Efficient multi-hop broadcasting in dense nanonetworks

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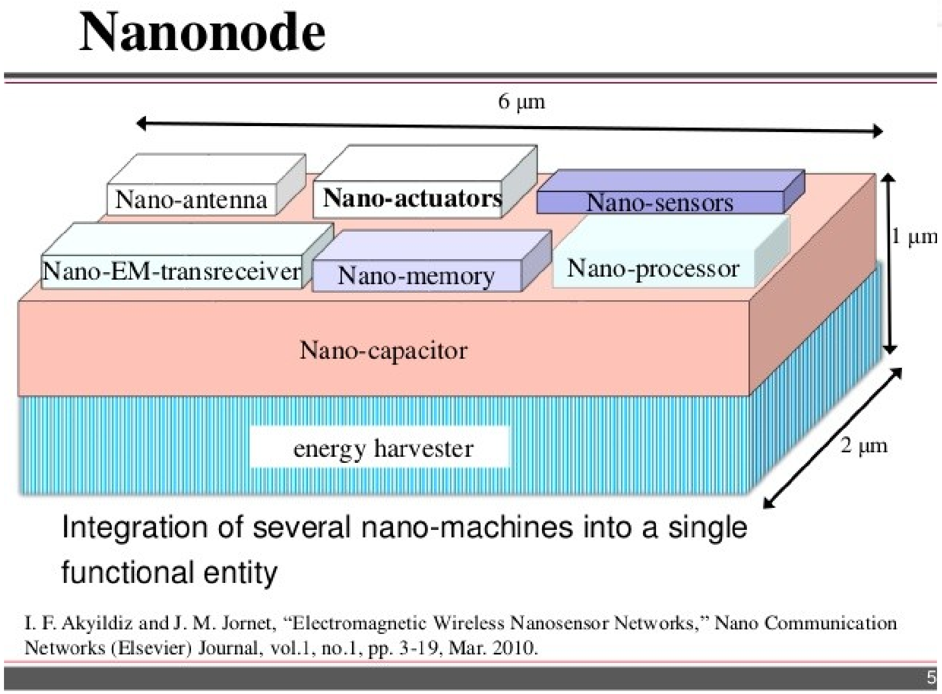
THz wireless nanonetworks

- Small communication range: ~cm
  => Need multi-hop for longer comm distances

- Nanonodes have not yet been built because of technological challenges
  => Need to develop simulation tools

- Nanodes have unusual characteristics:
  - specific modulation (TS-OOK)
  - specific collisions
  - ...

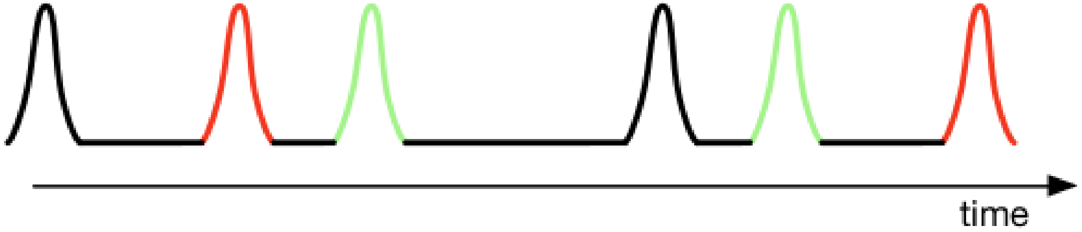


Complete machine of µm size

TS-OOK

- To send bits ”1” sender sends pulse, while for bits ”0” a silence is used
  Pulses are very short (e.g. ~100 femtoseconds)

- Pulses from a given frame are spread over a period much bigger than the pulse duration (e.g. 1000 times longer)
  This high spreading ratio makes frames from different communication overlap



- At this scale, node positions influence the reception date
  => the propagation delay (speed of light) cannot be neglected in studies

