CS450
Wireless Embedded Sensing Systems
Week 8: Routing II

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Outline

• Directed Diffusion model
  • Directed diffusion types
  • Evaluation results
  • Diffusion variants
• Sink mobility
• Reliable dissemination
Directed Diffusion

- Publish and Subscribe model
  - Benefit: Data sources need not know anything about data sinks
    - Network can scale independent of data consumption
    - Data are routed dynamically, according to their value and demand
- Data/requests have attributes
  - Key, operation, value
- Routes are known as *gradients*
- Attributes (data) is matched along gradients as it flows through the network
Attributes Implementation (1)

- Each attribute implemented as a key-type-value-operator tuple
- Key
  - Indicates the semantics of the attribute
    - Latitude, frequency, etc
- Type
  - Indicates the primitive type that the key will be
  - Available types
    - INT32_TYPE, FLOAT32_TYPE, STRING_TYPE, BLOB_TYPE
Attributes Implementation (2)

- **Operator**
  - Describes how the attribute will match when two attributes with the same key and type are compared
  - Available operators are: IS, EQ, NE, GE, GT, LE, LT, EQ\_ANY
  - IS operator specifies a known, actual value
  - Other operators specify a condition that must be satisfied

- **Examples**
  - LATITUDE IS 12.3
  - LONGITUDE LE 45.2
  - TEMPERATURE IS 72.7
  - CONFIDENCE GT 0.80
Matching Example (1)

Each formal must match some actual:

- **type EQ detection**: x \( \geq -100 \), x \( \leq 200 \), y \( \geq 100 \), y \( \leq 400 \), confidence \( > 0.5 \)
- **type IS detection**: x IS 10, y IS 150, confidence IS 0.7

**valid match**
Matching Example (2)

Each formal must match some actual:

- **type EQ detection**
  - $x \geq -100$
  - $x \leq 200$
  - $y \geq 100$
  - $y \leq 400$
  - confidence $> 0.5$

- **type IS detection**
  - $x \equiv 10$
  - $y \equiv 10$
  - confidence $\equiv 0.7$

*no match*
Basic Directed Diffusion

Setting up gradients

Source

Interest = Interrogation

Gradient = Who is interested

Fall 2008

CS 450
Basic Directed Diffusion

Sending data and Reinforcing the best path

Source

Low rate event

Sink

Reinforcement = Increased interest
Directed Diffusion and Dynamics

Source

Sink

Recovering from node failure

Low rate event
High rate event

Reinforcement
Directed Diffusion and Dynamics

Source

Sink

Stable path

Low rate event

High rate event
Initial simulation study of diffusion

- Key metric
  - Average Dissipated Energy per event delivered
    - indicates energy efficiency and network lifetime

- Compare diffusion to
  - flooding
  - centrally computed tree (omniscient multicast)
Diffusion Simulation Details

- Simulator: ns-2
- Network Size: 50–250 Nodes
- Transmission Range: 40m
- Constant Density: 1.95x10–3 nodes/m2 (9.8 nodes in radius)
- MAC: Modified Contention-based MAC
- Energy Model: Mimic a realistic sensor radio [Pottie 2000]
  - 660 mW in transmission, 395 mW in reception, and 35 mw in idle
Diffusion Simulation

- Surveillance application
  - 5 sources are randomly selected within a 70m x 70m corner in the field
  - 5 sinks are randomly selected across the field
  - High data rate is 2 events/sec
  - Low data rate is 0.02 events/sec
  - Event size: 64 bytes
  - Interest size: 36 bytes
  - All sources send the same location estimate for base experiments
Average Dissipated Energy (Standard 802.11 energy model)

Network Size

Average Dissipated Energy
(Joules/Node/Received Event)

Standard 802.11 is dominated by idle energy
Average Dissipated Energy (Sensor radio energy model)

Diffusion can outperform flooding and even omniscient multicast. **WHY?**
Impact of In-network Processing

Application-level suppression allows diffusion to reduce traffic and to surpass omniscient multicast.
Impact of Negative Reinforcement

Reducing high-rate paths in steady state is critical
Diffusion Variants

- Diffusion family of protocols includes variants optimized for specific scenarios
  - No one single protocol is optimal for all cases
- Two-Phase Pull Diffusion
  - Interests have global scope (are sent to the network)
  - Data has local scope (does not leave a node if there is no matching interest)
- Push Diffusion
  - Interests have local scope
  - Data has global scope
  - After rendezvous at a sink node, a positive reinforcement is sent on the reverse path
TTDD: A Two-tier Data Dissemination Model for Large-scale Wireless Sensor Networks

