

# Integrated Satellite Gateway for Hybrid Internet : Congestion Control, Multicasting and Security

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## Motivation

- Satellite networks have many features that make them different from wired networks, including
  - Long propagation delay
  - High bandwidth-delay product
  - High bit error rate
  - Bandwidth asymmetry between the uplink and downlink
- Incorporating high-speed satellite links in terrestrial networks leads to poor TCP performance:
  - Throughput is dramatically degraded
  - Some TCP flows obtain an unfairly large share of bandwidth, while others get very little
  - UDP flows such as multicast streams take up large amounts of bandwidth at the expense of TCP flows, because UDP does not have any congestion control scheme

## Internet over Satellite: Deployment Scenarios

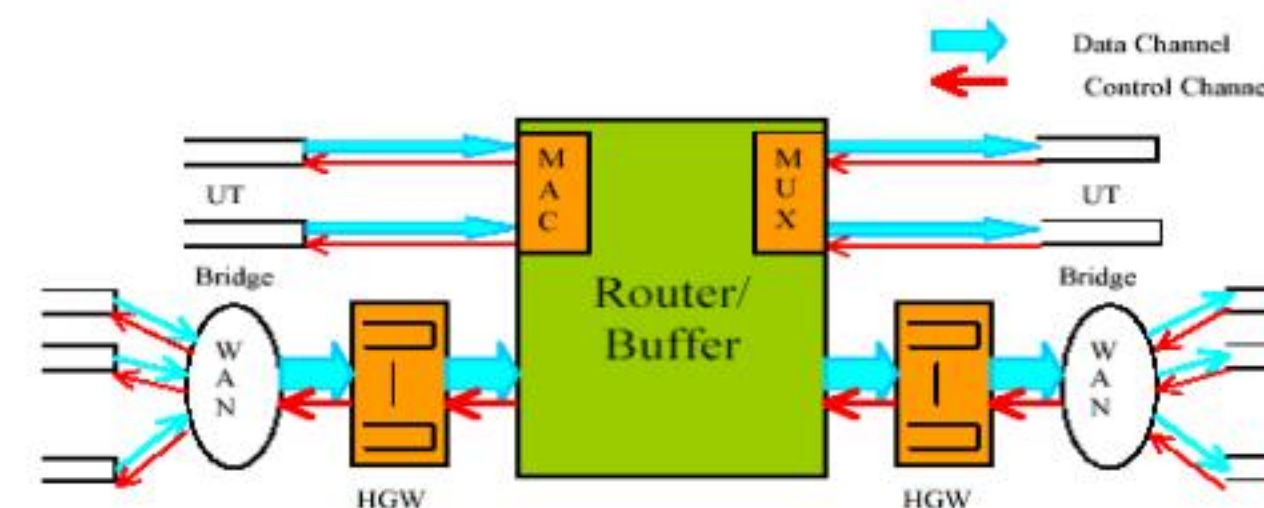
- Direct-to-user service
- Traffic trunks in terrestrial networks



