IBUBBLE: MULTI-KEYWORD ROUTING PROTOCOL FOR HETEROGENEOUS WIRELESS SENSOR NETWORKS

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Outline

- Introduction
- iBubble
  - Multi-keyword Routing Protocol for Heterogeneous Wireless Sensor Networks
- Evaluation
- Conclusion

Introduction

- Wireless sensor networks (WSNs) can be separated into two kinds
  - Homogeneous WSN
    - Multi-purpose
    - Multi-function
    - Node-centric
  - Heterogeneous WSN (HWSN)
    - Different functionality
    - Limited mission
    - Data-centric

Introduction

Introduction

- Data aggregation (DA)
  - Before sending data, a node will collect and compress data receiving from its neighbors.
  - DA can reduce message overhead
  - iBubble uses DA to decrease the cost of propagating messages.

Introduction

- Diffusion.
- Directed diffusion is firstly used for data-centric routing protocols. [1] [2]
- Directed diffusion
  - 2-phase-pull diffusion
    - sink->source; source -> sink
  - 1-phase-pull diffusion
    - sink->source; reverse link
  - 1-phase-push diffusion
    - Source->sink; reverse link

iBubble

- iBubble is a multi-keyword routing protocol and designed for HWSN.
  - iBubble is also a data-centric protocol
- iBubble provides a mechanism for communication between the BS and its nodes.
  - Node-to-node communication is not addressed
- iBubble aggregates keywords to minimize the cost of bubbling keywords up to the BS.

Design object

- Provide efficient data-centric routing.
- Provide aggregation mechanism to minimize bubbling cost.
- Support both static and mobile HWSN.
- Provide simple fault diagnosis and self maintenance.
- Remove reliance on global identifiers.

Protocol details

- Initialization phase
  - Setup the attributes and propagate keywords
- Bubbling phase
  - Keywords aggregation
- Querying phase
  - Let BS to find data

Initialization phase

- Nodes have to determine a vector (hop-count) to the BS.
- BS broadcasts a hop-count beacon (hc=1)
- Shortest path first.
- Before bubbling keywords, nodes will wait for a period of time, which depends on their hop-counts.

Bubbling phase

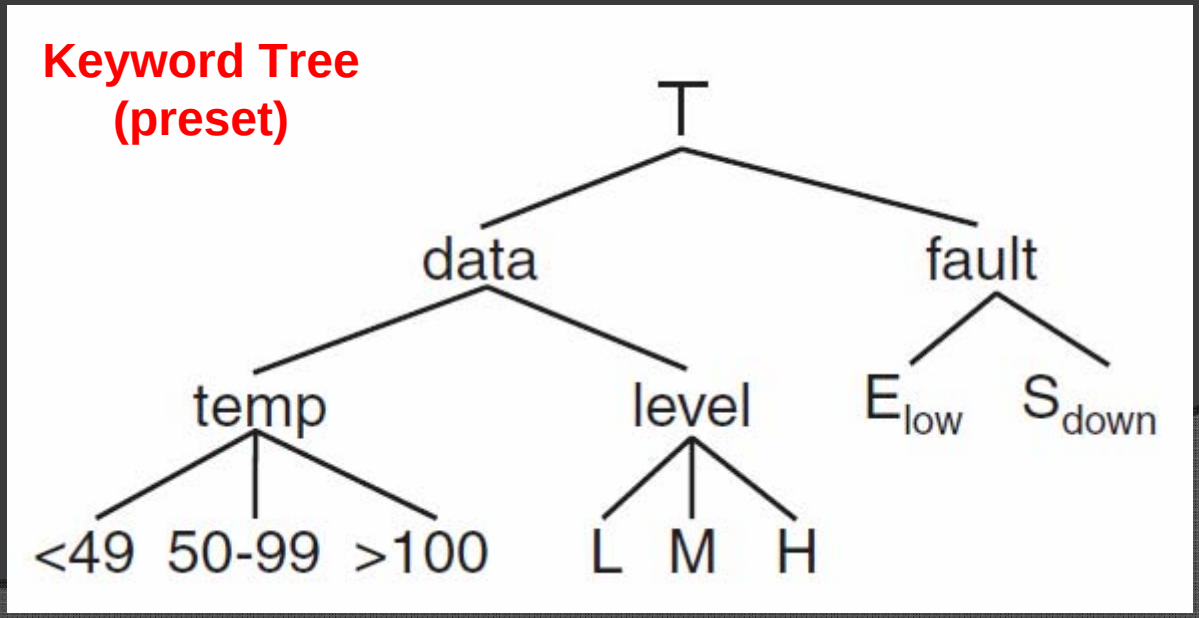
- Bubbling establishes the keyword set (***KL***) for every node.
- Whenever the ***KL*** for a node is changed it must bubble the new ***KL*** to the BS.
  - Update KL
  - Aggregate KL
- Hop-count can prevent loops and restricts the keyword bubbling towards the sink.

Keyword set

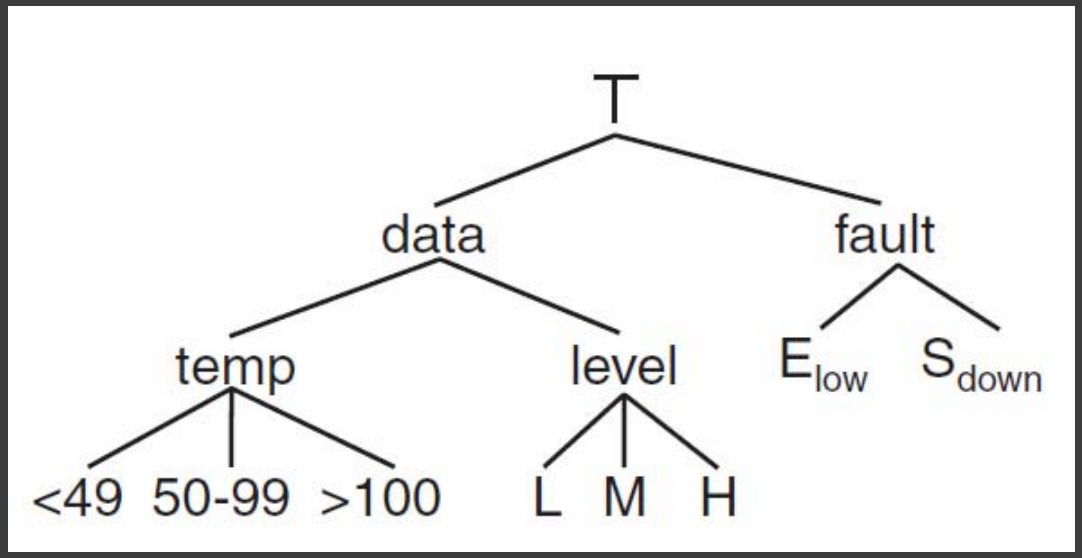
- Personal (KLp)
  - The KL describes the node
- All intermediate neighbors (KLN)
  - Neighbor's KL
- Published (KLP)
  - KLP = KLp U KLN

Keywords

- Keyword can be seen as the ability of a sensor node.
- For example
  - Temperature: *temp*.; *<49*; *50-99*; *>100*



