Performance of randomized forwarding methods in large ad hoc networks

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- MAC and routing in ad hoc networks
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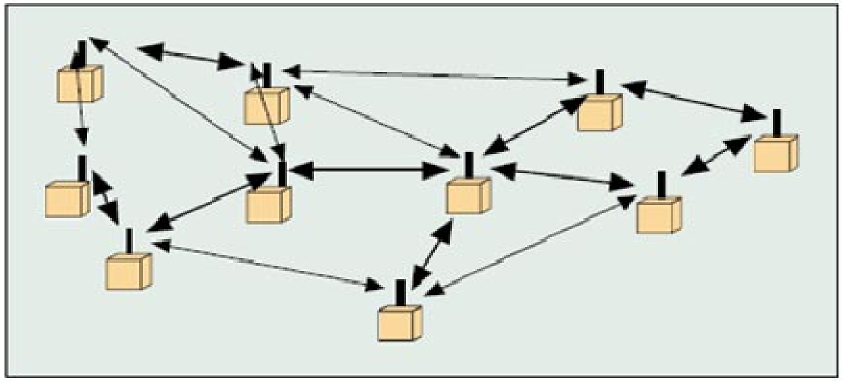
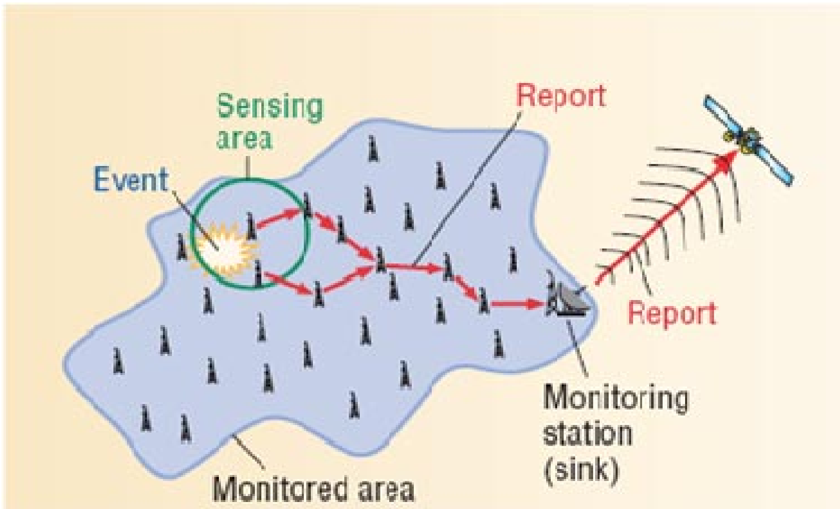
AD HOC NETWORKS

- Wireless nodes that communicate without fixed infrastructure or centralized control
- Multihop communications
  - Each node acts as a router
- Military and rescue applications
- Wireless sensor networks
  - Sensing, data processing and communications





OBJECTIVE OF THE STUDY

- Survey of MAC and routing methods in ad hoc networks
  - Clear classification and most important methods
- Simulation study to maximize network-wide throughput and to compare the performance of geographic forwarding methods in a large ad hoc network
  - Maximization of packet flow intensity with respect to network density and the slotted ALOHA transmission probability

MEDIUM ACCESS CONTROL

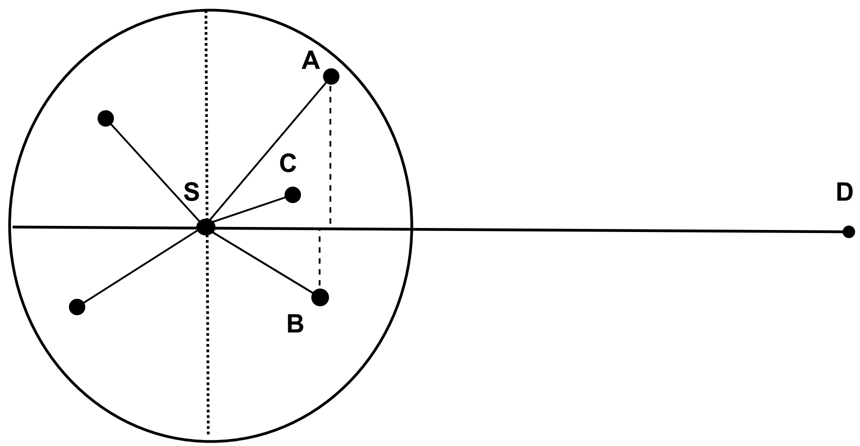
- MAC in early packet radio networks
  - Randomized access, no channel reservation
  - ALOHA, slotted ALOHA, CSMA
- Reservation-based protocols
  - Control packet exchange to reserve channel
  - MACA, MACAW, IEEE 802.11 DCF
- Power aware protocols
  - Power control, adjust power level to reach the receiver
  - Power management, allow nodes to turn off when idle, important in sensor networks
- Better performance by utilizing advanced hardware
  - Directional antennas
  - Multichannel transceivers

