Low-Power Wireless Links

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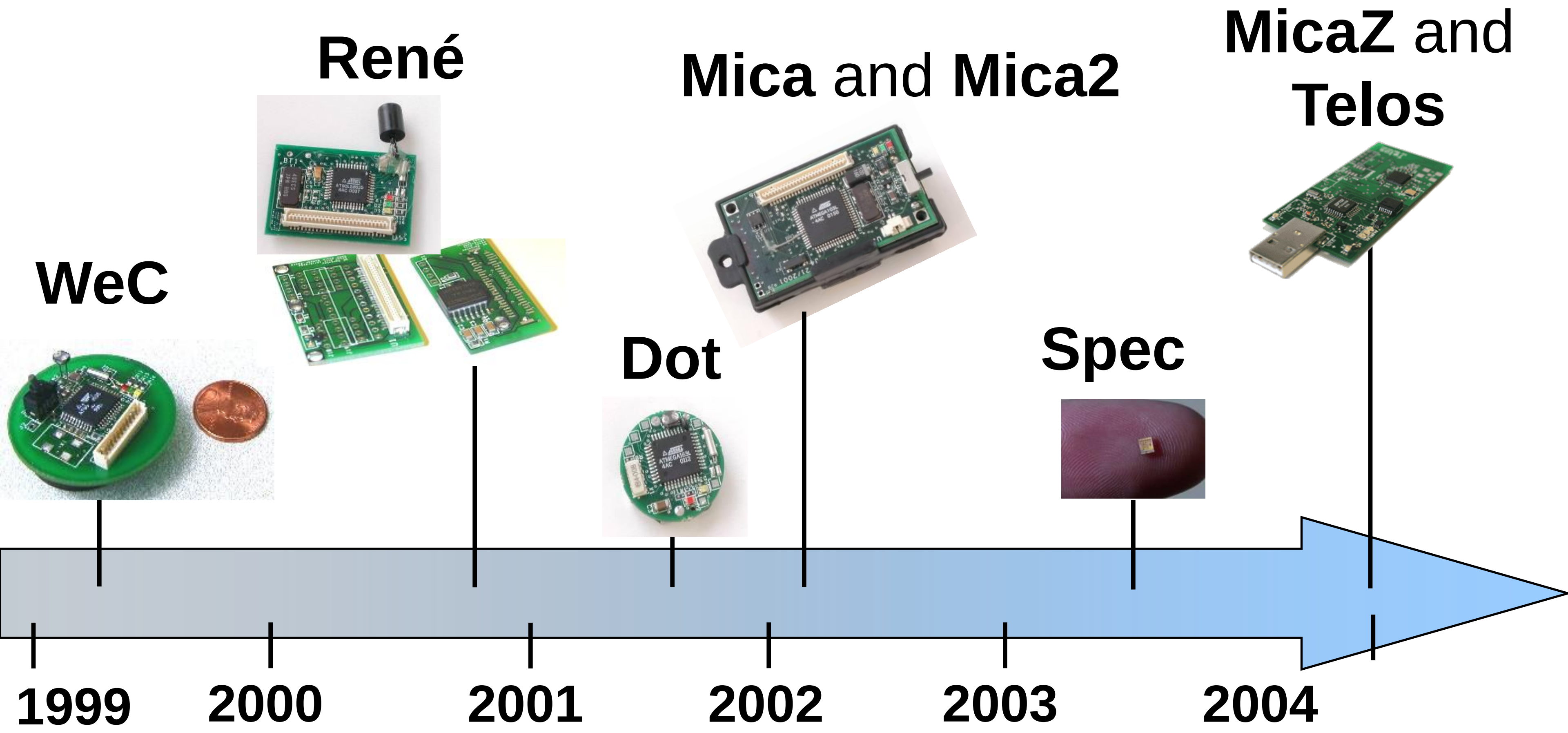
Berkeley Motes Timeline

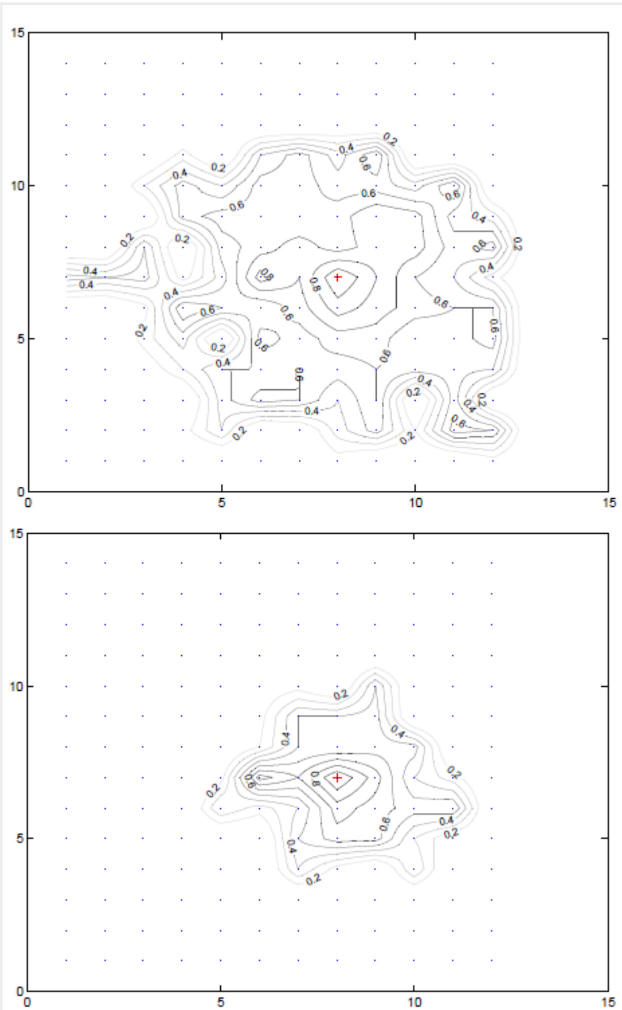


Adapted from Joe Polastre, Designing Low-Power Wireless Systems

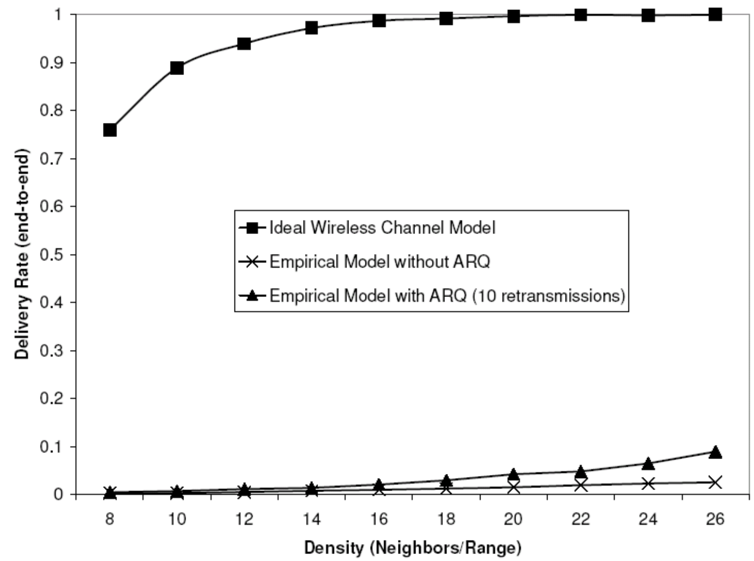
Inherent challenges

- Low-power radios are exposed to all sorts of RF phenomena
- Wireless links...an oxymoron?
- Single-hop or multi-hop?
- Even non-RF physical phenomena may impact communication

Disk Model?



