Outline

- Code propagation
  - Trickle and Deluge
  - Typhoon
- Reliable flooding
Code propagation

- **Motivation**
  - Sensor networks are deployed for long periods of time
  - Need to re-task the network
    - Bug fixes
    - Features
    - Parameter changes
Challenges

- While code is propagating, network is useless.
- Propagation must be a continuous effort because network membership is not static.
- High cost of metadata transmission:
  - Sending 40 bytes of data once a minute for a day is equivalent to transmitting a full 64KB image.
Metadata dissemination protocol

- Properties
  - Low maintenance
    - Metadata exchange should be infrequent in stable state
  - Rapid propagation
    - Code should propagate rapidly when motes need updates
  - Scalability
    - Protocol must maintain properties over wide range of network densities. Node density is not known in advance
Trickle

Main idea
- Node periodically broadcasts metadata if it has not heard a few (k) other motes transmit the same thing.

Results of broadcast
- Every mote that hears the broadcast is up to date
- Recipient detects the need for an update
- “As long as there is connectivity inconsistencies will be detected”
Example Trickle execution, \( k=1 \)
Trickle properties

- Each mote transmits \textit{at most} once per period (\( \tau \))
  - If it hears \( k \) neighbors it suppresses its transmission

- Number of transmissions per period in steady state
  - Lossless, single-hop network: \( k \)
  - \( n \) nodes in \( m \) non-interfering, broadcast domains: \( m^*k \)
  - Independent of number of nodes
  - Number of messages that a node transmits and receives per period is \( k \)
Maintenance with loss

- Total number of transmissions scales with \( O(\log n) \)
- Example: prob. that motes misses a packet is 0.1 thus requiring two transmissions. Prob. of missing two packets 0.01 (3 tx), etc.
Maintenance without synchronization

- Lack of synchronization leads to redundant transmissions
- Introduce *listening period*: transmit only during \([\tau/2, \tau]\)
- Total number of transmissions in lossless, single-hop network: \(2k\)
Maintenance in a Multi-hop Network

- Motes uniformly placed in a 50’x50’ area \( \tau = 1, k = 1 \)
- Collisions increase the effective loss rate and thus the total number of transmissions
Propagation

5 foot spacing

15 foot spacing
Accelerating propagation

- Adjust $\tau : \tau_l, \tau_h$
- When $\tau$ expires, double $\tau$ up to $\tau_h$
- When node hears newer metadata, set $\tau$ to $\tau_l$
- When node hears a summary with older code than it has, it sends the code
- When a node installs new code, it resets $\tau$ to $\tau_l$