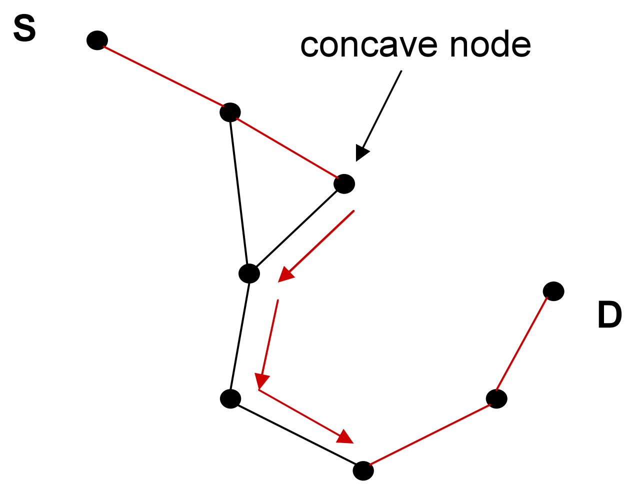
ROUTING

- Proactive protocols
  - Maintain an up-to-date network topology
  - Amount of routing traffic can be high
- Reactive protocols
  - Routes found and maintained on-demand
  - Less routing traffic but increased delay
- Hybrid protocols
  - Combine both proactive and reactive approaches
- Routing in sensor networks
  - Energy-efficiency, network lifetime maximization
  - Data-centric communications, the id of the original sender may be irrelevant
- Geographic routing

GEOGRAPHIC ROUTING

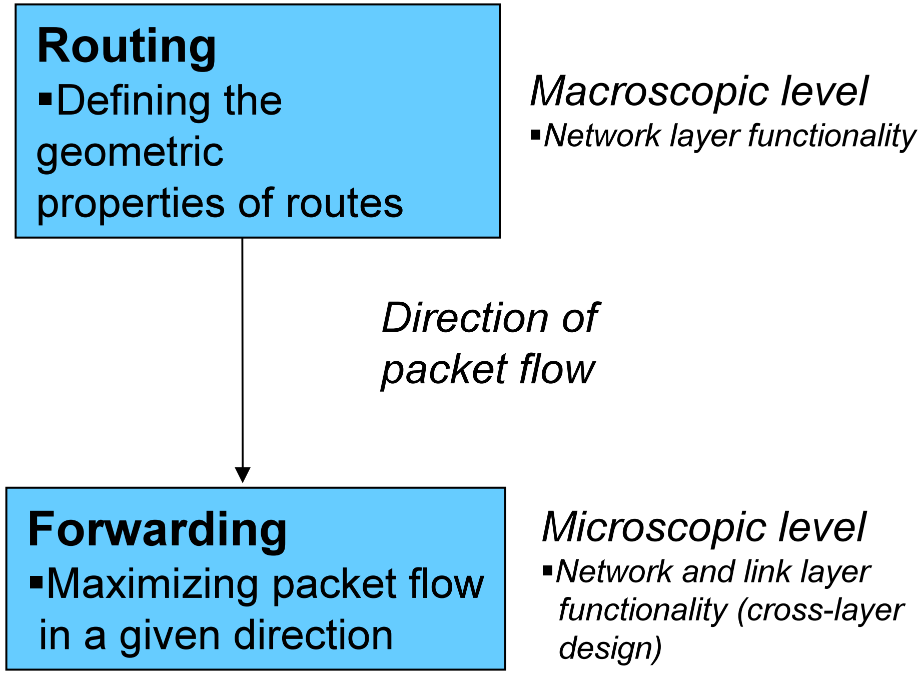
- Greedy forwarding
  - Progress(A), distance(B), angle(C)
- Routing around concave nodes
  - Face routing based on Gabriel graphs
- Location service
  - Responds to queries about the location of a destination





