Receiver Based Forwarding for Wireless Sensor Networks

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Context

- Routing/Forwarding in wireless networks is different from wired world
  - What is a link?
- Most protocols however create, maintain, and use link tables for routing
  - At each step the sender chooses an ‘outgoing link’
  - Many problems arise

Wireless Links

- Links are not binary

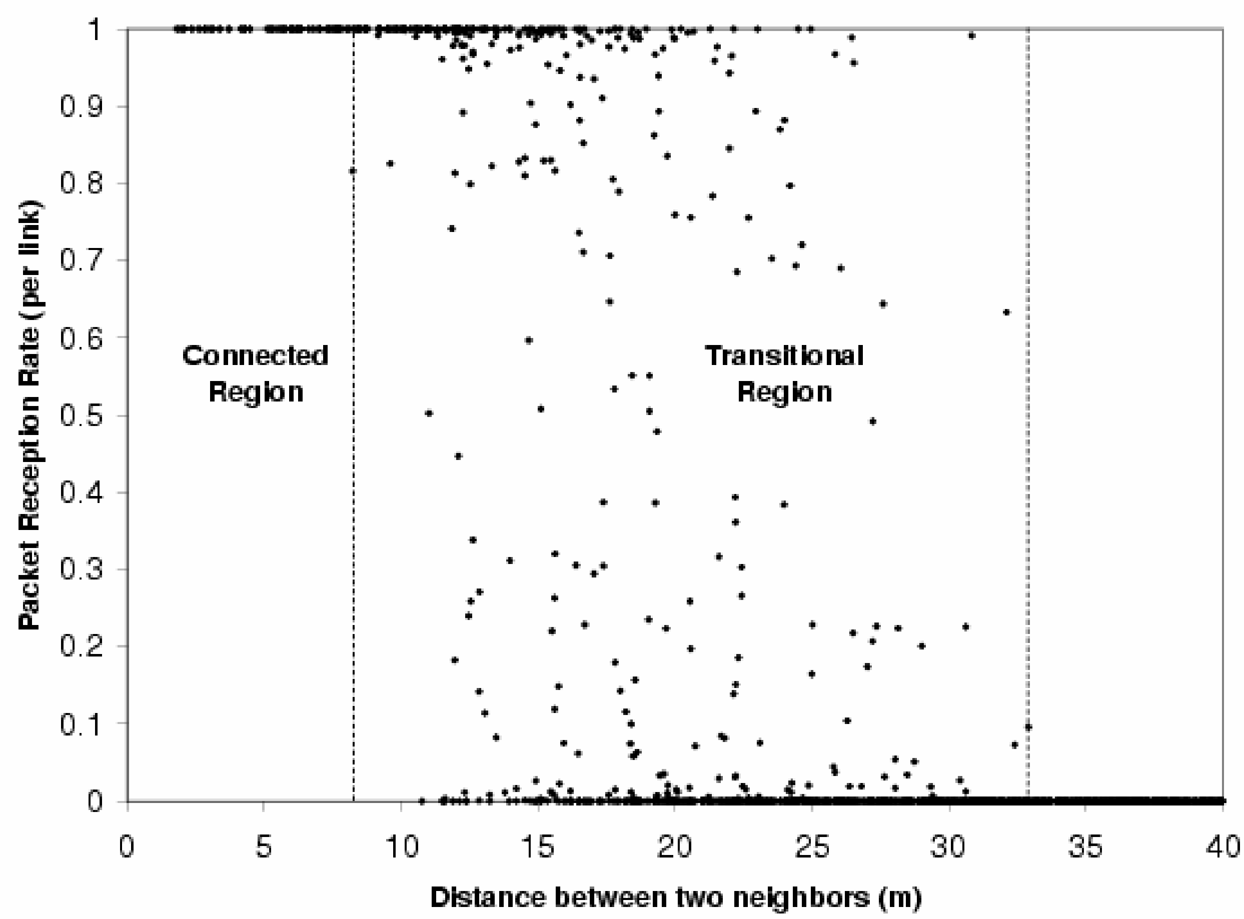


Image borrowed from Seada et al., Sensys 04

Wireless Links

- Links are not binary
- Further nodes may make more progress
  - If not careful, will pick long, unreliable links
  - Want to use nodes in the transitional region
- Distance-energy tradeoff
  - If one maximizes progress, too many retransmissions
  - If one maximizes reliability, too many transmissions
- State of the art routing takes quality and progress into account
  - ETX (DeCouto; Woo; Draves)
  - Requires quality estimation, link ‘caching’

Some problems

- Nodes are very resource constrained
- Need to keep a notion of neighborhood, with limited memory
  - Which subset of neighbors to keep?
  - Link quality estimation depends on storing history information
- Dynamic environment
  - Link estimation has to balance stability with reaction time to changes

Receiver-Based Forwarding

- Receiver-based forwarding techniques
  - Proposed in several works
    - MIT's Opportunistic Routing (Biswas & Morris)
    - Virginia's IGF (Blum et al.)
    - Geraf (Zorzi & Rao)
  - Receivers decide whether or not to forward
  - Applicable to a family of gradient routing protocols
    - Geographic, Pseudo-Geographic, Tree Based, Distance Vector Like

Our Study

- Focus on greedy geographic routing only
- Difference: one phase protocol, no extra control traffic
- Comparison with traditional, sender based approach
- Simulation and real implementation
  - Reliability, Latency, Cost, Security

