



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

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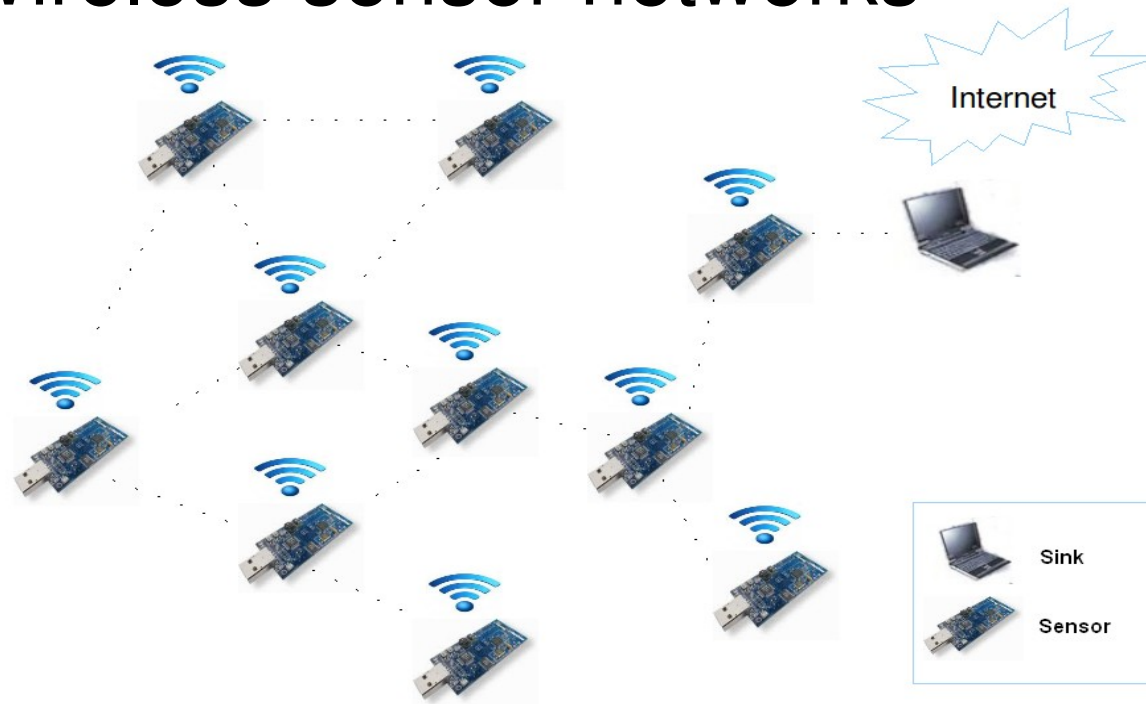
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Outline

- ❑ 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]