Keyword aggregation



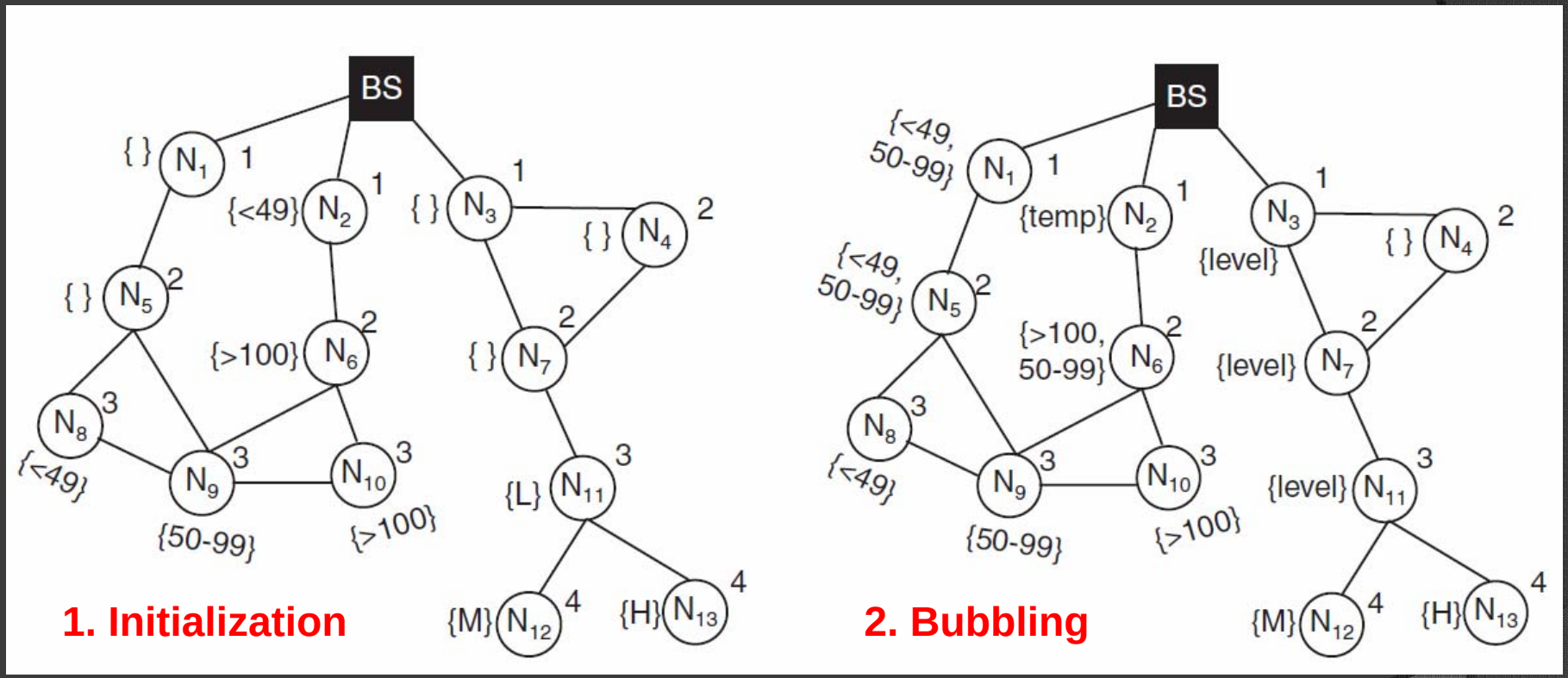
$$<49 \bigsqcup \text{50-100} = \{<49, \text{50-100}\}$$

$$<49 \bigsqcup temp = \{temp\}$$

$$data \bigsqcup fault = \{\top\}$$

$$\bigsqcup\{<49, \text{50-100}, L, M, H\} = \{<49, \text{50-100}, level\}$$

Example


BS
{ } N1 1
{<49} N2 1
{ } N3 1
{ } N4 2
{ } N5 2
{>100} N6 2
{ } N7 2
N8 3
{<49}
N9 3
{50-99}
N10 3
{>100}
{L} N11 3
{M} N12 4
{H} N13 4
1. Initialization
BS
{<49, 50-99} N1 1
{temp} N2 1
N3 1
{level}
{ } N4 2
{<49, 50-99} N5 2
{>100, 50-99} N6 2
{level} N7 2
N8 3
{<49}
N9 3
{50-99}
N10 3
{>100}
{level} N11 3
{M} N12 4
{H} N13 4
2. Bubbling

