QoS and Security in Energy-harvesting Wireless Sensor Networks

Antonio V. Taddeo, Marcello Mura,
Alberto Ferrante
ALaRI, Faculty of Informatics, University of Lugano

e-mail: ferrante@alari.ch

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Outline

Introduction

Security and QoS Management

Case Study

Wireless Sensor Networks

Composed of a large number of nodes:

- small;
- inexpensive;
- capabilities:
  - sensing,
  - processing,
  - communication.

Energy In WSN Nodes

- Local power source:
  - limited;
  - non-replaceable;
- not enough
  for environment monitoring applications:
  - energy harvesting.

Energy Harvesting For WSN Nodes

Solar panels:

- the most used technology at the moment;
- they introduce a further level of uncertainty in the amount of energy available.

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Security for WSN

- Required by many applications;
- resource consuming;
- increases consumed energy;
- static.

Problem Statement

- There may be periods of time in which the energy available is very limited:
  - maximize node lifetime;
  - maximize the number of packets sent with the energy available.

Security and QoS Management

- Change security settings dynamically to:
  - maximize security;
  - maximize the number of packets sent.
- Use QoS to:
  - increase the probability of delivering critical packets.

Optimization Mechanism (1/2)

- Monitor-Controller-Adapter loop:
  - *Monitor*: monitors available energy, packets to be sent;
  - *Controller*: decides which packets to send and the security suites to be used;
  - *Adapter*: actuates the decisions taken by the Controller.

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Optimization Mechanism (2/2)

The *Monitor* requires:

- an energy model;
- packet characteristics.

Energy Model

- Necessary to estimate the energy that will be used to send the packets in the queue;
- $E_{packet} = E_{tx} + E_{errors}$
- available energy updated with real data after the packets have been sent;
- in each transmission time slot $\sum E_{packet}$ must be below E_{frame}.

Packet Characteristics

- Payload size;
- priority:
  - 1-4;
- security requirements:
  - choice of security suites that fit the security needs of the considered packets.

Optimization Strategies

- Composition of actions to be performed to meet the energy constraint;
- two goals:
  - maximize the number of high-priority packets delivered;
  - ensure that the security requirements of packets are met.

Possible Actions

- Change the security suite used for packets;
- limit number of packets to be sent:
  - drop or delay packet transmission according to priorities.

Security Considerations (1/2)

- The use of multiple cryptographic algorithms may lower global security:
  - limited problem
    when packets are independent;
- the self-adaptation mechanism
  is designed to provide the highest security level
  compatible with packet settings
  and system conditions;

Security Considerations (2/2)

- the minimum level of security specified in the security requirements is always granted.
- our solution provides the ability to guarantee at least *some* security even when energy is scarce.

Case Study (1/2)

- 7-node WSN;
- 802.15.4, beaconed mode;
- star topology;
- each node is equipped with:
  - a solar cell;
  - a super-capacitor of 310Farad;
- node lifetime of 3 days without solar recharge;

Case Study (2/2)

- each node is equipped with a digital camera:
  - it acquires an image every 30s;
  - it sends the image to the base station;
  - for every image:
    - 160 packets of 90 bytes;
    - pictures divided into 5 segments;
    - priorities uniformly assigned to packets of the same segment.

