Ubiquitous Networks

WSN Routing Protocols

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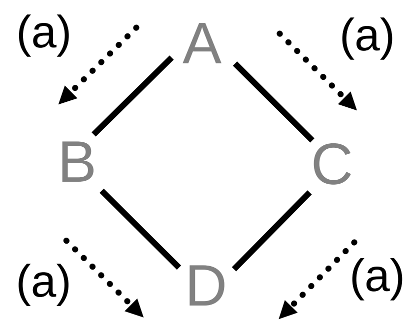
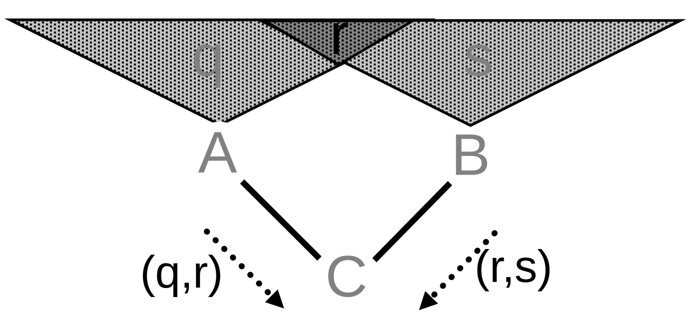
Flooding

- **Idea**
  - Each node broadcasts a packet if the maximum hop-count of the packet is not reached and the node itself is not the destination
  - Does not require topology maintenance or route discovery
- **Disadvantages**
  - Implosion
    - A node receives copies of the same message
  - Overlap
    - The same event may be sensed by more than one node due to overlapping regions of coverage
  - Resource blindness
    - The protocol does not consider the available energy at the nodes, reducing the network lifetime

- Implosion



- Data overlap



Gossiping

- **A modified version of flooding**
  - Instead of broadcasting, send it to a randomly selected neighbor
  - Plus
    - Avoid the problem of implosion
    - Lower overhead, less traffic
  - Minus
    - Longer delay
    - Does not guarantee the delivery

Directed Diffusion

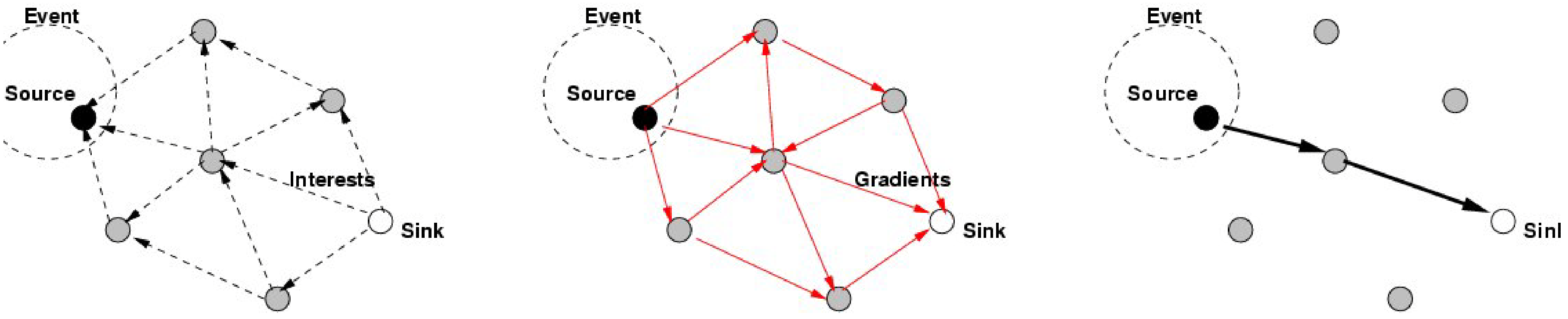
Data centric

- Data is named by ‘attribute-value’ pairs (rather than node address)
- A node requests data by sending interests for named data
  - “Detect vehicle location in [100,100] and send me events every 20ms.”

Data diffusion procedure

- Interest propagation
  - Sinks broadcast interest to neighbors (request-driven)
  - Gradients are set up pointing back to where interests came from
  - Interests and data are cached by intermediate nodes
- Data propagation
  - Once a source receives an interest, it routes measurements along gradients
- Reinforcement
  - After sink starts receiving events, it enforces a particular (low-delay) path to receive high-quality data
  - Gradients from Source (S) to Sink (N) are initially small but increase during reinforcement
- Supports multiple sources and multiple sinks

Directed Diffusion



(a) Interest propagation (b) Initial gradients set up (c) Data delivery along reinforced path

TTDD (Two-Tier Data Dissemination Protocol)

