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# ATP: A Reliable Transport Protocol for Ad-hoc Networks

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# Introduction

- TCP is the de-facto transport layer protocol used in ad-hoc networks
- Several related works have identified the problem and inefficiencies in using TCP over ad-hoc networks [ Holland et. al. Mobicom'99, Anantharaman et. al. Sigmetrics'02]
- We address the issues with TCP by taking the stand-point of proposing a new transport protocol called ATP

# Outline

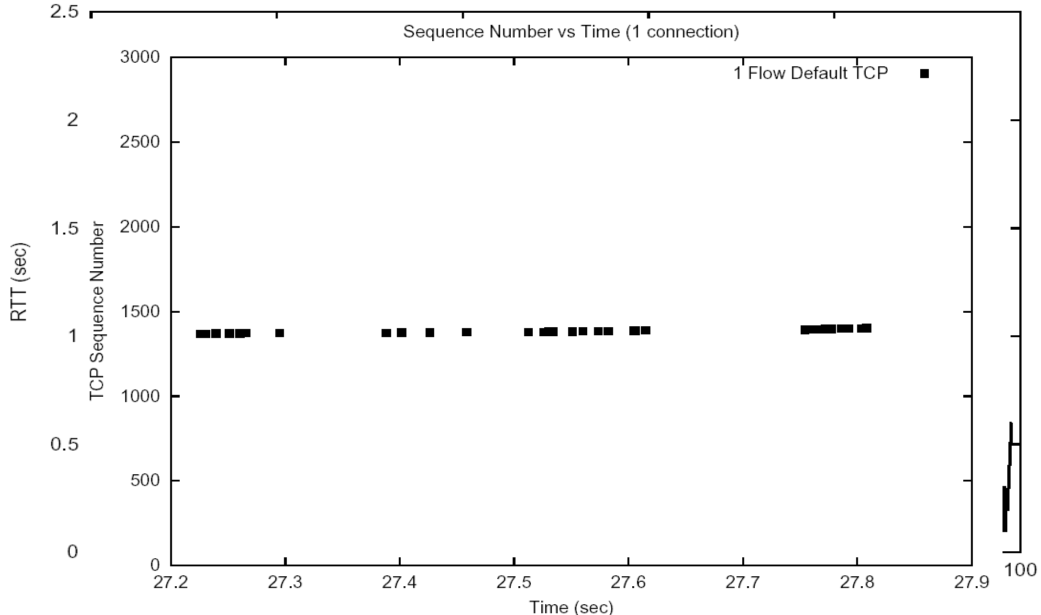
- Problems with TCP
- ATP design elements
- ATP Protocol details
- Performance evaluation
- Conclusion

# Problems with TCP

- Anatomy of a TCP connection
- Components
  - Window based transmissions
  - Slow start
  - Loss based congestion detection
  - LIMD
  - Dependence on ACKs
- Scenario
  - FTP as application, DSR as routing protocol and CSMA/CA as MAC protocol
  - 100 nodes in 1000m * 1000m grid
  - Varying mobility and load conditions

# Window based transmissions

- Window based transmissions work well in wireline network




- Burstiness in packet transmissions in ad-hoc networks
  - Varying 'rtt' estimates affect RTO computation
  - Induces a load higher than the average load resulting in higher MAC layer contention

