On the Potential of Structure-free Data Aggregation in Sensor Networks

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Presented by L. C. Chen

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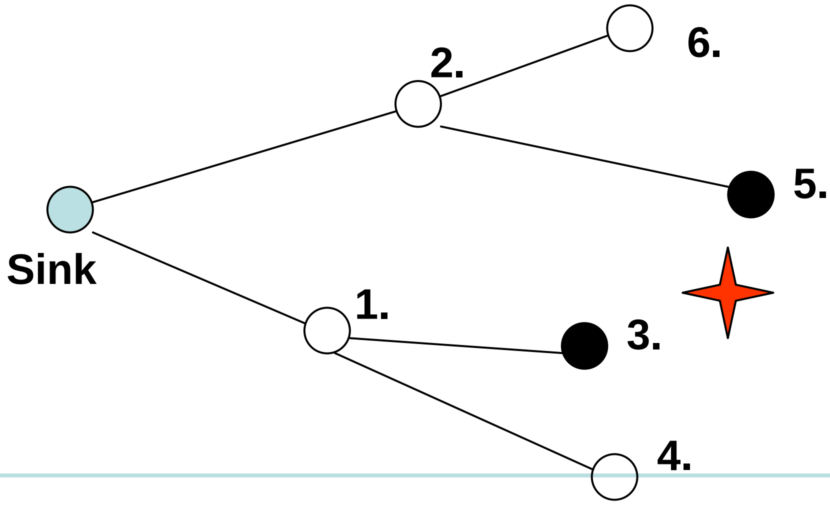
Outline

- Introduction
- Related Works
  - Cluster-Based Approaches
  - Tree-Based Approaches
- Spatial and Time Convergent Protocol
- Performance Evaluation
- Experiment Evaluation

Introduction

- Communication cost is higher than computation cost.
- Structured approaches
  - Cluster-Based
  - Tree-Based
- Limitations of structured aggregation techniques



Introduction

- Structure-free data aggregation for event-based senor networks

- Two main challenges
  - No pre-constructed structure
  - Nodes don’t know their upstream nodes

Related Work

- Cluster-Based Approaches --LEACH
  - With cluster-heads and base station
  - Cluster-heads have to send many packets to the base station using high transmission power.
- Tree-Based Approaches --Shortest Path Tree
  - Need a lot of message exchange to construct and maintain the tree.
  - Not designed for event tracking applications.
  - Lead to high cost in moving event scenarios.

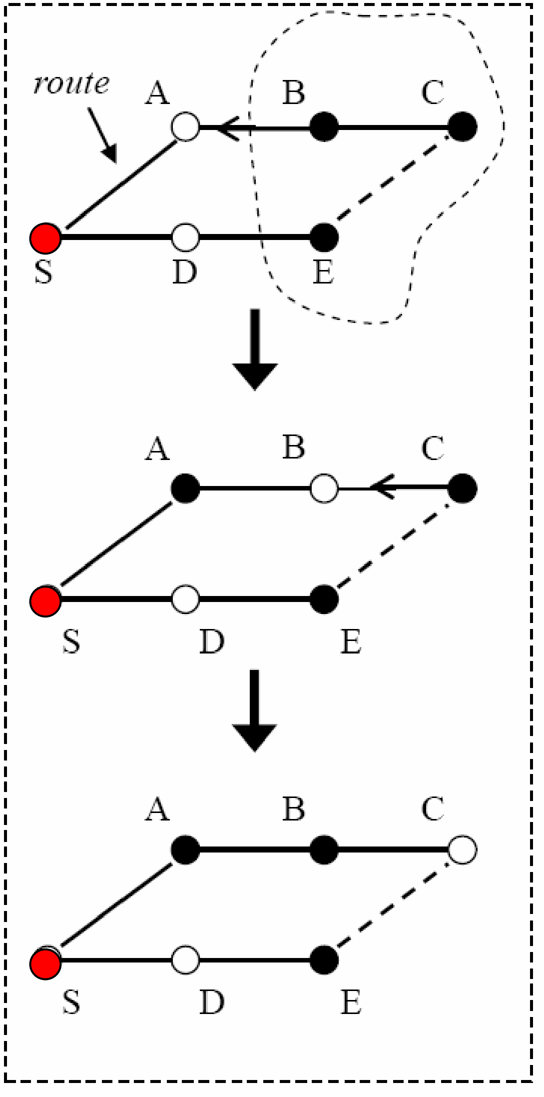
Goals of the Design

- Early aggregation
- Tolerance to event dynamics
- Robust to interference
- Fault tolerance