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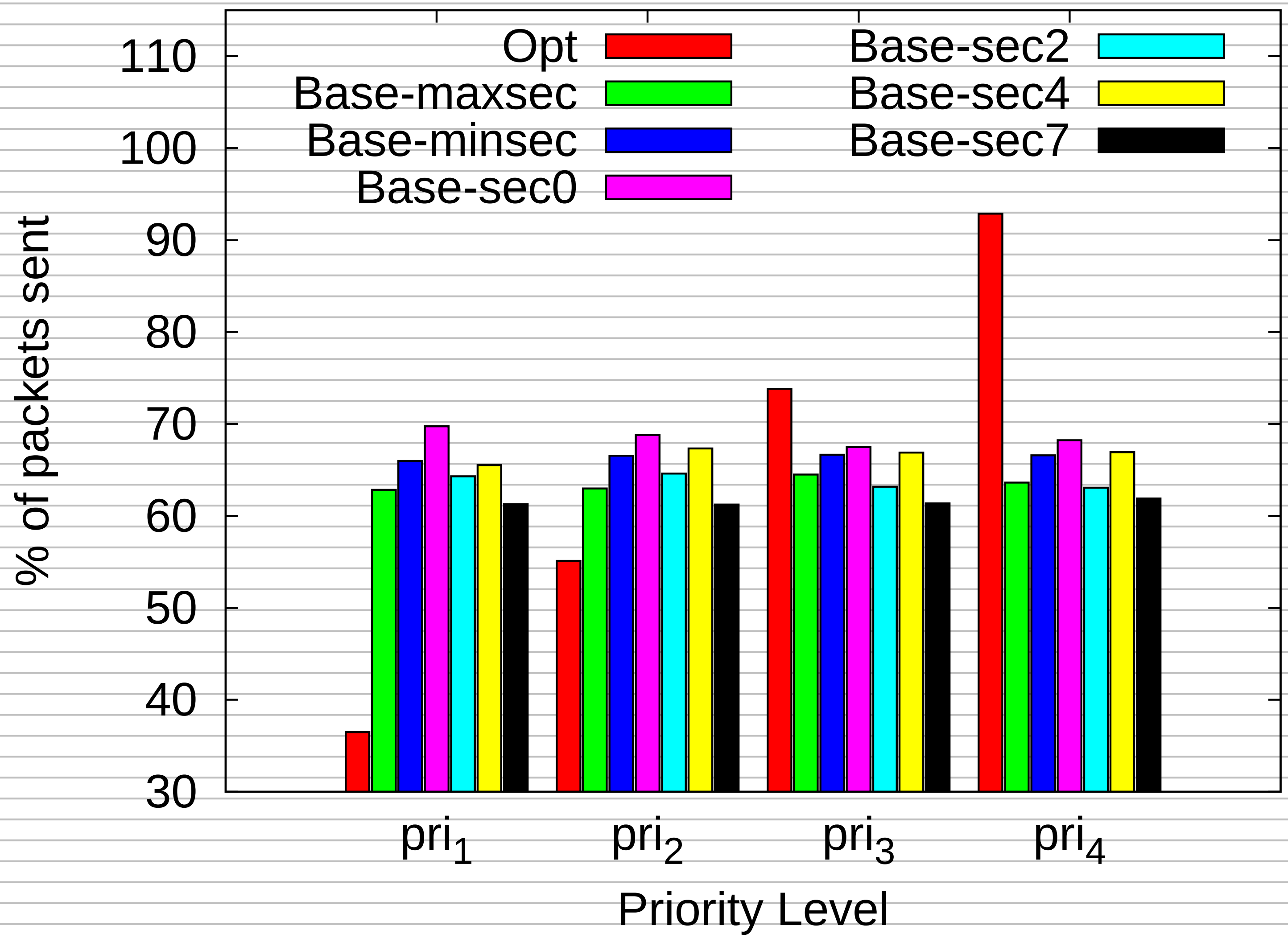
Simulations

- Case study simulated through a SystemC network simulator:
  - based on an implementation-independent model;
  - simulates node operations;
  - simulates network operations;
  - annotates power consumption;
  - manages channel contention and retransmission.

Results (1/4)

- Each node lasts 4 days instead of 3 when a limit on consumed energy is set;
- security adaptation improves security;
- QoS improves the management of important packets.