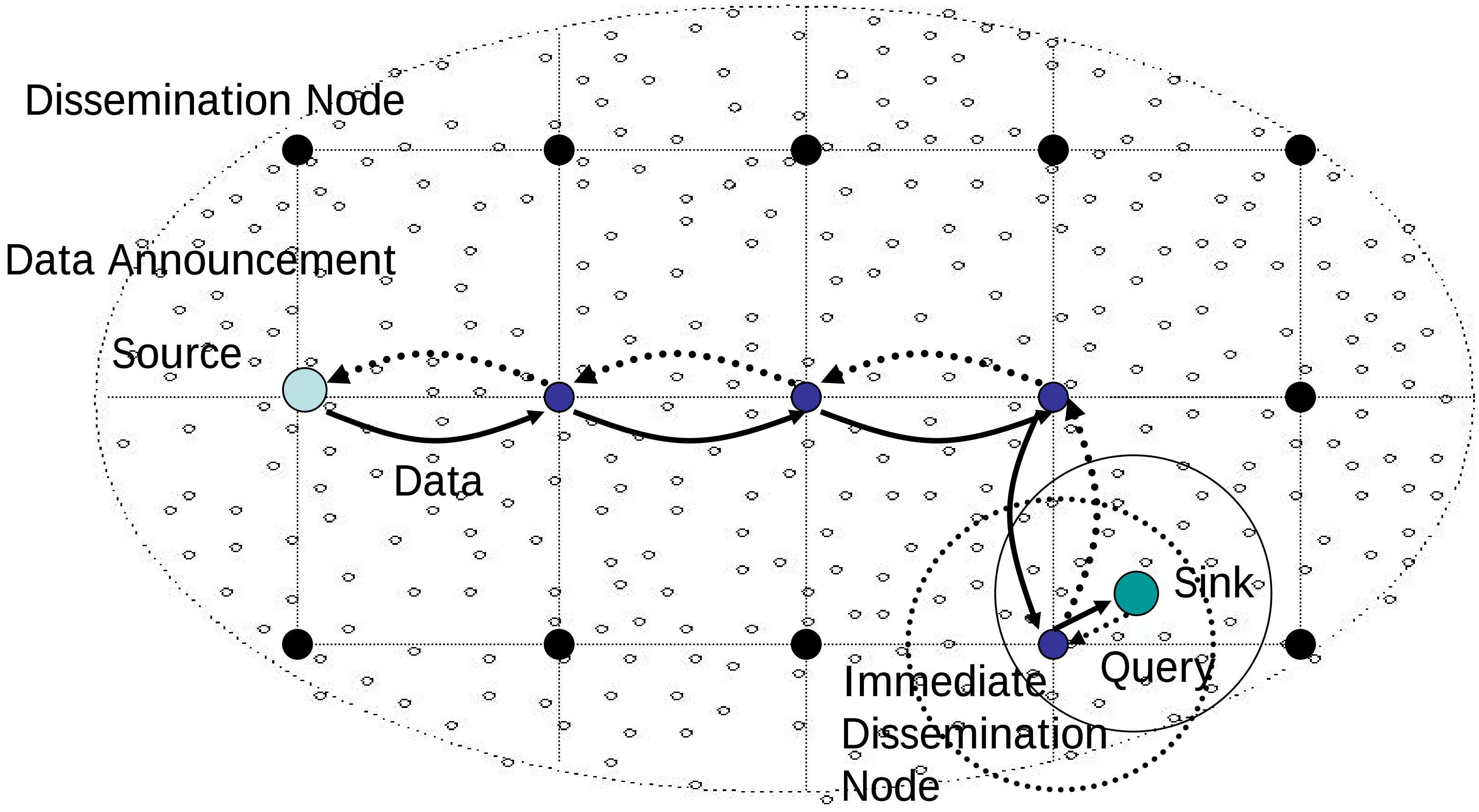
Mobile sinks bring new challenges

- The location of a mobile sink needs to be continuously propagated throughout the sensor field
- Frequent location updates from multiple mobile sinks lead to
  - Excessive energy drains of sensor nodes
  - Increased collisions

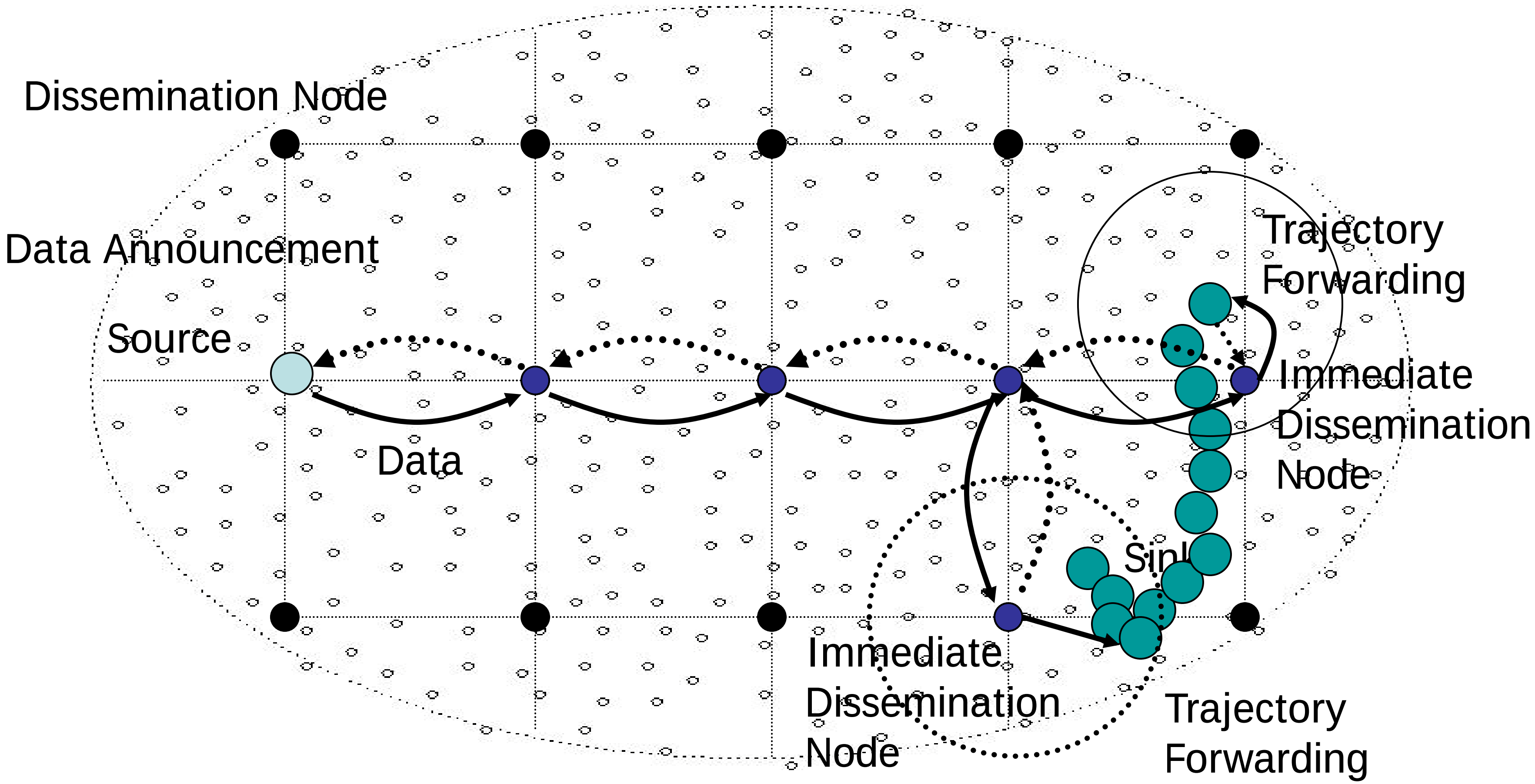
Two-tier forwarding model

- Assumption
  - Sensor nodes are stationary and location-aware (GPS-enabled)
- Each data source proactively builds a grid structure
- Each source forwards its data to a set of sensor nodes called *disseminating nodes* (at grid points)
- This enables each mobile sink to receive data by flooding in each local cell only
  - Localize impact of sink mobility on data forwarding

TTDD (Two-Tier Data Dissemination Protocol)



TTDD (Two-Tier Data Dissemination Protocol)



Ubiquitous Networks

Virtual Sink Rotation (VSR)

Existing Solutions

- **Several schemes have been proposed to target mobile sinks specifically**
  - TTDD (Two-Tier Data Dissemination) : UCLA, Mobicom ‘02
  - SEAD (Scalable Energy-efficient Asynchronous Dissemination): SNU, SenSys ‘03
  - HLETDR (Hybrid Learning-Enforced Time Domain Routing): USC, LCN’04
- **However, most of them suffer from the following limitations**
  - Local flooding (TTDD) guided by geographical grids pre-maintained
  - Global flooding (HLETDR,DD) based on interest propagation and reinforcement
  - Assumption of location awareness: SEAD, TTDD
    - However, GPS receivers are too expensive and do not work indoors
    - Existing localization techniques using recursive trilateration/multilateration techniques are not accurate enough
- **No practical routing solutions so far**

