Energy-Efficient Visual Monitoring Based on the Sensing Relevancies of Source Nodes for Wireless Image Sensor Networks

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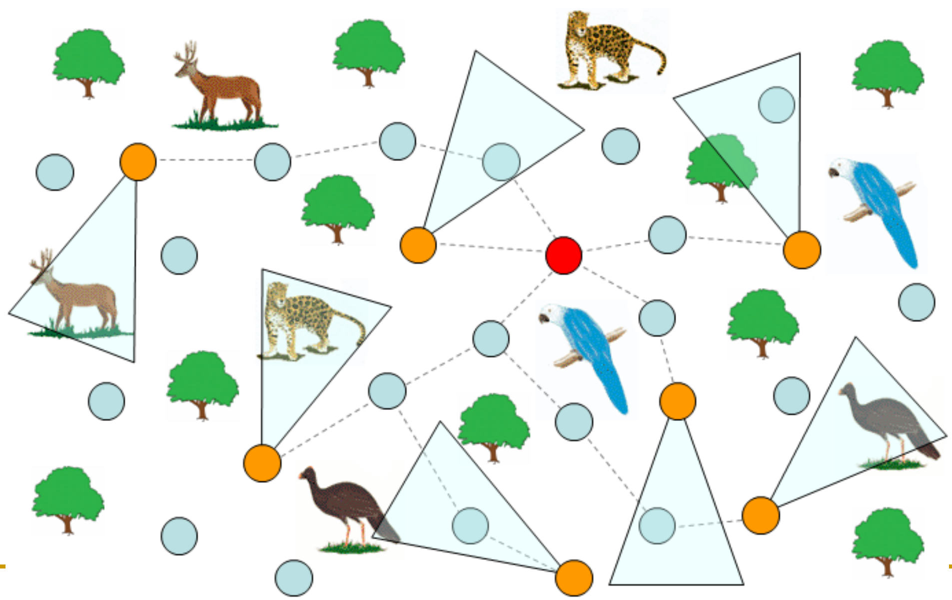
Outline

- Wireless Image Sensor Networks
- Sensing relevancies of source nodes
- Energy-efficient visual monitoring
  - Energy consumption
- Experimental results
- Conclusions
- Future works

Wireless Image Sensor Networks

- Resource-constrained self-organizing networks composed of camera-enabled source nodes
  - Low cost cameras and more powerful processors.
  - Scalar information can complement the retrieved visual data
- WISNs allow a wide range of new applications and challenging problems:



Wireless Image Sensor Networks

- Energy is a crucial issue
  - Image transmissions demand very more resources of the processing and network than scalar data.

Temperature

Luminosity

Pressure

Many bytes

Few bytes

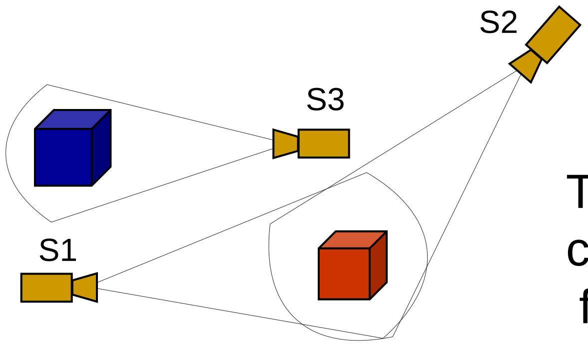
  - For example, a small uncompressed 128x128 pixels 8-bit grayscale image: 16,384 bytes + Header of the packet.

Wireless Image Sensor Networks

- Reduction of the amount of information to cross the network is important to:
  - save energy.
  - avoid overload.
- How can we reduce the traffic on the network?

Wireless Image Sensor Networks

- Monitoring quality depends on how well an area of interest is viewed by the source nodes
  - Network deployment
  - Application requirements (!!!)
- Source nodes may have different sensing relevancies



The application may be most concerned with the blue target, for example.

