# Effect of Congestion Control on the Performance of SCTP in a Satellite Network

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# Introduction

- TCP is the main transport protocol in the Internet protocol suite
- Original TCP did not perform very well in satellite networks because of errors and long delay.
- Many schemes have been proposed to enhance TCP for satellite networks.
- IETF is developing the Stream Control Transmission Protocol for carrying PSTN signaling messages over IP.

Open question: How good is SCTP when it operates in satellite networks?

# Objectives

- Determine the suitability of Stream Control Transmission Protocol (SCTP) in satellite networks.
- Propose changes to SCTP to make it more suitable for satellite networks.
- Performance comparison of SCTP and TCP.

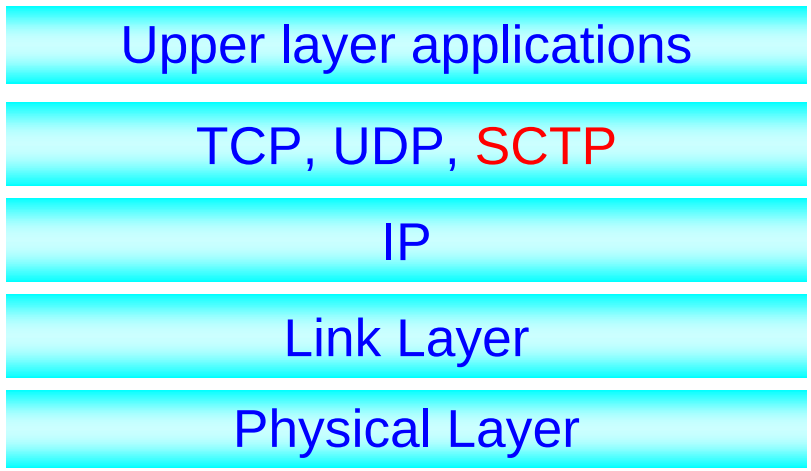
# Outline

- SCTP
  - Multistreaming
  - Multihoming
- Suitability of SCTP for satellite networks
- Performance of multistreaming
- Comparison of congestion control of SCTP and TCP

# Stream Control Transmission Protocol

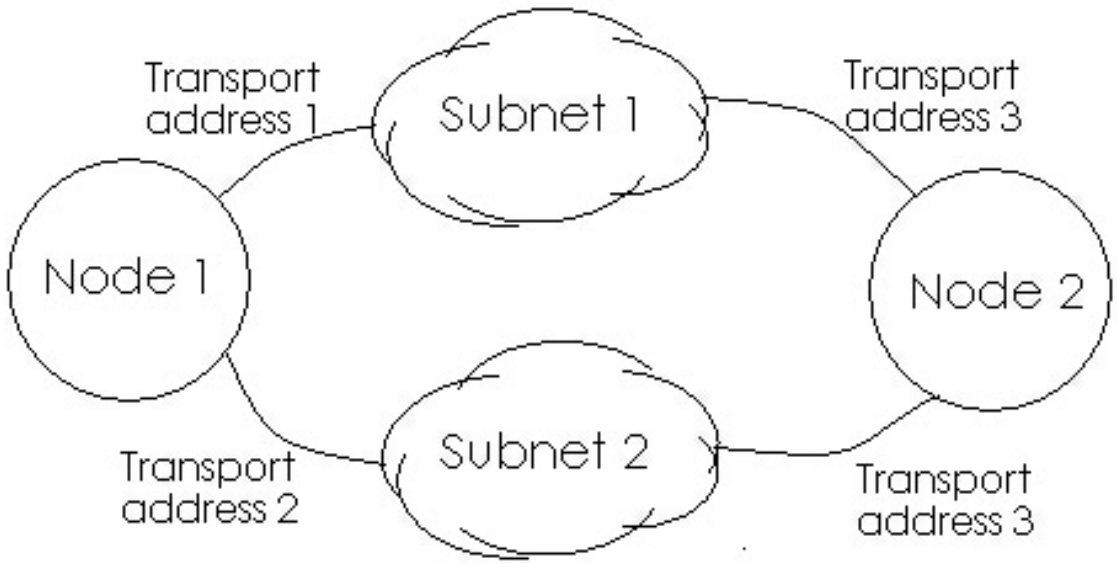
- SCTP (RFC 2960) is being developed by IETF as a transport protocol for carrying PSTN signaling.
  - Reliable: retransmission of lost packets, ack of packets.
  - Non-duplicated service: uses sequence numbers.
  - In-order delivery: re-sequencing at the destination.
- Transport layer protocol which operates on top of an unreliable connectionless network layer such as IP.
  - Transparent to IPv4 or IPv6
- Key features:
  - Multistreaming – multiple streams per association
  - Multihoming – multiple IP addresses per host

# SCTP in the protocol stack



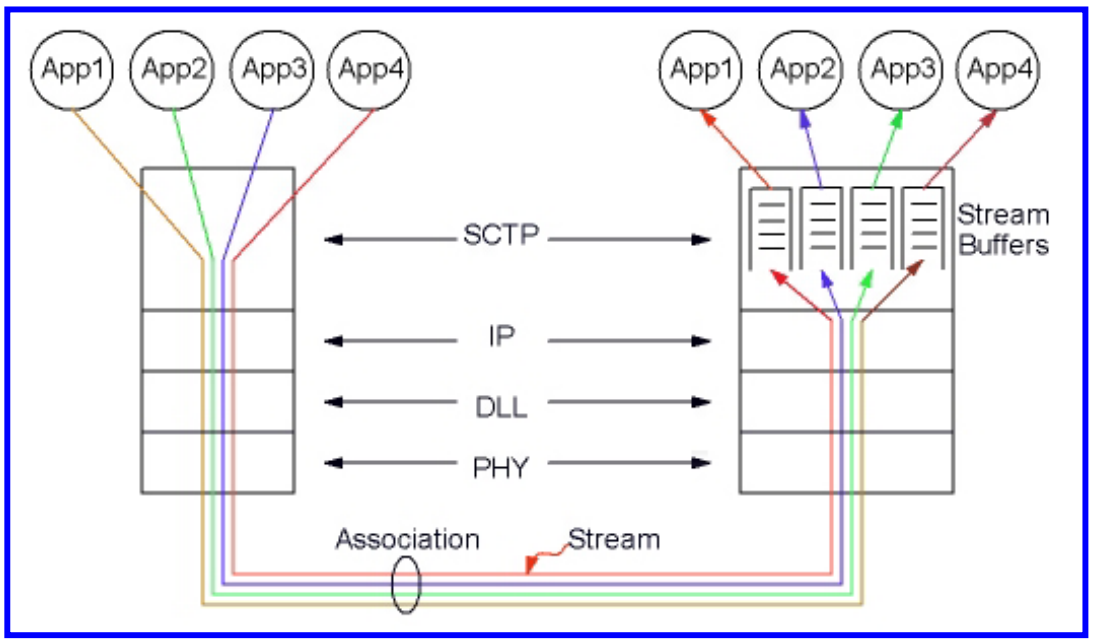
# Multihoming

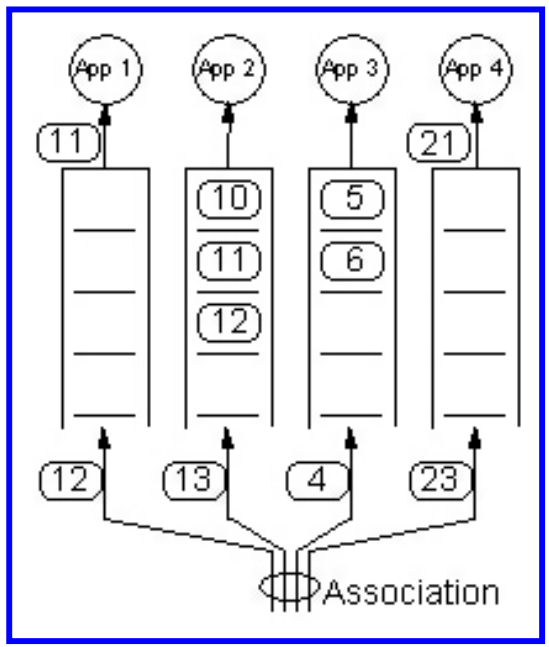
- Supports multiple IP addresses in an *association.*
- Requires multiple Network Interface Cards – already quite common in laptops !!



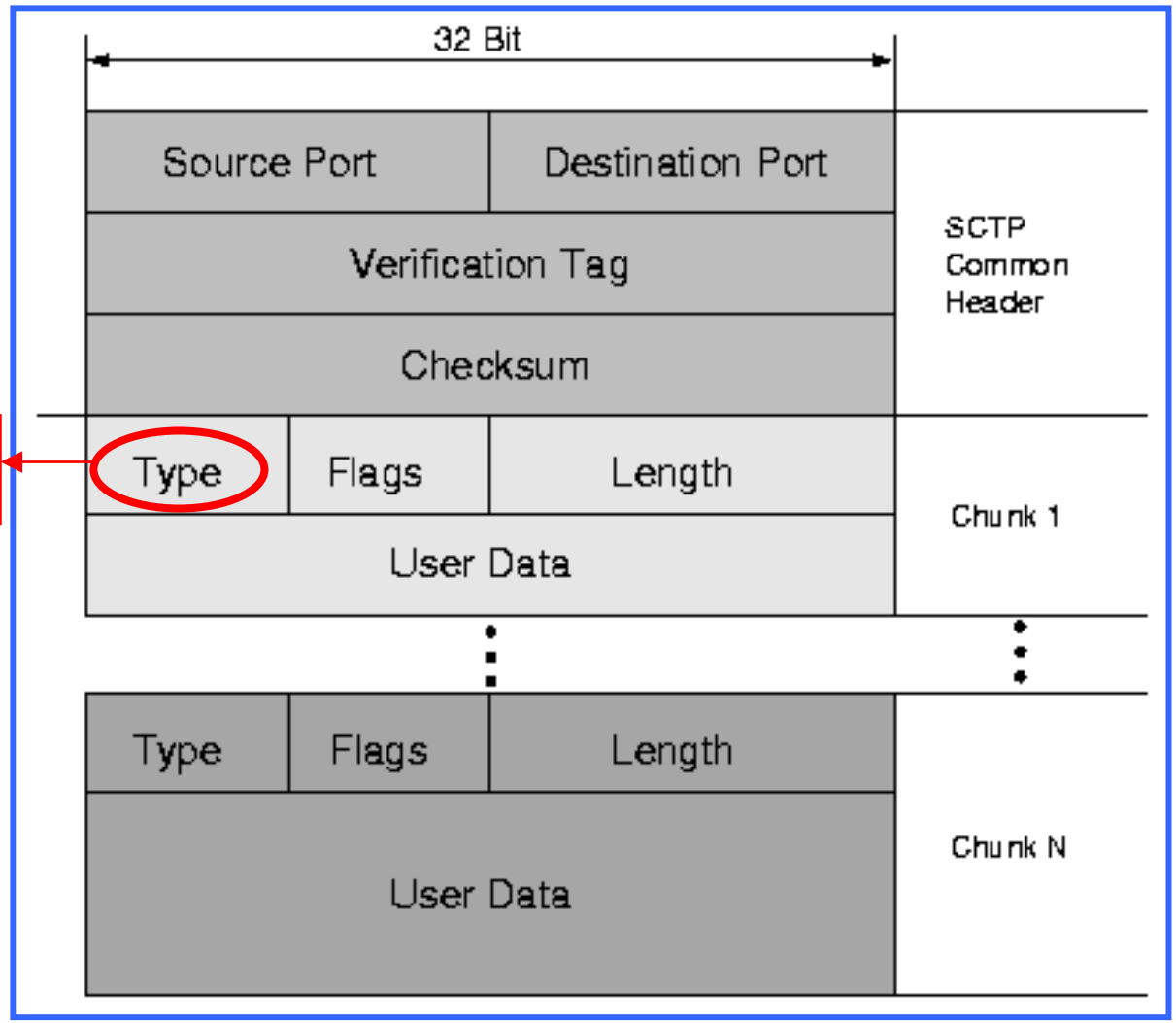
# Multistreaming

- SCTP accomplishes multistreaming by creating independence between
  - data transmission (uses Transport Sequence Number)
  - data delivery (uses Stream Sequence Number)