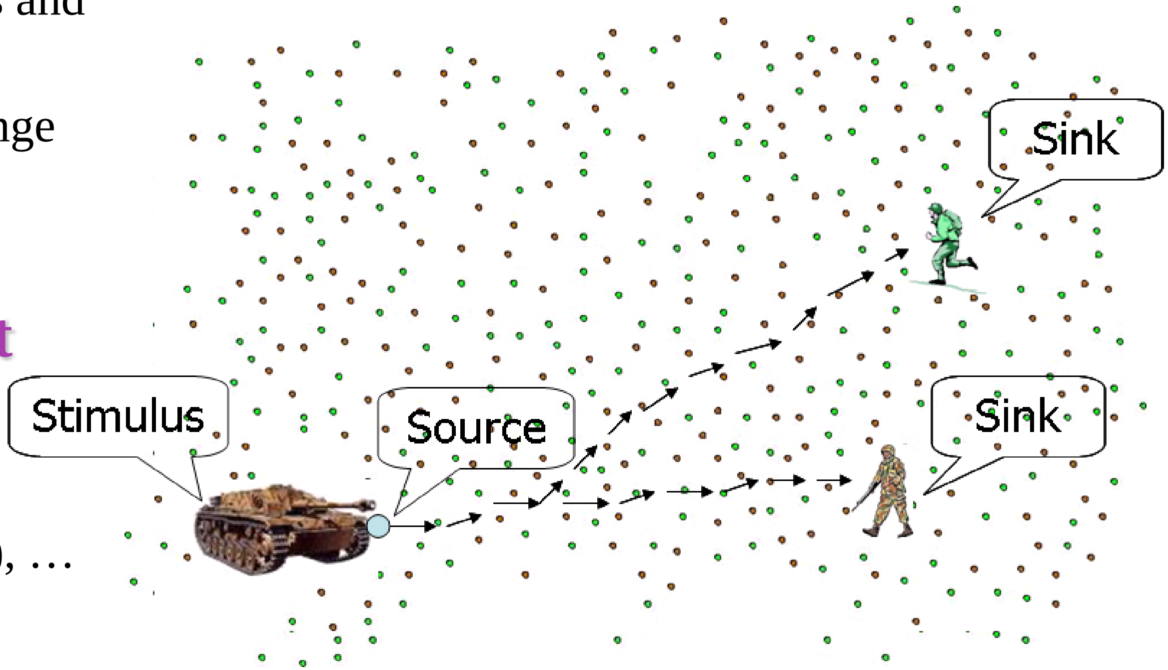
VSR (Virtual Sink Rotation)

Sensor network model

- Stationary sensor nodes and mobile sinks
- Homogeneous short-range radios
- GPS-free sensor nodes

Target environment

- Battlefield
- Habitat exploration
- Robots (in home/space), …
- overhead



VSR Ideas

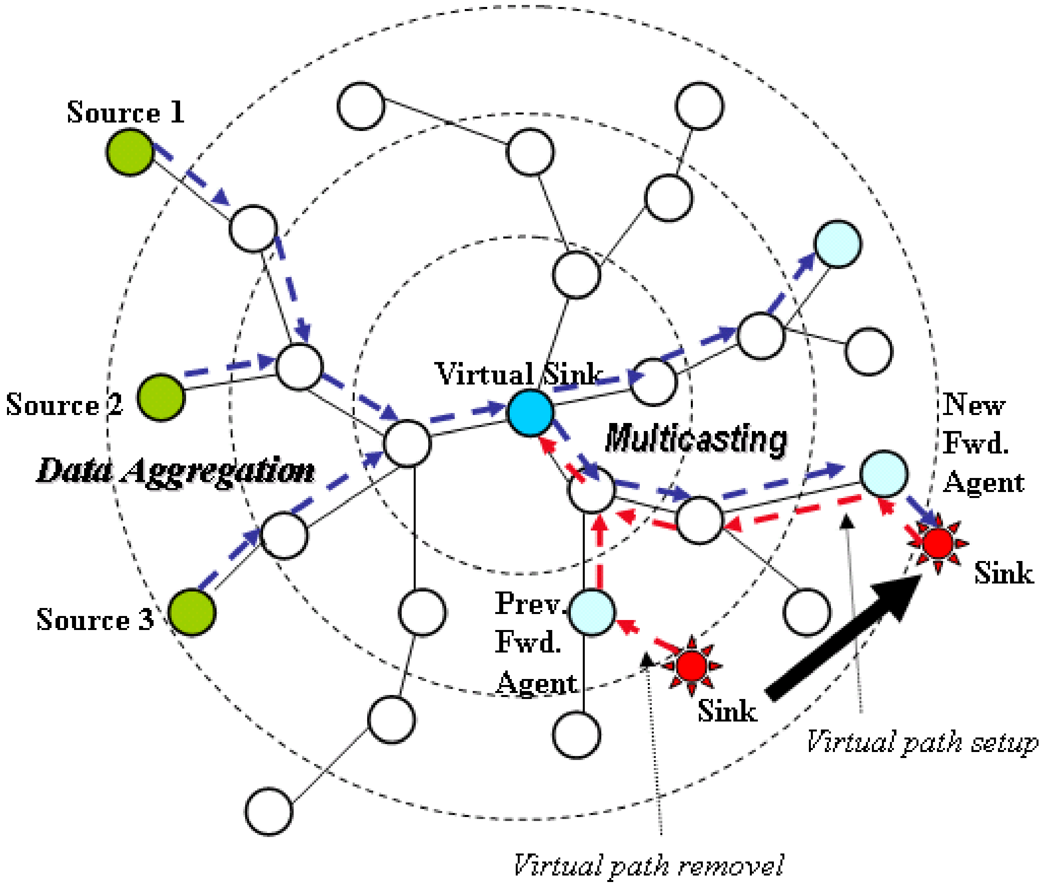
Virtual Sink: a sensor node acting as a real sink

- Functions
  - Builds a spanning tree (*VS tree*) in lieu of the actual sink
    - VS tree is constructed at the initial deployment and can be repaired or reconstructed from time to time due to node failures, excessive energy drains
  - Data collection center: collect all messages/events from sources
    - Can aggregate if necessary
  - Data dissemination center: forward messages/events to sinks
    - Need to maintain *virtual path* from the virtual sink to real sinks
- Advantages: all the path information is already embedded in the VS tree
  - Can easily support multiple sinks
  - Can easily support mobility

