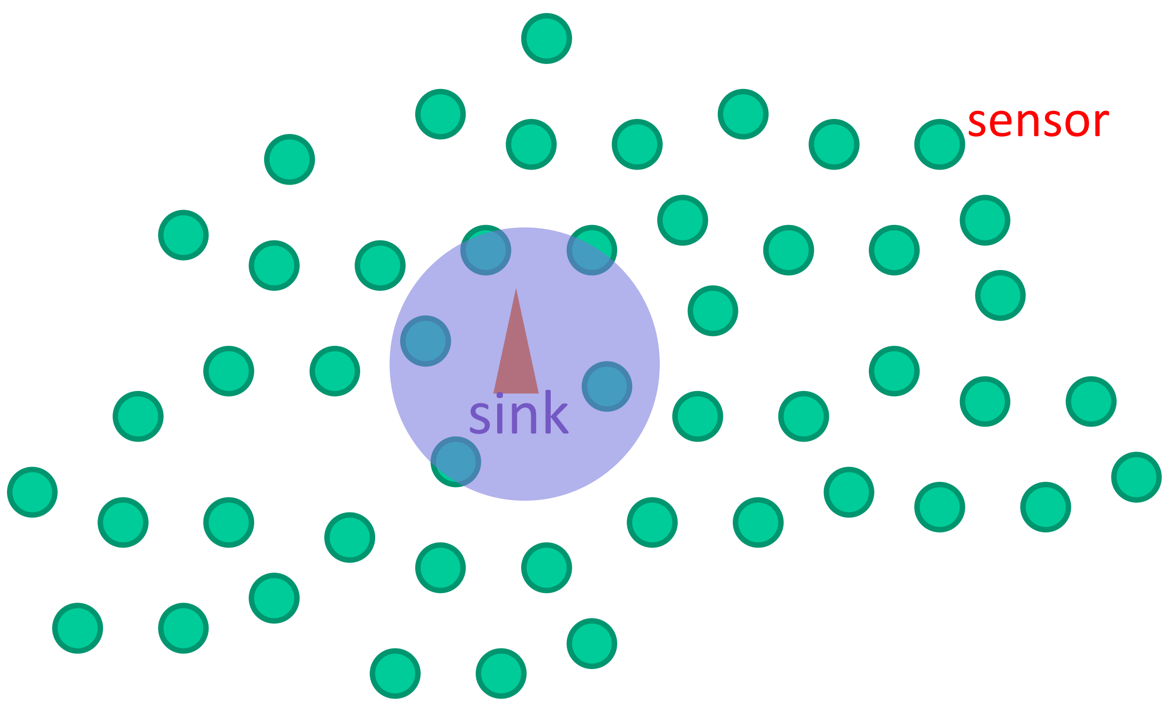
Broadcasting Techniques for Mobile Ad Hoc Networks

Broadcasting: It is a process in which one node sends a packet to all other nodes in a network.

Broadcast: 1 → all communication

Applications of broadcasting

- Broadcasting of net-wide control information
  - Ex.: The **sink** broadcasts its location and ID to all sensors.
- Provides route establishment functionality
  - The sink may locate a mobile sensor.
  - Serves as a building block in ad hoc networking