- No such thing for WSNs!



• K. Seada et al., "Energy Efficient Forwarding Strategies for Geographic Routing in Wireless Sensor Networks," ***ACM Sensys*** **2004.**

• D. Ganesan et al., Complex Behavior at Scale: An Experimental Study of Low-Power Wireless Sensor Networks, UCLA Tech Rep 2002

Dealing with RF

- Low-power transceivers are even more vulnerable to the vagaries of RF propagation
- Path loss: power loss due to distance between rx and tx
- Shadowing: power loss due to the presence of an obstacle
- Reflections: wave hits a surface and part of the energy bounces back, part goes through
- Fading: several reflected paths make it to the rx

Flavors of Fading

Dynamic Fading

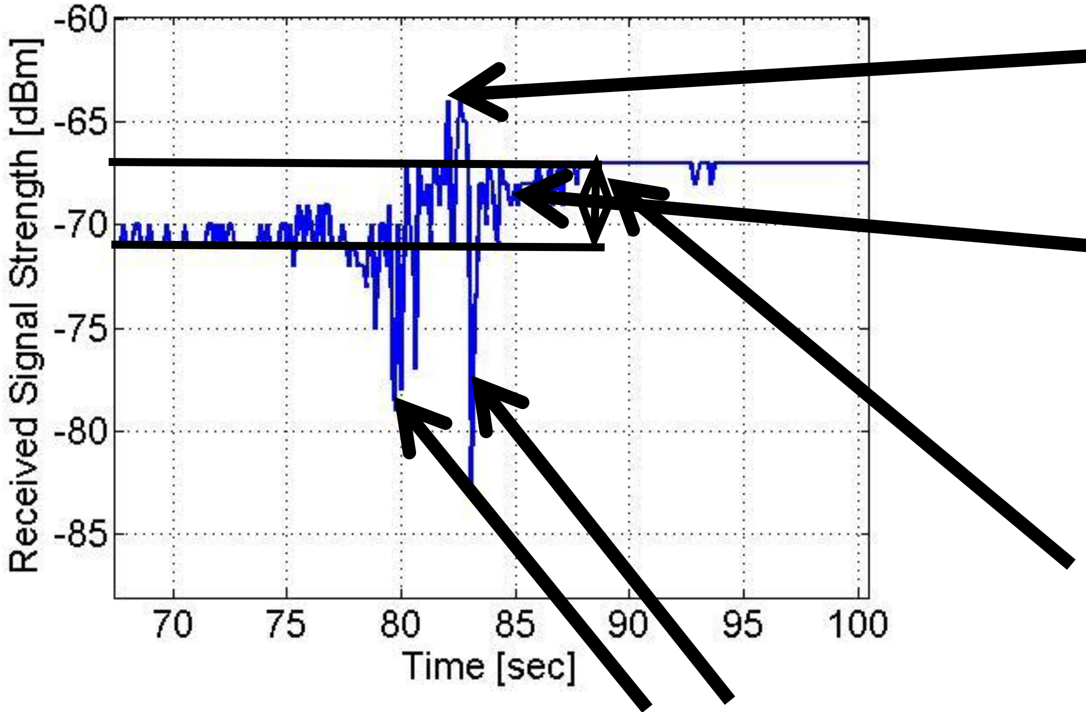
- Nodes in motion relative to one another
- Fading patterns naturally change
- Comes with changes in the path loss as well

Static Fading

- Fading patterns change only if the area layout changes

Induced Fading

- Fading patterns are temporarily modified by the motion of people or objects

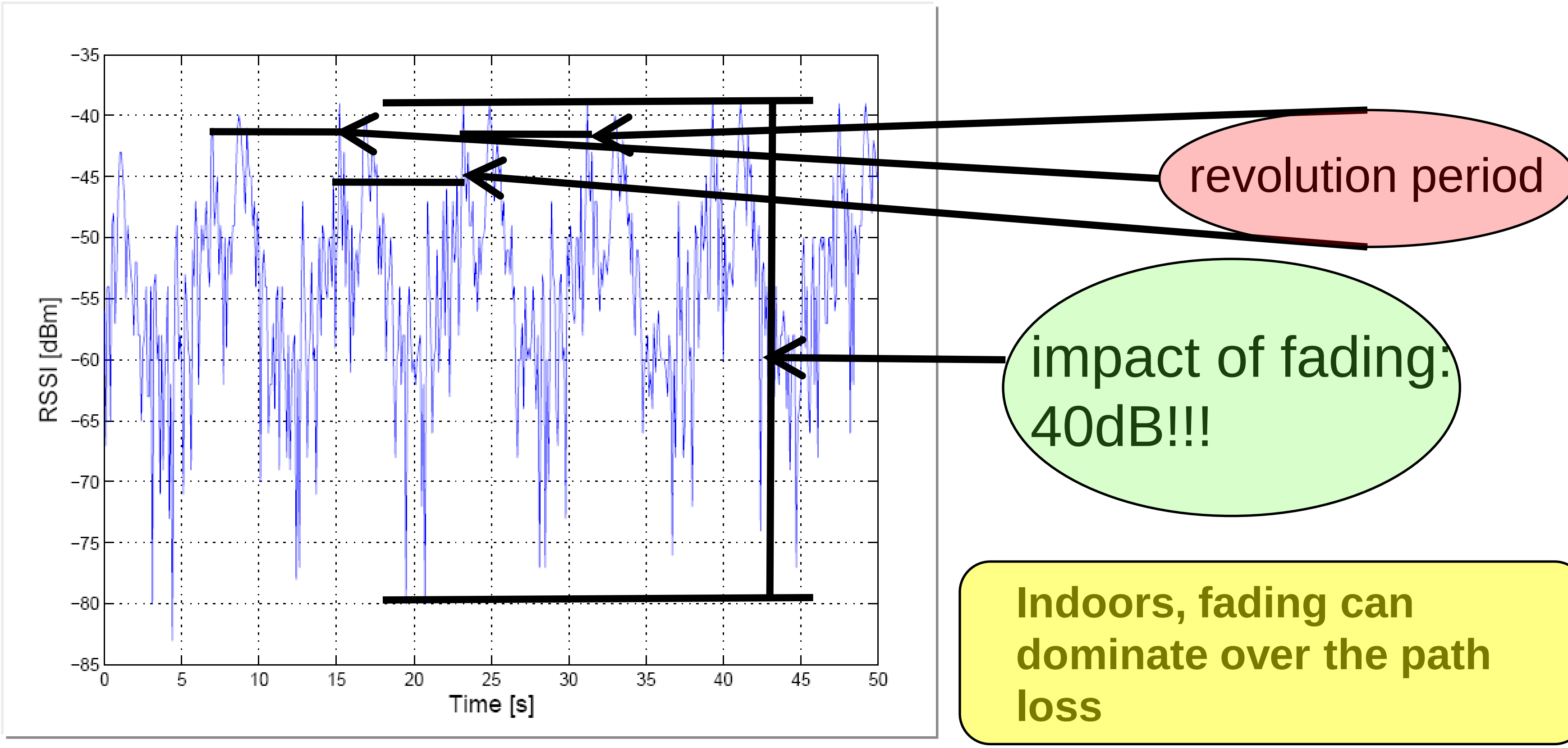


fading (!)

