TCP Performance For Users On Trains in Presence Of Hand-Overs Due To Tunnels

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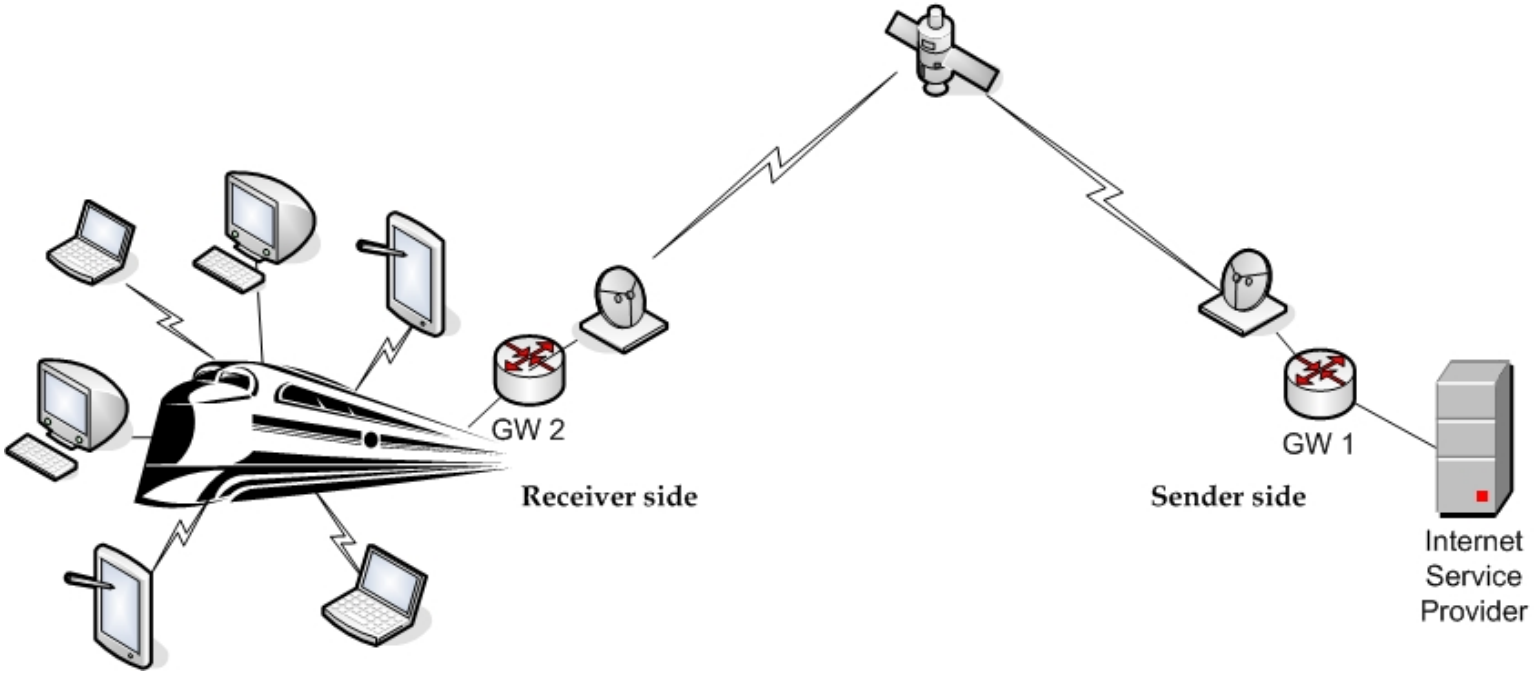
Outline

- Introduction: reference scenario
  - multi-segment satellite network
- Target: end-to-end performance evaluation
  - users on board of trains
  - satellite links out of service due to tunnels
  - switching time from satellite to terrestrial gateway
  - comparison among different TCP flavors
- Numerical results
  - Simulation through ns2 tool
- Conclusions

Interoperability and Internetworking

- **<u>Heterogeneous networks</u>:** terrestrial, wired and wireless, and satellite networks will have a crucial role in future infrastructures for multimedia applications
  - Define hand-over procedures between subnetworks
- Provide seamless service provisioning across heterogeneous networks
  - Manage delays inherent to satellite systems
  - Optimize TCP/IP architectures and protocols for satellite and space networks
- End-to-end Quality of Service: network models for QoS has to be refined
- Application layer must allow the creation of flexible applications that adapt to the heterogeneous network scenario