Sensing Relevancies of the Source Nodes

- Sensing relevance = source QoS
  - Relevance is a function of the expected targets to be monitored, instead of the deployed network characteristics
- Sensing relevance assignment
  - Automatic: location of the sources after deployment and the retrieved images may be used to compute the relevancies
  - Human-based: a operator can view the retrieved images and decide the most relevant sources for the application
  - Deterministic: assignment before deployment, and the WISN is deterministically deployed

Sensing Relevancies of the Nodes

SR_s	**Description**
0	**Irrelevant**. No visual information should be transmitted to the sink
1	**Low relevance**. Applications may need only low quality versions of the retrieved images or less visual information for a period of time
2	**Medium relevance**. Source nodes transmit complementary information of the target, but application can tolerate some monitoring quality loss
3	**High relevance**. It is assigned to source nodes that retrieve important visual information of the monitored field
4	**Maximum relevance**. Some networks may have a few number of source nodes with the most privileged view of the monitored field

Sensing Relevancies of the Nodes

- How can we use the Sensing Relevance Index?
- In this paper, source nodes may transmit images in different frequencies
  - Less relevant sources may transmit fewer images in a period of time
  - The overall quality is preserved
  - Energy is saved over the network

Energy-efficient Visual Monitoring

- SR_s can be mapped into a transmission frequency (f_s) of image snapshots

SR_s	f_s
0	0
1	0.1
2	0.2
3	0.5
4	1.0

Energy Consumption Model

- In a period of T seconds, a set of $T.f_s$ images have to be transmitted from the source node s.
  - For packets sizing k bits, a packet overhead of z bits and original images sizing B bits, we have (based on [12]):

$$Et_{ph} = T.f_s.\left\lceil \frac{B}{k-z} \right\rceil .k.\left(e_e + e_t.d^2\right)$$

$$Er_{ph} = T.f_s.\left\lceil \frac{B}{k-z} \right\rceil .k.e_e$$

$$E_p = \sum_{h=1}^{H_p}\left(Et_{ph} + Er_{ph}\right) + Et_{p0} + Er_{p(H_p+1)}$$

Energy Consumption

- Energy is proportional to f_s
  - More relevant source nodes transmit more packets and consume more energy

$$Et_{ph} = T.f_s.\left\lceil \frac{B}{k-z} \right\rceil .k.\left(e_e + e_t.d^2\right)$$

$$Er_{ph} = T.f_s.\left\lceil \frac{B}{k-z} \right\rceil .k.e_e$$

$$E_p = \sum_{h=1}^{H_p} \left(Et_{ph} + Er_{ph}\right) + Et_{p0} + Er_{p(H_p+1)}$$

Energy-efficient Visual Monitoring

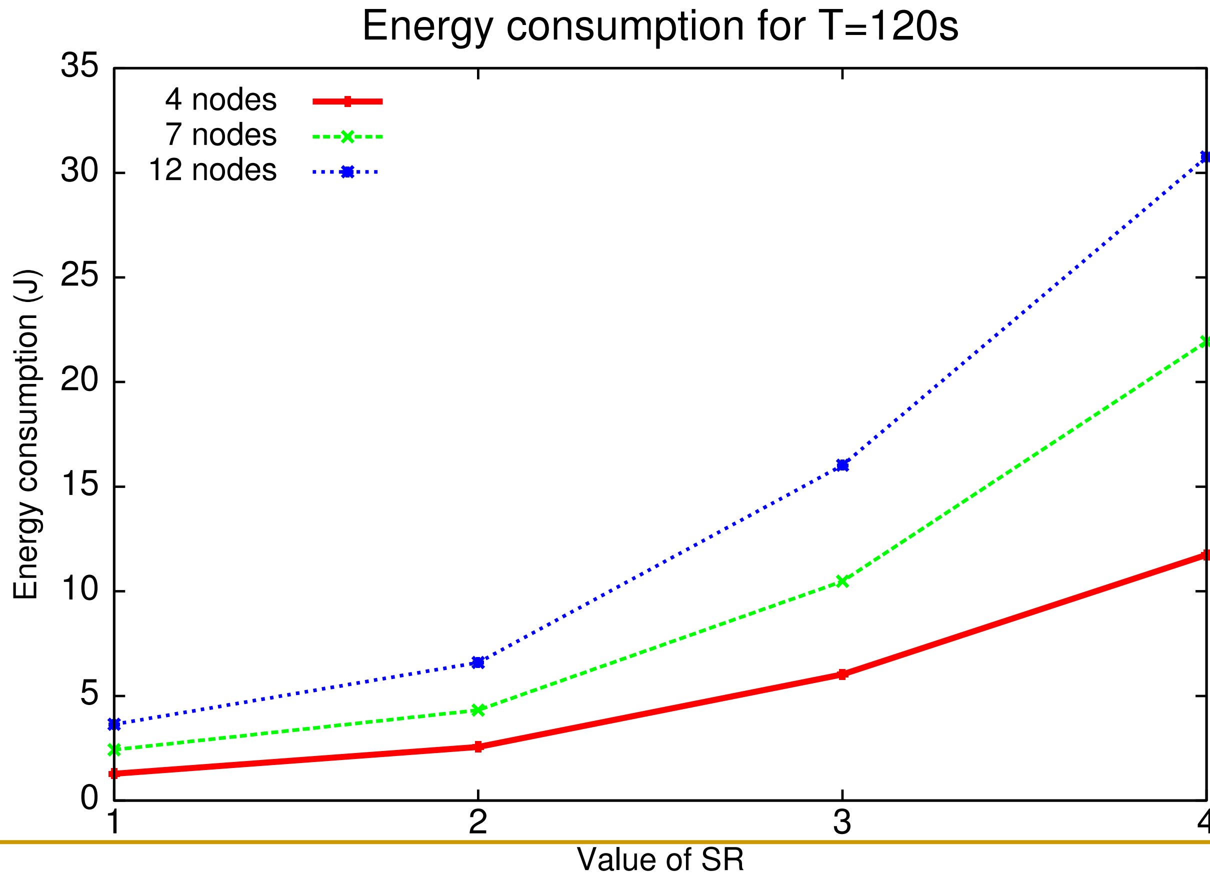
- Energy saving is achieved when less sensing-relevant source nodes are identified
  - They can transmit less images and reduce the overall energy consumption
  - High relevant sources are unaffected with our strategy
- When compared with traditional transmission approaches, SR-based monitoring is more energy efficient
  - Low impact to the monitoring quality

