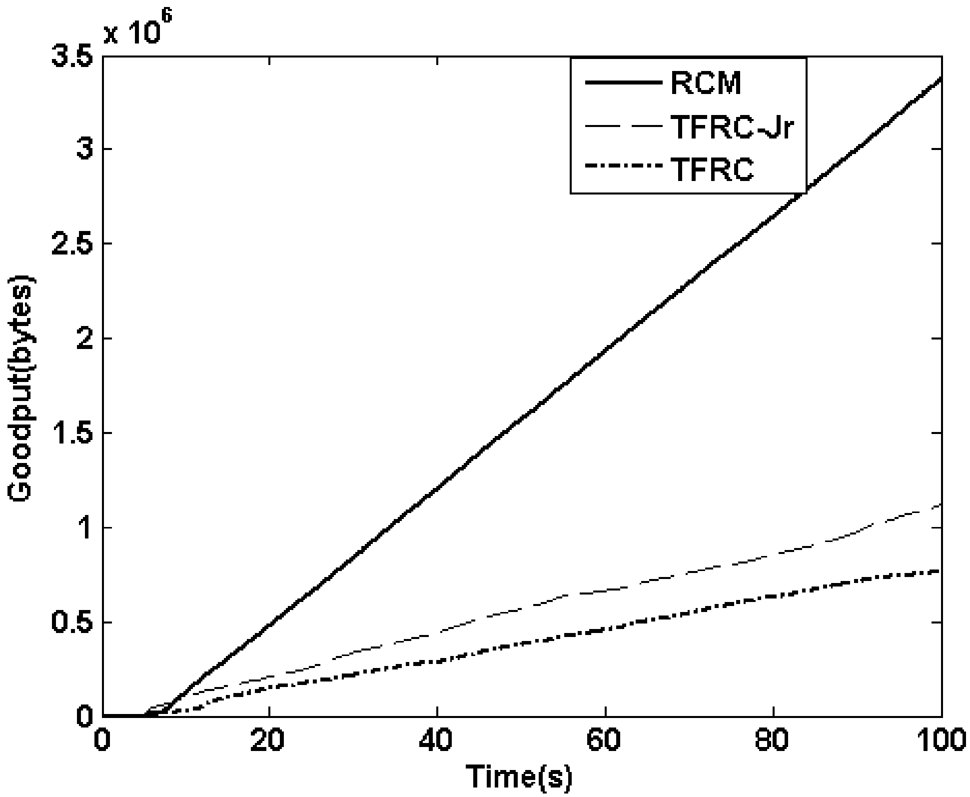
- Pareto traffic to generate congestion losses in wired bottleneck
- Three state markov model for wireless losses

Performance Metrics

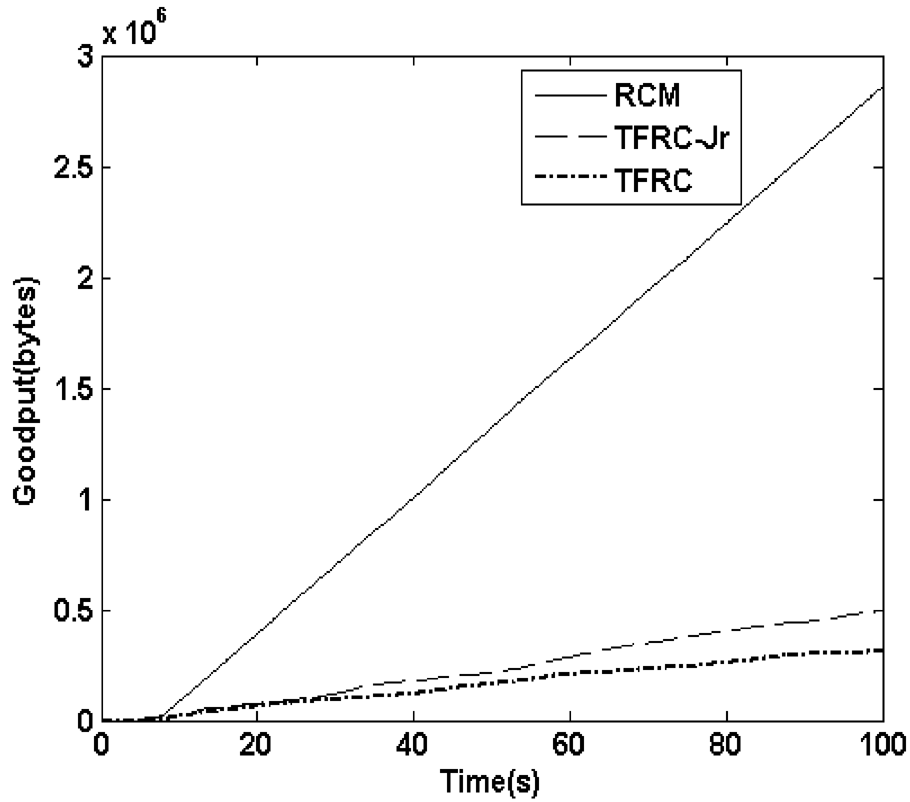
- Throughput or Goodput.
- Delay or latency.
- Delay Variation - Jitter.
- Packet loss rate.
- Fairness Index, $$F.I = \frac{\left(\sum_{i=0}^{n} Throughput_i\right)^2}{n\left(\sum_{i=0}^{n} Throughput_i^2\right)}$$

Ref: RFC5166,S.Floyd,March 2008.

