SIMPLE: using Swarm Intelligence Methodology to design data acquisition ProtocoL in sEnsor networks with mobile sinks

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Outline

- Introduction
- Related work
- Background
- data acquisition protocol: SIMPLE
- Simulation
- Conclusion

Introduction (1/2)

- This paper addresses the data acquisition problem in sensor networks with multiple sources and multiple mobile sinks
  - Source: sensor nearest to the target
  - Sink: soldier or policeman

Introduction (2/2)

- Motivation
  - Sensor's low computation capability
  - Sensor's limited energy
- Problem
  - How should the static sources report their data to the mobile sink so that network and individual sensor's lifetime is maximized

Related work (1/2)

- Obstacle: sink's location changes constantly
- Most of the existing proposal
  - Sink continuously updates all sensors with its current location information

Related work (2/2)

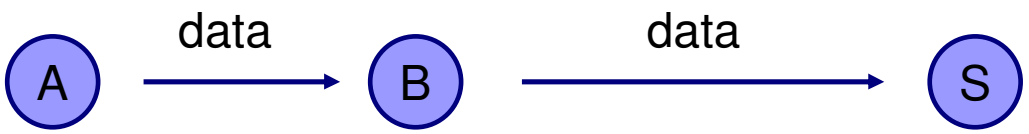
- TTDD
  - Each source forms a grid like path to the sink
  - The Communication and state overheads associated with maintaining these routes degrade its scalability and ability to maximize network lifetime
  - Energy unaware

Background (1/3)

- Assumptions
  - No prior knowledge about the sink's mobility characteristics is available
  - No prior knowledge about source data generation characteristics is available

Background (2/3)

- Terminology
  - Lifetime of the network
    - The time till the first node in the network die
  - Gradient of a node
    - A node's next hop neighbor on the shortest path leading to the sink



Background (3/3)

- “Shortest path” definition
  - Between a given source and destination there exist several paths
  - The path which contains the node with the highest minimum residual energy

SIMPLE

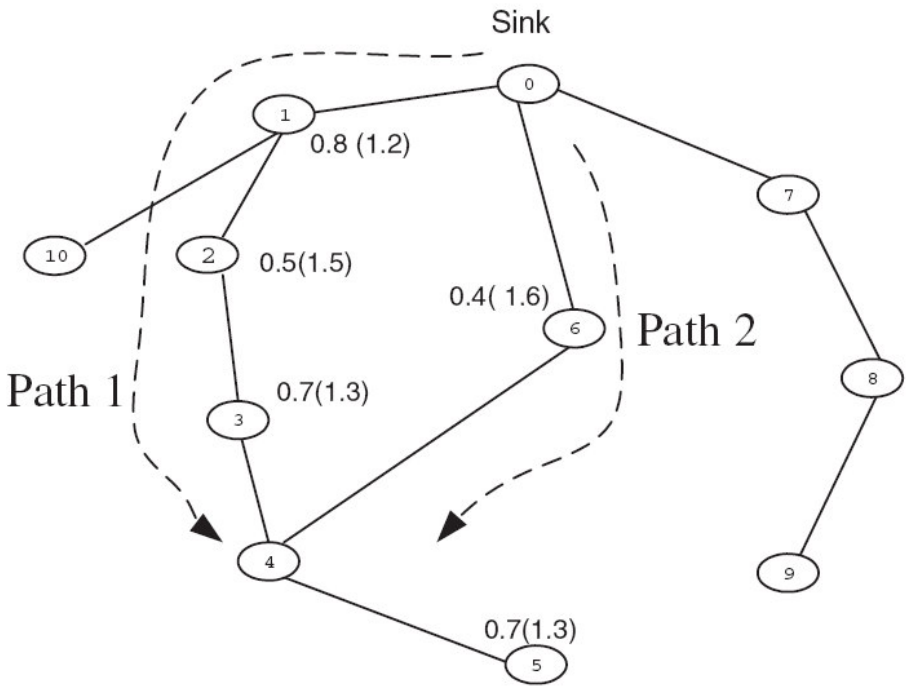
- Swarm agent
- Advertisement suppression scenarios
- Probabilistic Advertising Model
- Networks with multiple sinks