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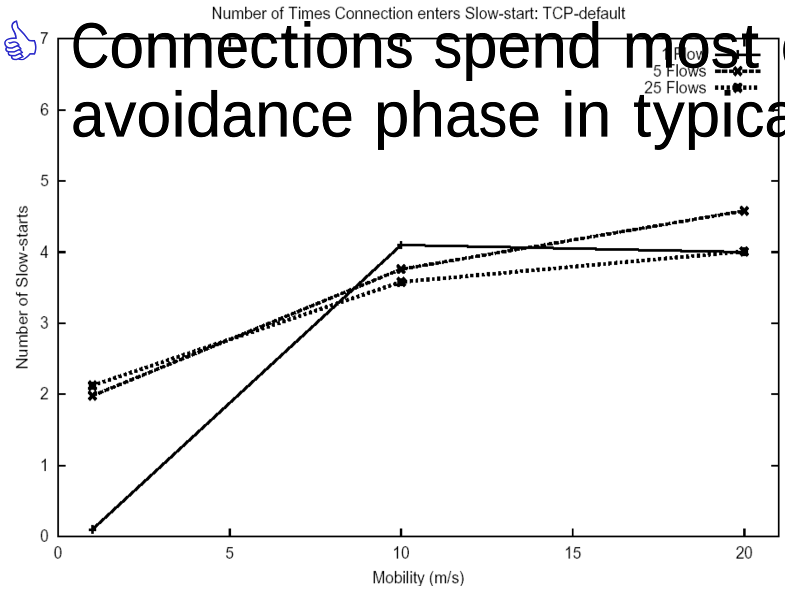
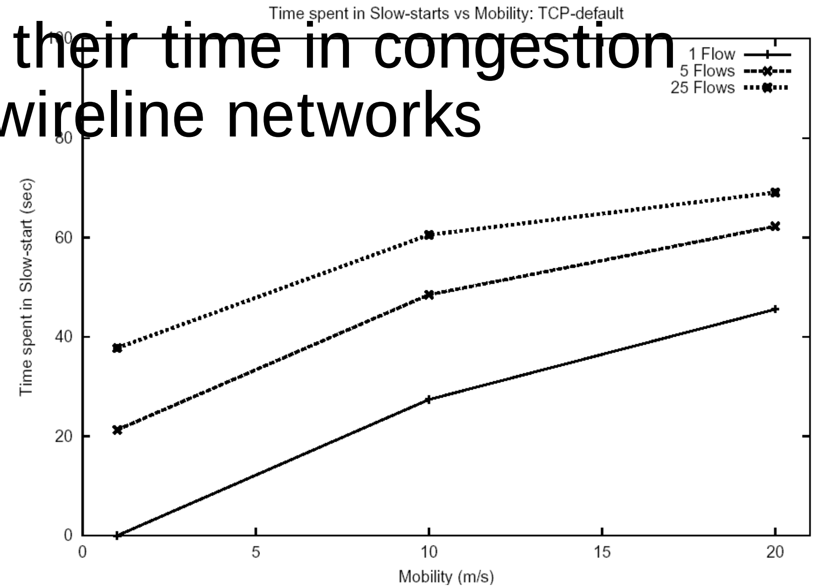
# Slow start

- Connections spend most of their time in congestion avoidance phase in typical wireline networks




- Connections enter slow start several times, spending a significant portion of their time in slow start in ad-hoc networks
  - Under-utilization of network resources
  - Unfairness

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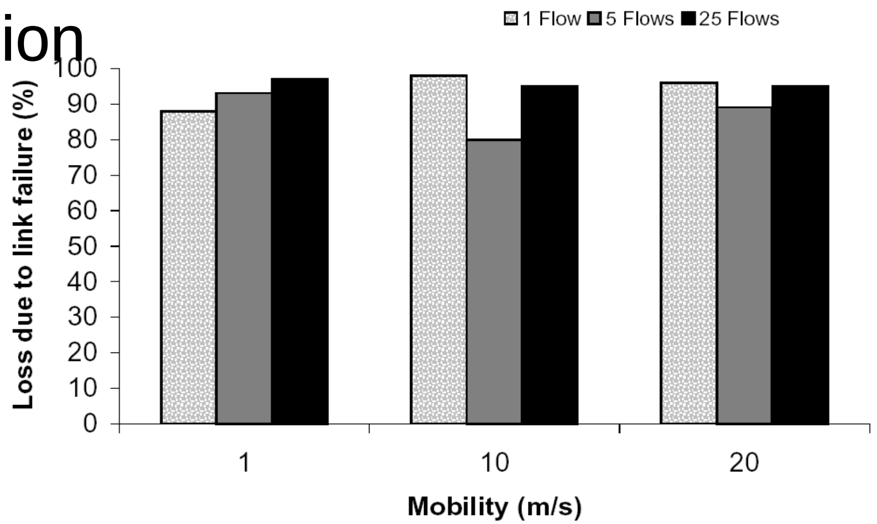
# Loss based congestion detection

