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2-hop Scheme for Data Collection in Wireless Sensor Networks

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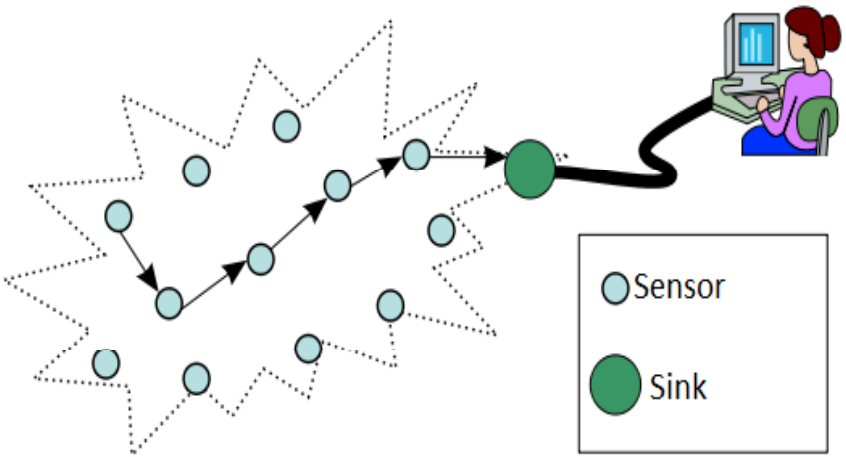
Presentation Outline

1. Introduction
2. Research Motivation
3. Research Problems
4. Related Work
5. Research Objective
6. Proposed Scheme: 2HOP Scheme
7. Theoretical Analysis
8. Simulation Studies
9. Concluding Remarks

1. Introduction



- Wireless sensor network (WSN) consists of many sensors and one sink
- Applications
  - Environmental (habitat monitoring, fire detection)
  - Health (monitoring patients' physiological data)
- All sensors use radio signal to send their sensed data to the sink
- Process of sending the sensed data to the sink is called data collection

Data collection is one of the important tasks in a WSN

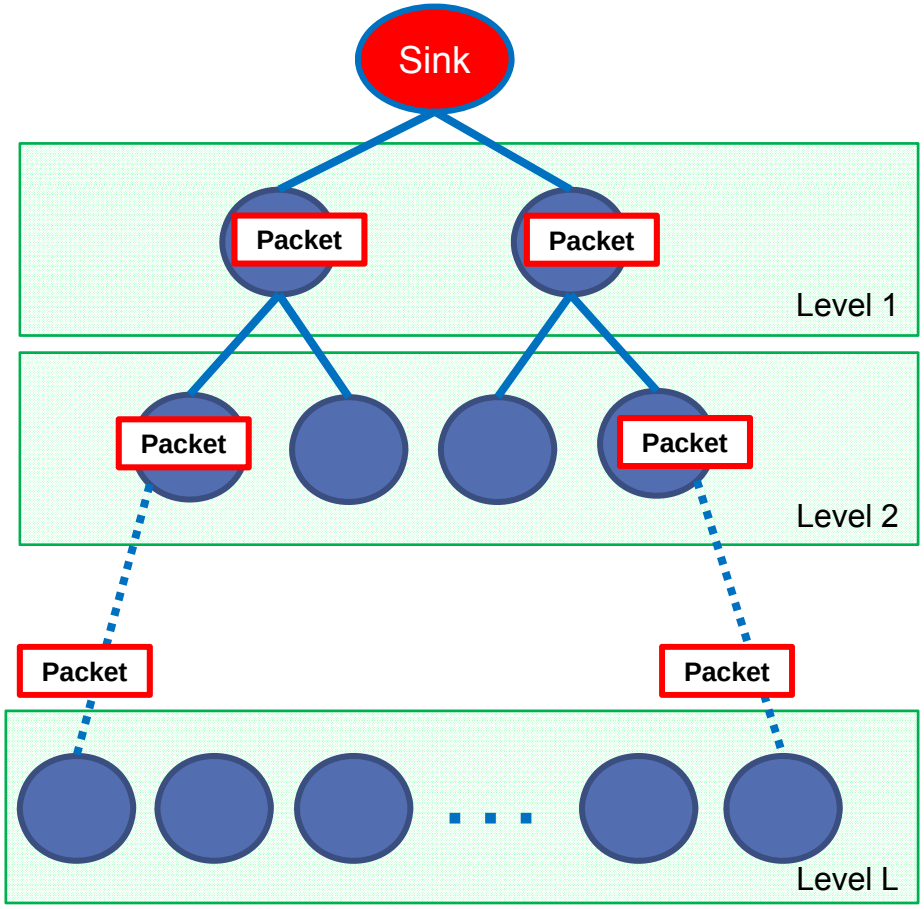
- Data collection is usually performed in Data Gathering Cycle (DGC) in which all sensors wake up, generate one packet and send to the sink

2. Research Motivation

- In practical, sensors in such network use small batteries and are expected to operate for a long time
- Replacing or recharging the batteries of the sensors is impractical after they have been deployed
- In any data gathering application, especially in large-scale network, small delay in data collection is desired

Prolonging the network lifetime and reducing data collection delay are important considerations while designing or deploying a WSN

3. Research Problems



With multihop communication, sensors at level 1 & level 2 consume plenty of energy so their batteries drain very fast

Also with multihop communication, a packet is relayed at so many nodes before arriving at the sink

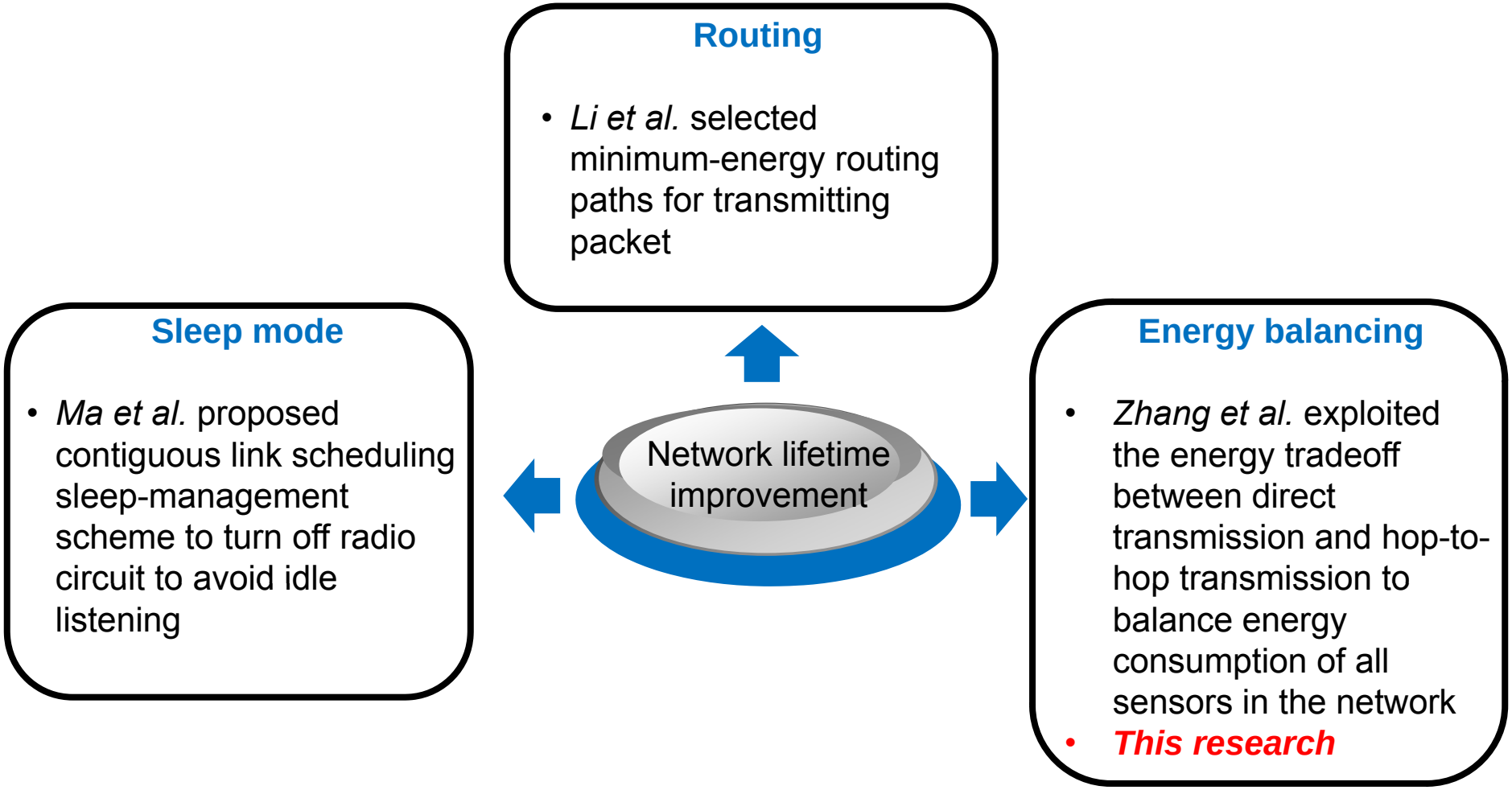
Problems

Unbalanced energy consumption throughout the network (causing a decreased network lifetime) & long delay in data collection

