Efficient Routing from Multiple Sources to Multiple Sinks in WSN

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Outline

- WSN definition
- Motivation
- Goal
- System model
- Finding optimal solution
- Distributed solution formalization
- Evaluation
- Conclusion

WSN Definition

- Wireless Sensor Network:It is a network of sensors communicating by means of wireless transmission.
- It is used to monitor physical or environmental conditions like temperature, sound, vibration, pressure.

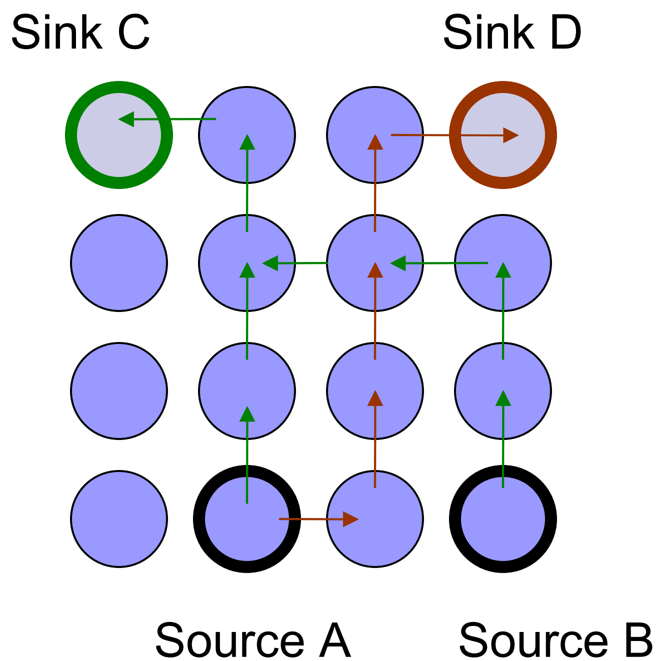
Application of WSN

- Health Care
- Fire rescue
- Habitat monitoring
- Automobile etc

Motivation

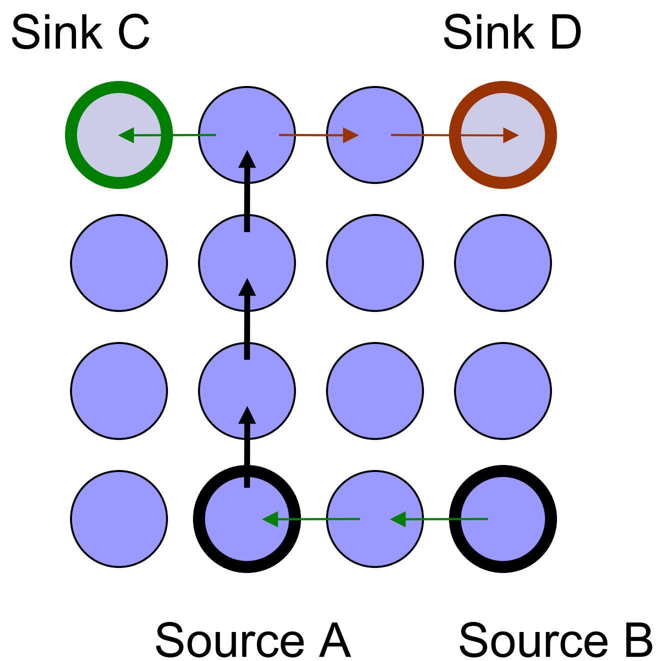
- WSN serving multiple applications
- Use of Actuator nodes in WSN
- In implementation of advanced applications and programing abstarctions

Scenario 1: Two Trees Rooted Independently (existing many to many)



Uses 13 Network links and 13 Nodes

Scenario 2: Two Trees Merged (many to many)



Uses 8 Network links and 9 Nodes

Advantage

- Decreases redundant information flow
- Less nodes are involved in Routing
- Increases system life-time
- Reduces contention on wireless medium
- Increases reliability of communication
- Reduces per reading header costs

Goal

- Efficient routing of messages from sources to the corresponding sinks by minimizing the number of network links exploited.