Spatial and Time Convergent Protocol

- Spatial Convergence
- Temporal Convergence

Spatial Convergence

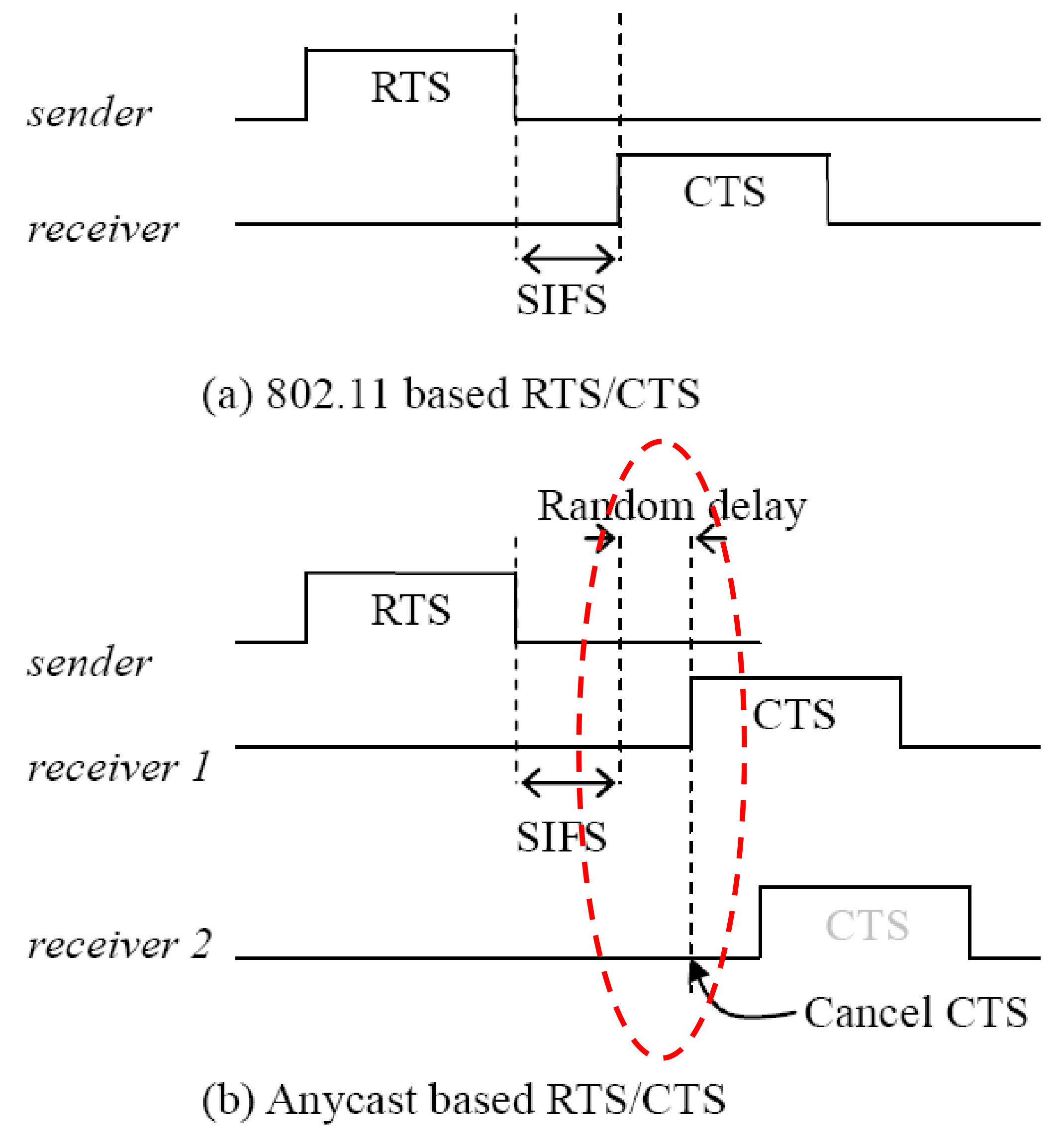


(a) Three packets left in the network.

Data-Aware Anycast Protocol (DAA)

- Aggregation ID
  - AID is the measurement timestamp
  - The RTS contains the AID of the transmitting packet.

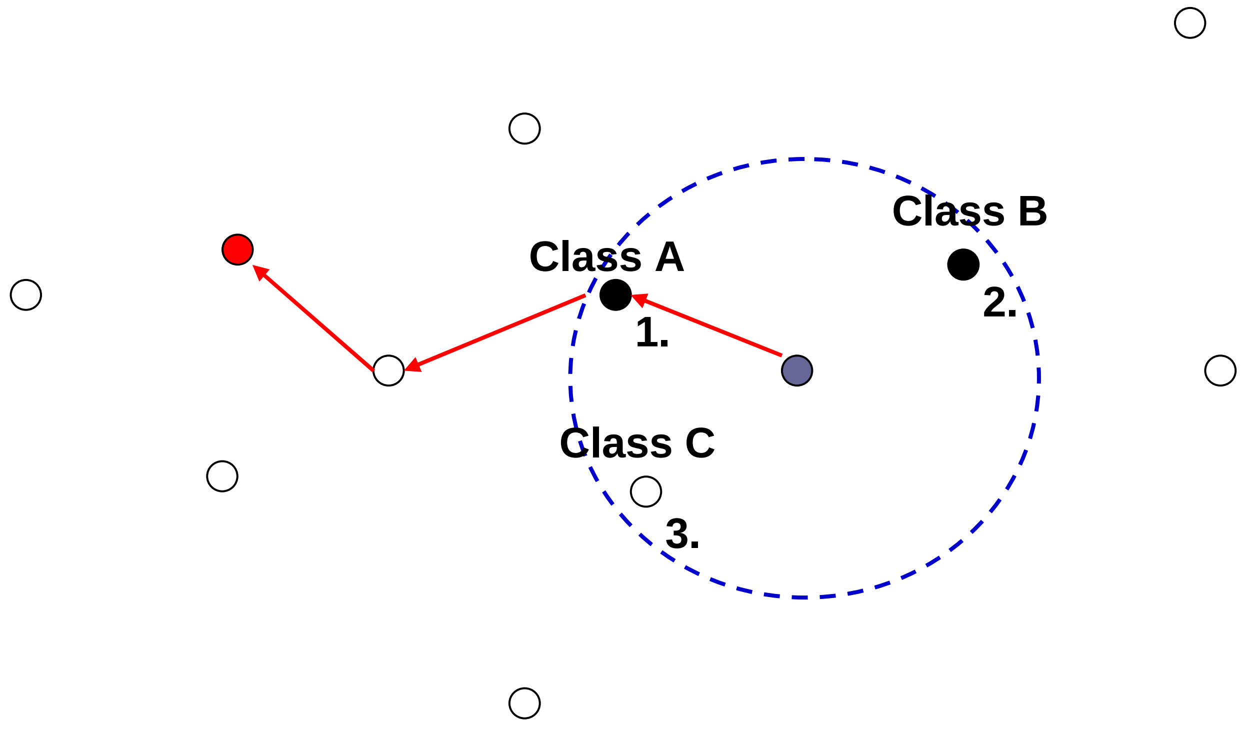
Data-Aware Anycast Protocol (DAA)