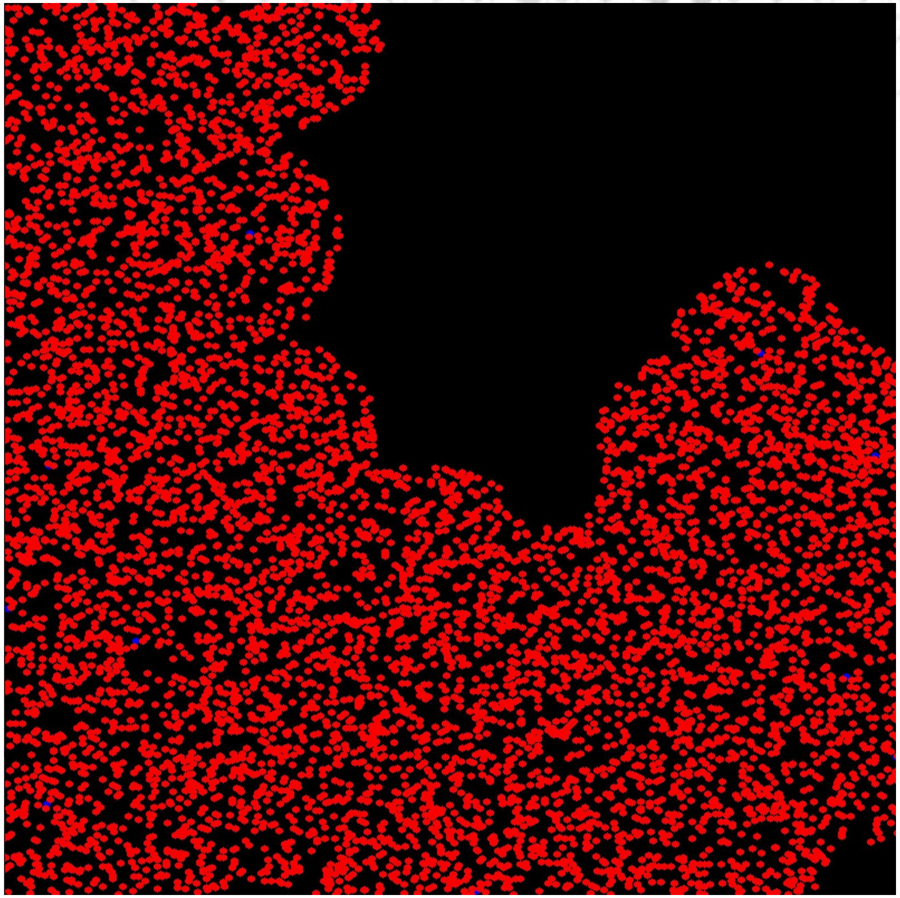
Our problem: overcrowding

- A possibly huge number of nanonodes
- Even with very small communication range nodes can have thousands of neighbours and much more
- To transmit an information to whole network: broadcast
  - Pure flooding: all nodes repeat the message, a lot of resources are wasted
    - energy
    - chanel usage
- Some technique are needed to replace the naive pure flooding approach in order to reduce the number of forwards in broadcast in THz nanonetworks

Historical solutions:
Adaptive probabilistic flooding

- Use probability to broadcast a packet
- The number of forwarded message is fixed and tune the probability
- Very simple

  p = f /n
  p the forwarding probability
  f the desired number of forward
  n the number of neghbours
- Zero memory footprint
- May cause die out

