Exploiting Addresses Correlation to Maximize Lifetime of IPv6 Cluster-based WSNs

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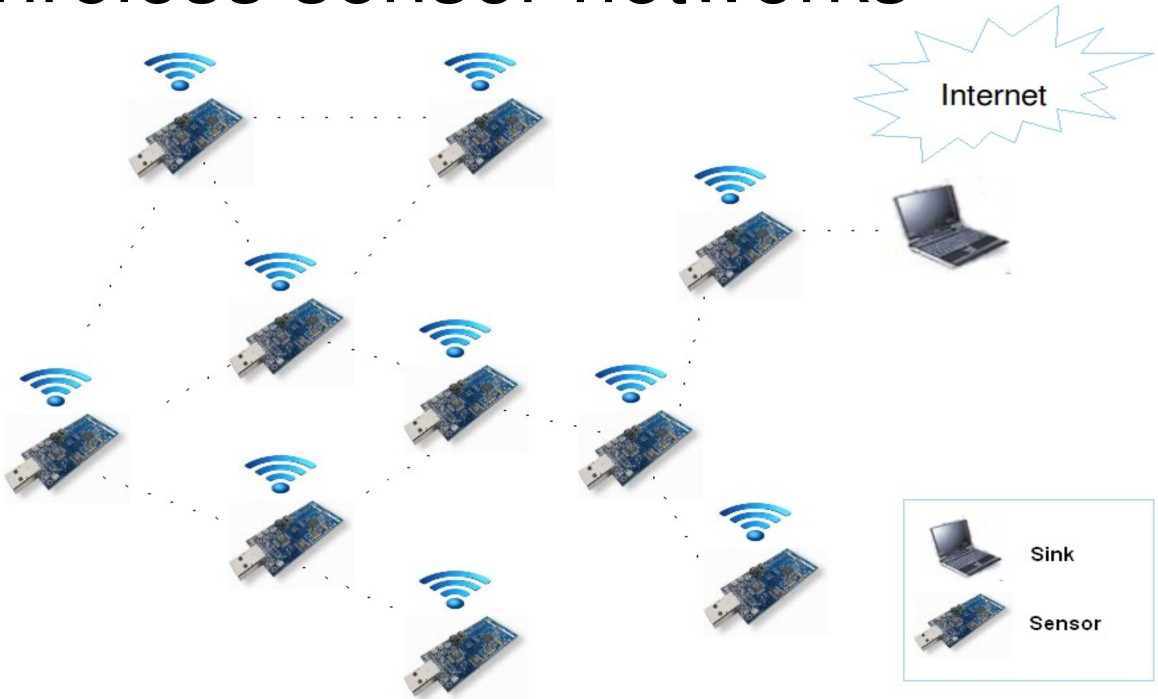
Outline

- Introduction
- Related Work
- Network Lifetime Optimization
- Results
- Conclusion and Future works

Introduction

- Wireless sensor networks



- Need of network lifetime improvement
  - Lifetime of several years

Lifetime improvement methods

- Energy harvesting
- Duty cycling
- **Compression / aggregation**
- Energy-efficient networking protocol
- **Clustering**
- Cross layering
- Power management
- Sinks mobility

Compression

- Compression / aggregation
  - Minimizes the number and the size of the packets transmitted
- Packet = control + payload
- Most of studies target payload (data)

Packets in IPv6 context

- 6LoWPAN networks
- IEEE 802.15.4 MTU 127 octets
  - 25 octets MAC Header
  - 21 octets Security (AES)
  - **40 octets IPv6 Header**
  - 8 octets UDP Header
  - **33 octets for data**

- We focus on the control header, namely addresses fields

Control Part Compression

Header compression

- Link compression
  - RFC1144 [1]
  - IP header compression IPHC [2]
  - RObust header compression ROHC [3]
- Hop by Hop 6LoWPAN
  - LoWPAN HC1 (link-local unicast addresses) [4]
  - LoWPAN HC1g (link-local + global intra 6LoWPAN) [5]
  - LoWPAN IPHC (link-local+ global+multicast) [6]