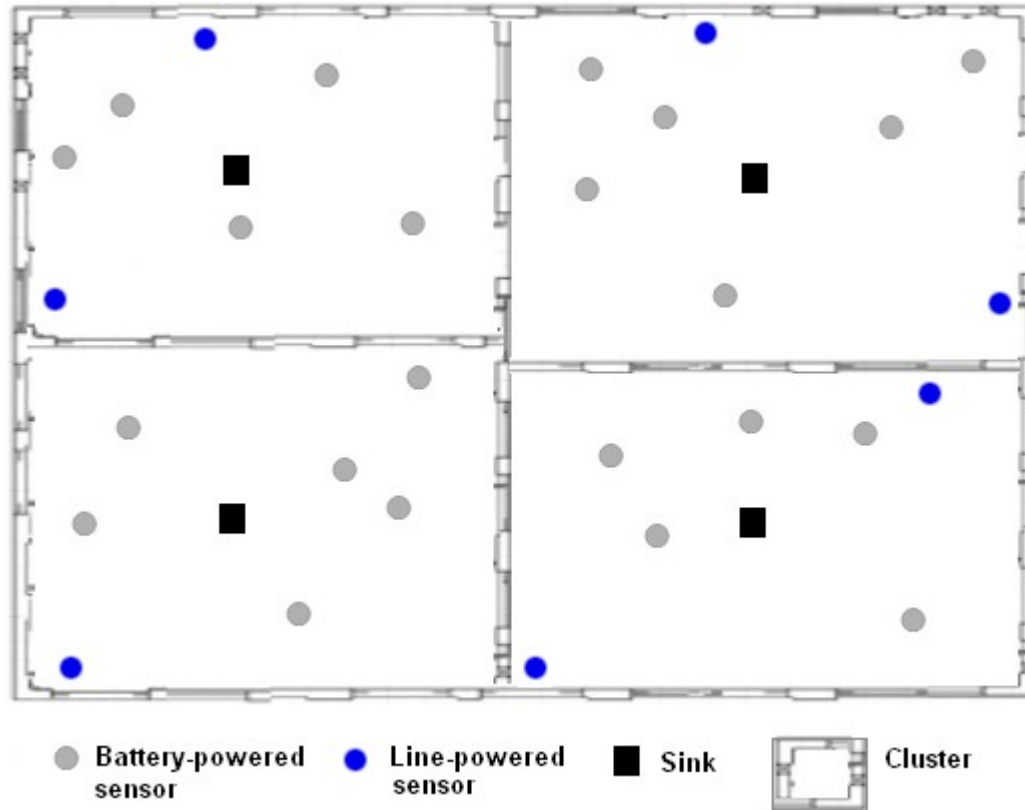
Kronewitter

- ❑ 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 destined 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