Procedure

- Model to multi-commodity network design problem: optimal solution
- Propose a decentralized solution

System Model

- WSN:Directed Graph

  N: Set of Nodes

  A: Set of Arcs

  arc(i,j): between two nodes i and j – within communication range

- Goal in multi-commodity network design problem:

  Given a set of commodities C, **route** each commodity $k \in C$ through a network from a set of sources O(k) $\leq$ *N* and set of destination D(k) $\leq$ *N* by **minimizing a given metric**.

System Model

We design message routing with help of following decision variables:

- $r^k_{i,j}$ is 1, if the route for source-sink pair k **contains arc(i,j)** otherwise 0
- $u_{i,j}$: It represents whether a network link represented by arc(i,j) is **used to route** in source-sink pair.
- *UsedLinks(C,A)* : **Total** number of links used to route messages for a given source-sink pairs is computed

Goal is to find value assignment for $r^k_{i,j}$ that **minimizes** value of *UsedLinks(C,A)*

Accomplishment:

- By minimizing *UsedLinks(C,A)* we reuse as much as possible links that have already been used for other sorce-sink pairs.

Finding Optimal Solution

Conditions

1. $r^k_{i,j} < u_{i,j}$
2. $\forall i \in N, \forall k \in C,$

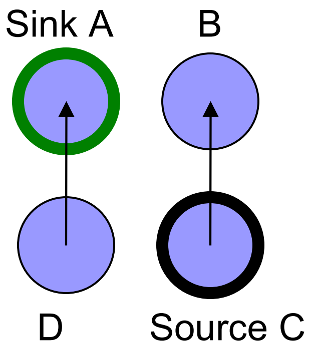
   $\sum r^k_{i,m} - \sum r^k_{n,i} = 1, -1, 0$

   m:(i,m) ε *A*

   n: (n,i) ε *A*

Checks connectivity

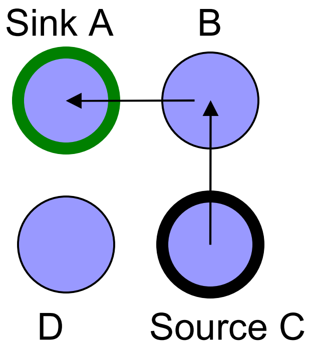
Sample Assignment (check connectivity)



Case 1:

i=B $r_{B,?} - r_{C,B} = -1$

i=D $r_{D,A} - r_{?,D} = 1$



Case 2:

i=B $r_{B,A} - r_{C,B} = 0$

i=D $r_{D,?} - r_{?,D} = 0$

Why distributed scheme

- With the above formulation to find optimal assignment requires global knowledge of the system and hence computationally expensive
- Impracticle for WSNs
- Therefore distributed scheme which relies on local knowledge(1-hop) is computed