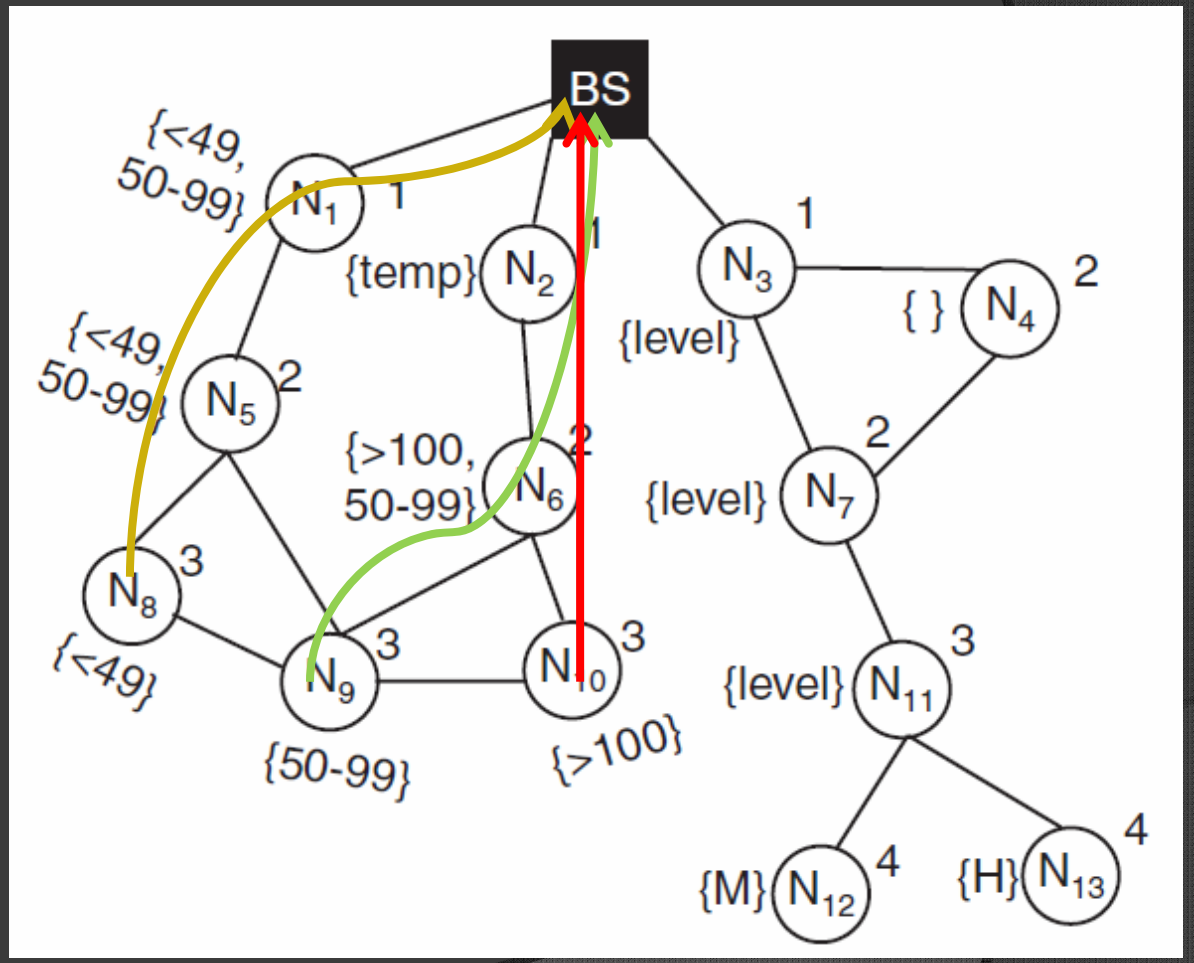
Querying phase

- Queries are always initialed by BS and propagated throughout the network utilizing the published KLs.
- Query message=<*Query, AppTest*, *UID*>
  - *Query* specifies high level query types
  - *AppTest* is used to refine the query
  - *UID* is the unique id of the query

Example

Query=<temp, <100, ID1>
Response:
<N8, N5, N1>
<N9, N6, N2>

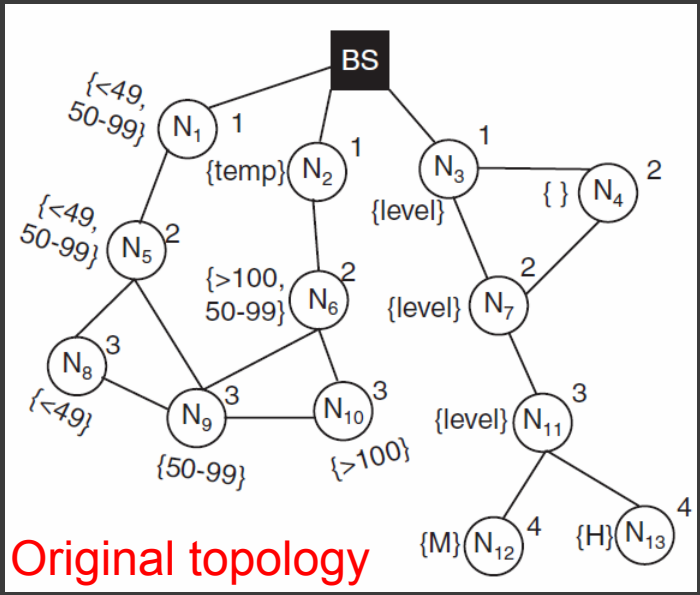
Query=<temp, >100, ID2>
Response:
<N10, N6, N1>



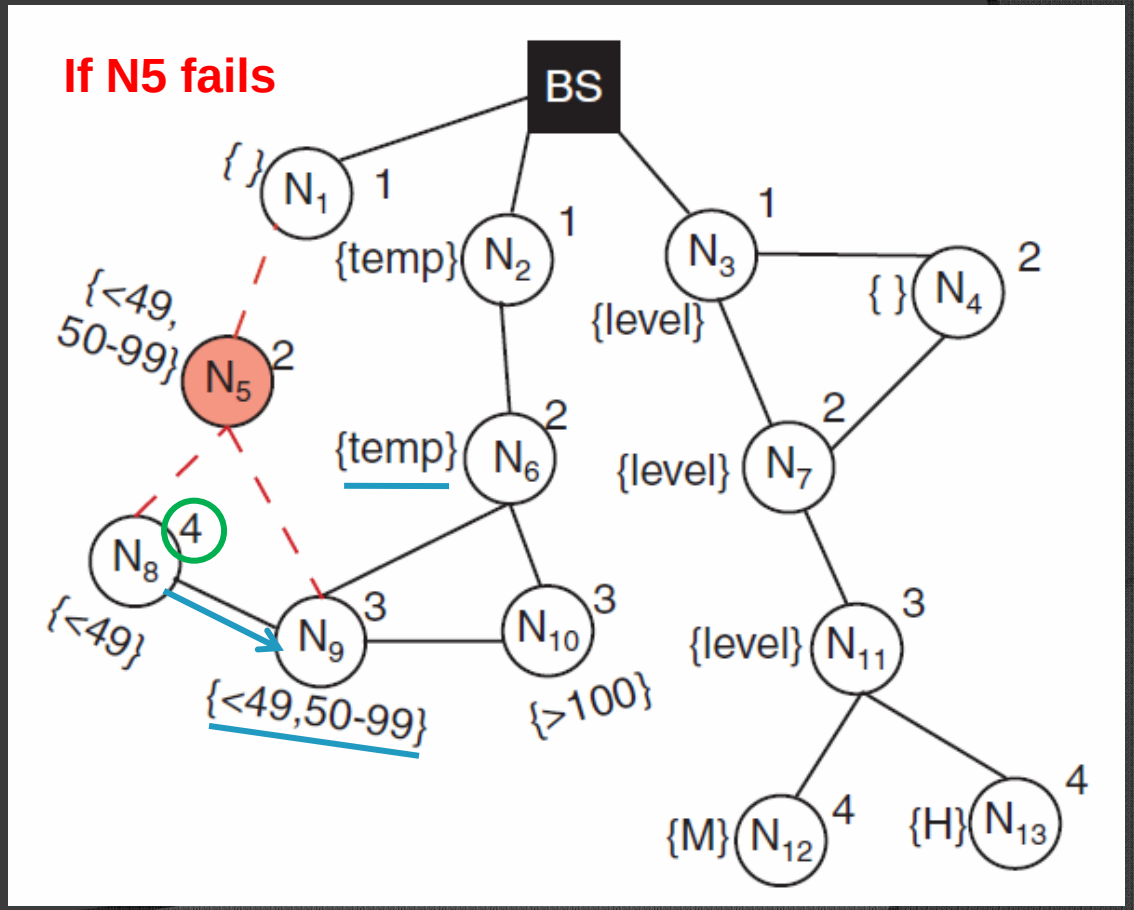
Fault tolerance & Mobility

- Redundant paths
  - KL are propagates along *all* neighbors with *lower* hops
- ✓ Re-routing
- ✓ Keyword set updating
- When a node detects a fault or move, it will
  - Determine its new hop-count
  - Determine its KLN and KLP
  - Broadcast its new KLP