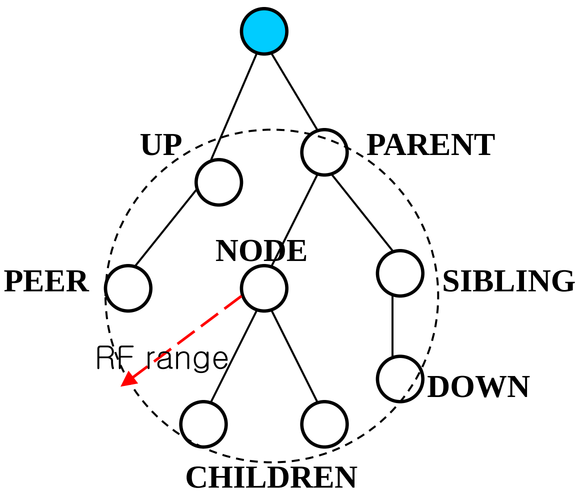
Virtual Sink Rotation

- Rotate the role of virtual sink among all candidate sensor nodes
  - Because a virtual sink and its neighbors consume more energy than leaf nodes
- Evenly distribute the energy consumption among all nodes
  - Can increase the lifetime of the sensor network

Virtual Sink Rotation Routing

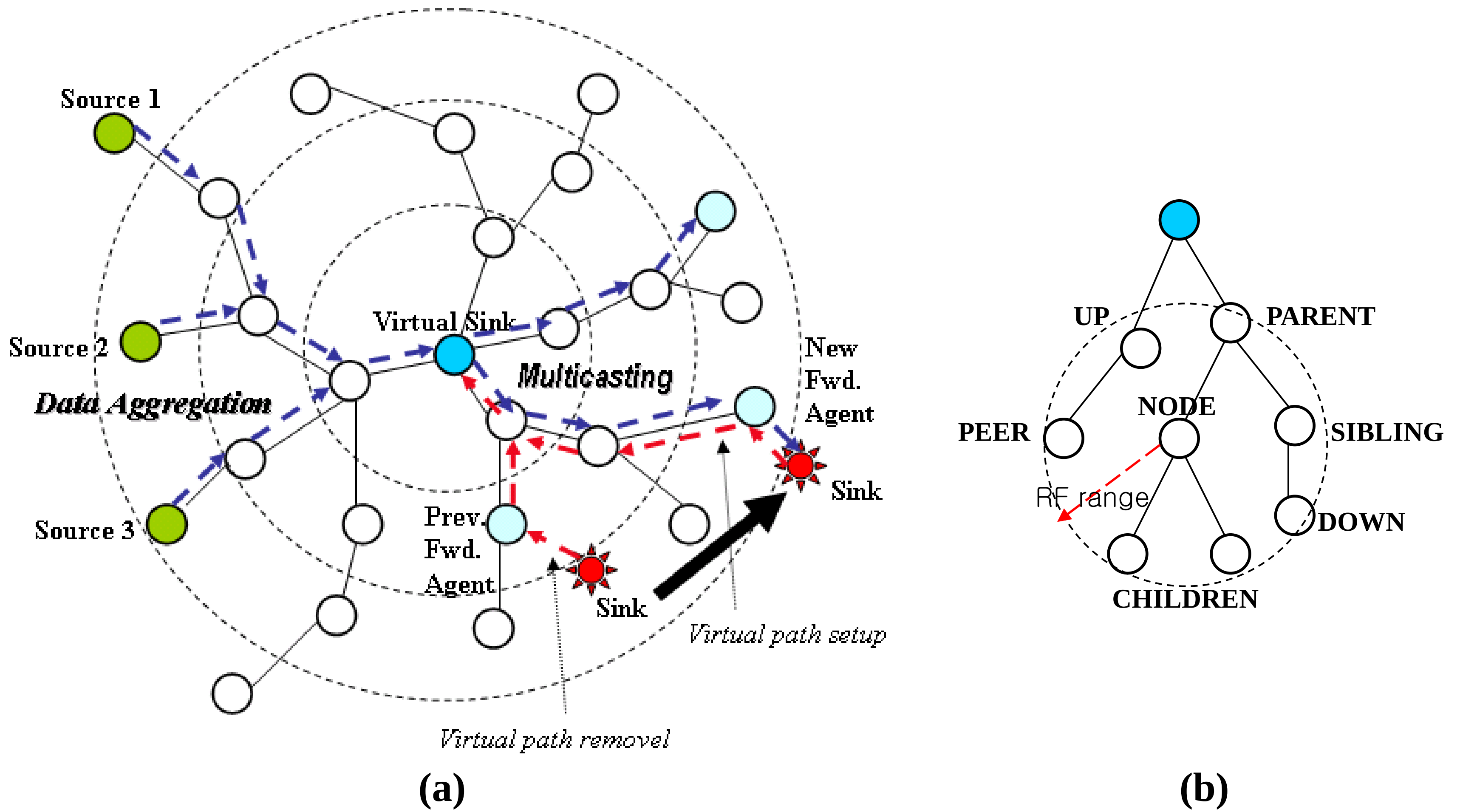


(a)



(b)

Virtual Sink Rotation Routing



VSR - NS2 Simulation

Simulation Environment

- Network size: 2000m x 2000m (for 400 nodes)
- Number of nodes : 100 ~ 800 nodes
- MAC layer : 802.11
  - Modified to model sensor network energy model
  - Tx : 0.66w
  - Rx : 0.395w
  - Idle : 0.035w
- Simulation time 100 sec
- Each event is modeled as a 64B packet