Distributed Solution formalization

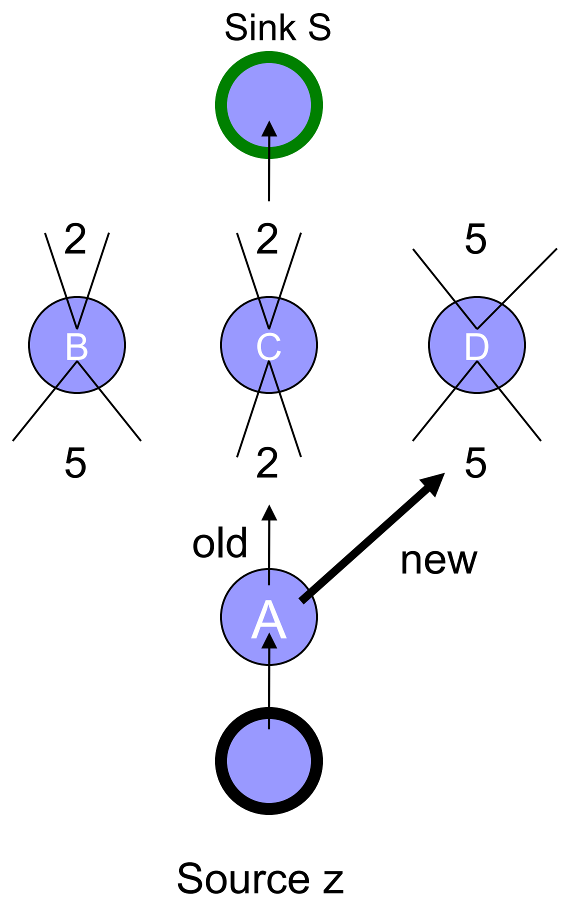
- The main goal is to maximize overlapping.
- We define a quality metric *q(n,s)* which computes the quality of the neighbor node could become a parent.
- The value of *q* should be the maximum among all neighbors for Sink *s*

We have the quality metric *q* dependent on:

- *dist(j,s):* distance from a node *j* to a given sink *s*
- *paths(j):* number of source-sink paths passing through node *j*
- *sinks(j):* number of sinks a given node *j* currently serves

$q(n,s) ::= \delta.dist(n,s) + \alpha 1.paths(n) + \alpha 2.sinks(n)$

Concept: Parent node selection



Sink Served

Overlaping paths

Information used to compute quality metric for neighbor node

Field Name	**Description**
NeighborId	
dist	
paths	
sinks	

Determining the value

neighborId: It is determined locally based on the information from lower layers.

dist: It is determined from the messages flooded by sink

1. During tree set up phase
2. Successive flooding operations

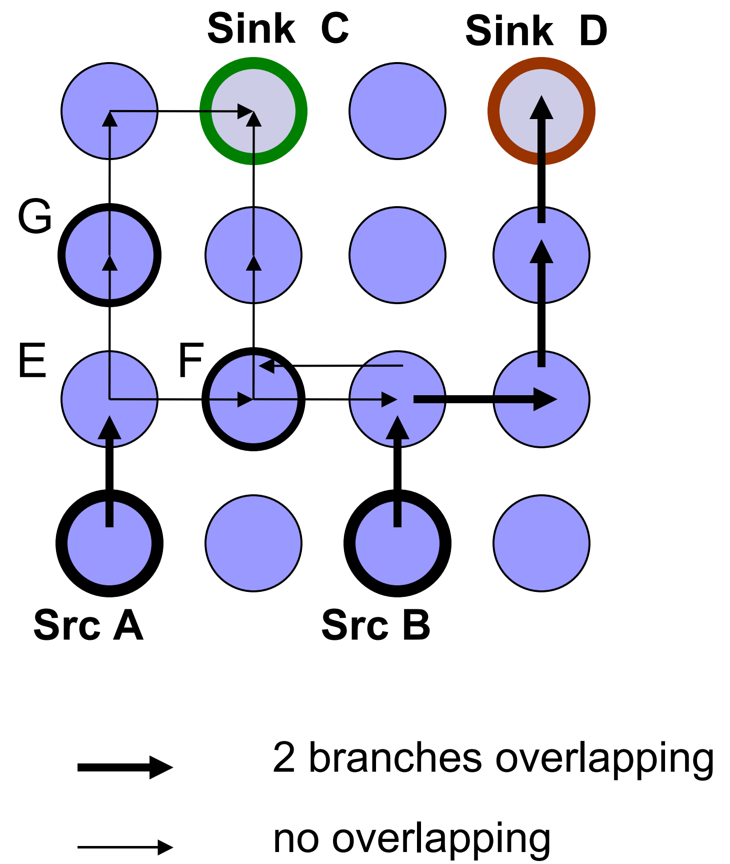
paths(n) & sinks(n): It is determined through overhearing of messages sent by n.

