Considering Interference and Link Quality of Multi-Radio Wireless Mesh Networks

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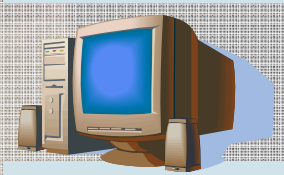
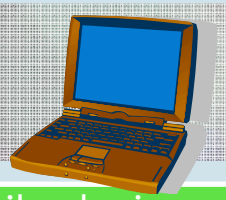
Structure

- Motivation
- Problem Definition
- Proposed Scheme
- Simulation Result
- Concluding Remarks & Discussion

Motivation

- Future Internet environment extends to…

Fixed & wired networks	Wireless networks (with attachment points)	Mobile ad-hoc networks
		
Fixed & static devices connected to wired networks	Mobile devices with single wireless interface	Mobile devices with multiple wireless interfaces

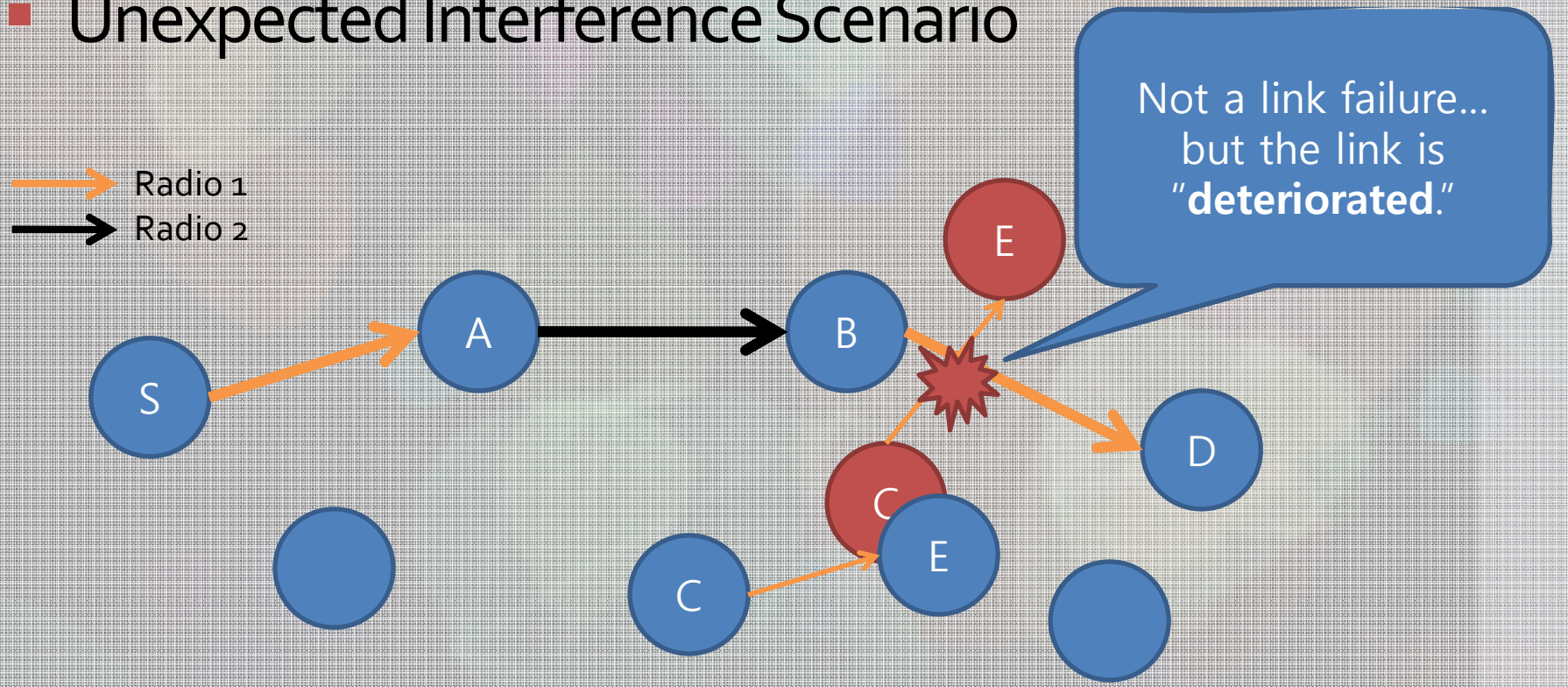
- Spontaneous & social networking via wireless networks
  - e.g. Mobile social software (MoSoSo)
  - Capacity of wireless network should be improved to support MoSoSo.
    - Throughput, scalability, reliability, mobility, …

