Connectivity Aware Routing in Ad-Hoc Networks

Jérémie Leguay

PWC'05

With: Timur Friedman (LIP6), Vania Conan(Thales), Serge Fdida (LIP6), André Cotton(Thales)

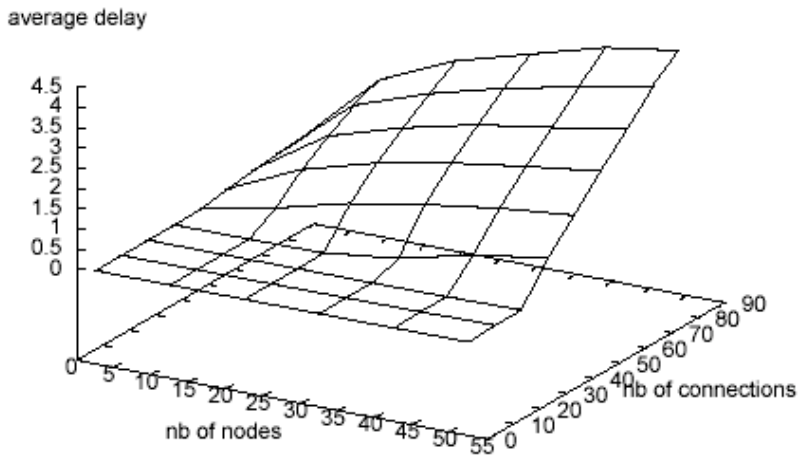
Ad-Hoc Networks

- Properties
  - Ease the spontaneous set up of communication systems
  - Several mobile nodes sharing the same wireless channel
  - Nodes only communicate with the ones within their transmission range
  - Nodes have routing capabilities for multi-hop communications

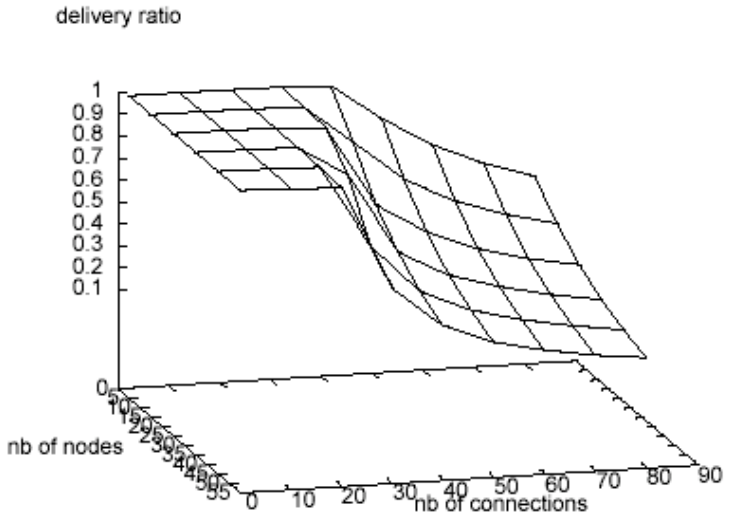
- Performances issues at MAC/PHY layers (IEEE 802.11b)
  - MAC
    - Contention due to the competition to access the media
    - Route lengths impacts end-to-end performance
    - Each transmission have a large impact on the neighborhood
  - PHY
    - Interferences level impact on performances
    - Channel suffers highly from quality variations

Impact of the network connectivity

- Simulation parameters
  - Play ground: 100m x 100m
  - Transmission range: 250m
  - CBR: 4 packets/sec – Packet size: 512 bits
  - MAC 802.11 b – Rate: 2 Mbits – RTS/CTS
  - AODV
  - Simulation time: 300s
- Results with ns2