Goodput Performance of RCM

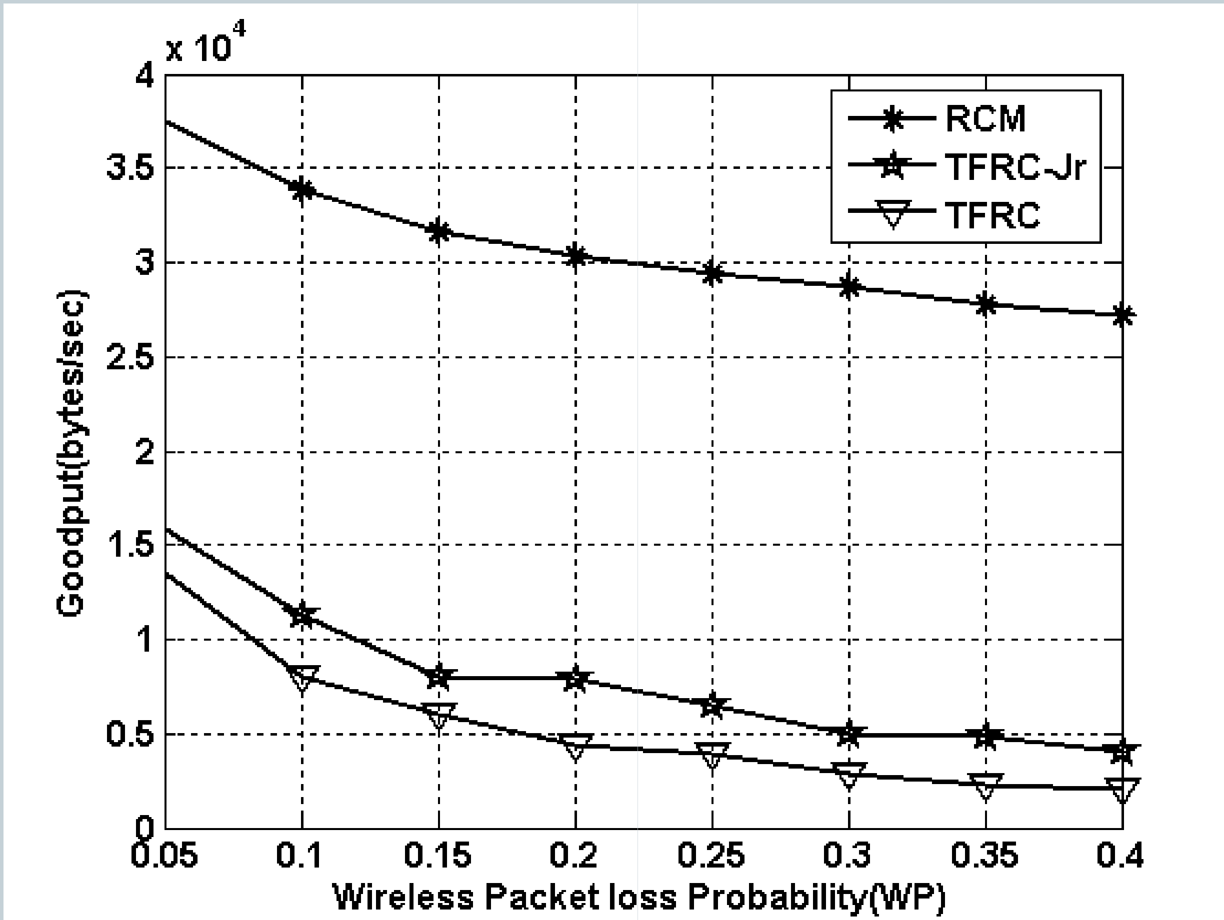


GoodPut Vs Time for WP=0.1.

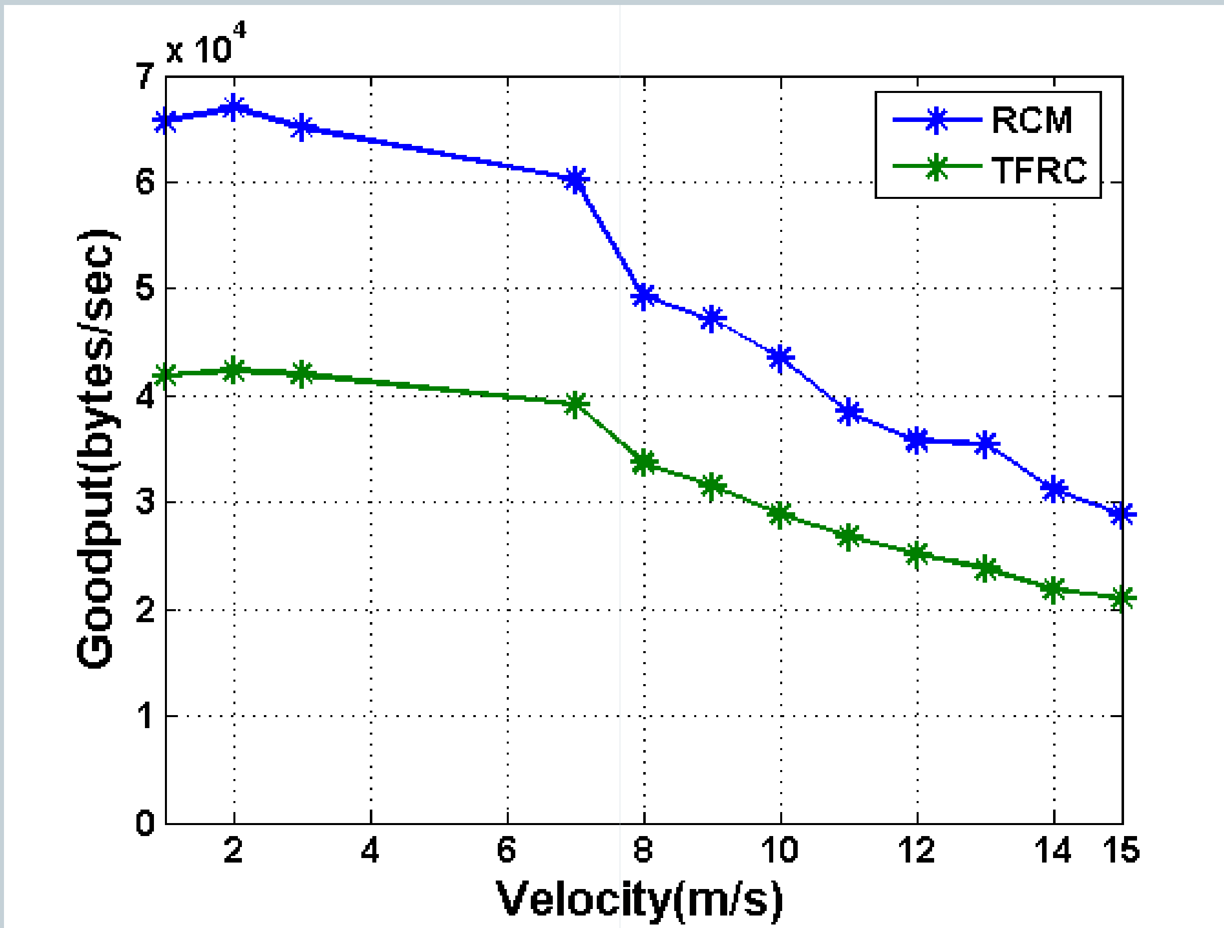


GoodPut Vs Time for WP=0.3.