Motivation (cont'd)

- Obstacle for increasing capacity of wireless networks
  - Interference (between intermediate nodes)
  - Multiple wireless interfaces in a device enables to select radio-diverse multi-hop paths.
    - → Interference can significantly be reduced.
- Existing multi-radio routing protocols
  - MR-LQSR [1]
  - AODV-MR [4]
  - HOLSR [2]
  - …
- Existing protocols can select optimal paths considering radio diversity, link quality, and other factors.

Problem Definition

- Link quality of a multi-hop path is deteriorated by:
  - Unexpected Interference
    - By instant communication sessions or node mobility
- Unexpected Interference Scenario

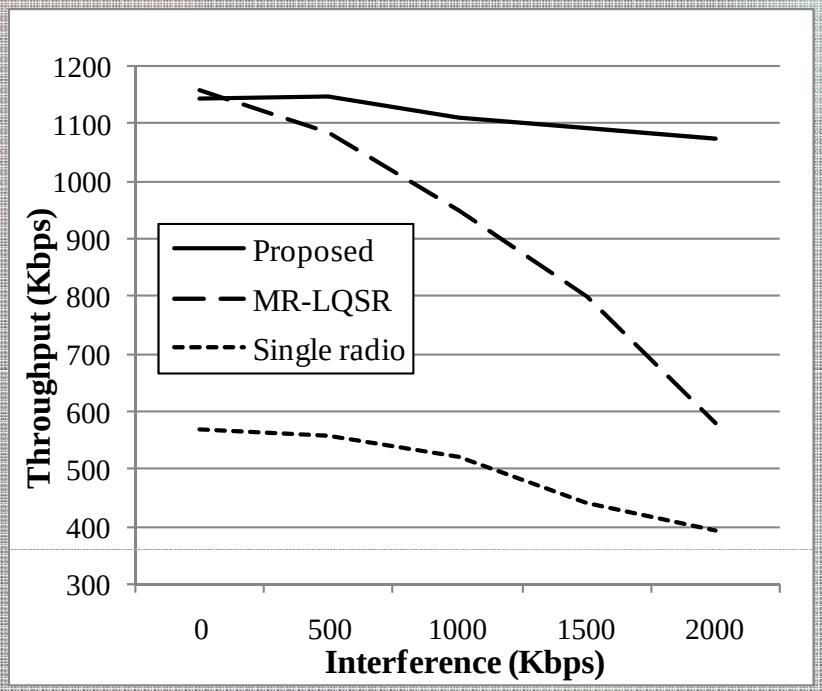


Problem Definition (cont'd)