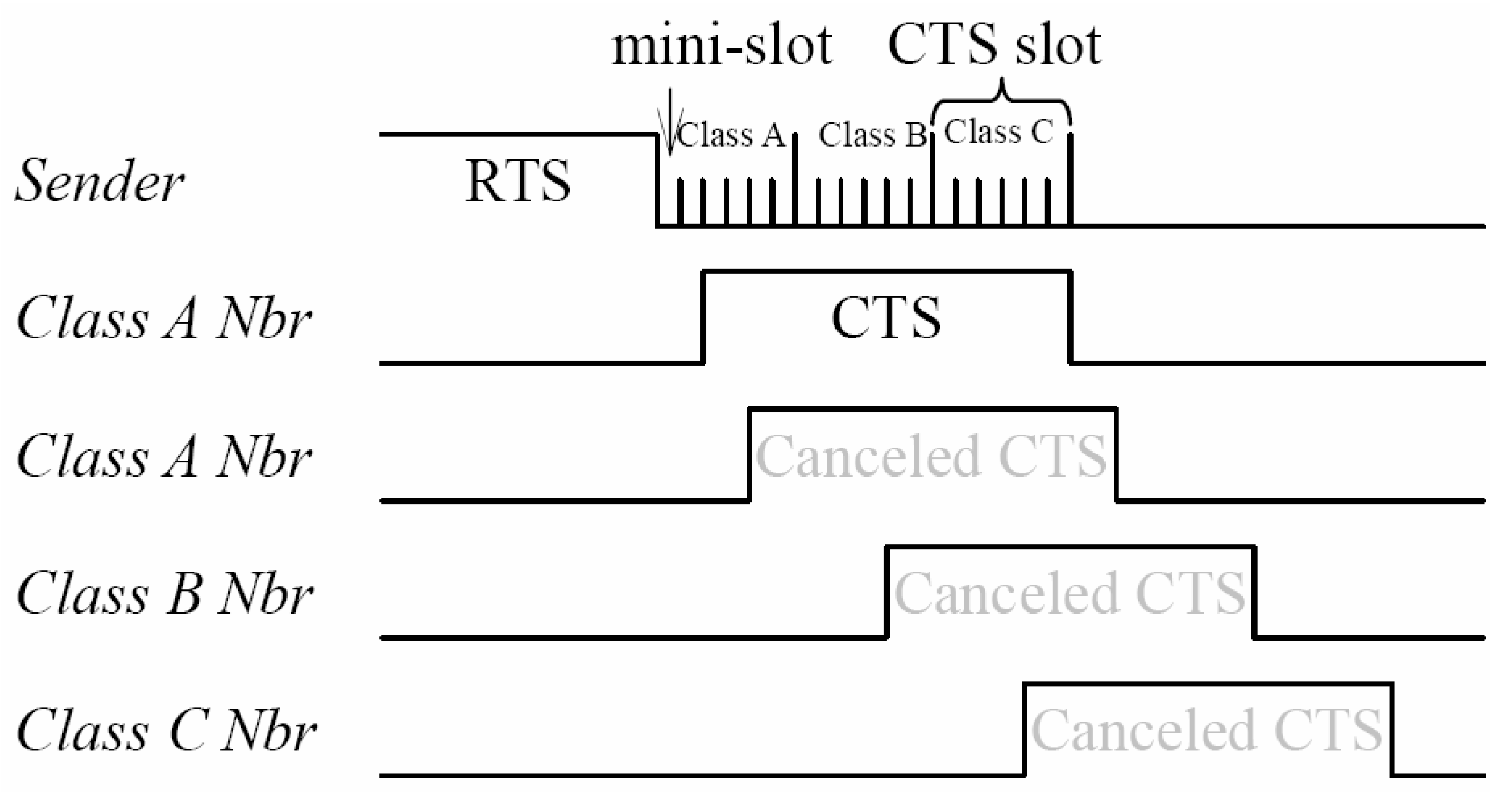
CTS Priorities

- Class A
  - The receiver has the packet with the same ID as specified in RTS, and is closer to the sink than the sender.
- Class B
  - The receiver has the packet with the same ID as specified in RTS, but is farer away from the sink than the sender.
- Class C
  - The receiver does not have the packet with the same ID, but is closer to the sink than the sender.