Sample adaptation process

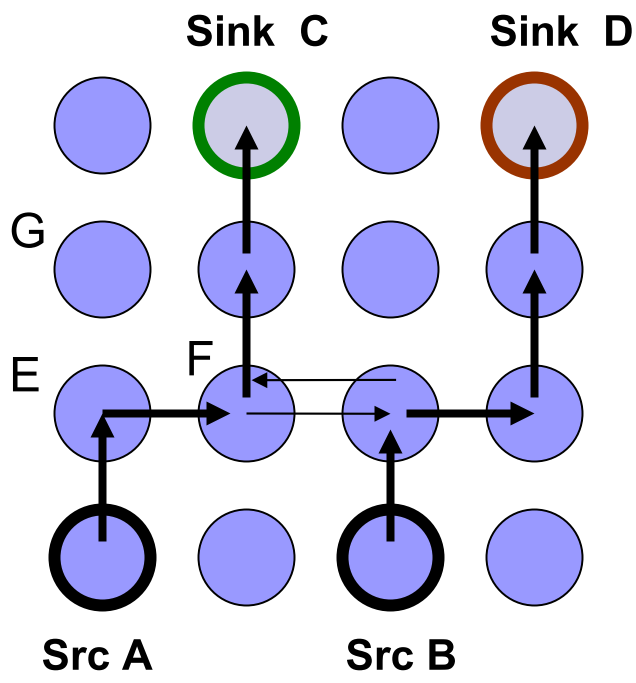
Assume: $\delta = \alpha 1 = \alpha 2 = 1$

Field Name	**Description**
neighborId	**G**
dist	**C=2, D=4**
paths	**1**
sinks	**1**

Field Name	**Description**
neighborId	**F**
dist	**C=2, D=4**
paths	**2**
sinks	**2**



Result of adaptation process



q(G,C) = 2+1+1 = 4

q(F,C) = 2+2+2 = 6

F is chosen

Evaluation

- Simulation results are obtained by comparing adaptive method vs base method.
- It also shows impact of various constituents of quality metric q.

Simulation setting:

Operating System: TinyOS

Simulator: TOSSIM

Regular Grid

- Each node communicates with 4 neighbors
- Nodes are placed 35ft apart and communication range 50ft

Source & Sink settings

- 10% of the nodes are sources
- Data is sent to sinks at the rate of one reading per min
- Two successive readings from the same source is called **epoch**
- Sources are not synchronized
- Sources and sinks are placed randomly

Tree construction

- Tree construction is done by flooding- msg from every sink
- Node stores the path of msg from sink with least hop count
- Thus minimized tree is built
- Works like directed diffusion protocol

Simulation results criteria

Parameters:

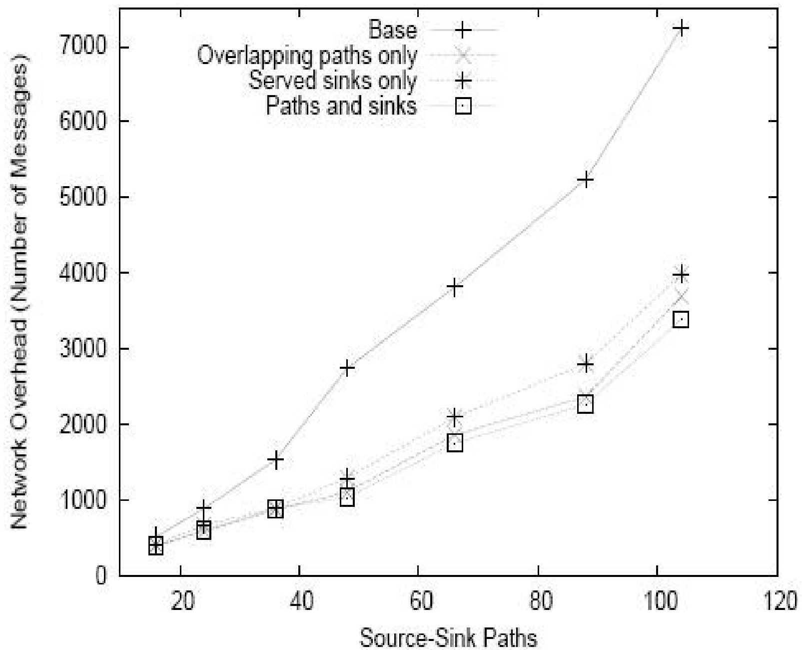
- Number of served sinks (α_1)
- Number of overlapping paths (α_2)
- Distance from sinks (δ)

