3/27/12 EE 597.

Routing in Multihop Wireless Networks

Categories of Multihop Networks:

- Static Wireless Mesh Networks
- Wireless Sensor Networks
- Mobile Ad Hoc Networks
- Intermittently Connected Mobile Networks

Overview of Different Routing Approaches

Wireless Mesh Networks / Wireless Sensor Networks

static deployments

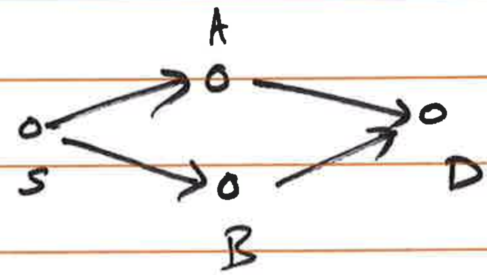
main focus: reliability of delivery

- Metrics for reliable routing

ETX - expected # of transmissions

- OSPF + ETX or RIP + ETX
- CTP - Collection Tree Protocol (also uses ETX)

- Exploiting the <u>wireless</u> Broadcast Advantage



Routing between end points taking place through "sets" of nodes

- Anypath Routing
- opportunistic routing

A generalization of Dijkstra's algorithm can be used for optimal-ETX Anypath routing

Backpressure routing:
use both link metrics for reliability, as well as queue differentials in deciding where to route.

BCP: Backpressure Collection Protocol for WSN

Dynamic packet by packet

forwarding decisions based on a combination of ETX & queue differentials

$$w_{ij} = (Q_i - Q_j) - V \cdot ETX_{ij}$$

MANETs:

How to develop routes that handle topological changes.

- Route Discovery
- Route Maintenance

Proactive vs. Reactive

↳ Create Routes On-Demand

AODV - Ad hoc On Demand Distance Vector (Reactive)

OLSR - Optimized Link State Routing (Proactive)

Barrage Relay Networking:

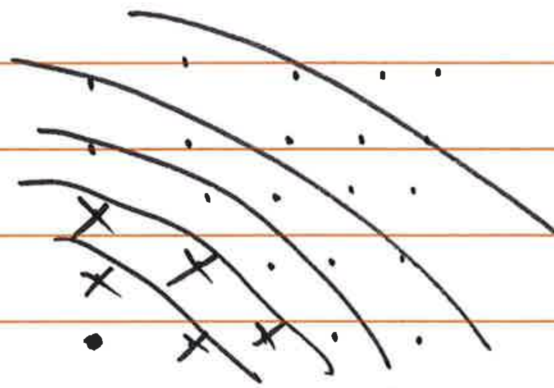
Cooperative MIMO-based approach to MANET operation pioneered by Trellisware

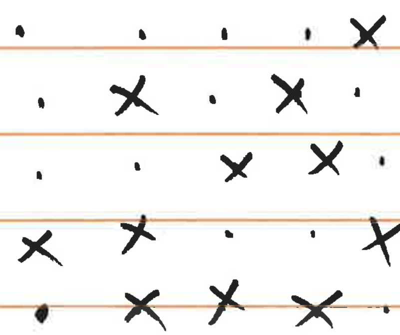
Intermittently connected mobile networks

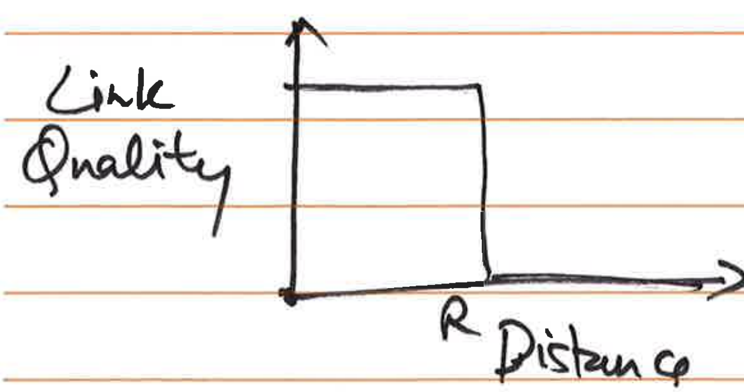
- Epidemic routing
- K-copy routing : Spray & Wait
- Bacpressure with Adaptive Redundancy