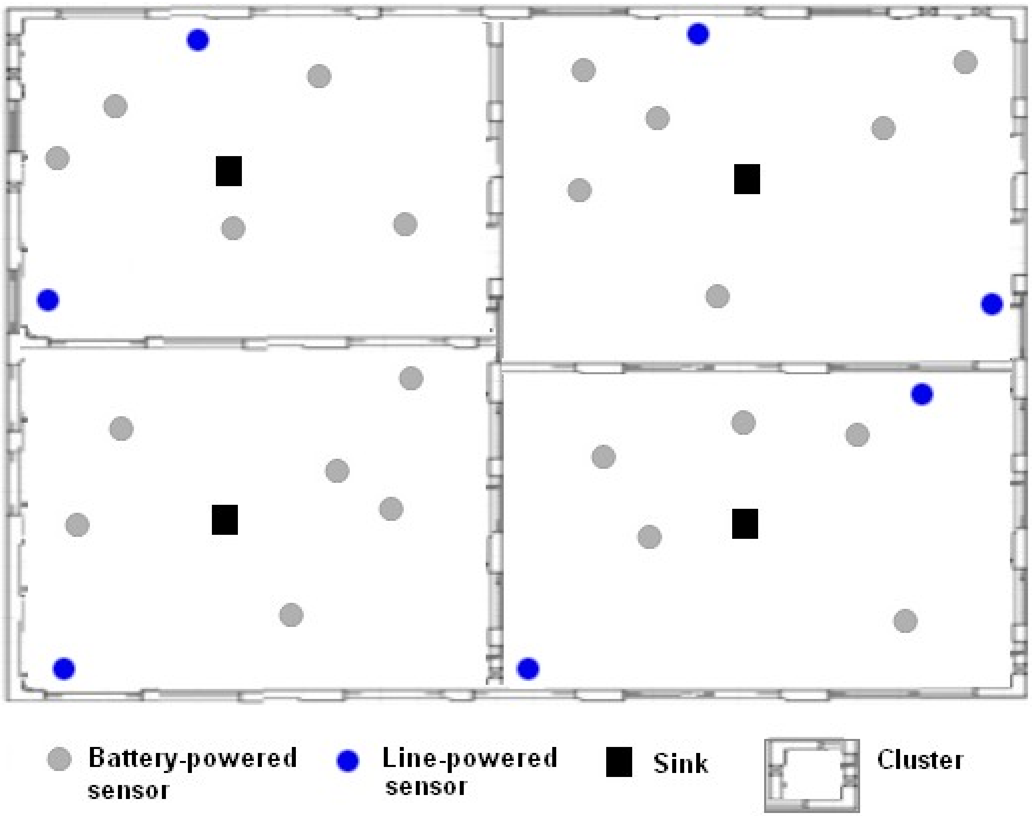
Kronewitter

- Short addresses assigned to nodes with lowest energy [7]

Motivation

- Is there a **distributed method** than can offer further reduction of the addresses size ?
- Can nodes take advantage of the traffic that is not destinated to them ? (**overhearing**)

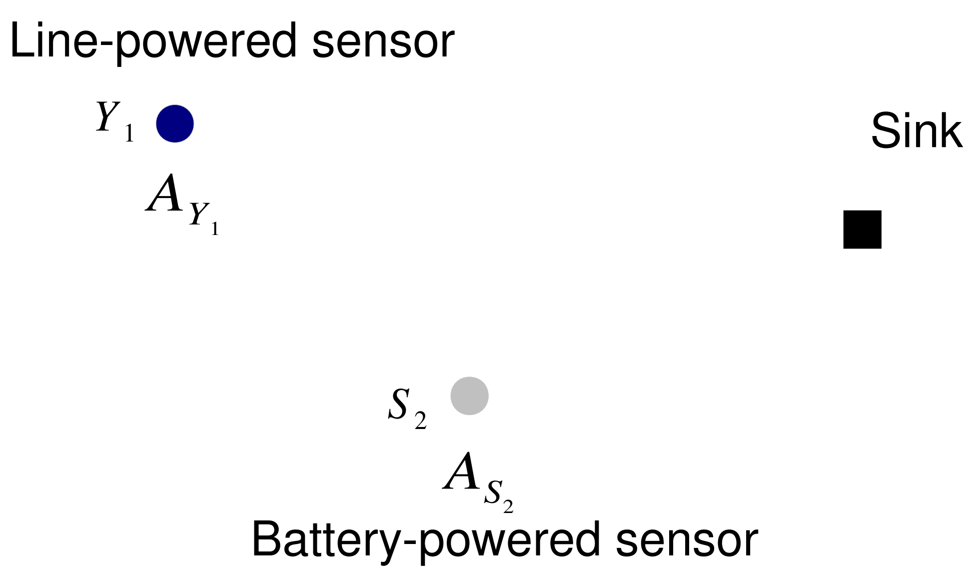
Network Model



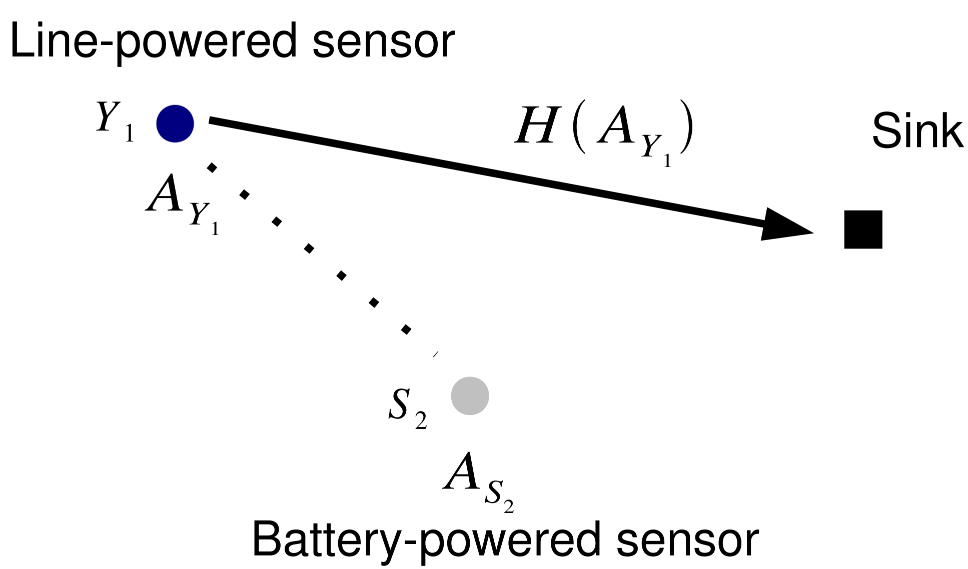
Lifetime Improvement

- Optimize the placement of line-powered nodes to allow battery-powered nodes to :
  - Exploit overhearing and correlated addresses
  - Reduce the size of the transmitted addresses

