System Architecture, Mobility Concepts, and Modeling of Wireless Ad Hoc Networks

Project duration: Aug 2000 - July 2003

Prof. Dr.-Ing. Jörg Eberspächer, Christian Bettstetter, Jin Xi

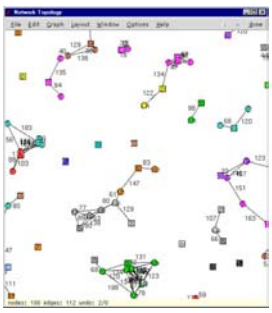
Technische Universität München
Institute of Communication Networks

Christian Bettstetter is now with
DoCoMo EuroLabs, Future Networking Lab

Talk at DFG Colloquium, Frankfurt, Nov 24, 2003.

Topics of the Project

- Modeling and simulation aspects: esp. mobility modeling
- Analytical analysis of topology attributes
- Design and analysis of distributed mobility-adaptive clustering algorithms
- Interconnection of ad hoc networks and fixed IP networks



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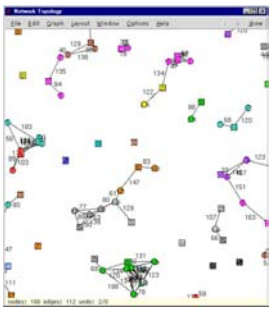
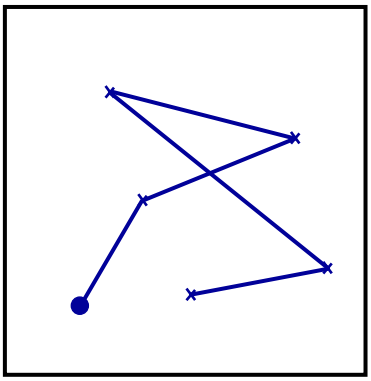


Random Waypoint Model

A simple stochastic model almost all studies on ad hoc networks.



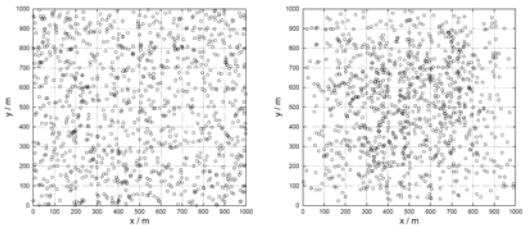
1. Node randomly chooses destination point in area
2. Moves with constant speed to point
3. Waits for a certain pause time
4. Chooses a new destination, moves to this destination

... and so on ...

Destination points are taken from a uniform distribution.

How does this model influence simulation results?

Spatial distribution of nodes



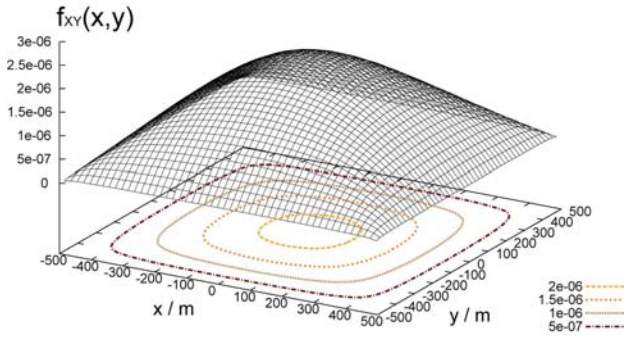
(a) Initial uniform distribution ($t = 0$)

(b) After $t = 100\,\mathrm{s}$ with $v = 10\,\mathrm{m/s}$ i.e., on average 1.9 periods

(c) After $t = 1000\,\mathrm{s}$ with $v = 10\,\mathrm{m/s}$ i.e., on average 19 periods

(d) After $t = 10000\,\mathrm{s}$ with $v = 10\,\mathrm{m/s}$ i.e., on average 192 periods

Asymptotically Stationary Node Distribution



- **Be aware** of transition phase and non-uniform node distribution!
- **Be careful** when you compare simulation results with analytical values!