fading

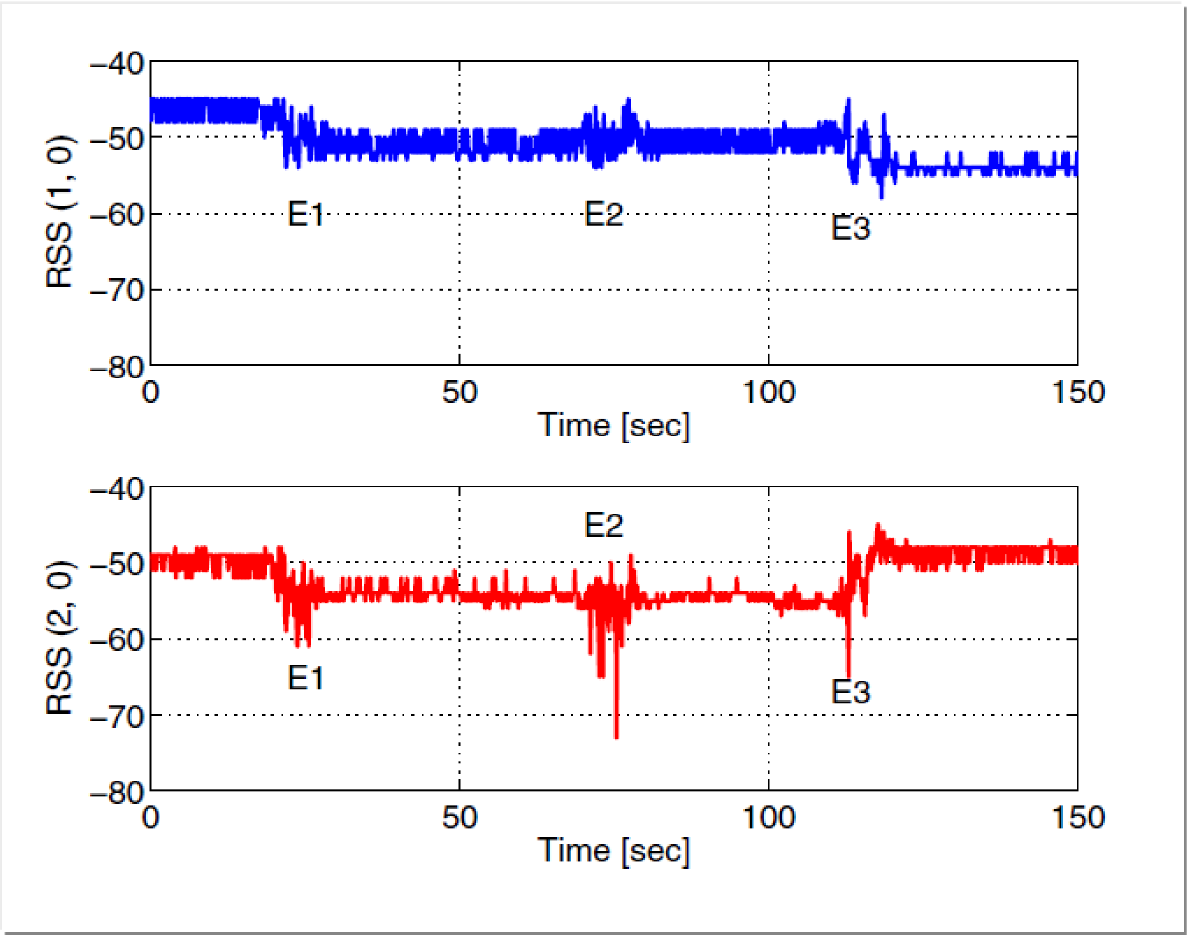
different static
fading levels

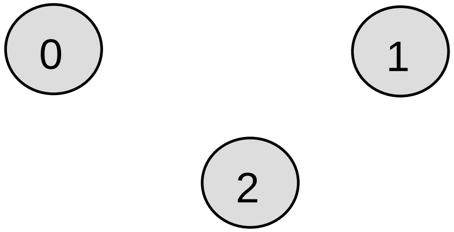
shadowing



Indoors, fading can dominate over the path loss

Induced Fading



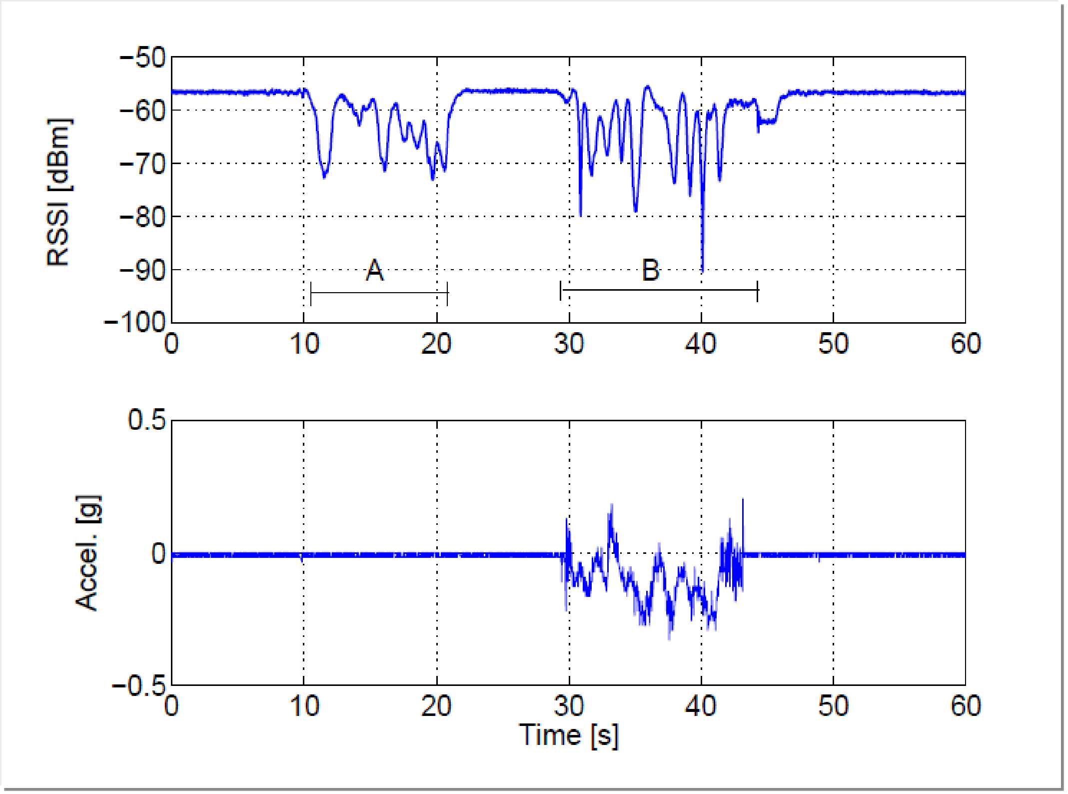


E1
Chair moved close to node 1

E2
Person through (2, 0)