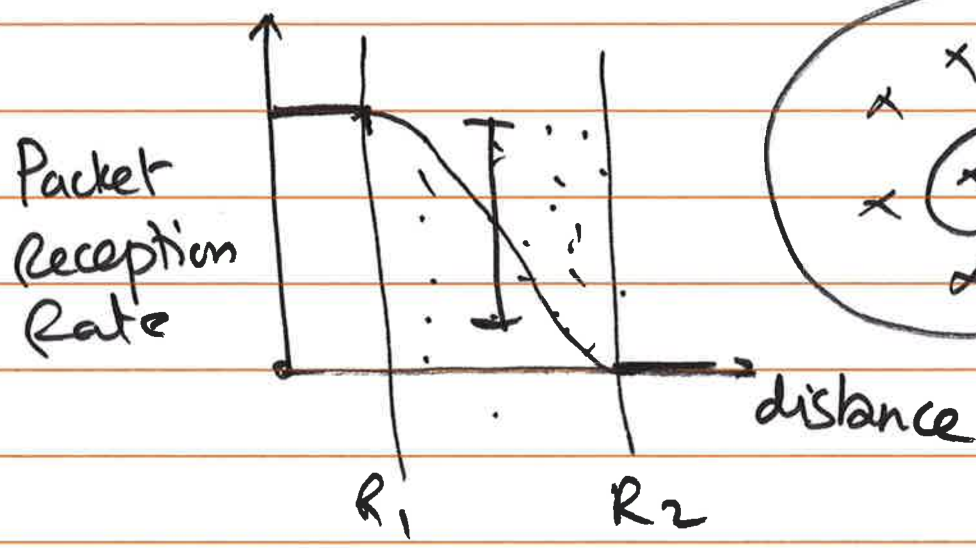
EE 649 Stochastic Network Optimization

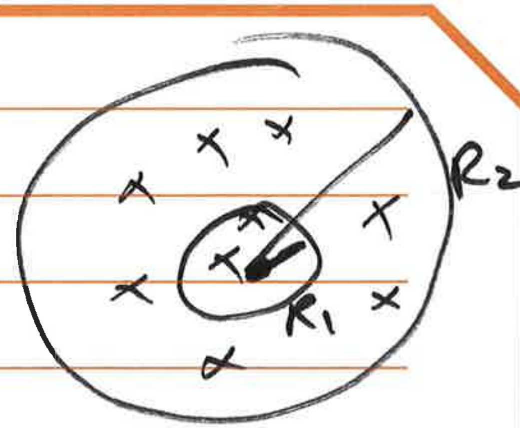
ETX metric





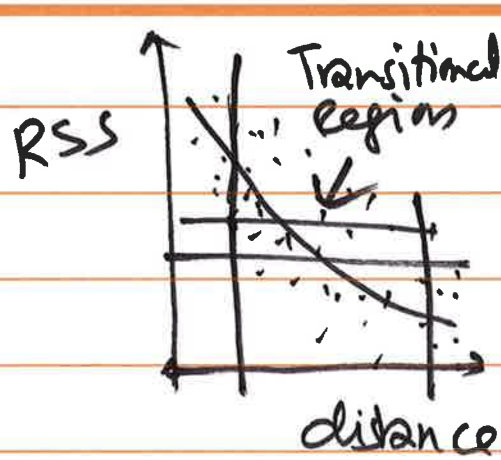


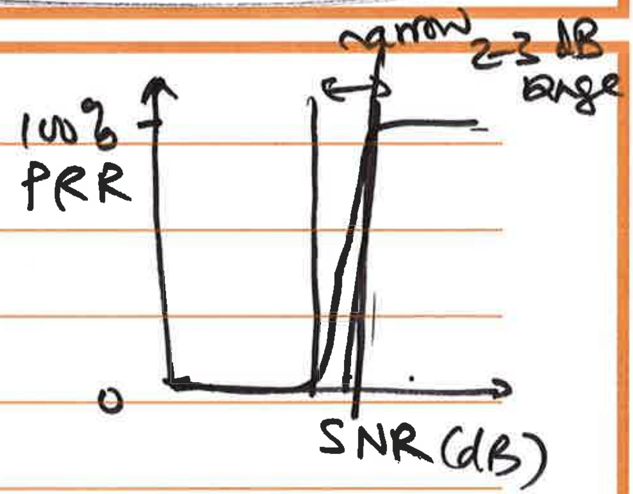




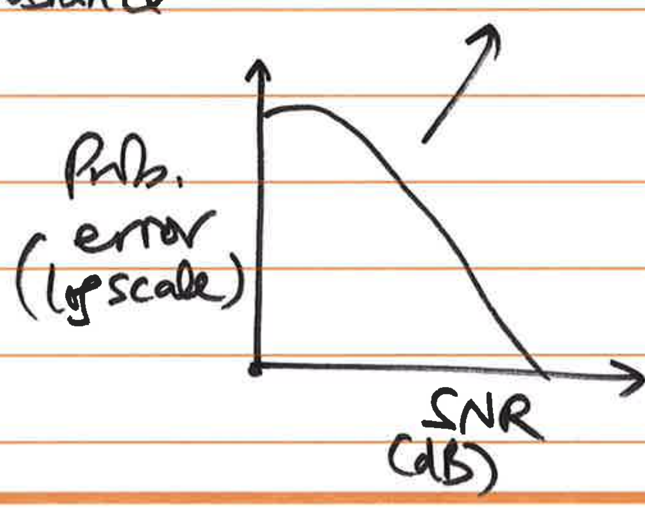
$R_2 - R_1 \approx 2$ to $3 \times R_1$

8 : 1 area ratio for 2x





SNR > θ



In many practical deployments

~90% of "neighbors" are "flaky"!
i.e. affected by
high spatio-temporal variation
in link quality.

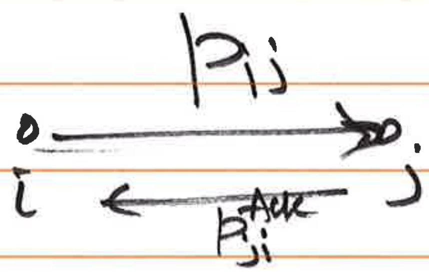
2 approaches to handle this:

① Black listing : works well
only in dense deployments,
& can sometimes partition/
disconnect the network

② ETX-based link metric
which sorts neighbors
based on the quality of
the link & prefers
better neighbors when routing.