Example

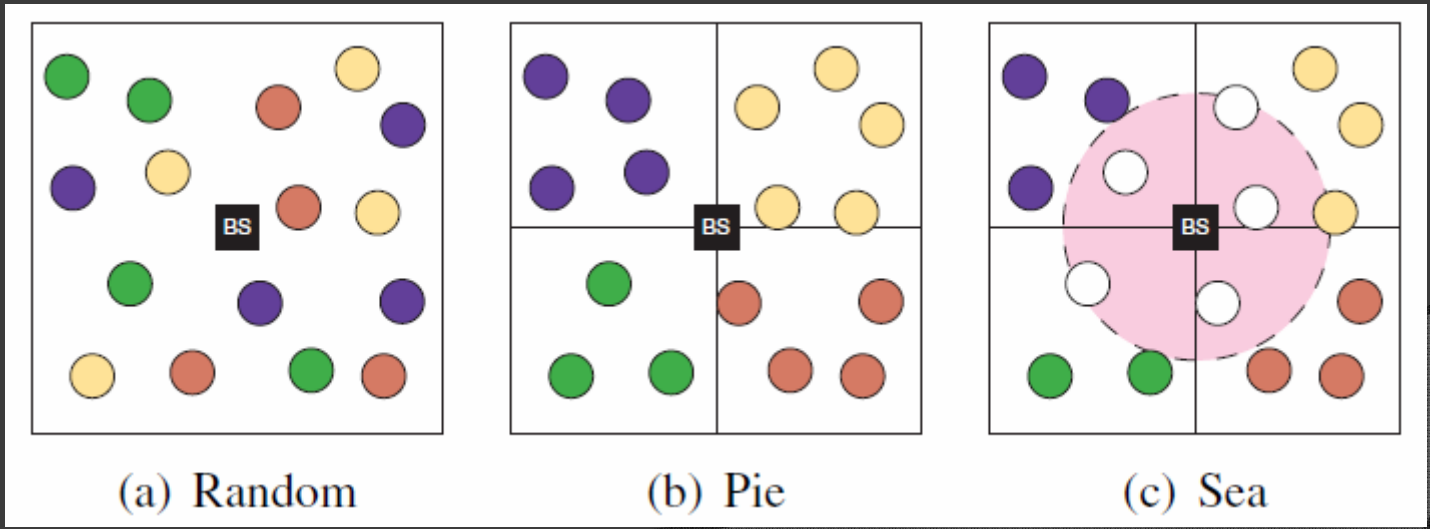


Original topology



Evaluation

- Comparison with 1-phase pull diffusion
- 1000m*1000m area with one BS
- Communication range is 240m
- Three key distribution schemes

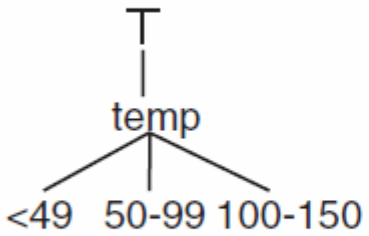


A color means a keyword

Message comparision

type $= temperature$
low $= 100$
high $= 150$
region $= 1$

Directed diffusion

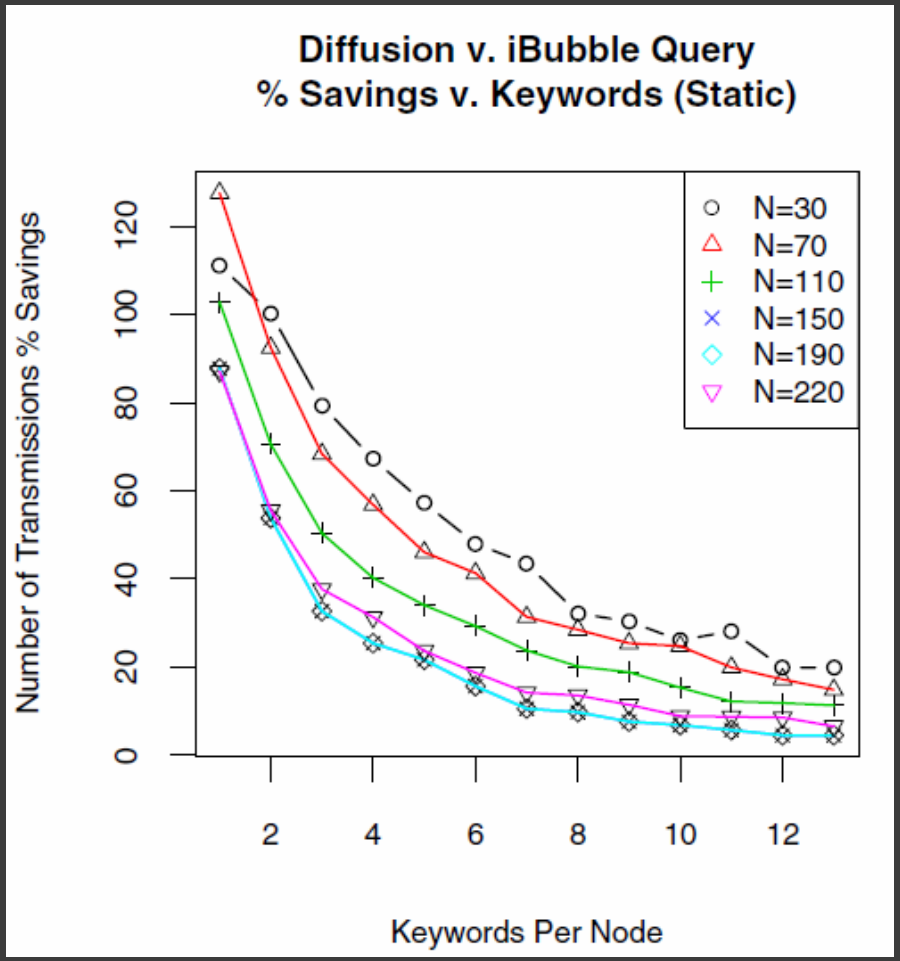


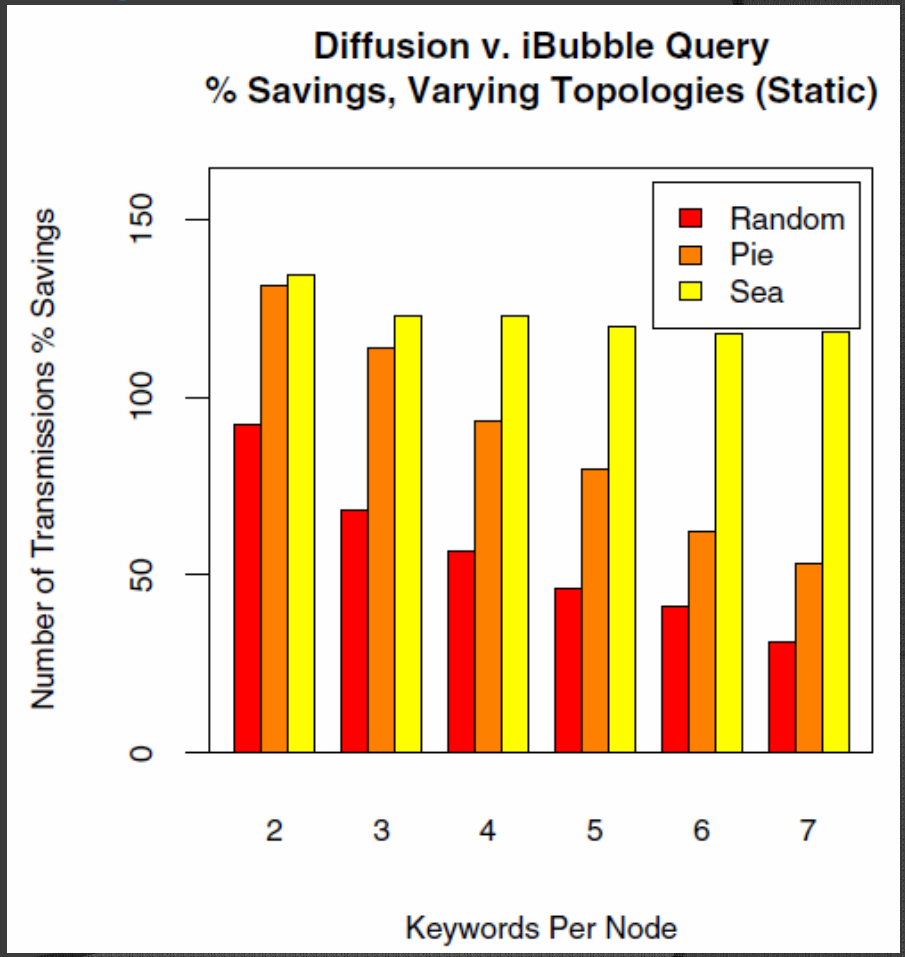
Query: $100 - 150$
AppTest: $region = 1$