Speed Behavior

- New speed is chosen from uniform distribution on the interval $[v_{min}, v_{max}]$
- Average speed over time

$$\overline{v} = \frac{v_{max} - v_{min}}{\ln\left(\frac{v_{max}}{v_{min}}\right)}$$

- Many authors choose $v_{min} = 0$

  → For a long running simulation the network converges toward an almost **static one**!

  (see also Yoon et al. Infocom03)

Further Work

- C. Bettstetter, G. Resta, and P. Santi. **The Node Distribution of the Random Waypoint Mobility Model for Wireless Ad Hoc Networks**. *IEEE Trans. on Mobile Computing*, July 2003.
- C. Bettstetter, H. Hartenstein, and X. Pérez-Costa. **Stochastic Properties of the Random Waypoint Mobility Model**. Accepted for *ACM/Kluwer Wireless Networks*, to appear 2004.
- C. Bettstetter. **Mobility Modeling in Wireless Networks: Categorization, Smooth Movement, and Border Effects**. *ACM Mobile Comp. and Commun. Review*, July 2001.

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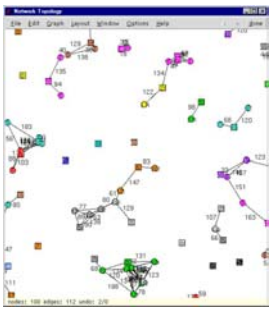


Connectivity in a shadow fading environment

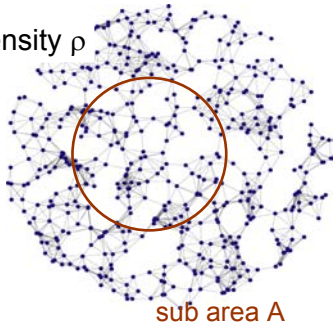
- Node are distributed according to a homogeneous Poisson point process of density ρ
- Signal attenuation between node *u* and *v*

$$\beta(u,v) = 10 \log \frac{p_t(u)}{p_r(v)} \,\mathrm{dB} = \beta_1(u,v) + \beta_2$$

$$\beta_1(u,v) = \alpha \, 10 \log \frac{s(u,v)}{1\,\mathrm{m}} \,\mathrm{dB}$$

$$f_{\beta_2}(\beta_2) = \frac{1}{\sqrt{2\pi}\sigma} \exp\left(-\frac{\beta_2^2}{2\sigma^2}\right)$$

$s(u,v)$



$$\beta(u,v) \leq \beta_{th} = 10 \log \frac{p_t}{p_{r,th}} \,\mathrm{dB}$$ → link between *u* and *v*

What is the minimum ρ such that all nodes in A are connected?

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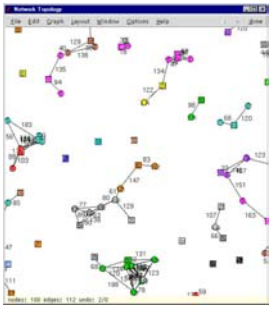
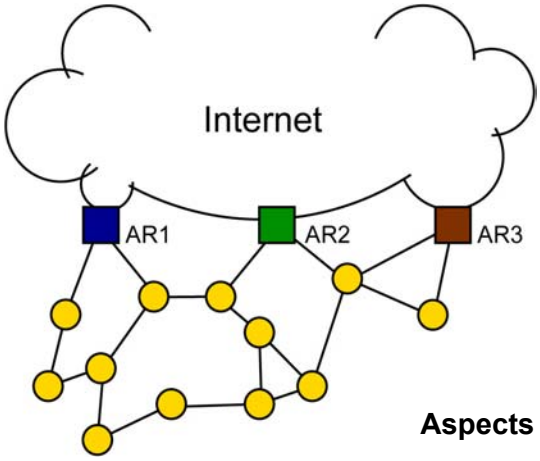