NETWORK MODEL

- Nodes distributed according to the two-dimensional Poisson point process with intensity λ
- Boolean interference model with a fixed transmission range R
  - Collision if a receiver hears more than one transmissions
- Slotted ALOHA MAC protocol with transmission probability p
- Each node knows its own and neighbors' location as well as the direction of packet flow



MEAN DENSITY OF PROGRESS

- The packet flow intensity is maximized

  $I = \rho \boldsymbol{v}_x$ [1/(m·s)],

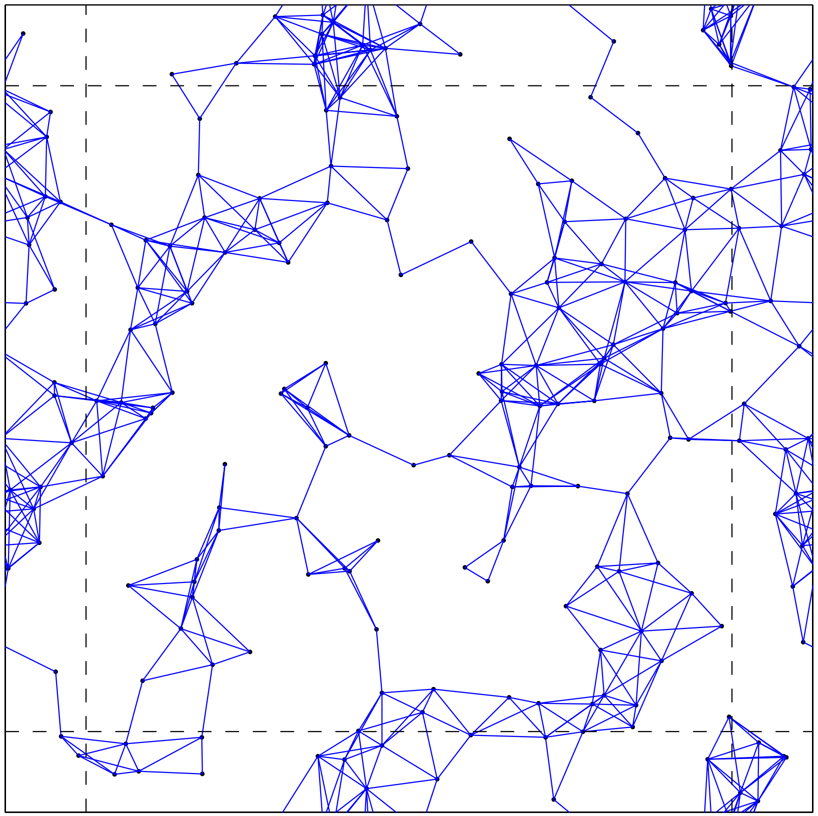
  where ρ is the packet density [1/m²] and $\boldsymbol{v}_x$ is the mean packet velocity projected to the direction of the packet flow
- Alternative definition for I: mean density of progress

  $I = (\sqrt{\lambda}/t)\cdot u(N_R,p)$ [1/(m·s)],

  where t is the time slot length [s], $N_R = \lambda\pi R^2$ is the average degree of a node and $u(N_R,p)$ is the mean progress of packets per time slot per node measured with $1/\sqrt{\lambda}$ as a unit length

SIMULATION MODEL

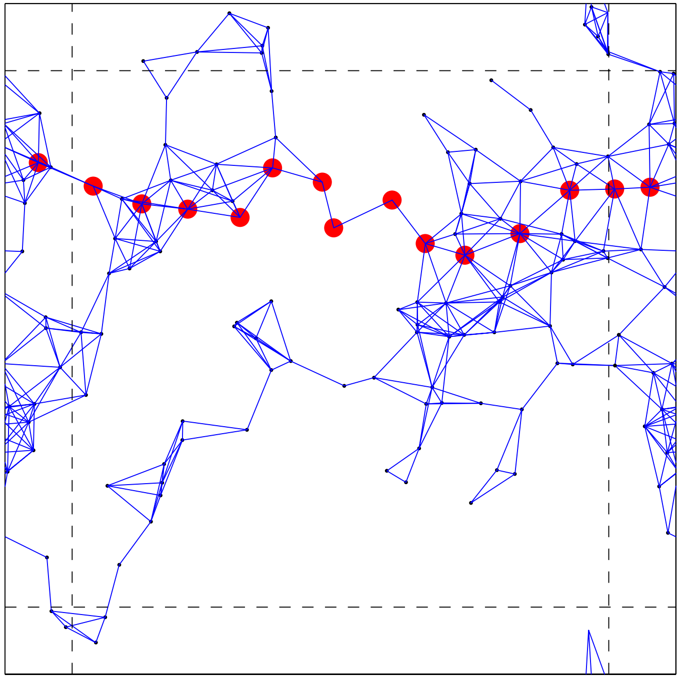
- Surface of the network plane seamed together into a torus
- Heavy traffic by initially placing 50 packets in each node
- Packets have infinite lifetime, no new packets generated
- Implementation using C++