  δ= -2 for all simulation runs

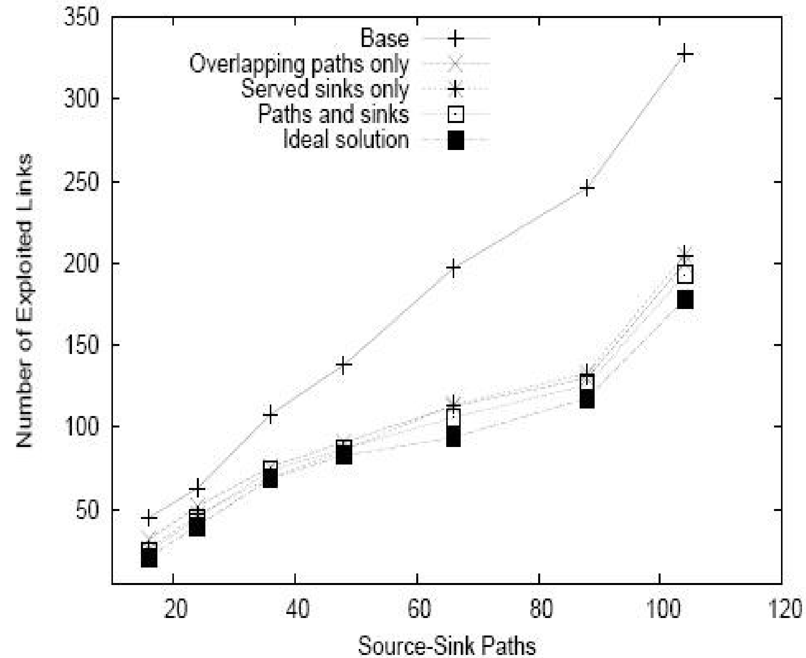
Measured:

7. Network overhead
8. No. of links exploited

Result1



(a) Network overhead (forwarded messages).



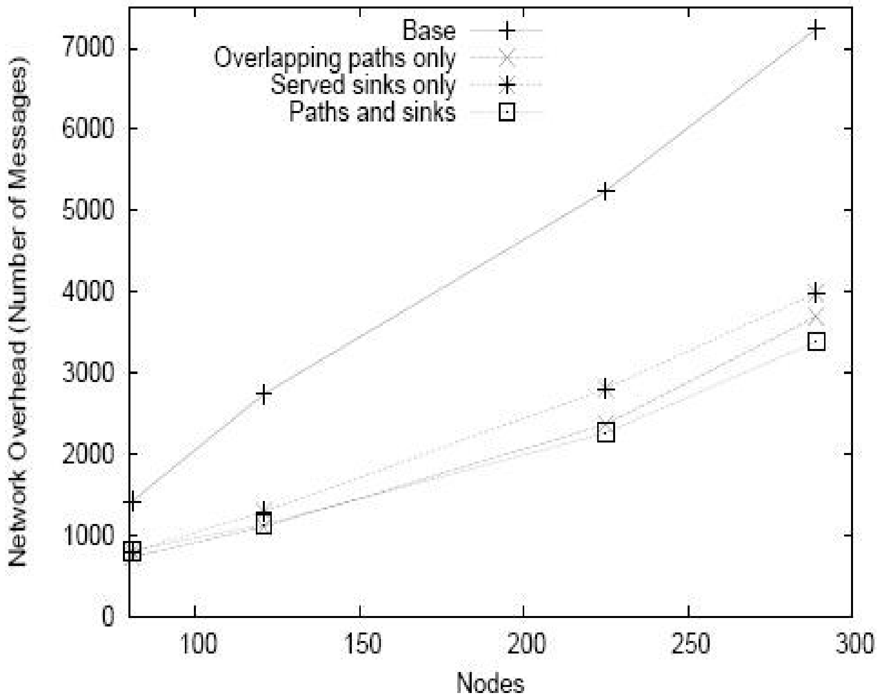
(b) Number of links exploited.