Network lifetime: the time until ***one*** sensor runs out of battery

Data collection delay: the time for ***all packets*** from ***all sensors*** to be received by the sink

4. Related Work

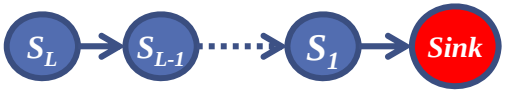


5. Research Objective

- Increasing the network lifetime and reducing data collection delay of WSN (compared to that with hop-to-hop communication) by balancing the energy consumption of each sensor throughout the network

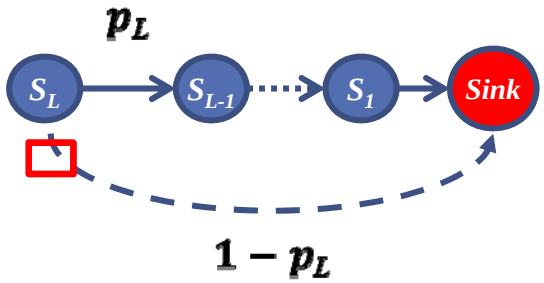
6. Proposed 2-hop Scheme

H2H scheme
(Conventional scheme)



S_i receives packets from S_{i+1} and forwards all to S_{i-1}

Direct scheme
(*Zhang et al.*)



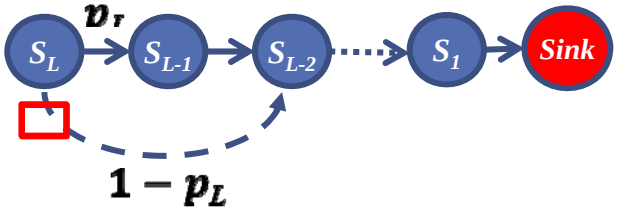
S_i forwards a packet to S_{i-1} with probability p_i or sends it directly to the sink with probability $1 - p_i$

Disadvantage

Direct scheme requires plenty of energy

- If sensors too far from the sink, direct scheme may be impossible

2HOP scheme
(Proposed scheme)



S_i forwards a packet to S_{i-1} with probability p_i or sends it to S_{i-2} with probability $1 - p_i$

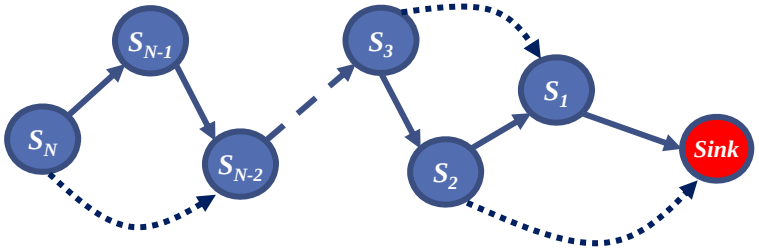
Advantage over Direct scheme

2-hop transmission requires less energy than Direct transmission

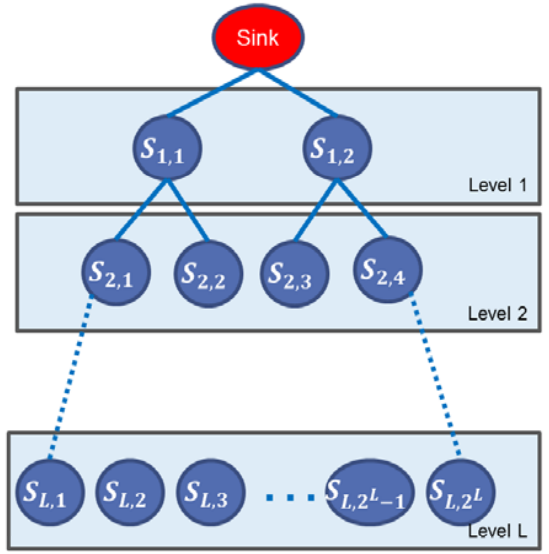
7. Theoretical Analysis

Two performance metrics are evaluated:

1. Network lifetime
   - When the initial battery level is either same or different
   - When the pathloss exponent is varying
2. Data collection delay
   - When the number of levels is varying
   - When the transmission probability is varying



Chain network



Binary tree network

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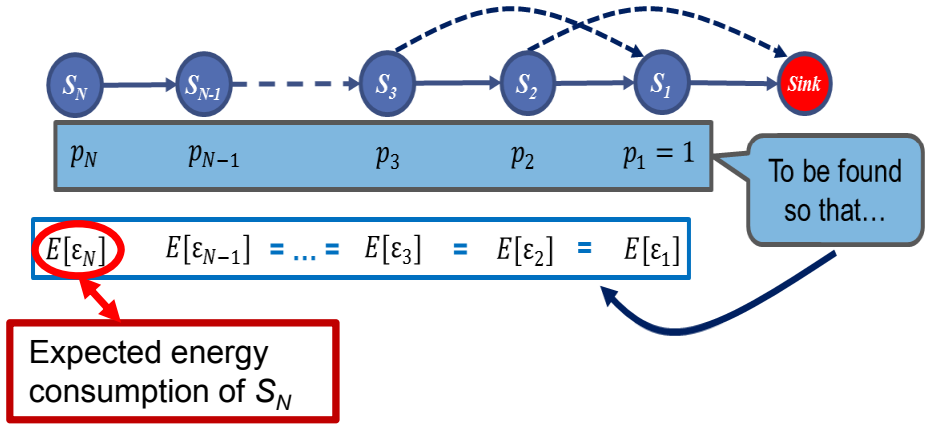
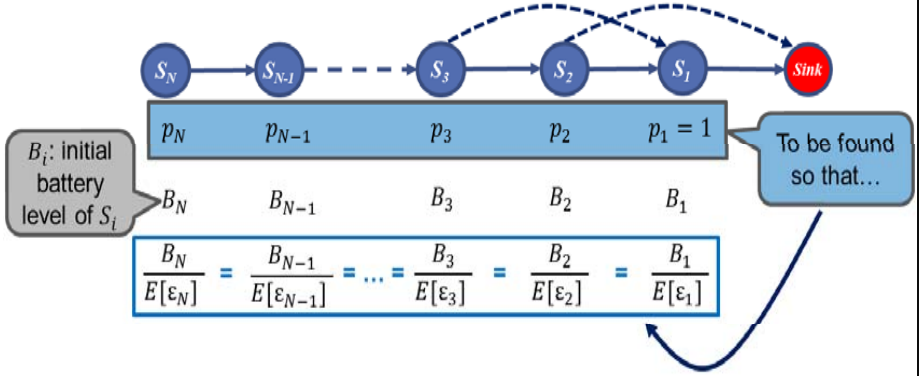
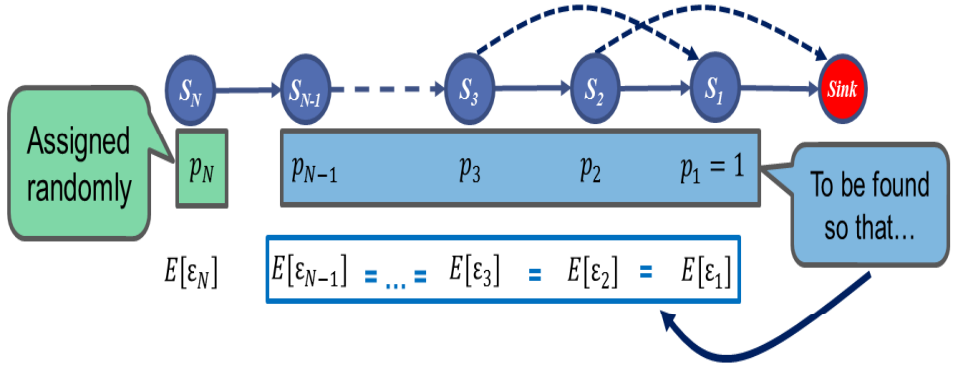
7.1 Optimal Probability Computation