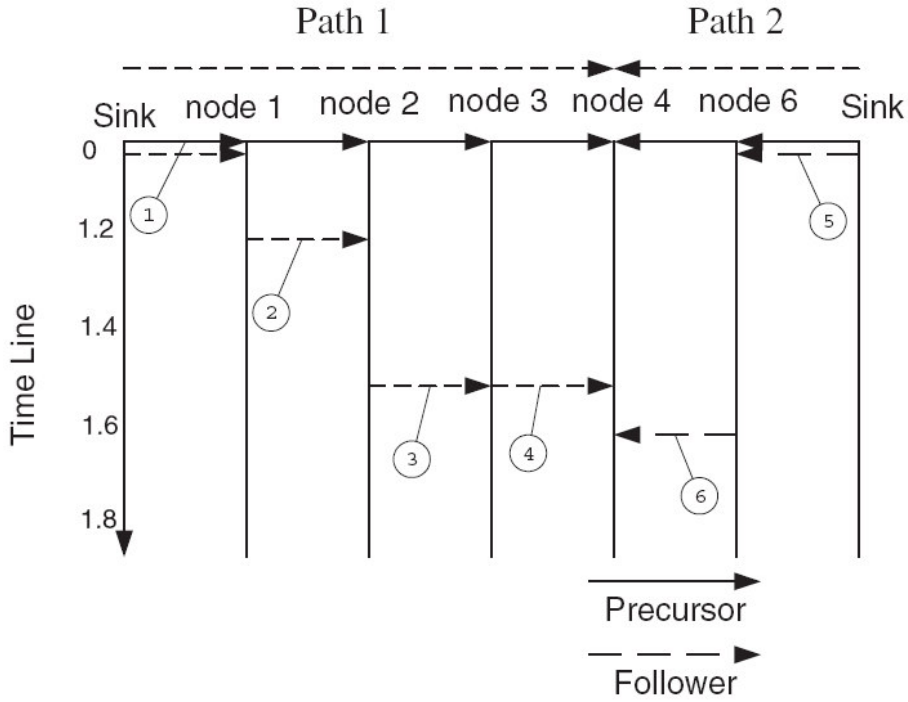
Swarm agent

- stamped with an unique and increasing sequence number and consists of two very short packets, namely the precursor and follower
- advertised by the sink periodically or only when the sink loses contact with some of its one hop neighbors

Swarm agent

$T = 2 - e_r$ e_r is the node's remaining energy (normalized between [0,1])