- In wireline networks most of the losses are due to congestion




- Losses can be due to congestion, random wireless errors or due to mobility
  - ‘link failure’ or ‘congestion’ induced losses
  - Large fraction due to ‘link failure’ with mobility being a dominant contributor
  - Using loss as an indicator of congestion is inappropriate

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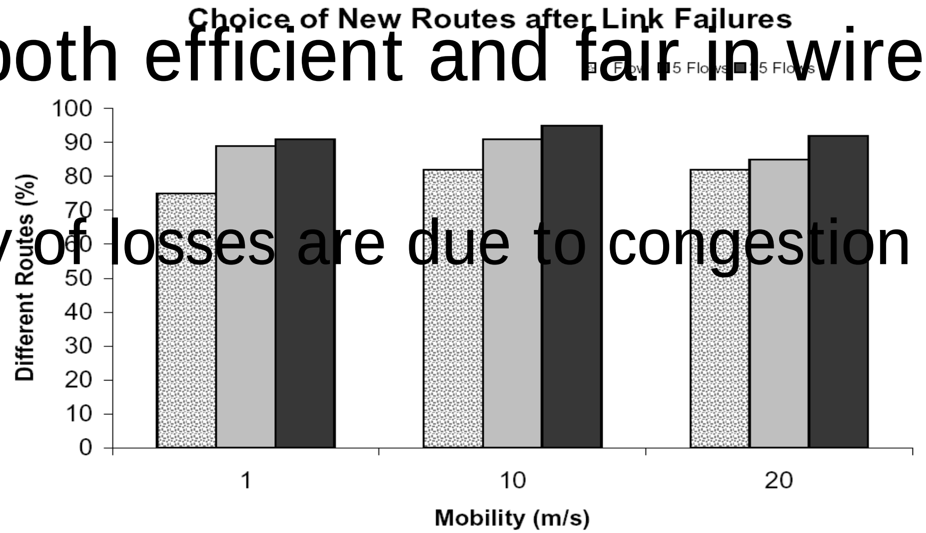
# LIMD window adaptation

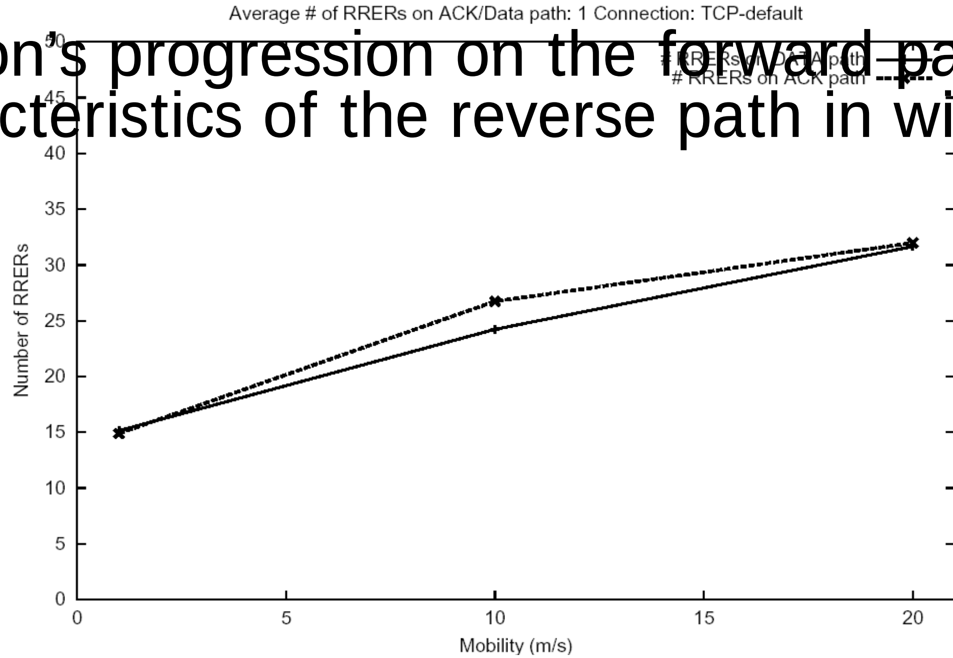
- LIMD is both efficient and fair in wireline networks
  - Majority of losses are due to congestion