E3
Chair moved close to node 2

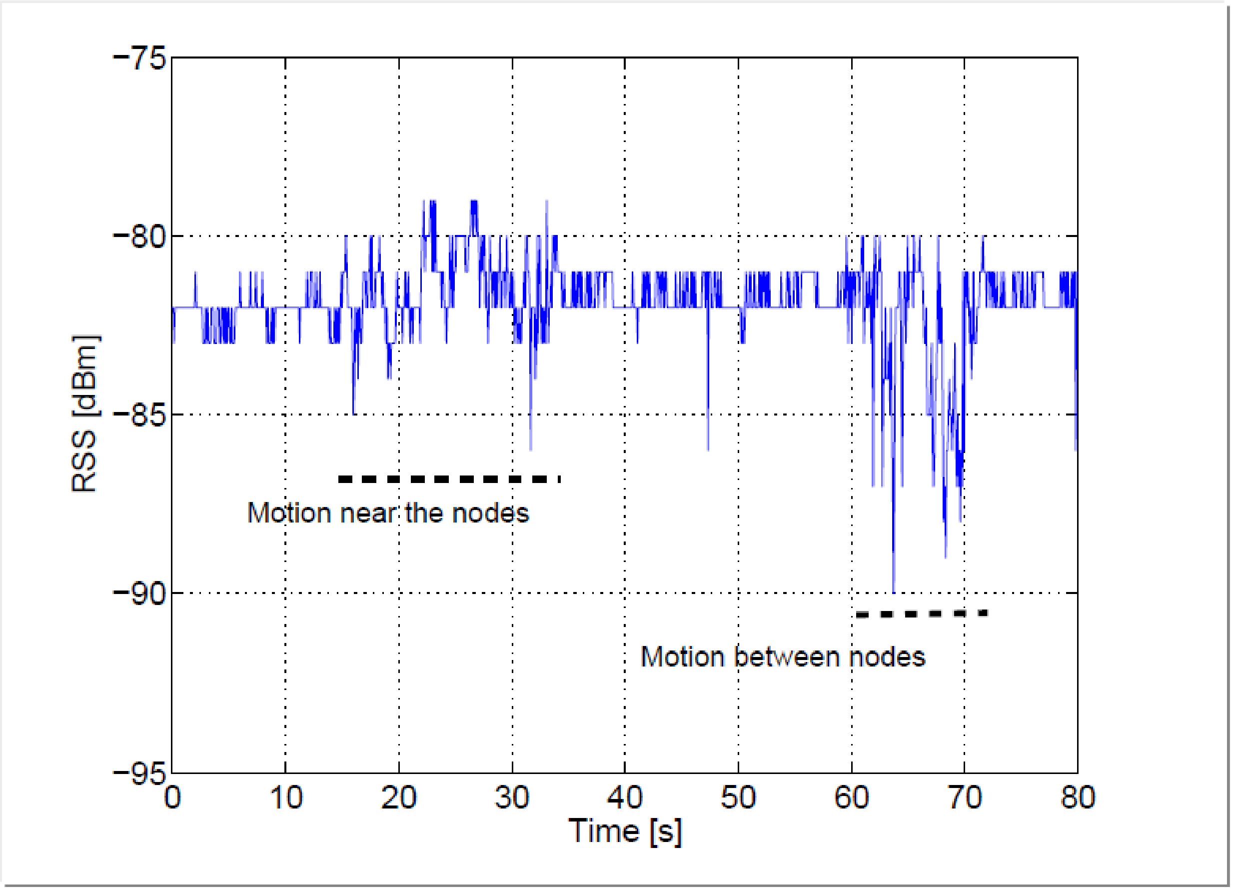
Impact of Induced Fading



A
Induced
Fading

B
Dynamic
Fading + Path
Loss

Impact on Higher-End Radios

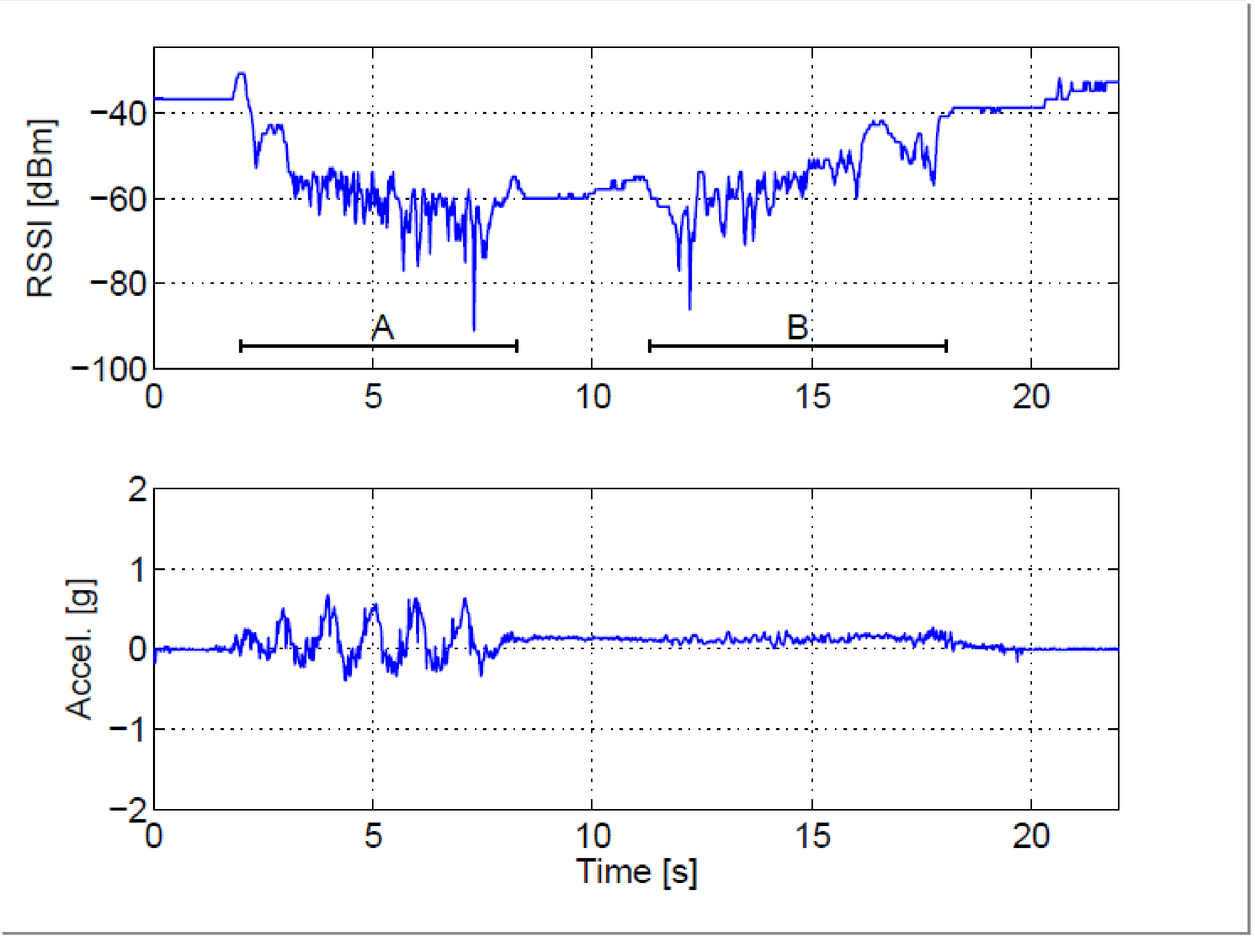


- Fading is still there but
- May use higher power
- Better Sensitivity

CISCO Aironet 350

11Mbps => -85 dBm
5.5 Mbps => -89 dBm
2 Mbps => -91 dBm
1 Mbps => -94 dBm

Sensorless Motion Detection



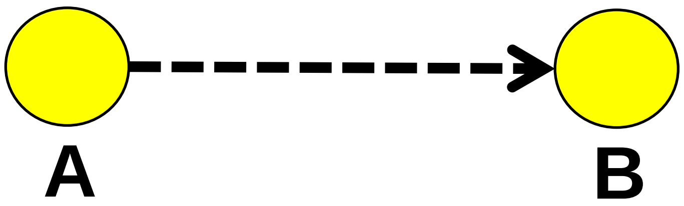
A

Erratic motion detected by accelerometer

B

Accelerometer can’t make it, RSS can!

Low-power wireless links



