Autonomous Networks Research Group - USC

FLOW: An Efficient Forwarding Scheme to Mobile Sink in Wireless Sensor Networks

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Introduction:

Motivation

•We consider the class of applications where a mobile sink makes periodic tours along a fixed path/set of paths and does not explicitly query for data (e.g. wildlife monitoring, intrusion detection). Flooding or Periodic querying can be inefficient in terms of energy and delay.

•Data dissemination schemes can often take advantage of the underlying "spatio-temporal" pattern in the sink's movement.

•Over time, the network can learn this pattern and then this information can be used to discover good paths that route data to the sink while it is "on the move" with a degree of confidence about energy efficiency and delivery guarantees.

Strategy: Exploit underlying pattern in mobility

•Define ***Moles*** as nodes that lie in the vicinity of the sink's trajectory.

• Moles learn the sink's movement pattern over time and characterize it as probability distribution functions. These are then used by each node to calculate its likelihood of being on a good path to the sink

• Note that a source node need not know the precise location of the mobile sink; information about which neighbor is *towards* and which is *away* from the sink is sufficient for forwarding decision. Can this information be maintained in a distributed fashion using only *local* information obtained from the neighboring nodes?

FLOW: Forwarding using Likelihood-based Weights:

•Consider a deployment of sensor nodes in a grid-based structure as shown in **Fig. 1**. Each sensor node is assumed to have a unit radio range so that it can communicate with nodes at its left, right, top and bottom. A hierarchical structure is created where nodes that are k hops away from a mole are assigned level k

•Define the event A_i as the event that the sink is in the vicinity of Mole **A** between time t_i and t_{i+1}. Similarly define $E_i = A_i \cup B_i$, $H_i = E_i \cup F_i$ and so on. Since the sink cannot simultaneously be in the vicinity of **A** and **C**, we have $P(H_i) = P(E_i) + P(F_i) - P(B_i)$

•In general, likelihood values at any node can be obtained from *local* neighborhood. Forwarding decisions at each node are made using these values with the intent of forwarding to a node/set of nodes that are most likely to lead to the sink

•The FLOW algorithm has two tunable parameters ε_1 and ε_2 that affect the degree of multi-path routing and delivery guarantees

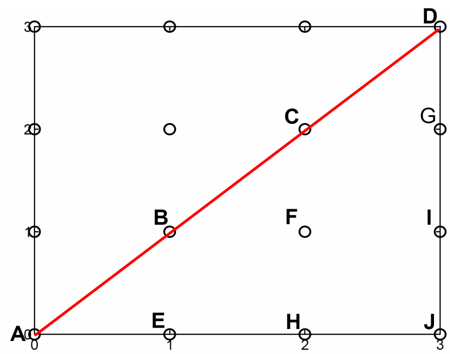

Fig. 1: A section from a Grid-based sensor field showing moles **A, B, C, D** and source nodes **E, F, G, H, I, J**

Preliminary Results:

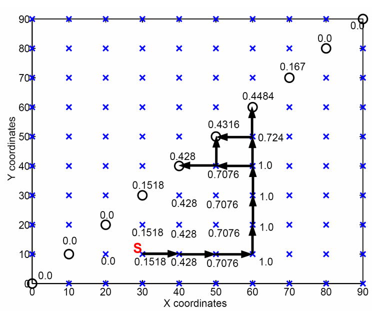

Fig. 2: An illustration of the set of paths generated by FLOW scheme

ϵ_1, ϵ_2	$\epsilon_1 = 0.25$	$\epsilon_1 = 0.50$	$\epsilon_1 = 0.75$	$\epsilon_1 = 1.00$
$\epsilon_2 = 0.25$	(0.2, 3)	(0.4, 4)	(0.5, 6)	(0.8, 10)
$\epsilon_2 = 0.50$	(0.2, 3)	(0.4, 6)	(0.6, 9)	(0.85, 11)
$\epsilon_2 = 0.75$	(0.2, 3)	(0.45. 6)	(0.7, 11)	(0.9, 12)
$\epsilon_2 = 1.00$	(0.2, 3)	(0.45, 6)	(0.7, 11)	(1.0. 14)

Table 1: Delivery Ratios and Energy Cost for different ε_1 and ε_2

•It can be seen from **Fig. 2** that FLOW scheme finds a set of paths from the source node to those moles that have a high probability of being in the sink's vicinity. Furthermore, when the probabilities are similar, the algorithm selects *both* neighboring nodes. This results in *multipath* routing which offers more robustness over single path routing.

•**Table 1** shows the trade-off between delivery ratio and energy-cost which is nicely captured by the tunable parameters ε_1 and ε_2

Key Advantages of FLOW

•Energy Efficiency: FLOW avoids wastage by selecting good paths

•Distributed Nature: Nodes use only local information to calculate likelihood values

•Scalability: Each node needs to maintain information about only its local neighborhood

•Robustness: because of multi-path nature

•Flexibility: using tunable parameters ε_1 and ε_2

Future Work: We would like to generalize the current setting that considers a regular grid-based sensor field to random sensor fields.

References

[1] F. Ye, G. Zhong, S. Lu, L. Zhang, "GRAdient Broadcast: A Robust Data Delivery Protocol for Large Scale Sensor Networks," *to appear in ACM Wireless Networks (WINET)*, Vol. 11, No.2, March 2005