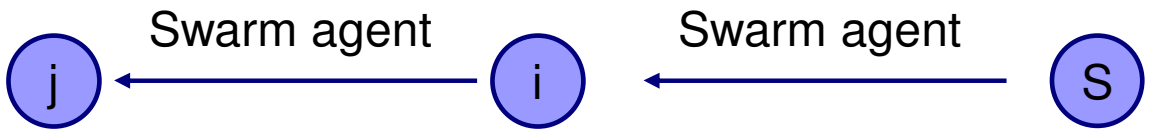




back

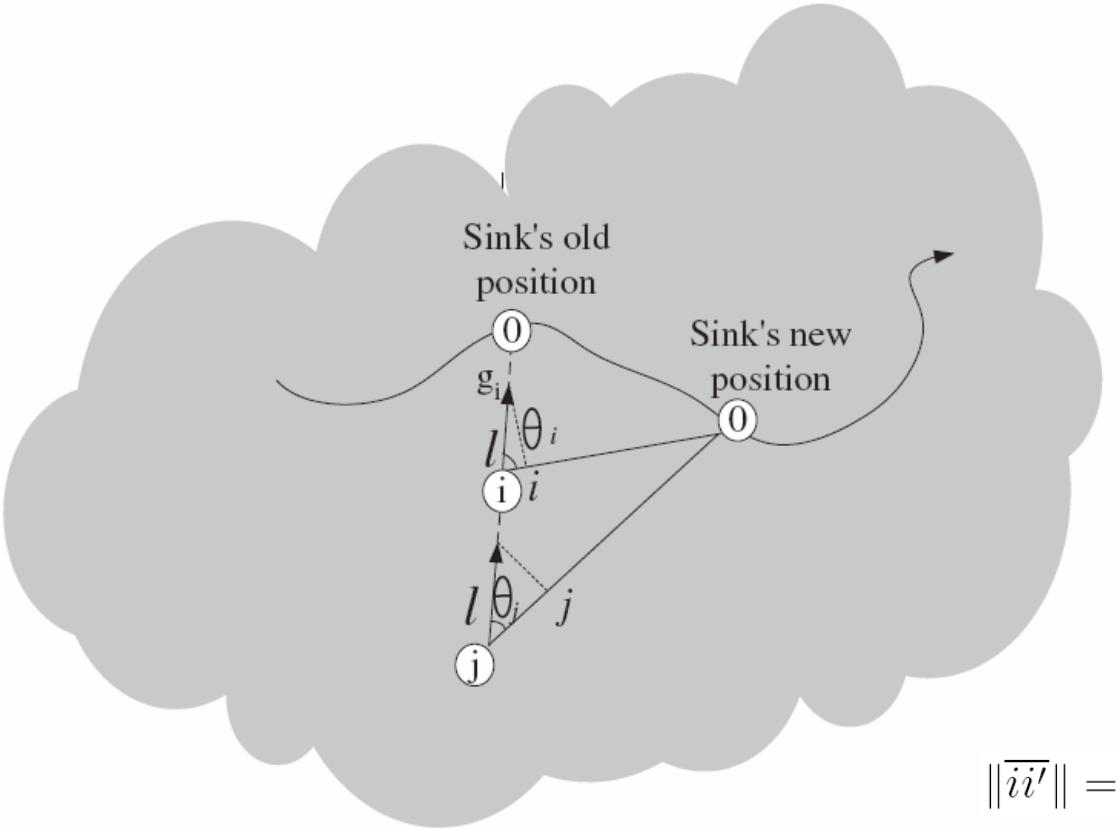
Advertisement suppression scenarios

- Node *i*'s utility increases for each node *j* that picks *i* as its next hop on the shortest path based on node *i*'s advertisement