Experimental Results

- The presented energy consumption model is indeed very simple
  - It does not consider contention mechanisms and state transitions
  - However, it is a good indication of the relation between energy consumption and f_s
- The proposed solution was validated in the Castalia/OMNet++ network simulator
  - T-MAC as the MAC layer protocol (IEEE 802.15.4)
  - Payload size → ($k - z$) = 720 bits (90 bytes)
  - Header size → 30 bytes
  - B = 32,768 bits (64 x 64 pixels, 8-bit, grayscale) → 46 packets with 120 bytes each.
  - T = 120s → 120 image snapshots for the highest relevant sources and 12 image snapshots for the lowest relevant sources.

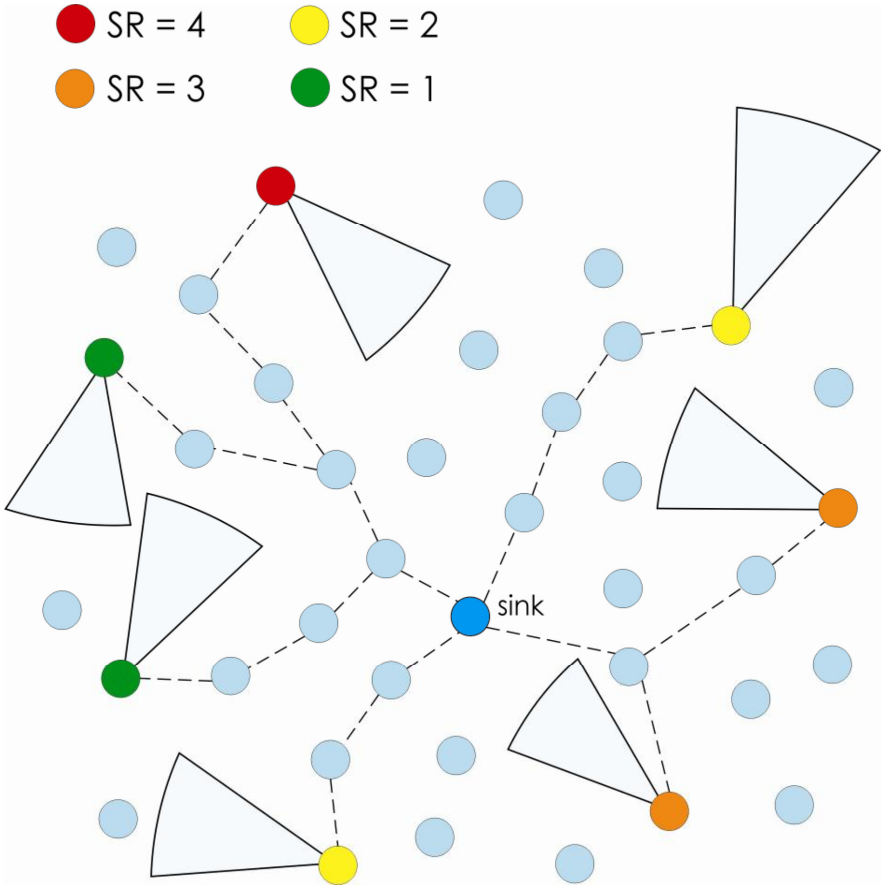
Experimental results

- Scenario when all sources have the same SR_s index, from 1 to 4



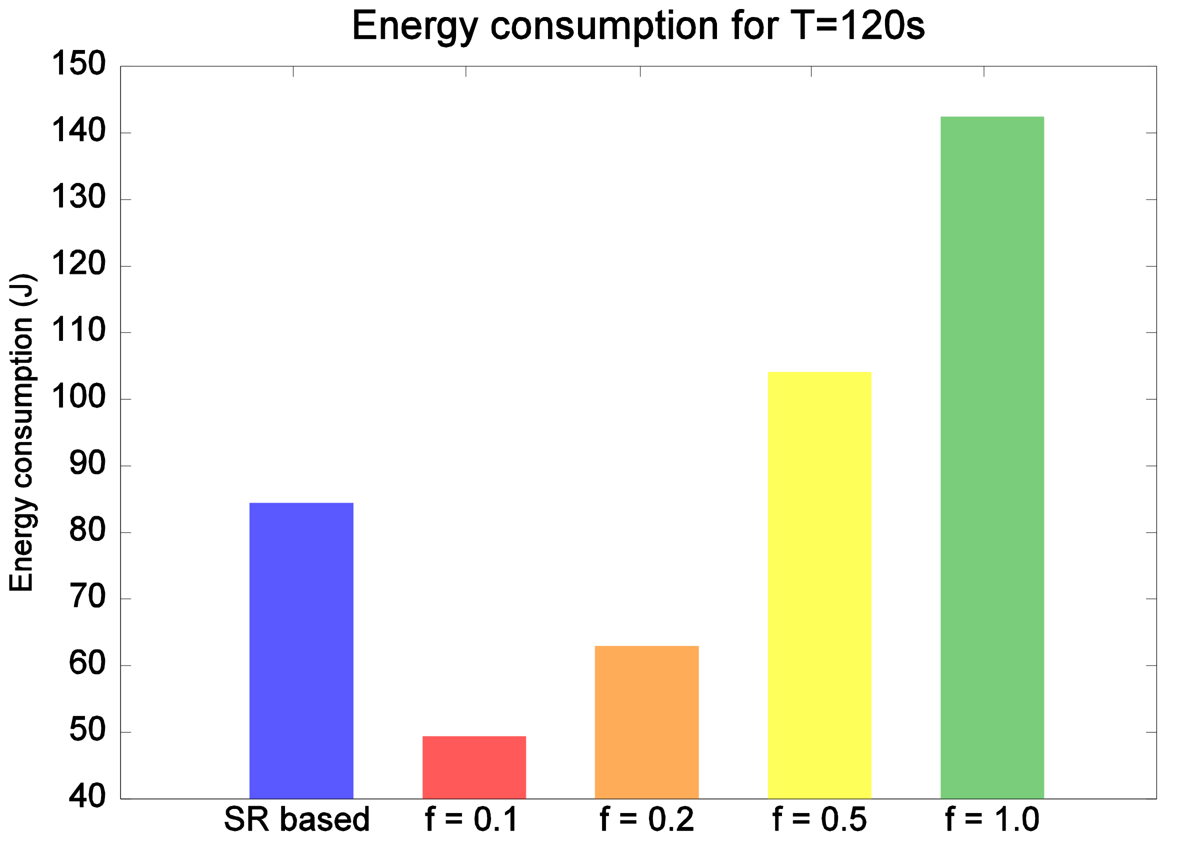
Experimental Results

- The proposed solution is only useful when source nodes can be differentiated
  - In traditional approaches, all sources transmit images equally
- In this deployed network, 4 of 7 source nodes have medium or low relevance
  - They are important, but application requires less visual information from them



Experimental results

- The proposed solution and 4 different “traditional” approaches



Conclusions

- The proposed solution could be used to prolong the monitoring capability of wireless image sensor networks
- The sensing relevancies of source nodes are a valuable concept that can be largely exploited for wireless sensor network optimizations
- Different sources should be treated differently

Future Works

- Additional experimental verifications.
- Measurement of the visual monitoring quality using some Mean Opinion Score (MOS) mechanism.
- Automatic/adaptive assignment of SR_s to deployed source nodes
  - Centralized or distributed approach?
- Others mapping process between SR_s Index and image → compress level, for example.
- Assignment the SR_s to the packet instead of the image.

Thank you!

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