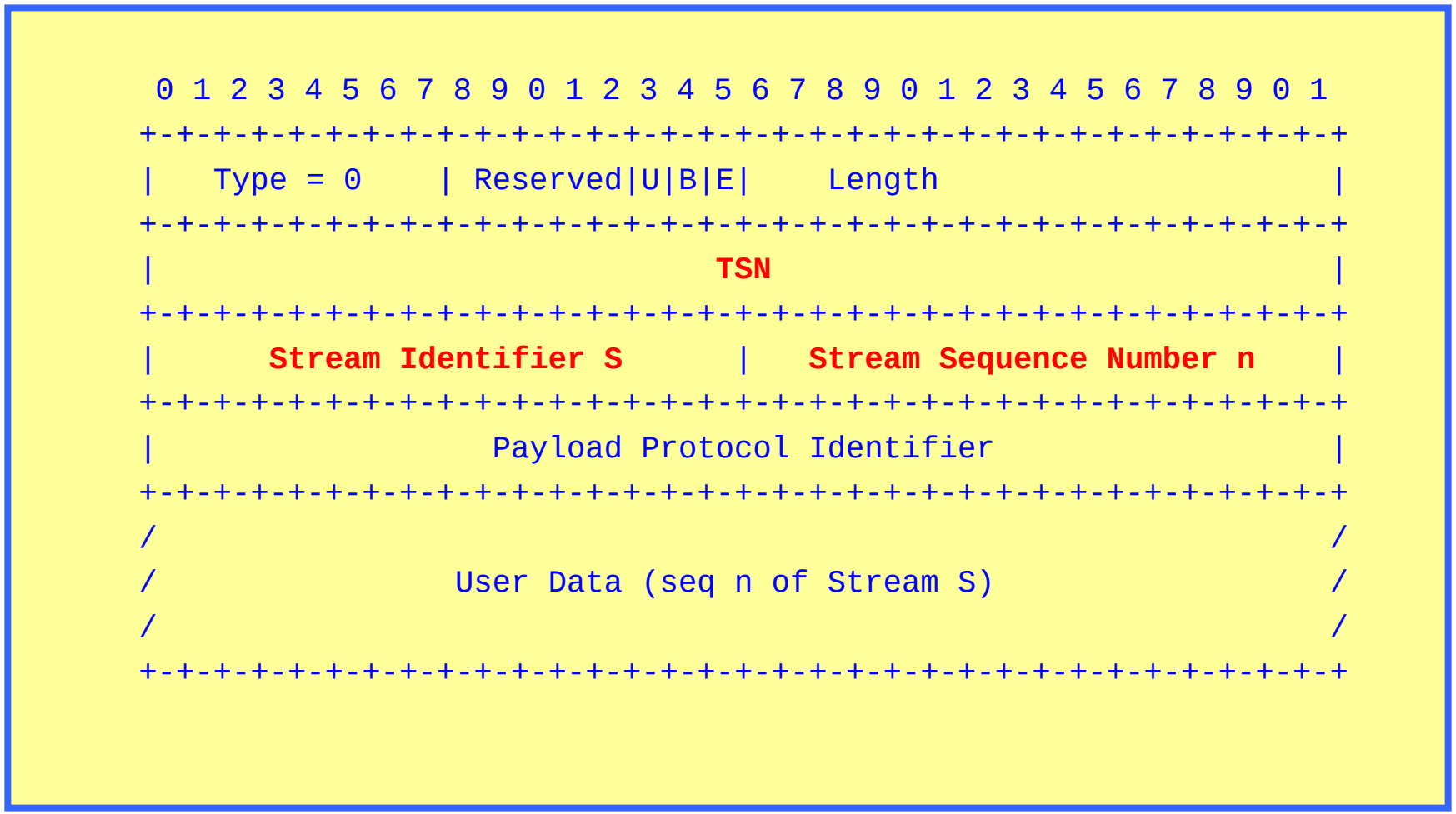


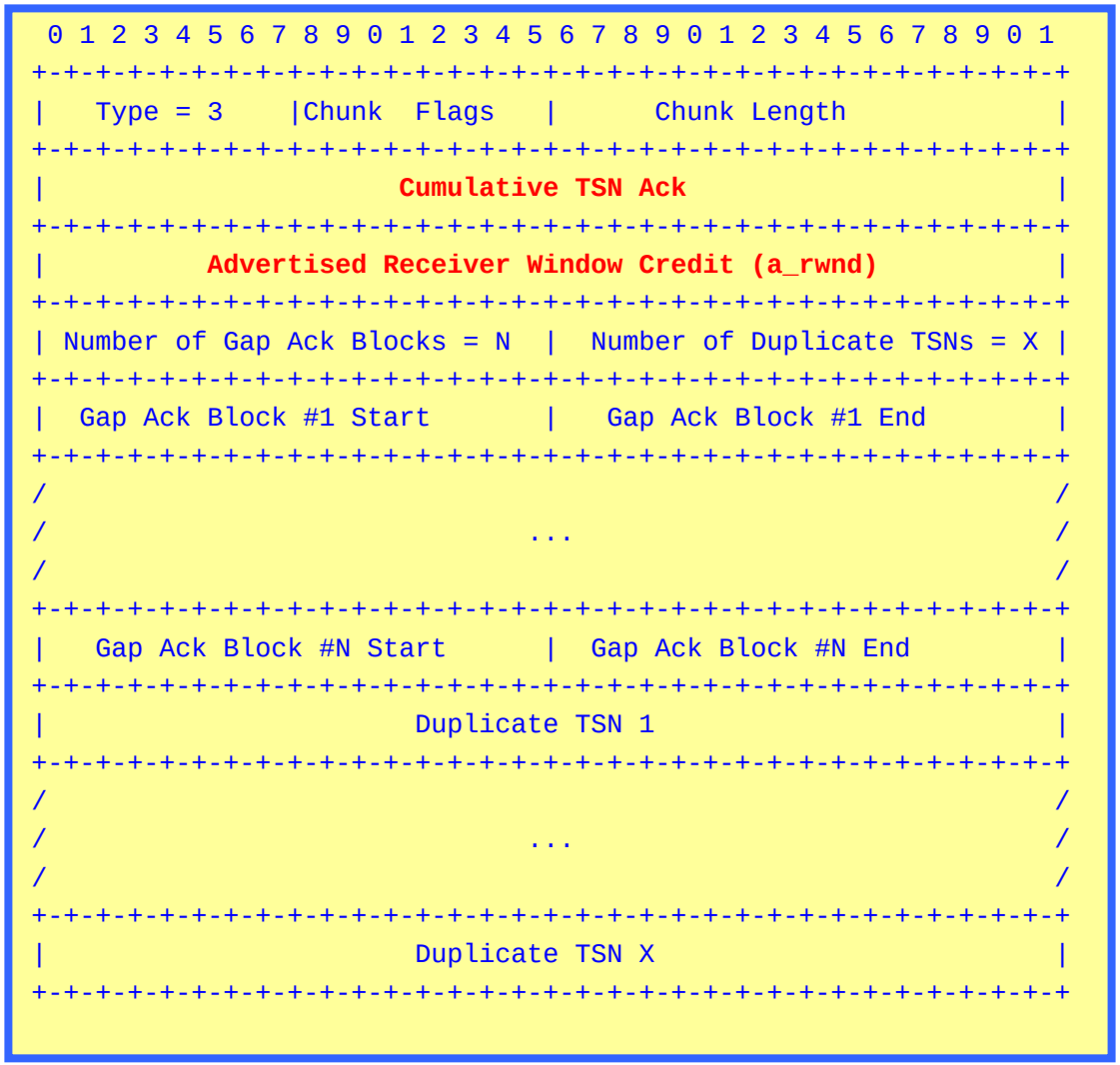
# SCTP Packets



# Chunk Type: Payload



# Chunk Type: SACK



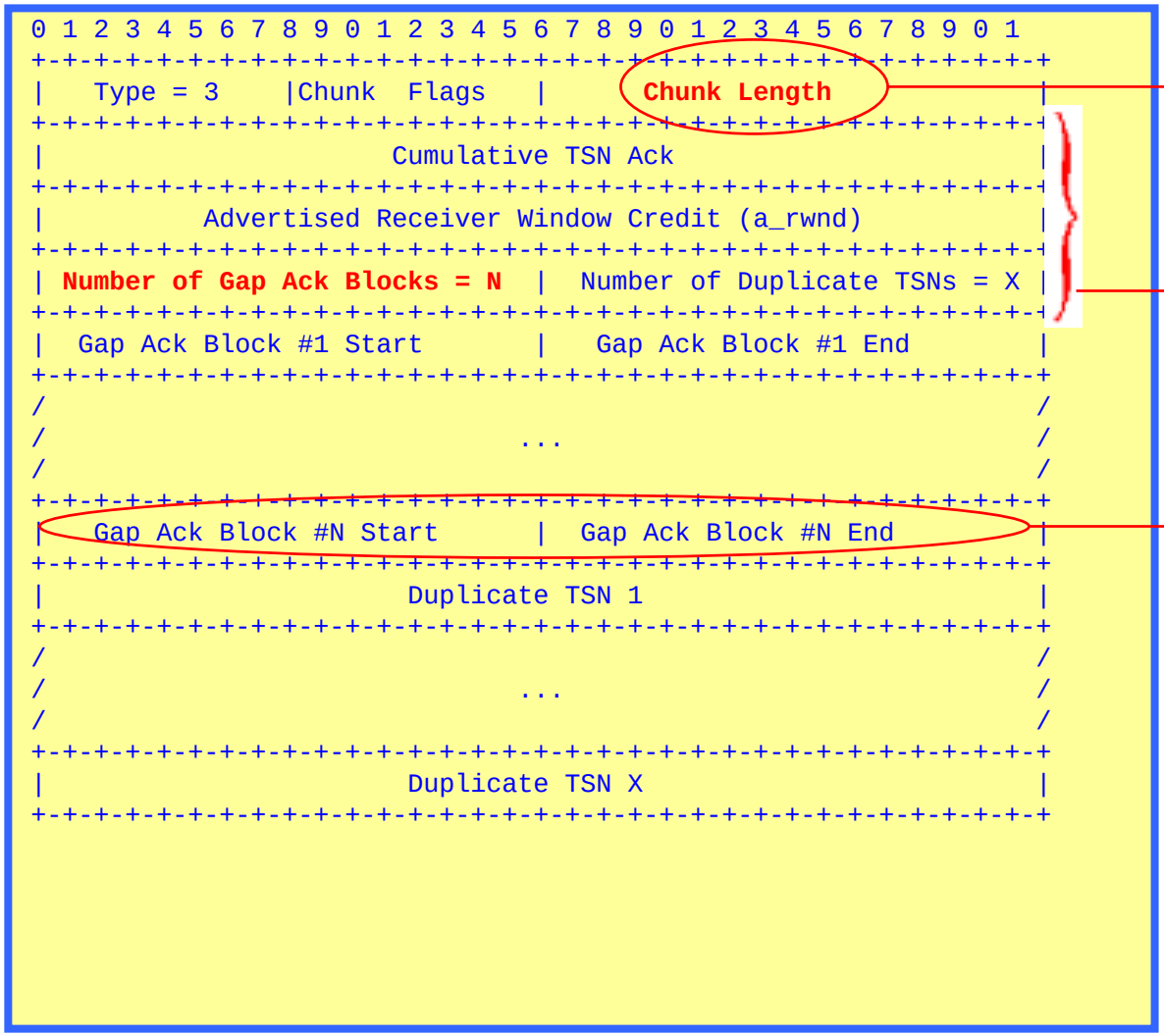
# SCTP Congestion Control

- SCTP congestion control assures that the traffic behaves in the network in the same way as TCP traffic.
- Enables a seamless introduction of SCTP services into existing IP networks.
- SCTP is rate adaptive similar to TCP.
  - Slow Start, Congestion Avoidance, Fast Retransmit
  - Fast Recovery is implemented, but in a slightly different way than TCP.
- Differences with TCP
  - Number of bytes acknowledged to increase *cwnd.*
  - SACK is mandatory
  - No explicit fast recovery phase
  - Unlimited number of Gap Ack Blocks in SACK

# Suitability of SCTP over

# Satellite Networks

# SCTP Selective Acknowledgment



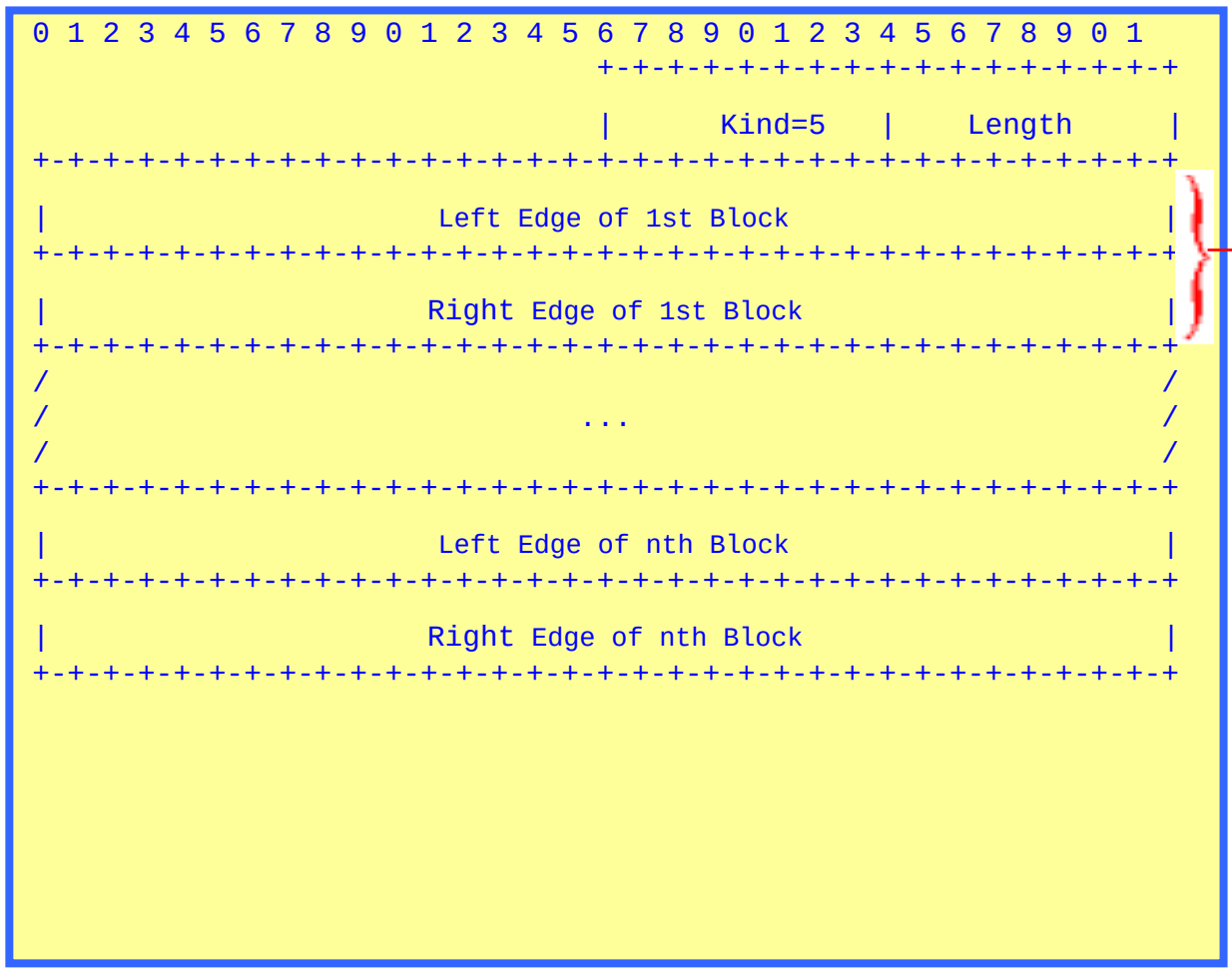

Total available chunk space: $2^{16}$ Bytes

Space used by other fields: 4×4 Bytes

Space required for each Gap Ack Block: 4 Bytes

Maximum number of Gap Ack Blocks: $(2^{16}-4\times4)/4=16380$

# TCP Selective Acknowledgment




4-bit "Header Length" field limits the maximum space available for TCP options: 40bytes

Space required for one SACK block: 8 bytes

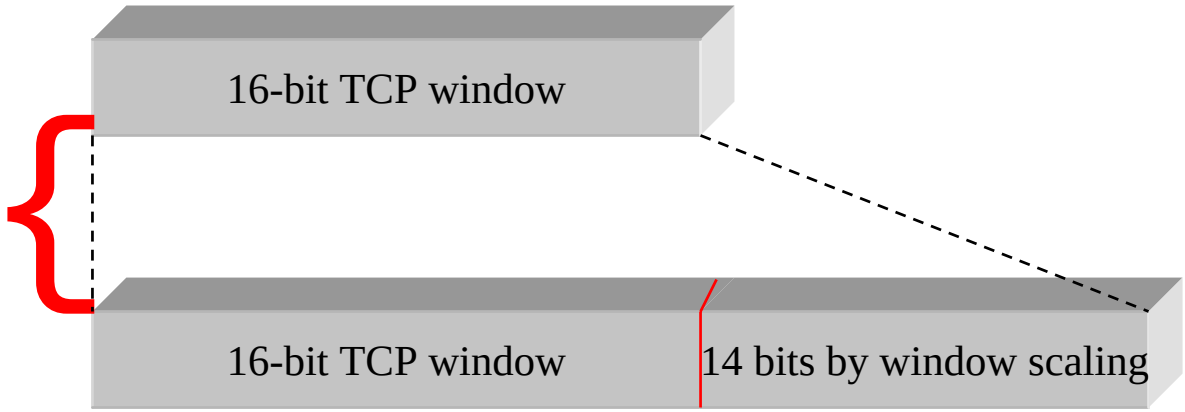