iBubble

Query saving without bubbling

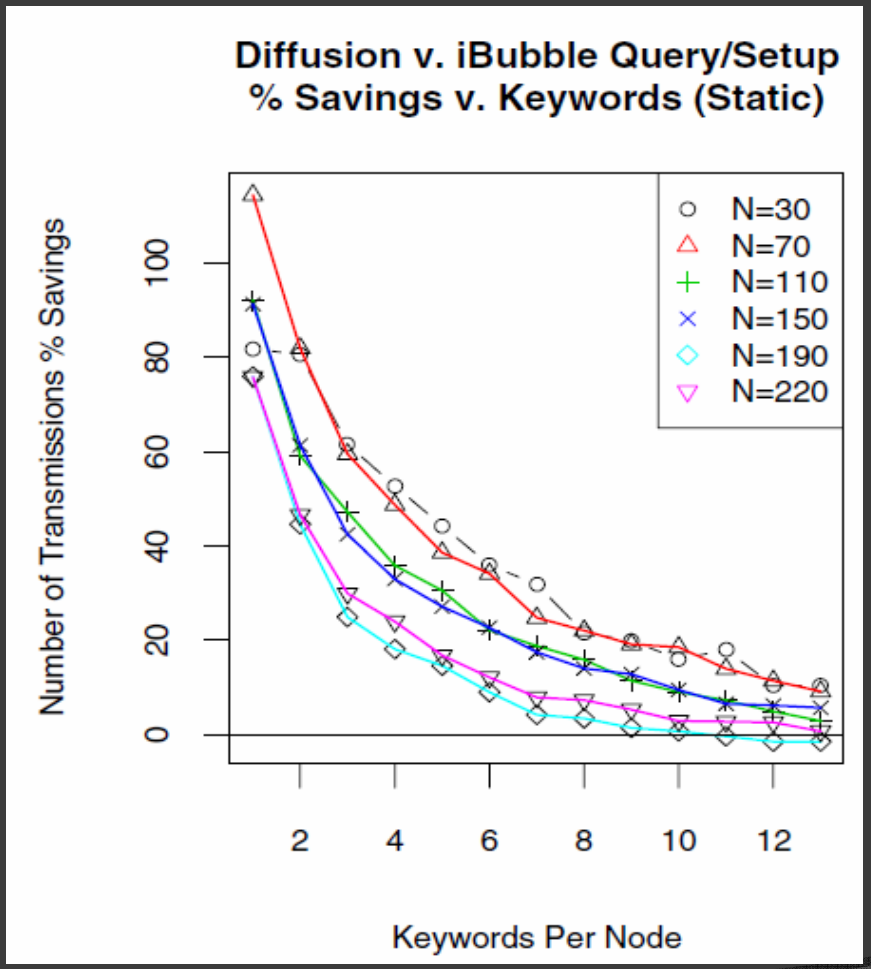
No mobility

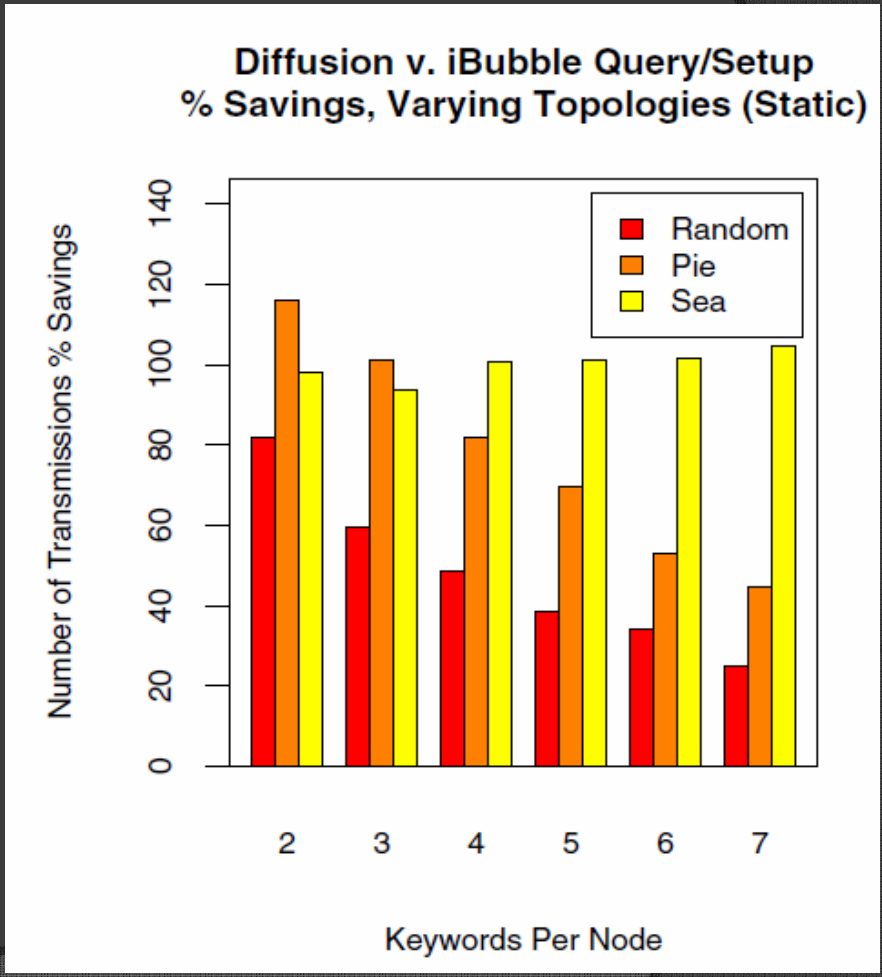




Query saving with bubbling

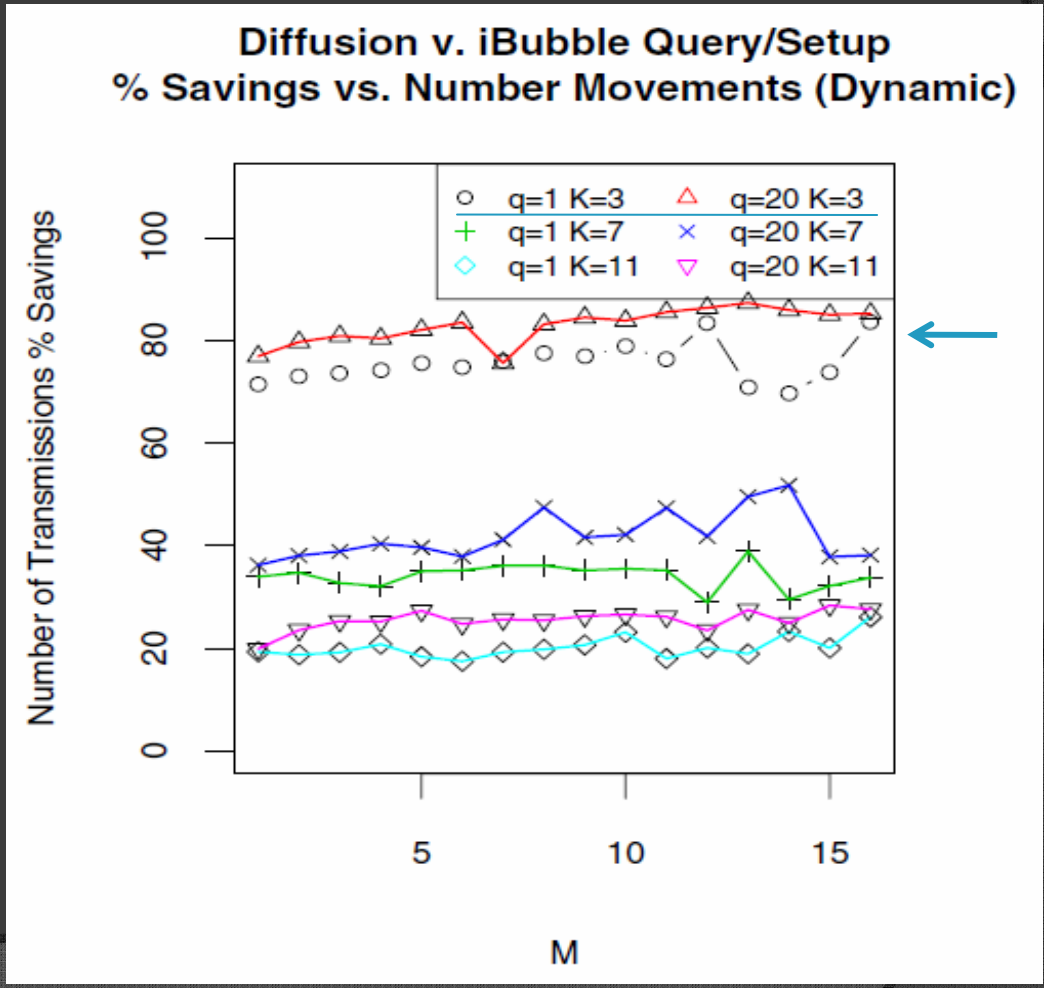
No mobility



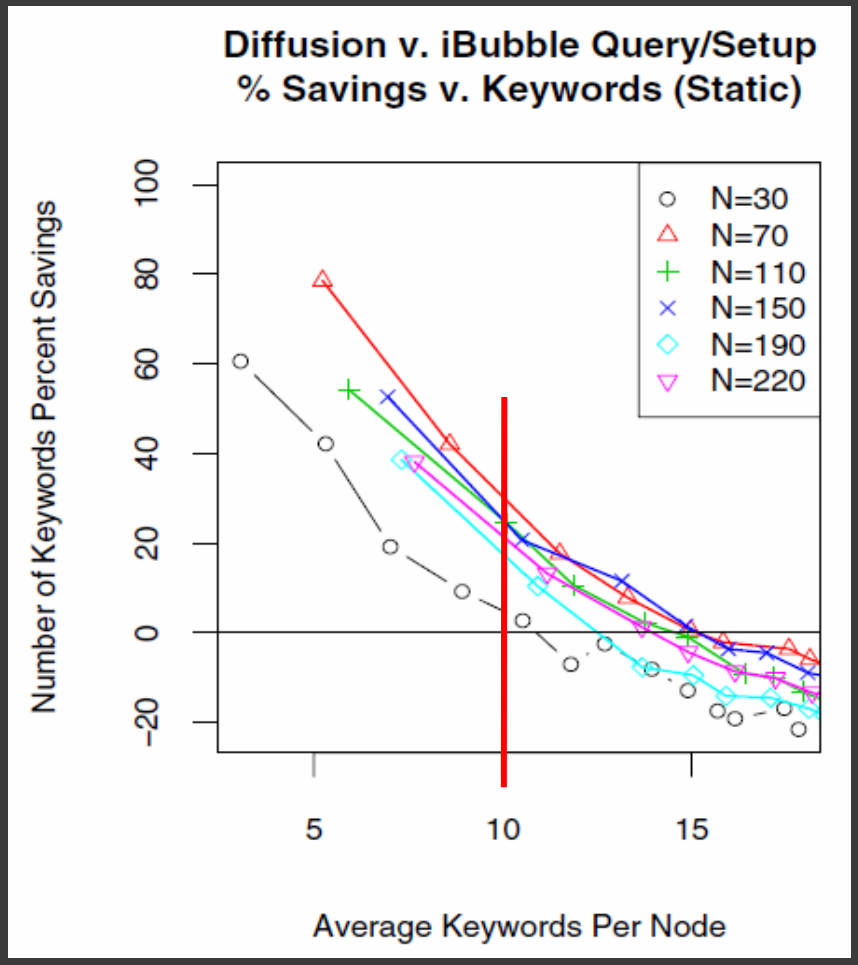


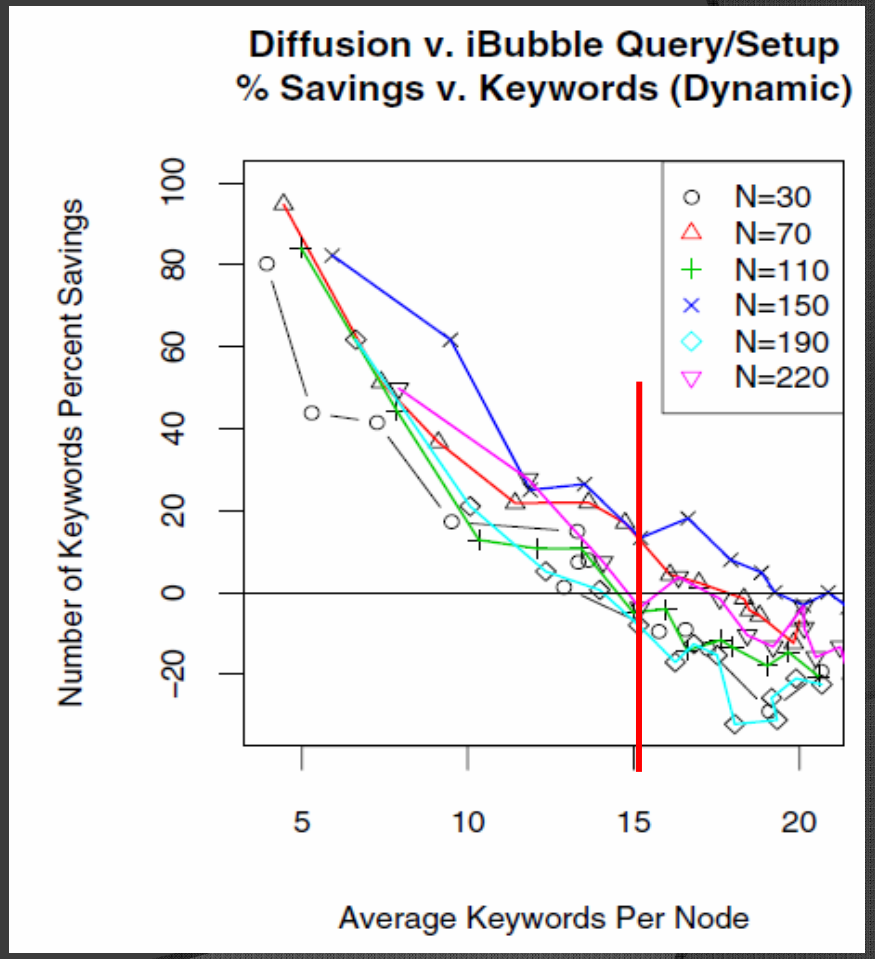
Movement vs. Saving

- *M* random nodes move and between each move there are *q* queries