Example



CTS Priorities



Temporal Convergence

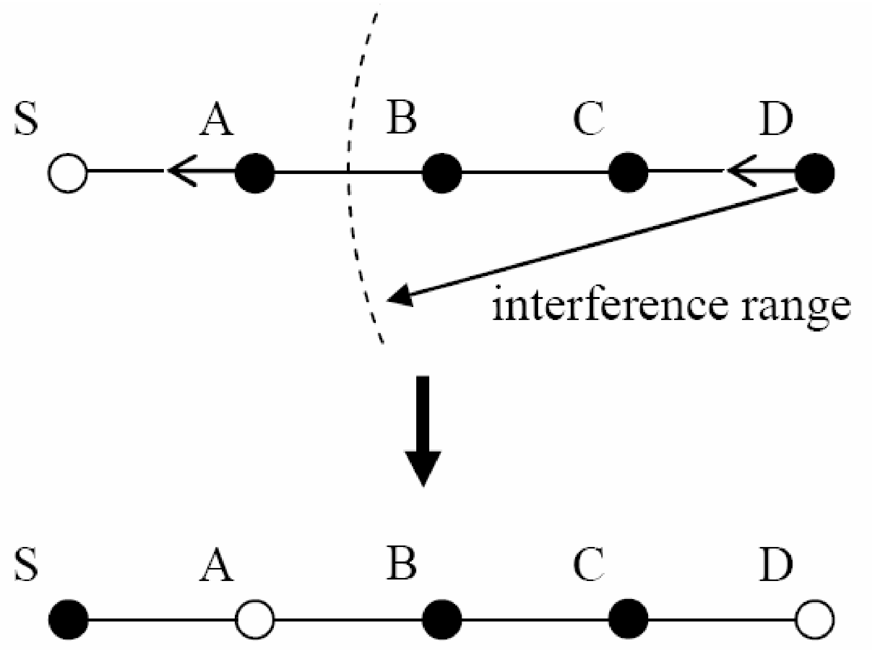


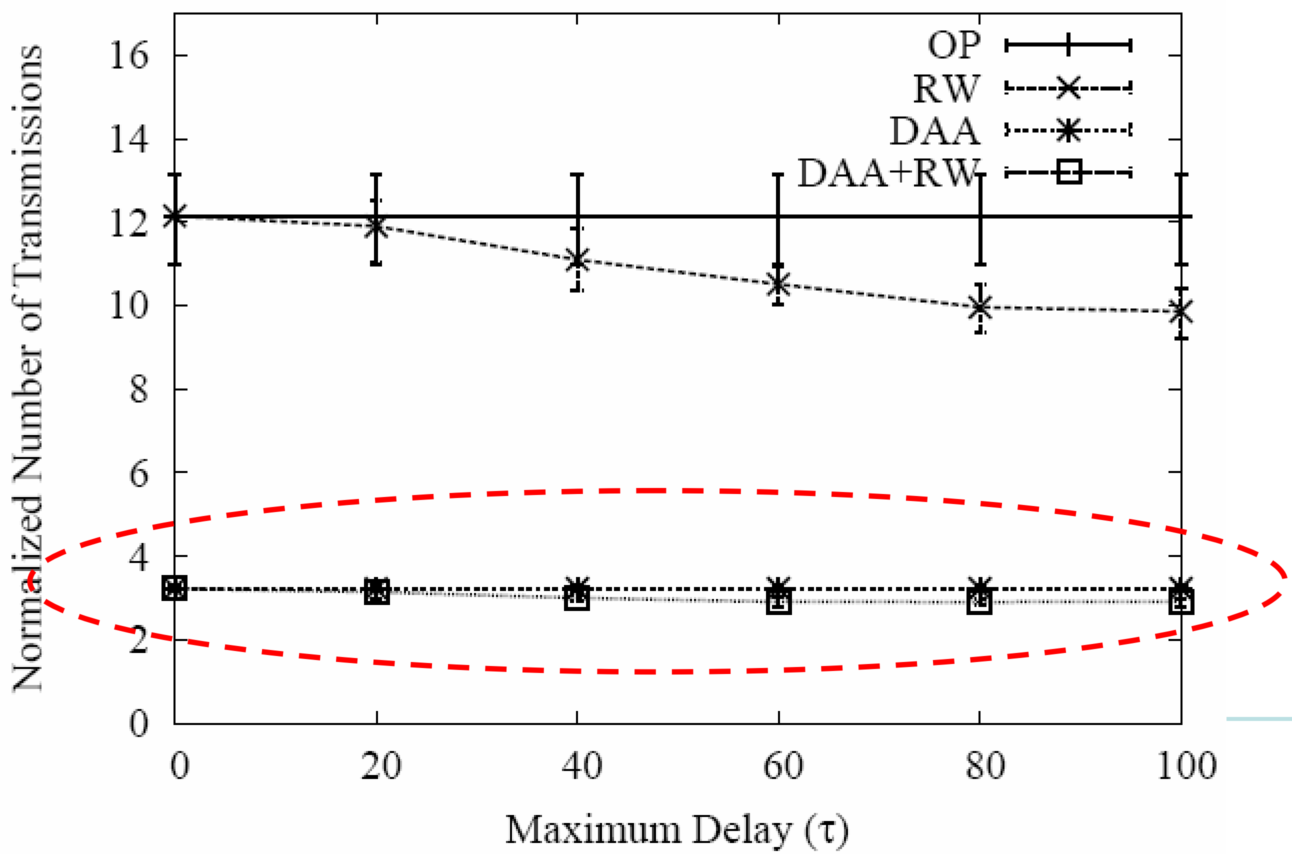
Fig. 5. Packet from D and A can hardly be aggregated if nodes forward packet in lock-step.