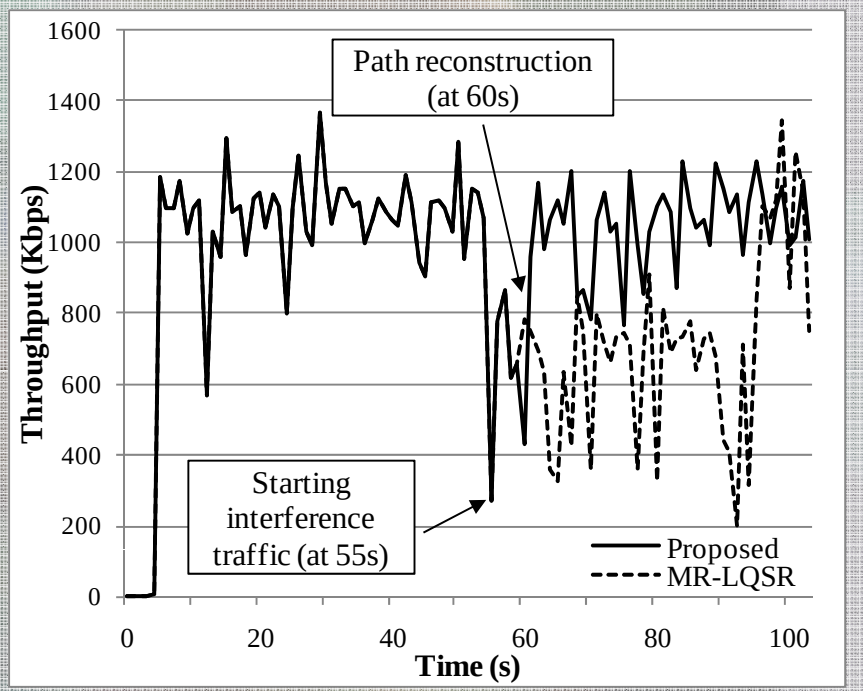
- Existing routing protocols tend to maintain established paths even though a link is interfered by node mobility until link failure occurs.
  - The link is "deteriorated."
  - Existing protocols do not have an appropriate routine to check this.
  - → We suggested a detection scheme for this link deterioration.

Problem Definition (cont'd)

- Effect of Deterioration Detection
  - An optimal radio-diverse path is created, and a sudden interference traffic session is started.



Throughput changes for different interference levels



Throughput for 1Mbps interference traffic on a link

Proposed Scheme

- Interference-aware Link-Quality based Routing protocol (ILQR)
  - (1) Link quality measurement
  - (2) Deterioration detection
  - (3) Path reconstruction

문제 상황의 recognition

문제 해결을 위한 decision

Proposed Scheme (cont'd)

- (1) Link Quality Measurement
  - We utilize Expected Transmission Time (ETT) [1] metric.
    - See appendix 1.
  - Every node checks ETTs of all neighbors.
    - Updated by beaconing (interval: 2 seconds)
  - After route discovery, WCETT to the destination is set.

Proposed Scheme (cont'd)