- A higher utility / energy consumption ratio is desired for each node

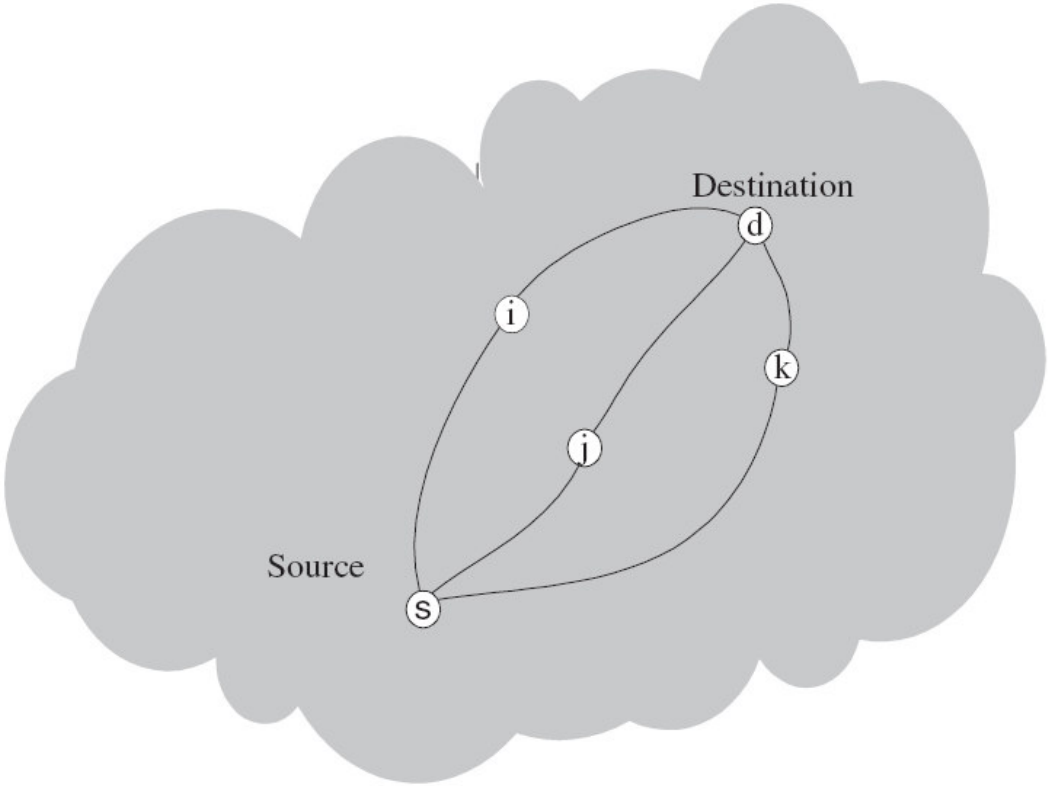
Advertisement suppression Scenario 1



$$\|\overline{ii'}\| = l \times cos(\theta_i)$$

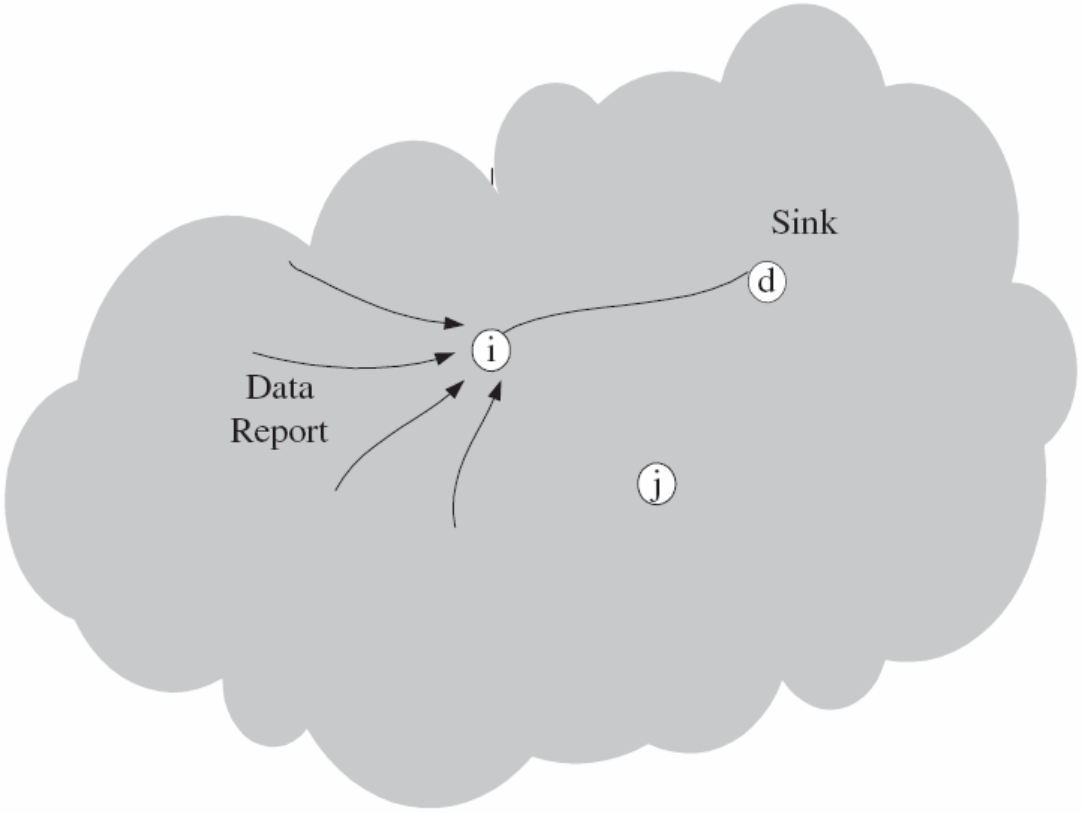
Sink's movement has lower effect on nodes further away.

Advertisement suppression Scenario 2



Sensors with more residual energy should advertise more actively.

Advertisement suppression Scenario 3



Sensors relaying more data should advertise more actively.

Probabilistic Advertising Model

- Each node re-advertises the swarm agent based on a probability ρ
- Have ρ :
  - Increase each time it relays data for its neighbors
  - Decrease if the node does not relay any data as time elapses
  - Have a higher lower-bound when the node has more residual energy
  - Will never reach 0 except sensor's energy is fully depleted

Networks with multiple sinks

- Two schemes to avoid the energy consumption incurred by too much swarm agent broadcast
  - networks of small scale
    - Node relays swarm agent from the closest sink
    - Node reports to the closest sink
  - networks of large scale
    - Pre-divide an area into sub-regions with one sink in each of them