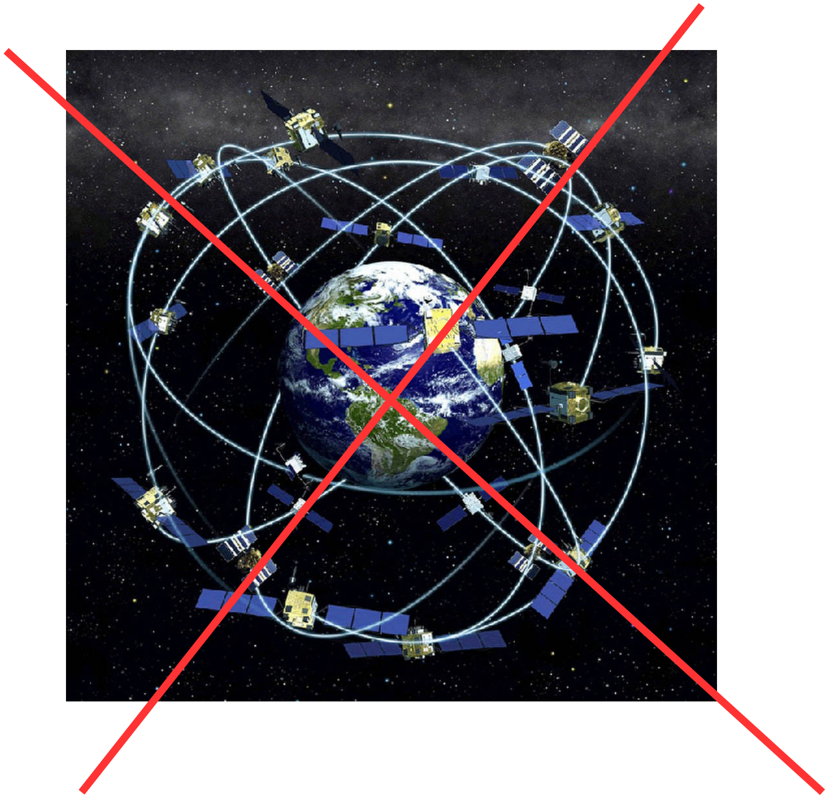


Historical solutions: Geoforwarding and OLSR

- No GPS => No geoforwarding
  Nodes are too small to embed GPS

- No infrastructure => No relative positioning

- No memory => No OLSR
  Too many neighbours to select precisely
  Maybe no unique IDs



Historical solutions:
Adaptive counter-based schemes

- Counting the number of transmissions to take the forwarding decision
- Backoff and wainting time not appropriate
  Have to be tuned correctly
- Density in nanonetworks varies widely
  Needs to take density into account
- Backoff flooding is adaptive counter-based

Our solution: Backoff flooding

When a node receives a packet it waits for a random time and check the number of copies he receives during this time. If the number of copies is below a threshold r, the node forwards the packet and otherwise drops it

- Waiting time:

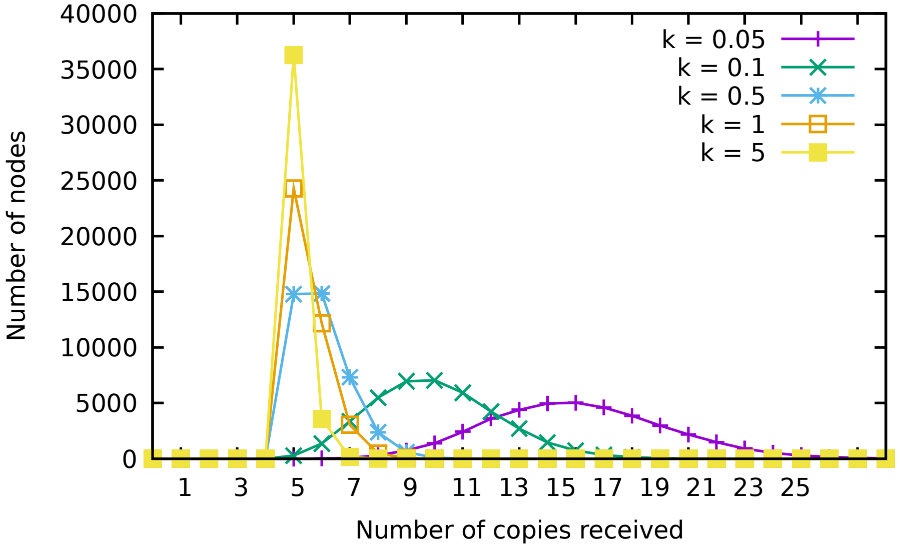
  twait = n * k * 2(Tpkt)