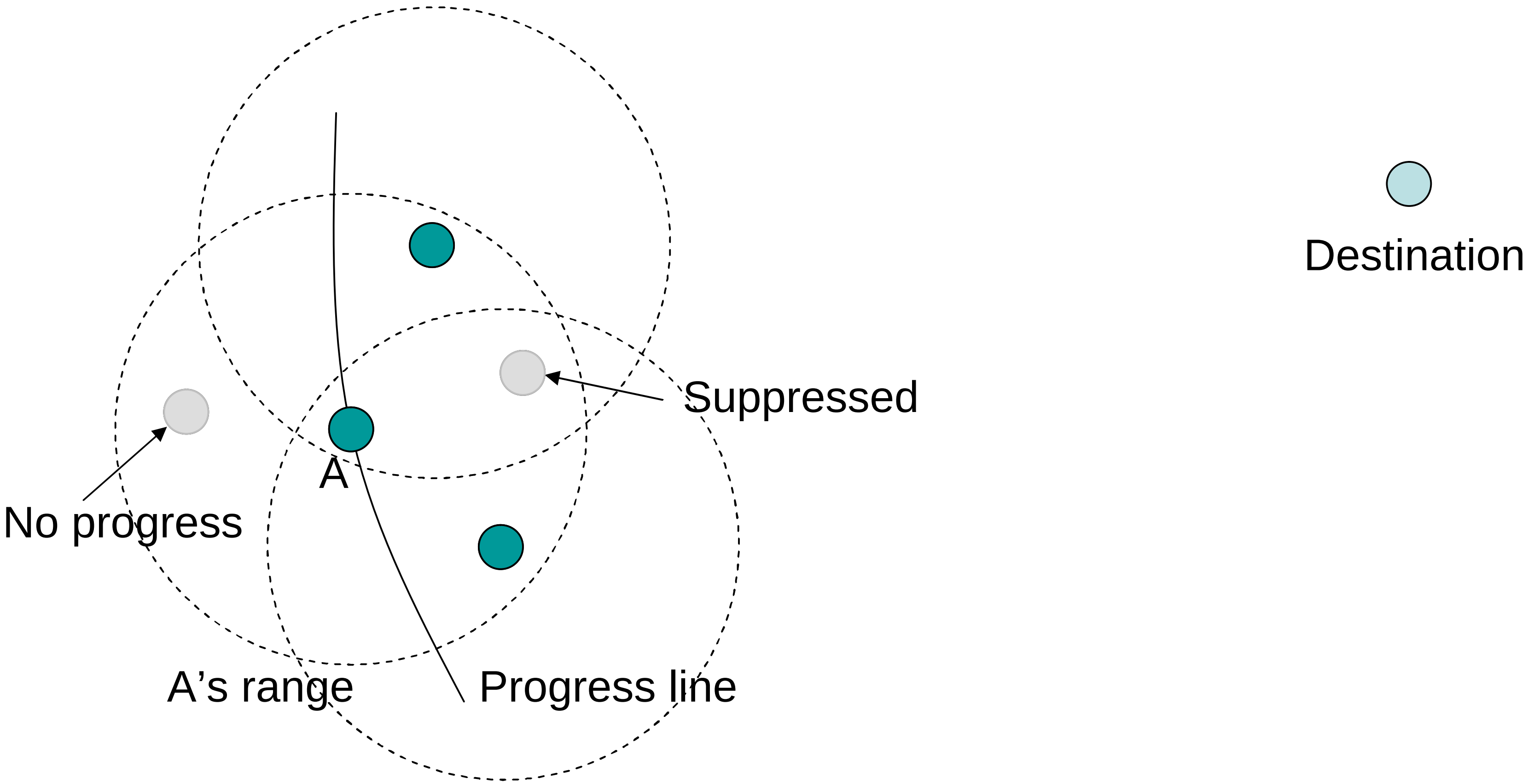
Traffic Assumptions

- Sensor network traffic
  - Low channel utilization, small packets
- Metrics of most interest
  - Energy, reliability, latency
  - Throughput not the major concern

RBF Protocol

- Sender broadcasts
- Receiver determines if elligible (progress)
- Receiver sets a timer for retransmission
- If another retransmission is heard, cancel timer
- Keep messages heard in a cache