Maximum number of TCP SACK Blocks: Integer[(40-2)/8]=4

# Adv. of more SACK blocks in SCTP

- Satellite link features high BER and large TCP window.
- There is high probability of multiple losses in a large window.
- 3 or 4 blocks (as in TCP) may not be sufficient for reporting segment losses for long bandwidth delay product networks.
- Availability of larger number of SACK blocks make SCTP robust in the case of multiple losses.

# Large Window Support in SCTP

Maximum TCP window size: $65535 \times 2^{14}$ bytes

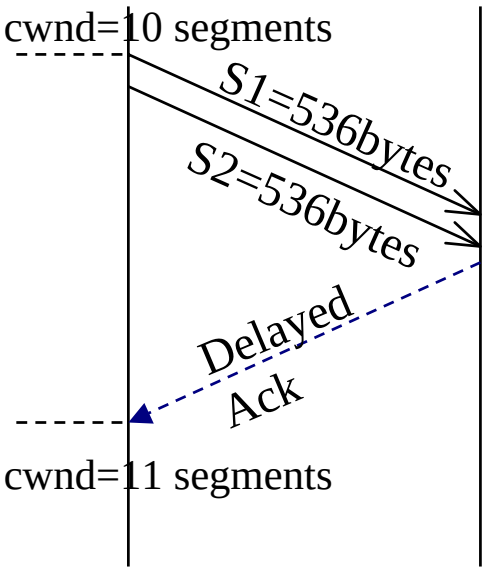



Maximum SCTP window size: $2^{32}-1$ bytes

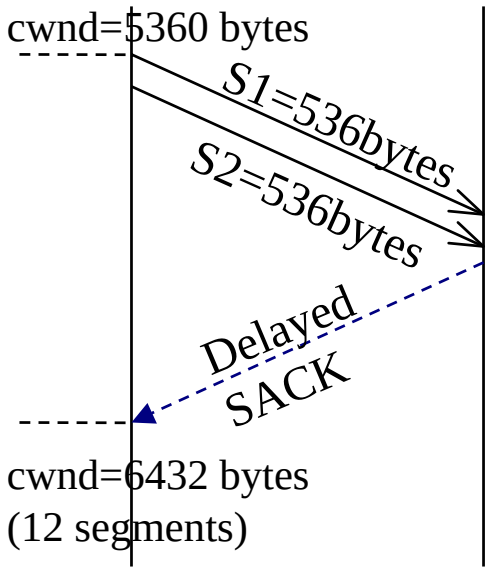
# Delayed Acknowledgment & Byte Counting

- Byte counting: *cwnd* is increased by the number of bytes acknowledged by the SACK instead of by the number of ACKs as in TCP.
- Byte counting decouples the *cwnd* increase from the arrival frequency of the SACKs, which is important in satellite environments by speeding up the slow start stage.
- SCTP limits the *cwnd* increase to one PMTU per SACK. When the total number of bytes acknowledged by a single SACK exceeds PMTU, the benefit of byte counting is impaired.

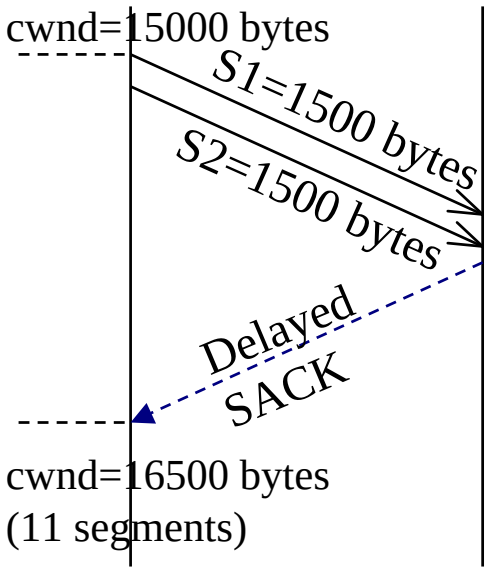
# Delayed Acknowledgment & Byte Counting (cont.)