General Scenario



Telecommuncation network composed of

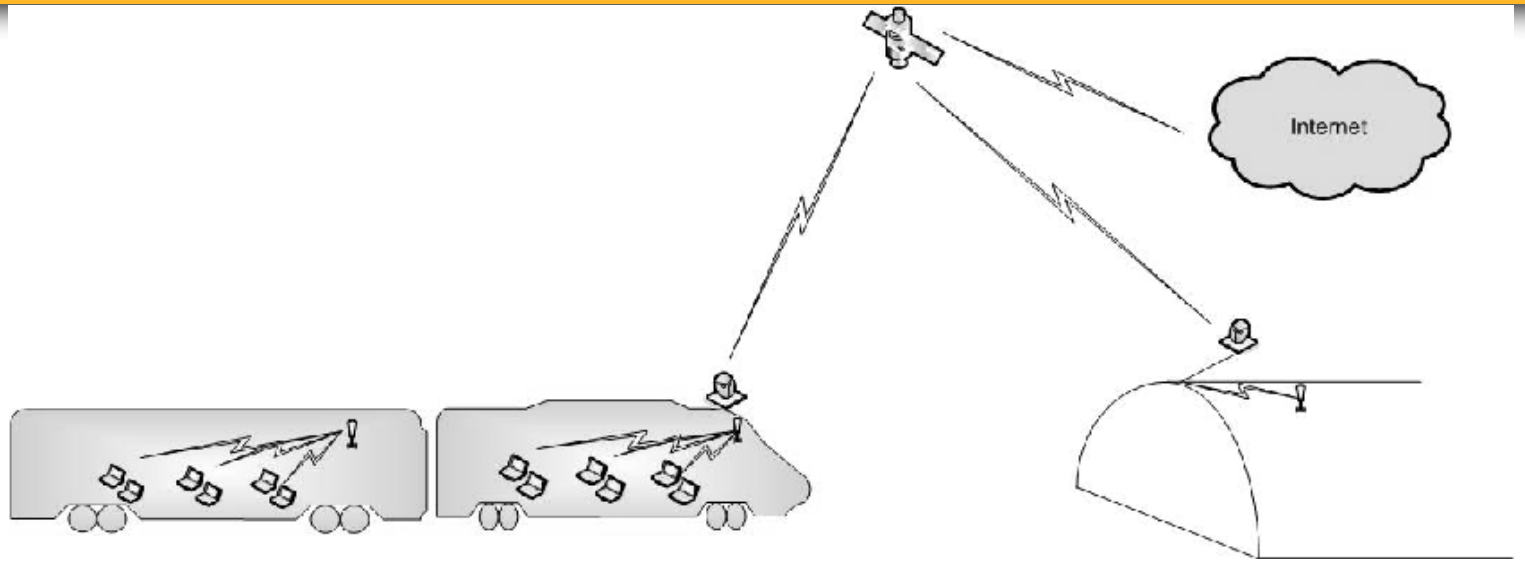
1. IEEE 802.11b WLAN within a train coach
2. wireless satellite links for connection to a ISP via a GW on board of train

Broadband Satellite Links

Many advantages:

- global coverage
- bandwidth flexibility
- reliability
- multicast capability
- ....

Investigated Scenario



Challanging scenario (satellite link suddenly is unreacheable):

- on board GW has to switch as fast as possible to a terrestrial GW at the entrance of the tunnel
- service provisioning for multimedia and interactive applications
- in case of very long tunnel several GWs are needed
- once the train gets out of the tunnel, its GW has to switch back to satellite
- impact of the switching time to complete the hand-over on TCP performance?