RBF Protocol

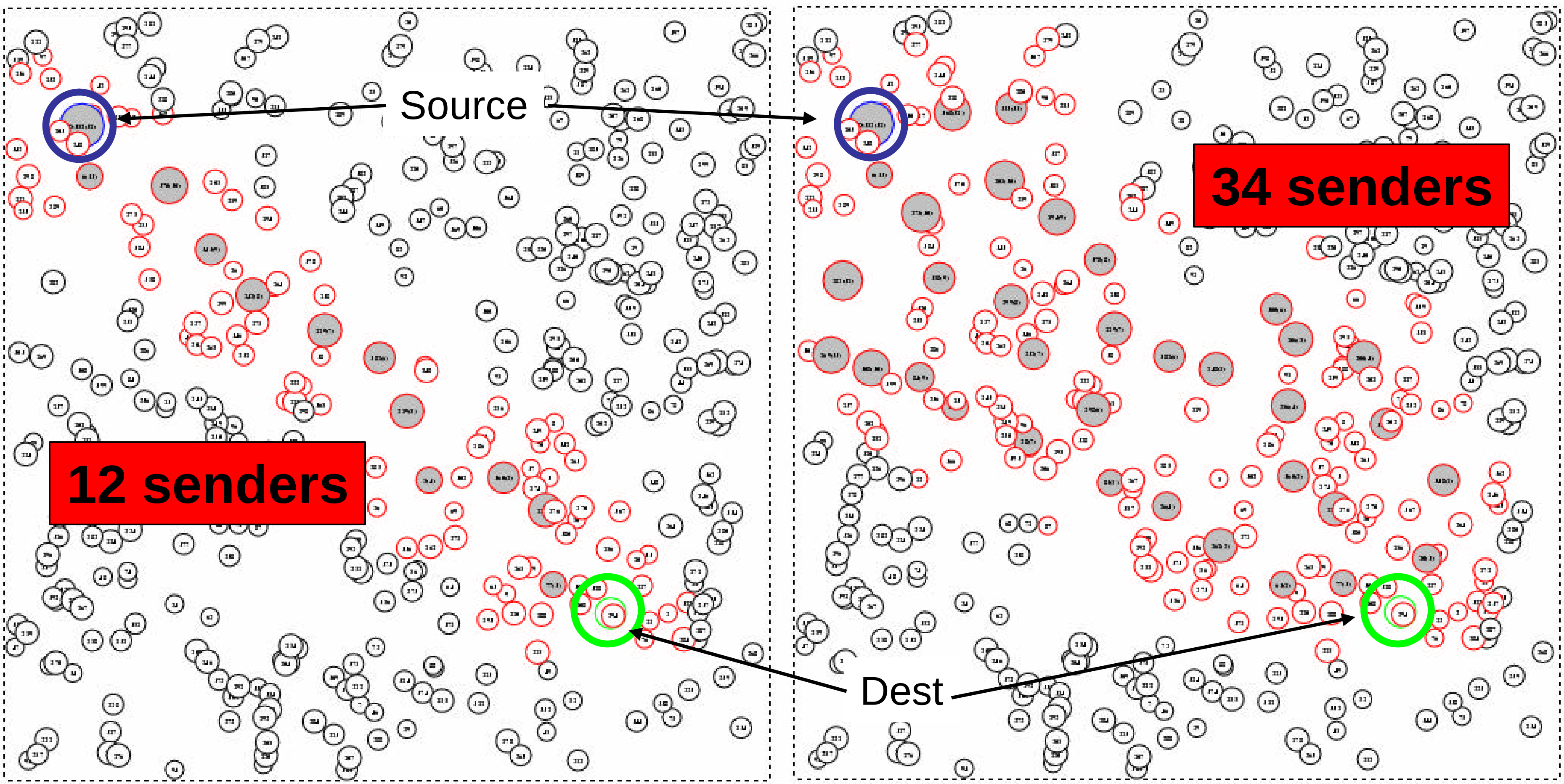


Challenges

- Control the number of messages
  - Hidden terminals will not suppress eachother
    - Sender can help by sending suppress ctl msg
  - Setting the timers
    - Random
    - Based on progress (closest fires first)
    - ...?
  - Caching is important to avoid duplicates
  - Experimental validation with real radios fundamental

Sample Route
(400 node simulation)

- Sender Based
- Receiver Based



Advantages

- Simplicity
  - Only knob is how to set the timer
- No state required
  - No neighborhood maintenance, link estimation
- Less retransmissions required
- Reliability
  - Multiple paths
- Low density/sleep cycles accommodated
- Security
  - Nodes can only do harm by actually transmitting the right message

Disadvantages

- Multiple paths
  - Extra transmissions hard to avoid w/o sender coordination
- Aggregation is not trivial
  - But there is recent work on duplicate resilient aggregation (Gibons et al., Sensys 04)

Results

- Simulation
  - Ideal radios (circular range, no interference
  - Varying network size and density
    - 50 ~ 1000 nodes, 12 to 20 neighbors
- Summary
  - Better delivery rate, specially with lower density and larger networks
  - Similar average hopcount
  - Energy between 2 and 3 times worse
- Poster with more details

