











## Problem: Large Round-Trip Time Variations

Example: Metricom Ricochet Wireless Network





- Mean rtt = 2.45s, std deviation =  $1.5s \Rightarrow$  long timeout!
- Long idle periods after multiple losses (~ 20 Kbps)
- In contrast, UDP throughput = 50-64 Kbps
- ACK flow affects data latency











## Bandwidth Asymmetry Performance

- TCP transfers in the forward direction alone
- Maximum window size 100 KB; no losses on forward path



- Large reverse channel buffer hurts for Reno and ACC
- Fairness greatly improves using AF and ACC for multiple transfers

## Summary: Asymmetric Effects

- *General* definition of asymmetry
  Problem: ACK channel impacts TCP performance
- *Classification* of types of asymmetry
  - *Bandwidth* asymmetry due to technologies
  - Latency asymmetry due to MAC interactions
- General solutions: Two-pronged approach
  - Reduce frequency of ACKs (AF, ACC)
  - Handle infrequent ACKs (SA, AR)
- Status
  - BSD/OS 3.0 implementation
  - Soon-to-be Internet RFC





## Performance: Concurrent Transfers

- Metrics: *utilization* and *fairness*
- Simultaneous connections over 2-hop network
  - Performance more predictable and consistent with AF
- Unpredictable performance caused by long timeouts