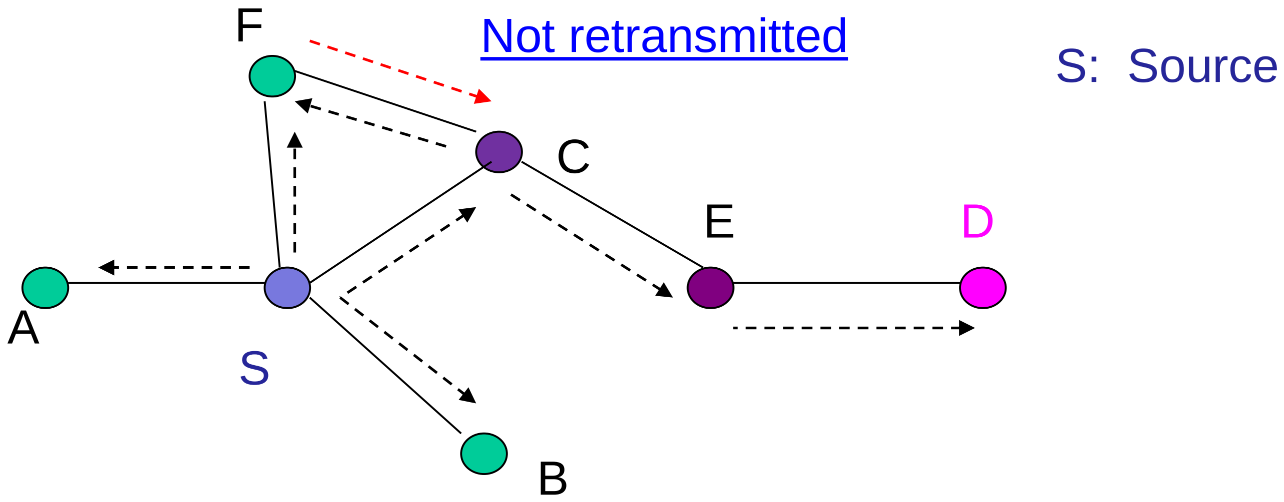


A simple form of broadcasting: flooding

- Flooding:
  - Protocol:
    - The source transmits its packet to all its neighbors.
    - Each receiving node retransmits each received unique packet exactly once.
  - Data structure: Each node maintains and uses a table with the following structure:

Source node	**Most recent sequence number of packet from the source**

Flooding



In a network with N nodes, there are about N (re)transmissions.

Efficient broadcasting

- Goal: Minimize the number of retransmissions.

  ➔ Some nodes do **not** retransmit.

- (Attempt to) ensure that a broadcast packet is delivered to each node in the network.

$$\text{Delivery ratio} = \frac{\text{\# of nodes receiving a copy of the packet}}{\text{Total \# of nodes in the network}}$$

Delay (aka Latency) = How long does it take for the last node to receive a copy of the packet?

Common attributes

- MAC layer assumption
  - Example: 802.11 MAC with no RTS/CTS
- <u>Jitter</u> the scheduling of a broadcast packet:
  - Schedule it for **re**transmission after a random delay (reduces the probability of collision between neighbors)

- Random Access Delay
  - After a node receives a new packet, it **waits** for a while to receive the same packet from other neighbors. Based on this info, the node decides to broadcast or not.

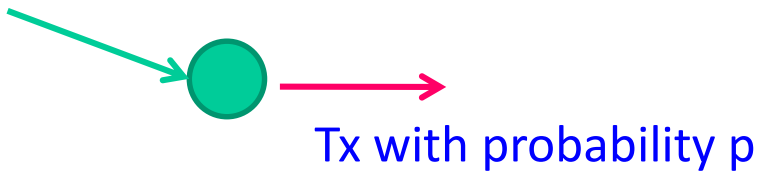
- A packet is not transmitted more than once: prevent loop

Classes of efficient flooding algorithms

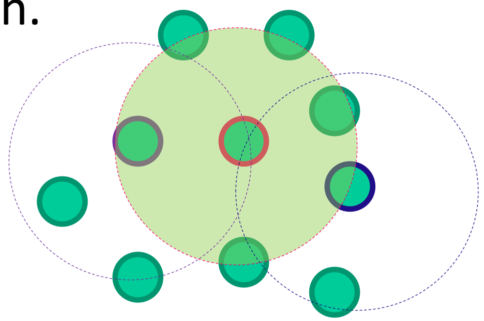
- Probability based methods
  - » Probabilistic scheme, counter-based scheme
- Area based methods
  - » Distance based
- Neighbor knowledge methods
  - » Flooding with self pruning
  - » Scalable broadcast
  - » Dominant pruning
  - » Multipoint relaying

Probabilistic scheme (Prob. Based)

- This works similar to **flooding**.
- Nodes **re**broadcast with a **predetermined probability.**



- Impacts of network **density**
  - **Dense networks:** multiple nodes share similar transmission coverage areas. (➔ some nodes need not retransmit.)
  - **Sparse networks:** there is much less shared coverage. The **probability** parameter needs to be high.



Counter-based scheme (Prob. Based)

- **Observation**
  - There exists an **inverse relationship** between the number of times a packet is received at a node and the probability of the node reaching additional area.