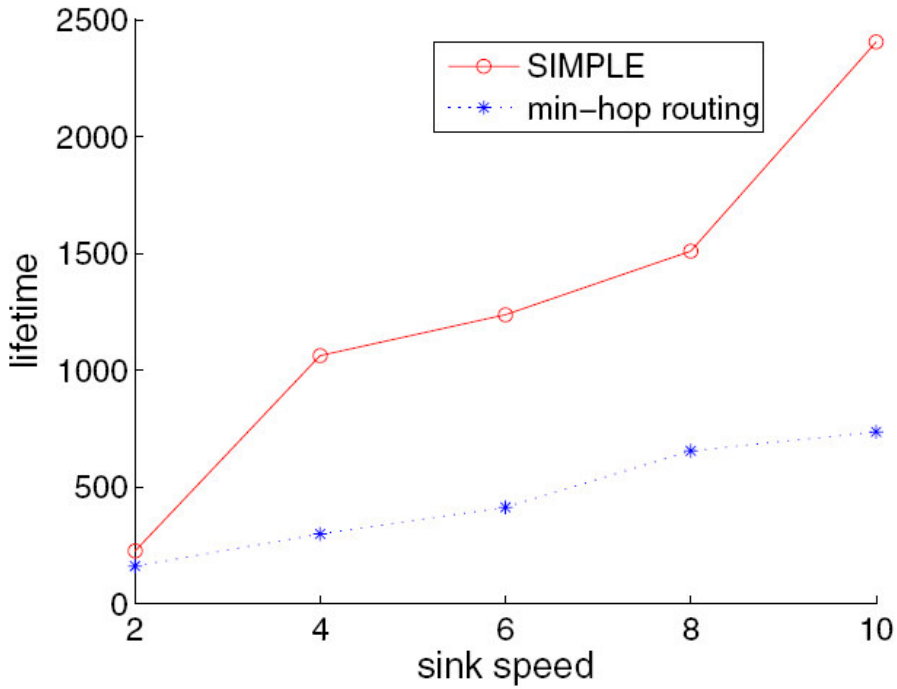
back

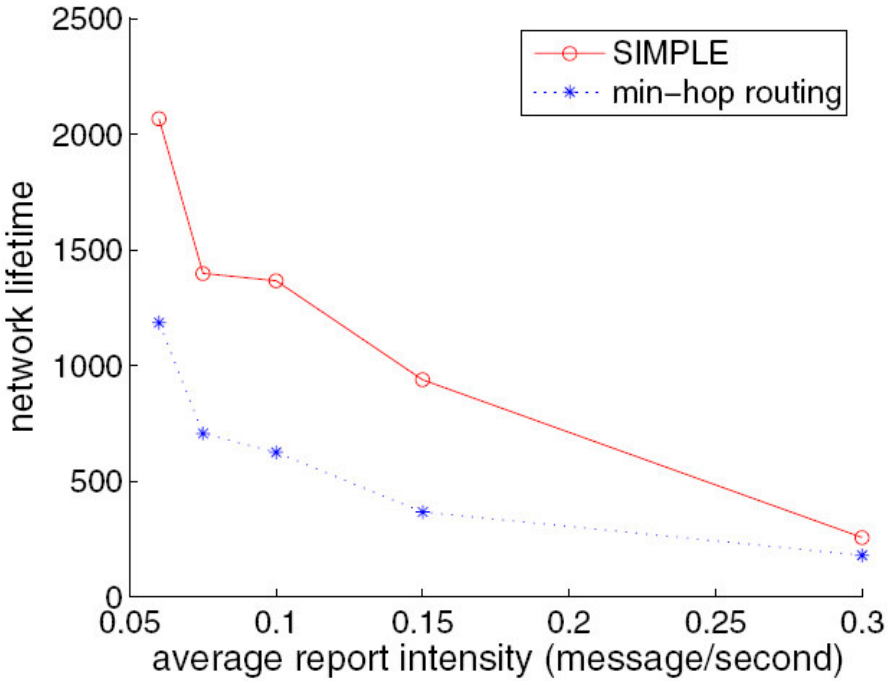
Simulation Setup 1

Compare with min-hop routing

- 200 nodes are uniformly distributed in a 100 x 100m^2 network area
- swarm agent is 64 bytes
- report message is 512bytes
- Node's transmission range = 25m
- Each node's initial energy is 500 units
- Data reports generated at each node with Poisson arrival rate $\lambda = 0.3$ messages per second

