Routing in Wireless Mesh Networks

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About me

- **2005-:** PhD student at WIT (Kappel, IS)
  - Advisors: Dietrich (EE), Kastner (CS)
  - WP-Leader EU-Project Track & Trade
- **2001-2005:** Telecommunications Research Center Vienna (ftw)
- **Master:** Computer Science, Specialization: Computer Engineering
- **Research Interests:**
  - Wireless Computing and Telecommunications
  - Wireless Mesh / Ad-Hoc Networks
- Thesis (working title): **"Routing in Wireless Mesh Networks"**

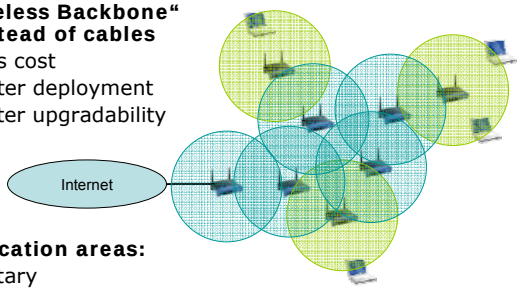
Overview

- **My Thesis: "Routing in Wireless Mesh Networks"**
  - Definition
  - State-of-the-Art
  - Approach
  - Time Plan
- **Current Work**
  - Ns-2 Random Generator
  - Wireless Network Modelling

Definition / 1: Wireless Mesh Network

"Wireless Backbone" instead of cables

- Less cost
- Faster deployment
- Better upgradability

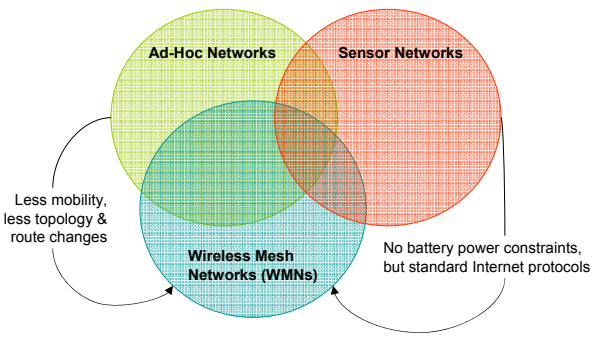


Application areas:

- Military
- Disaster areas / emergency response
- Civilian: access network to the Internet

Wireless Station WLAN Router/AP

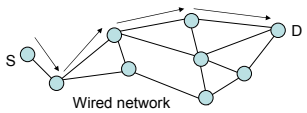
Definition / 2: Field of Research



Definition / 3: The Problem

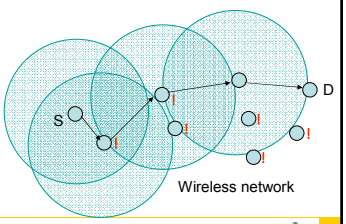
Routing:

- Hop-count is a bad metric:
  - Links vary over time
  - Far links are usually worse than short links



MAC Interaction:

- Hidden node problem
- Exposed terminal problem
- Flow-in-the-middle problem



State-of-the-Art / 1: Protocol types

- Reactive (on-demand)
  - Build route when flow starts
  - Destroy route when flow ends
  - Drawback: route setup delay
  - Good for frequent route changes
- Pro-active
  - Build route in advance
  - Keep routes up-to-date (communicate changes)
  - Drawback: communication overhead
  - Good when routes change seldom
- Hybrid

State-of-the-Art / 2: Protocols

"Classical":

- **OLSR** - Optimized Link State Routing protocol
  pro-active, *RFC 3626* (Clausen, Jaquet, 2003), used in firmwares
- **AODV** - Ad-hoc On-Demand Distance Vector
  reactive, *RFC 3561* (Perkins, Royer, Das, 2003)
- **DSDV** - Dynamic Destination-Sequenced Distance Vector
  pro-active, one of the oldest (Perkins, 1994)
- **DSR** - Dynamic Source Routing
  reactive (Johnson, 1994)

Nature inspired:

- Eg. Ant Hoc Net
  hybrid (DiCaro et al, 2004)