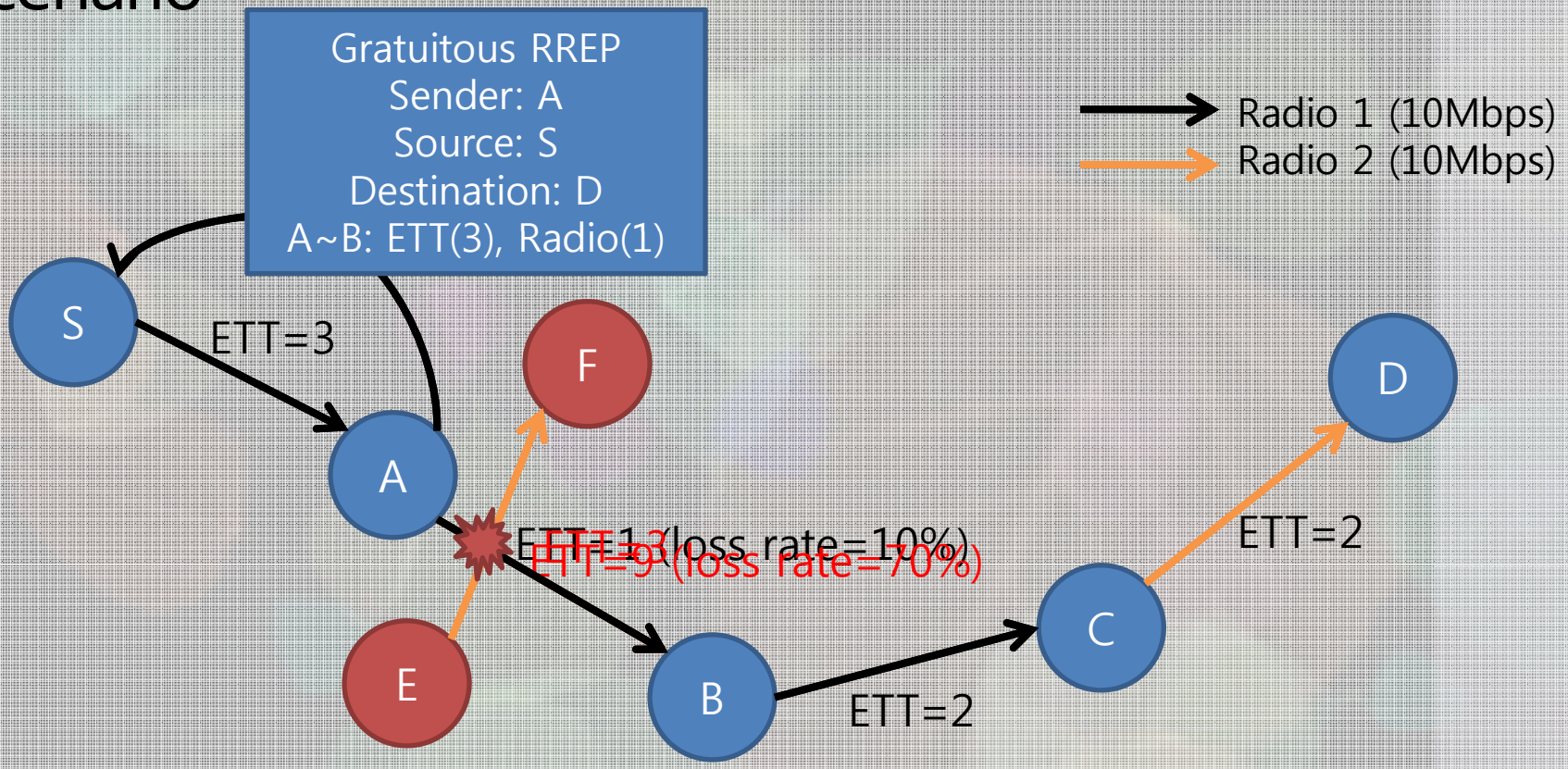
- (2) Deterioration Detection
  - Deterioration is determined by
    - How deep the quality is degraded
    - How long the situation continues
  - → Deterioration Threshold
    - ETT checking interval: 2 seconds
    - If ETT of a link worsens four times and it is used by data transmission,
      → "Link Deterioration"

Proposed Scheme (cont'd)

- (3) Path Reconstruction
  - The simplest approach to reconstruct a path:
    - Route discovery again
    - This is not cost-effective. (contains flooding)
  - The other way: local repair (AODV-based)
    - Gratuitous RREP.
    - Contains updated link to destination. (updated ETT value, radio of the link)

Proposed Scheme (cont'd)