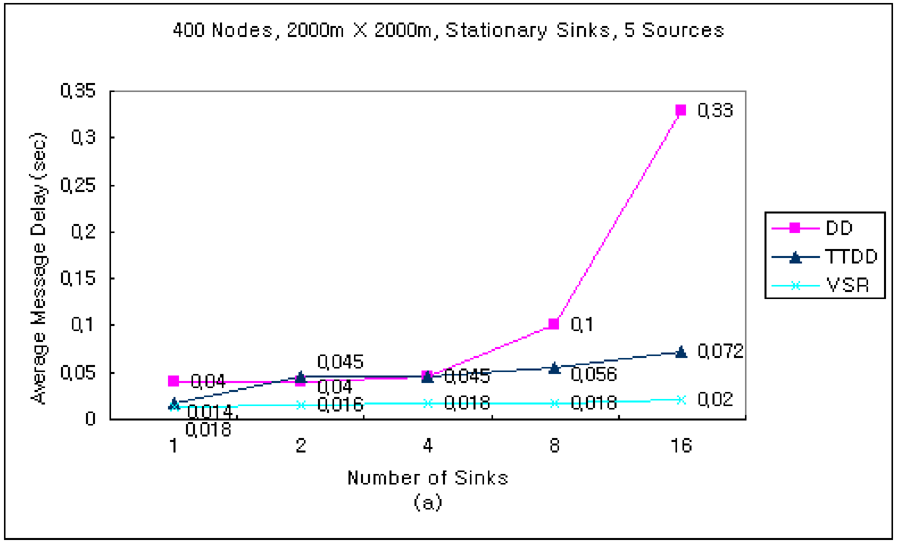
Impacts of

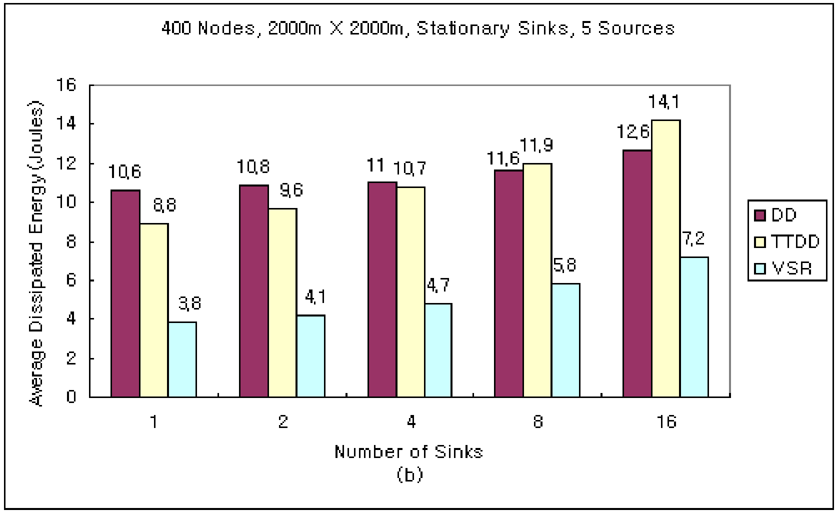
- Number of sources
- Number of sinks
- Sink mobility
- Node failures, scalability and density, rotation policy

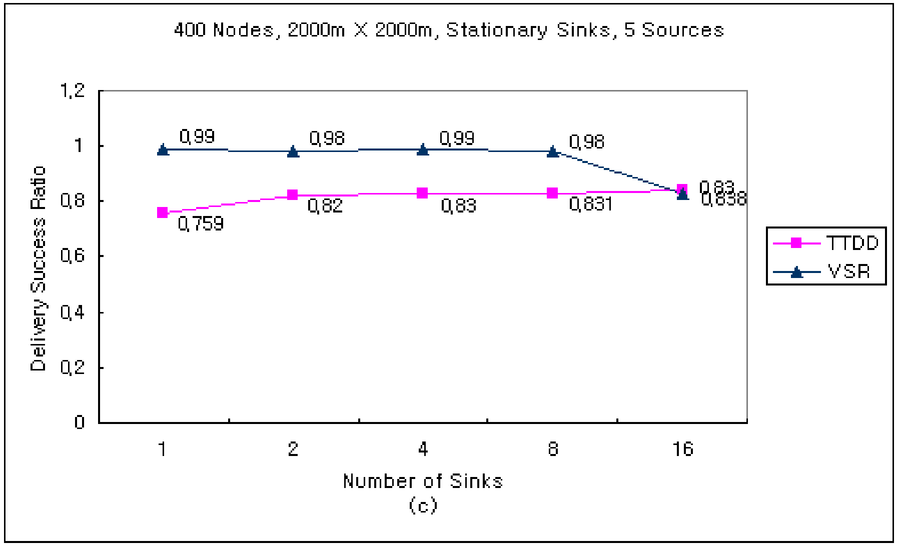
Performance Metrics

- *Energy consumption, delay, success rate*

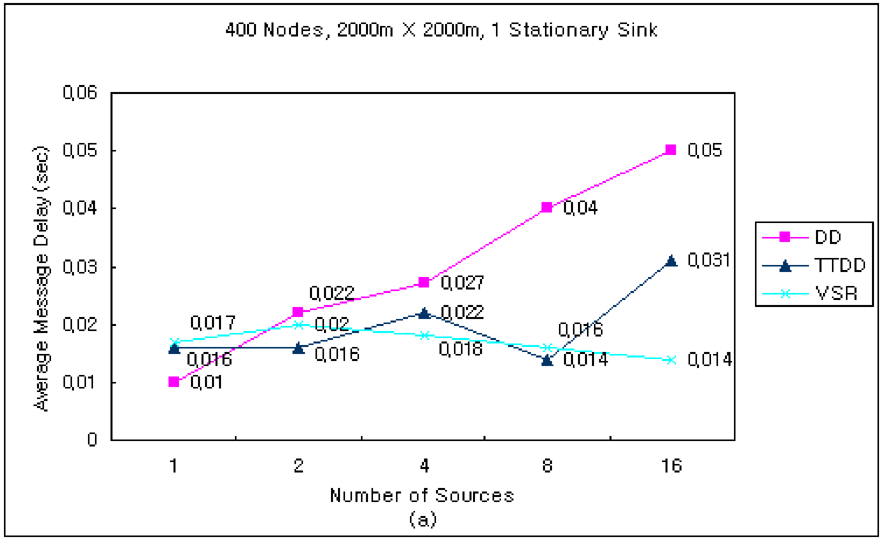
VSR – Stationary Sinks: Different # Sinks