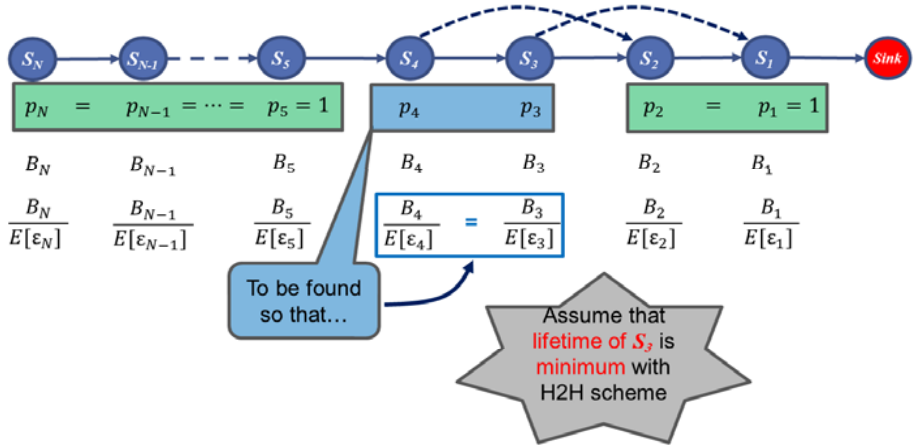
Same initial battery level



Different initial battery level







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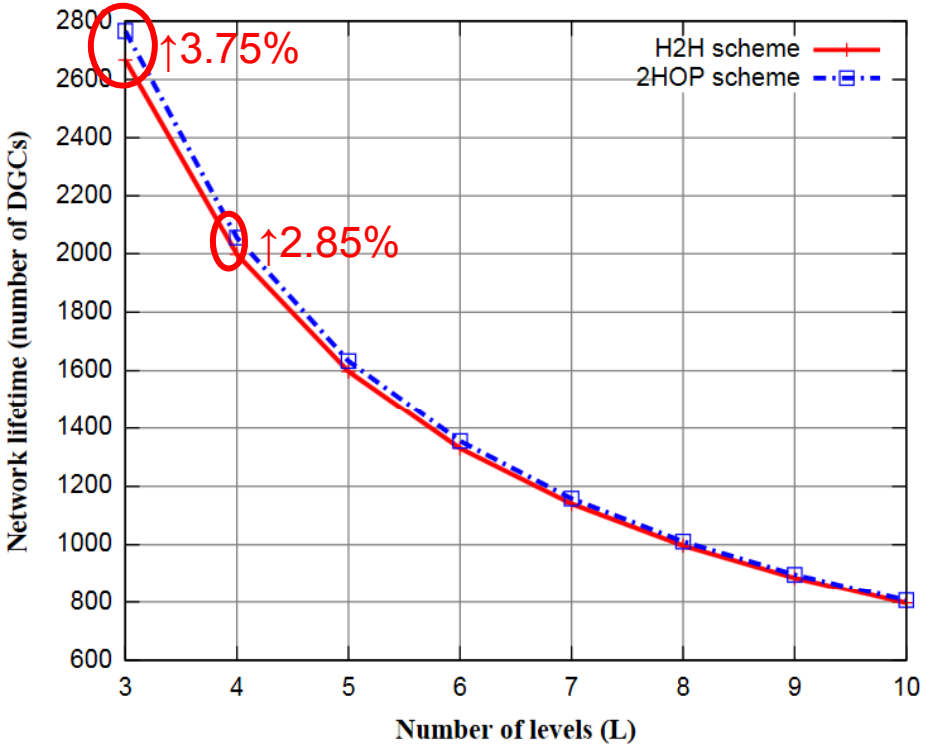
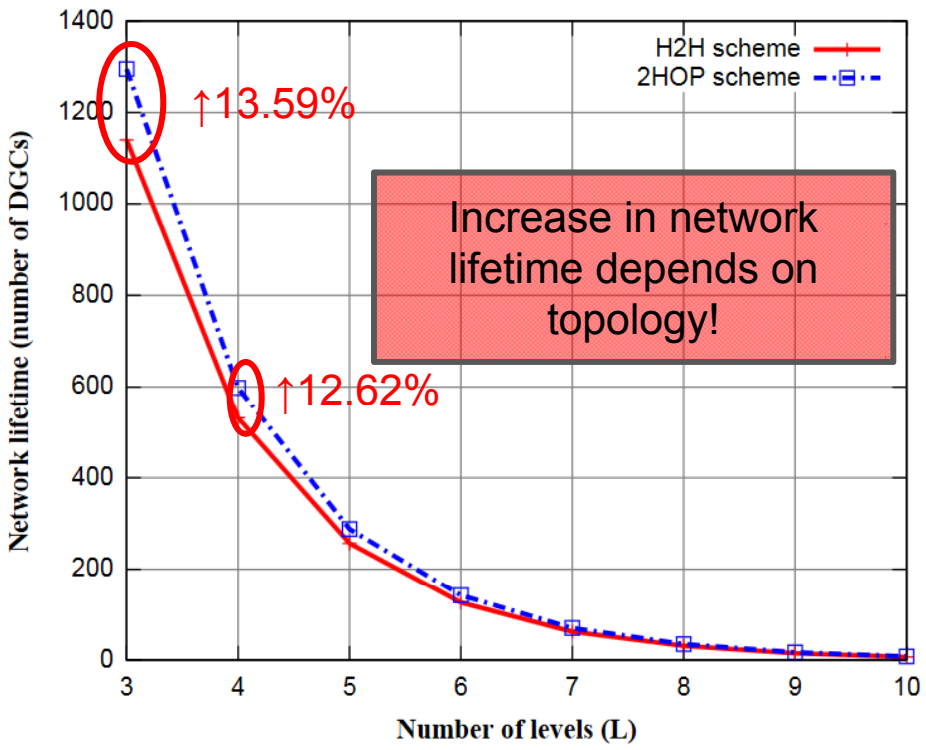
7.2 Network Lifetime with Same Initial Battery Level (30 J)

Chain network



Binary tree network



Increase in network lifetime depends on topology!