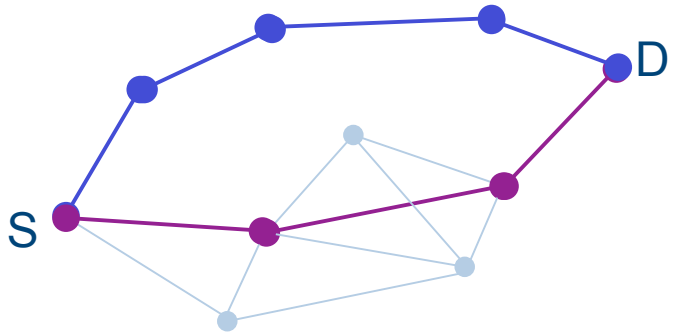
Delay



Delivery ratio

Basic Idea

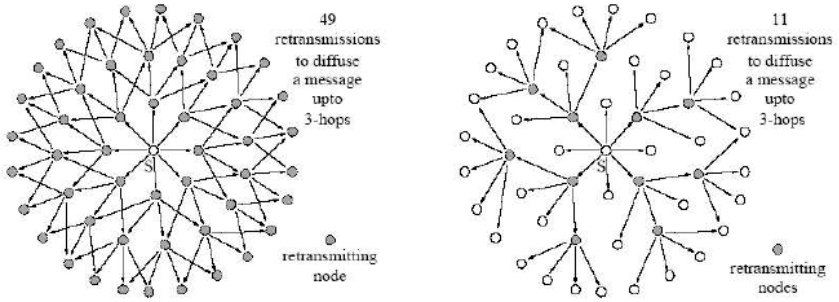
- Benefits from low connected parts of the topology



- Solution: QoS routing using local connectivity metrics

Integration with OLSR

- OLSR – Optimized Link State Routing protocol (MANET - IETF)
  - Proactive Ad Hoc routing protocol
  - Use MPR (Multi-Point Relays) to:
    - To optimise the broadcast mechanism
    - To reduce the amount of control traffic



  - Each node maintains a view of the network topology.
- Integration
  - Modification of the route computation algorithm:
    - Dijkstra with weights on links representing the local connectivity level
    - Additive metric combination (Multiplicative could also be interesting as well)

The different *link*-metrics we used:

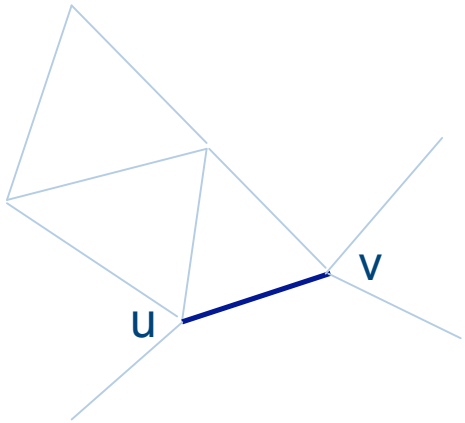
K = 1

- K-hop node density
  - Number of node in the k-hop neighborhood — 5
- K-hop link density
  - Number of links in the k-hop neighborhood — 6
- Link clustering coefficient
  - Probability that two links in the neighborhood of a link are connected. — $\frac{1}{6}$

$$cc(u,v) = \frac{|N(u) \cap N(v)|}{|N(u) \cup N(v)|}$$

- K-hop beta index — $\frac{6}{5}$

$$\beta = \frac{E}{V}$$



QoS routing with local connectivity metrics

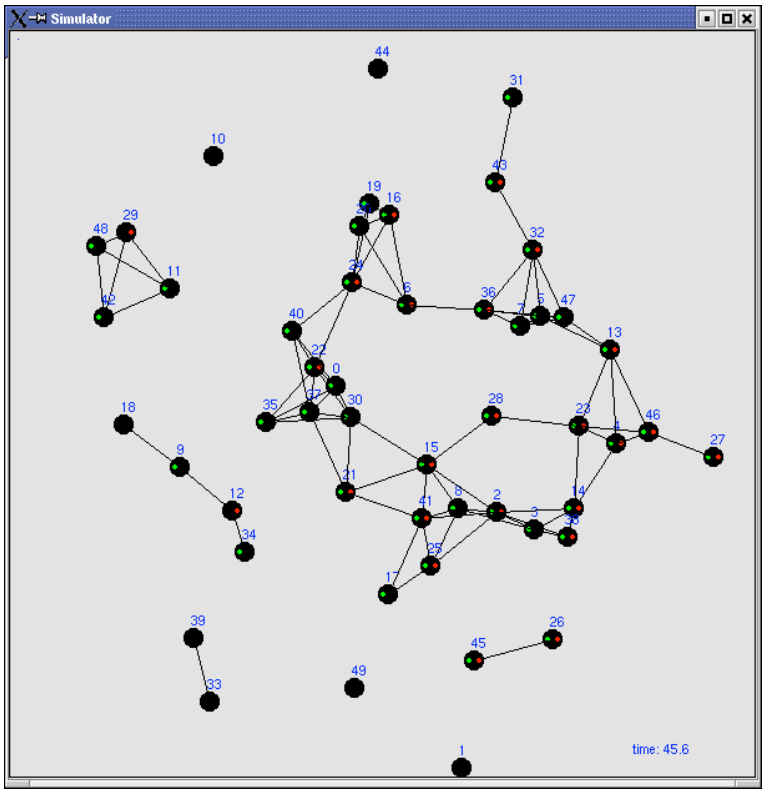
- Advantages
  - Easy to compute (computation remains at the network layer)
  - Easy to integrate with routing protocols
  - Do not suffer from *self-interference*
- Drawbacks
  - May lead to the overload of low connected parts
  - May induce *path inflation*
  - Only relies on implicit properties of MAC layer (not on real-time measurements)