TCP delayed Ack



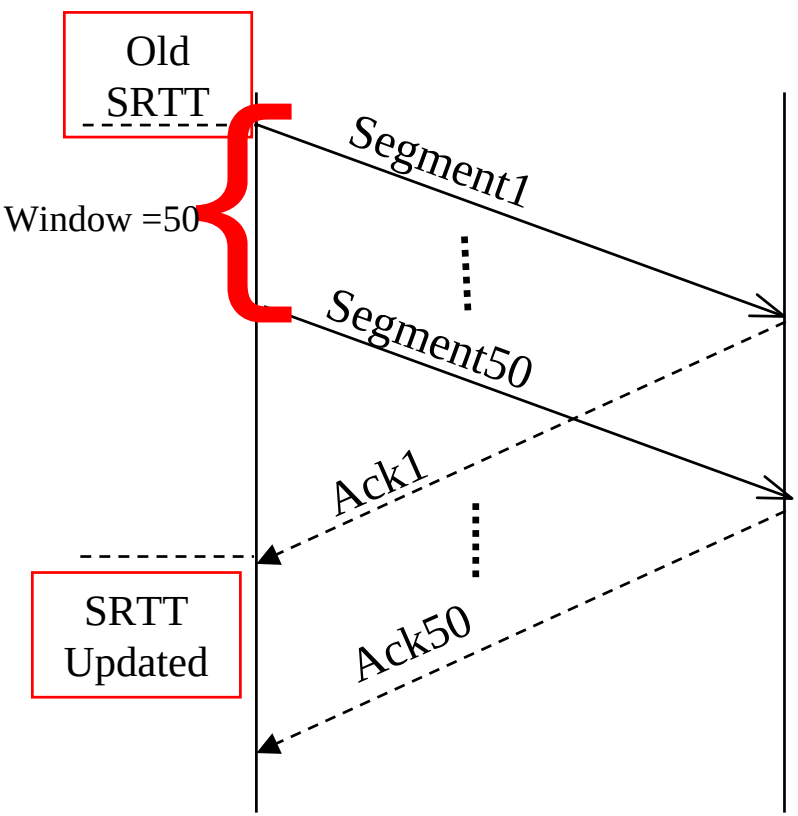

SCTP delayed SACK
(PMTU=1500 bytes)



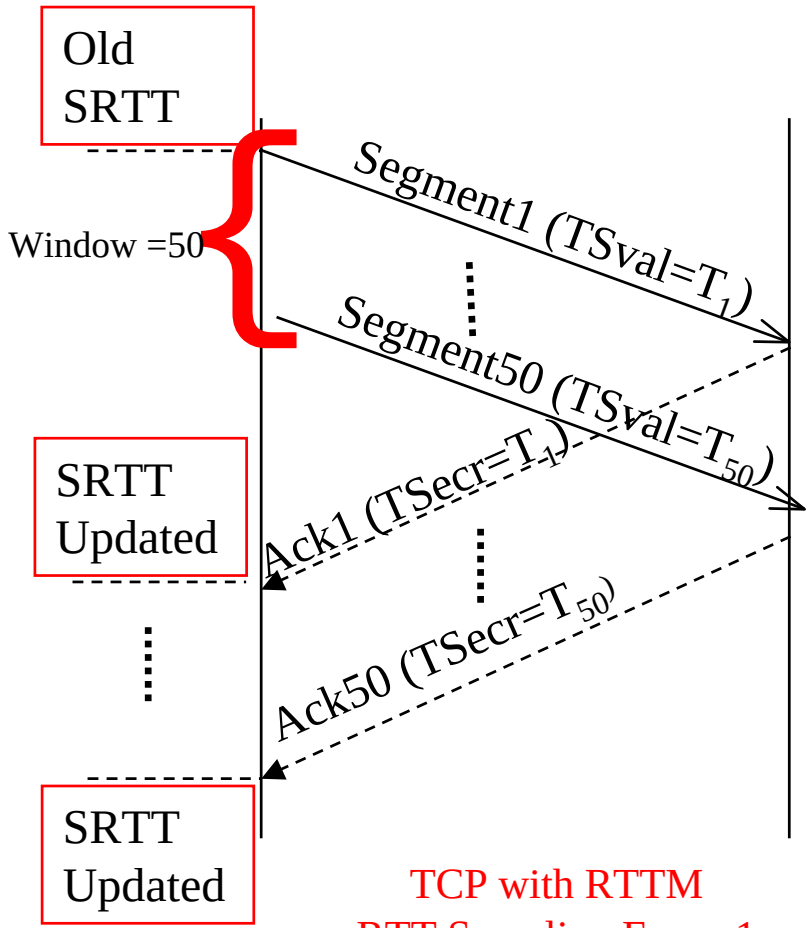

SCTP delayed SACK
(PMTU=1500 bytes)

We recommend increasing the byte counting limit to 2 PMTU in SCTP when delayed SACK is used.

# RTTM: Round Trip Time Measurement

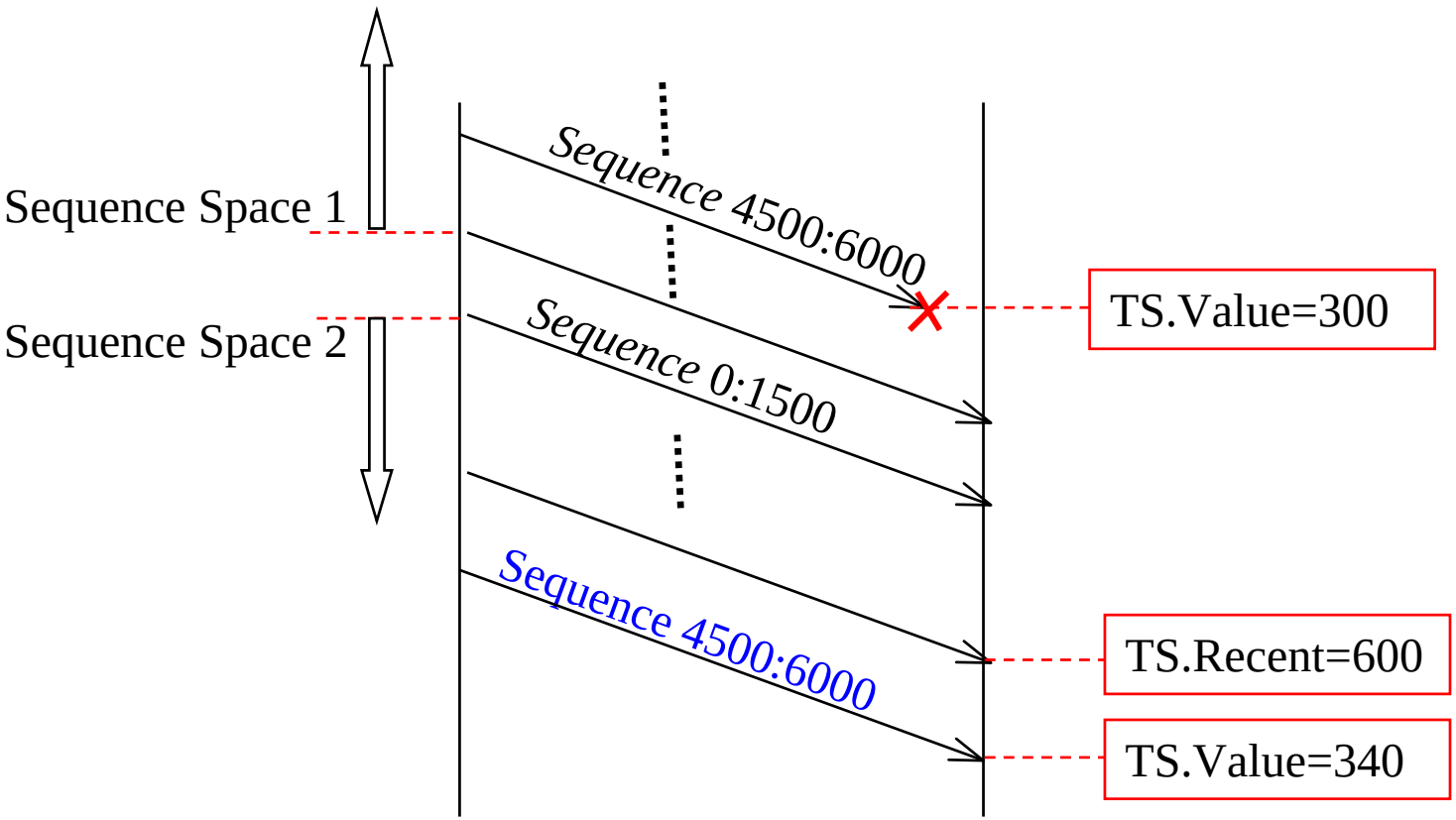



TCP without RTTM
RTT Sampling Freq.=1/50




TCP with RTTM
RTT Sampling Freq.=1

# PAWS: Protect Against Wrapped Sequence Numbers




Timestamp Option is used as a 32-bit extension to TCP *sequence number* field

# Recommended Use of SCTP over Satellite Networks

| Mechanism | TCP Use (RFC 2488) | SCTP Use | Where |
|---|---|---|---|
| Path MTU Discovery | Recommended | Recommended | S |
| Slow Start | Required | Required | S |
| Congestion Avoidance | Required | Required | S |
| Fast Retransmit | Recommended | Recommended | S |
| Fast Recovery | Recommended | Implicitly Used | S |
| SACK | Recommended | Implicitly Used | S, R |
| Delayed SACK | Recommended | Recommended | R |
| Byte Counting | N/A | Implicitly Used | S, R |
| Larger Byte Counting Limit | N/A | Recommended | S |
| Larger Initial cwnd | N/A | Recommended | S |
| Large Receiver Window | Recommended | Implicitly Used | S, R |
| PAWS and RTTM | Recommended | Needs new chunk | S, R |
| ECN | N/A | Recommended | S, R |
| SCTP Multi-Streaming | N/A | Recommended | S, R |

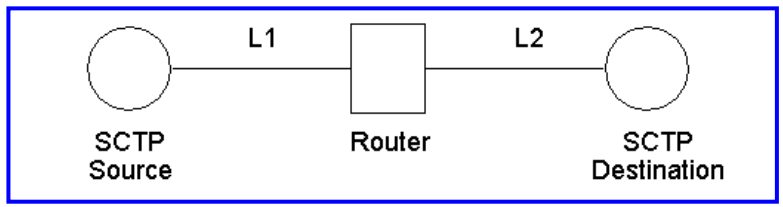
# SCTP Multistreaming over

# Satellite Networks

# ns-2 Simulation Setup

## Assumptions

- *Ftp* traffic between source and destination.
- Packets are of *fixed length* of one MTU.
- Upper layer at destination is always ready to accept data.
- Association consists of a number of streams.
- Receiver buffer size = *B*