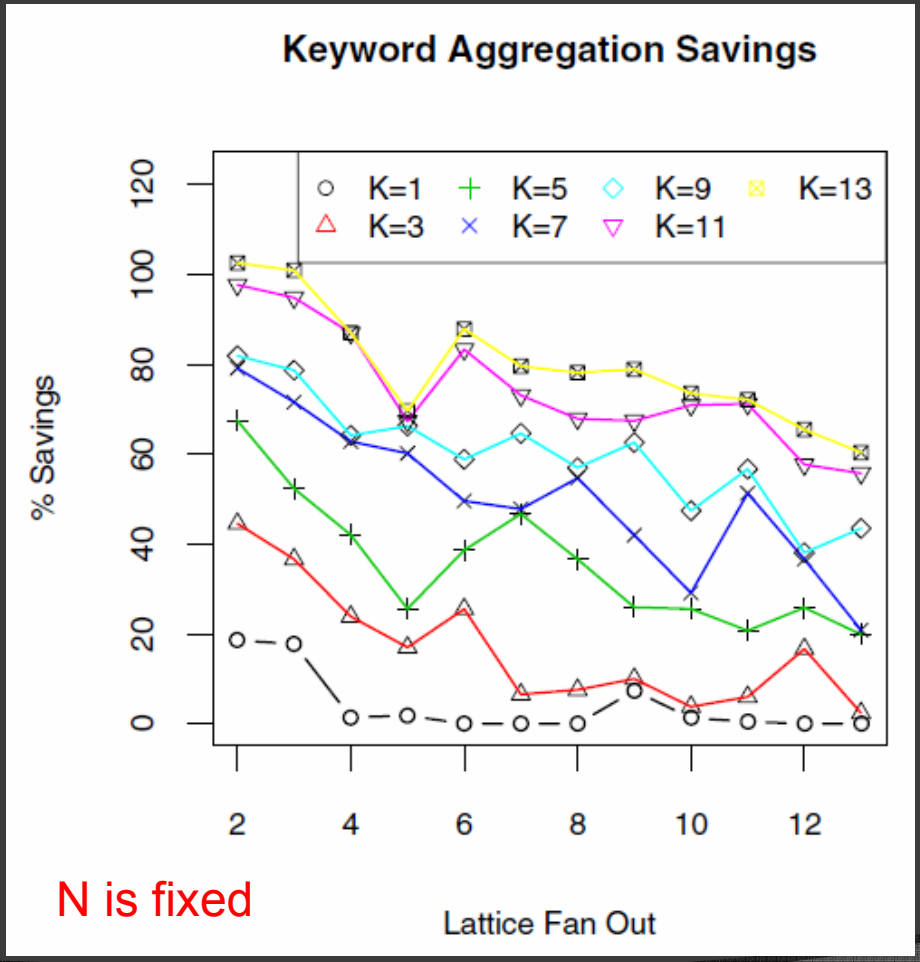
Overall cost



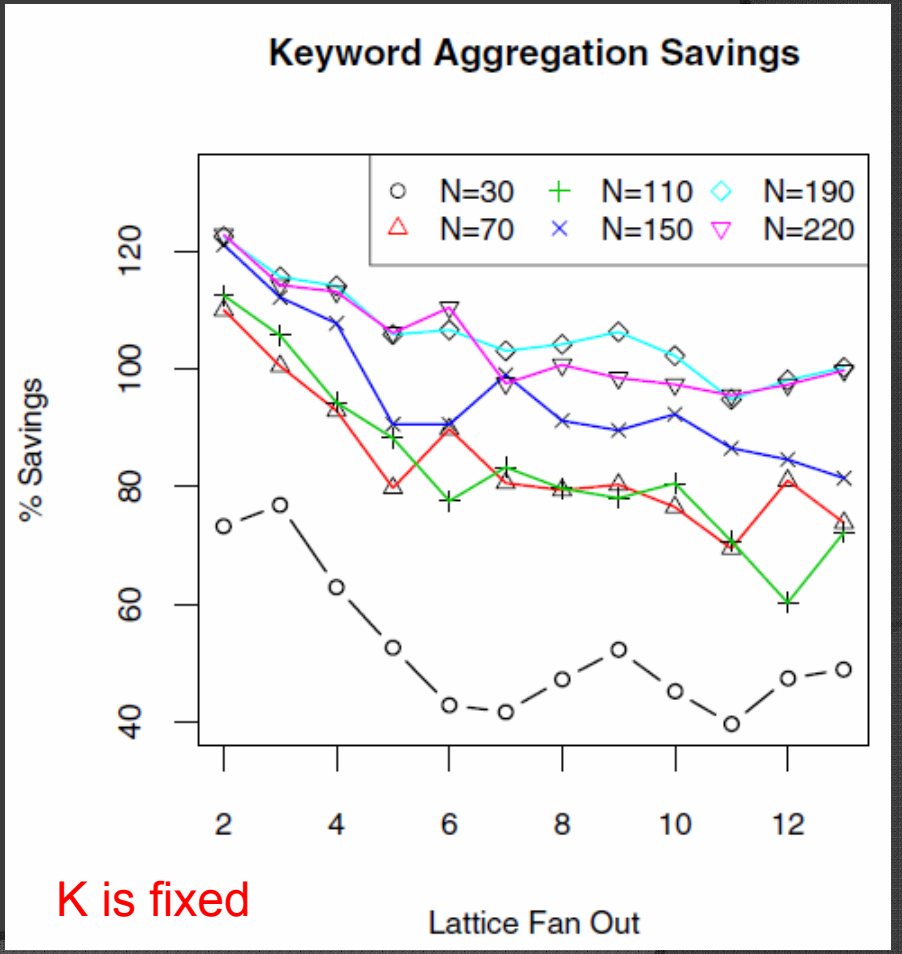


Aggregation savings

Random key distribution

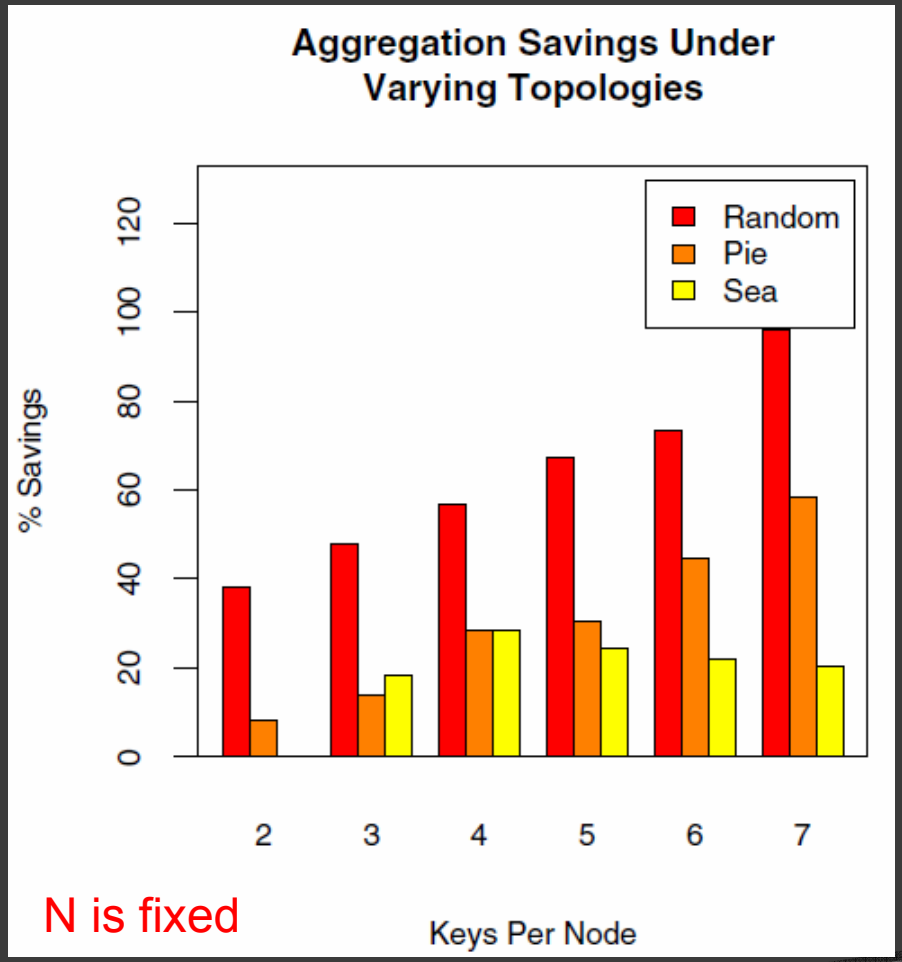


N is fixed

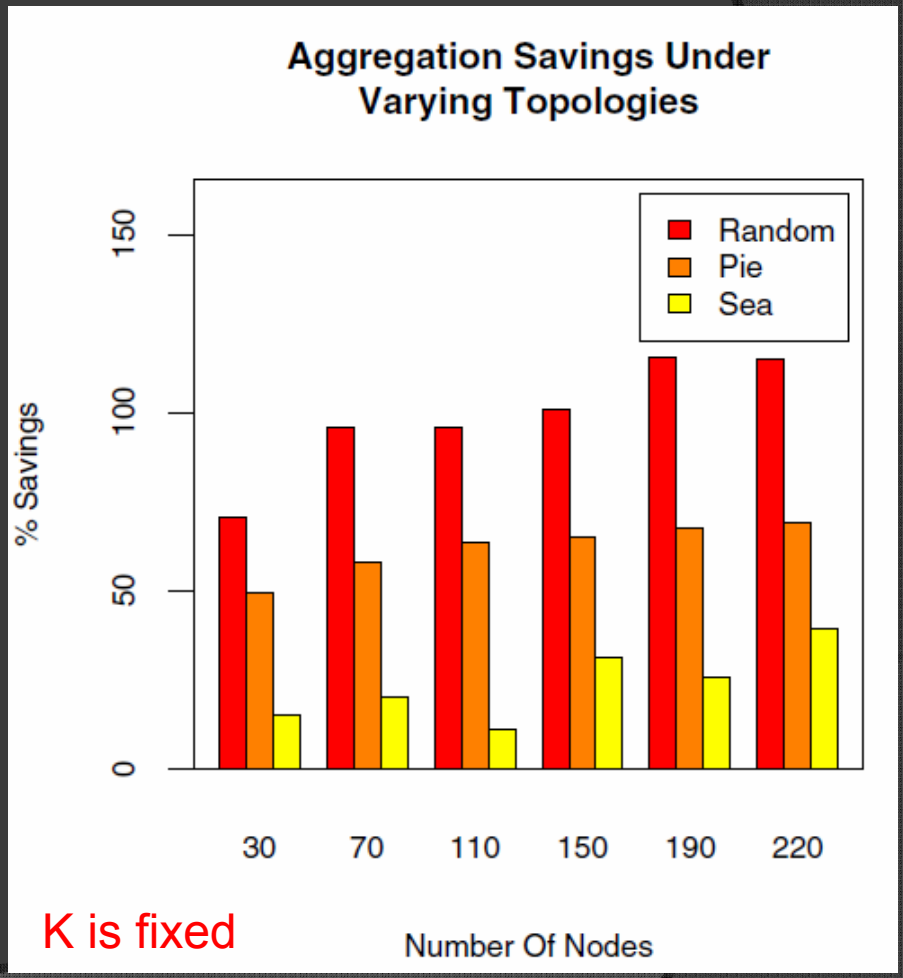


K is fixed

Aggregation savings



N is fixed



K is fixed

Conclusion

- iBubble is a data-centric routing that allows queries based on a set of keywords.
- iBubble provides source mobility, fault-tolerance and self-healing support.
- The aggregation scheme can minimize the cost of message propagation.
- iBubble provides a simple and uniform solution in HWSN.

References

1. C. Intanagonwiwat, R. Govindan, and D. Estrin, “Directed diffusion: ascalable and robust communication paradigm for sensor networks,” in Mobile Computing and Networking, 2000, pp. 56–67.
2. J. Heidemann, F. Silva, and D. Estrin, “Matching data dissemination algorithms to application requirements,” USC/Information Sciences Institute, Tech. Rep. ISI-TR-571, April 2003.
3. L. Banks, S. Ye, Y. Huang, and S. F. Wu, “Davis social links: Integrating social networks with internet routing,” To appear in ACM SIGCOMM 2007 Workshop on Large-Scale Attack Defense (LSAD), August 27, 2007, Kyoto, Japan.