- n the number of neighbours and k is a multiplier factor discussed later
- 2(Tpkt) is the time for the furthest neighbours to receive and send back the packet
- r is the redundancy threshold: the number of copies that should be send

Properties: Window size

- Theoretical results
- k determine the number of copies received
- The number of copies seen be each node should be 5
- When k becomes too small, the waiting time before transmitting is not large enough and nodes forward the message before noticing that 5 copies have already been sent

neighbours: 1150
twait: 8 nanoseconds
r: 5 (fault tolerance)
k: various values



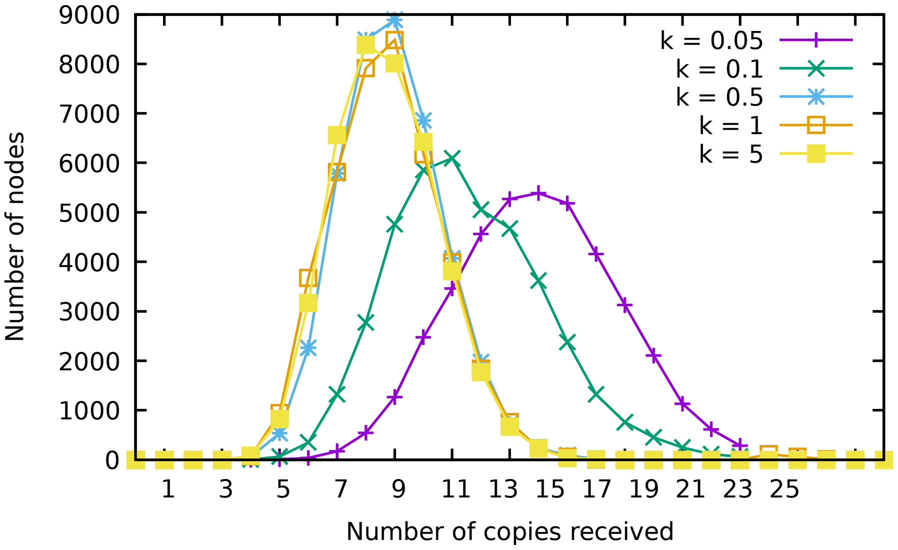
Properties:
Number of copies received

- The number of copies received is higher when simulated due to the “geographical effect”

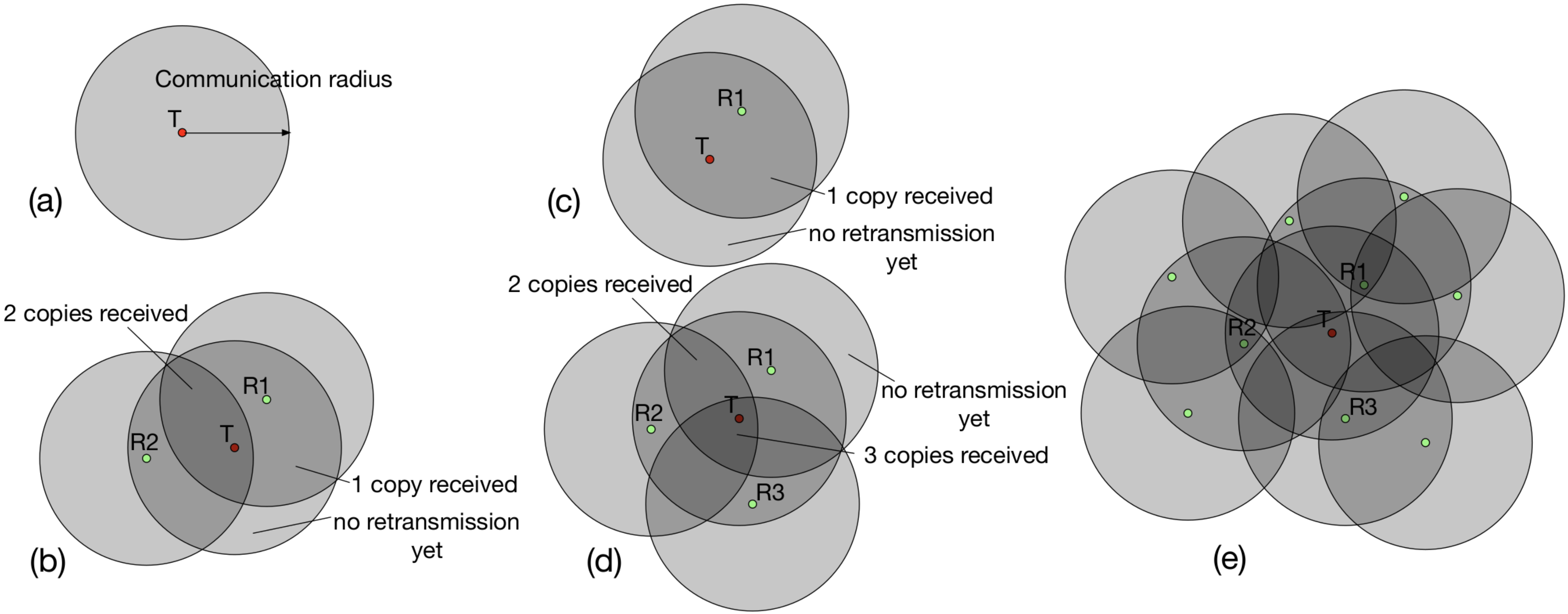
- Even with high waiting time, nodes receive more than r copies of the packet