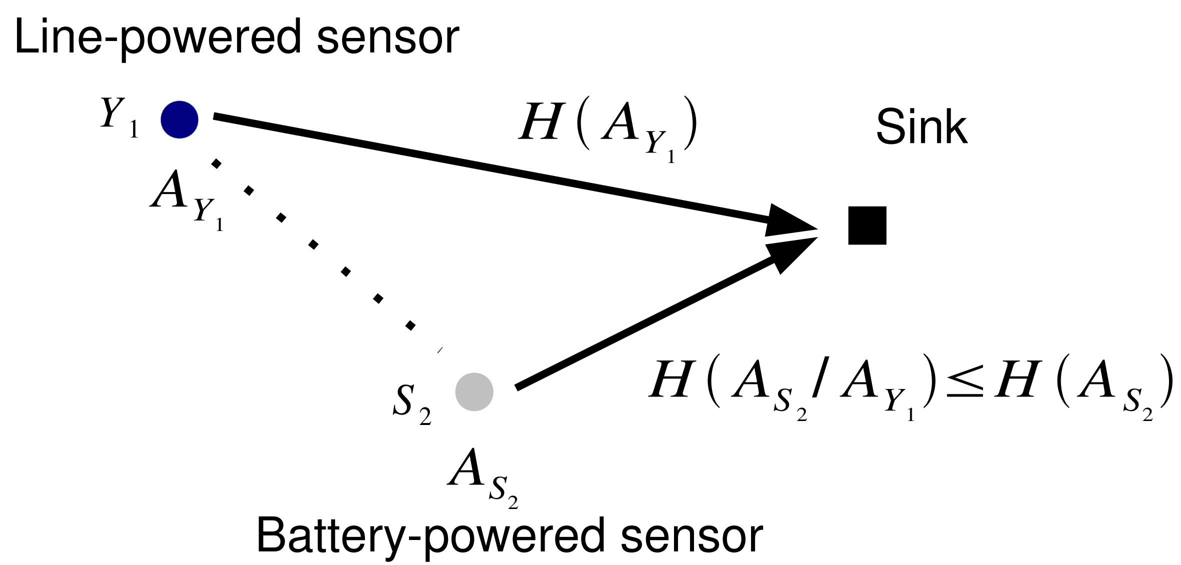
Exploiting overhearing



Exploiting overhearing



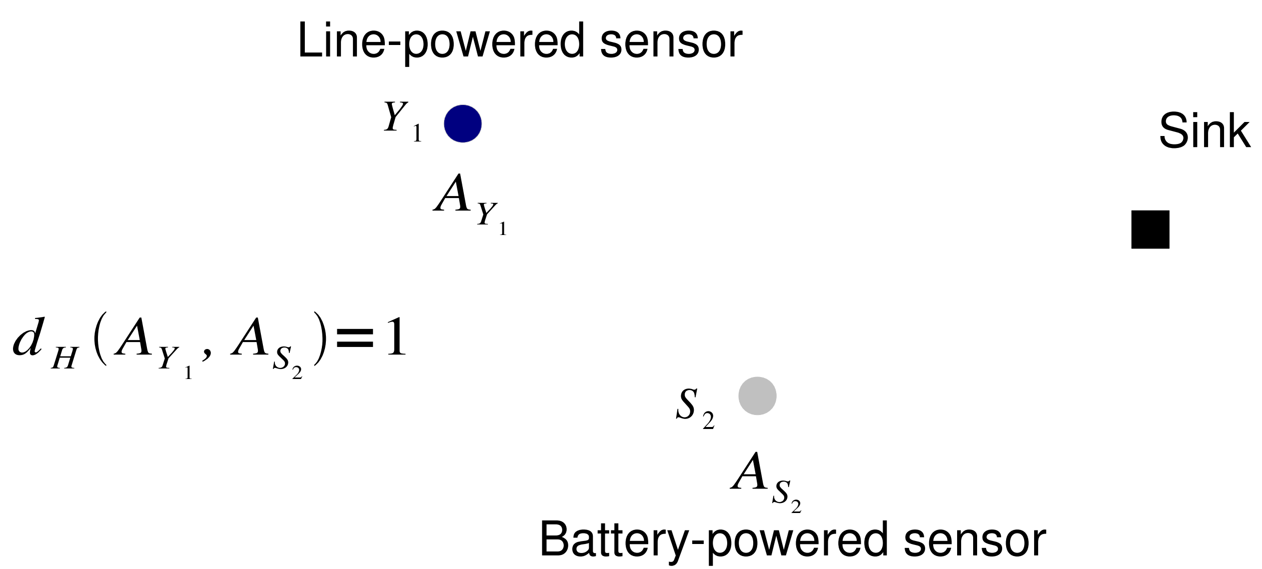
Exploiting overhearing



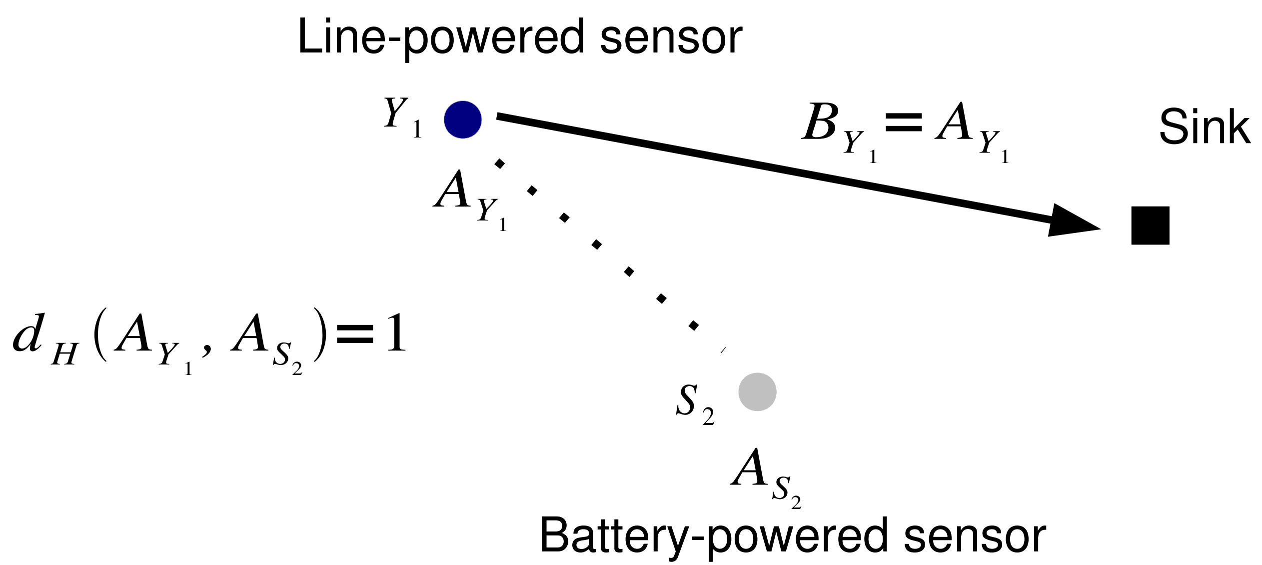
Slepian-Wolf coding [8]

- Lossless distributed source coding
- Represents in the most concise way the information produced by a source
- High compression rate in high correlated sources