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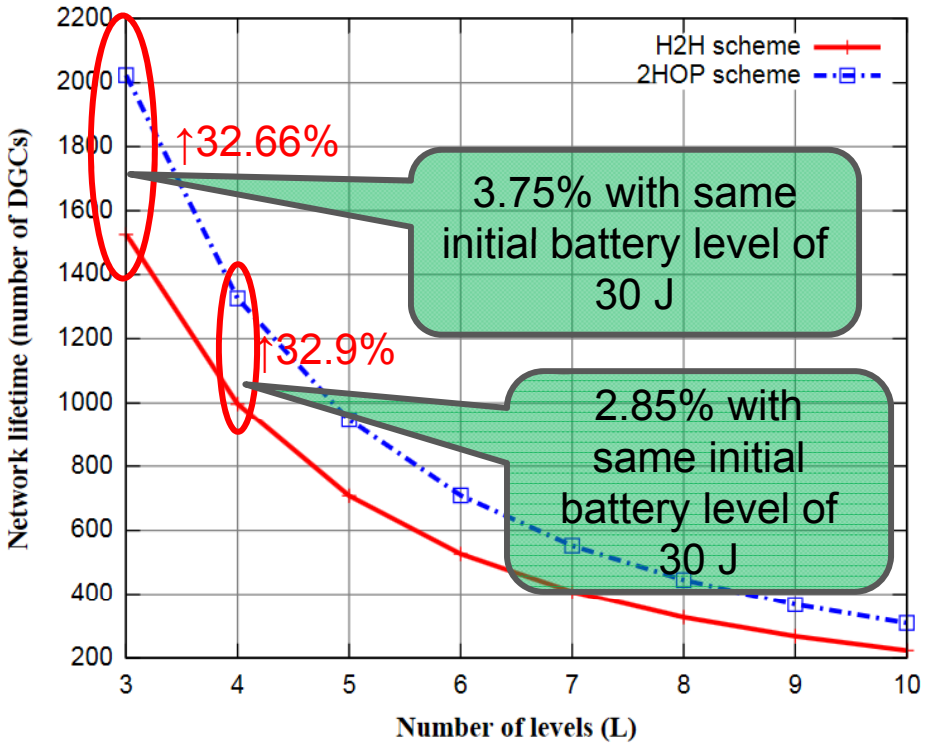
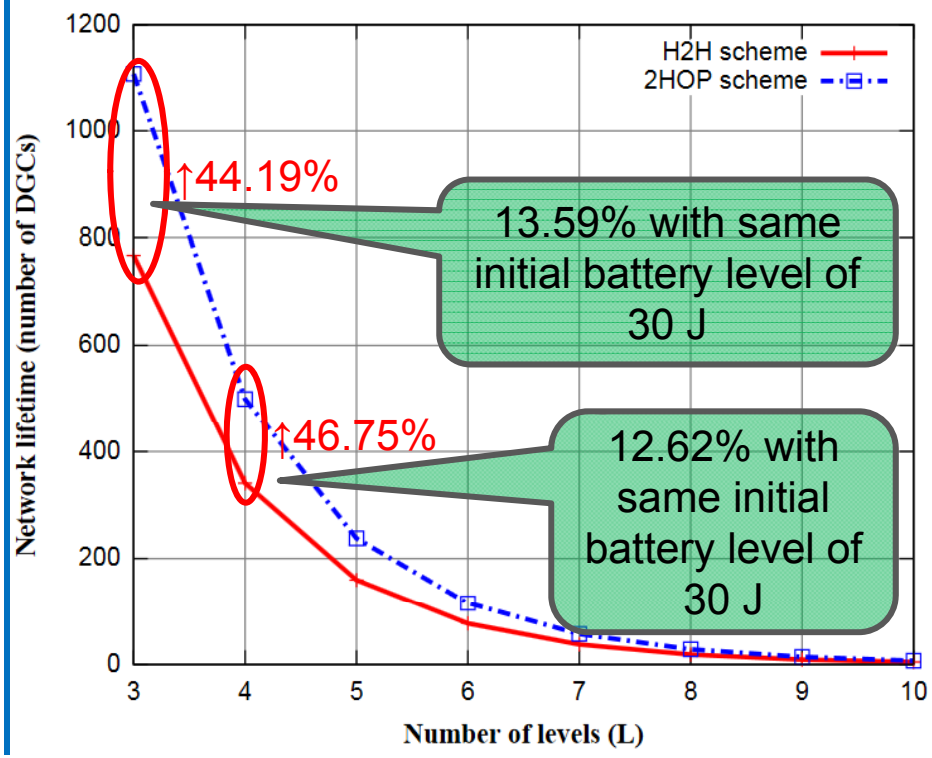
7.3 Network Lifetime with Different Initial Battery Level (Average 30 J)

Chain network



Binary tree network



For random initial battery levels, the increase in network lifetime is better than that when battery level is the same

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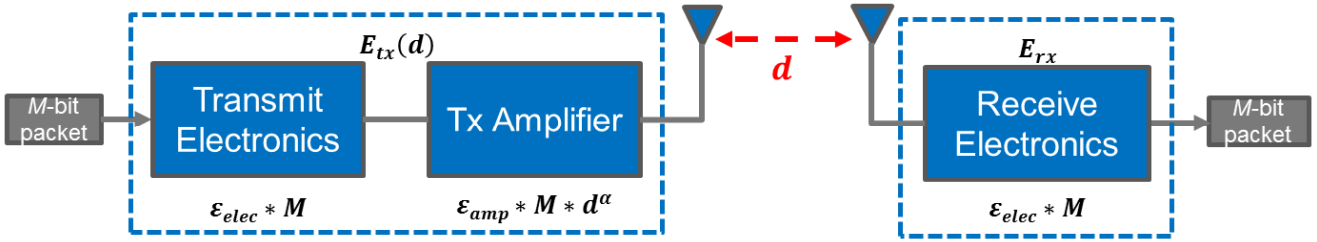
7.4 First-order Radio Model



$$E_{tx}(d) = (\varepsilon_{elec} + \varepsilon_{amp} * d^{\alpha}) * M$$

$$E_{rx} = \varepsilon_{elec} * M$$

Note:

ε_{elec}: energy spent by the electronic circuit when transmitting or receiving one bit data

ε_{amp}: transmission amplifier

α: path loss exponent

α depends on the environment where the network is operating (α = 2 in free space, α is larger in more lossy environments)

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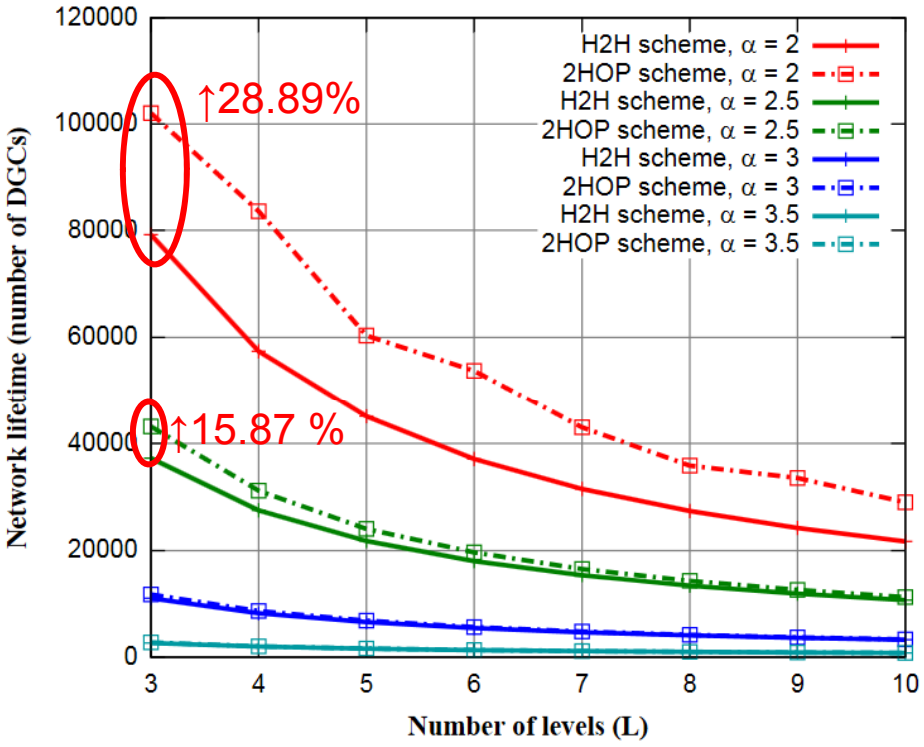
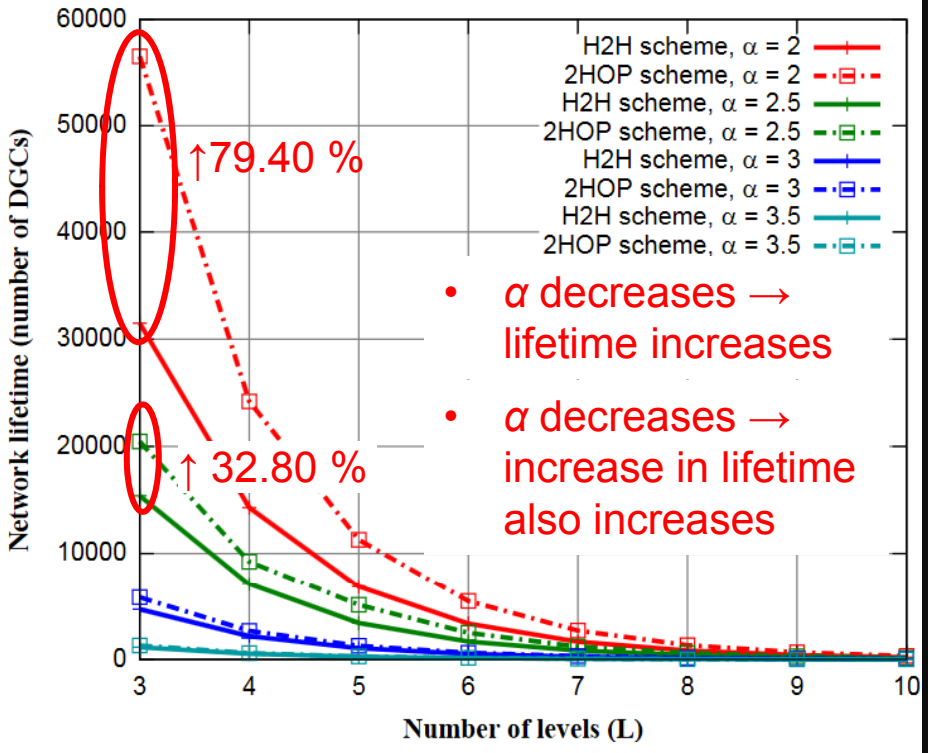
7.5 Network Lifetime with Different Pathloss Exponential