Some TCP Flavours

TCP SACK

- SACK option: the receiver informs the sender about the successfully received segments
- sender retransmits lost segments only

TCP Westwood

- estimation of the available bandwidth
- sender continously monitors ACKs from receiver and computes the Eligible Rate Estimate (ERE)
- after a packet loss, sender modifies the values of ***ssthresh*** and ***cwnd*** as a function of ERE

Performance Evaluation: Metrics

- **Throughput**
  - Measure of the variability of the bandwidth usage over a given time-scale

- **Channel Utilization**
  - Related to throughput

$$U = \frac{\sum_{i=1}^{n} B_{P_i}}{Bandwidth}$$

  - B_{Pi} : i-th flow throughput for general transport protocol P

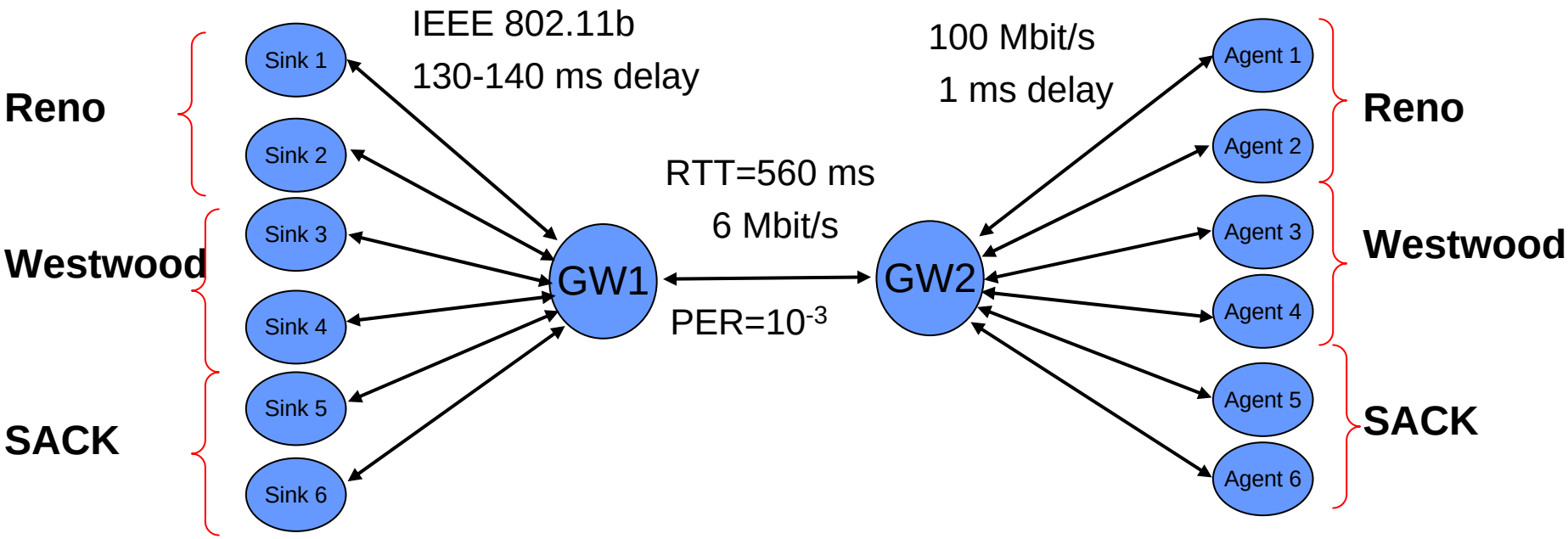
- **Fairness**
  - Chiu/Jain's Fairness Index
  - Best fairness => F=1

$$F(TCP,P) = \frac{(\sum_{j=1}^{m} T_{TCP,j} + \sum_{i=1}^{n} T_{P,i})^2}{(m+n)\cdot(\sum_{j=1}^{m} T_{TCP,j}^2 + \sum_{i=1}^{n} T_{P,i}^2)} \quad \text{(Inter)}$$

$$F_{\text{intra}} = \frac{B_{P,\min}}{B_{P,\max}} \quad \text{(Intra-fairness)}$$