Line-powered sensor

Y_1 ●
 A_{Y_1}

Sink



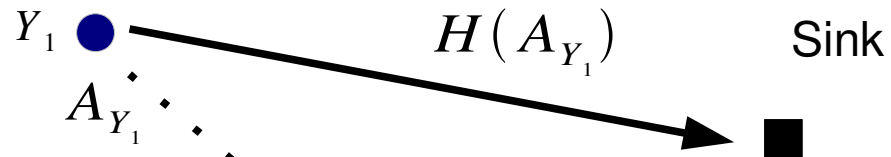
S_2 ●

A_{S_2}

Battery-powered sensor

Exploiting overhearing

Line-powered sensor



Battery-powered sensor

Exploiting overhearing

Line-powered sensor

Y_1

A_{Y_1}

$H(A_{Y_1})$

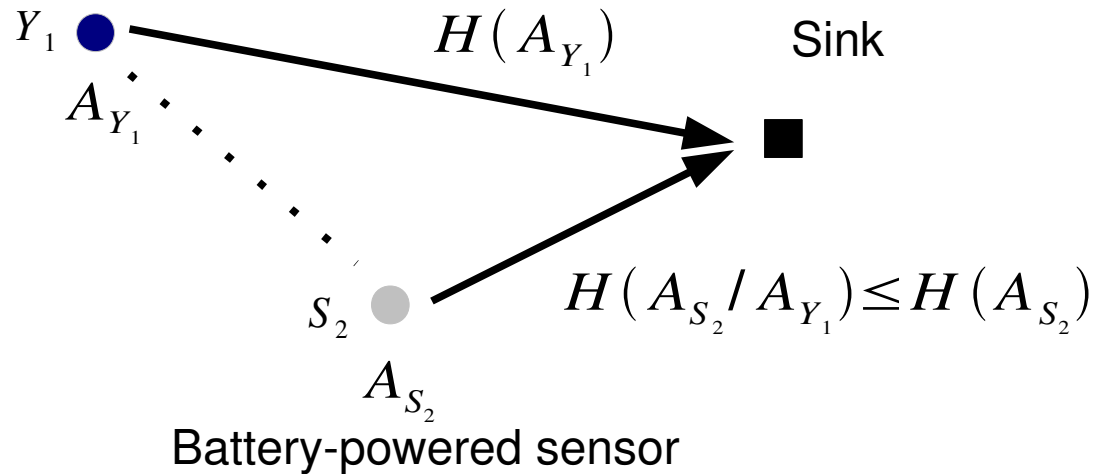
Sink

S_2

A_{S_2}

$H(A_{S_2} / A_{Y_1}) \leq H(A_{S_2})$

Battery-powered sensor



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