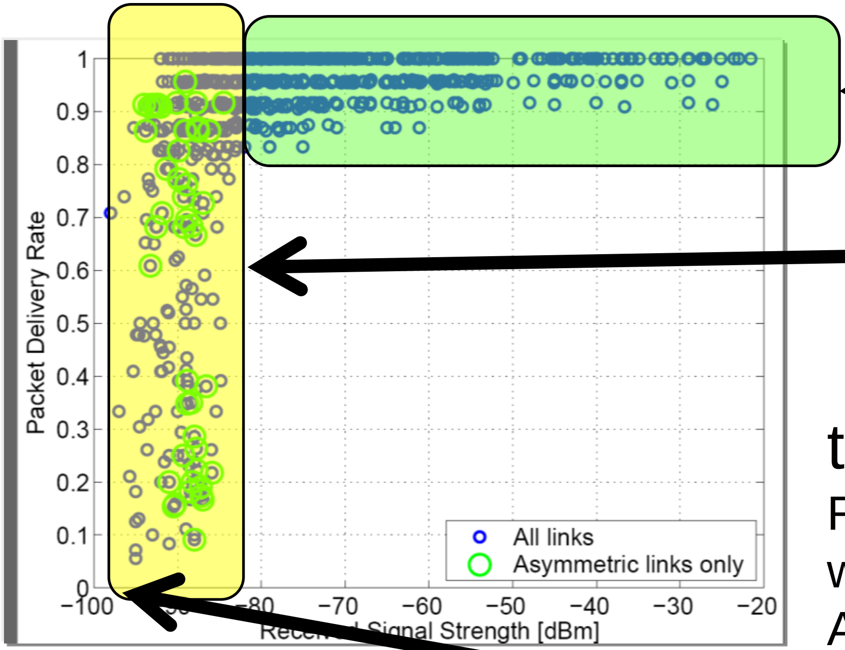
Links are NOT Boolean:
If B can hear A once, it doesn't mean they're connected

Links are NOT bidirectional:
if A can hear B, B doesn't necessarily hear A

Links are probabilistic: B can hear A with a given probability

In practice, a link can be characterized in terms of
- Received Power (RSS)
- Packet Delivery Rate (PDR)
- Required Number of Packets (RNP)

Transitional links



solid links (PDR>0.8)

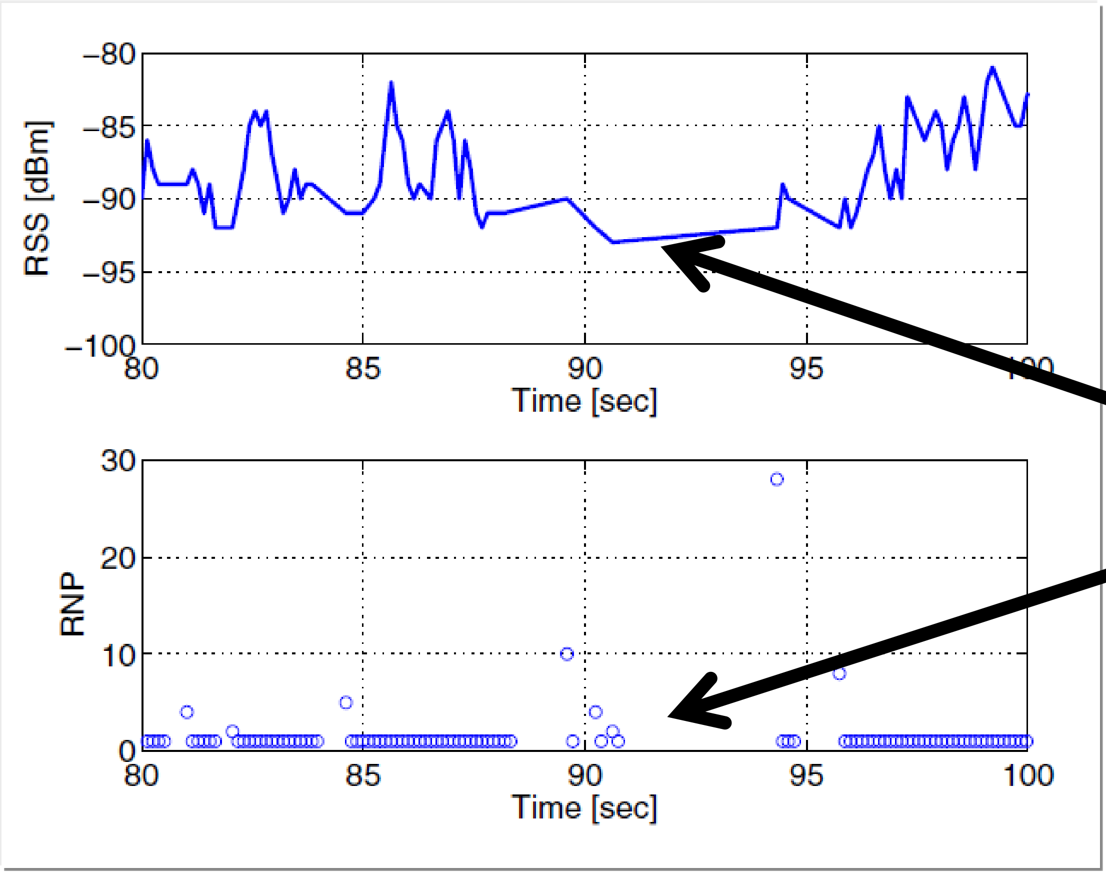
transitional links

RSS range between -95 and -80dBm
where PDR has a huge variance
Asymmetric links all lie within this region