Chain network



Binary tree network



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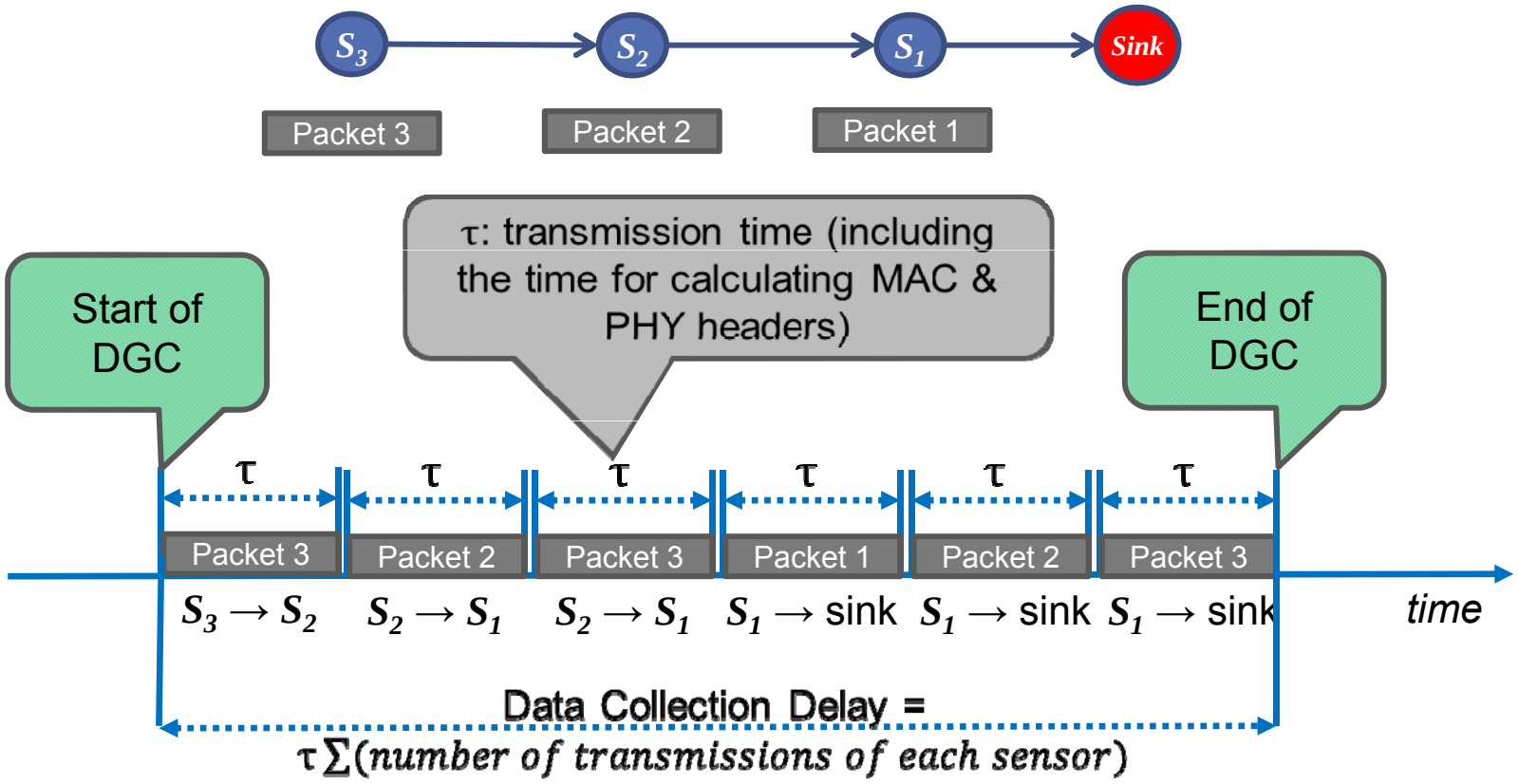
7.6 Data Collection Delay

The time for all packets to be received by the sink in one Data Gathering Cycle



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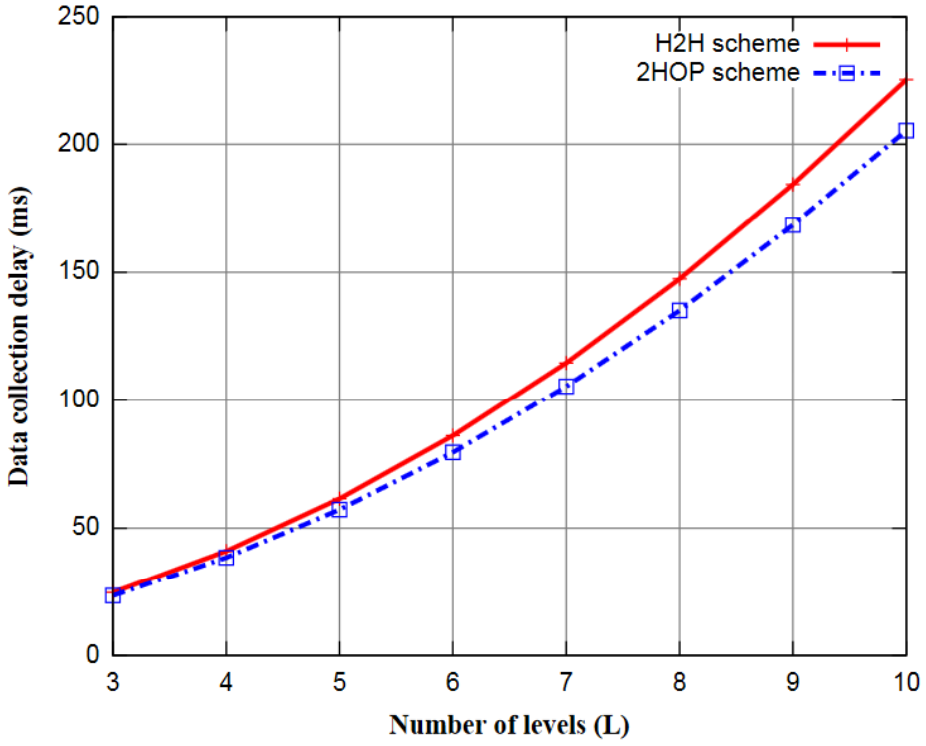
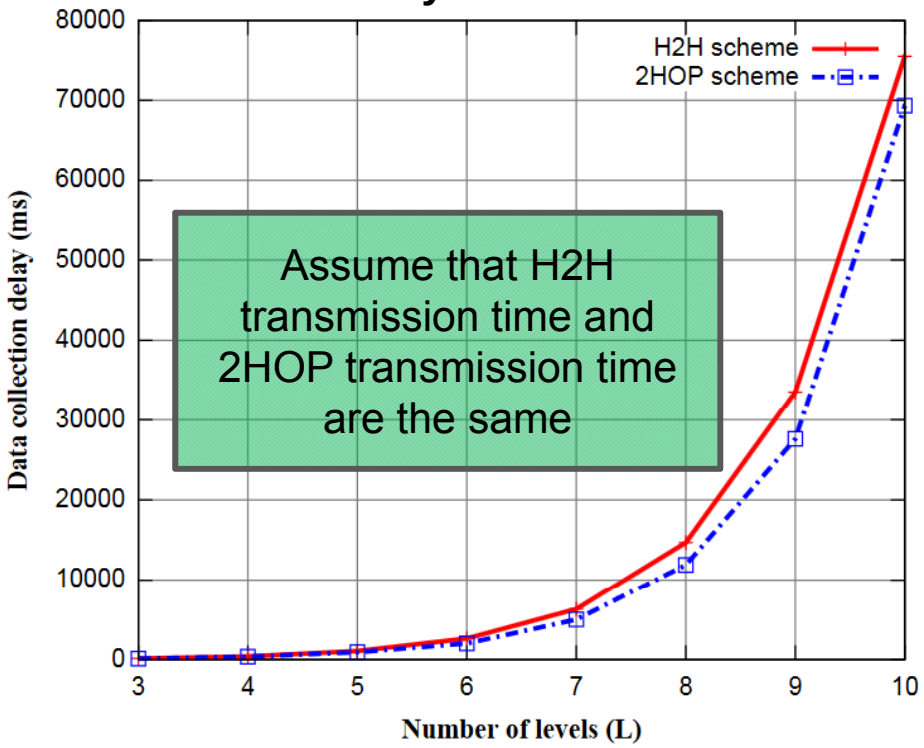
7.7 Data Collection Delay as a Function of Number of Levels