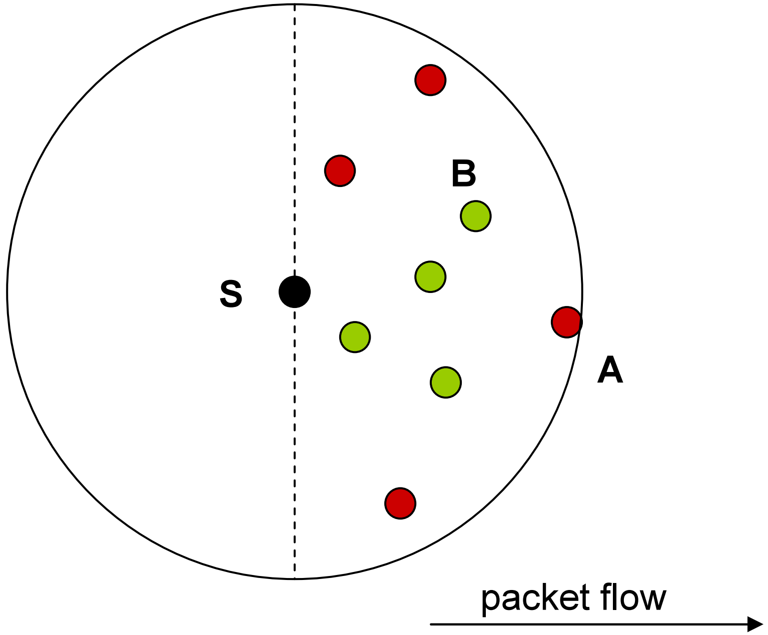


USED FORWARDING ALGORITHMS 1/2

- Most forward within radius (**MFR)**
  - Packet is forwarded to the most forward neighbor
- Random forwarding (**RF**)
  - Packet is forwarded to a random forward neighbor
- Weighted random forwarding (**WRF**)
  - Packet is forwarded to forward neighbor i with a probability q_{i} that is weighted with the progress from sender to i
- Opportunistic forwarding (**OF**)
  - Packet is forwarded to all forward neighbors
  - The most forward neighbor that succesfully received the packet accepts the packet, others drop it