disconnected links

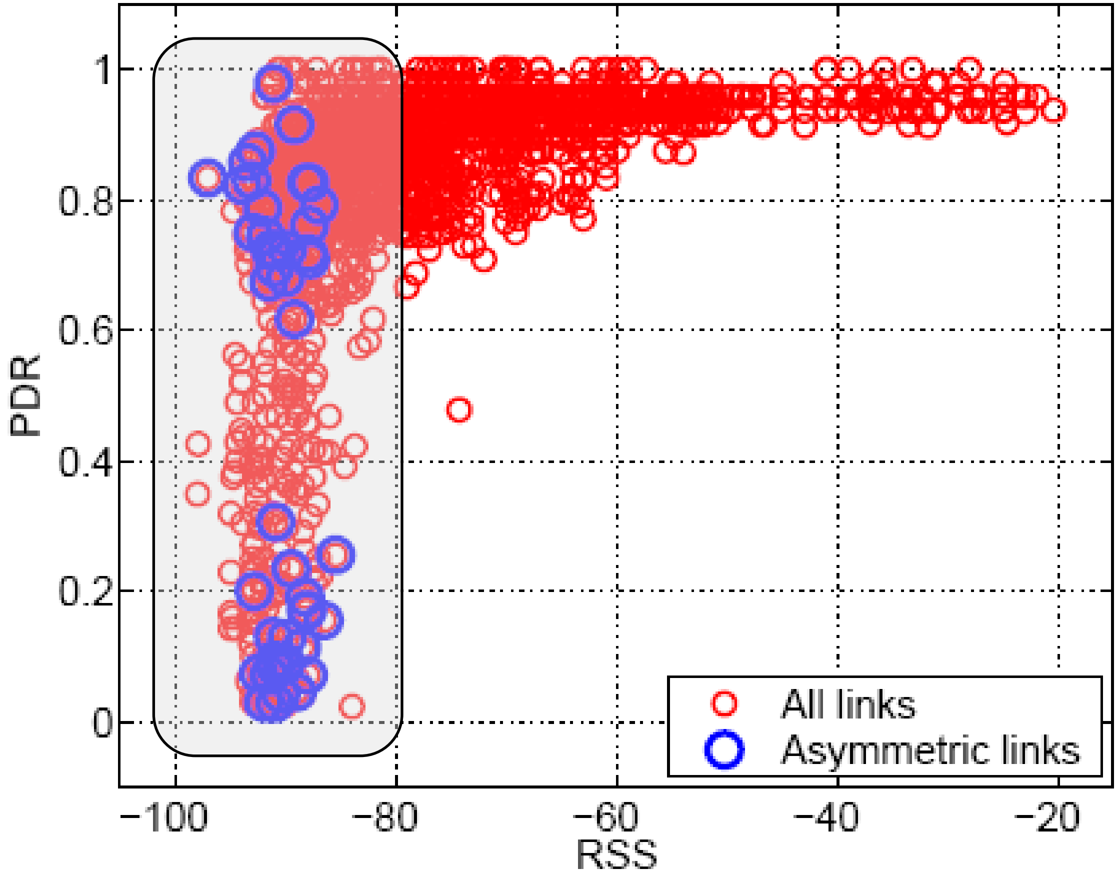
below -95dBm, PDR is virtually 0

Transitional Can Become Disconnected



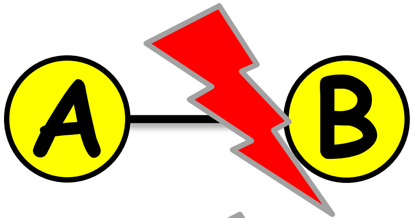
Shadowing!

PDR vs. RSS

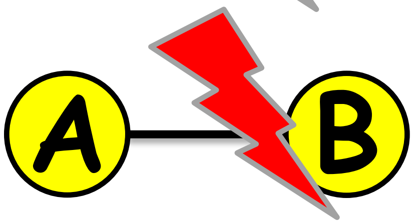


1
0.8
0.6
0.4
0.2
0
PDR
−100
−80
−60
−40
−20
RSS
All links
Asymmetric links

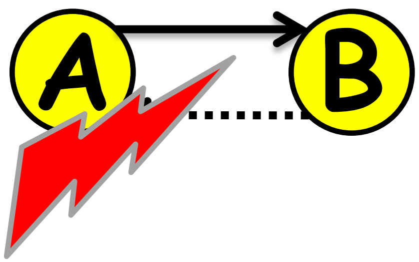
RNP: the cost of using a link



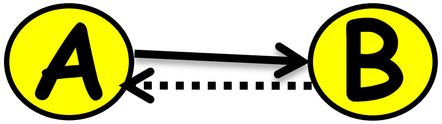
Node A sends, B does not receive, no ACK: RNP ≥ 2