Methodology

- Type of graphs
  - Node degree variance: low / medium / high
- Graph oriented performances evaluation
  - Correlation with a very simple metric: *1-hop node density*
  - Path length inflation
  - Routing discrimination level
  - Path stability
- Networking oriented performances evaluation
  - Average delay
  - Average delivery ratio

Graph oriented simulations

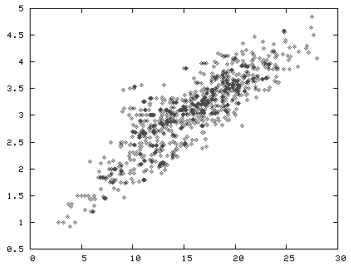
- With a stand alone simulator



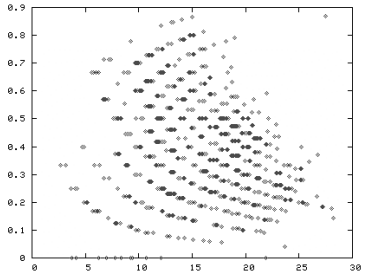
- Simulation parameters
  - 200 nodes
  - Play ground: 2000m * 2000m
  - Transmission range: 250m
  - Simulation time: 300s

Graph oriented simulations

- Correlation with a very simple metric: *1-hop node density*

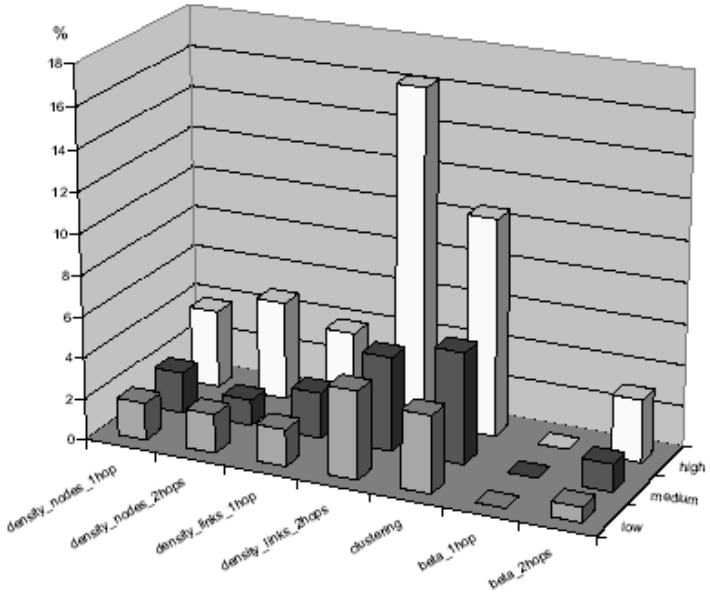


Beta_2_hops



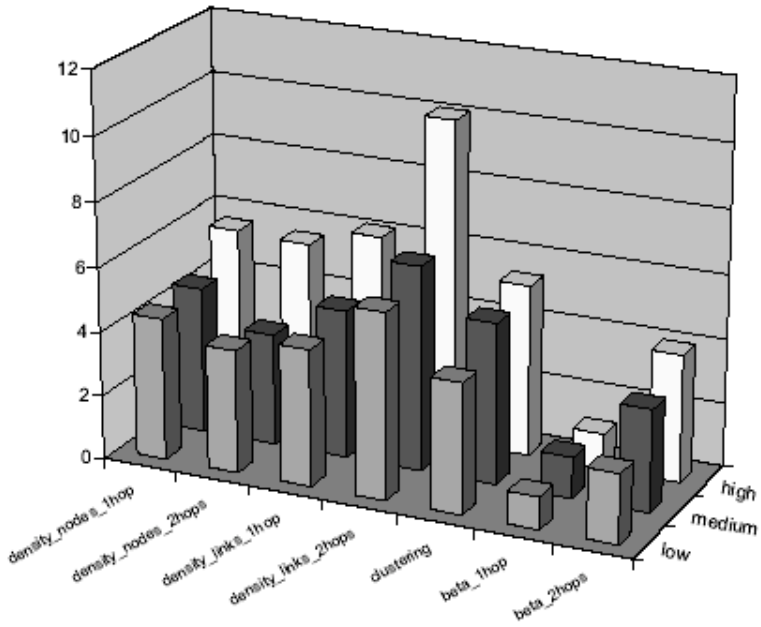
Clustering Coefficient

- Path length inflation



Graph oriented simulations

- Routing discrimination level

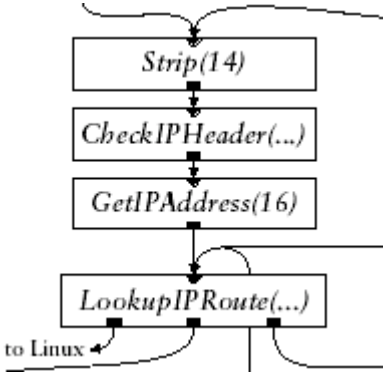


- Path stability

Metric	Number of route changes
hop count	82.99