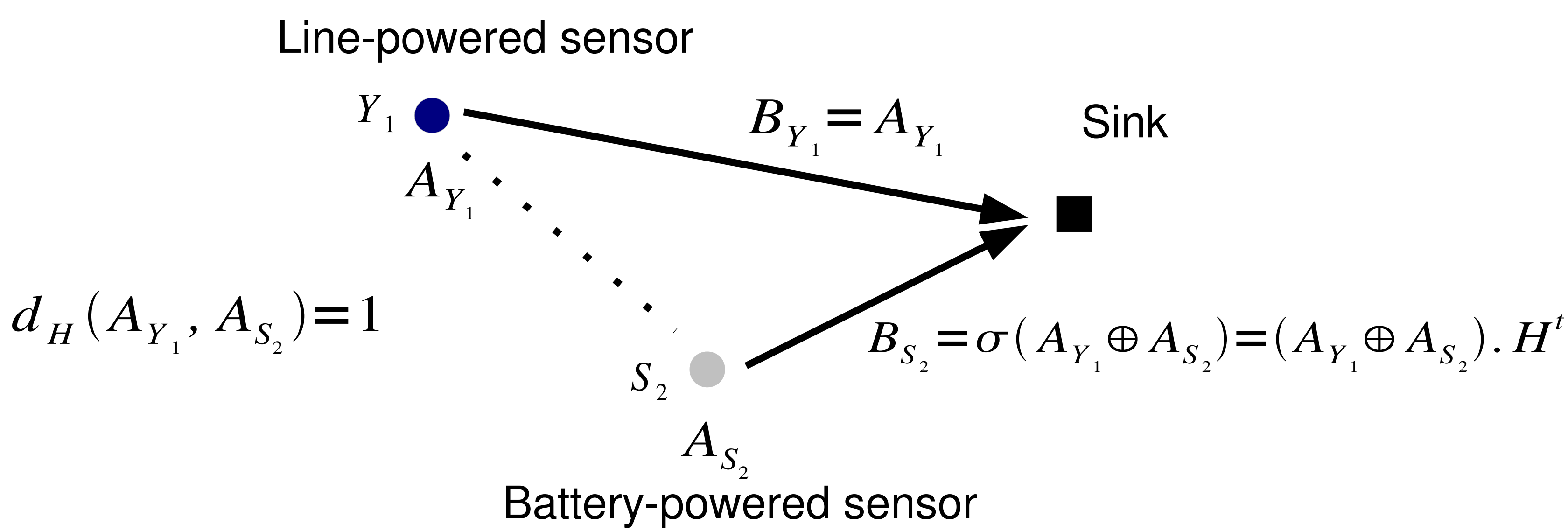
Exploiting overhearing



Exploiting overhearing



Exploiting overhearing

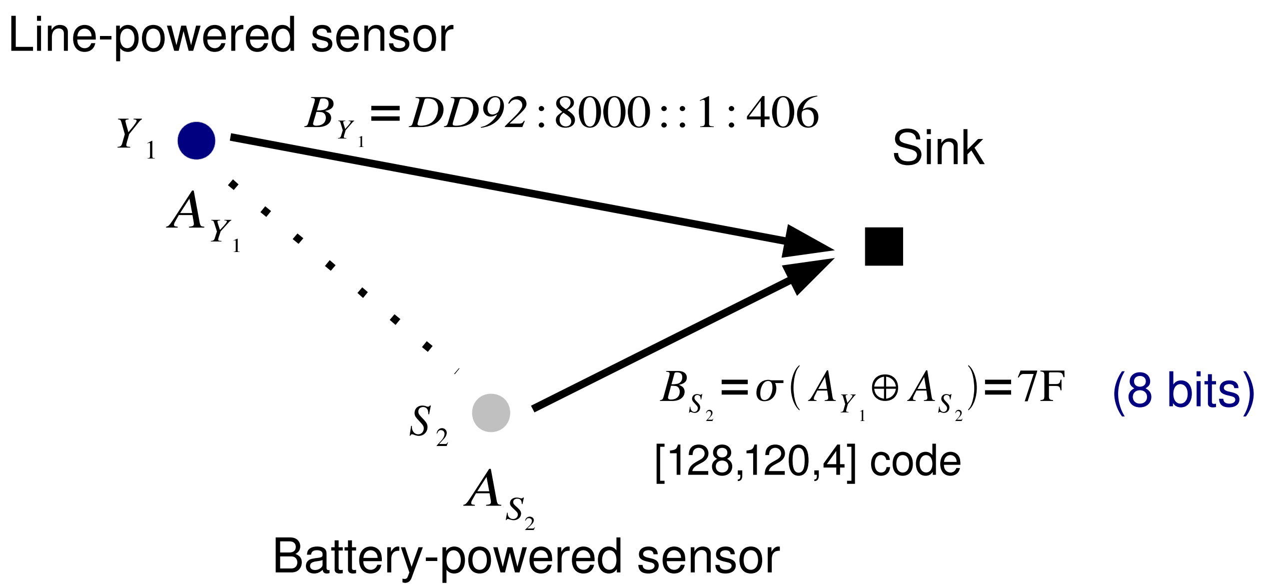


$$[n, k, d]\ \textit{binary linear code}\ C,\ d \geq 2\, d_H(A_{Y_1}, A_{S_1}) + 1,$$

$$n\ \textit{code length},\ k\ \textit{code dimension},\ d\ \textit{minimum weight of the code}$$

$$\textit{compression gain}: n - k$$

Example



$$d_H(A_{S_1}, A_{S_2}) = 1$$

$$A_{S_1} = DD92:8000::1:406 \quad \text{(128 bits)}$$

$$A_{S_2} = DD92:8000::1:407 \quad \text{(128 bits)}$$

Compression gain

- If the correlated addresses differ only in one bit
  - 16-bits address and [16,11,4] code → 5 bits
  - 32-bits address and [32,26,4] code → 6 bits
  - 64-bits address and [64,57,4] code → 7 bits
  - 128-bits address and [128,120,4] code → 8 bits

Optimization problem-1

- The maximum network lifetime and the optimal placement of line-powered nodes

$$T = max_{l \in L}[min_{i \in S} t_i^l]$$

$$t_i^l = (\frac{e0}{p_i^l}), l \in L, i \in S$$

Optimization problem-2

- Power consumption

$$p_i^l = \delta_i \times (g_r \times E_e + g_r \times E_c) + r_{iz}^l \times (E_e + E_{amp} \times d_{iz}^{\beta}), i \in S, j \in N_i^l, l \in L$$