Node A resends, B does not receive, no ACK: RNP ≥ 3

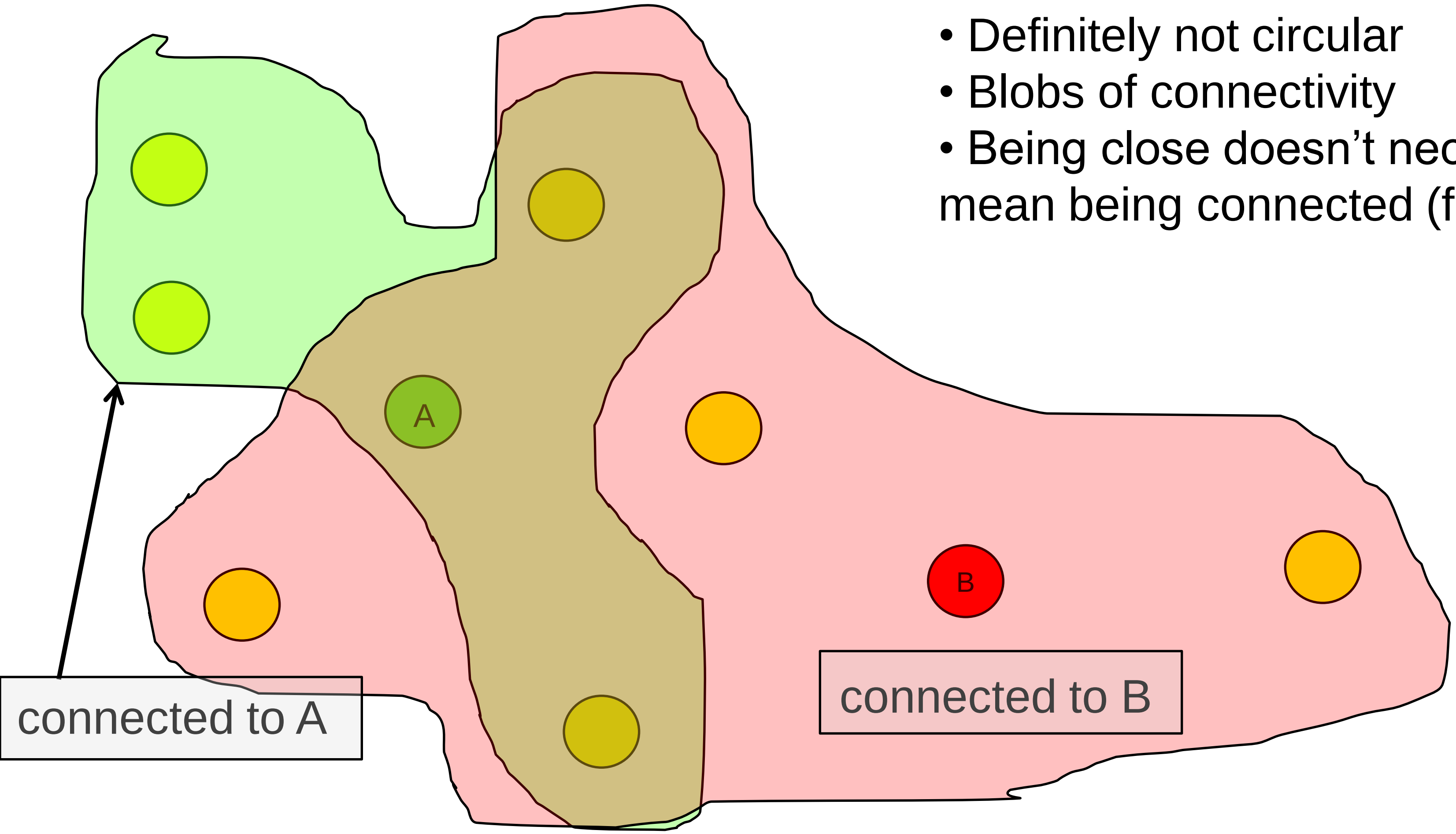


Node A resends, B receives, ACK is lost: RNP ≥ 4



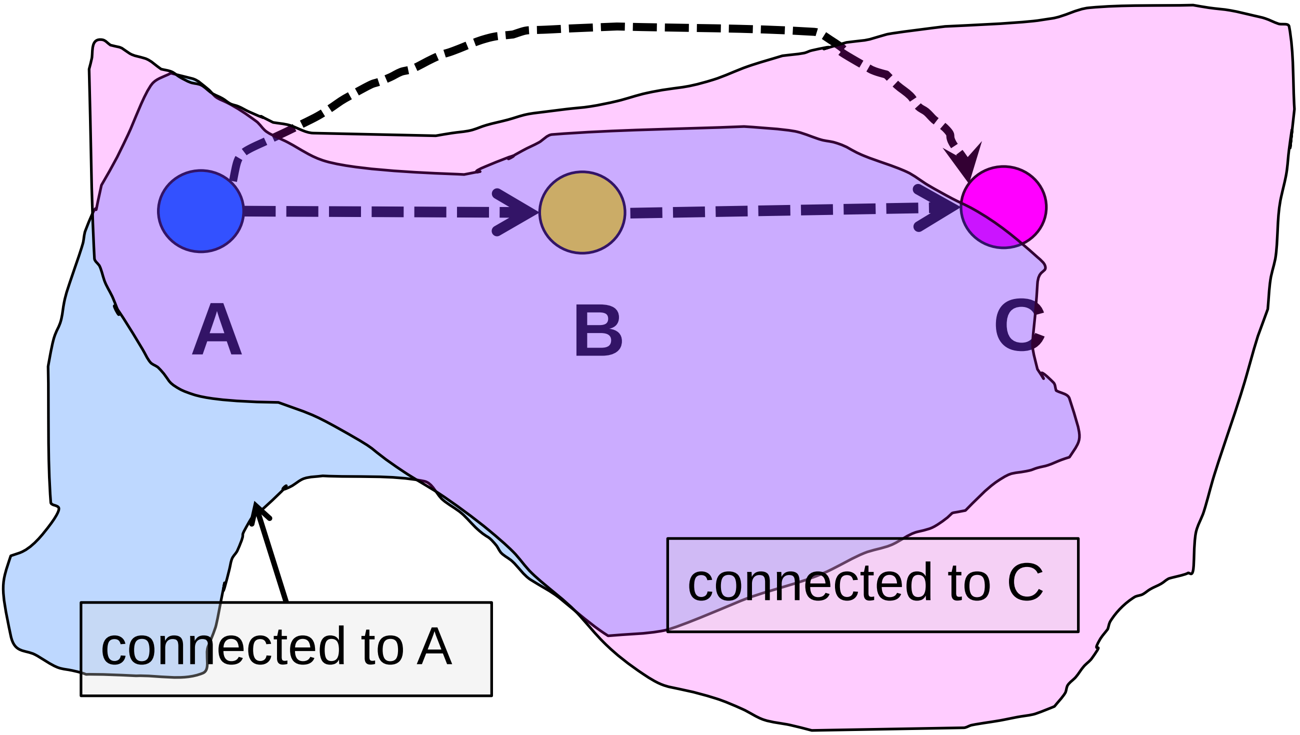
Node A resends, B receives, ACK is received: RNP = 4

Connectivity



- Definitely not circular
- Blobs of connectivity
- Being close doesn’t necessarily mean being connected (fading!)

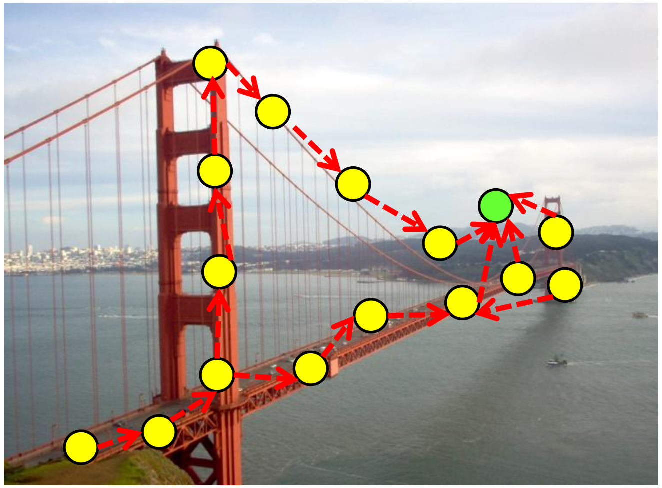
Single-hop or multihop?