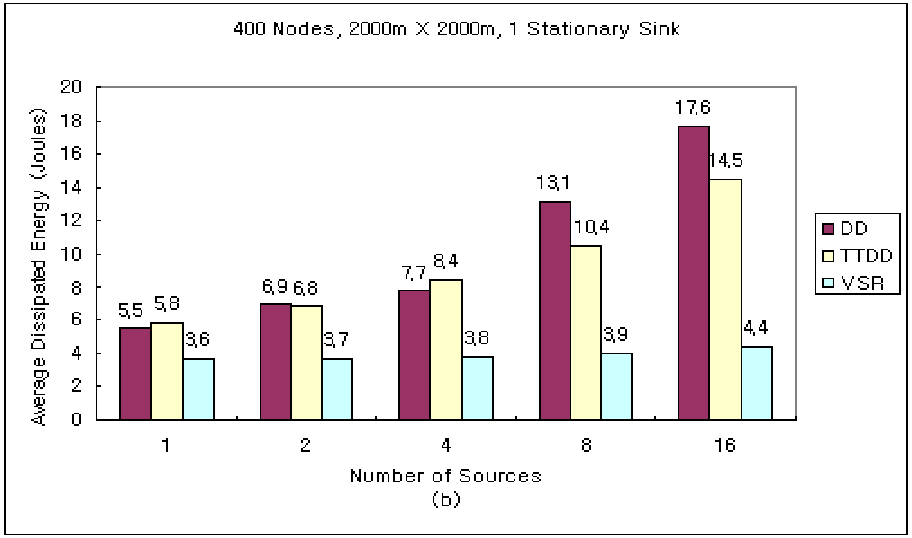


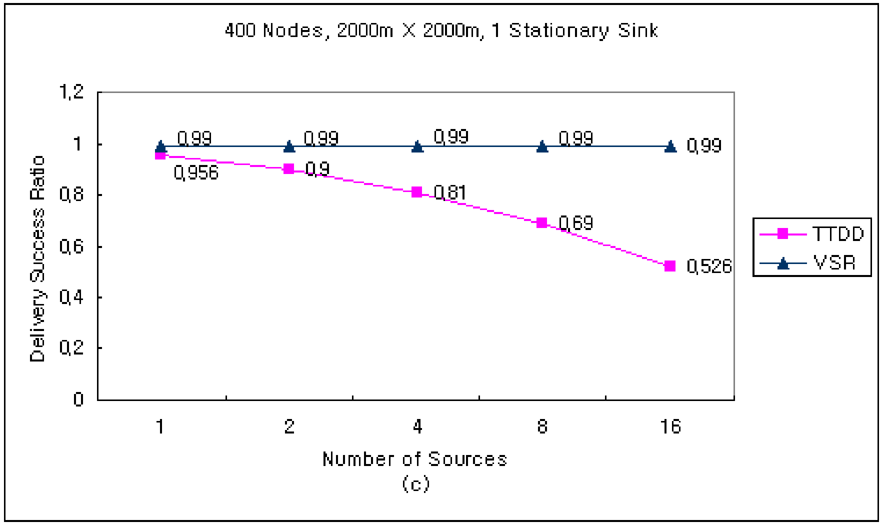




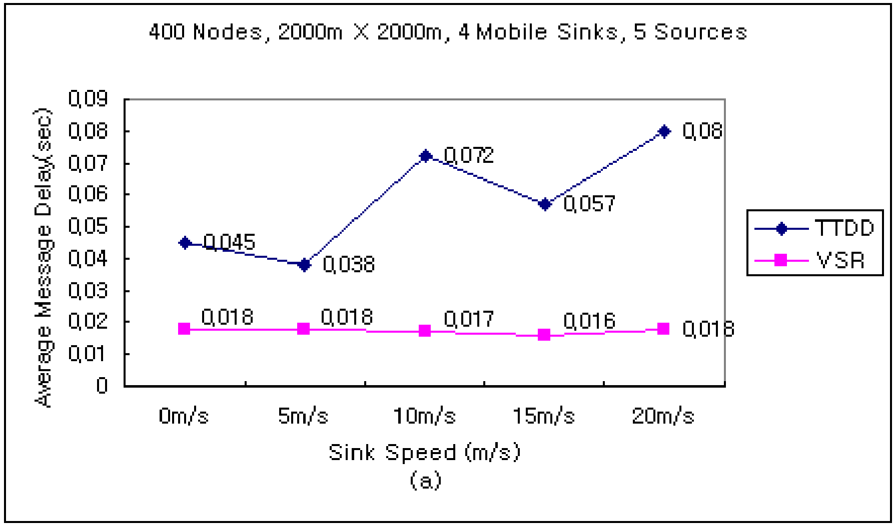
VSR – Stationary Sinks: Different # Sources