- Connections are vulnerable to route failures in ad-hoc networks
  - A different route is chosen 90% of the time
  - Multiplicative decrease is unwarranted during route failures
  - Linear increase causes slow convergence to optimal operating bandwidth

# Dependence on ACKs

- Connection's progression on the forward path is tied to the characteristics of the reverse path in wireline networks




- Coupling between the forward and reverse paths is even more in ad-hoc networks
  - If DATA and ACK paths are the same, ACK traffic will contend with the DATA traffic
  - If the paths are different, chances of connection stalls are potentially increased

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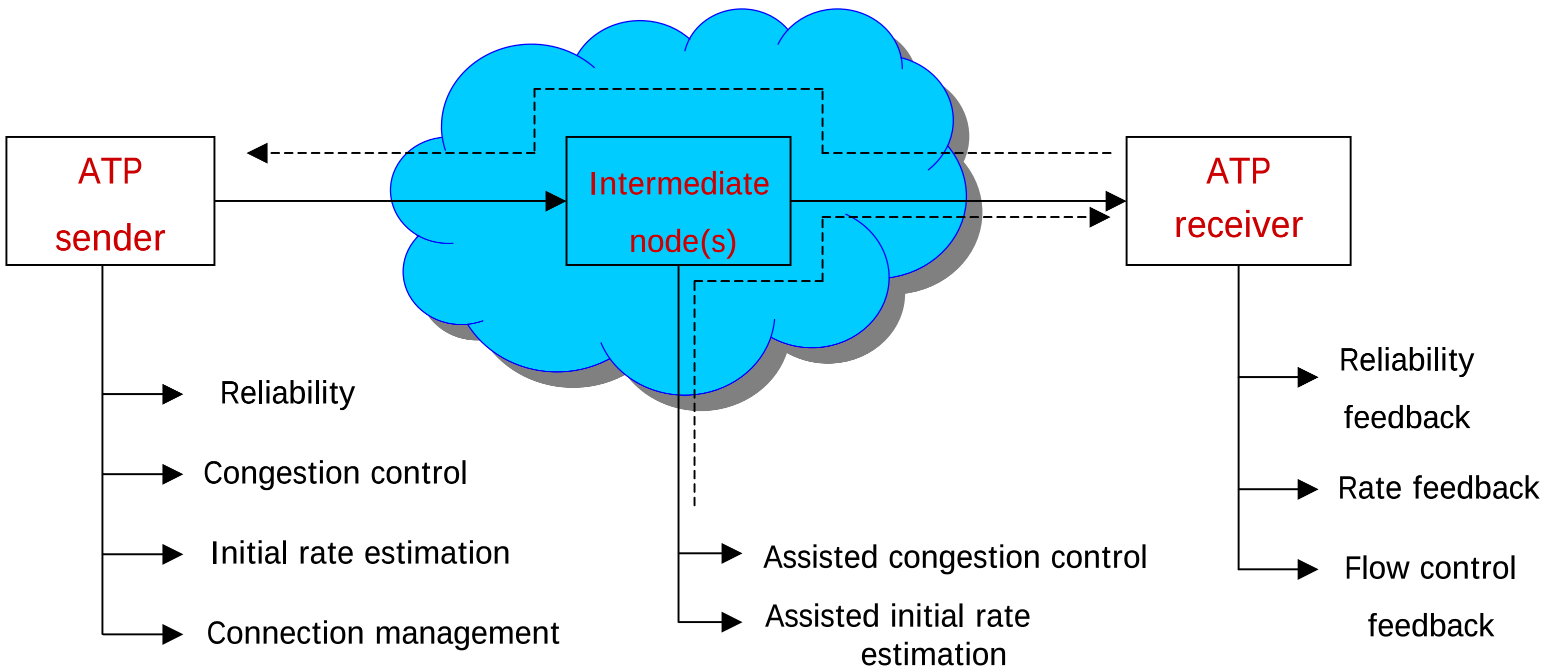
# ATP: Ad-hoc Transport Protocol