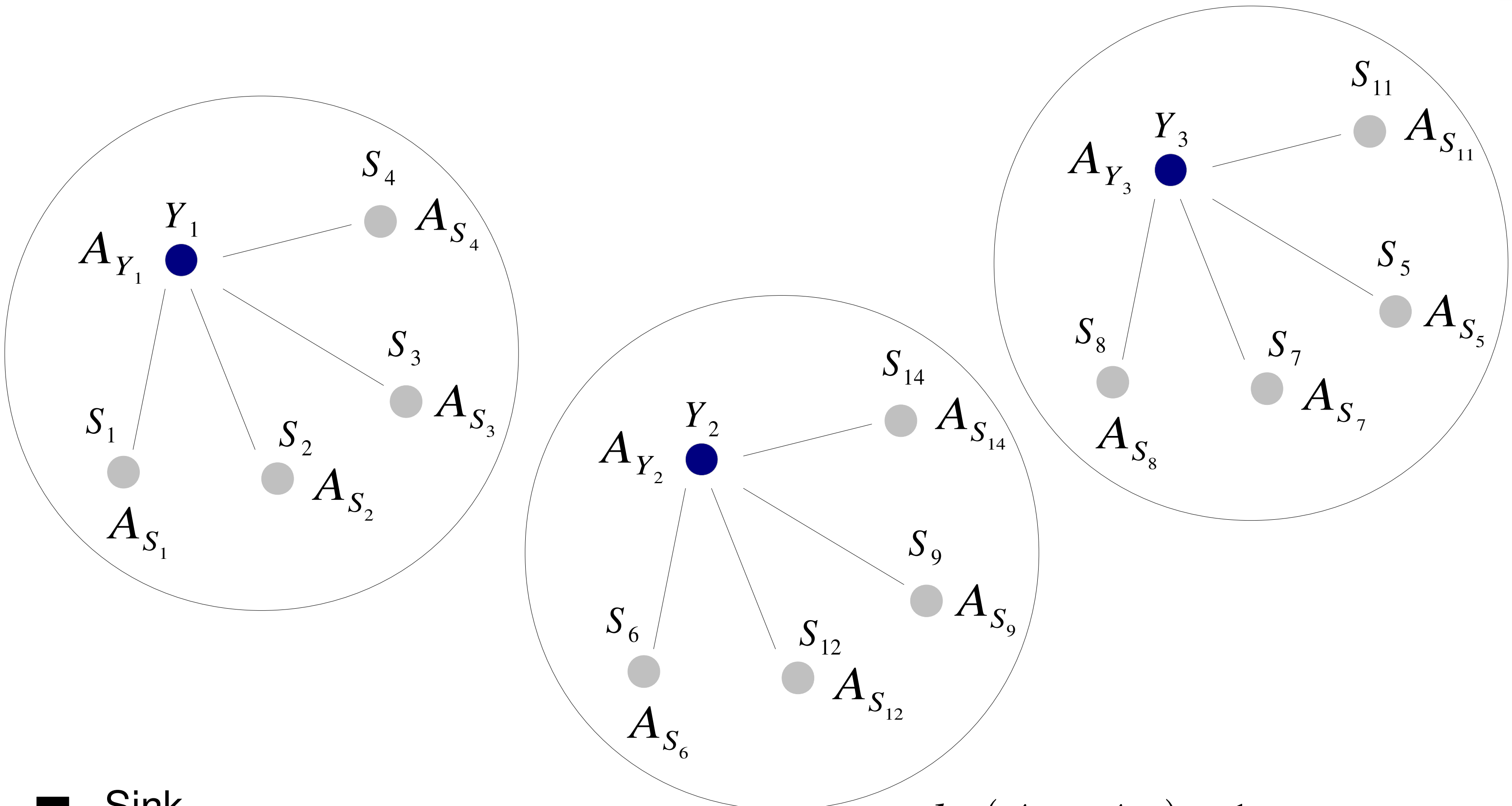
$$r_{iz}^l = \begin{cases} \gamma \times g_r & \text{if } N_i^l \neq \emptyset \text{ and } d_{iz} > d_{min} \\ 0 & \text{otherwise} \end{cases}$$

$$\delta_i = \begin{cases} 1 & \text{if } N_i^l \neq \emptyset \text{ and } d_{iz} > d_{min} \\ 0 & \text{otherwise} \end{cases}$$

Distance bound

$$d_{min} = \left(\frac{E_e \times \gamma + E_c}{E_{amp} \times (1 - \gamma)} \right)^{\frac{1}{\beta}}$$