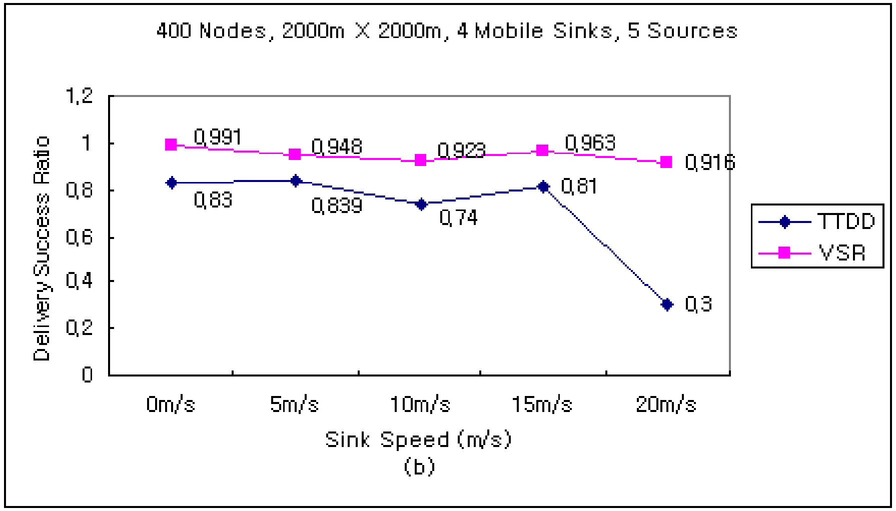


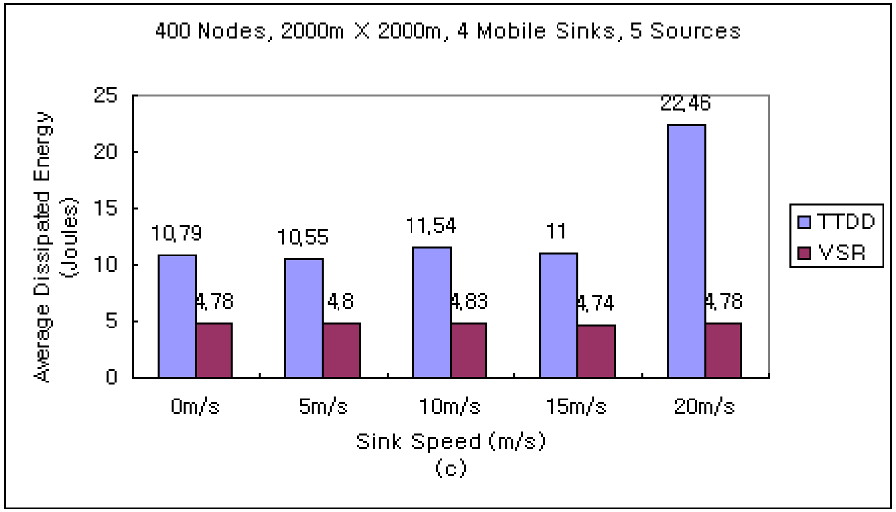




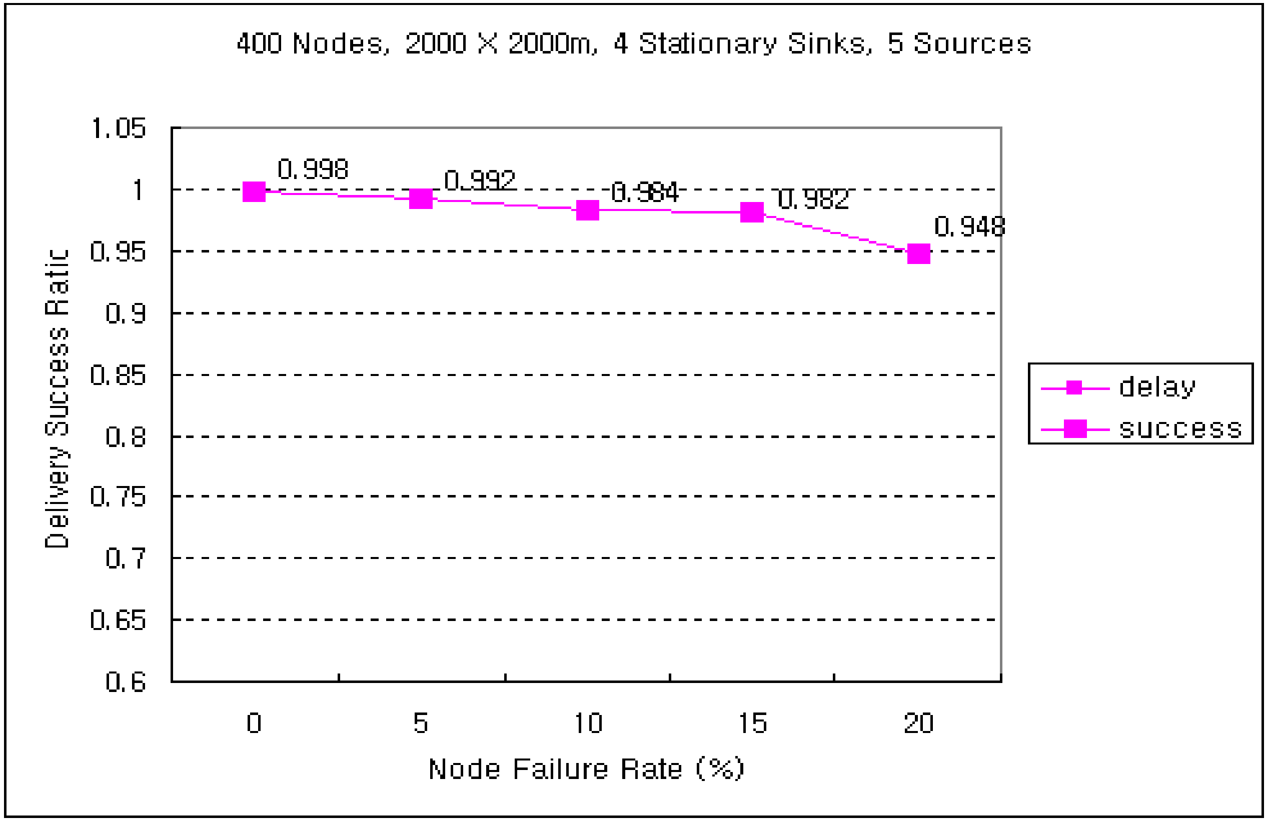
VSR – Mobile Sinks



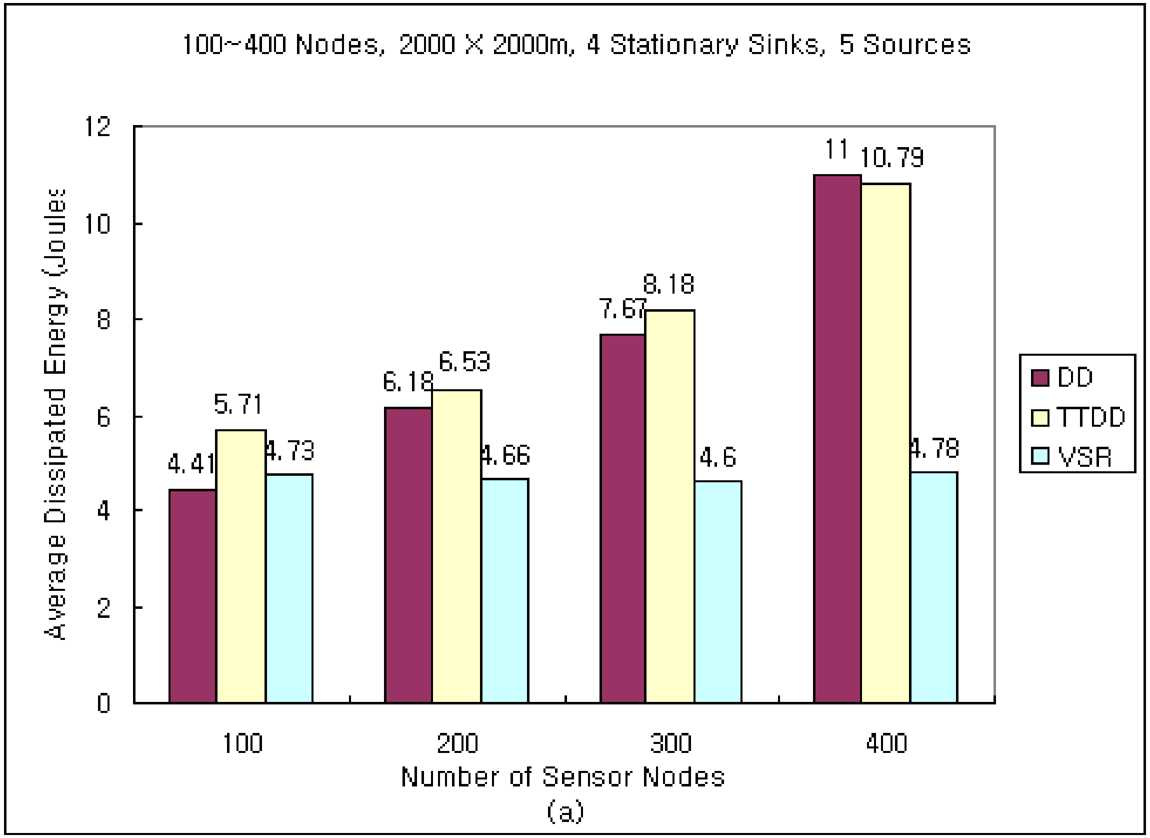




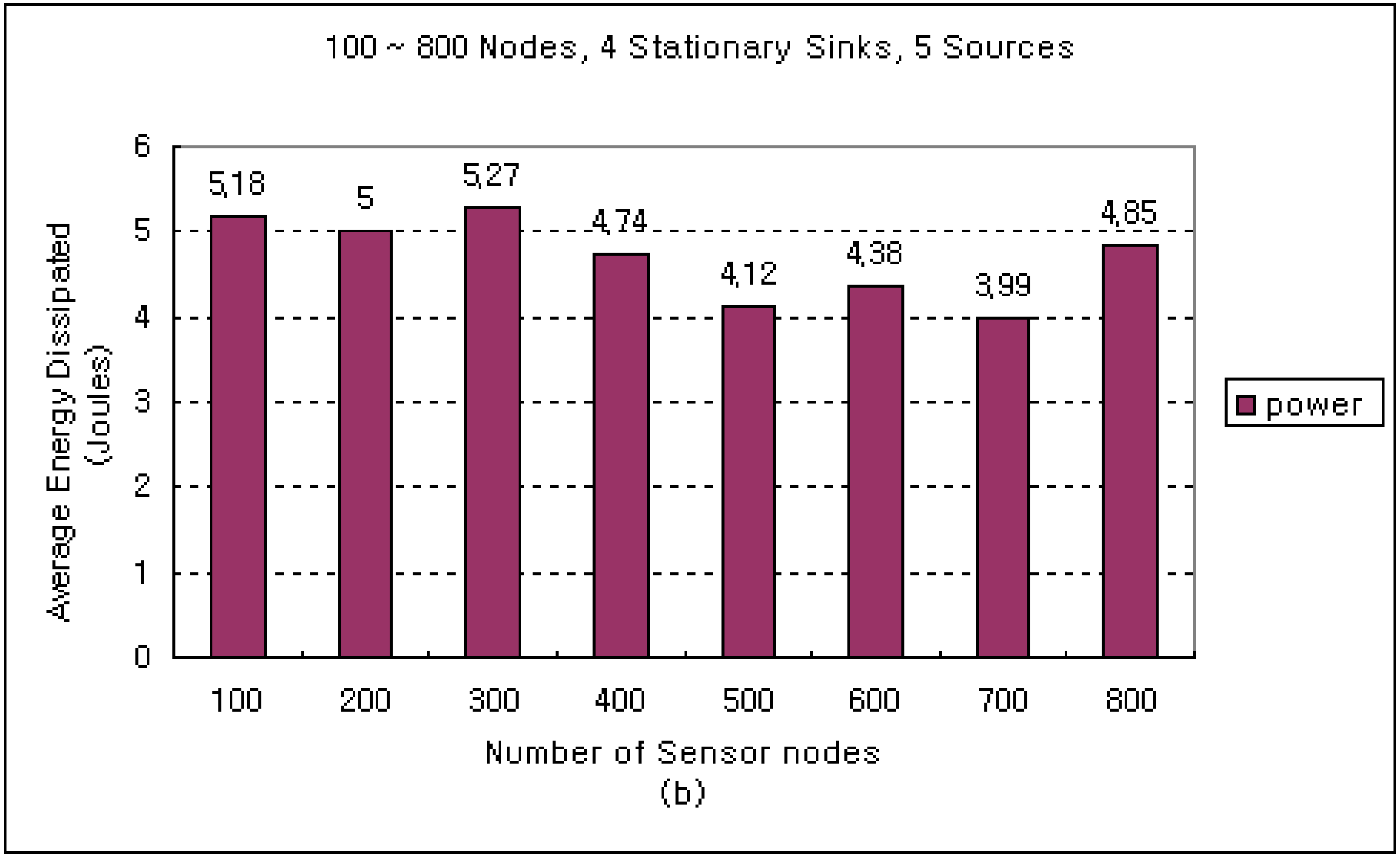
Node Failures



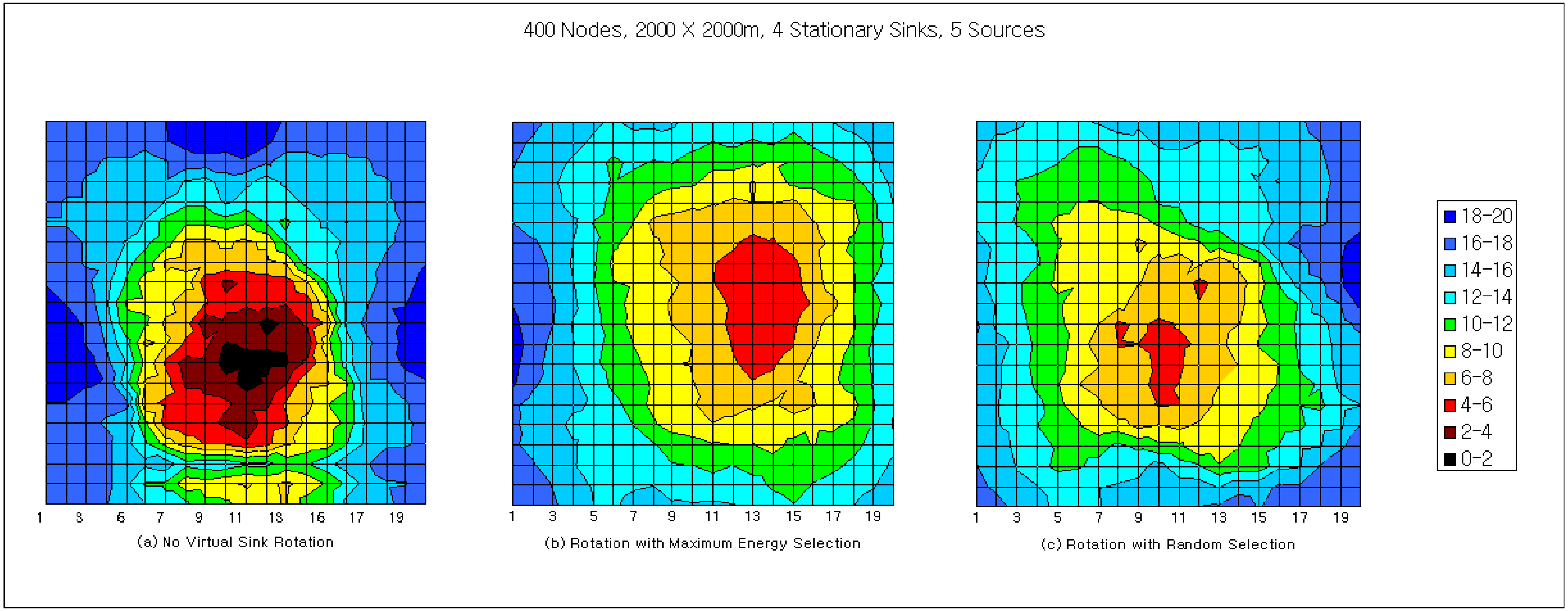
Node Density



Scaling the Sensor Field



VSR – Rotation Policy



Conclusion & Future Work

- **VSR**
  - Virtual sink
    - Can avoid local/global forwarding for the location update by pre-constructing the VS tree around a virtual sink
    - Each node is not required to know the global network topology nor its position
  - Virtual sink rotation
    - Global distribution of energy as compared to local energy optimization
  - May be a viable solution for large-scale sensor networks with low-cost sensor nodes and mobile sinks
  - Impact of aggregation, caching, and multicasting on the VSR framework
  - Implemented on existing sensor boards such as MICA2 Motes