- Scenario

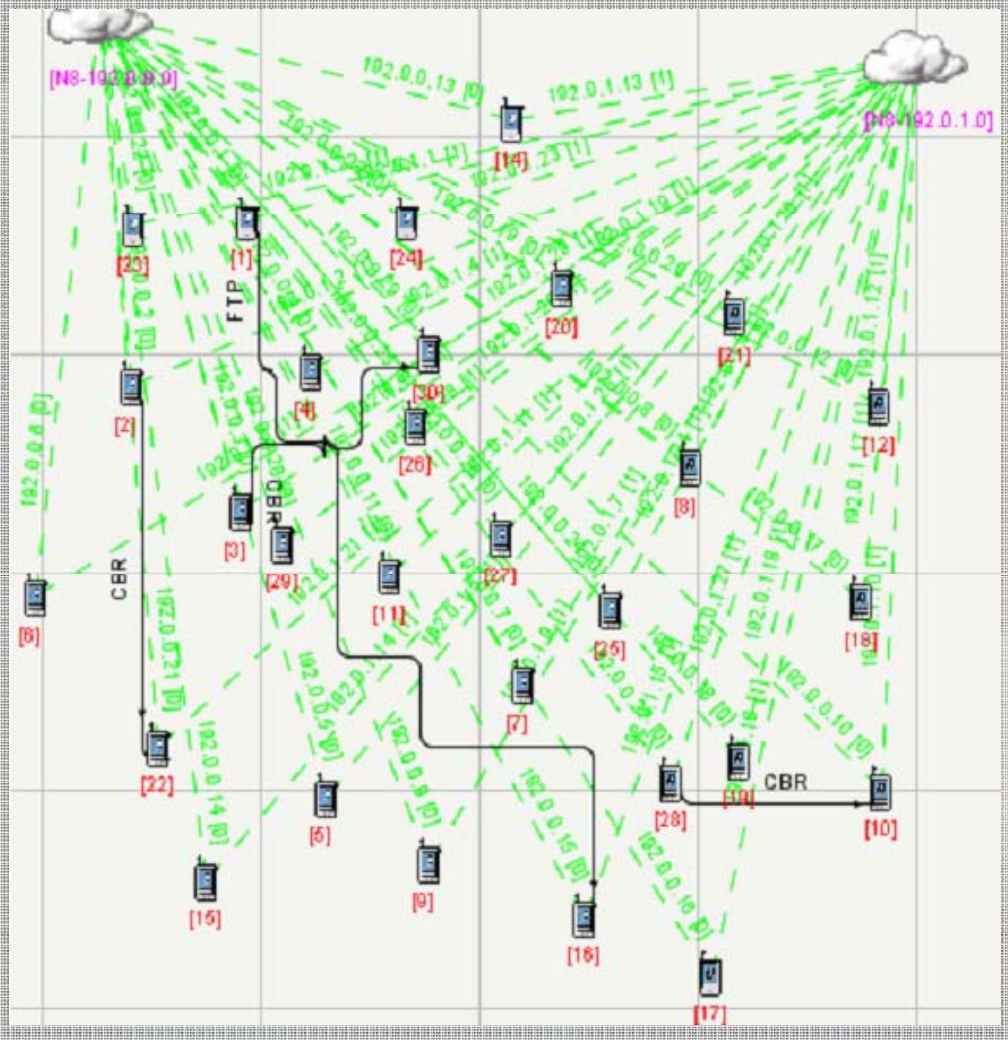


Simulation

- Simulator: QualNet 4.5.1
- Simulation Parameters
  - Examined Protocols
    - AODV, AODV-MR, AODV-WCETT, ILQR (proposed)
  - Environment
    - Simulation time: 100s
    - Area: 1500 x 1500 m
    - Mobility: Random waypoint, pause: 3 seconds, max speed: 5m/s
  - Number of interfaces of a node: 2
    - Radio model: 802.11b
  - Deterioration threshold: 4
    - See appendix 2.

Simulation (cont'd)