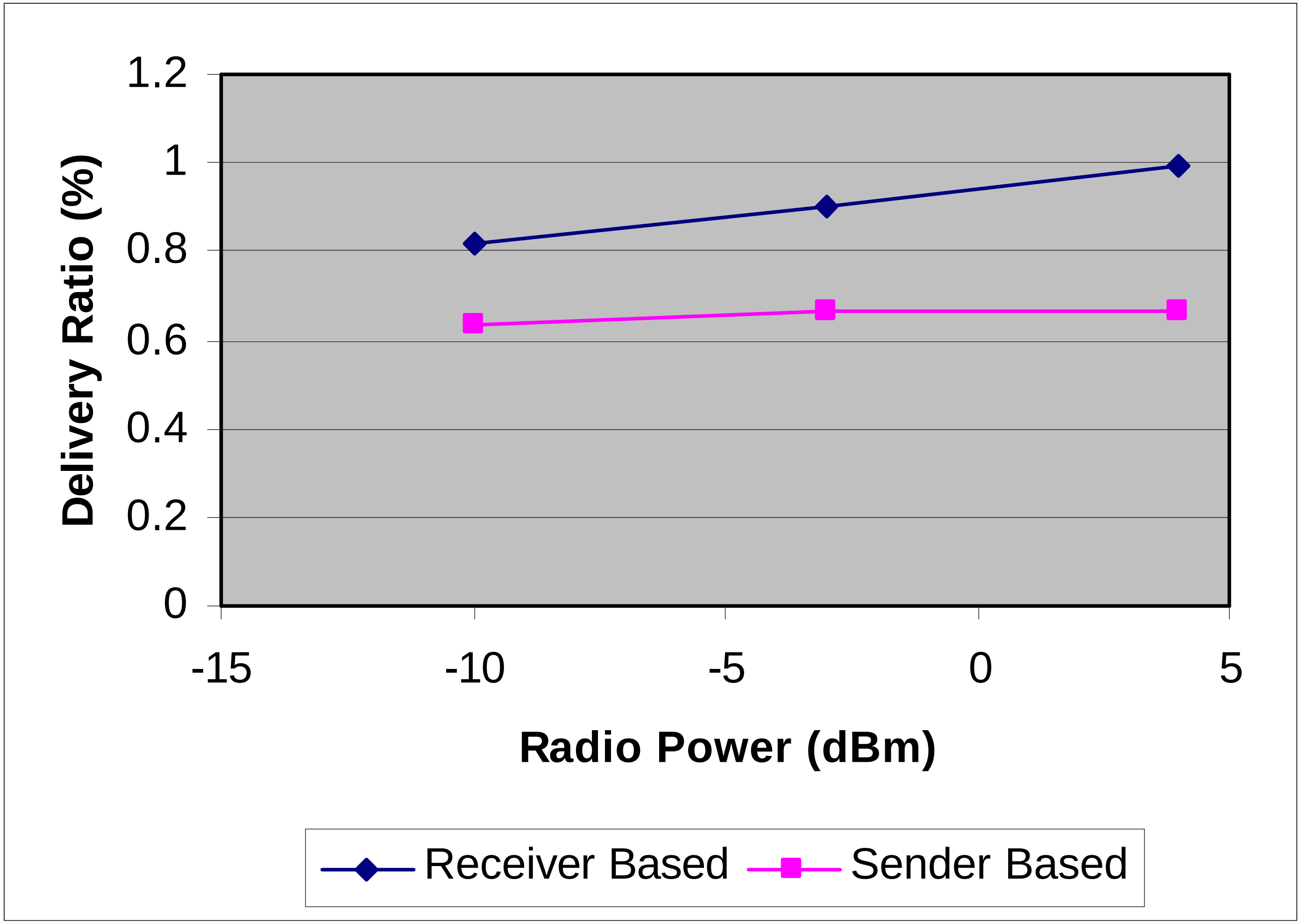
Experimental Results

- Implementation on TinyOS, mica2dot “motes”
  - 4Kb RAM, ~4KHz 8 bit processor, CC1000 Radio
- Sender Based
  - Greedy geographic forwarding, link quality estimator, max neighborhood cache size of 18 nodes per node
  - Sender chooses next hop with largest progress X quality metric (Seada et al. 2004)
  - 5 retransmissions per node, choose next best after failure
- Receiver Based
  - Random timers, uniformily between [0~500ms]
  - No sender suppression (suppression only from neighbors)
  - No retransmissions