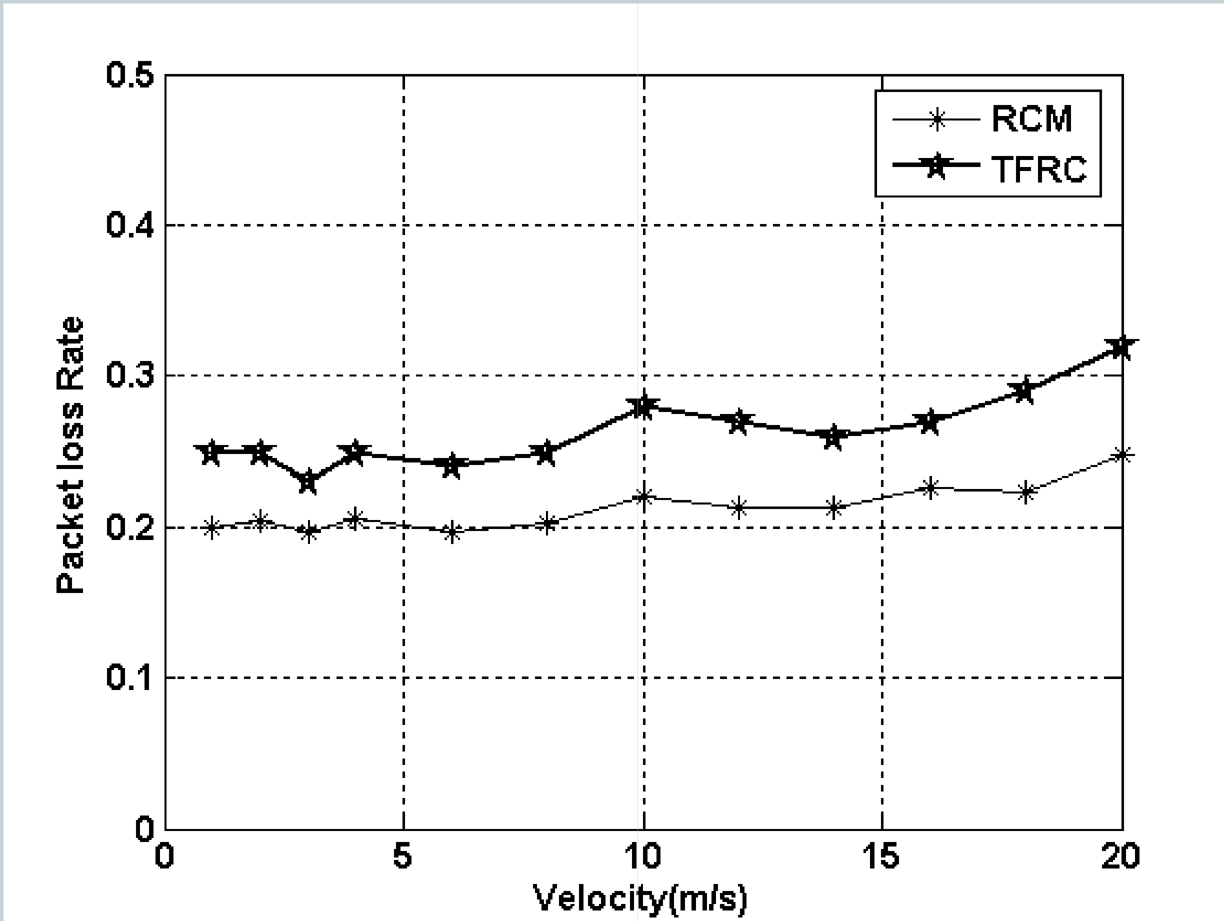
Goodput Performance of RCM



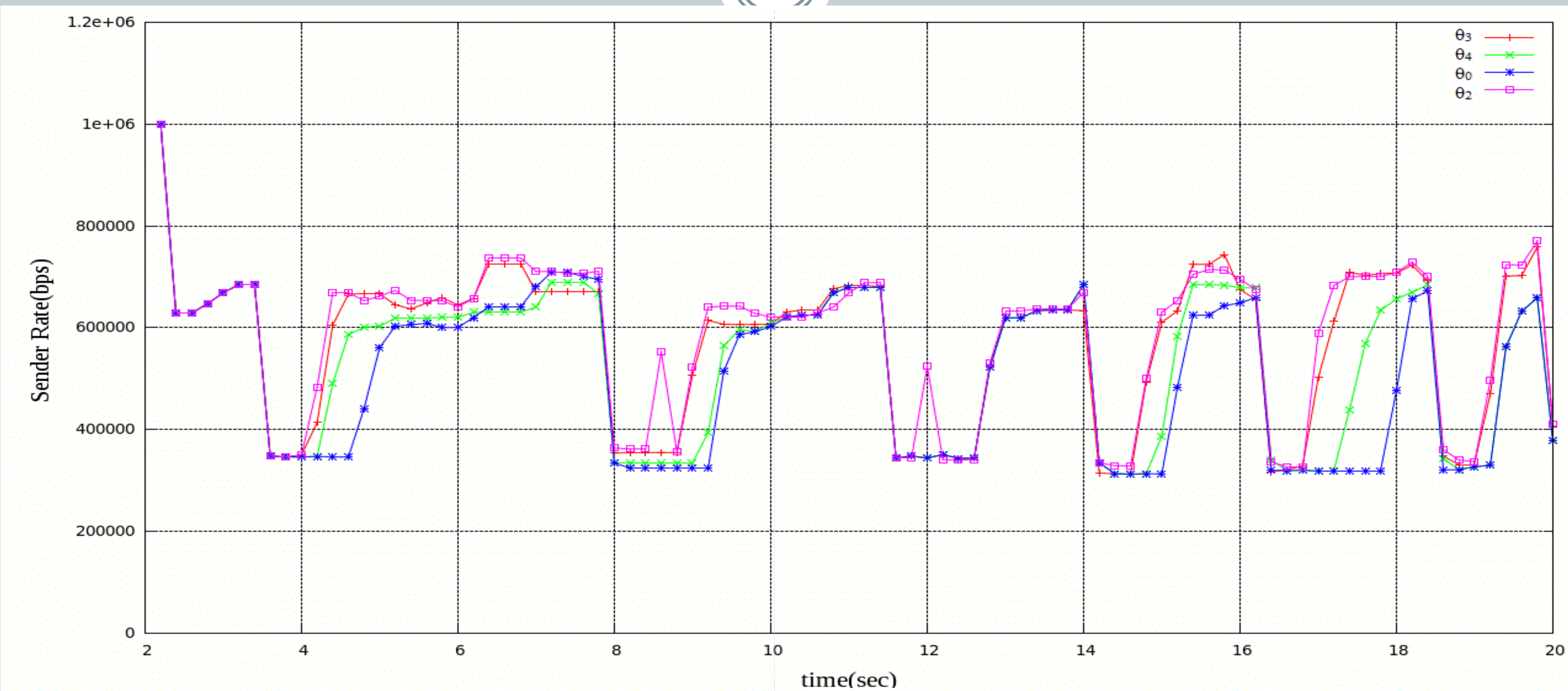
Good Put Vs Velocity of Mobile Node



Packet loss rate Vs. Velocity of mobile node



Analysis on decision factor(θ)