Ant-based Algorithms / 1

- Inspired by nature: behavior of ants
- Single ants are quite stupid, but the whole system exhibits "intelligent" behavior
- Ant Colony Routing (ACR) – distributed version of Ant-based Algorithm, eg.: **AntNet** by Di Caro and Dorigo, 1998
- **AntHocNet** for MANETs by Di Caro, Ducatelle, Gambardella, 2004:
  - AntNet concept + Extensions
  - Hybrid routing approach: reactive/pro-active

Ant-based Algorithms / 2

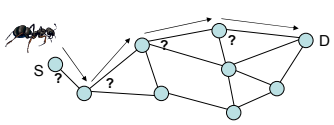
1. Whenever an ant moves, it lays a pheromone trail
2. To find its way, an ant:
   - Follows existing trails if there are any.
     Probability for choosing a trail is proportional to amount of pheromone on the trail.
   - Walks randomly if there are no trails.
3. Pheromone evaporates over time -> unused trails vanish.

- **Trail following (state transition rule)**
  determines how the ant chooses its way depending on link cost and amount of pheromone found on the trails
- **Trail laying (pheromone update rule)**
  determines how the pheromone is updated
- **Evaporation (evaporation rule)**
  determines how fast pheromone evaporates

Ant-based Algorithms / 3

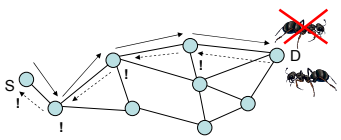
- Forward ants: regularly created, choose next link based on transition rule:

  P = Trans(pheromone, link cost)



Ant-based Algorithms / 4

- Backward ants:
  created when forward ant reaches destination node, travels back to from where it came, updates pheromone amounts and measured link costs at all nodes on way back



My Approach

- Simulation with ns-2 simulator
- An implementation of AntNet has just become available

Find new algorithm:

- Based on ant concept
- Probably hybrid between classical and ant-based
- Probably hybrid proactive/reactive routing approach – WMNs are less mobile than MANETs
- Use better cross-layer info to determine link costs
- Reduce number of ants by observing TCP traffic in the network (possible?)
- Idea: use "colored pheromones" to signify QoS classes -> different traffic takes different routes in the network

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Time Plan

- **25.7.:** Student poster at INDIN
- **-1.8.:** Book chapter of ns-2 RNG paper
- **-5.8.:** Define and implement algorithm in ns2; paper for BIONETICS 2007, Budapest
- **-21.9.:** Evaluation of wireless models in ns-2; SIMUTools 2008, Marseille
- **7.-9.11.:** FET (Toulouse) – short paper (wireless modelling) under review
- **-12/2007:** performance evaluation; publish 2 papers about algorithm
- **-05/2008:** Finish Thesis

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Current Work: Ns-2 Random Generator

- Martina Umlauft, Peter Reichl, *Experiences with the ns-2 Network Simulator - Explicitly Setting Seeds Considered Harmful*
- Presented at Wireless Telecommunications Symposium WTS '07, 26.-28. April, Pomona, CA, USA
- Selected to be published as book chapter in *Wireless Technology: Applications, Management, and Security*, Springer

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The ns-2 RNG

- ns-2 versions <= 2.1b8: **old RNG**
  Minimal Standard multiplicative Linear Congruential Generator [Park and Miller, 1988]
  Period $p=2^{31}-2$
  API: `$rng seed $s;`
  Sensitive to seeds [Entacher, Hechenleithner, 2002]
- ns-2 versions >= 2.1b9 until today: **new RNG**
  MRG32k3a [L´Ecuyer, 1999]
  Period $p = 3.1x10^{57}$
  API: `$rng next-substream;`
  Promises to fix seed-sensitivity **-> true?**

BUT: bad documentation -> people use old API!

