Energy Aware Routing in Wireless Sensor Networks

- Ms. Sucheta Raut

Outline

- Wireless Sensor Networks
- Routing strategies
- Reducing energy impact of routing
- Simulation as a design tool

Wireless Sensor Networks

- A type of MANET
- Every node is a router and a data source
- Nodes are severely resource-constrained
- Rapidly changing topology
- May contain thousands of nodes
- Resilient to failure of individual nodes
- Self-organising

What does a WSN do?

- Nodes monitor the environment
- Sensor data has geographical context
- Identity of individual node is unimportant
- Hostile environments
  - Environmental monitoring
  - Military
  - Surveillance
  - Emergency and disaster management

Sensor Nodes



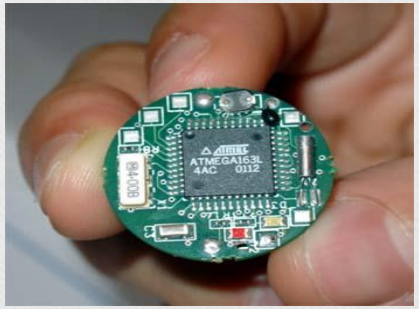
MICA [Polastre03]



MICA 2 [Crossbow06]



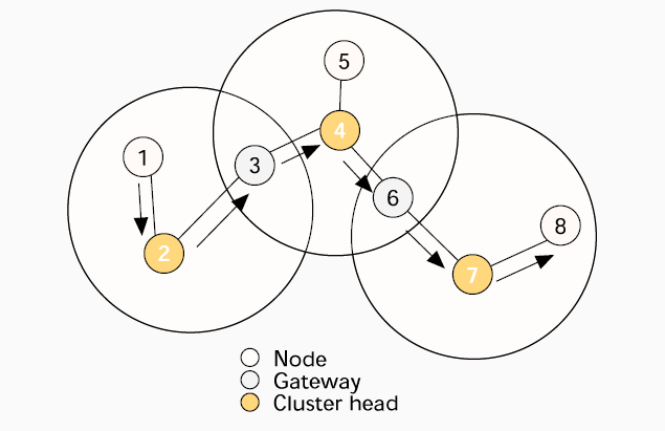
Spec chip [Berkley03]



Intel mote [Club04]

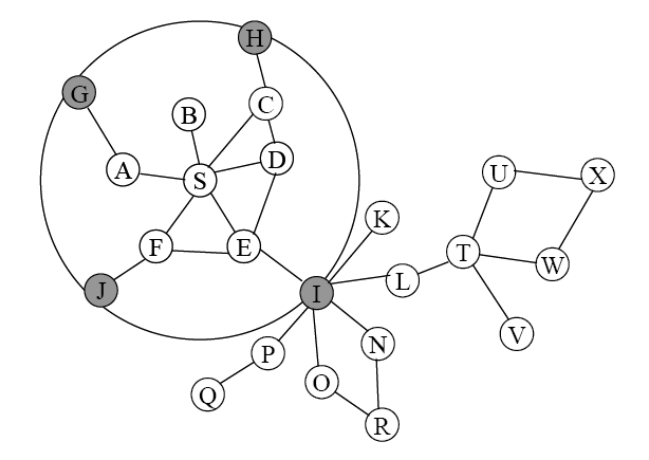
Topology Control

- No control over physical location of nodes
- Signal strength modulation to control



Inter-cluster routing

verla



Node-centric zones of two hops

Energy-Aware Routing

- Maximise network lifetime (no accepted definition)
- Communication is the most expensive activity
- Possible goals include:
  - Shortest-hop (fewest nodes involved)
  - Lowest energy route
  - Route via highest available energy
  - Distribute energy burden evenly
  - Lowest routing overhead
- Distributed algorithms cost energy
- Changing component state costs energy

Routing Strategies

- Aim to make communication more efficient
- Trade-off between routing overhead and data transmission cost
- Strategies incur differing levels of communication and storage overhead
- Hybrid approaches are possible

Stateless Routing

- Nodes maintain no routing information
- Flooding
  - Messages rebroadcast to neighbours
- Gossiping
  - Messages rebroadcast to neighbours, probability <1
- Geographic
  - Need to know direction to destination
- Epidemic
  - Pairwise exchange of messages between carriers
  - Copes with temporary network partition
  - No routing state, but message buffering infeasible in WSNs

Proactive and Reactive Routing

- Proactive routing
  - Routes created and maintained in advance
  - Low latency, high resource demand
  - Does not scale to large networks
- Reactive routing
  - Routes created and cached as required
  - High latency, lower resource demand

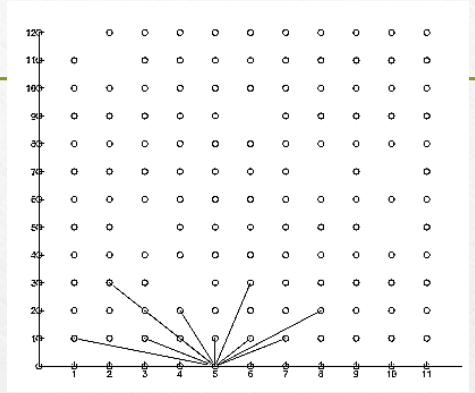
Data-centric Routing

- Routing application data rather than packets
- Node identities unknown to users
- Data naming and labelling
- Users express interests in named data, protocol sets up data flows
- Combines routing and distributed data management
- Data aggregated and summarised in flows
- Well suited to WSN paradigm