Experimental Setup

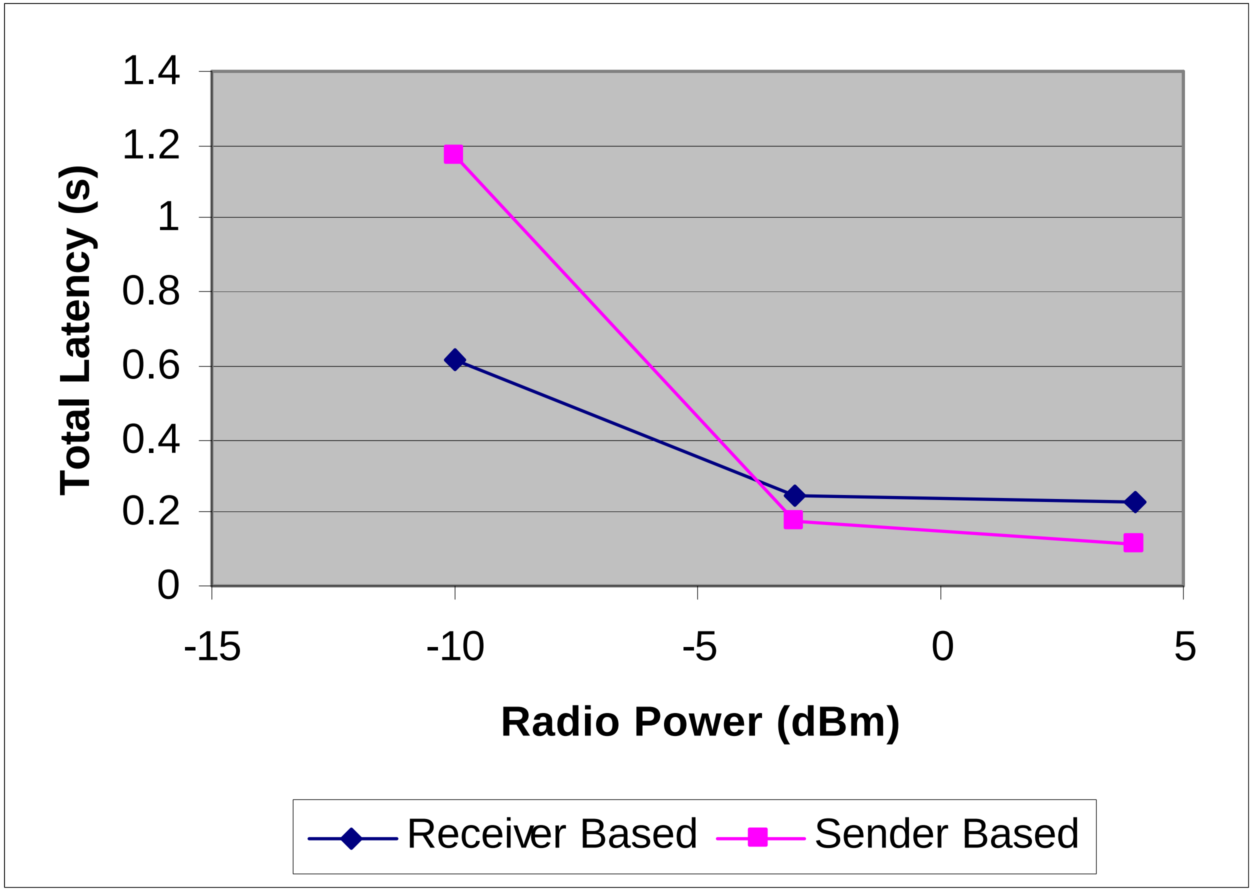
- 52 node testbed, Intel Research Berkeley
  - Office space, approx. 13x50 m
- Varying radio power (~ network density)
- Pairs selected at random, one node from each of two groups of nodes
  - Average distance 30m