Addresses allocation



z ■ Sink

Y_i ● Line-powered sensor

S_j ● Battery-powered sensor

$$d_H(A_{Y_i}, A_{S_j}) = 1$$

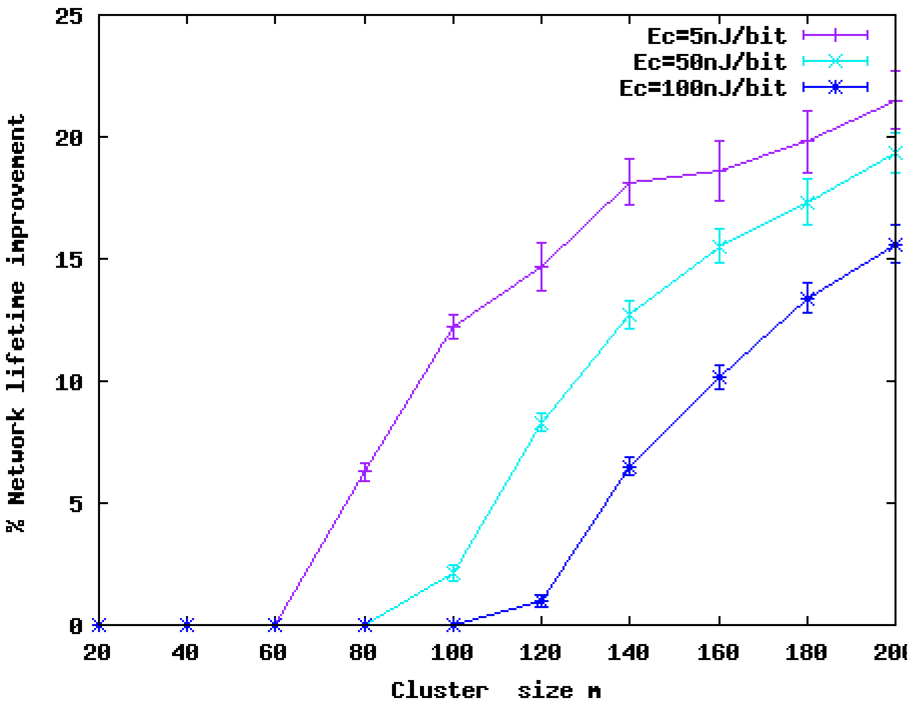
$$d(S_i, z) \geq d_{min}$$

$$d(Y_i, S_j) \leq d(Y_i, z)$$

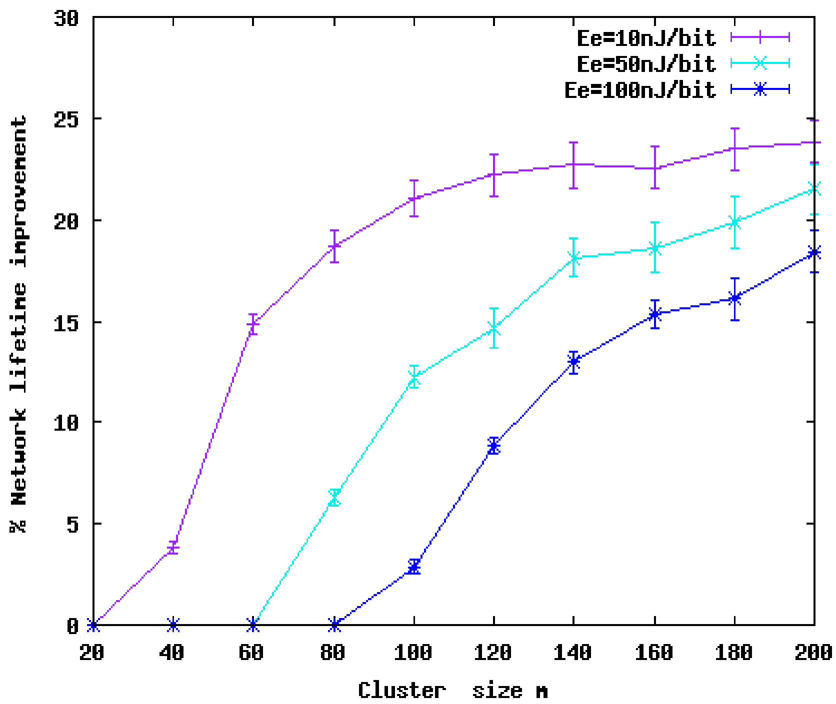
Simulations

Parameters	Values
Battery-powered nodes $|S|$	40
Line-powered sensors $|Y|$	4
Packet size U	508, 762, 1016 bits
Address size X	16, 32, 64, 128 bits
gr	1 packet per hour
Ec	5, 10, 50 nJ/bit
Ee	10, 50, 100 nJ/bit
β	2
Eamp	100 pJ/bit/m2
e0	16200 J (AA battery, 3 Ahr, 1.5V)
Confidence interval	95 %