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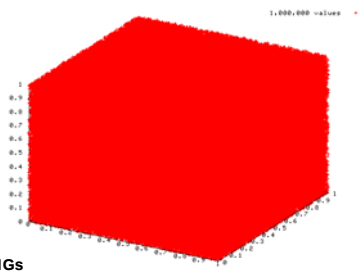
Correlation Experiment



- **Set up 3 RNGs**
- **Draw triplets of values**
  `$u($i)` from `$rng($i)` 1,000,000 triplets drawn
- **Interpret as vector**
  `<$u(1), $u(2), $u(3)>`

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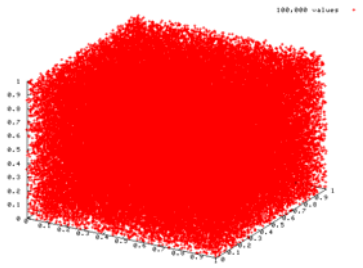
Correlation Experiment



100,000 triplets drawn

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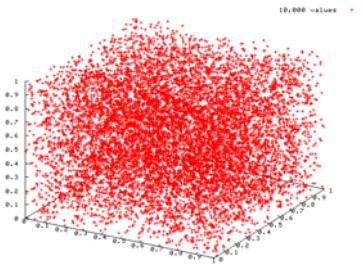
Correlation Experiment



10,000 triplets drawn

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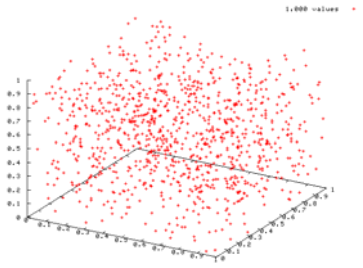
Correlation Experiment



1,000 triplets drawn

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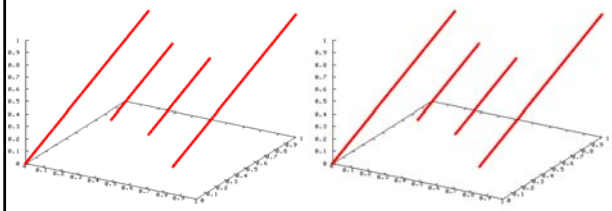
Result for bad Seed Set 2

Old RNG /w
bad seed set

New RNG ! /w
old method & bad seed set



10,000 triplets drawn

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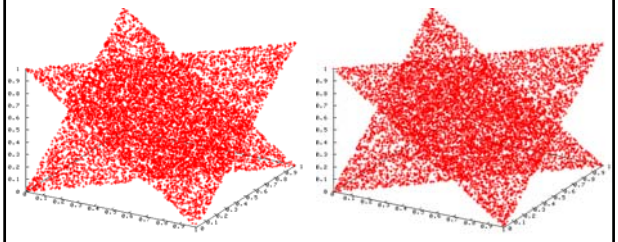
Result for bad Seed Set 3

Old RNG /w
bad seed set

New RNG ! /w
old method & bad seed set



10,000 triplets drawn

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Wired Topology Example / 1

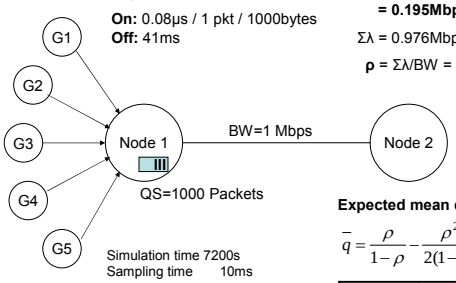
Exponential On/Off-Traffic:

On: 0.08µs / 1 pkt / 1000bytes
Off: 41ms

λ = 8000bits / 41ms
= 0.195Mbps

Σλ = 0.976Mbps

ρ = Σλ/BW = 0.976 …utilization factor



Simulation time 7200s
Sampling time 10ms

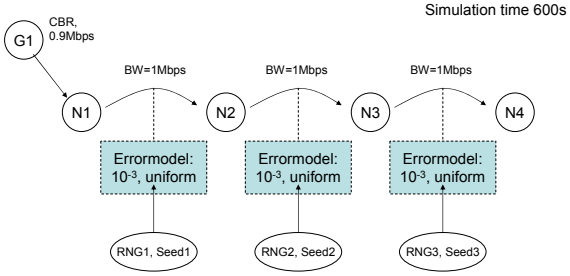
Expected mean queue length:

$$\bar{q} = \frac{\rho}{1-\rho} - \frac{\rho^2}{2(1-\rho)} = \mathbf{20.488pkts}$$

New RNG	New method	20.2996
New RNG	Set 2 – bad	29.4527
Old RNG	Set 1 – good	19.4398
Old RNG	Set 2 - bad	24.2785

Bad seed sets: higher average queue lengths!