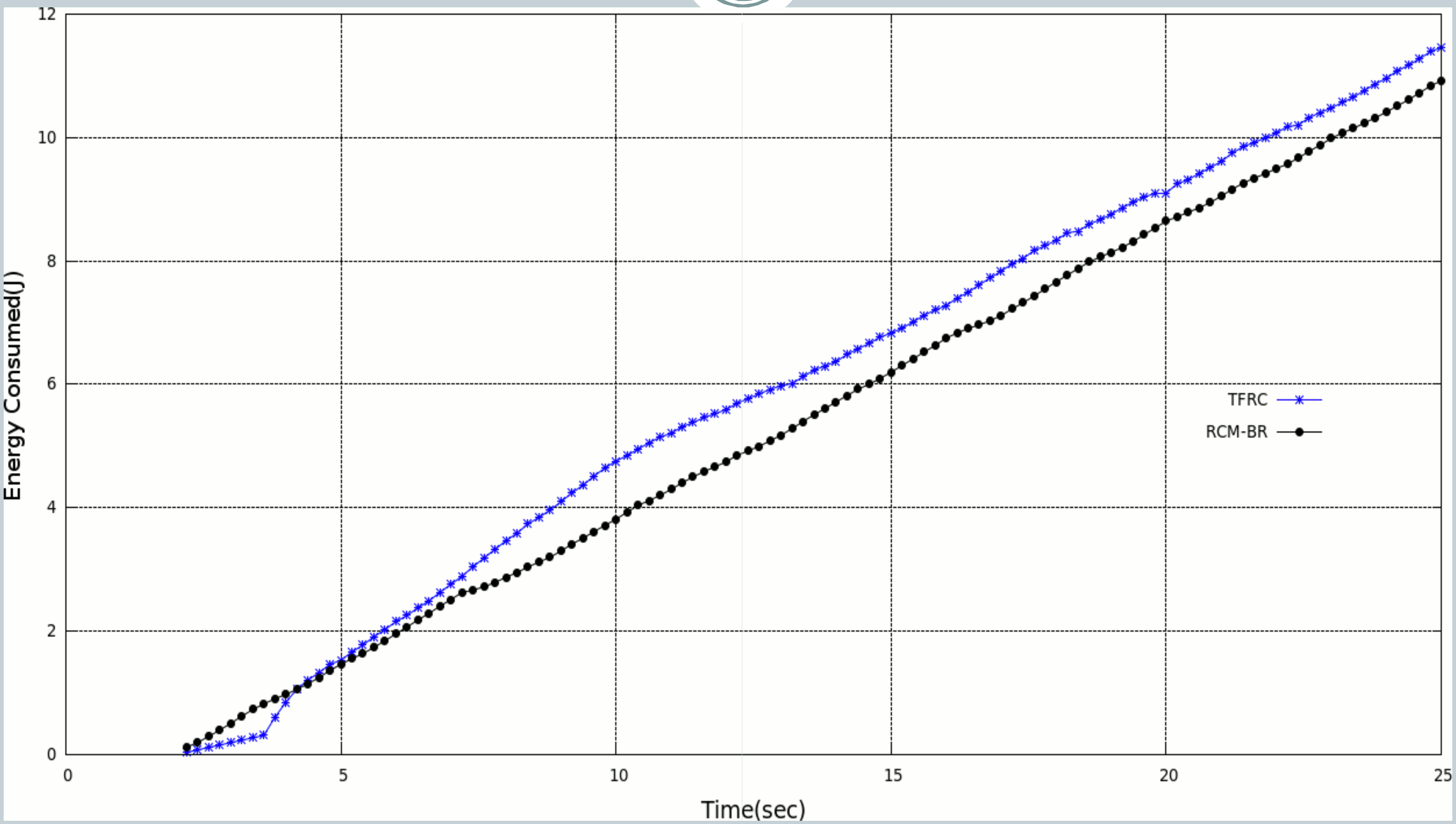
Where, $\theta_0 = 0$,

$\theta_4 = \max(2, prevrate*rtt/4)$

$\theta_2 = \max(2, prevrate*rtt/2)$ and

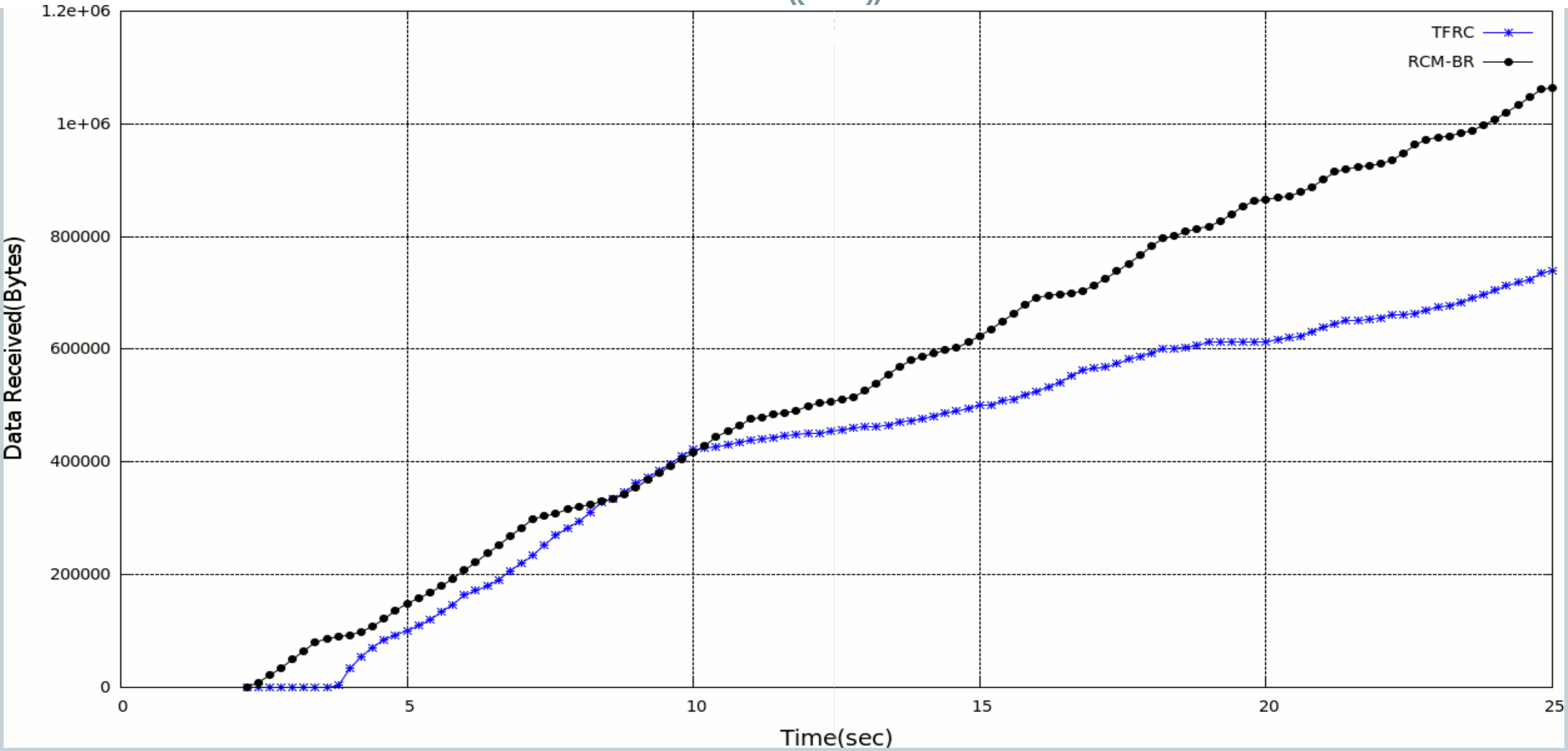