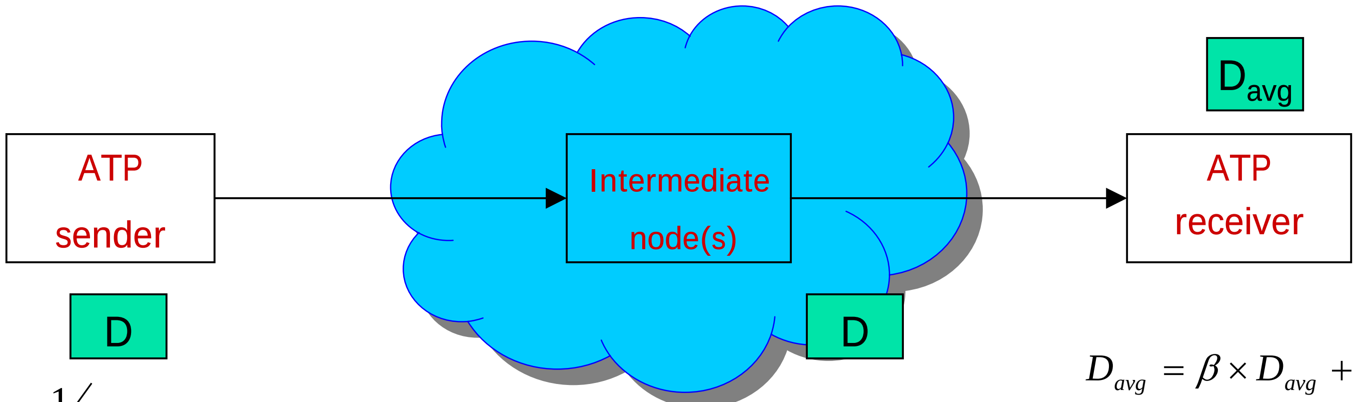
- TCP's components
  - Window based transmissions
  - Slow start
  - Loss based congestion detection
  - LIMD
  - Dependence on ACKs
- ATP's design
  - Rate based transmissions
  - Quick start
  - Delay based congestion detection
  - 3 phase rate adaptation
  - Coarse-grained receiver feedback

# Protocol functionality



# Congestion control

- $Q_t$ is the average queuing delay
- $T_t$ is the average transmission delay
- $D = \max(Q_t+T_t)$ along the path traversed




$$D_{avg} = \beta \times D_{avg} + (1-\beta) \times D$$

$$R = 1/D_{avg}$$

If $S < R - \phi \times S$, $S = S + \frac{R-S}{k}$

Else if $S > R$, $S = R$

Else maintain S

$$Q_t = \alpha \times Q_t + (1-\alpha) \times Q_{sample}$$

$$T_t = \alpha \times T_t + (1-\alpha) \times T_{sample}$$

If $D > sum(Q_t + T_t)$

$D = sum(Q_t + T_t)$

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# Initial rate estimation

- Quick start
  - Performed during connection initiation and when underlying path changes
  - ‘Probe’ packets are sent at a periodic interval to elicit feedback rate from the receiver
  - Behavior of intermediate nodes is different from that in assisted congestion control
  - Probes for available network bandwidth within a single ‘rtt’