Chain network



Binary tree network



Assume that H2H transmission time and 2HOP transmission time are the same

With optimal probabilities, not only lifetime increases but data collection delay also decreases (faster)

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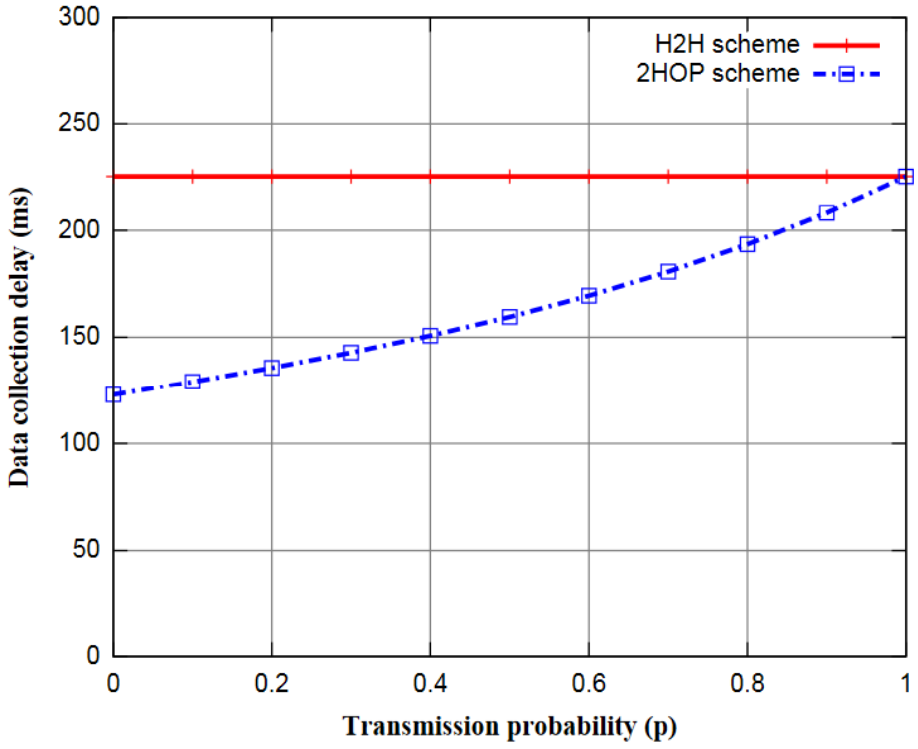
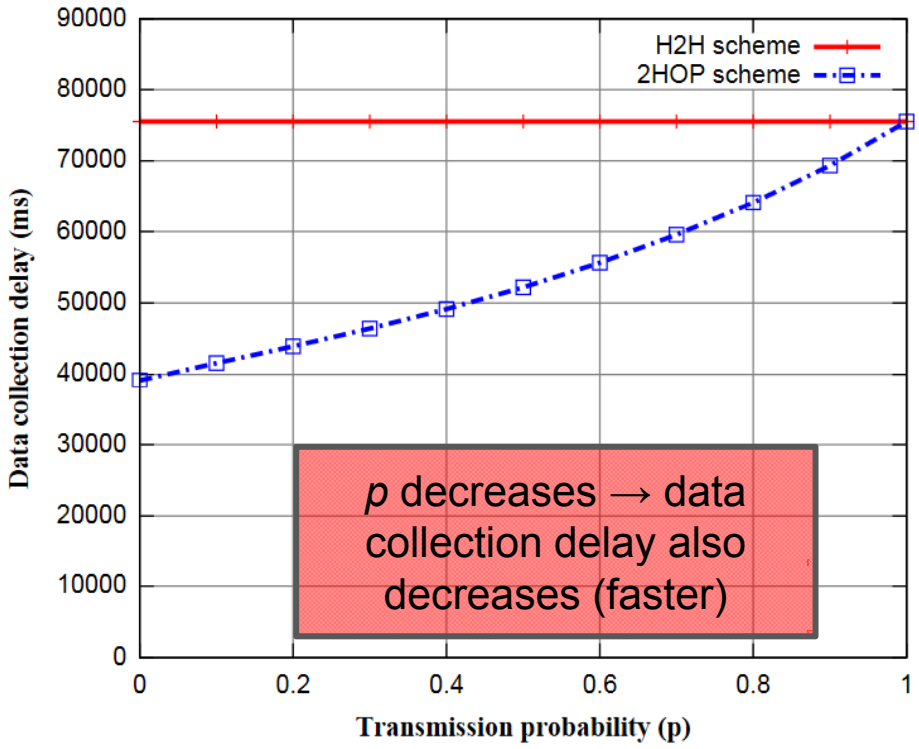
7.8 Data Collection Delay as a Function of Transmission Probabilities

Chain network



Binary tree network



p decreases → data collection delay also decreases (faster)