$\theta_3 = \max(2, prevrate*rtt/3)$

Total Energy consumed

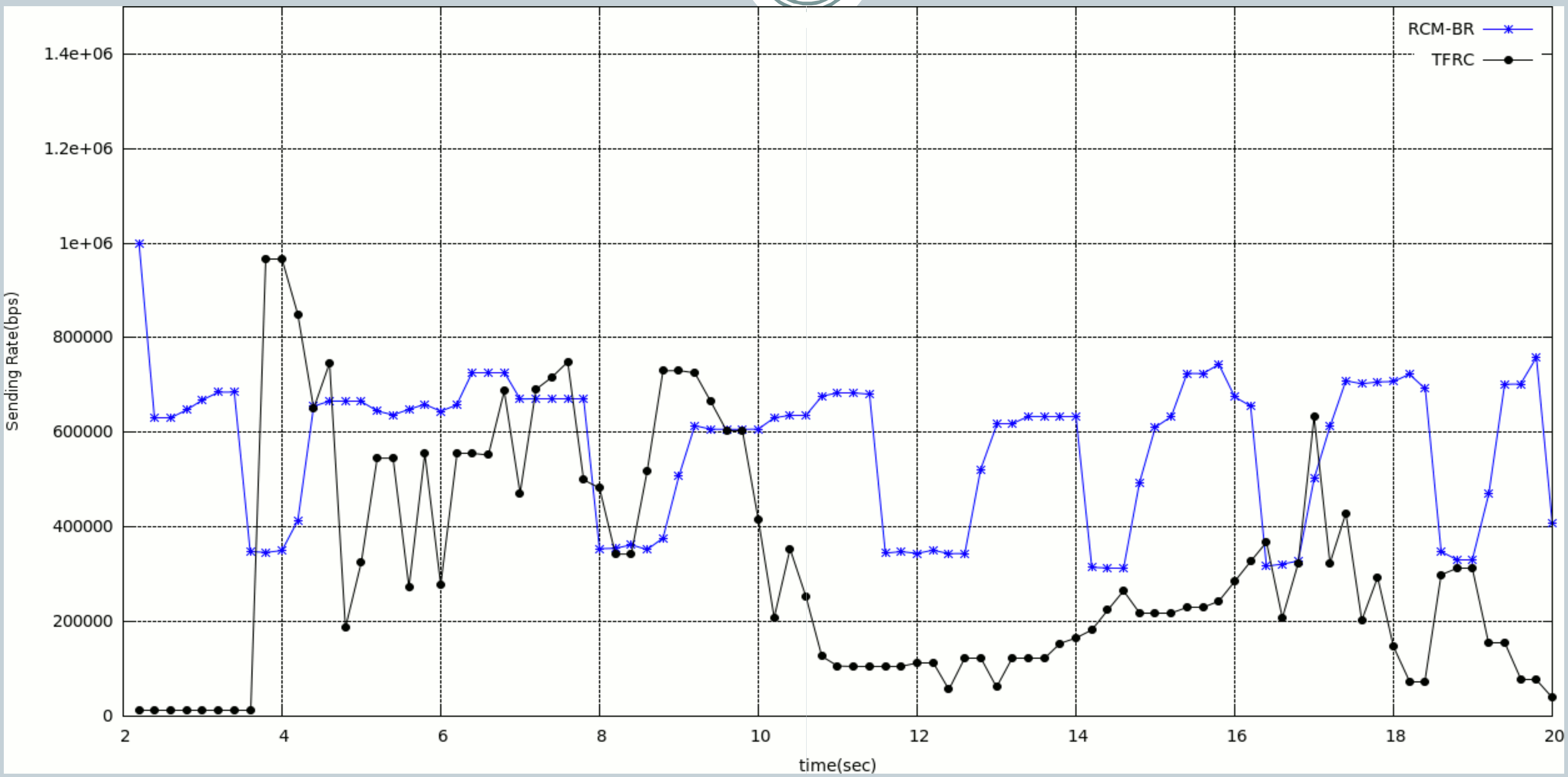


- With wp=0.2

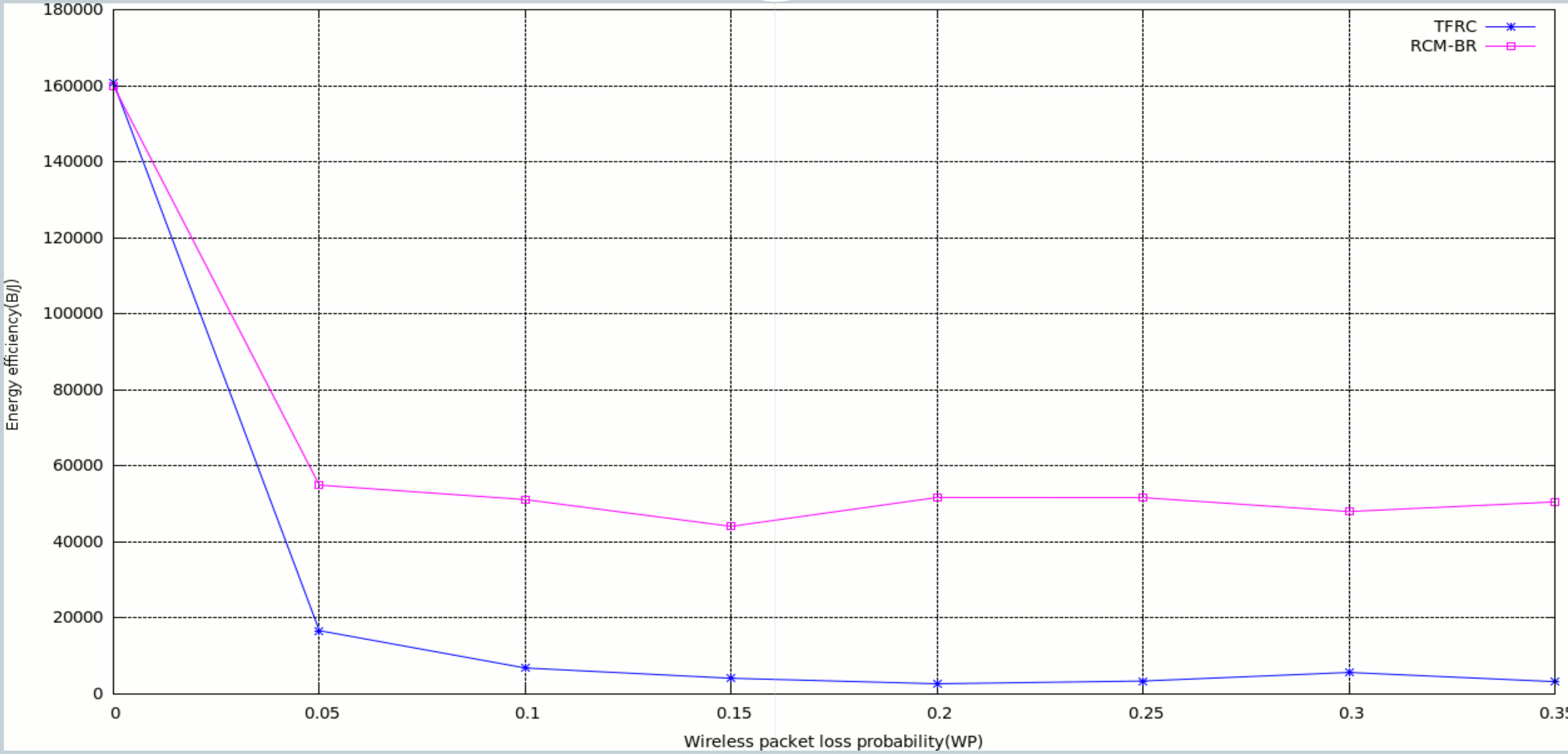
Data received