Line-powered sensor

Y_1 ●
 A_{Y_1}

Sink

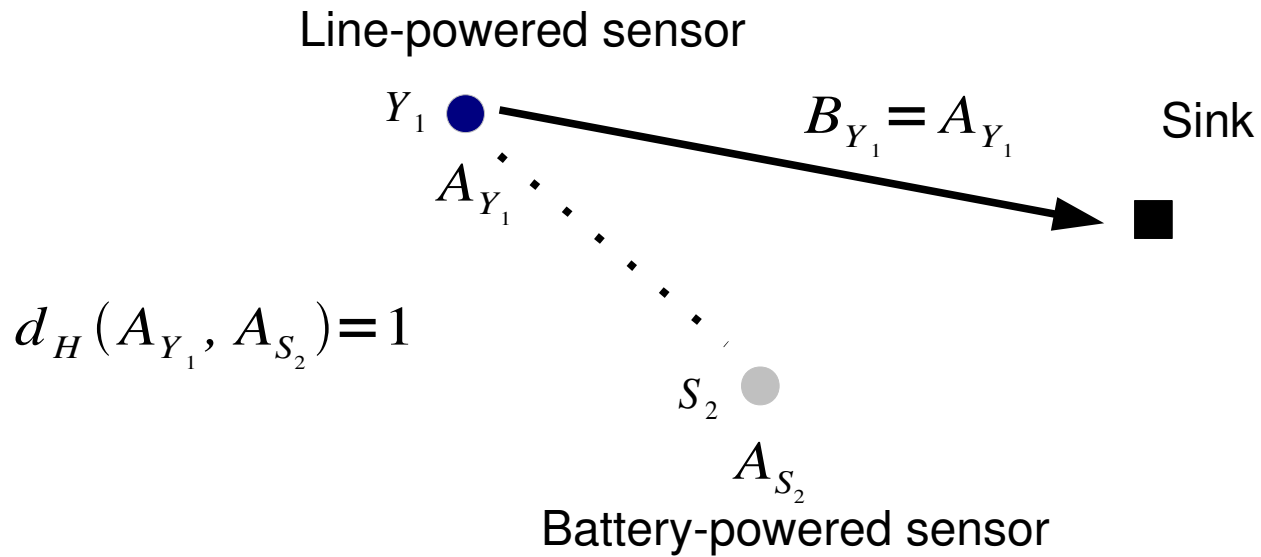


$$d_H(A_{Y_1}, A_{S_2}) = 1$$

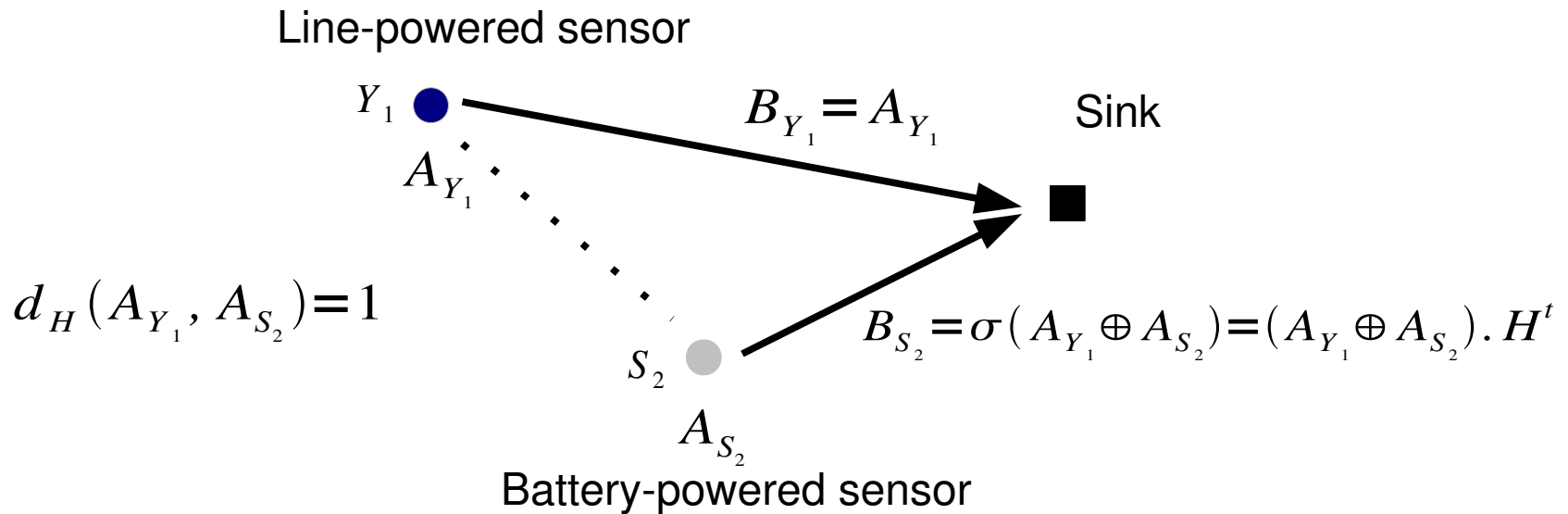
S_2 ●
 A_{S_2}

Battery-powered sensor

Exploiting overhearing



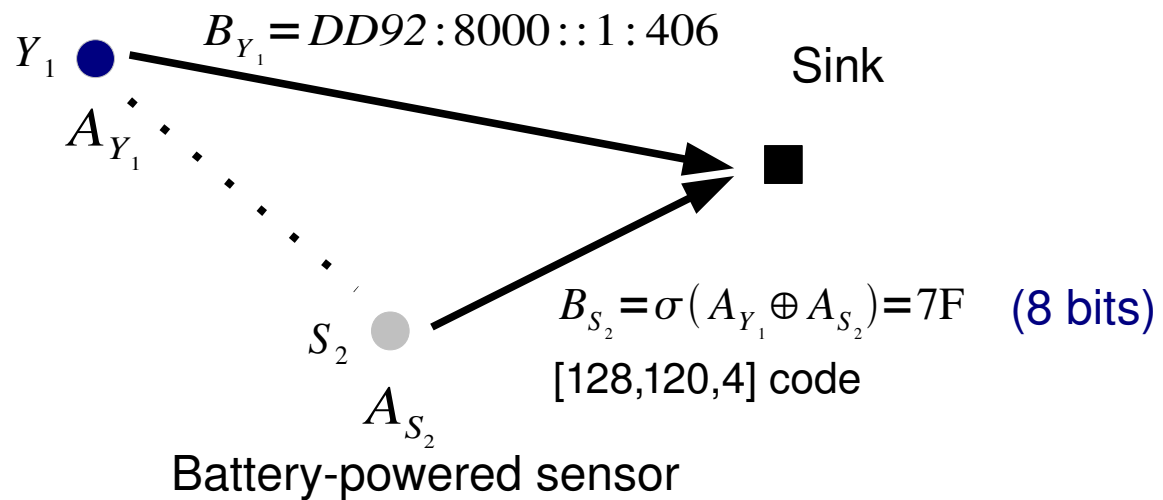
Exploiting overhearing



$[n, k, d]$ binary linear code C , $d \geq 2d_H(A_{Y_1}, A_{S_1}) + 1$,
 n code length, k code dimension, d minimum weight of the code
 compression gain: $n - k$