Link delay (L1+L2) = 260 msec

# Performance Metrics

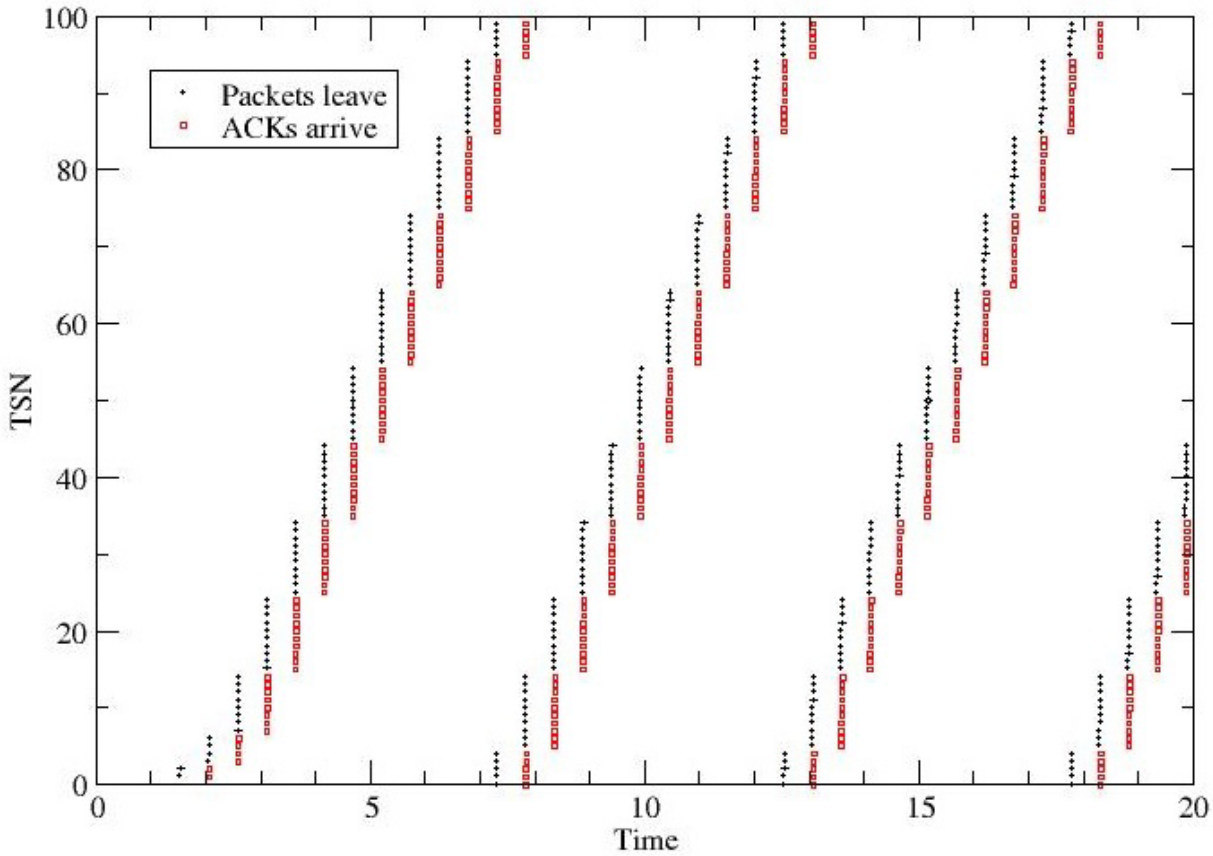
- Goodput
- Optimal receiver buffer size

as a function of

Error probability (e) = Prob. that a packet is lost in the network.

# Packets Plot: No loss

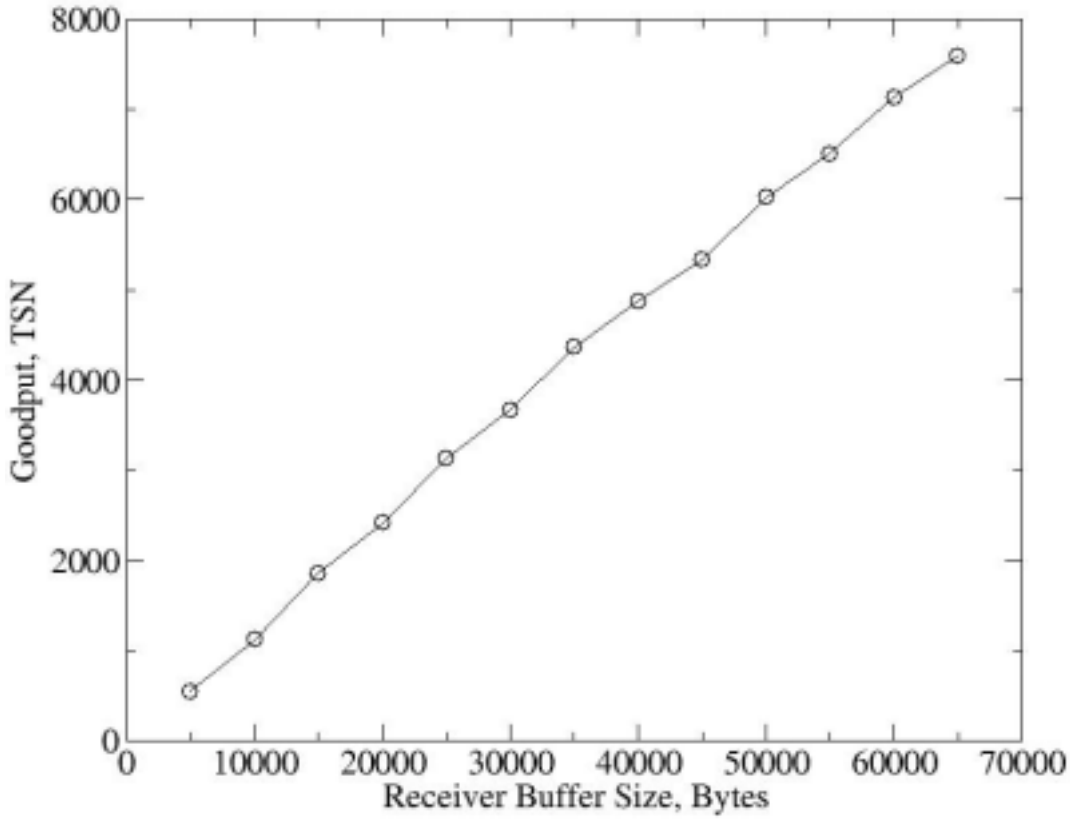
- No packet loss means no blocking at the receiver.
- *cwnd* initially increases until it reaches *B.*
- Goodput is limited to *B/MTU* packets every RTT; Goodput therefore increases linearly with *B.*




s = 4, e = 0, B = 15K

# Goodput: No loss

- Since goodput is limited to *B/MTU* packets every RTT; it increases linearly with *B.*