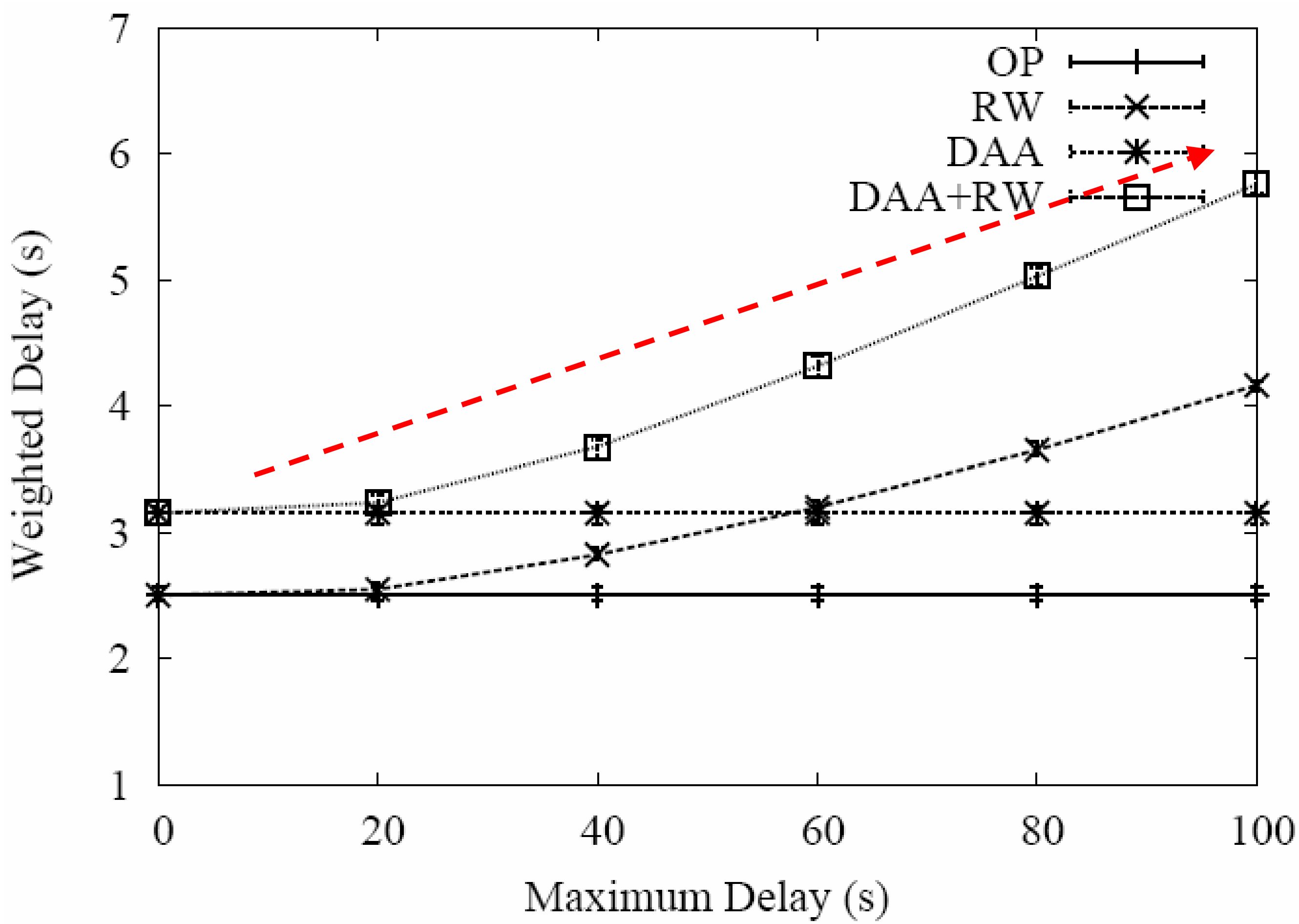
Randomized Waiting (RW)

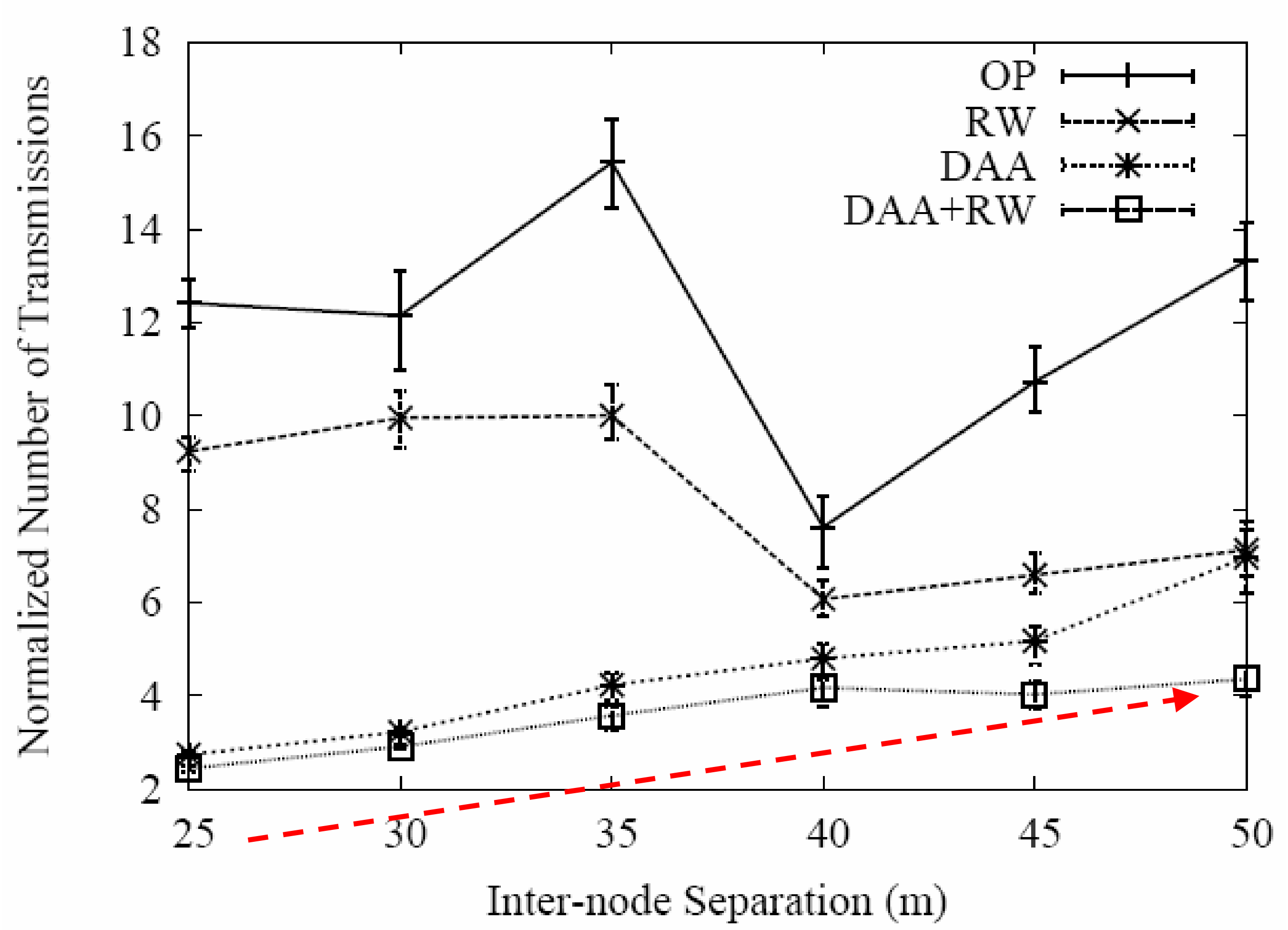
- At the source for each packet to introduce artificial delays
- Delays is chosen from 0 to τ