Interconnection of Ad Hoc Networks to the Internet

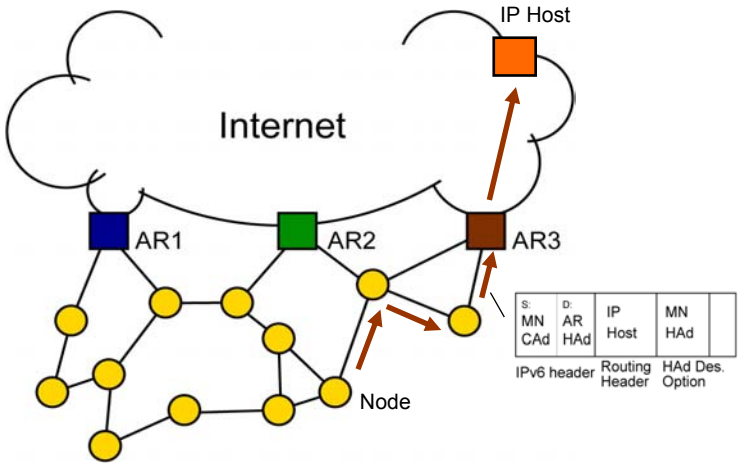


Access Routers

Aspects in the network layer

Mobile ad hoc nodes

Interconnection of Ad Hoc Networks to the Internet



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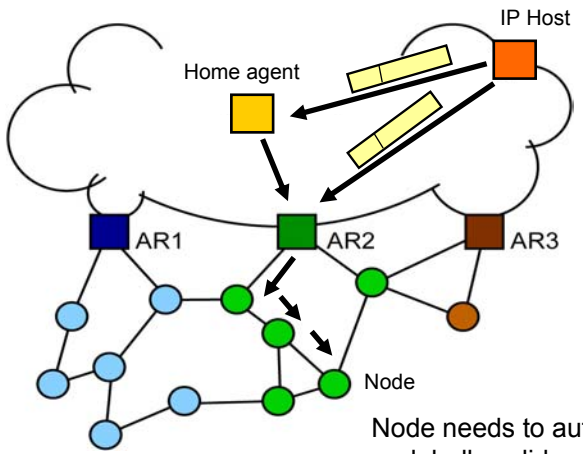

Node needs to auto-configure:

- globally valid care-of address with subnet prefix of AR
- local address valid in ad hoc network

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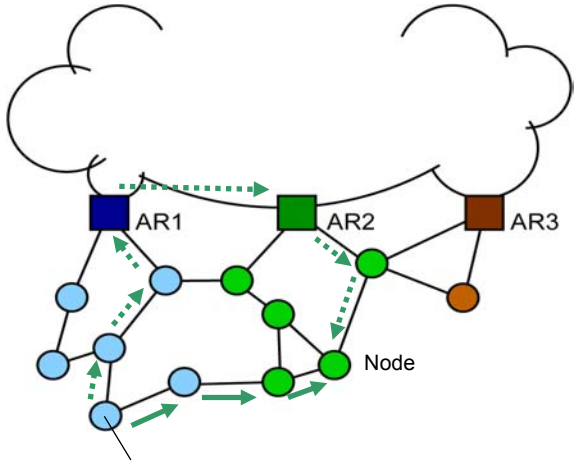
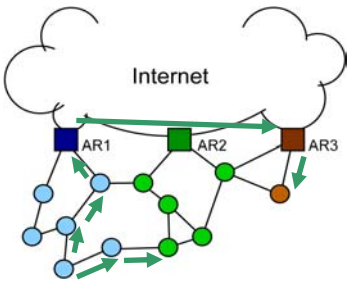


Path selection dilemma (if nodes are in different subnetworks)

Interconnection of Ad Hoc Networks to the Internet

- Investigated principles for AR discovery
  - with AODV (ad hoc on-demand routing)
  - with NDP (neighbor discovery)



- Designed a principle for route optimization by using three different IP addresses
  - home address
  - care-of address
  - ad hoc site-local address

  Presented our approach in the IRTF working group ANS

- Performance simulation with GloMoSim

Summary

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