Delivery Ratio



RB 20 to 30% better

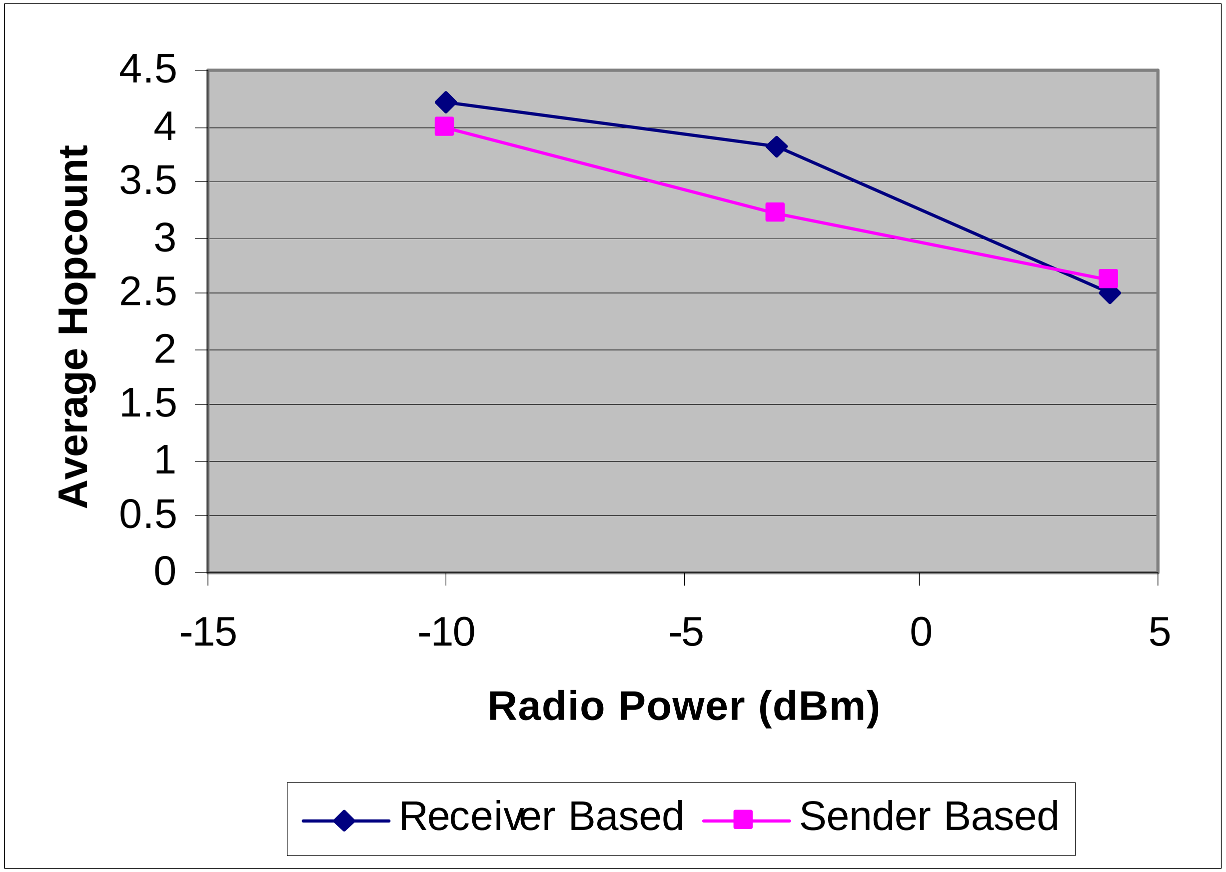
Latency



- **Time for the first packet to arrive at the destination**
- Recall that the sender based approach has to do retransmissions