density_nodes_1hop	109.047
density_nodes_2hops	109.849
density_links_1hop	110.366
density_links_2hops	109.223
clustering	140.723
beta_1hop	128.592
beta_2hops	123.094

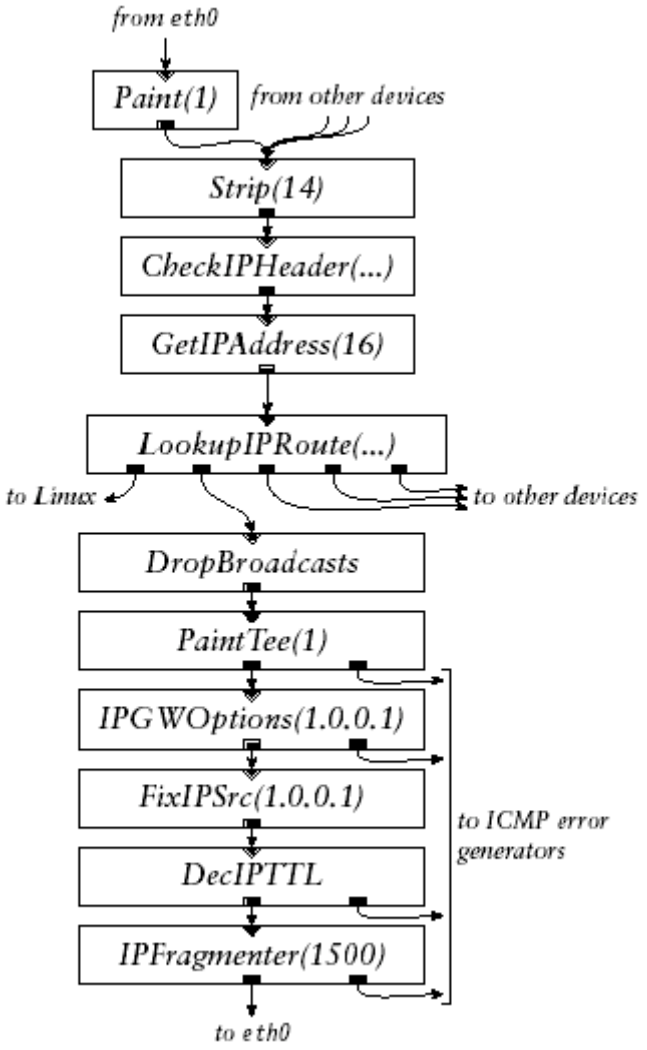
Networking oriented simulations

- Simulation parameters (ns2+click router)
  - 30 static nodes
  - Play ground: 500m x 500m
  - Topology with node variance degree: low / medium / high
  - MAC 802.11b – 2 Mbits – RTS/CTS
  - Transmission range: 250m
  - CBR traffic sources: from 10 to 90 randomly allocated
  - Simulation time: 300s



(Click router)

- NS2 + click router
  - The Click Modular Router
    - Modular, extensible, and flexible.
      - Elements are implemented in C++
      - A router (combination of several elements) is build through a simple configuration file.
      - Basic elements are provided in the distribution
      - An element can be a data structure share by other elements.
    - The optimized Click IP router's steady-state forwarding rate is 400,000 minimum-size packets per second;