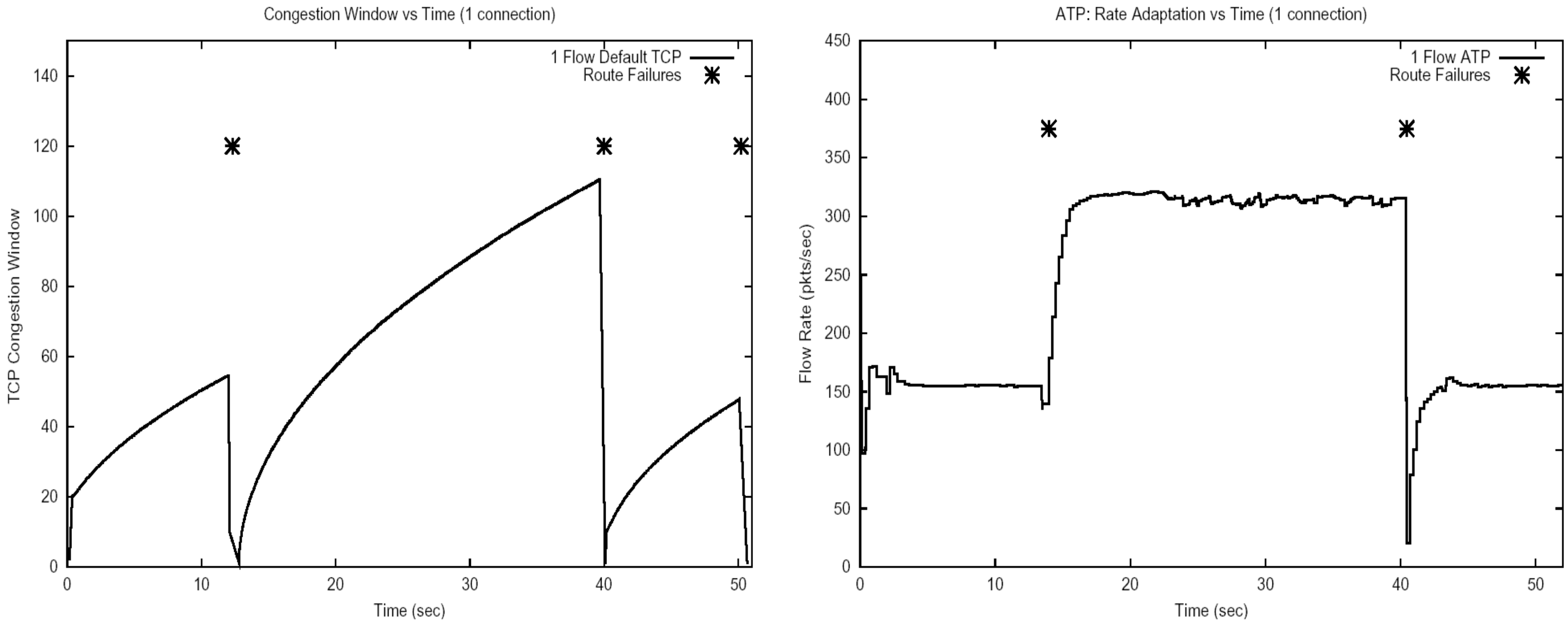
# Reliability and flow control

- Reliability
  - Receiver uses SACK blocks to provide loss information
  - Feedback provided on a periodic basis keeps the reverse path overhead small
  - Sender uses the SACK information by means of a scoreboard data structure as in TCP-SACK
  - Since sender does not use retransmission timer, receiver always provides loss information starting from the first hole
- Flow control and connection management
  - Similar to the mechanisms in TCP