Sender rate

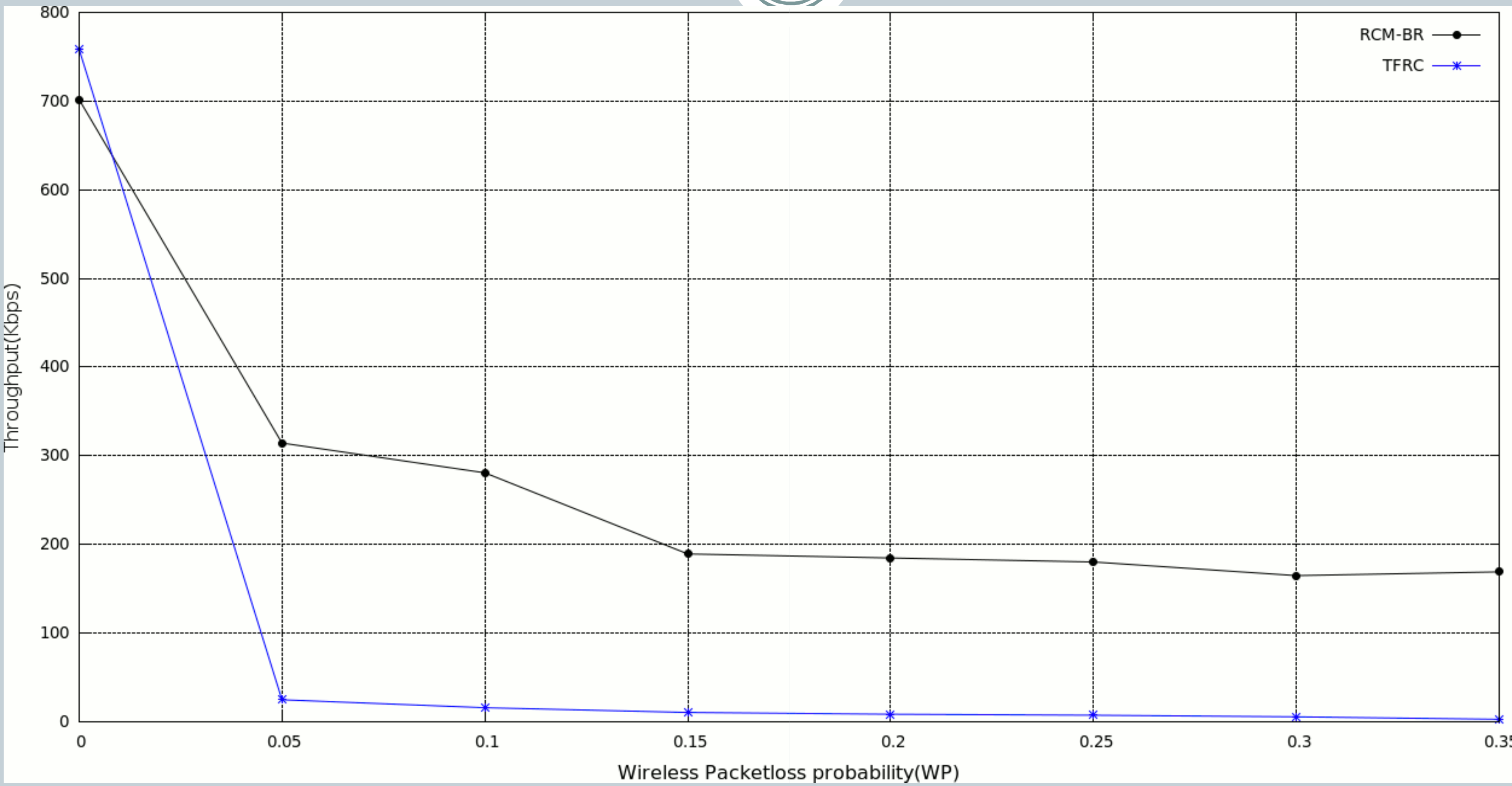

RCM-BR
TFRC
1.4e+06
1.2e+06
1e+06
800000
600000
400000
200000
0
Sending Rate(bps)
2
4
6
8
10
12
14
16
18
20
time(sec)