Compare with min-hop routing

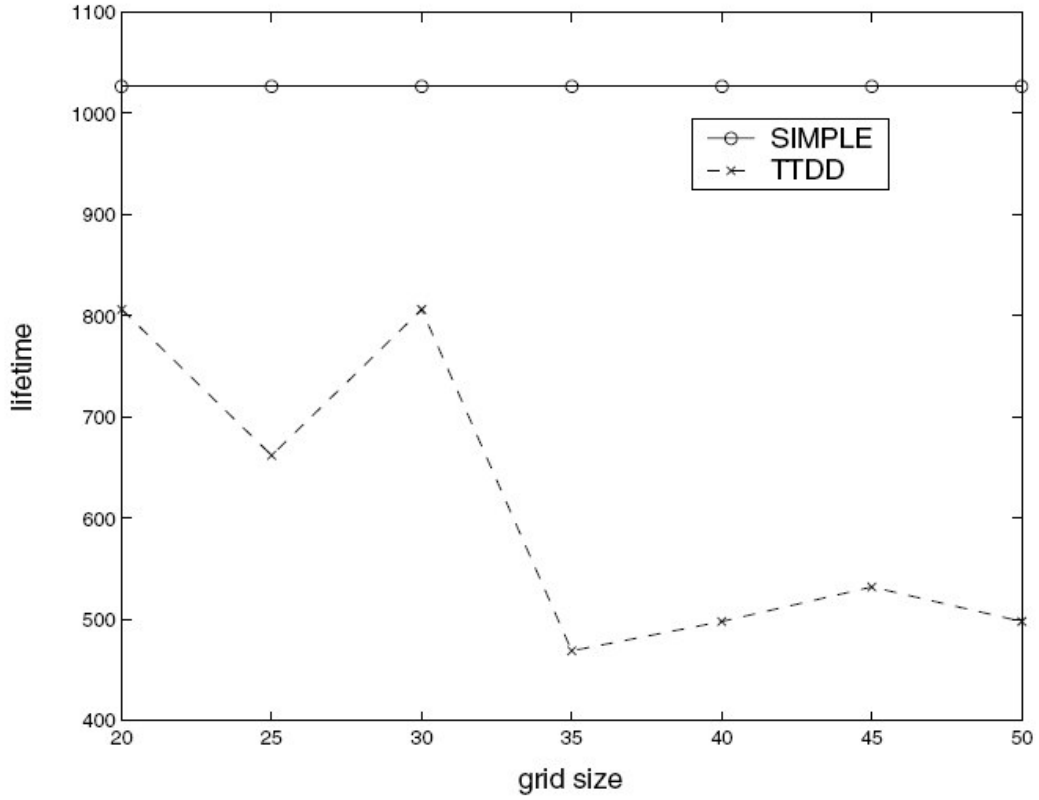




Simulation Setup 2 Compare with TTDD

- 100 nodes located in 100 x 100m^2 region
- The area is divided into 10 x 10 grids, and all nodes are located at cross point of grids
- swarm agent is 64 bytes
- report message is 512bytes
- Sink speed = 10 m/s
- Node's transmission range = 11m
- Each node's initial energy is 250 units
- λ = 0.05 message per second
- Ignore TTDD's overhead induced by each source to construct and maintain the grid
- SIMPLE without suppressing any swarm agents