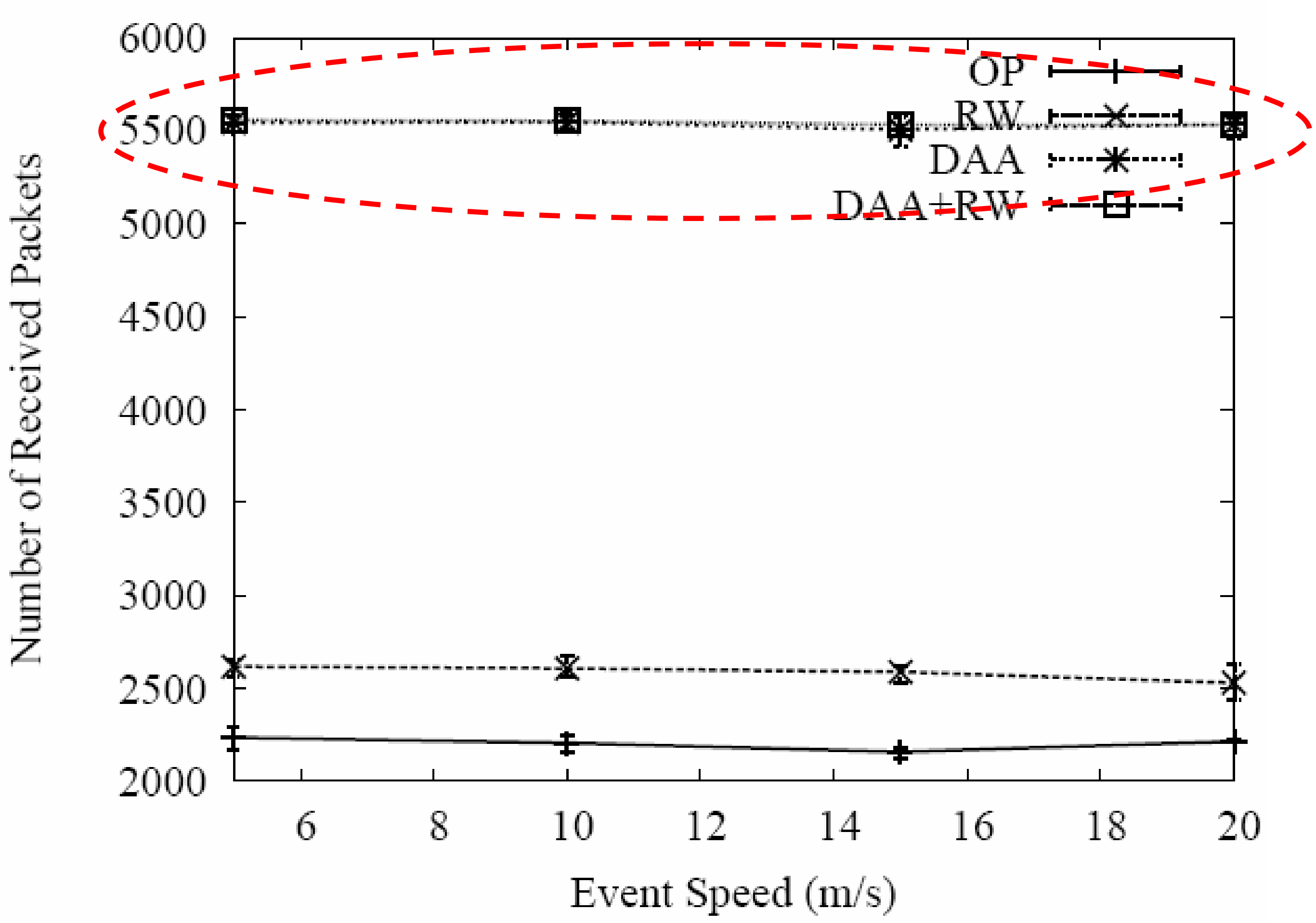
Randomized Waiting (RW)

- Normalized number of transmissions: (Number of transmissions in the network) / (Number of Contributing Sources)
- Number of Contributing Sources: the effective information that are generated by all sources in the network and are aggregated at the sink.