Energy efficiency



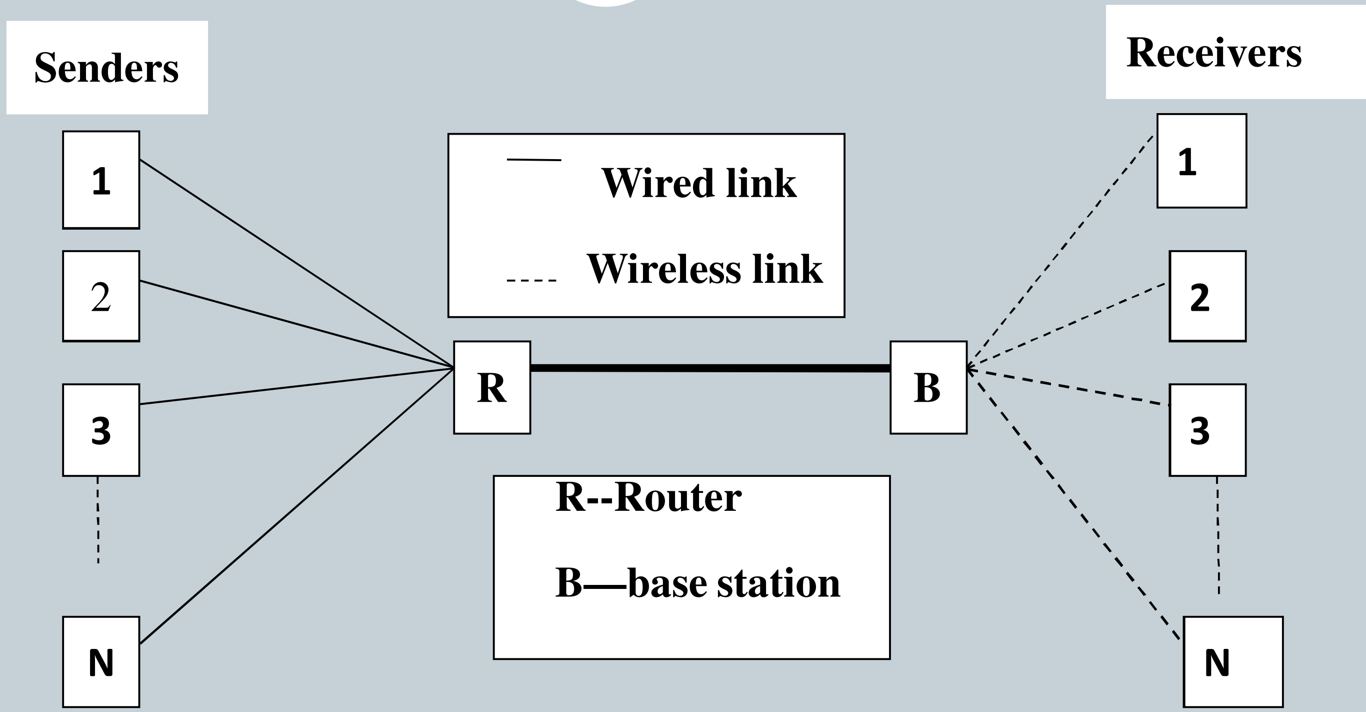
- Energy efficiency Vs Wireless loss probability