Haiyun Luo
Fan Ye, Jerry Cheng
Songwu Lu, Lixia Zhang
UCLA CS Dept.
Sensor Network Model

Stimulus

Source

Sink
Mobile Sink

Excessive Power Consumption

Increased Wireless Transmission Collisions

State Maintenance Overhead
Goal, Idea

- Efficient and scalable data dissemination from multiple sources to multiple, mobile sinks
- Two-tier forwarding model
  - Source proactively builds a grid structure
  - Localize impact of sink mobility on data forwarding
  - A small set of sensor node maintains forwarding state
TTDD Basics

Dissemination Node

Data Announcement

Source

Data

Immediate Dissemination Node

Sink

Query
TTDD Mobile Sinks

Dissemination Node

Data Announcement

Source

Data

Immediate Dissemination Node

Trajectory Forwarding

Trajectory Forwarding
TTDD Multiple Mobile Sinks
Grid Maintenance

- Issues:
  - Handle unexpected dissemination node failures
  - Efficiency
- Solutions:
  - Source sets the Grid Lifetime in Data Announcement
  - DN replication: each DN recruits several sensor nodes from its one-hop neighbor, replicates the location of the upstream DN
  - DN failure detected and replaced on-demand by on-going query and data flows
Grid Maintenance
Grid Maintenance (cont’d)
Performance Evaluation

• Compare with sink-oriented data dissemination (SODD) approaches
• $N$ nodes, $k$ sinks, $m$ number of cells traversed, area of size $A$
• Number of nodes in each cell

$$n = \frac{N\alpha^2}{A}$$

• Communication overhead

$$\frac{CO_{TTDD}}{CO_{SODD}} \rightarrow \frac{1}{mk} \left( 1 + \frac{4}{\sqrt{n}} \right)$$
Ns-2 Simulation

- Metrics
  - Energy consumption, delay, success rate
- Impacts of
  - Cell size
  - Number of sources and sinks
  - Sink mobility
  - Node failure rates

When number of sinks is small TTDD consumes much less power
Conclusion

- TTDD: two-tier data dissemination Model
  - Exploit sensor nodes being stationary and location-aware
  - Construct & maintain a grid structure with low overhead
- Proactive sources
  - Localize sink mobility impact
- Infrastructure-approach in stationary sensor networks
  - Efficiency & effectiveness in supporting mobile sinks
Reliable Data Dissemination

• Goal: Reliably deliver large objects to all network nodes
  • Application: WSN reprogramming
• Previous work
  • Contention based protocols (Deluge)
  • Calculating Connected Dominating Sets (Sprinkler)
Typhoon

- Contention-based protocol
  - Attempts to minimize idle listening
- Three protocol components
  - Metadata dissemination
    - Announce the existence of a new object
  - Request handshake
    - Request pages and select publishers
  - Data delivery
    - Recover from packet losses
Data Request Handshake

- Receivers broadcast requests
- Publishers send unicast offers
- Receiver selects one publisher
- Receivers in the same broadcast domain can overhear data packets
Data Delivery

• Packet losses must be recovered through retransmissions
• Alternatives
  • NACKs at the end of transmission window
  • Hardware ACKs after each packet reception
  • System ACKs after each packet reception
• Typhoon uses system-level ACKs
Channel Switching

- If single broadcast channel is used then can inject one page for every three time slots
- If multiple channels are available it is possible to send one page for every two time slots
Evaluation

• Metrics
  • Completion time
  • Energy consumption
• Parameters
  • Network density
  • Network size
  • Packet loss
• Results from simulation and prototype implementation
Results: Network Size

Completion Time

Energy Cost

Typhoon

Deluge
Results: Network conditions

- Study the effect of packet loss
  - Random loss: increase node spacing ⇒ lower signal strength ⇒ lower PRR
  - Bursty losses: interference from 802.11 network

<table>
<thead>
<tr>
<th></th>
<th>Quiet</th>
<th>Noisy</th>
</tr>
</thead>
<tbody>
<tr>
<td>Typhoon</td>
<td>54.3</td>
<td>73.4</td>
</tr>
<tr>
<td>Deluge</td>
<td>80.7</td>
<td>241.4</td>
</tr>
</tbody>
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High-level insights

• Minimizing idle listening time is most important goal
• Timer values have to be density-aware
• Channel switching reduces contention, improves spatial re-use