Do we use (A, C)?

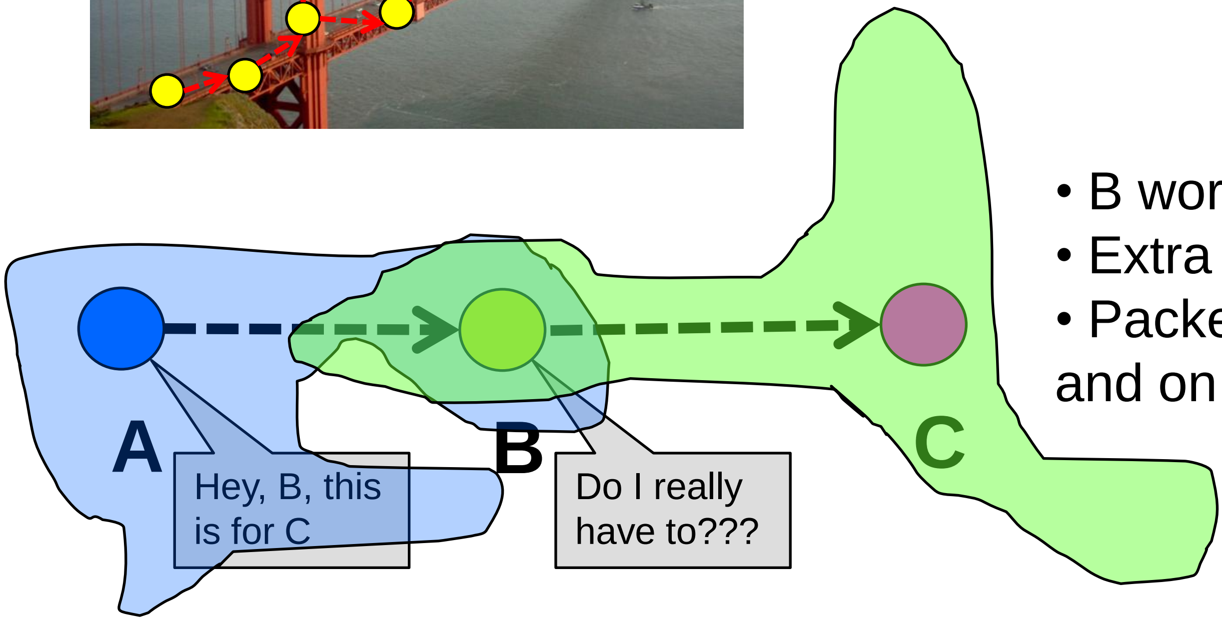
Or do we use
(A, B) and (B, C)?

Multihopping



Nodes need to relay on behalf of others...
...but relaying is not free:

- energy cost
- risk of packet loss



- B works for free on behalf of A
- Extra energy cost for B
- Packet may get lost on (A, B) and on (B, C)

Benefits of a few long hops

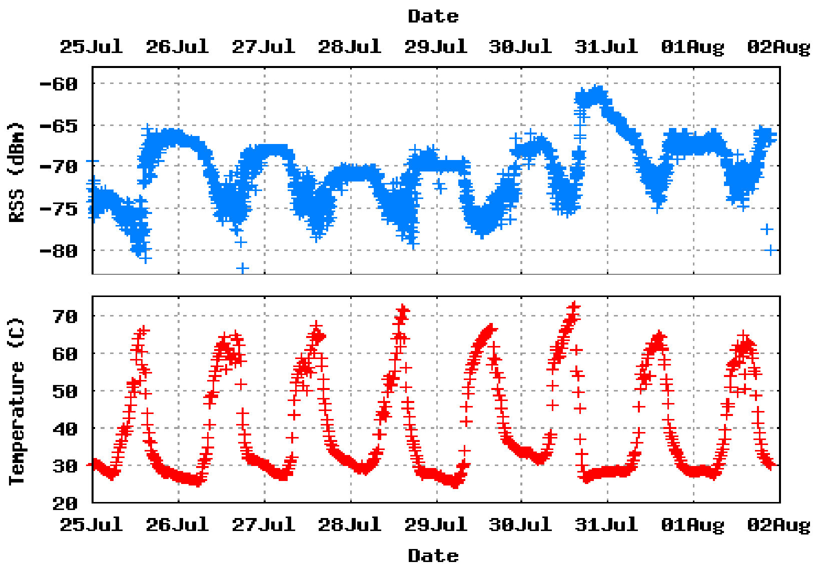
- Less radio activity: less interference
- Tx power reduction does not yield proportional energy savings
- Not relaying means you can sleep!
- Less overhead
- Energy balancing

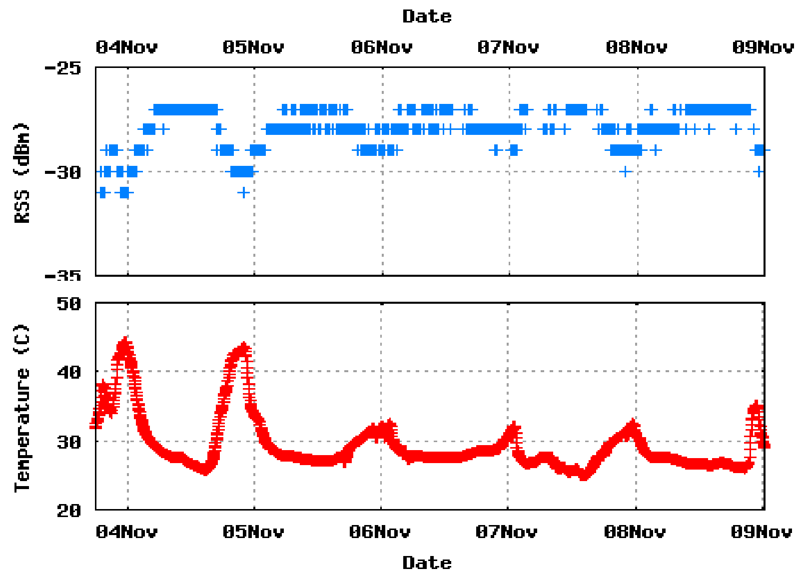
When multihopping:

- if any of the links breaks, the end-to-end route breaks
- if any of the relays moves, the route is endangered

Impact of non-RF phenomena

Temperature has a huge impact on received signal strength





Wireless Sensor Networking for “Hot” Applications:
Effects of Temperature on Signal Strength, Data Collection and Localization
K. Bannister, G. Giorgetti and S.K.S. Gupta, HotEmNets’08

Reading List

1. M. Zuniga, B. Krishnamachari, "An analysis of unreliability and asymmetry in low-power wireless links", ACM Transactions on Sensor Networks, Jun. 2007

2. K. Srinivasan, P. Dutta, A. Tavakoli, and P. Levis, “An Empirical Study of Low-Power Wireless”, ACM Transactions on Sensor Networks, Feb. 2010