# Performance evaluation

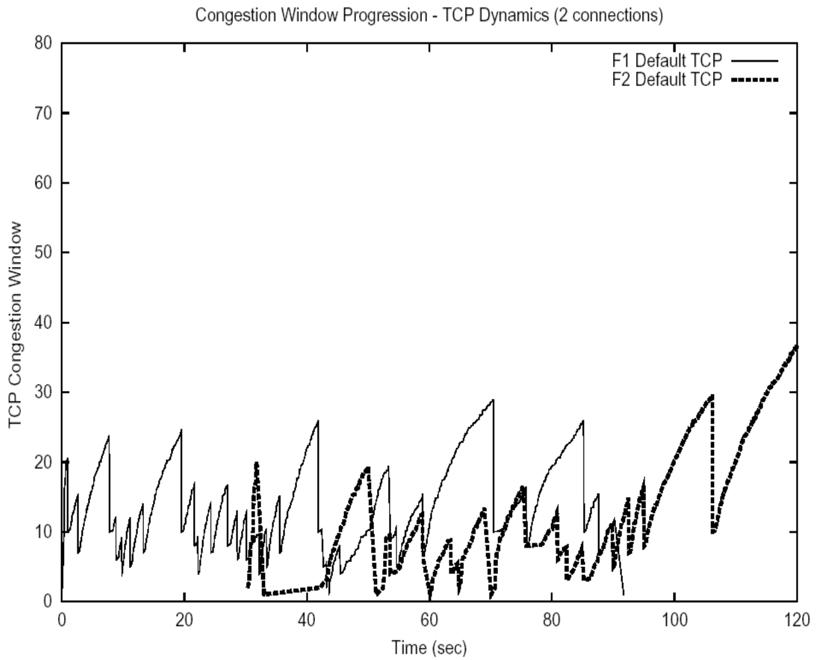
- Simulation environment
  - NS2 network simulator
  - Random topologies using random way-point model in 'setdest' tool
  - 100 nodes in 1000m * 1000m grid
  - Mobility of 1, 10 and 20 m/s
  - Load of 1, 5 and 25 connections
  - FTP as application with a packet size of 512 bytes
  - Protocols considered: TCP, TCP-ELFN and ATP
- Metrics considered
  - Instantaneous and aggregate throughput, and normalized standard deviation

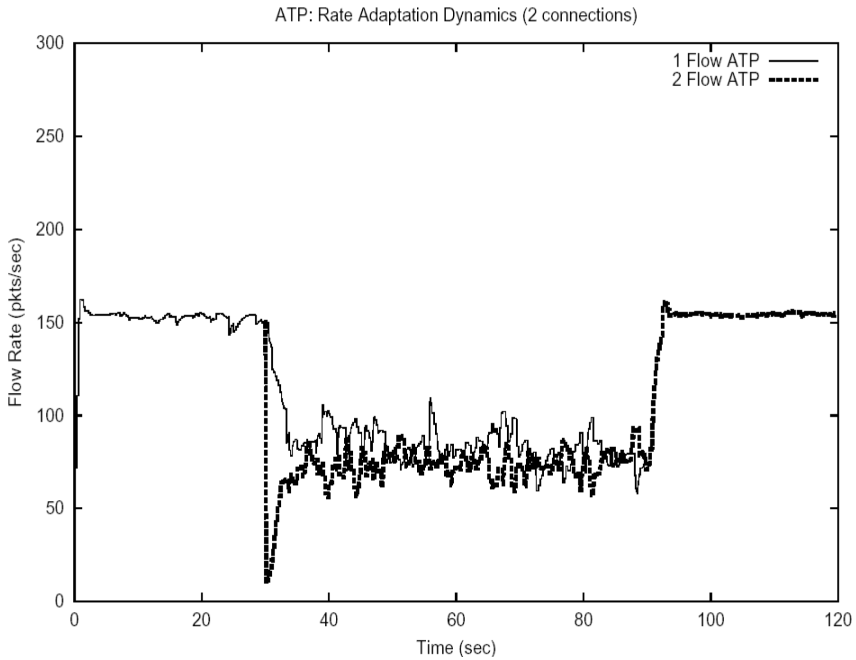
# Instantaneous throughput (1)




- Path failures do not result in rate decrease unless indicated by the feedback mechanism
- Quick start helps estimate the available bandwidth quickly on the new path on a route failure
- Enters maintain phase on reaching the available capacity

# Instantaneous throughput (2)




- Flow F1 exists from [0,90]s while F2 exists from [30,120]s
- On arrival of F2, both flows arrive at the fair share almost instantaneously
- On departure of F1, F2 is able to catch up to the available capacity in no time