Example

Line-powered sensor



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

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

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

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

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

$$t_i^l = \left(\frac{e_0}{P_i} \right), l \in L, i \in S$$

Optimization problem-2

□ Power consumption

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

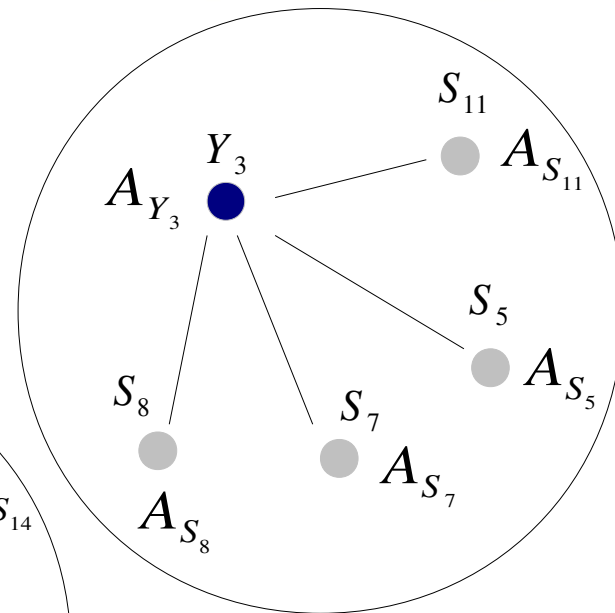
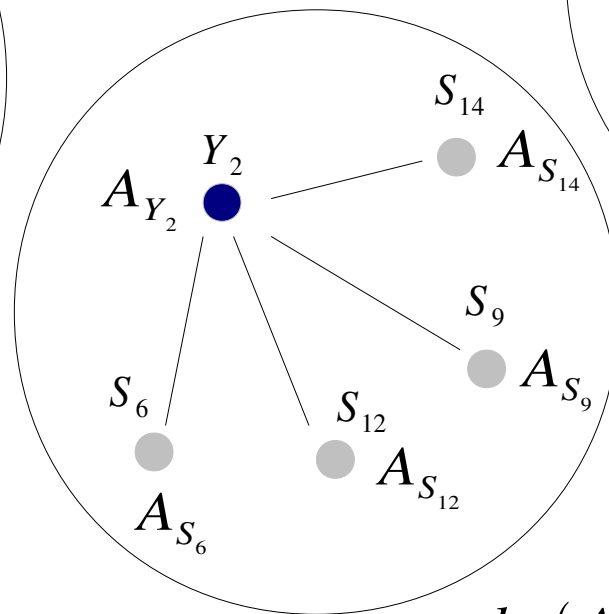
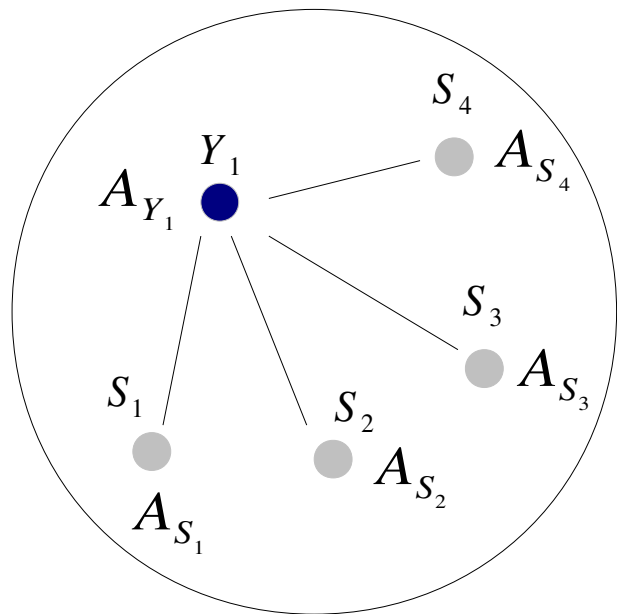
$$r_{iz}^l = \begin{cases} \gamma \times g_r & \text{if } N_i^l \neq \emptyset \text{ and } d_{iz} > d_{min} \\ 0 & \text{otherwise} \end{cases}$$

