Electrical Engineering Department
UNIVERSITY OF SOUTHERN CALIFORNIA

Improving Stability and Performance of Multihop 802.11 Networks

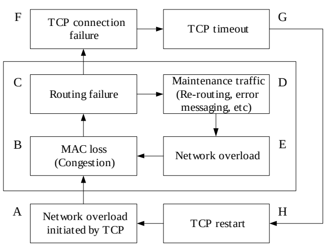
Kitae Nahm, Ahmed Helmy, C.-C. Jay Kuo
helmy@usc.edu,{nahm,cckuo}@sipi.usc.edu

Introduction

- The instability of ad hoc routing badly affects TCP performance over 802.11 multihop networks
- We consider improving TCP performance by stabilizing routing dynamics over 802.11 networks
  - We introduce a simple reaction policy of DSR protocol to link failure in 802.11 networks
  - We study the tradeoff of the proposed policy with respect to node mobility, channel error, and MAC contention loss

Cross-layer Interaction in 802.11 Networks

- Lack of coordination in sharing network resource
  - The cross-layer interaction among 802.11 MAC, transport, and network layers are unorganized and inefficient
- TCP drives MAC contention loss instead of queuing loss in 802.11 networks
  - TCP pushes as many packets as possible into 802.11 network, which intensifies contention in wireless medium
  - Extended hidden/exposed terminal problem[1,2]
- TCP drives on-demand ad hoc routing unstable in 802.11 networks
  - DSR protocol performs routing maintenance and rediscovery operations by taking link loss for node mobility and wireless channel error
  - TCP congestion (MAC contention loss) misleads routing agent into unnecessary routing maintenance operations



Connection blackout cycle[3] in chain topologies for the case of DSR protocol

Tolerability of 802.11 Link Failure

- MAC loss needs to be treated differently depending on the types of the associated networking events
  - On-demand routing is unstable with TCP because wireless channel error, node mobility, and congestion are treated in the same way
- Node mobility
  - Node is no longer available
  - A new route should be established no matter how it might cost
- Congestion
  - Congestion is a part of TCP operation
  - The current route should remain intact
- Wireless channel error
  - Channel error is a just matter of connection quality, not of the end-to-end connectivity
  - Without a better alternative path, channel error should be tolerated
  - Link-layer retransmission can help if needed

Sensitivity to Link Failure (β-factor)

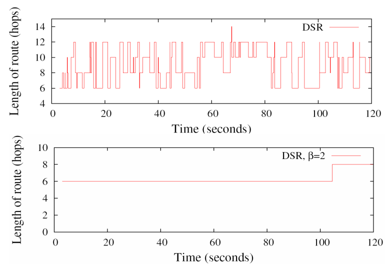
- Introduction of β factor for DSR protocol
  - Generalized sensitivity parameter to link failure
  - Response to link failure only for a number (β) of **successive** link failures
  - **No retransmission** of the lost packets by DSR protocol

L: the number of ***successive*** link failures
L< β: The current packet is dropped and the transmission is resumed for the next packet
L= β: Routing maintenance/re-discovery. Reset L=0

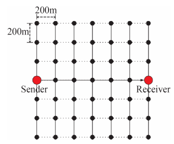
- β =1
  - The conventional DSR implementation
- β >1
  - DSR protocol responds after 7β successive retransmissions in 802.11 MAC*
  - Pro: suppressing unnecessary routing at congestion
  - Con: slower mobility response

***Not necessarily with the same packets**

Routing Stability and TCP Throughput



Routing changes in a static 7x7 grid topology



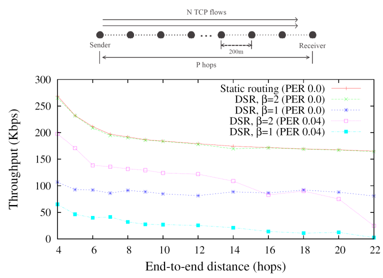
TCP THROUGHPUT (KBPS) IN THE 7X7 GRID TOPOLOGY

Routing	Flow 1	Flow 2	Total	Improvement over $DSR_{\beta=1}$
Static	89.36	116.86	202.22	13.5%
$DSR_{\beta=2}$	92.06	108.76	200.82	12.72%
$DSR_{\beta=1}$	87.59	90.57	178.16	N/A

- DSR (β=1, original) has 13% lower throughput than static routing
  - The route was changed over 100 times during the simulation session, and the shortest path is utilized only under 50%
- DSR (β=2) experienced has almost the same throughput as static routing
  - The route was changed only a single time and the 6-hop shortest path was utilized over 85%

β-factor Tradeoff: Wireless Channel Error

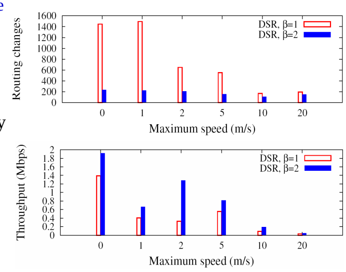
- No channel noise (PER 0.0)
  - DSR (β=2) almost achieves the TCP performance bound of the static routing
  - DSR (β=1) achieves about 50% TCP throughput of the static routing
- PER (packet error rate) 0.04
  - DSR (β=2) achieves over 200% improvement of TCP throughput of DSR (β=1) in 4-20 hop chain topologies



- TCP vulnerability to channel error is the same, but the improvement of routing robustness with β=2 is more beneficial to the overall system performance including TCP throughput

β-factor Tradeoff: Node Mobility

- Manhattan mobility model
  - 200 mobile nodes in 500x500m space
  - Transmission range 60m, carrier sensing/interference range 140m
- β=2 makes noticeable difference in low mobility (< 5m/s) scenarios where TCP throughput is practically meaningful
  - 65-85% less route changes
  - 35-200% higher TCP throughput
- The impact of the increased mobility-reaction latency with β=2 on the overall system performance is practically negligible



Conclusions

- The on-demand ad hoc routing protocols can be extremely inefficient in 802.11 networks because different types of networking events such as wireless channel error, node mobility, and congestion are treated in the same way
- Our proposed reaction policy applied to DSR protocol noticeably improves the performance and stability of 802.11 networks without any effort to distinguish those events

Network Events	Tolerability of Link Failure	Impact of β > 1
Node Mobility	Intolerable	-
Congestion	Should be tolerated	+
Channel Error	Tolerable	0

Reference

[1] Z. Fu, *et al.* "The impact of multihop wireless channel on TCP throughput and loss", INFOCOM 2003
[2] K. Chen, *et al.* "Understanding bandwidth-delay product in mobile ad hoc networks", Computer Communications, 2004
[3] K. Nahm, *et al.* "TCP over multihop 802.11 networks: issues and performance enhancement", ACM MobiHoc, May, 2005

NS-2 code will be available soon at
http://biron.usc.edu/~nahm/research