Wireless Example / 1



Run lenghts vs. burst lengths:

Bad seed sets: higher percentage of short run lengths!

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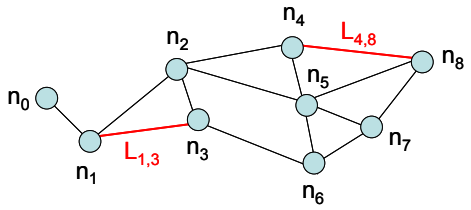
Current Work: Wireless Network Modelling

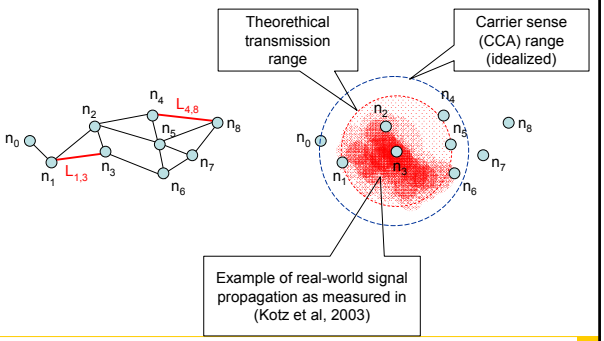
- Martina Umlauft,
  A Better Way to Model Wireless Networks,
  short paper, submitted to FET '07
- Martina Umlauft,
  Some Thoughts on Wireless Network Modelling,
  Student Poster, accepted at INDIN '07,
  to be presented 2007-07-25

Traditional Reachabilitiy Graph *G*



- Edges $L_{1,3}$ and $L_{4,8}$ seem independent
- Edges encourage thinking of links as "tunnels" between nodes

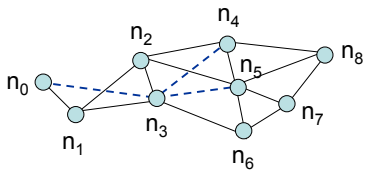
Vs. Real World Situation



Some Observations

- No "tunnel" - so what is a "link"?
  - Unicasts "do not exist" – can lead to:
    hidden node problem, exposed node problem
  - (Padhye et al, 2005):
    $\exists L_{i,j}$ *in G iff:* $n_i \text{->} n_j \cap n_i \text{->} n_j$
    with packet loss rate below certain threshold (ETX ≤ 3)
    ETX (DeCouto et al, 2003)
- Carrier sensing (CCA)
  - A node can "hear" the transmission but SINR is too bad to successfully decode the packet
  - CCA function: channel is busy! Do not send (**exposed node problem**)
- "Layer 2 interference" vs. "Interference" on layer 1

Proposal: new graph G* with CCA-edges



Only one paper found which informally uses such a graph (Das et al, 2006).

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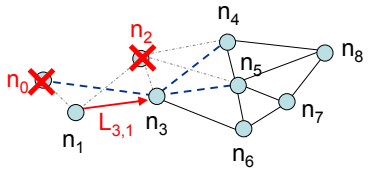
Transmission of Data Packet n_1->n_3



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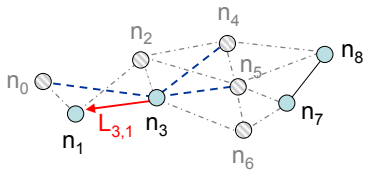
Transmission of ACK n_3->n_1



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References / Wireless Network Modelling

- Das et al, 2006: **Characterizing Multi-Way Interference In Wireless Mesh Networks.** In *Proc. 1st Intl. Workshop on Wireless network testbeds, experimental evaluation & characterization (WiNTECH '06)*, Los Angeles, CA, USA, Sept. 2006.
- DeCouto et al, **A High-Throughput Path Metric for Multi-Hop Wireless Routing.** In *Proc. ACM MobiCom*, San Diego, CA, USA, Sept. 2003.
- Kotz et al, 2003: ***The mistaken axioms of wireless network research.*** Technical Report TR2003-467, Darthmouth College of Computer Science, 2003.
- Padhye et al, 2005: **Estimation of Link Interference in Static Multi-Hop Wireless Networks.** In *Proc. ACM/USENIX Intl. Measurement Conference*, Berkeley, CA, USA, Oct. 2005.

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Thank You!

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