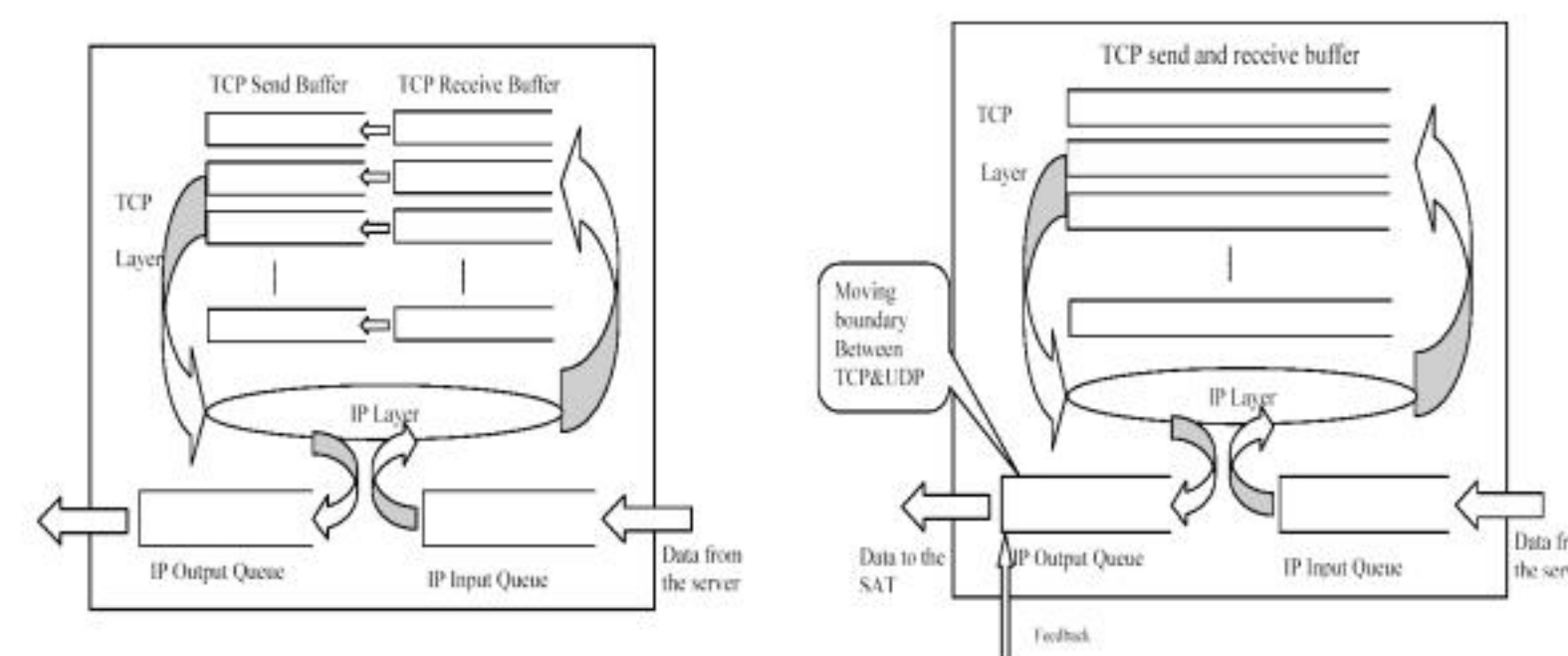
## Project Objectives

- Develop a congestion control algorithm for the hybrid gateway to couple the terrestrial and satellite networks together while maintaining high utilization of the satellite link and fairness among TCP flows
- Develop algorithms for sharing bandwidth between TCP and UDP flows while satisfying QoS of UDP flows
- Address security issues, including IPSEC interoperability
- Explore innovative uses of multicast, to improve system throughput by using the natural broadcast capability of satellite links

## Hybrid Gateway Architecture

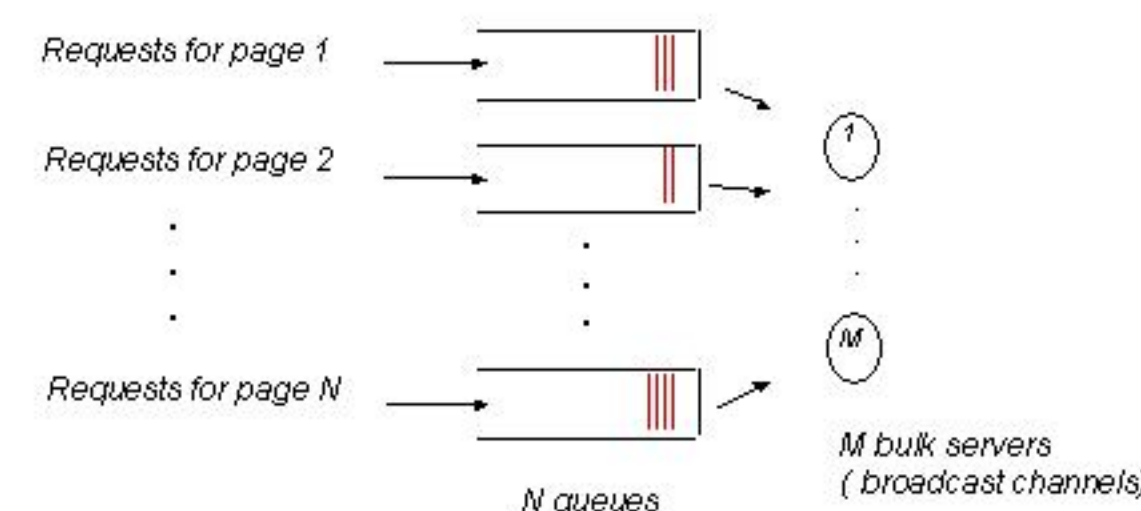


## Queuing Model at Hybrid Gateways



## Implementation Highlights

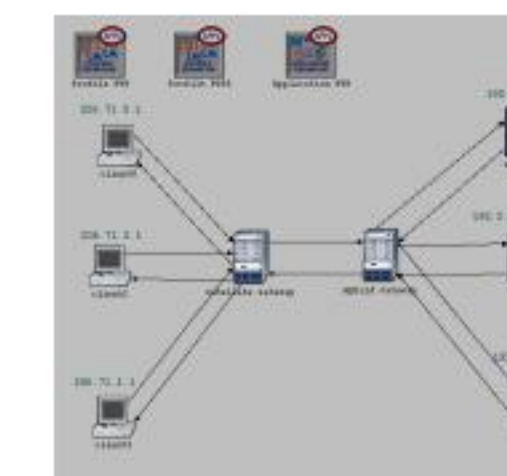
- TCP Connection Splitting: the hybrid gateways have a transport layer module which buffers data at the TCP layer rather than the IP layer. An adaptive congestion control scheme is used on the satellite link.
- UDP bandwidth is limited to a fixed fraction of link capacity.
- Layered IPSEC technique used to provide security - TCP headers in packet are encrypted with one key, and the rest of the packet is encrypted with a different key. The hybrid gateway only has the key to decrypt the header. This approach is more secure and uses less CPU resources than IPSEC tunnel mode.
- Web caches located at each hybrid gateway use reliable multicast to answer queries from other gateways, so that "popular" objects need only be sent over the satellite link once. This increases overall system throughput.