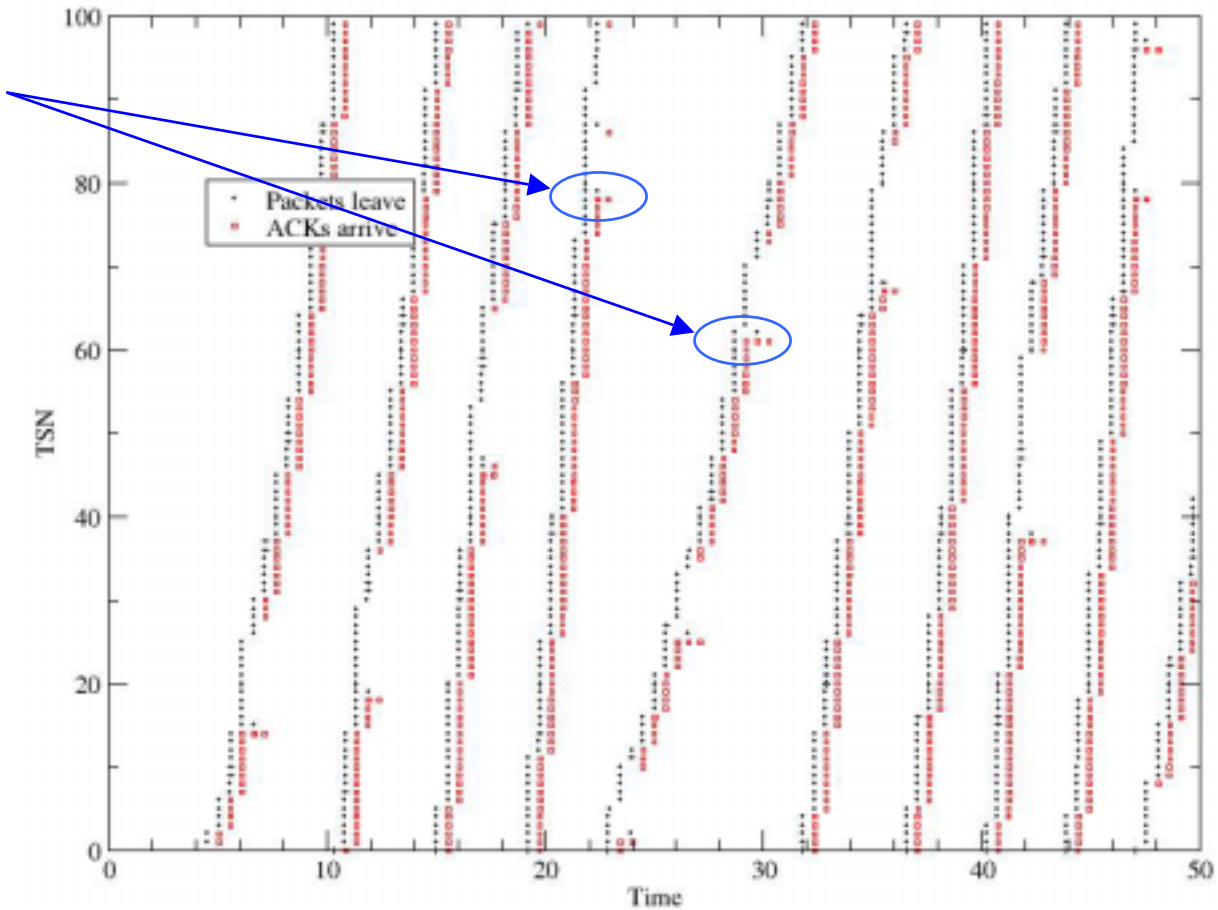

s = 4, e = 0

# Packet plot: Congestion Control limited

- Long delays in Retx of lost packets while waiting for DupAcks

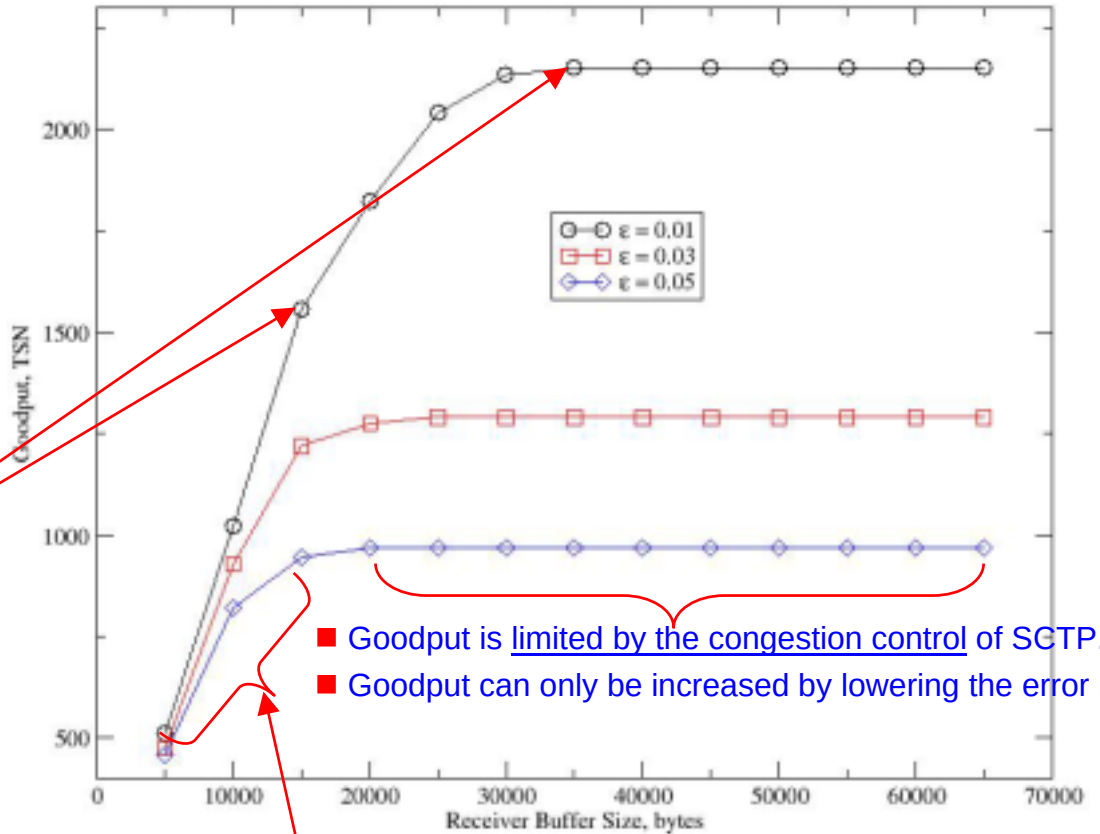
  +

  drop in *cwnd* due to Retx results in poor goodput when receiver buffer is not a constraint.




s = 4, e = 0.01, B = 35K

# Goodput with errors




See *a_rwnd* and *cwnd* in the next two figures

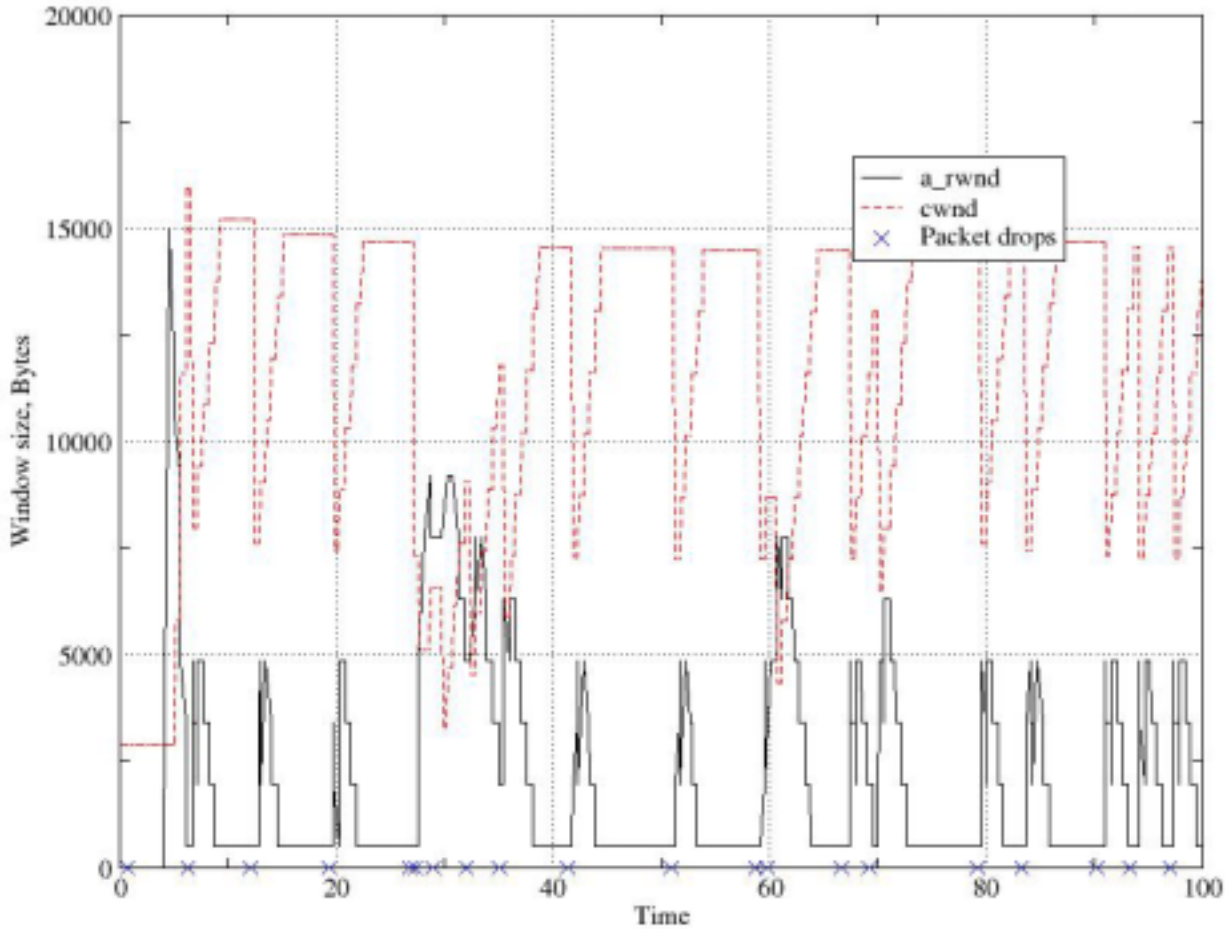
- Goodput is limited by the congestion control of SCTP.
- Goodput can only be increased by lowering the error rate

Goodput initially increases as *B* increases when the goodput is constrained by B (*a_rwnd* frequently drops below 1 MTU)

s = 4, e > 0

# *cwnd* and *a_rwnd* with errors: Receiver buffer limited

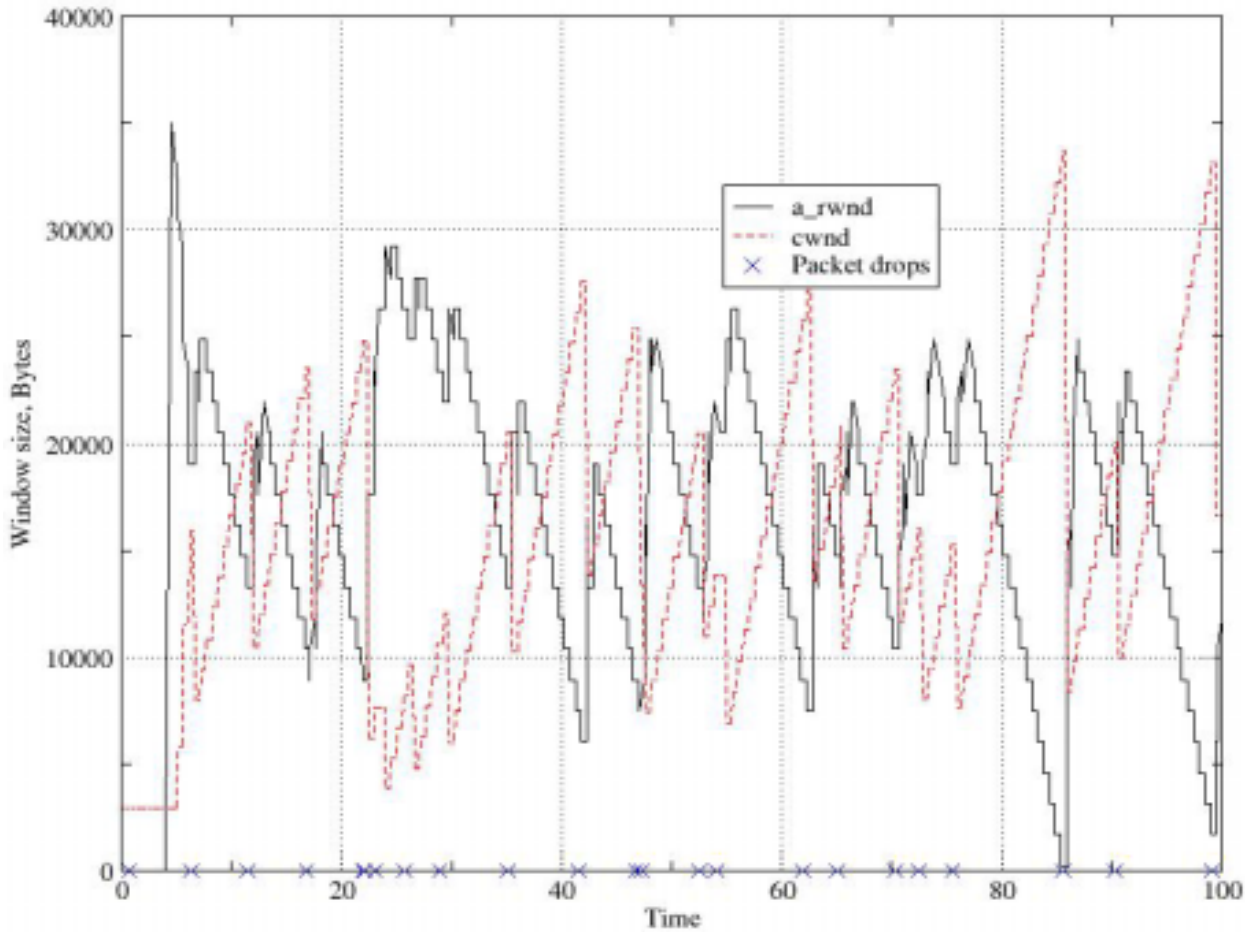
- *B*=15K results in the throughput being constrained by the receiver buffer size
- *a_rwnd* frequently drops below 1 MTU, and *cwnd* is restricted to 15K.