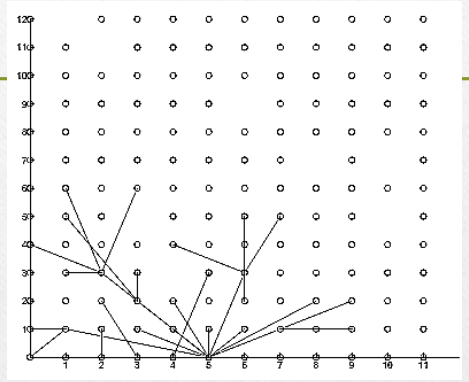
Flooding

- Used in data delivery or route discovery
- Very simple algorithm, implicit multicast
- Observed results surprisingly complex
  - Stragglers, Backward Links, Long Links, Clustering
- Last 5% of nodes take as much time as preceding 95%, independent of radio power
- Some nodes will never receive the message
- Redundant communications waste energy

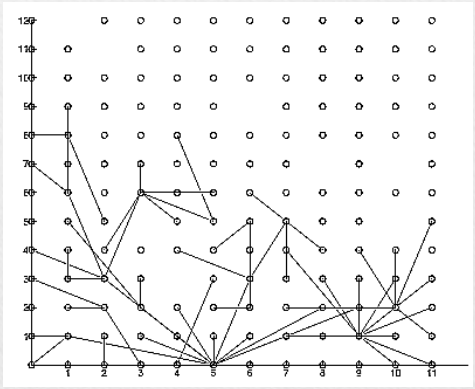
Flooding Behaviour



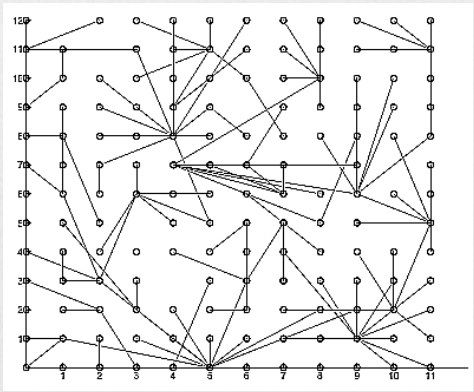
1st broadcast



2nd broadcast



3rd broadcast



Final state

Broadcast Storm Problem

- Flooding is appropriate if topology changes rapidly; other approaches cannot keep up
- Broadcast Storm Problem
  - Redundancy
  - Contention
  - Collisions
- WSN nodes cannot afford energy or computation cost of wasteful communication

Solving the BSP

- Cannot ignore problem as flooding is needed
- Nodes attempt to determine how much the network will benefit from rebroadcast
- Proposed classes of solution:
  1. Probabilistic (gossiping)
  2. Counter-based
  3. Distance-based
  4. Location-based
  5. Cluster-based
- WSNs require simple, low-resource solution

Gossiping

- Simple extension of flooding
- Probability of rebroadcast, $p<1$
- Bimodal behaviour theory
  - For given p, results are consistent
  - Very few nodes receive message, or almost all
  - Critical probability, p_c, at which switch occurs
  - Significant energy savings by setting p just above p_c
- Protocols modified to use gossiping perform better (e.g. AODV+G, DSR+G)

Gossiping

- Bimodal behaviour formalised and analysed
- p_c varies between systems
- p_c cannot be determined analytically
- Determine p_c for a system by simulation
  - Depends on reliable, accurate simulation
- Simulations find no evidence of phase transition behaviour at p_c, contradicting theory
  - Is the theory or simulation result correct?

Network Simulation

- Real-world experiments often infeasible
- Reproducible conditions
- Simulated entities may not yet exist
- No simulation is 100% accurate
  - Too little detail harms accuracy
  - Too much detail harms scalability

Existing Simulators

- Numerous simulators have been used in WSN and MANET research
- ns2, SeaWind, MaRS, PowerTOSSIM, TOSSF, Tython, SensorSim, Aeon, EmStar, SENS, Avrora, Atemu, SWAN, GloMoSim, …
- Few simulators scale to large networks
  - Hard to partition problem for parallel simulation as any given pair of nodes could interact at any time
  - Cannot manage level of simulation detail appropriately

The ns-2 and ns-3 Simulators

- ns-2 widely used in network research
- Does not directly execute mote code
- Exponential execution time in the number of nodes
- Impractical to model networks larger than 100-150 nodes
- ns-3 proposed, but not yet implemented
- ns-3 uses parallelisation for scalability, but still won't scale to very large networks
  - Using multiple processors increases capacity, perhaps to ~1000 nodes at best due to coordination overhead
  - Still nowhere near a million node network

Simulation as a Design Tool

- GP used to evolve cluster head election algorithm in [Weise06]
- Candidate algorithms evaluated for fitness in a simulated network
- Offline tuning of algorithm to a network
- Simulation time restricts feasible exploration of search space

Possible Future Directions

- Design for analysis
- Logical structures with specialist nodes
- Online evolution through GP in-network
- Hierarchical simulation
- Application-level protocols
- Distributed scheduling
- Distributed knowledge management

[Weise06]

Conclusions

- WSNs monitor hostile environments using resource-constrained nodes
- Communications activity is expensive
- Network lifetime depends on energy management policy
- Algorithms must suit the target network
- Large-scale simulation is vital in design, tuning and evaluation of WSN algorithms

Thank you…