Throughput



- Throughput Vs Wireless loss probability

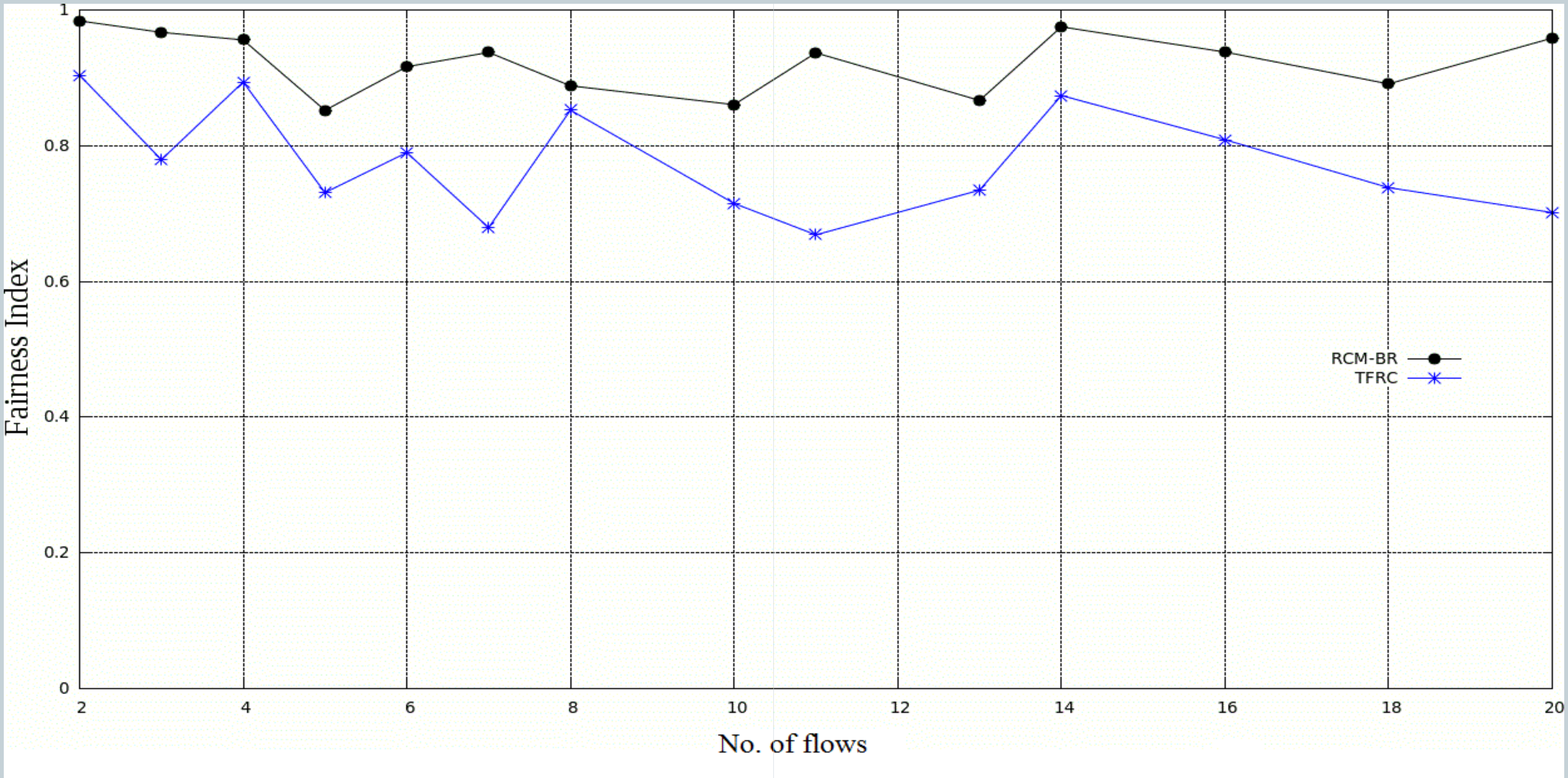
Fairness



- With wp=0.1
- Starts between 1 and 3 sec

Fairness Index

$$F.I = \frac{\left(\sum_{i=0}^{n} Throughput_i\right)^2}{n\left(\sum_{i=0}^{n} Throughput_i^2\right)}$$



- FI Vs No. of flows

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Conclusion

- RCM protocol augmented with burst recovery(RCM-BR) improves the utilization and fairness of the transport protocol, while achieving high energy efficiency.
- Improve the end-to-end loss differentiation algorithm
- Improve burst detection mechanism


QUESTIONS?


Thank You

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Back-up slides

Goodput?

- **Goodput** is the application level throughput, i.e. the number of useful data bits delivered by the network per unit of time.
- Excludes protocol overhead bits as well as retransmitted data packets.

RCM

- "now" is the current time and "lastchange" is the time when RTT was changed last.
- RTT is round trip time calculated using exponential weighted moving average.

- In the equation S_init=max(1, n_ack)/RTT,
- "n_ack" is the number of acknowledgements received by the sender for the probe packets sent in second RTT time.
- Initially the probe packets will be sent with a rate of "S_target", which will be given by the application to achieve highest quality (maximum rate needed). In the simulation it is given manually in the TCL file with the variable like target_rate.

Goodput?

- For example, if a file is transferred, the goodput that the user experiences corresponds to the file size in bits divided by the file transfer time. It is lower than the throughput.
- Examples of factors that cause lower goodput than throughput are:
- *Protocol overhead,* such as transport layer, network layer and sometimes datalink layer protocol overhead is included in the throughput, but is excluded from the goodput.
- *Transport layer flow control and congestion avoidance*, e.g. TCP slow start, may cause a lower goodput than the maximum throughput.
- Retransmission of lost or corrupt packets due to transport layer automatic repeat request (ARQ), caused by bit errors or packet dropping in congested switches and routers, is included in the datalink layer or network layer throughput but not in the goodput.

Performance of Loss differentiation algorithm

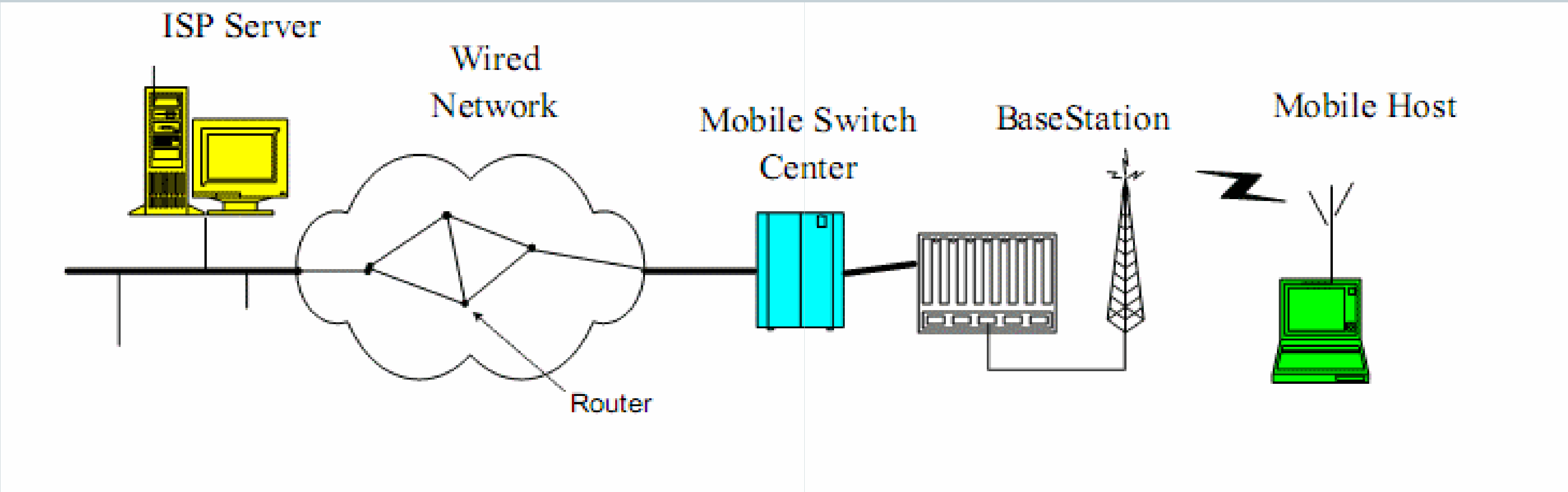
- **Accuracy of Adaptive loss differentiation without link layer ARQ**

C/C	W/W	C/W	W/C
82.5%	85.38%	14.62%	17.5%

Accuracy of Adaptive loss differentiation with link layer ARQ

C/C	W/W	C/W	W/C
95.3	0%	0%	4.7

Wireless internet



Combination of wired and wireless networks