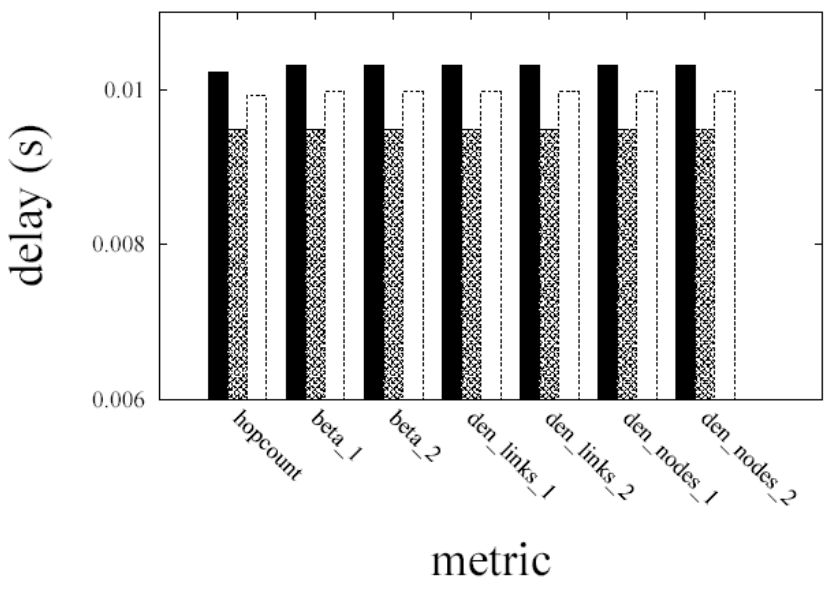
www.pdos.lcs.mit.edu/click/

Networking oriented simulations

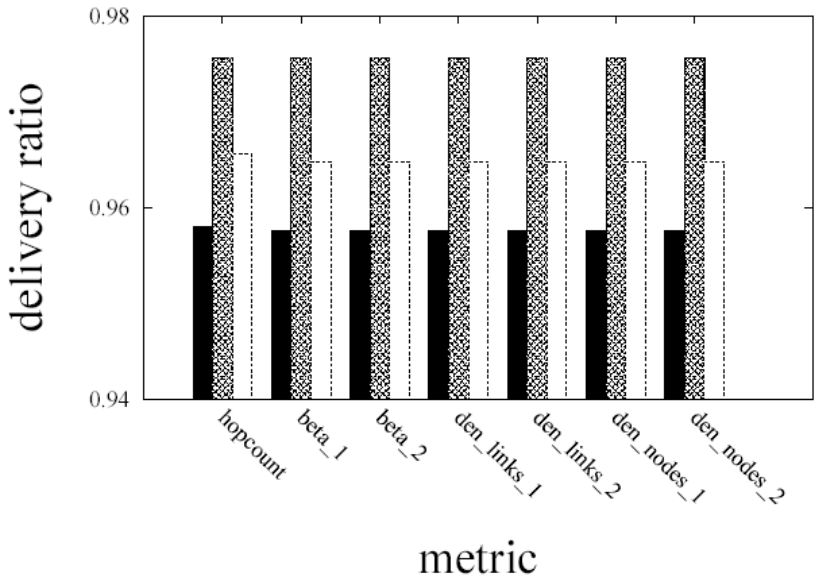
- Results
  - Low traffic load

Connectivity level:

Low
Medium
High



(a) Average delay (10 CBR)



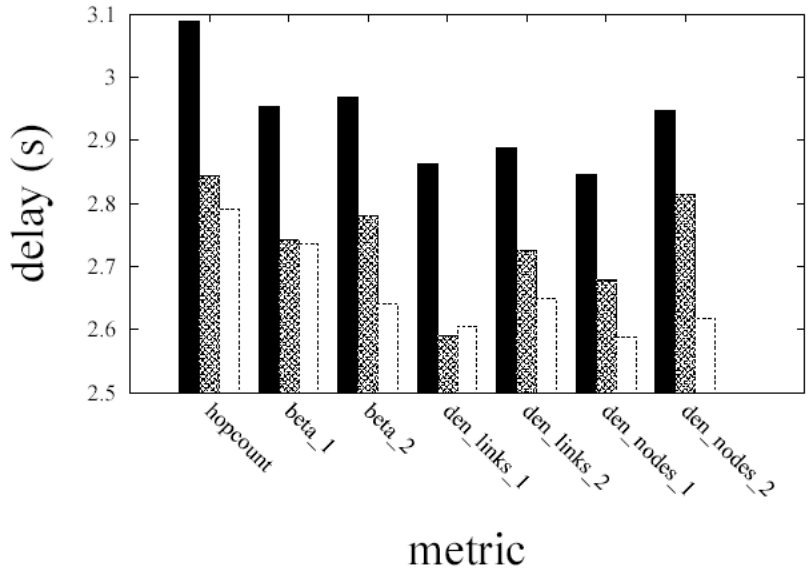
(b) Average delivery ratio (10 CBR)