- No node received LESS than r copies of the packet

neighbours: 1150
twait: 8 nanoseconds
r: 5 (fault tolerance)
k: various values



Properties: Geographical effect

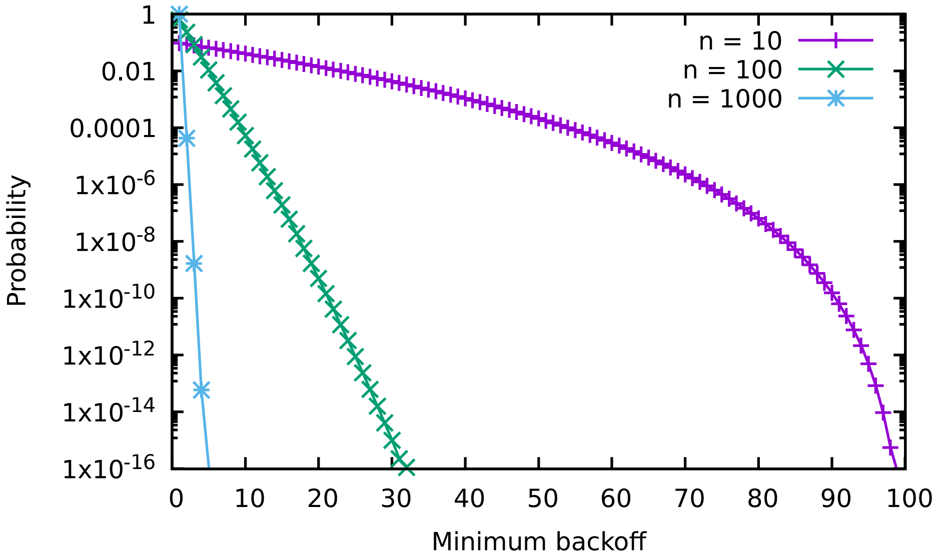


Properties:
Minimum backoff probabilities

- Different node densities

- Show the probability for the minimum backoff (the first transmission) to be at x^{th} percentage of the window