Note: Shortest hop routing is a BAD idea because it explicitly picks long (likely to be unreliable) links.

Expected # of transmissions to have a successfully delivered packet



link layer ARQ mechanism

$ETX_{ij} := E(\#\text{ transmission till Ack})$

$\simeq \dfrac{1}{p_{ij}}$ (more carefully: $\dfrac{1}{p_{ij} \cdot p_{ji}^{Ack}}$).

for i.i.d. trials

goes from 1 to ∞

smaller the better

ETX as a metric for routing:
Compute end to end paths that minimize the sum of ETX across the entire path.

Practically, estimated using an exponentially weighted moving average (EWMA)

$$\hat{ETX}_{ij}(t+1) = \alpha\, ETX_{ij}(t) + (1-\alpha)\, ETX_{ij}^{INST}(t+1)$$

# of times the last pkt was transmitted before an ACK was received

$\alpha \in [0, 1)$

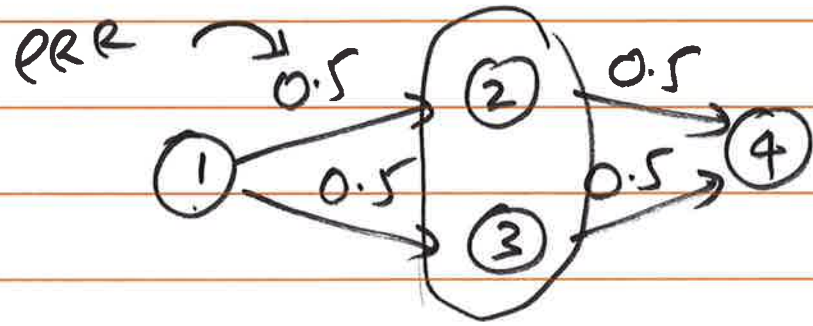
typically 0.9-ish.