Compare with TTDD

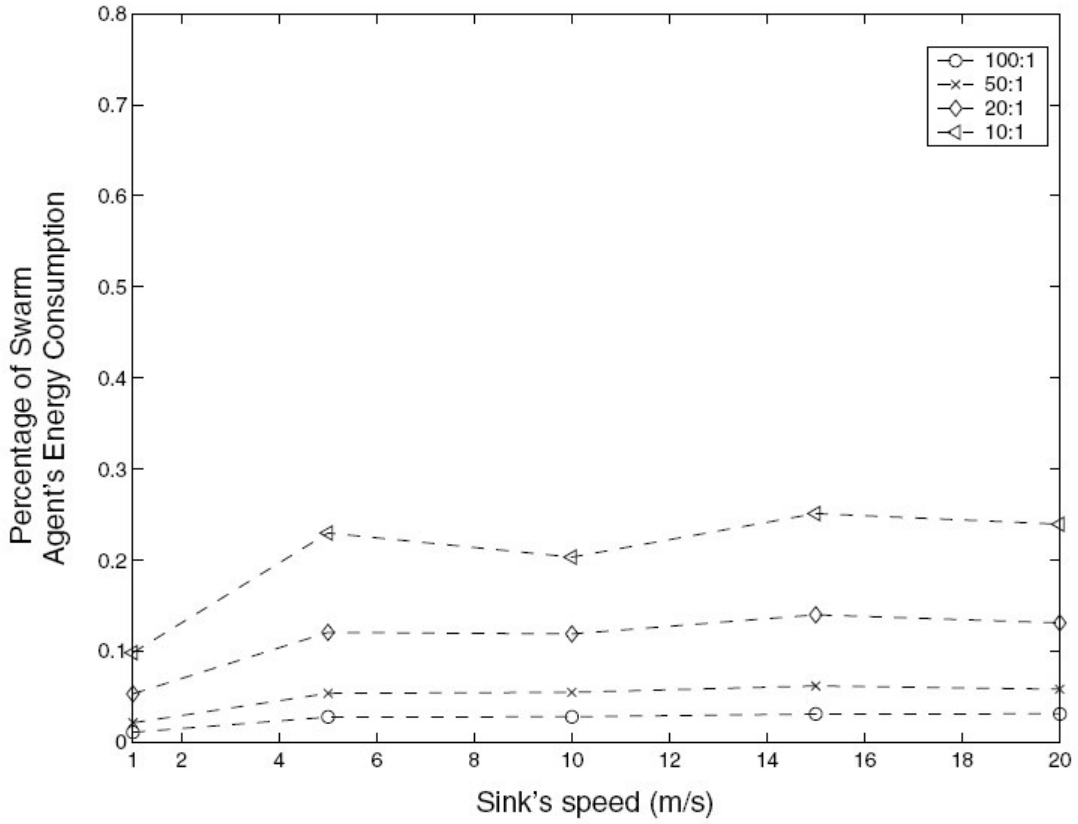


Simulation Setup 3

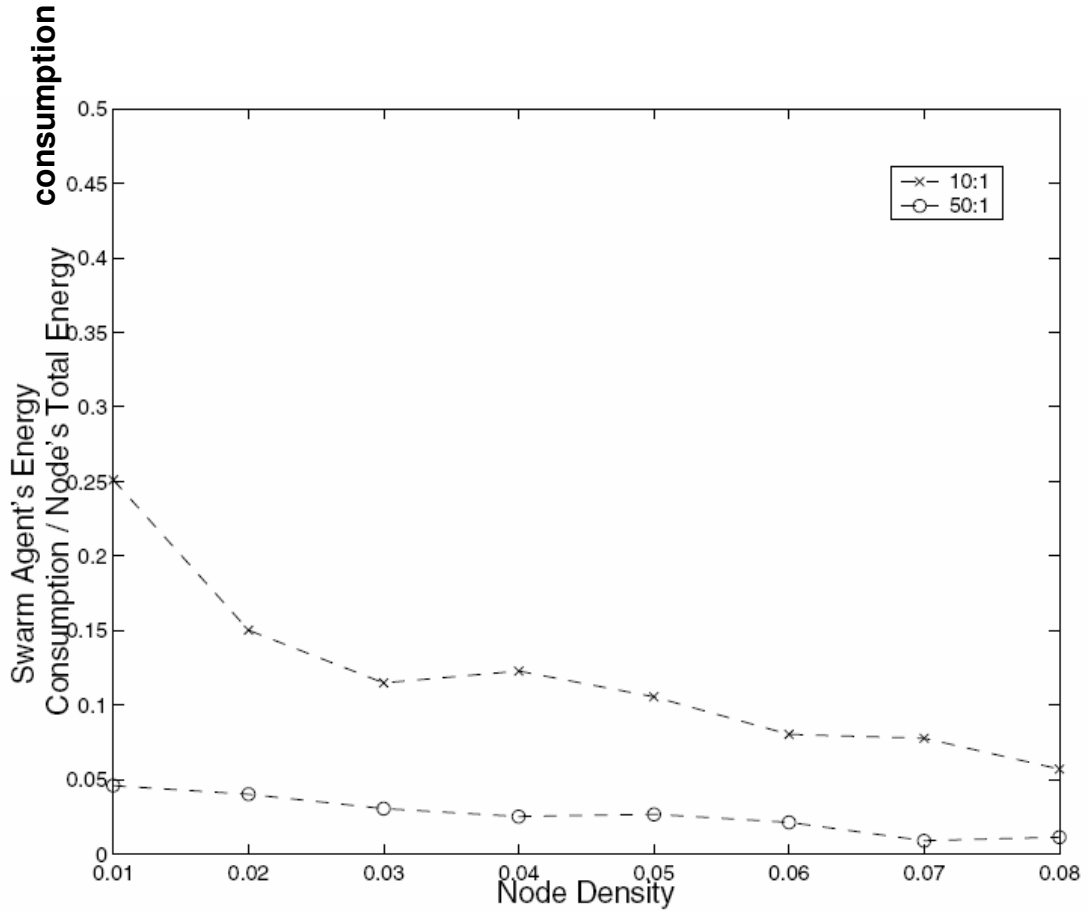
effect of the Environmental factors

- 200 nodes are uniformly distributed in a 100 x 100m^2 network area
- Node's transmission range = 25m
- Each node's initial energy is 500 units
- Suppression is involved