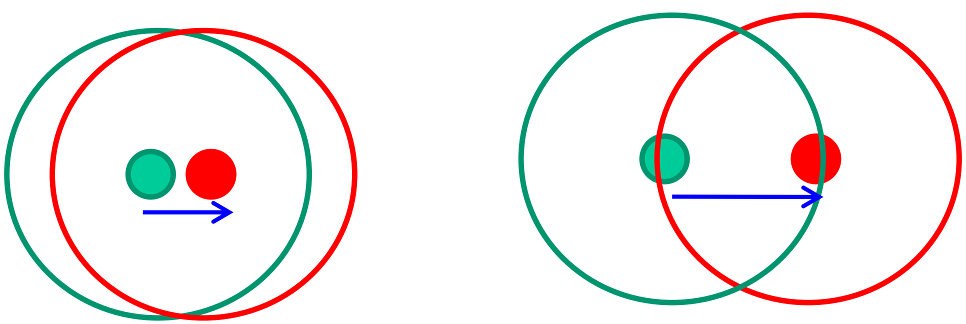
    Prob(reaching additional area) = k. 1/#of copies received

- **Protocol:** (when a **new** packet is received)
  - Initialize: Counter = 1 and RAD = random(0, Tmax)
  - Decision based on RAD
    - » RAD not expired: **Counter++** for each redundant packet received.
    - » RAD expires: **If Counter < Threshold**, rebroadcast the packet;

      else, drop the packet
- Advantages: Simplicity, adaptability to local topology

Area based methods

- **Observation**
  - If a receiving node is **very close** to the sender
    - The additional area covered by the receiver is **very small.**
  - If a receiving node is **farthest** from the sender, the additional area covered by the receiver is **large** (61%).
- **Idea:** A node can evaluate **additional coverage area** based on all received redundant packets.



Distance-based scheme

- Protocol (when a new packet is received)
  - Initiate a RAD.
  - Decisions based on RAD
    - RAD has not expired: Cache all redundant packets.
    - RAD expires: examine the locations of all transmitters of the redundant packets:
      - If the distance between **this node** and **any node** (from above) is less than a threshold, drop the packet.
      - Else, **re**transmit the packet.

Neighbor knowledge methods

- Flooding with self-pruning
- Scalable broadcast algorithm (SBA)
- Dominant pruning
- Multipoint relaying
- Ad hoc broadcast protocol

Flooding with self pruning

- Self pruning ➔ a receiving node decides whether or not to further send the packet …

- Protocol (Each node knows its 1-hop neighbors)
  - Sender: Includes its 1-hop neighbors in packet header before (re)transmitting.
  - Receiver: (when a **new** packet is received)
    - » Compare own neighbor list with the sender's.
    - » If the receiving node would not reach any additional nodes, drop the packet. Else, retransmit.

Scalable Broadcast Algorithm (SBA)

- Protocol
  - **Sender (say, A):** (Re)transmits a packet (no neighbor info)
  - **Receiver (say, B):** A **new** packet is received
    - » B knows all its neighbors common to A that have received the packet. 🡐 via **"hello"** packets.
    - » B starts a RAD.
      - For each redundant packet, **find** if B can reach more nodes by retransmitting the packet.
      - RAD expires: Retransmit, if B can reach more nodes.