ETX helps simultaneously for multiple objectives:

1. Reliability
2. Throughput because of
   - lower overhead per pkt delivered
   - reducing interference to other nodes.
3. Delay
4. Energy

—

Anypath routing



Shortest ETX paths: (1) → (2) → (4)

(1) → (3) → (4)

Total / Sum ETX $= 2 + 2 = 4$

$= 1/0.5 + 1/0.5$

Assume we can work out the coordination between 2 & 3 so that if 2 receives the pkt from 1, it will forward, else if 3 receives the pkt from 1, it will forward, what will be the total ETX for an Anypath Approach.

ETX distance from node to set

$$D_i = d_{i,J} + D_J$$

ETX distance from set J to the Destination

$$d_{iJ} = \frac{1}{p_{iJ}}$$

$$p_{iJ} = 1 - \prod_{j \in J} (1 - p_{ij})$$

in our example:

$p_{ij} = 0.5$ for both, so $p_{iJ} = 0.75$

$d_{iJ} = 4/3$

$$D_J = \sum_{j \in J} w_j D_j$$

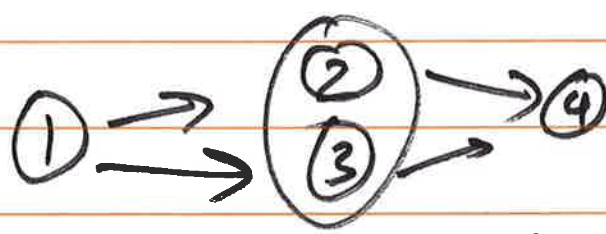
(Prob. that node j in the receiver set got it & no other higher priority node got it | someone got it)

$$\omega_j = \frac{p_j \prod_{k=1}^{j-1} (1 - p_k)}{1 - \prod_{j \in J} (1 - p_j)}$$

$$\frac{1/2}{3/4} \cdot 2 + \frac{1/4}{3/4} \cdot 2$$

$$= 2$$

for the Anypath route



The total anypath ETX

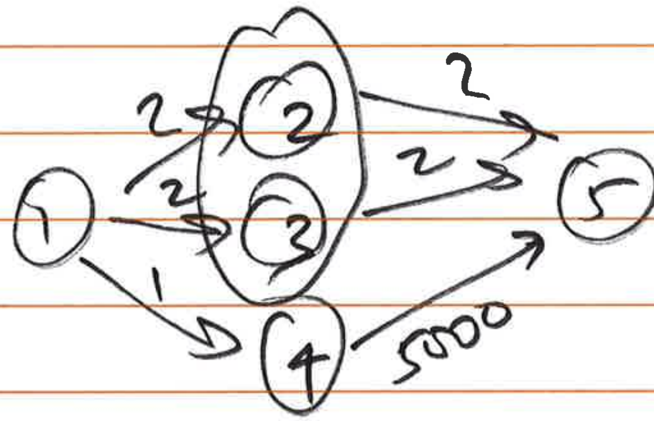
$$= 4/3 + 2 = 3\,1/3$$

$$= 10/3 < 4$$

Resolving the contention:

Approach 1: sender informs the receiver set of priorities. There is a relay delay proportional to the priority order where forwarders listen to see if higher priority nodes are forwarding. If not, they forward (assuming they got the packet)

Approach 2: low-overhead 3-way handshake w/ explicit ACKs in prioritized order & an explicit "go ahead"/ CTS message from sender.



1
2
3
4
5
2
2
1
2
2
5000