Grid Topology

Derived result

- Seeing above charts we can see reducing number of links exploited reduces network overhead

Result2



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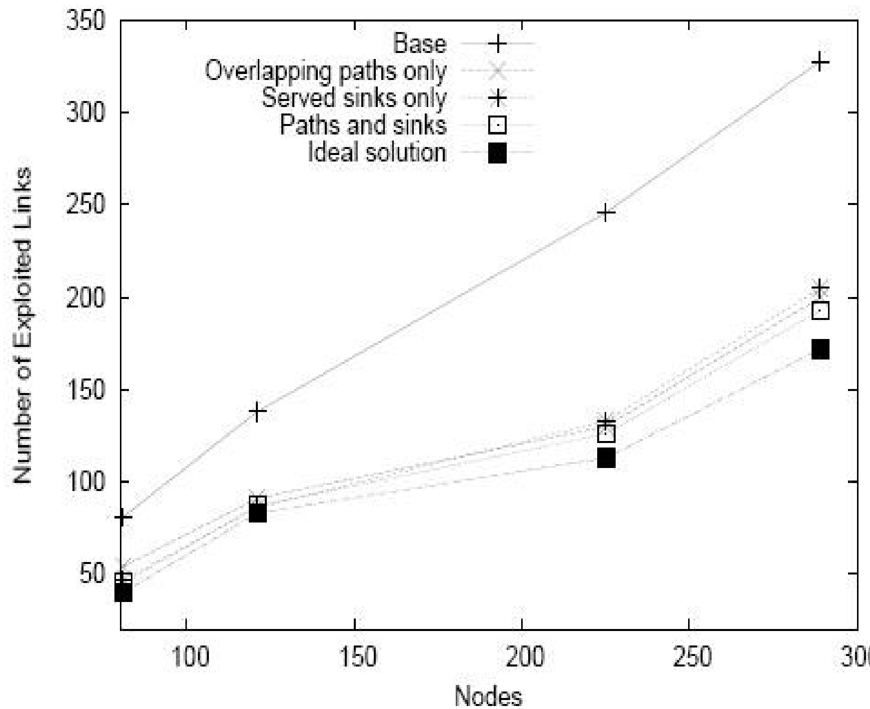
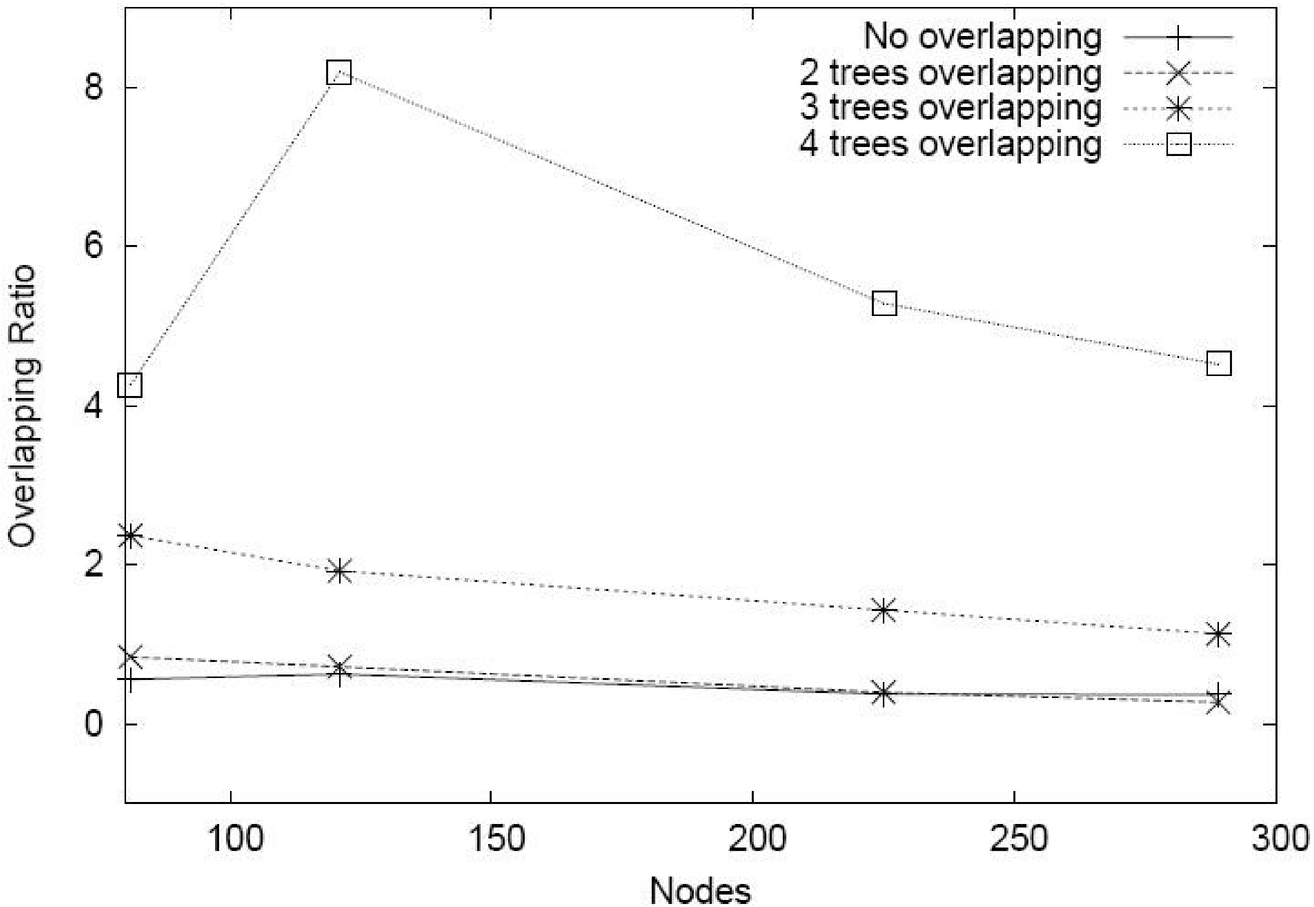