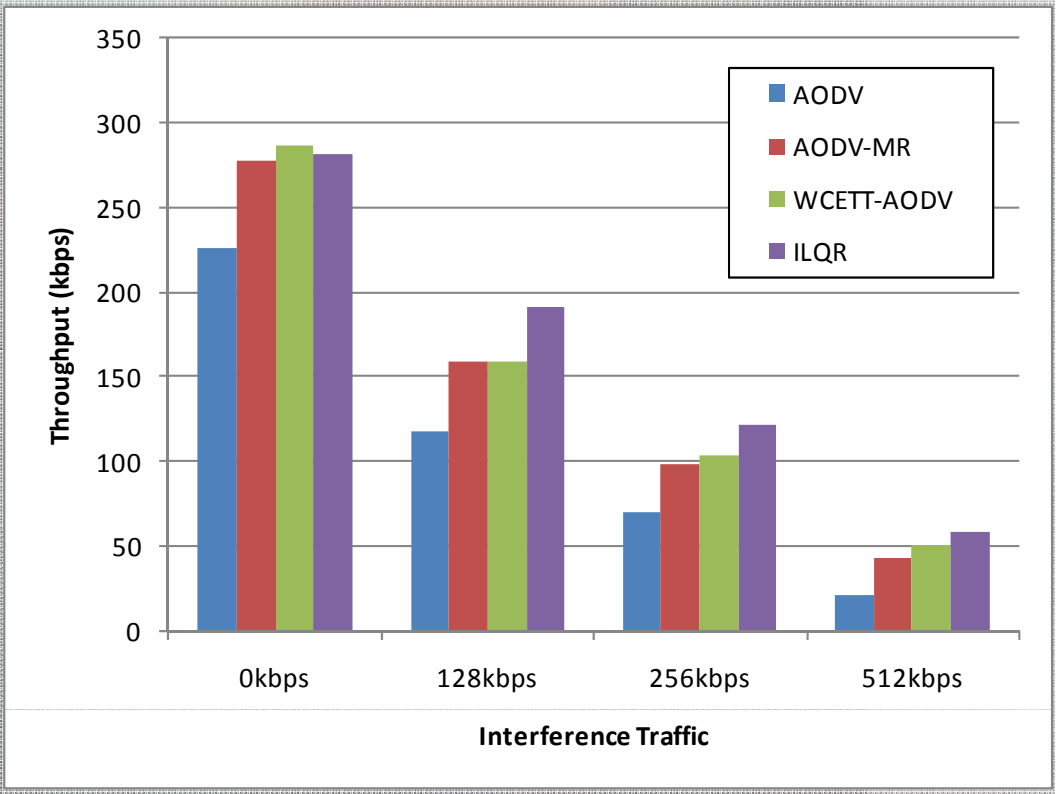
- Network topology of simulation



Simulation Result

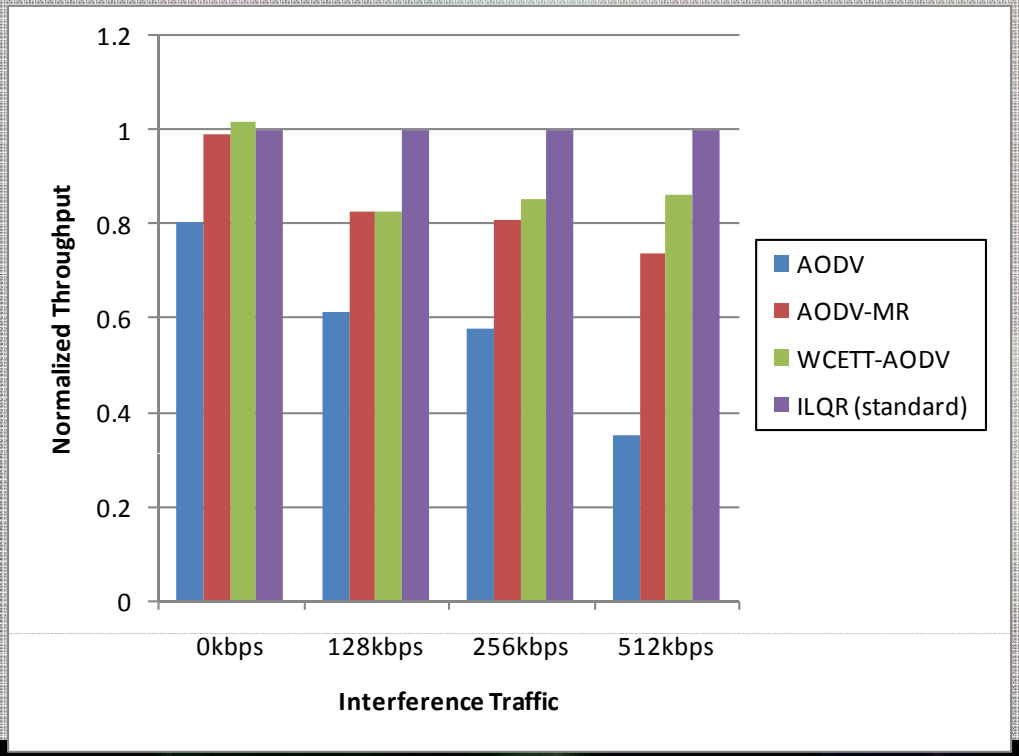
- Throughput for different interference levels
  - ILQR's performance is the best for medium interference levels.