Results (2/4)



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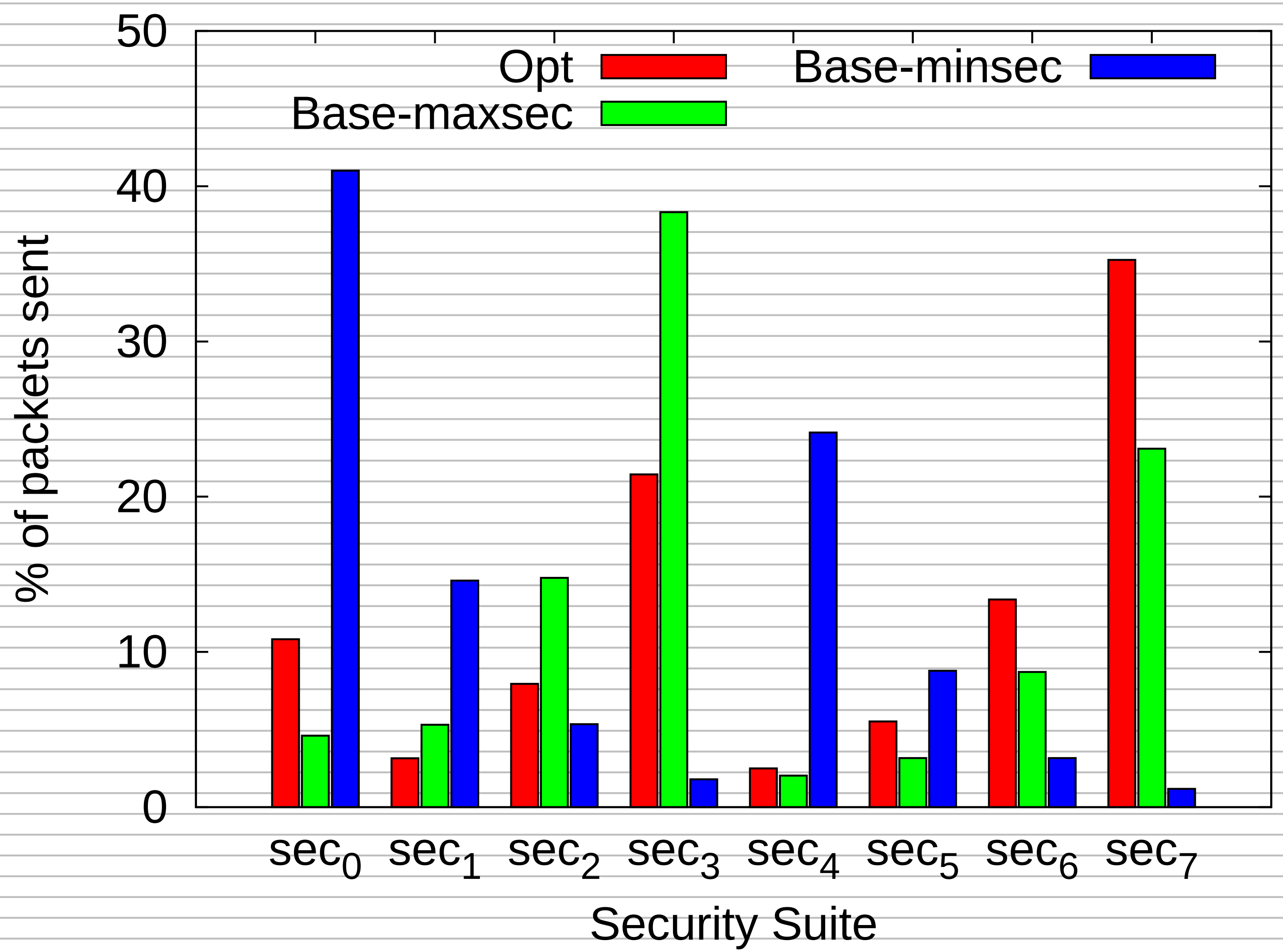
Results (3/4)