Similar Latency, better at low density

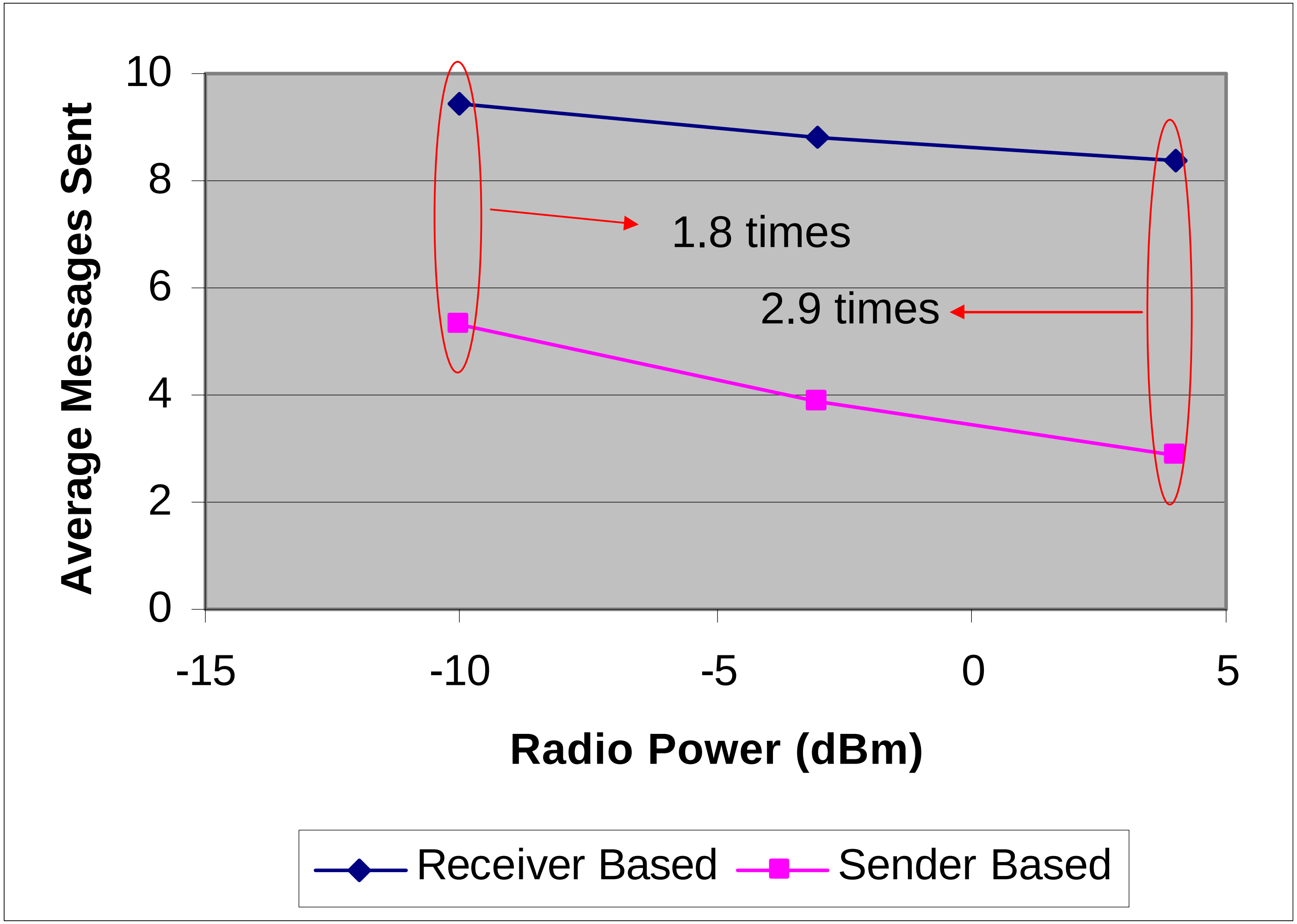
Average Hopcount



- **Hops traversed by the first packet to arrive at the destination**

Similar hopcount

Energy spent



2 ~ 3 times more , better in less dense networks

Conclusion and Future Work

- Receiver Based Forwarding is a good candidate for many applications
  - Good for use with sleeping cycles
  - Tendency to use nodes in the connectivity transition zone, *when the "links" work*
- Generalize to other routing protocols
  - Beacon Vector Routing
  - Tree aggregation

Thank you