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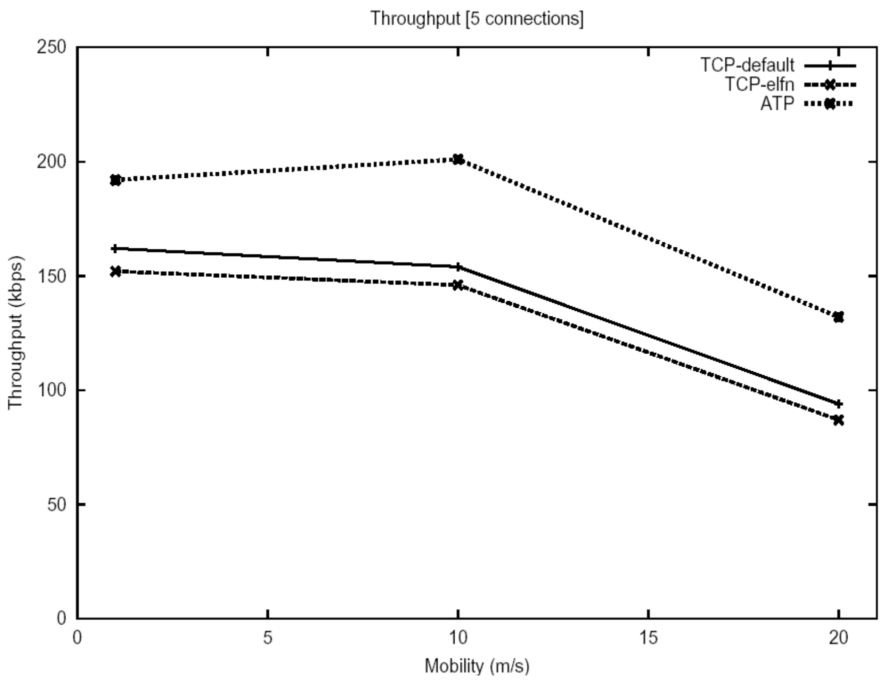
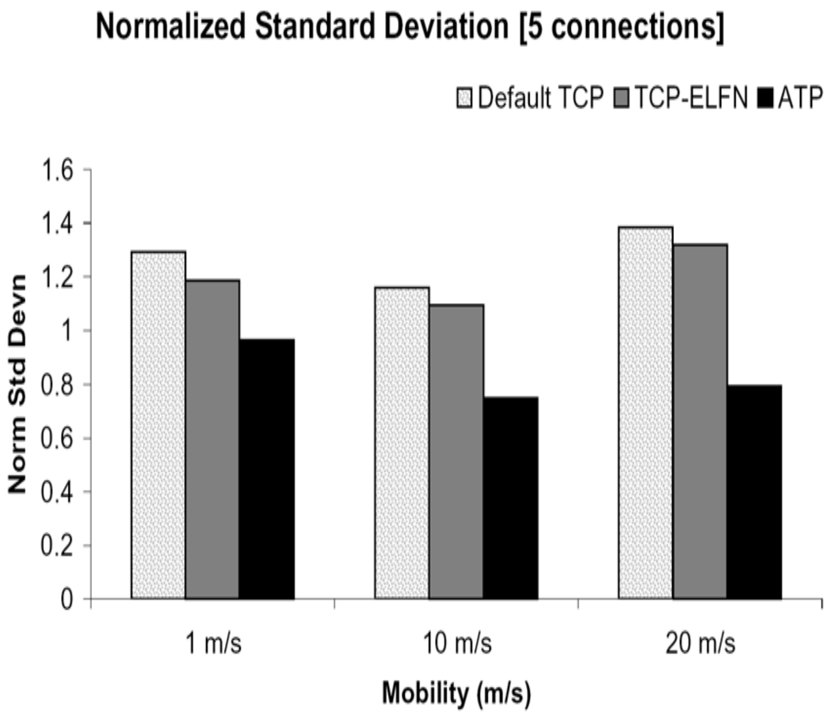
# Aggregate throughput and fairness

## Aggregate throughput




## Fairness

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# Conclusions

- Comprehensive study of the behavior of TCP over ad-hoc networks
- Majority of TCP's components are not suited to ad-hoc networks
- Insights gained from study motivate the design of a new transport protocol ATP
- ATP shows significant performance improvement over TCP and TCP-ELFN in the target environment
- ☞ Study ATP's inter-operability with TCP and sensitivity to the parameters employed in rate adaptation
- http://www.ece.gatech.edu/research/GNAN/