Simulation Scenario

ns-2 version 2.28

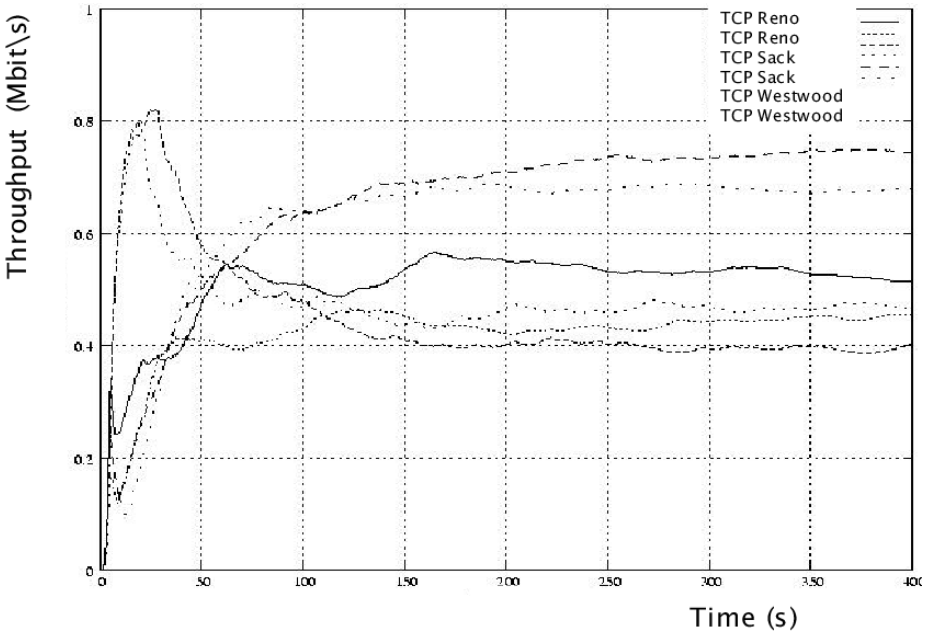


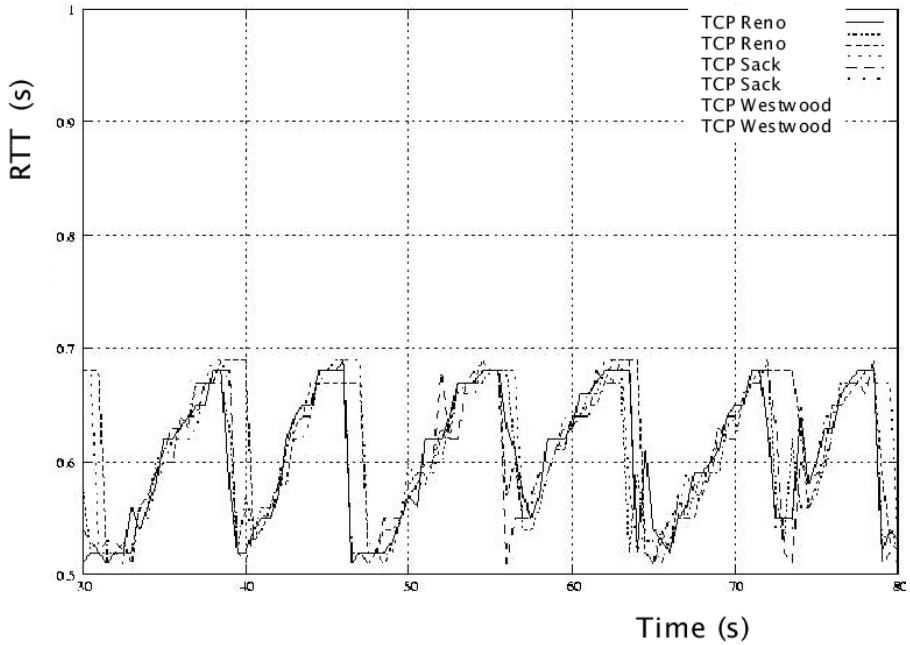
FTP

segment size = 1500 bytes

Recv Adv Window = 64 Kbytes

Average TCP Throughput and RTT (1/3)