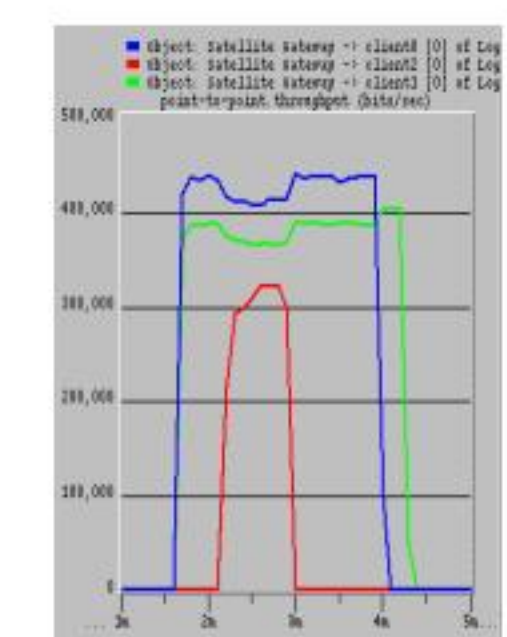
## Hybrid Gateway Congestion Control

- Fair share of the bandwidth (FBW) for each TCP connection is  $TCP\_BW / \text{Number of TCP connections}$ .
- Set the combined receive and send buffer to  $FBW * (SatRTT + TerrRTT) + \text{CONSTANT}$  for the right hand connection. Keep CONSTANT number of backlog packets to maintain high utilization in case number of the connections in the system decreases
- Set the CWND of the left hand connection to  $FBW * SatRTT$ . Send additional packets if the number of packets in the IP output queue are less than some threshold even if the CWND is exhausted. The first is for fair share of the BW while the second is for backlogged connection to send more while waiting the newly started connections to reach their FBW
- Memory usage at hybrid gateways due to TCP connection splitting converges to  $SatBW * (SatRTT + \text{Maximum TerrRTT})$  independent of the number of connections, using our adaptive buffer allocation scheme.
- Achieve high satellite link utilization and almost perfect fairness without an additional scheduler.

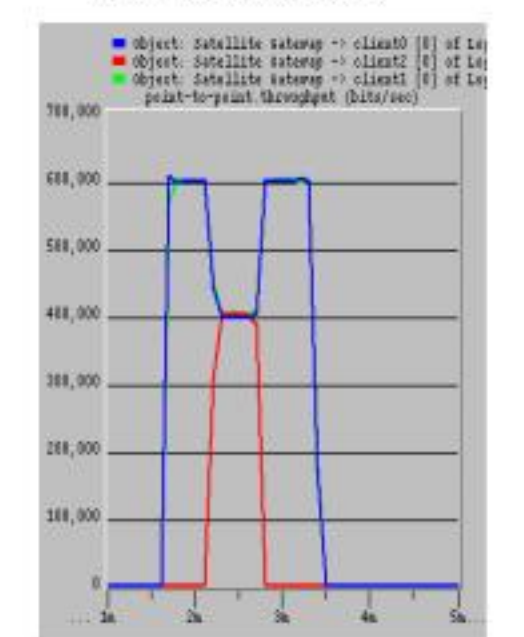
## Simulation results



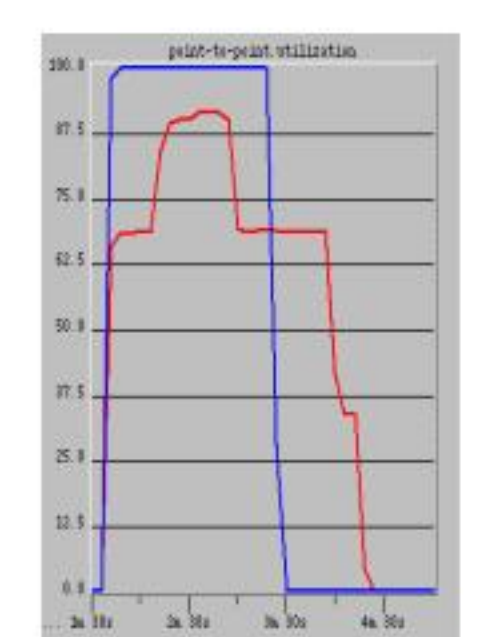
- The three servers have RTT to the Hybrid Gateway equal to 20, 80 and 160ms respectively
- All links are 1.2 Mbps
- Results show improved fairness and better throughput with adaptive buffer allocation compared to TCP and compared to connection splitting with fixed buffers



Case 1: Static buffer allocation



Case 2: Adaptive buffer allocation



Satellite link utilization Case 1 (red) vs. Case 2 (blue)