s = 4, e = 0.01, B = 15K

# *cwnd* and *a_rwnd* with errors: Congestion control limited

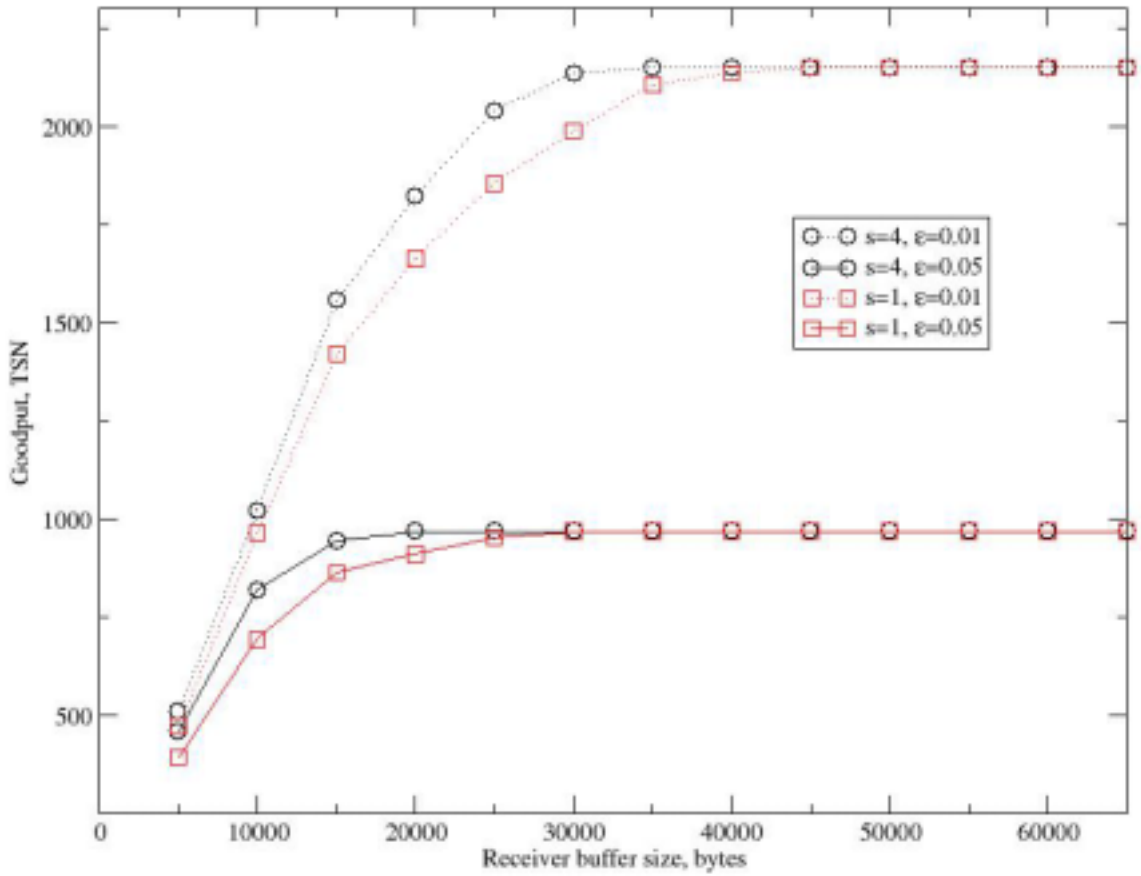
- *B*=35K makes the throughput constrained by the congestion control of SCTP.
- *a_rwnd* never drops below 1 MTU




s = 4, e = 0.01, B = 35K

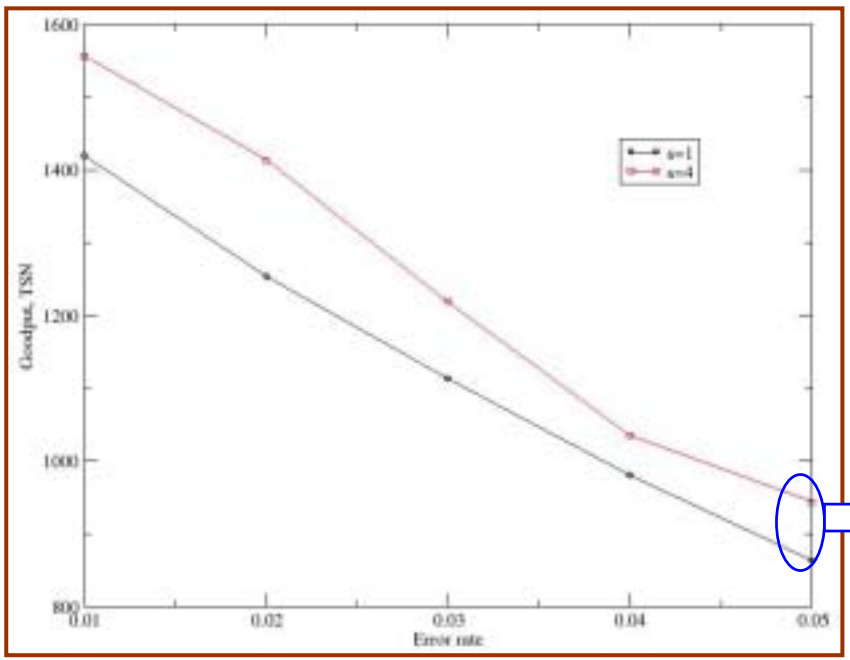
# One and four streams: Goodput vs. B

- For small *B*, mutlistreaming results in less HOL blocking
  - goodput of 4-streams is higher than 1-stream.
- For large *B*, the goodput is limited by the congestion control mechanism.

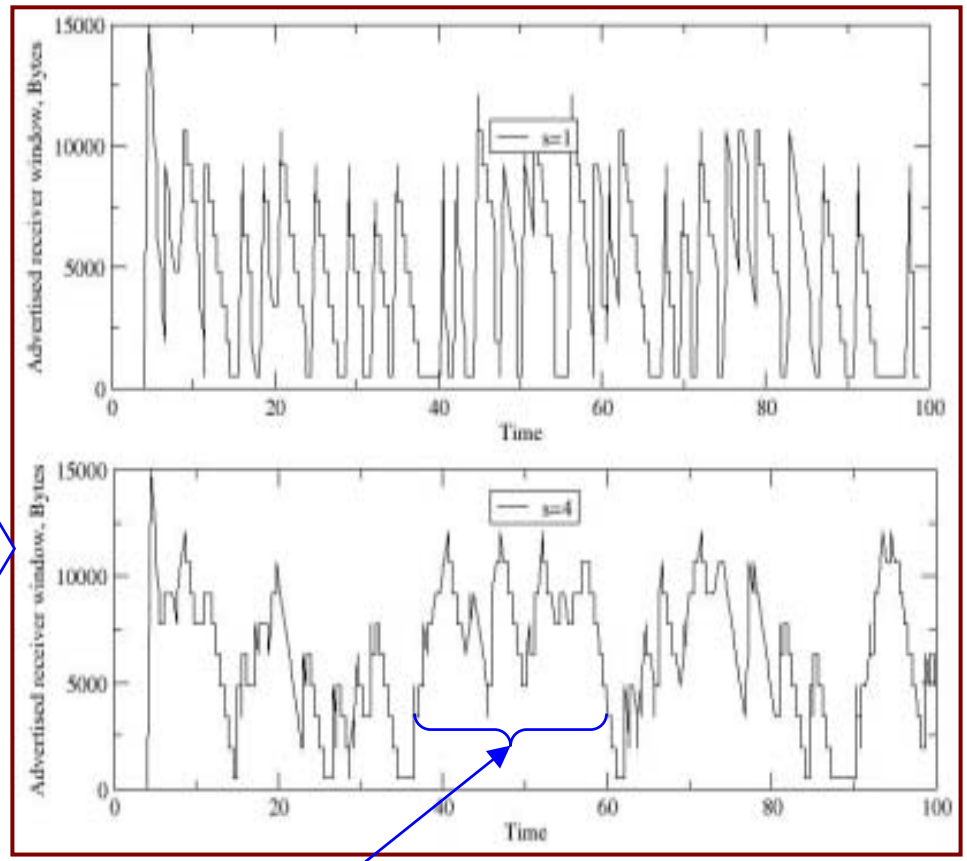



Multistreaming increases goodput for small receiver buffer sizes

# Advantage of Multistreaming: High Throughput




B = 15K

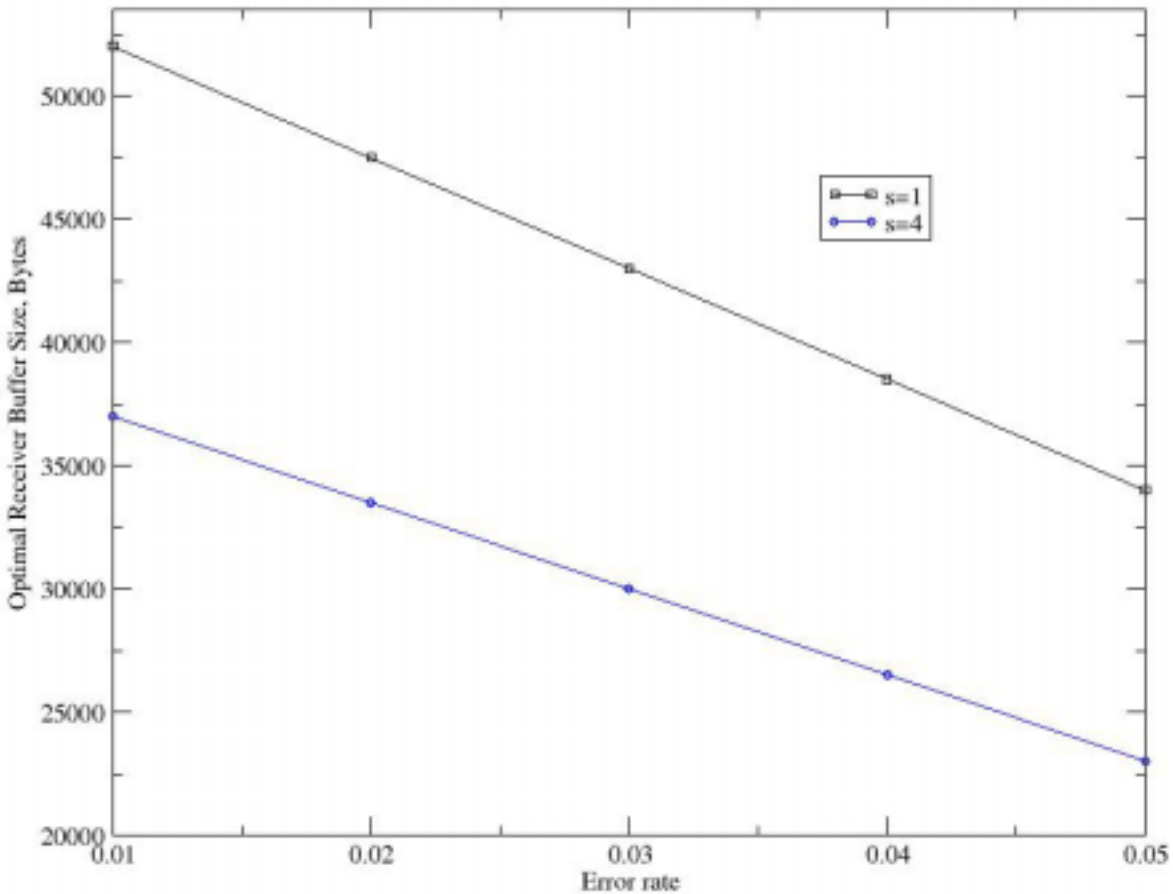



- Small Buffer size of 15K shows the advantage of multistreaming with four streams.

HOL blocking is eliminated as evidenced by the fact that *a_rwnd* is, not a limiting factor

# Optimal Buffer Size

- Optimal Receiver Buffer Size: The size beyond which the *a_rwnd* never falls below 1 MTU.