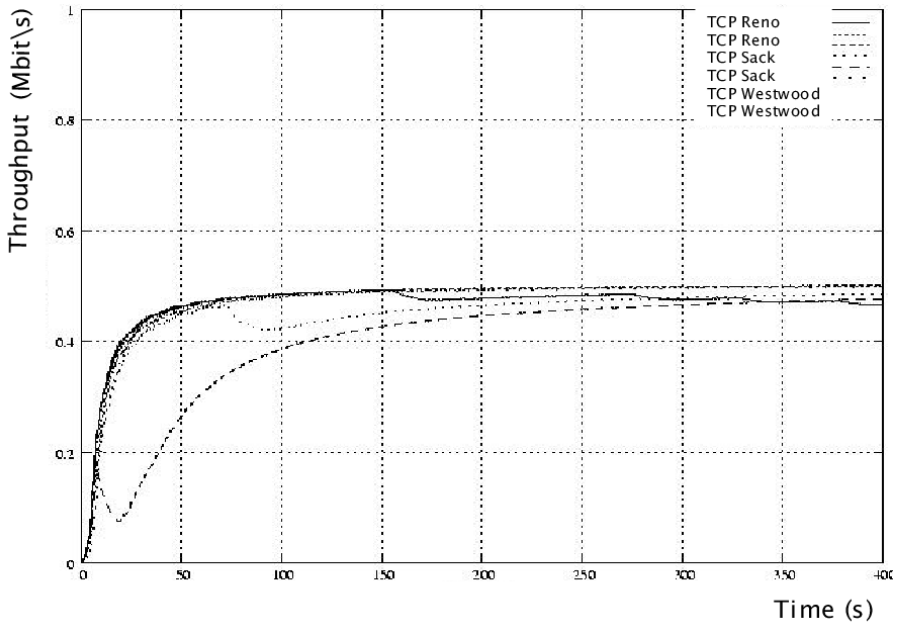


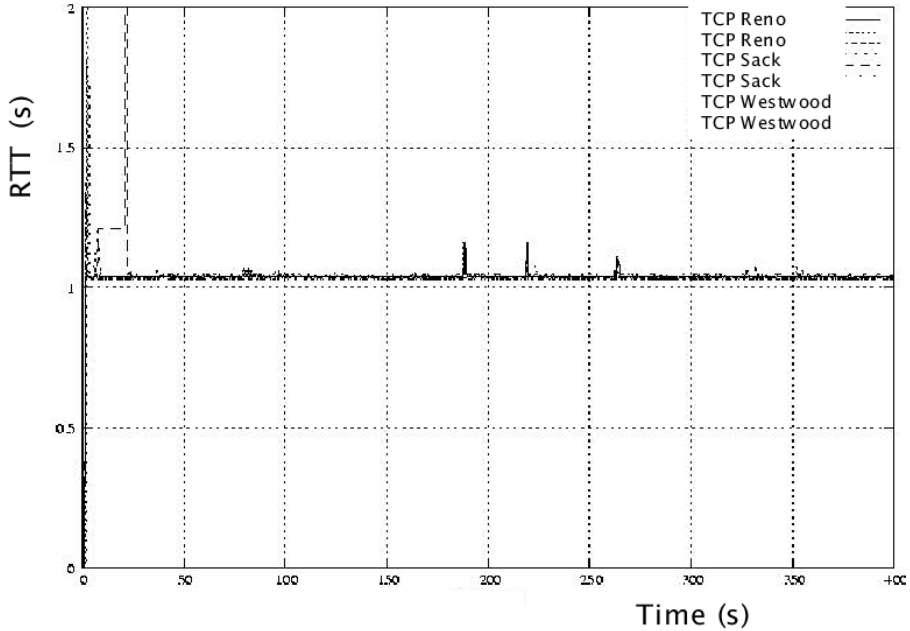
- **Ideal: PER on sat link = 0**
- **no hand-overs**

- TCP Westwood shows better performance
- most aggressive: inter-friendliness index=0.85
- quite unfair bandwidth allocation

- RTT is increased by 130-140 ms
- due to the IEEE 802.11b access

Average TCP Throughput and RTT (2/3)