USED FORWARDING ALGORITHMS 2/2



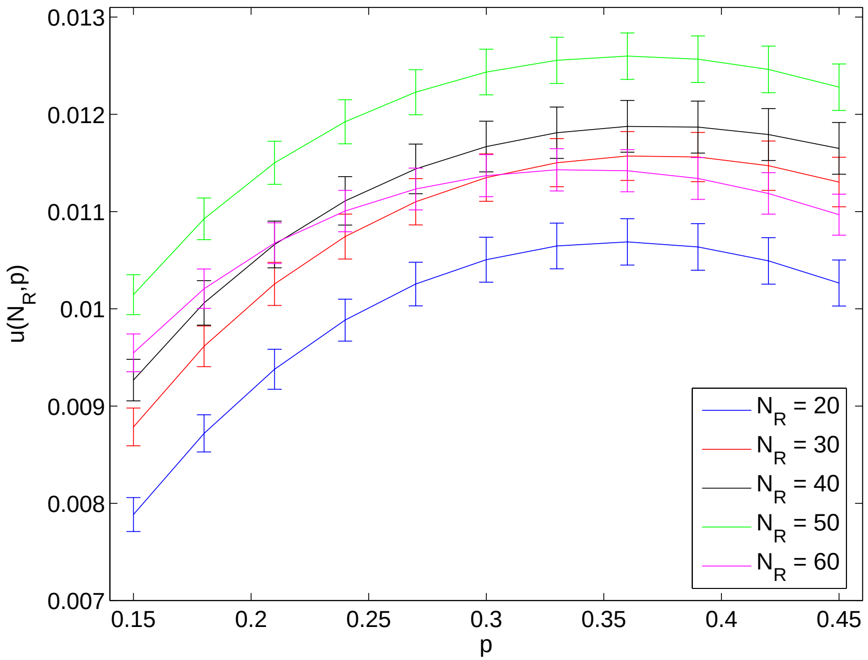


- MFR forwards packets into static paths

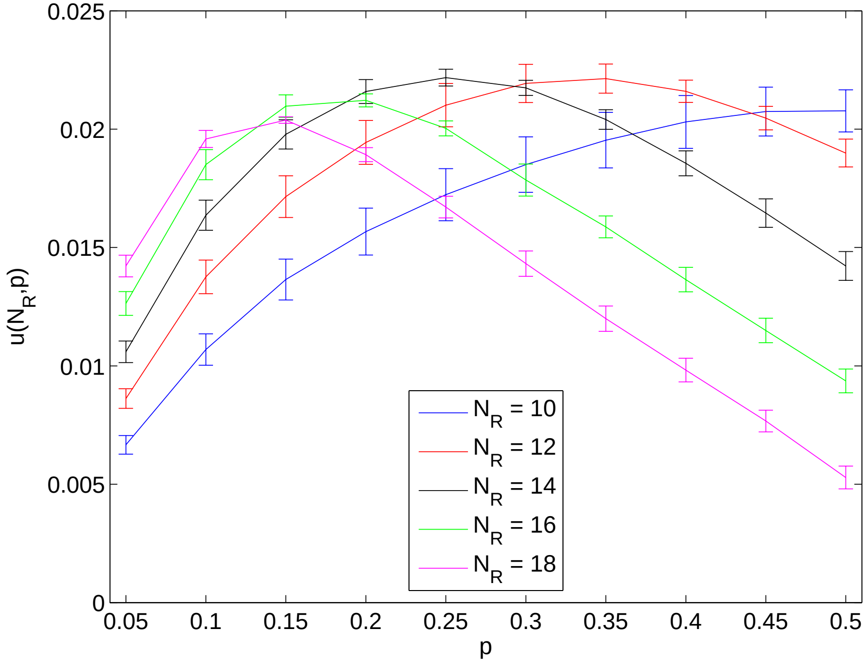
- MFR forwards to A, collision
- OF forwards to B, success
- RF may forward to any node, success probability 1/2