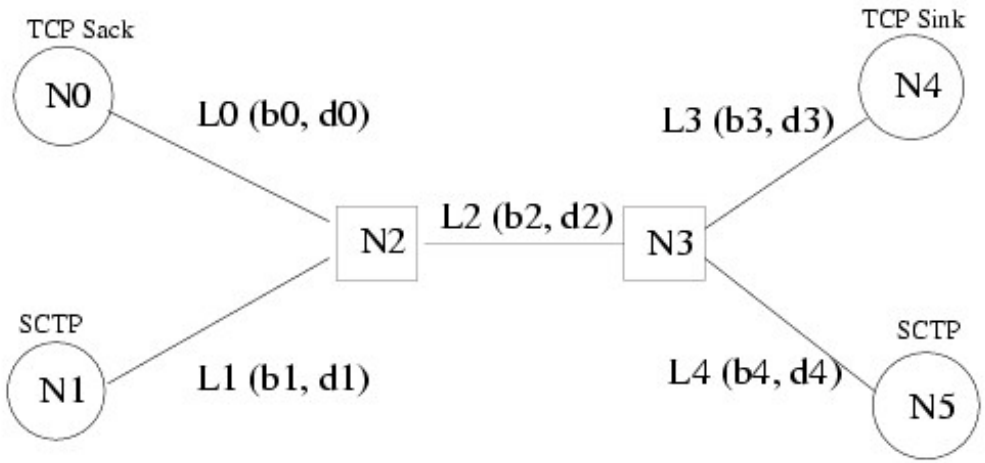



Multistreaming reduces receiver buffer requirements.

# Impact of SCTP Retransmission Mechanism on Throughput

# Simulation Setup

- SACK used for TCP.
- One stream per association in SCTP.
- Payload of both protocols: 1448 bytes
- Maximum receiver window of both protocols: 64 KB



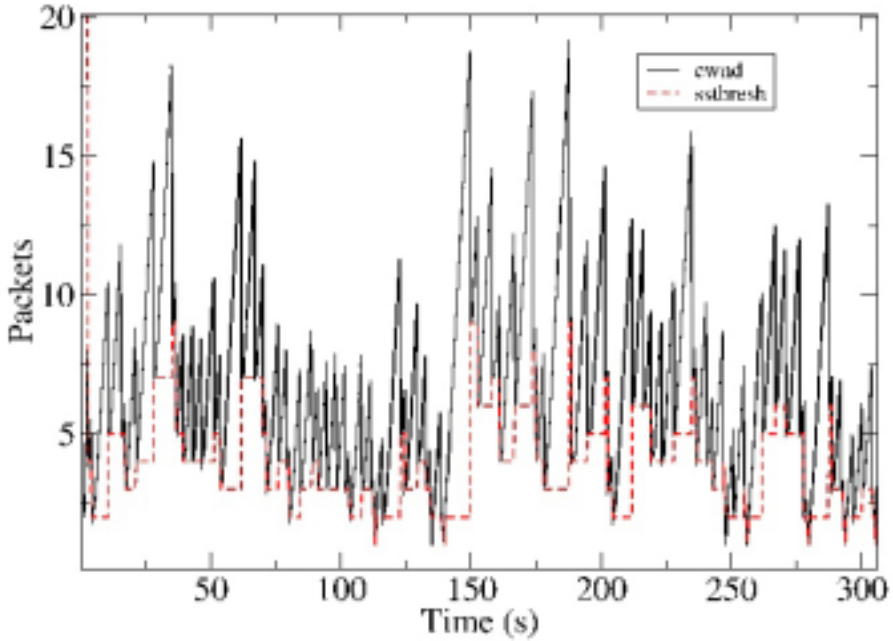

| | L0 | L1 | L2 | L3 | L4 |
|---|---|---|---|---|---|
| Bandwidth, $b$ Mbps | 10 | 10 | 3 | 10 | 10 |
| Delay, $d$ ms | 2 | 2 | 250 | 2 | 2 |

# Throughput

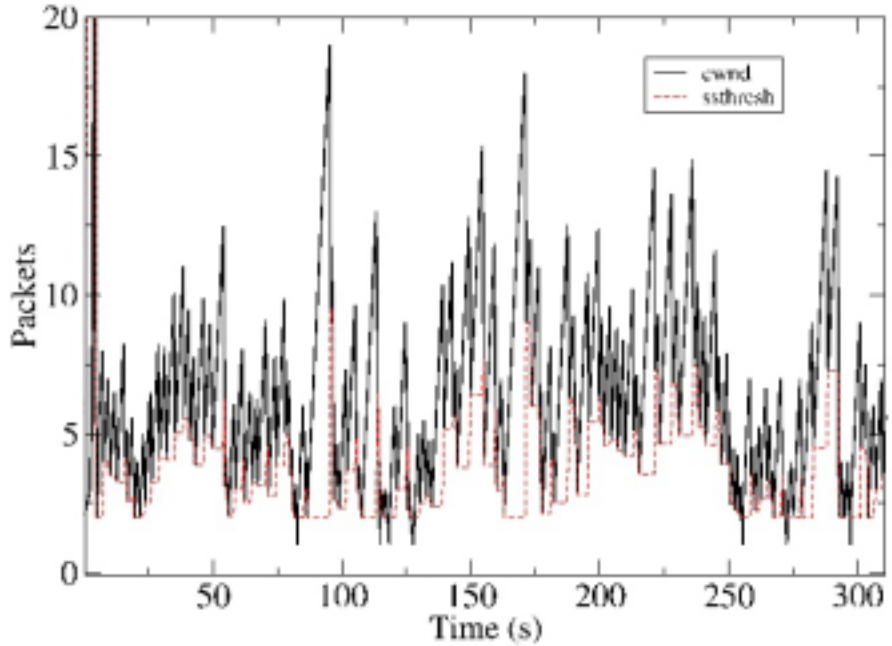
| Loss Prob. | Perc. Thpt. ($\Gamma_k$) | | Perc. Inc. in Thpt. ($\delta$) | Link Util ($\psi$) |
|---|---|---|---|---|
| | TCP | SCTP | | |
| 0.008 | 49.8 | 50.2 | 6.1 | 20.9 |
| 0.009 | 46.7 | 53.3 | 13.3 | 19 |
| 0.01 | 43.7 | 56.3 | 27.6 | 17.8 |
| 0.015 | 44.1 | 55.9 | 25.6 | 14.4 |
| 0.02 | 45.8 | 54.2 | 17.0 | 12.4 |
| 0.025 | 46.7 | 53.3 | 13.3 | 10.8 |
| 0.03 | 46.8 | 53.2 | 12.7 | 9.8 |

# *cwnd* and *ssthresh*

TCP

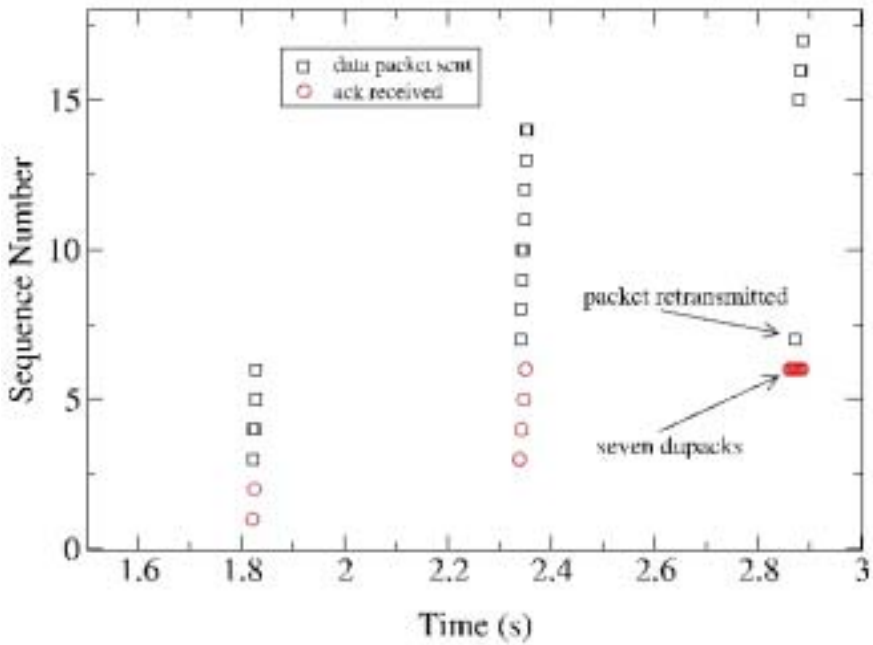



SCTP

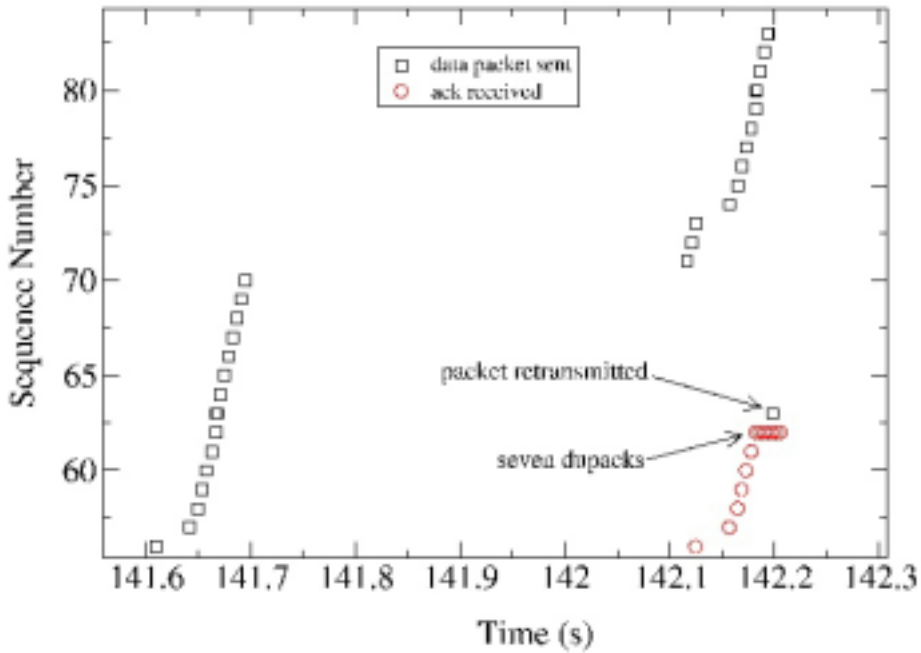



- *cwnd* of both TCP and SCTP vary within the same range (1-19 packets).
- Average *cwnd* was measured to be around 8 for both protocols.

# Packet retransmission




TCP




SCTP

# Conclusions/Recommendations

- SCTP will perform at least as good as TCP with window scaling, SACK and other recommendations in RFC 2488.
- Packet retransmission of SCTP results in slightly higher throughput of SCTP.

## Recommendations

- Use multistreaming in satellite networks.
  - Increases goodput in a satellite network when the receiver buffer size is small
  - Reduces the buffer size at the receiver – reduces weight and power requirement of handheld devices.
- Add a new data chunk to SCTP for implementing a timestamp option (as in TCP).

- Acknowledgements
  - NASA Glenn Research Center
  - Dr. Will Ivancic - NASA Glenn
  - Rumana Alamgir and Shaojian Fu - University of Oklahoma

- Further Information

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- These slides are available at

www.cs.ou.edu/~atiq