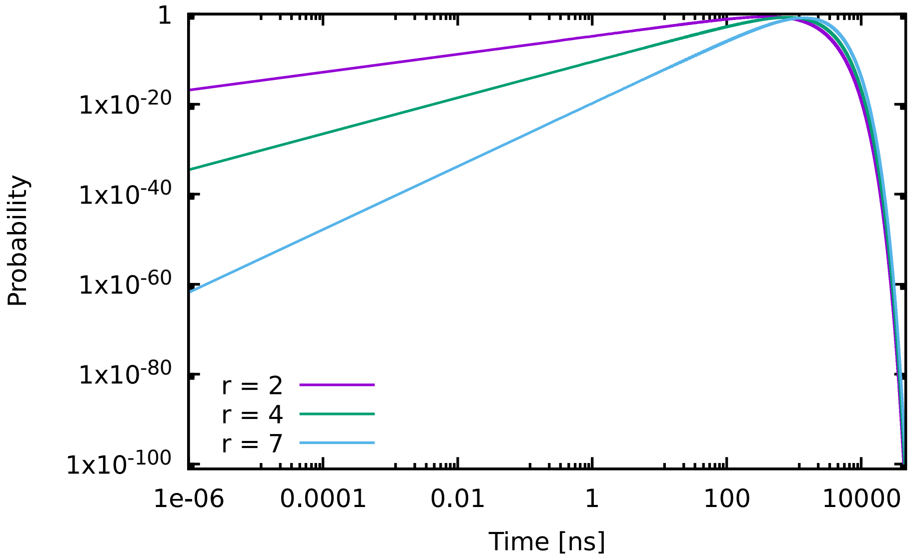
- The probability quickly decrease: the mean backoff is lesser than the usual window / 2
  => Because the message progress with the minimum backoff among neighbours



Properties: Delay

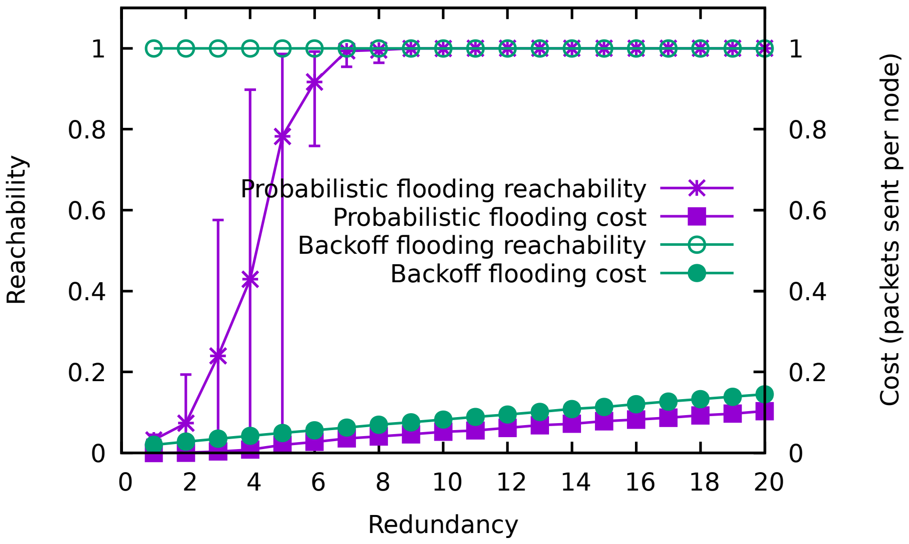
- Backoff flooding induces a predictable delay
- Figures represent the probability (y axis) for the rth node to transmit its copies after the time of the x axis
- Most of the probable vaules are in a narrow range. And the redundancy does not affect the delay
- It is a small percentage of the total window

neighbours: 1150
twait: 8 nanoseconds
r: various values
k: 1



Properties: Reachability

- Reachability comparison between probabilistic flooding and backoff flooding
- Backoff flooding is steady and reaches the whole network even with a redundancy of 1
- The backoff flooding sends fewer packets than the probabilistic flooding to reach the whole network



Conclusion

- Backoff flooding is a counter-based forwarding scheme adapted to nanonetworks
- Guarantees a minimum number of forwards
- Limits the number of forwarders
- Very high reachability
- Takes network density into account => Needs neighbours information
- Introduces a small and predictable delay
- Does not need any location system
- No die out problem, even with low redundancy
- Future work => Sleeping node: femtoseconds cycles