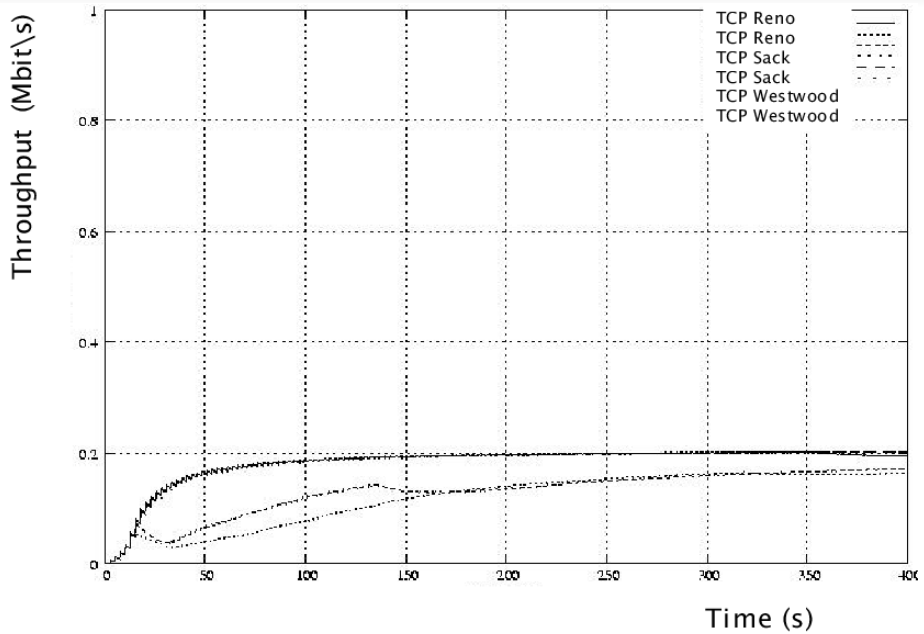


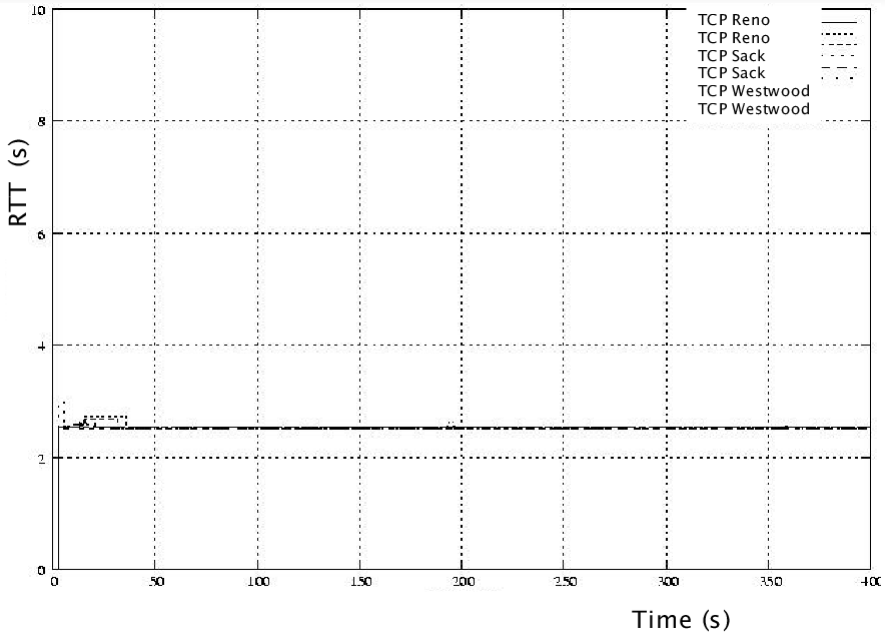
- **PER on sat link = 10^{-3}**
- **Hand-over delay = 250 ms**

- All TCP flows are similarly affected
- Throughput down to roughly 500 Kbit/s
- High intra and inter fairness

- RTTs in the range of 1 s
- three components: sat link (560 ms), WLAN (140 ms) and hand-off (250 ms)

Average TCP Throughput and RTT (3/3)





- **PER on sat link = 10^{-3}**
- **Hand-over delay = 1 s**

- Again, all TCP flows are similarly affected
- Throughput down to roughly 200 Kbit/s
- Connections still active but poor performance

- RTTs in the range of 2-3 s

Keep hand-over delays less than 1 s

Conclusions

- A multi-segment satellite network for serving fast trains has been studied in presence of hand-overs due to tunnels
- Multi-segment: IEEE 802.11b access on trains, sat links, terrestrial network on the ISP side
- Several TCP flavours have been employed and evaluated by means of simulation
- TCP performance determined by throughput and fairness
- Results:
  - with PER > 0 and hand-over delays > 0, all TCP flavours shows similar (degraded) performance in terms of throughput
  - basic result: to avoide users to get interrupted and starve, keep hand-overs < 1 s
- Current works deal with
  - more complex scenarios
  - introduction of real-time applications (system solutions on GWs on trains)

THANK YOU FOR YOUR ATTENTION

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… suggestions are very very welcome