Effect of the sink's speed and Length of the swarm agent



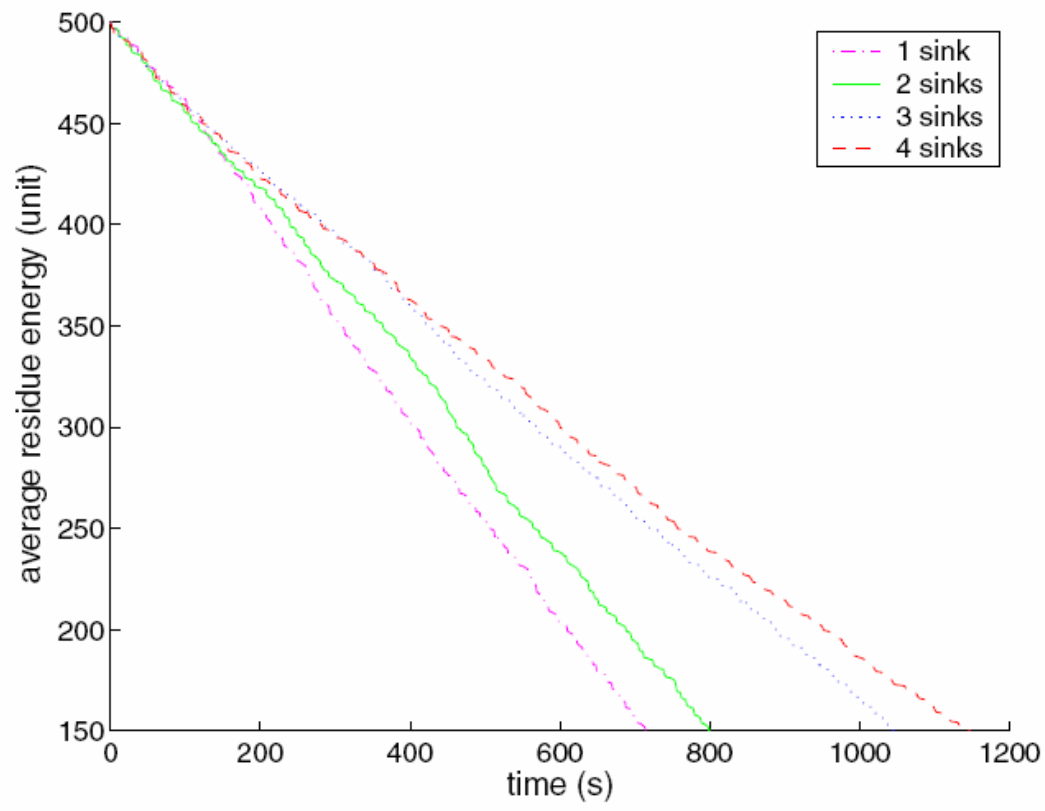
Effect of node density



Simulation Setup 4 Multi-sink Scenarios

- 400 nodes are uniformly distributed in a 200 x 200m^2 network area
- swarm agent is 64 bytes
- report message is 512bytes
- Node's transmission range = 25m
- Sink's speed = 10m/s
- λ = 0.05 message per second

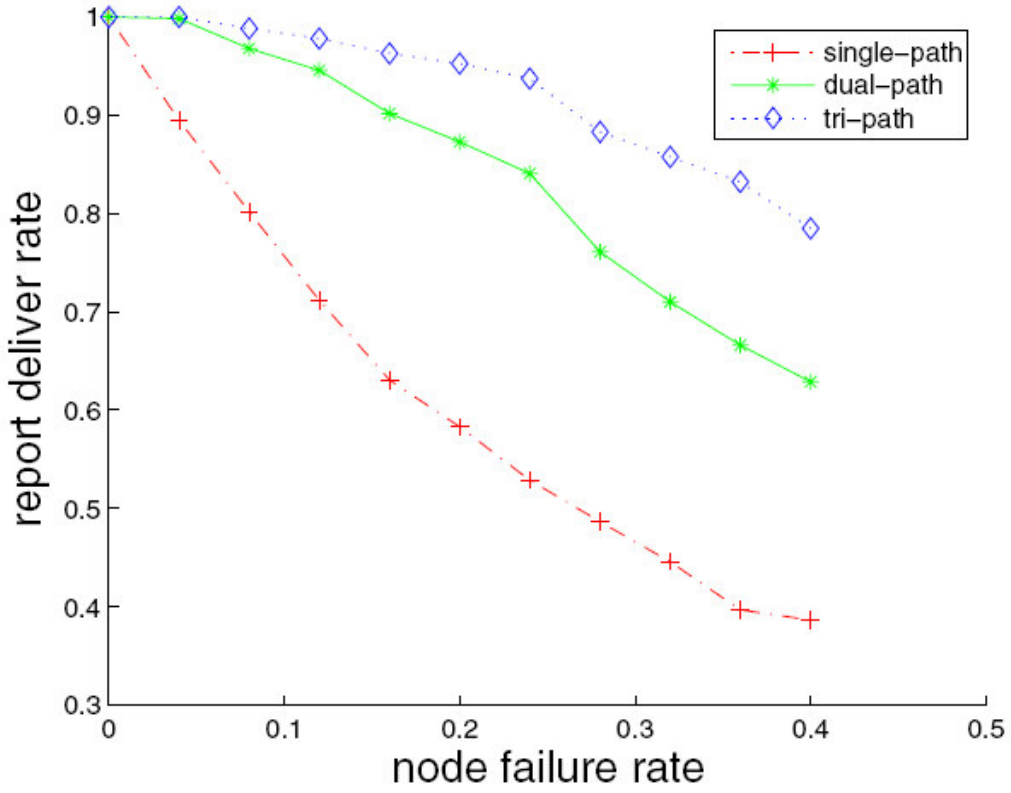
Multi-sink Scenarios



Simulation Setup 5 resilience against node failures

- 200 nodes are uniformly distributed in a 100 x 100m^2 network area
- Node's transmission range = 25m
- Sink's speed = 10m/s
- Each node's initial energy is 500 units
- λ = 0.05 message per second

Protocol resilience against node failures



Conclusion

- SIMPLE is design based on the techniques of swarm intelligence, energy-wise shortest path and a probabilistic model for dynamically updating the shortest paths
- Simulations demonstrate its robustness and superior performance as compared to existing protocols

Discussion

- Swarm agent
- Networks with multiple sinks