8. Simulation Studies

1. Network lifetime
   - When the initial battery level is either same or different
   - When the packet loss is varying

2. Data collection delay
   - When the transmission probability is varying

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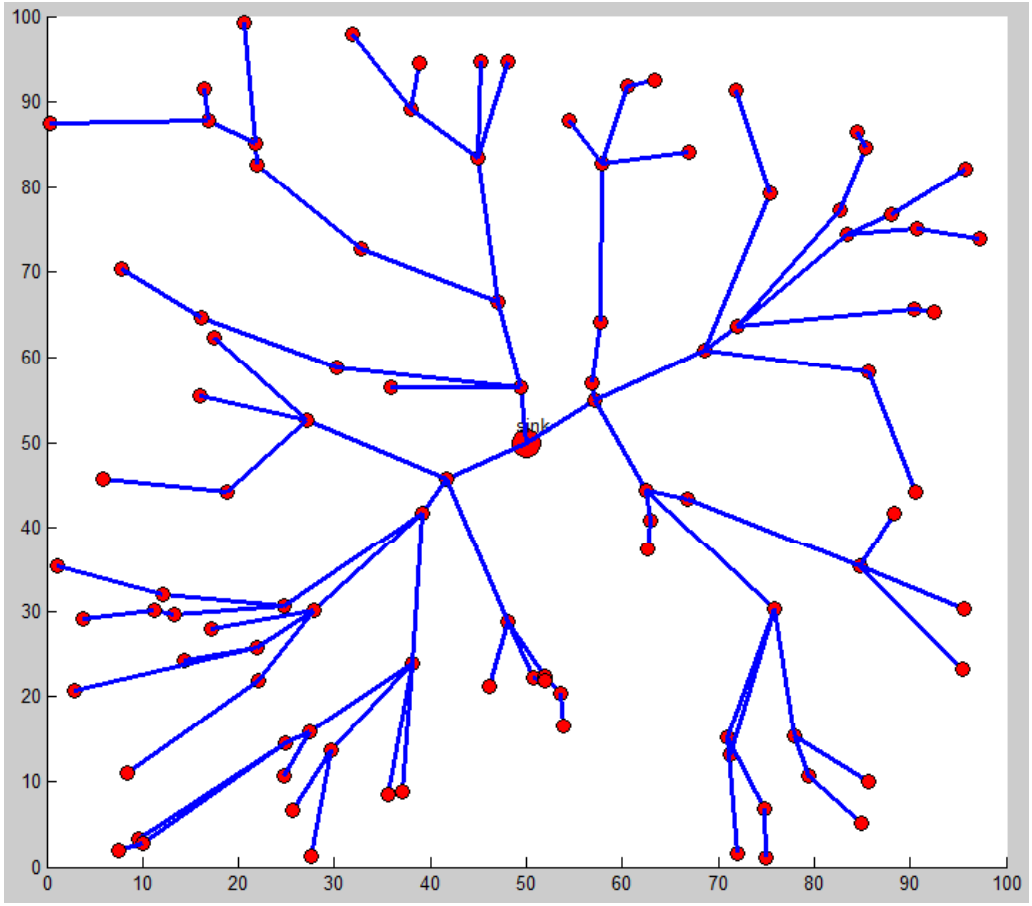
8.1 Simulation Scenario



Network coverage is 100 m × 100 m

- We examine the performance of 2HOP scheme and H2H scheme
- We construct a network simulator using C++ programming
- Tree topology is built using tree-based routing (TBR) protocol

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8.2 Parameters and Settings

Network configuration	
Number of sensors	100
Position of sensor	Randomly distributed
Number of sinks	1
Position of sink	In the middle of the network coverage
Sensor configuration	
Initial battery level	30 J
H2H transmission range	20 m
2HOP transmission range	30 m
Energy to receive one packet	0.0512 mJ
Energy to transmit one packet in H2H transmission	3.7147 mJ
Energy to transmit one packet in 2-hop transmission	15.1945 mJ
Transmission probability of each sensor	Pre-assigned before deployment
General configuration	
Data gathering cycle	10 s
Number of simulation topologies	30

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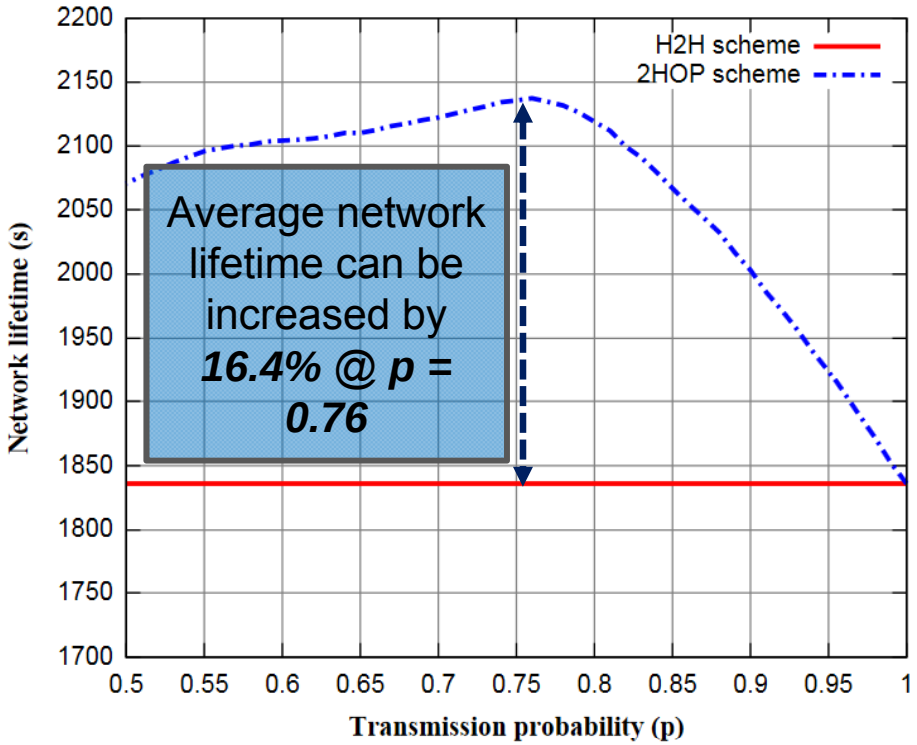
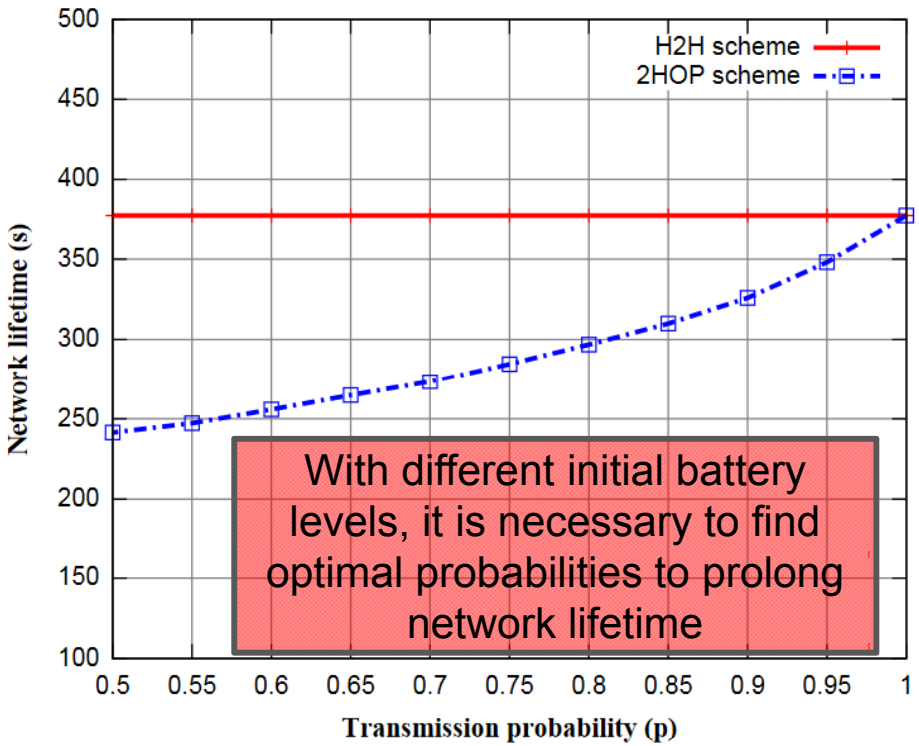
8.3 Results: Network Lifetime I