- No interference: deterioration detection is useless.
- Severe interference: more link failure than link deterioration



Simulation Result (cont'd)

- Normalized throughput for interference levels
  - Standard: ILQR
  - Consideration of link quality (ILQR, WCETT-AODV) might be more important as interference gets intense.



Concluding Remarks

- Optimal radio-diverse path can easily be "deteriorated" by unexpected interference in multi-radio MANETs.
- Proactive detection is effective for escaping deteriorated situations.

Issues

- (1) Cost effective link quality measurement
  - How precise should measurement be?
  - "Cost/benefit trade-off" + "Burden a network with additional traffic"
- (2) Path reconstruction decision making
  - Is it significant enough to affect to end-to-end performance? (L4 +)
    - Intensity & Span
  - Is it worse than alternative paths? (L3)
- (3) Fine-grained path reconstruction scheme
  - End-to-end/global repair vs. partial/local repair
    - Cost/benefit trade-off
    - Local optimum problem
  - Who decides new path?
    - Source node, intermediate nodes, destination node

Q&A

- ThankYou!

References

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[4] Asad Amir Pirzada, Marius Portmann, and Jadwiga Indulska, "Evaluation of multi-radio extensions to AODV for wireless mesh networks," in Proceedings of the 4th ACM international workshop on Mobility management and wireless access, pp. 45-51, 2006.

[5] D. De Couto, D. Aguayo, J. Bicket, and R. Morris, "High-throughput path metric for multi-hop wireless routing," in Proceedings of MOBICOM 2003, 2003.

[6] D. Johnson, Y. Hu, and D. Maltz, "The Dynamic Source Routing Protocol (DSR) for Mobile Ad Hoc Networks for IPv4," RFC 4728, http://www.faqs.org/rfcs/rfc4728.html, February 2007.

Discussion

- In application's view
  - How much interference is really a problem?
    - For streaming application in MANETs…
- Measurement of link quality affects performance?
  - ETT is checked by periodic hello message exchange (beaconing).
  - Overhead of beaconing is not ignorable.
    - → Another link quality metric w/o hello message?
- How to improve path reconstruction?
  - Route discovery: worst overhead & best path
    - Need to find a trade-off for those two factors.

Appendix 1: MR-LQSR

- MR-LQSR [1]
  - Uses "link quality" rather than hop count.
  - ETT (Expected Transmission Time)
    - Quality of a link (B = bandwidth, S = packet size, unit: ms)

$$\mathrm{ETT} = \mathrm{ETX} * \frac{S}{B}$$

ETX [5]:
- Expected Transmission Count
- Expected number of transmissions needed to send a unicast packet on a link

  - WCETT (Weighted Cumulative ETT)
    - Path quality considering path length and channel diversity
  - Based on DSR (Dynamic Source Routing)

Appendix 2: Deterioration Threshold

- Throughput changes for different deterioration threshold values
  - Application: CBR (125 pkts/s, packet size: 1024 bytes)
  - Interference: CBR (63 pkts/s)