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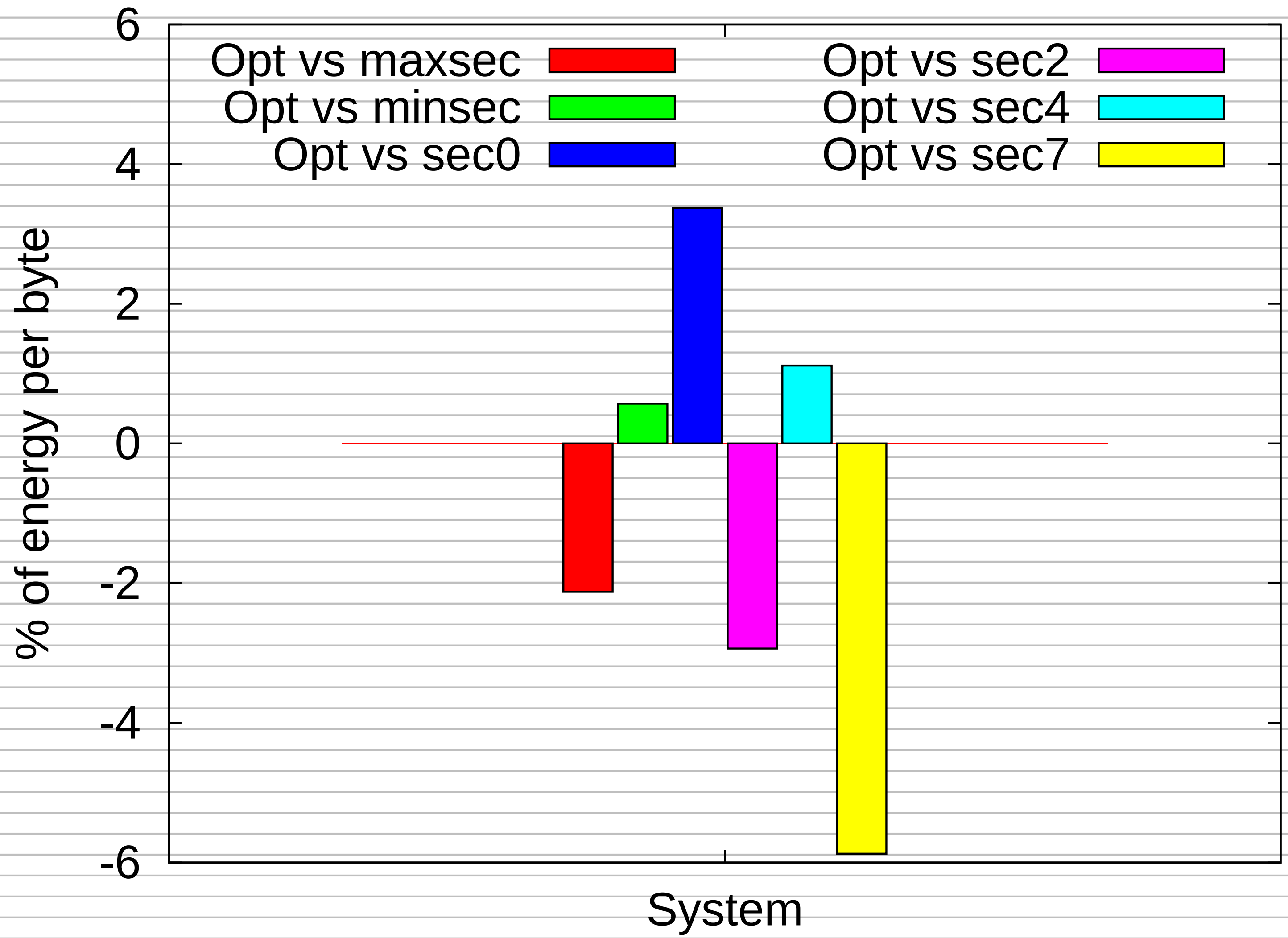
Results (4/4)


Opt vs maxsec
Opt vs minsec
Opt vs sec0
Opt vs sec2
Opt vs sec4
Opt vs sec7
% of energy per byte
6
4
2
0
-2
-4
-6
System

Conclusions and Future Work

Conclusions:

- our mechanism changes security dynamically;
- it implements a QoS system to privilege important packets;
- our mechanism allows the nodes to manage packet transmission in an efficient way.

Future work:

- refinement and extension of the methodology;
- implementation and testing in real nodes.