Networking oriented simulations

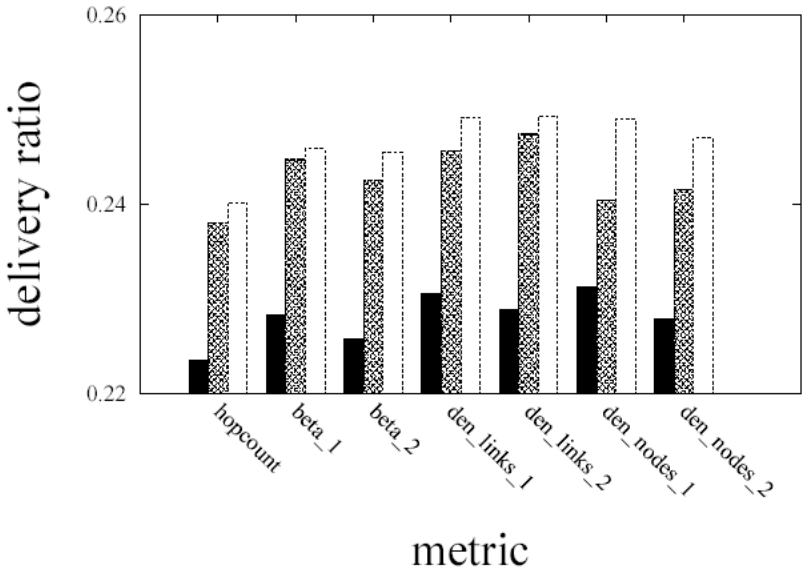
- Results
  - High traffic load

Connectivity level:

Low
Medium
High



(c) Average delay (90 CBR)



(d) Average delivery ratio (90 CBR)

Up to a diminution of 9% for the average delay and a gain of 4% for the delivery ratio.

Conclusion & Future works

- Conclusions
  - Study around the impact of the connectivity
  - Proposition of an easy solution with no additional control traffic to improve network utilization
  - Analysis of metrics behaviours and achievements (density_1_hop)

- Future Works
  - Proposition of metrics more related to multi-rate MAC layers
  - Simulations (ns2) with mobility of nodes
  - Combination with other QoS metrics
  - Hybrid mechanism (aware of the context)

References

[1] E. Belding-Royer C. Perkins and S. Das, “RFC 3561 : Ad hoc on-demand distance vector (AODV) routing, July 2003” .

[2] The network simulator ns-2. http://www.isi.edu/nsnam/ns/.

[3] T. Clausen and P. Jacquet, “RFC 3626 : Optimized link state routing protocol (OLSR), October 2003” .

[4] Amir Qayyum, Laurent Viennot, and Anis Laouiti, “Multipoint relaying: An efficient technique for flooding in mobile wireless networks,” Tech. Rep. Research Report RR-3898, INRIA, February 2000.

[5] K. Al Agha H Badis, “An efficient QOLSR extension protocol for QoS in ad hoc networks,” in *IEEE VTC’04-Fall*, September 2004.

[6] L. Lamont Y. Ge, T. Kunz, “Quality of service routing in ad-hoc networks using OLSR,” *The 36th Hawaii International Conference on System Sciences (HICSS-36)*, 2003.

[7] E. W Dijkstra, *A note on two problems in connexion with graphs*, Numerische Mathematik, 1959.

[8] Christian Bettstetter, “On the minimum node degree and connectivity of a wireless multihop network,” in *Proceedings of the 3rd ACM international symposium on Mobile ad hoc networking & computing*. 2002, pp. 80–91, ACM Press.

[9] Andree Jacobson, “Metrics in ad hoc networks,” M.S. thesis, Lulea University of Technology, Sweden, May 2000.

[10] Charles E. Perkins and P. Bhagwat, *A Handbook of Graph Theory*, 2003.

[11] The click modular router. www.pdos.lcs.mit.edu/click/.