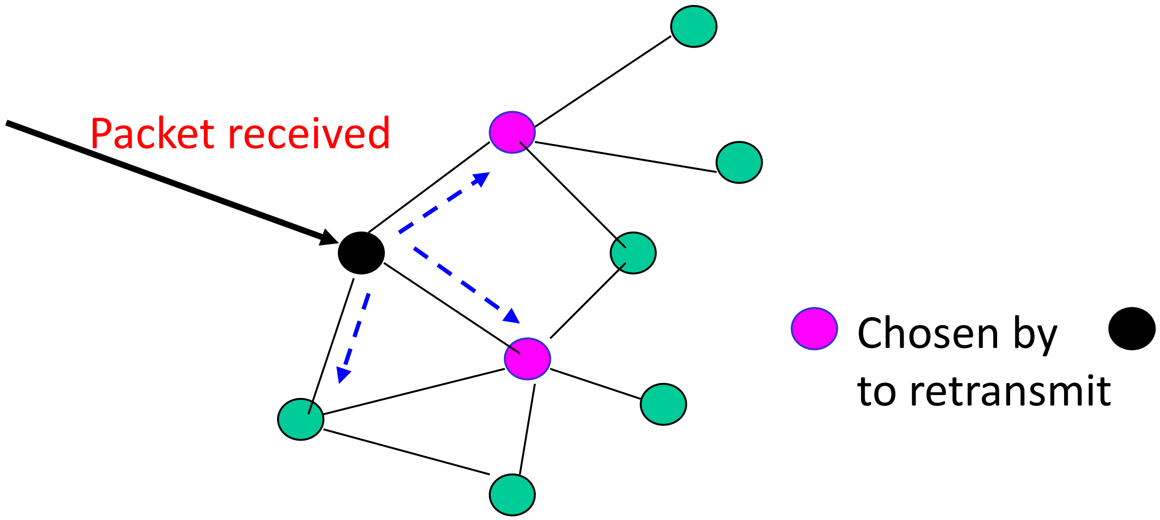
SBA (contd.)

- Dynamic adjustment of RAD
  - RAD is proportional to $(d_{Nmax}/\mathbf{d_{me}})$, where
    - » d_{Nmax} is the max neighbor degree among all neighbors.
    - » $\mathbf{d_{me}}$ is the node's neighbor degree.

- Idea: Nodes with most neighbors usually broadcast before the others.

Dominant Pruning

- Assumption: Nodes know their 2-hop neighbors.
- (Unlike SBA) Rebroadcasting nodes proactively choose some/all of their 1-hop neighbors as **re**broadcasting nodes.



Dominant Pruning (Contd.)

- Protocol: when a (new) packet is received
  - Check if the header contains the address of this node:
    - » No: Do not retransmit
    - » Yes: - Compute the subset of neighbors that should retransmit.
      - Include those nodes in the packet header and retransmit the packet.

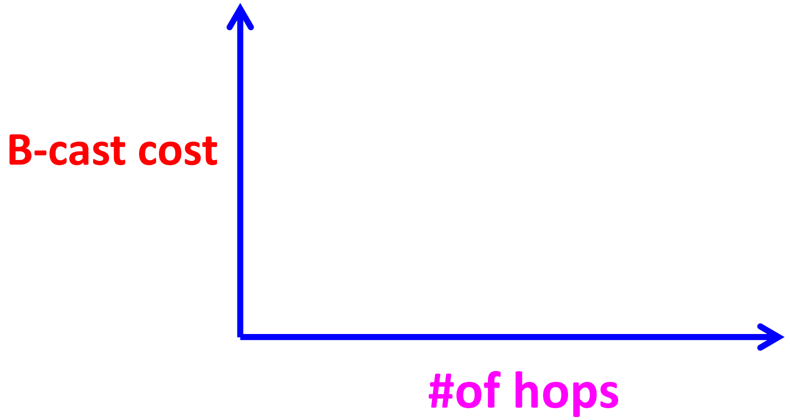
- Identification of neighbors who will retransmit (Greedy Set Cover alg.)
  - Identify some 1-hop neighbors such that **all** (not just remaining) 2-hop neighbors will be covered.

2002 Class

Parameterized neighborhood based flooding for ad hoc wireless networks

Vijay Dheap, M. A. Munawar, K. Naik, P. A. S. Ward

Military Communications Conference, 2003. MILCOM 2003. IEEE, Volume: 2



Multipoint Relaying

- Similar to Dominant Pruning
  – Forwarding nodes are chosen by upstream senders. Forwarding nodes are called *multipoint relays* (MRPs).

- Different from Dominant Pruning
  – MRPs are included in "Hello" packets.
  – "Hello" packets trigger packet retransmissions.

- Computation of MRPs
  1. Initialize: MRP = {one 1-hop neighbor}.
  2. Determine the 2-hop neighbors that are reachable via the MRP set.
  3. Identify a new 1-hop neighbor that will cover most of the uncovered 2-hop neighbor, and add it to MRP.
  4. **Repeat** steps 2-3 **until** all 2-hop neighbors are covered.