Weighted Delay (s)
Maximum Delay (s)
OP
RW
DAA
DAA+RW
1
2
3
4
5
6
7
0
20
40
60
80
100


Normalized Number of Transmissions
18
16
14
12
10
8
6
4
2
25
30
35
40
45
50
Inter-node Separation (m)
OP
RW
DAA
DAA+RW


6000
5500
5000
4500
4000
3500
3000
2500
2000
Number of Received Packets
6
8
10
12
14
16
18
20
Event Speed (m/s)
OP
RW
DAA
DAA+RW

Experiment Evaluation

- 5-hop network with 6 XSM placed in a row
- All sensor nodes detect each event almost at the same time.
- An event broadcast program runs on the Kansei server that connects directly to all the stargates through Ethernet.
- Use the RW approach for improving the performance of data aggregation.

Experiment Evaluation

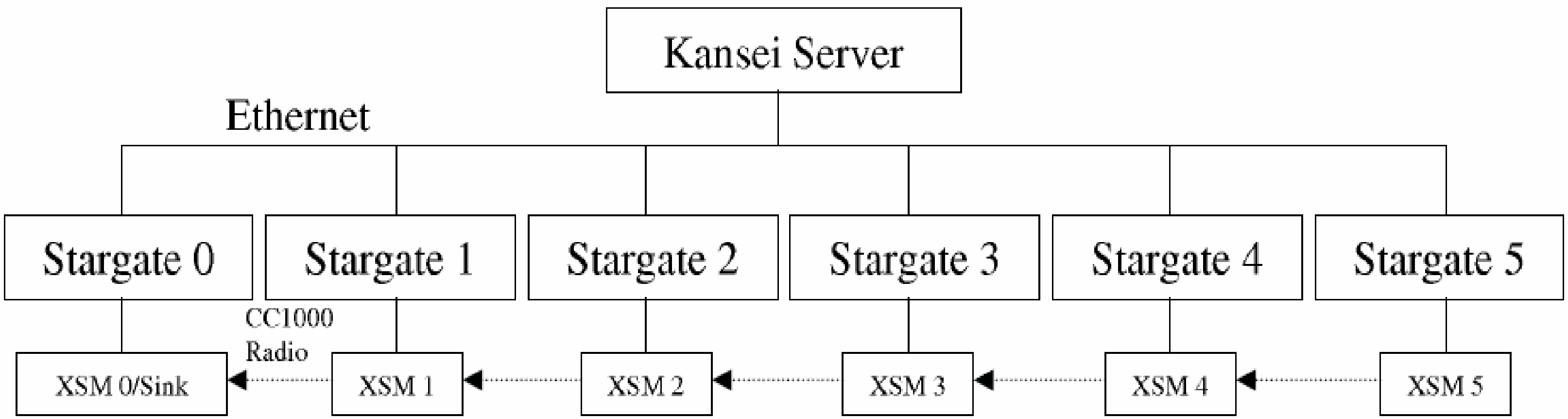
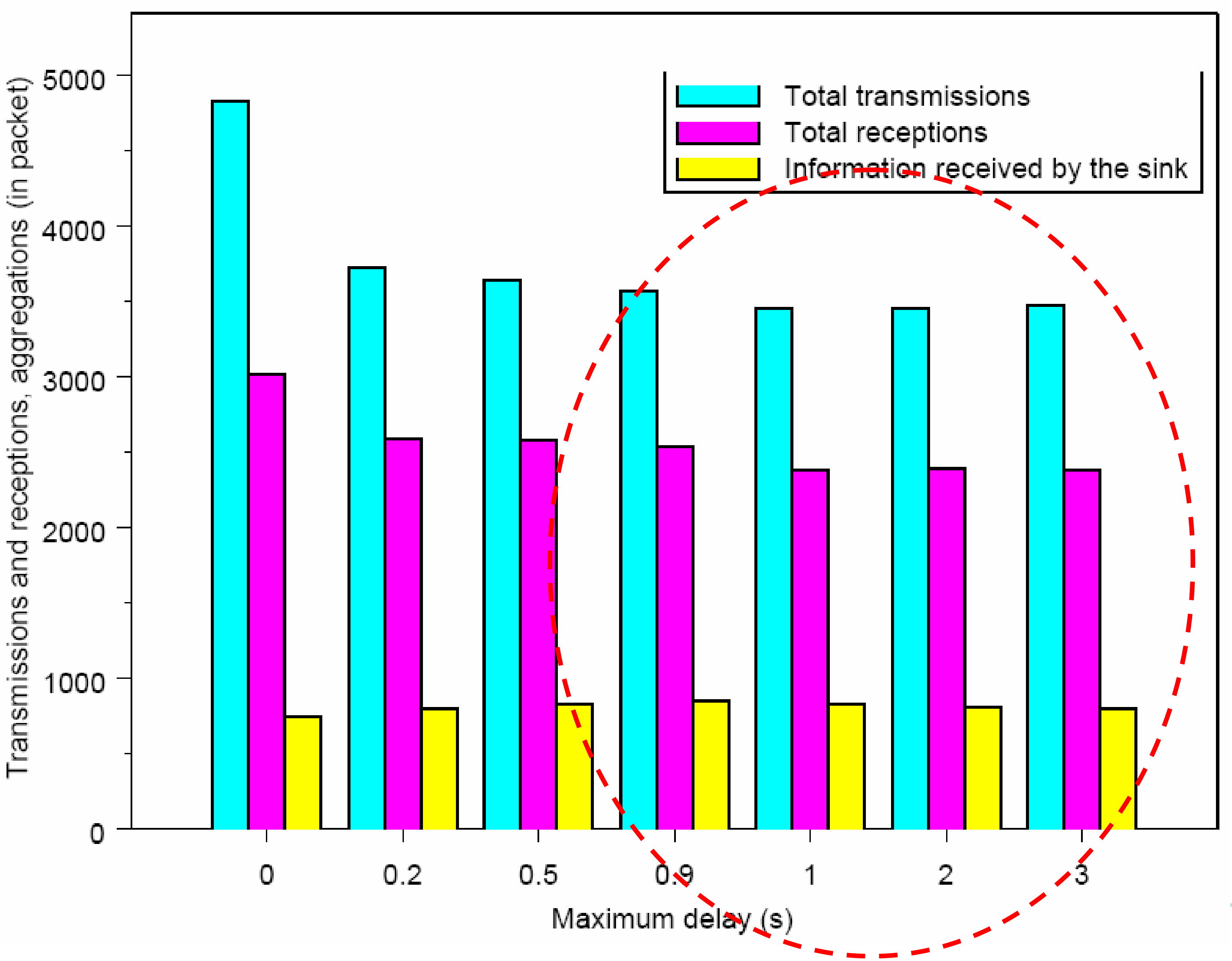