Same initial battery level



Different initial battery level



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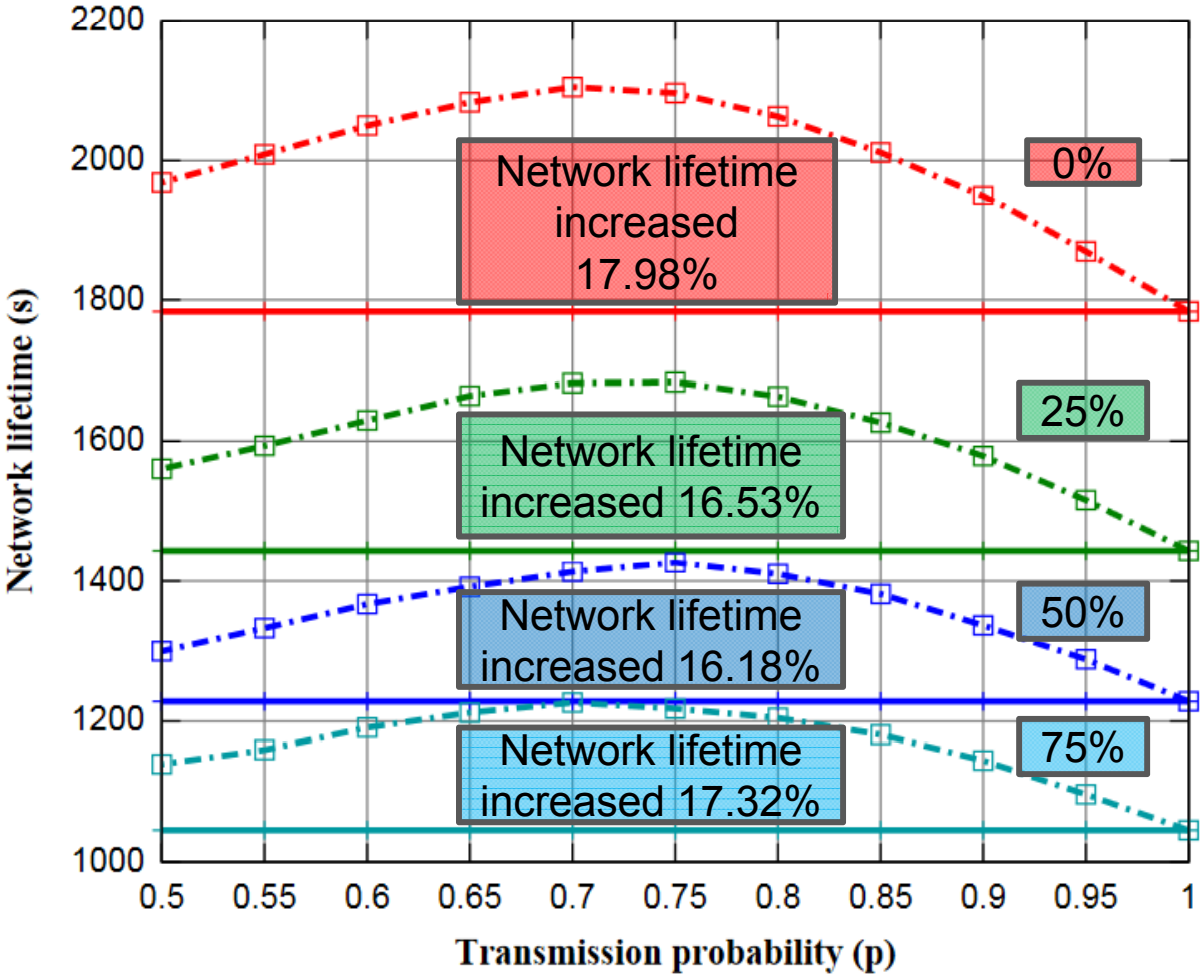
8.4 Results: Network Lifetime II



Packet loss of 25% means that, for a sensor in the network, 25% of its transmission need to be retransmitted due to error in transmission

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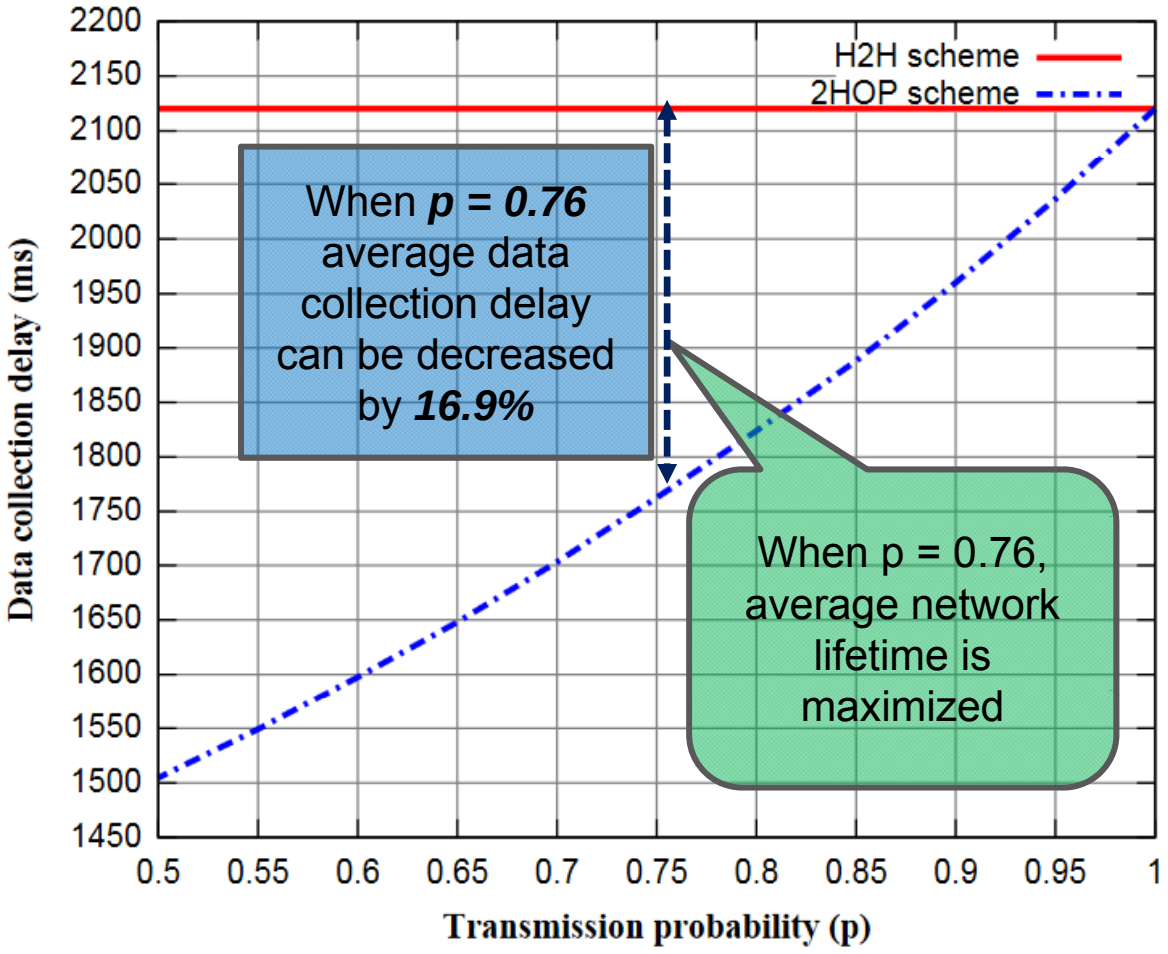
8.5 Results: Data Collection Delay



9. Concluding Remarks (1)

- Main contributions
  - Proposed 2HOP scheme
    - Can operate in large-scale networks where direct scheme cannot be well-deployed
    - Increases network lifetime (even with the presence of packet loss)
    - Decreases delay in data collection compared to H2H scheme
  - Solved optimal probabilities
    - Not only for chain but also for binary tree networks
    - With same or different initial battery levels
- Analysis of 2HOP scheme
  - Network lifetime depends on
    - Topology
    - Pathloss exponent
    - Initial battery levels
  - Data collection delay depends on
    - Levels of sensors in the network
    - Transmission probabilities

9. Concluding Remarks (2)

- Simulation results
  - Regardless of packet loss, 2HOP scheme can still increase network lifetime
    - Packet loss 0%, network lifetime can be increased 17.98%
    - Packet loss 25%, network lifetime can be increased 16.53%
    - Packet loss 50%, network lifetime can be increased 16.18%
    - Packet loss 75%, network lifetime can be increased 17.32%
  - In general trees, same initial battery levels, when p = 0.76
    - The average increase in network lifetime is maximum (16.4%)
    - Data collection decrease is 16.9%
  - With different initial battery levels, in order to increase network lifetime, it is necessary to compute optimal probabilities for the sensors

- Future works
  - A synchronized sleep / wake up for 2HOP scheme is an interesting research
  - 3HOP or 4HOP schemes may also be an interesting research

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Thank you for your attention!

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