Multipoint Relaying (Contd.)

- Protocol
  - Nodes transmit "Hello(MRP)" packets from time to time.
  - When a node receives a "Hello(MRP)" packet, it checks if it is a member of the MRP set.
    - » **Yes:** the node retransmits all data packets received from that source.
    - » **No:** Do not forward packets.
  - Note: frequency of "Hello" packets affect delay performance.

Performance Comparison

- Effect of a **"null"** (**perfect**) MAC
  - To know the inherent strength of the protocol
- Effect of **network congestion**
  - Packet size
  - Network size
  - Source rate

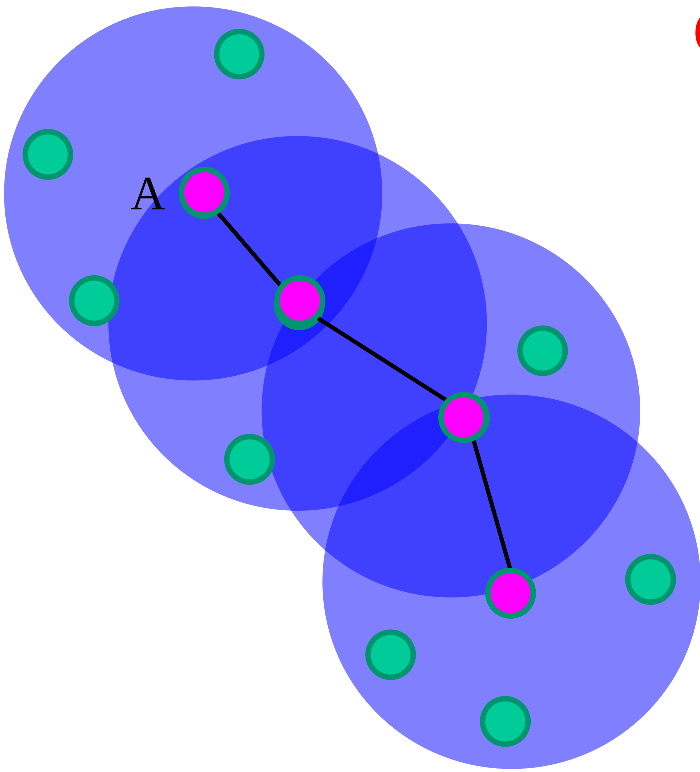
  (With 802.11, static network, and fixed # of nodes.)
- Effect of **mobility** (null MAC, fixed # of nodes)
  - Random waypoint mobility model with zero pause
    - » Nodes choose a random location and move there with a given mean speed. Next, choose another location and another speed to reach there, …
  - Constrained mobility ← more natural

Algorithm efficiency (Null MAC)

- **Delivery ratio:** The % of network nodes who receive a given broadcast packet.
    - » Dense network: All achieve 100%.
    - » Sparse networks: Simple flooding and protocols that utilize neighbor knowledge perform better.
- Number of **retransmitting nodes** vs. Node density
    - – Benchmarks
        - » Worst: Flooding (every node retransmits)
        - » Best (theoretical): Min. Connected Dominating Set (MCDS)

An MCDS is the smallest set of retransmitting nodes such that the set of nodes are connected and non-MCDS nodes are within 1-hop of at least one MCDS node.

Min Connected Dominating Set



Compute MCSD for A

MCSD for A = { }

Algorithm efficiency (Contd.)

- Number of **retransmitting nodes** vs. Node density
  - Benchmarks (Contd.)

MCDS **<** Neighbor knowledge **<** Area based **<** Prob. based **<** **Flood**

Effect of congestion (802.11)

- **Delivery ratio** degrades with higher packet rate.
  - Increased interference and no ACK→ more packet loss
- Protocols that minimize the number of retransmissions have better delivery ratio.
- **Delay:** The time it takes for the *last node* to receive a broadcast packet. ← **Latency**
  - Delay increases (exponentially?) with broadcast rate.
    - » Worst: Flooding
    - » Best: MRP
  - Proposal: The concept of RAD → higher delivery ratio

Effect of mobility (Null MAC)

- **Delivery ratio**
  - MRP: Worst
  - Others: Near 100%