Fig. 13. Experiment environment structure

Experiment Evaluation



Experiment Evaluation

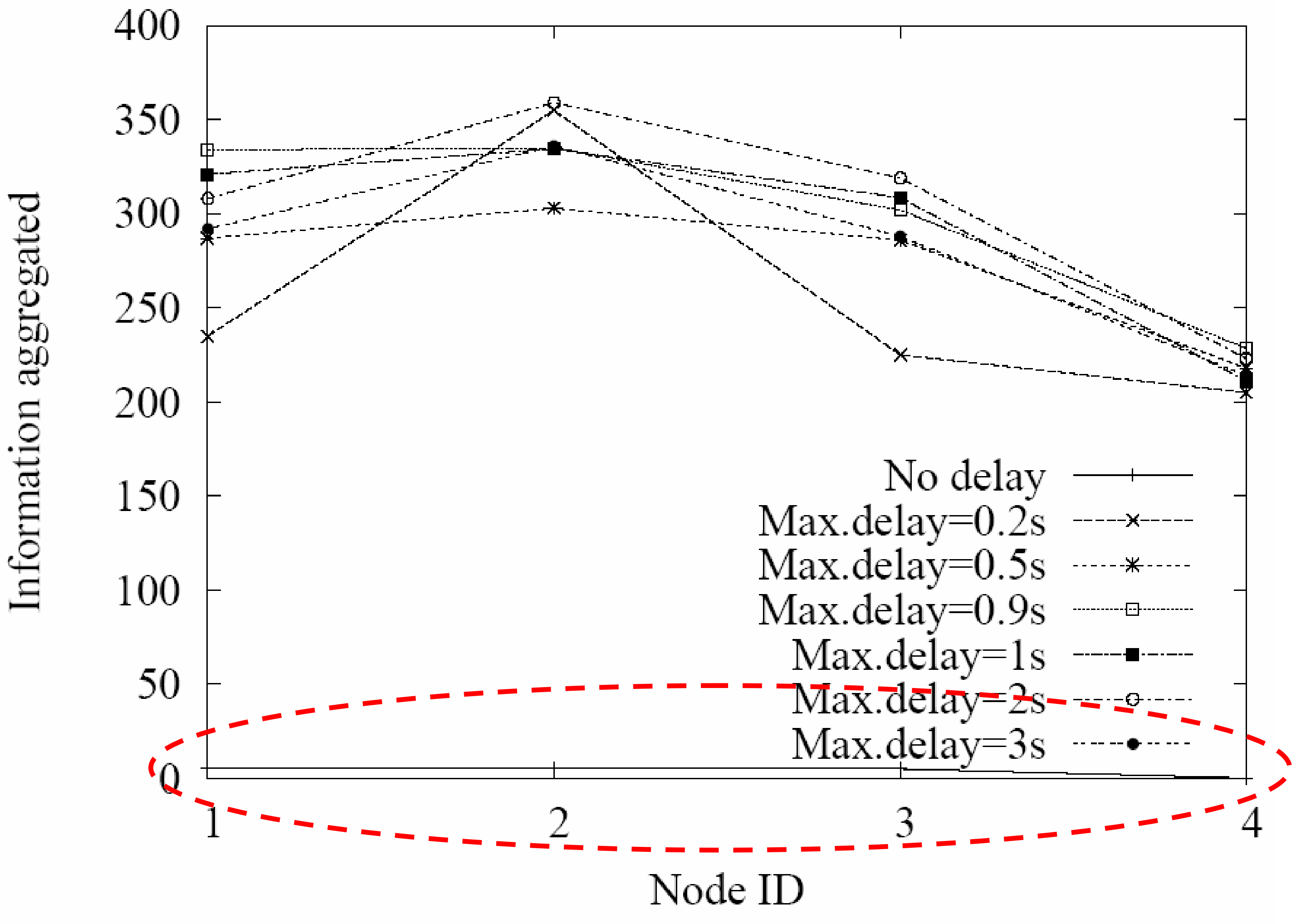


Fig. 16. Information aggregated at intermediate nodes

Discussion

- Comparison with structured approaches
  - Compare structured aggregation protocols with structure-free protocols for static as well as dynamic scenarios.
- Semi-structured approach
  - The structure-free approach has its advantages in dynamic scenarios, the structured approaches are suited for static scenarios.
- Anycast for other aggregation functions
  - Aggregation ID can be a function of the data itself that can be smartly used to compute the extent of aggregation.

Conclusions

- The author proposed techniques for data aggregation that do not use any explicit structures.
- Efficient aggregation requires packets to meet at the same node (spatial convergence) at the same time (temporal convergence).
- The combined DAA with RW approach can improve the normalized load by as much as 77%.