RESULTS 1/2

MFR

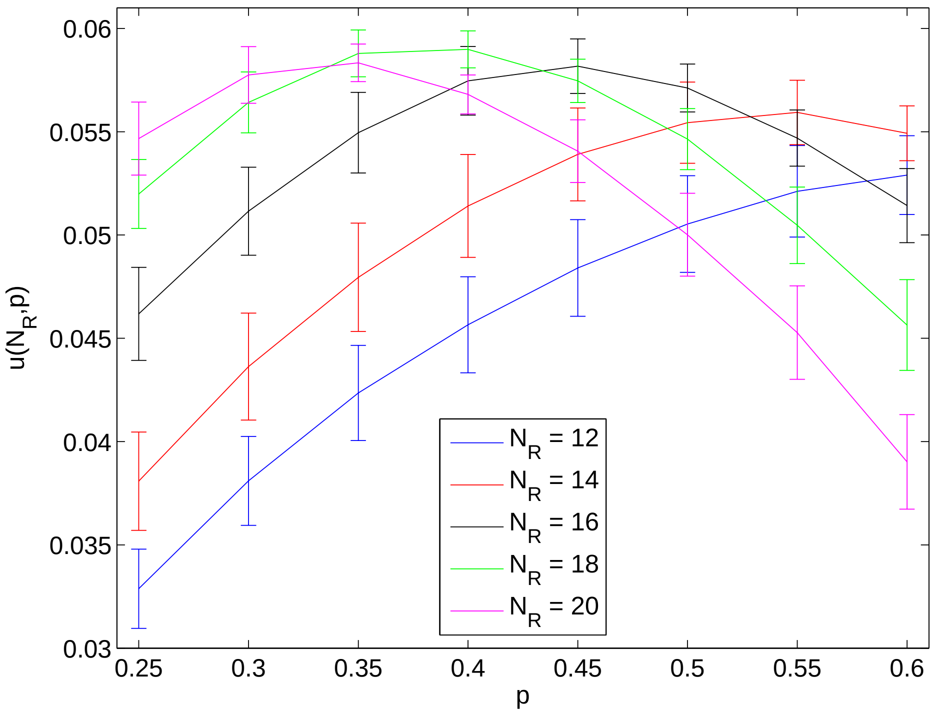


RF



RESULTS 2/2

OF

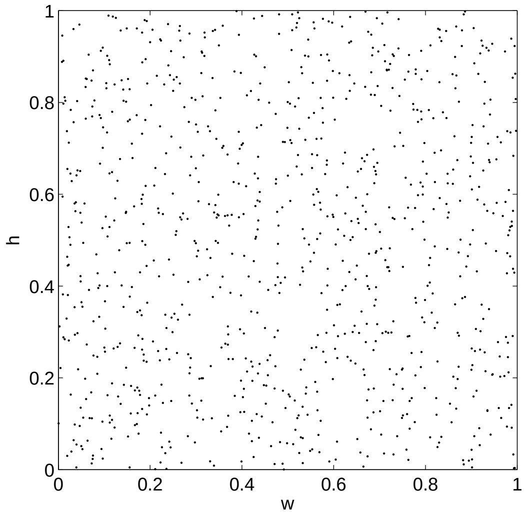


Maximum $u(N_R,p)$

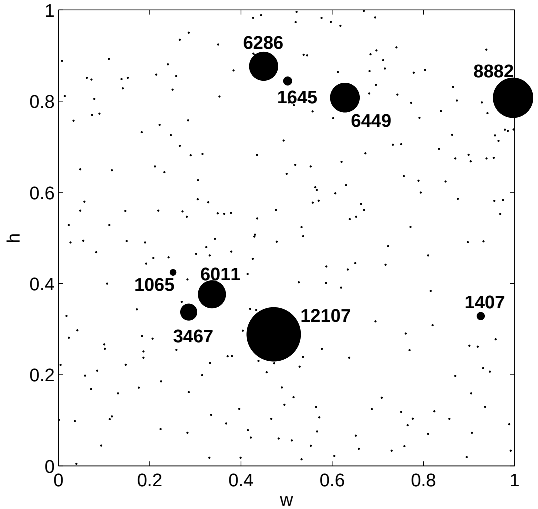
	$u(N_R, p)$	N_R	p
MFR	0.0126	50	0.35
RF	0.0222	14	0.25
WRF	0.0279	14	0.3
OF	0.059	18	0.4

- Opportunistic forwarding achieves clearly the best performance

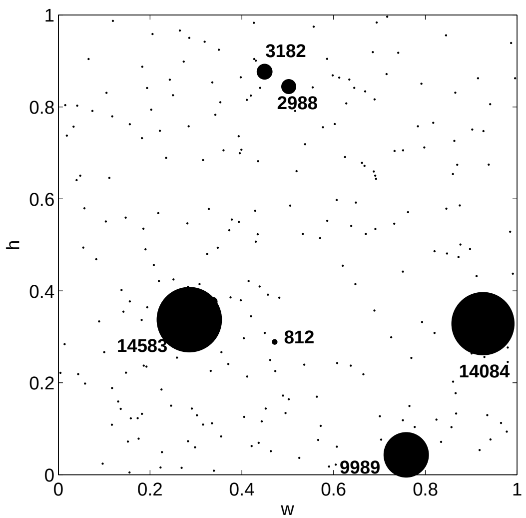
DISTRIBUTION OF PACKETS



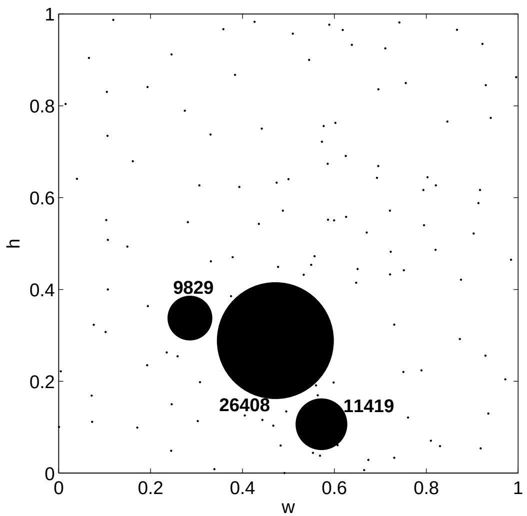
Node locations



RF



WRF



OF

CONCLUSIONS AND FURTHER WORK

- Randomized forwarding performs better than deterministic in a large ad hoc network
- Opportunistic forwarding improves throughput significantly
- Potential further work:
  - Take also into account the queue sizes at neighboring nodes when forwarding
  - Effect of power control
  - Effect of a more realistic interference model
  - Effect of node mobility