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

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

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

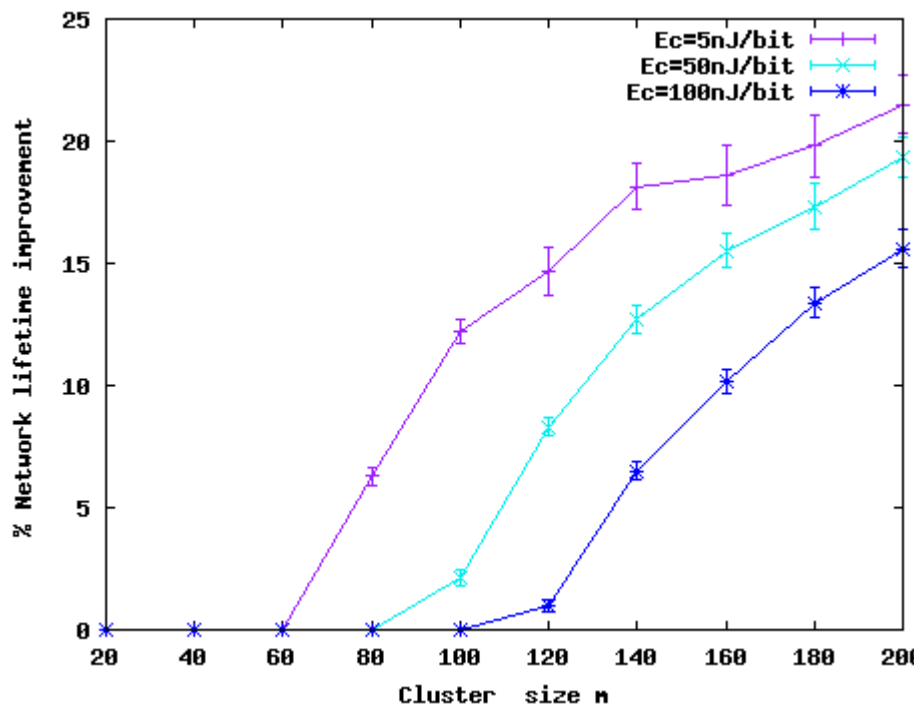
$$d(S_i, z) \geq d_{min}$$

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

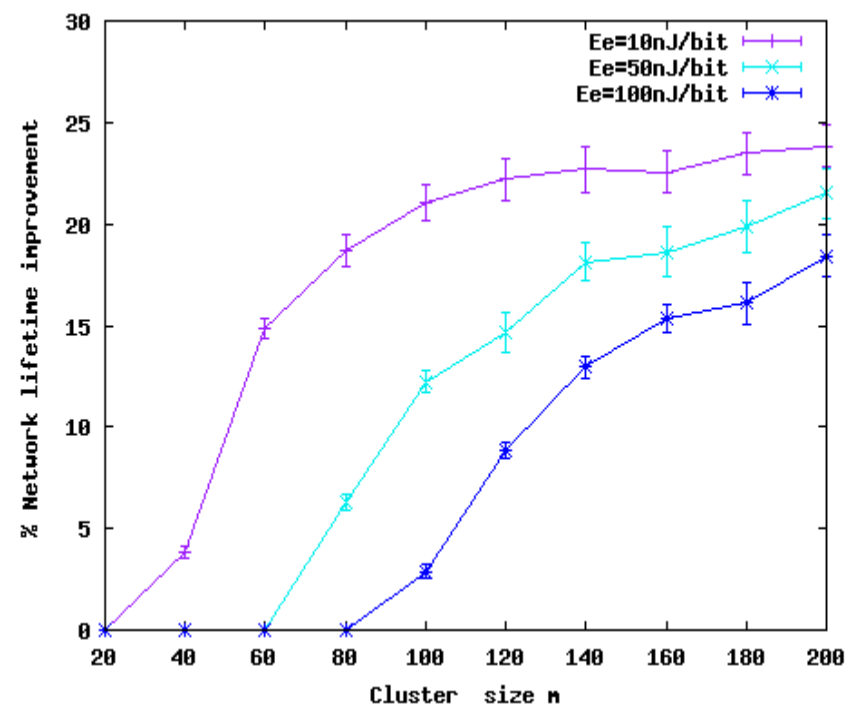
Simulations

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
g_r	1 packet per hour
E_c	5, 10, 50 nJ/bit
E_e	10, 50, 100 nJ/bit
β	2
E_{amp}	100 pJ/bit/m ²
e_0	16200 J (AA battery, 3 Ahr, 1.5V)
Confidence interval	95 %