Network Lifetime gain-1

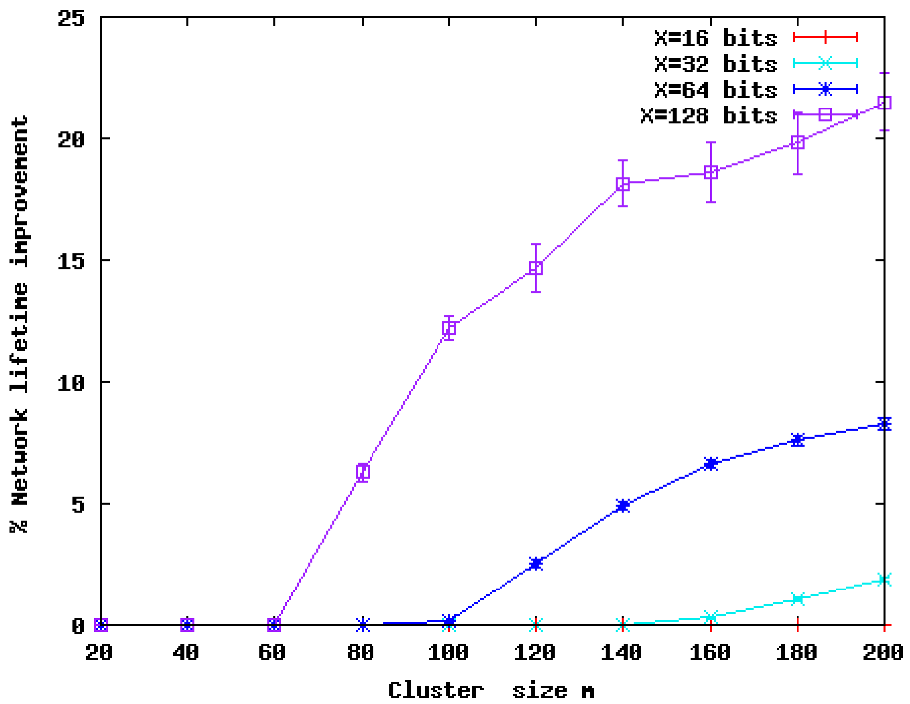


Ee=50nj/bit, U=508 bits, X=128 bits

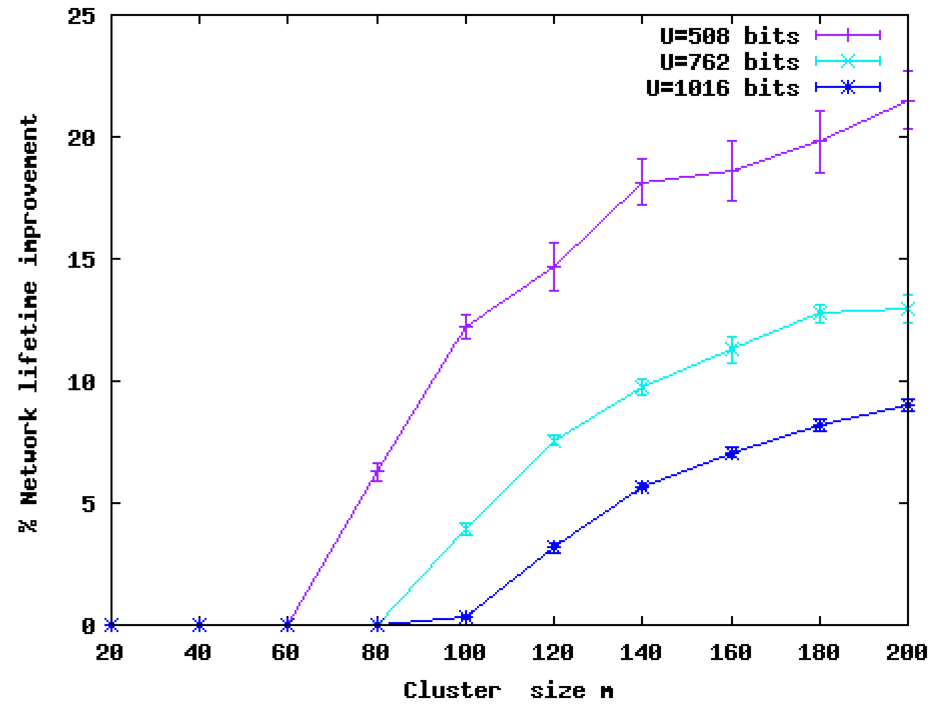


Ec=5nj/bit, U=508 bits, X=128 bits

Network Lifetime gain-2

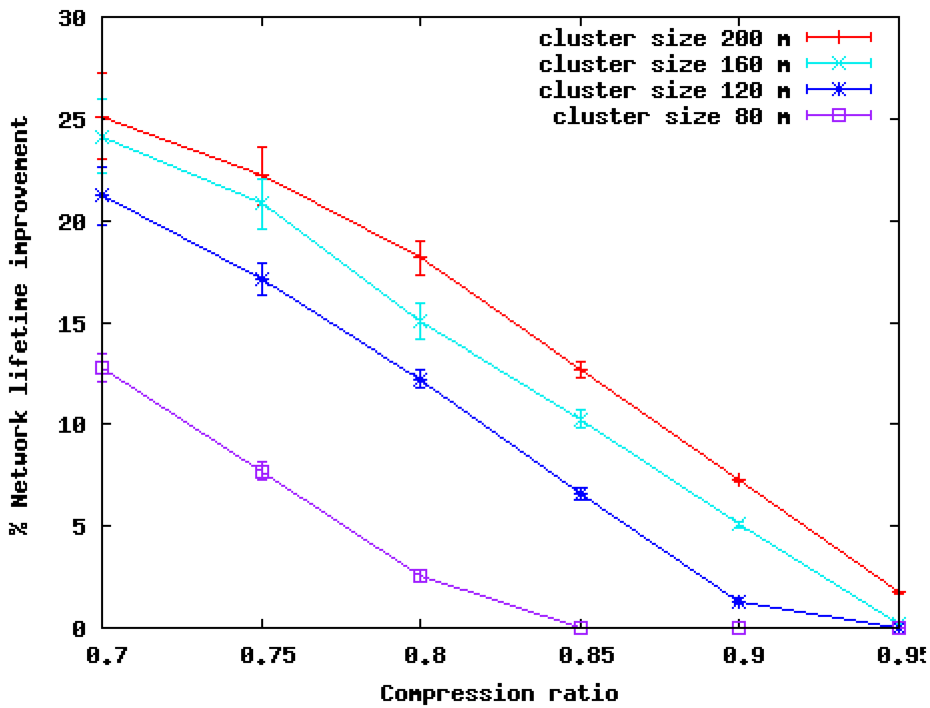


Ee=50nj/bit, Ec=5nj/bit, U=508 bits



Ee=50nj/bit, Ec=5nj/bit, X=128 bits

Network Lifetime gain-3



Ee=50nj/bit, Ec=5nj/bit

400mx400m network
4 clusters
4 Line-powered sensors
40 battery-powered sensors
Packet of 400 bits each hour
128 bits addresses
25 % network lifetime improvement

Conclusion

- Maximizing network lifetime
  - Propose an optimization problem of the placement of Line-powered nodes
  - Exploiting overhearing and addresses correlation
  - Reducing addresses size by using Slepian-Wolf coding
- Results show 25% lifetime improvement in cluster-based WSN

Future Works

- Evaluation in multi-hop large scale networks
- Addresses allocation scheme to guarantee high correlation in multi-hop networks

Thanks for your attention

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