(b) Number of links exploited.

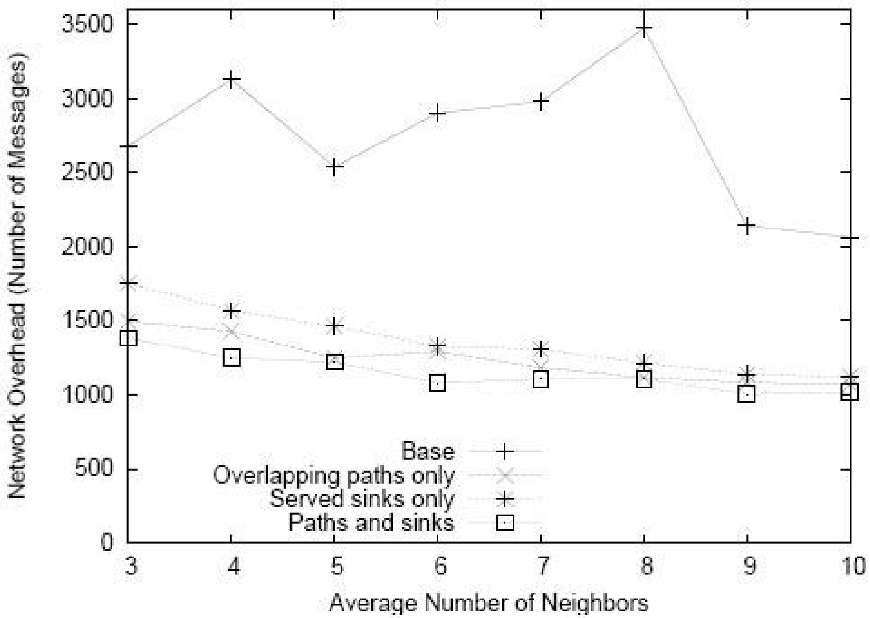
Grid Topology ,4 sinks

Result3



No overlapping
2 trees overlapping
3 trees overlapping
4 trees overlapping
Overlapping Ratio
0
2
4
6
8
100
150
200
250
300
Nodes

Result4



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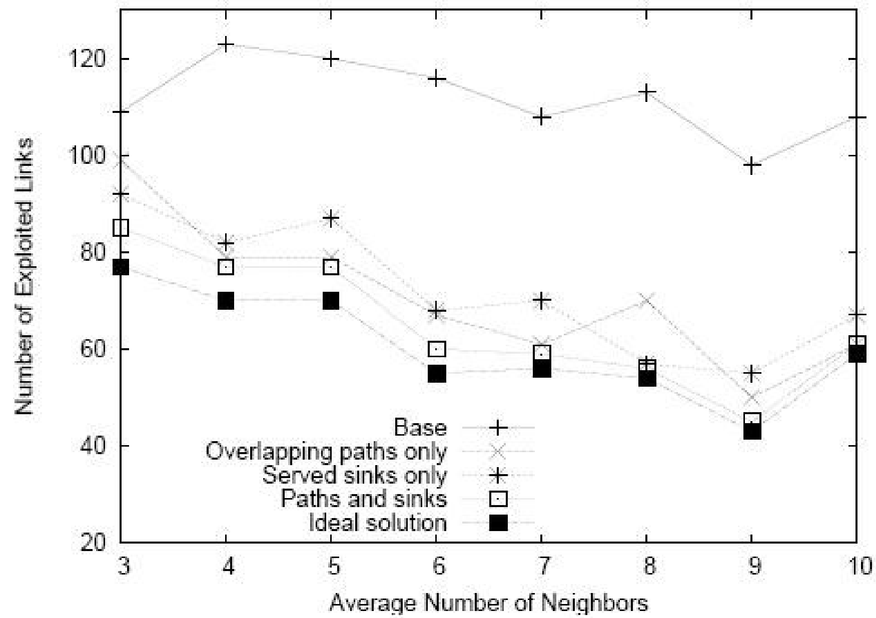

(b) Number of links exploited.

Random Topology

Conclusion

- Efficiency of overlapping trees- saves energy and network overhead
- Novel idea distributed solution to prove overlapping of sink trees
- Implementation results show 50% less overhead than base scheme
- Quality metric redefining: inclusion of remaining node energy
- Doesn’t address mobility of nodes

Reference

- Pietro Ciciriello, Luca Mottola, and Gian Pietro Picco, Efficient Routing from Multiple Sources to Multiple Sinks in Wireless Sensor Networks, EWSN 2007
- Kim, H.S., Abdelzaher, T.F., Kwon, W.H.: Minimum-energy asynchronous dissemination to mobile sinks in wireless sensor networks. In: Proc. of the 1st Int. Conf. on Embedded networked sensor systems (SENSYS). (2003) 193–204

Thank you