Network Lifetime gain-1

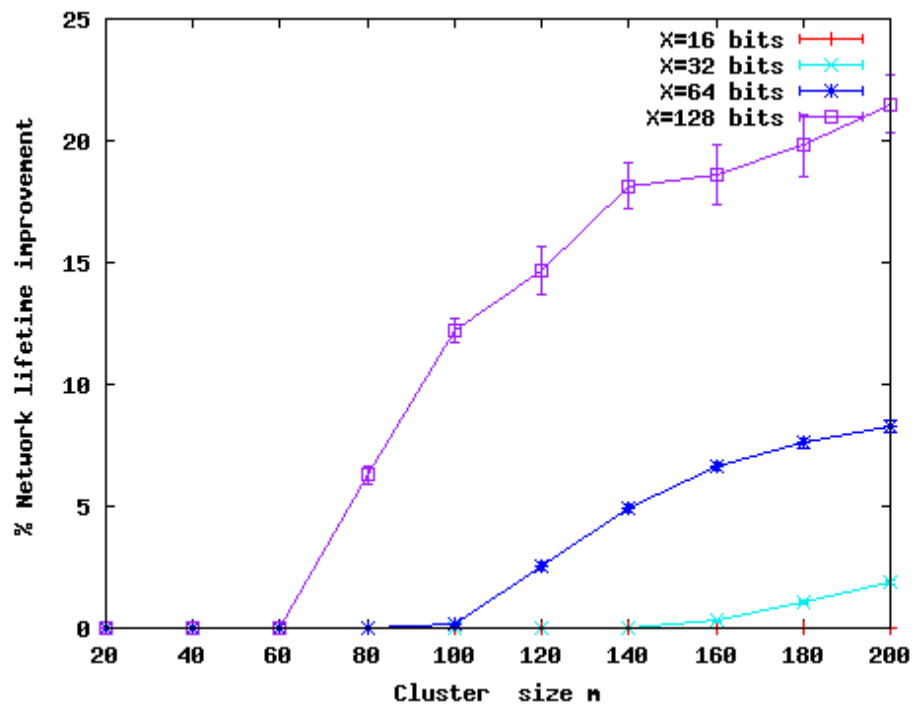


$E_e=50\text{nJ/bit}$, $U=508$ bits, $X=128$ bits

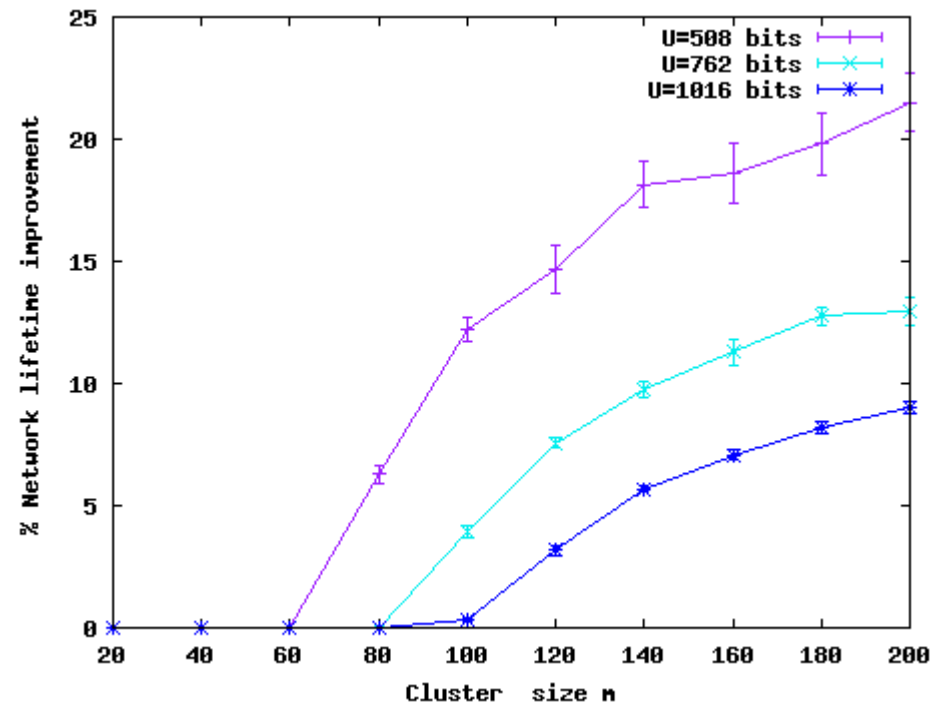


$E_c=5\text{nJ/bit}$, $U=508$ bits, $X=128$ bits

Network Lifetime gain-2

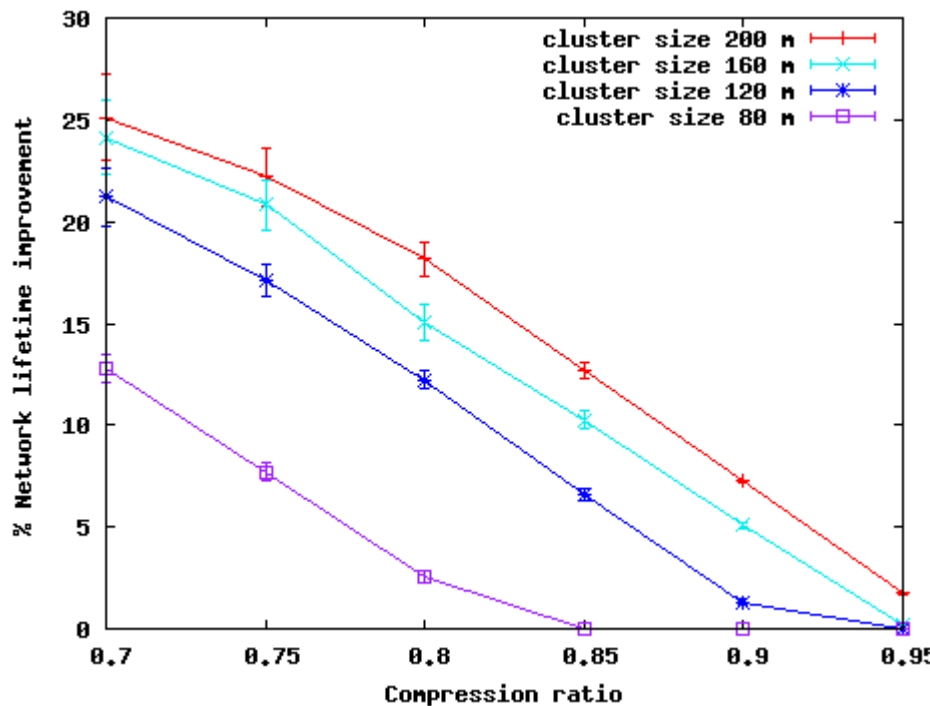


$E_e=50n_j/\text{bit}$, $E_c=5n_j/\text{bit}$, $U=508$ bits



$E_e=50n_j/\text{bit}$, $E_c=5n_j/\text{bit}$, $X=128$ bits

Network Lifetime gain-3



$E_e=50n_j/\text{bit}$, $E_c=5n_j/\text{bit}$

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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