



ITU Kaleidoscope 2014

Living in a converged world - impossible without standards?

An experimental test bed for the evaluation of the hidden terminal problems on the IEEE 802.15.5 standard

David Rodenas-Herraiz, **Antonio-Javier Garcia-Sanchez**,
Felipe Garcia-Sanchez and Joan Garcia-Haro

**Department of Information and Communications Technologies
Universidad Politecnica de Cartagena (Spain)**



Summary

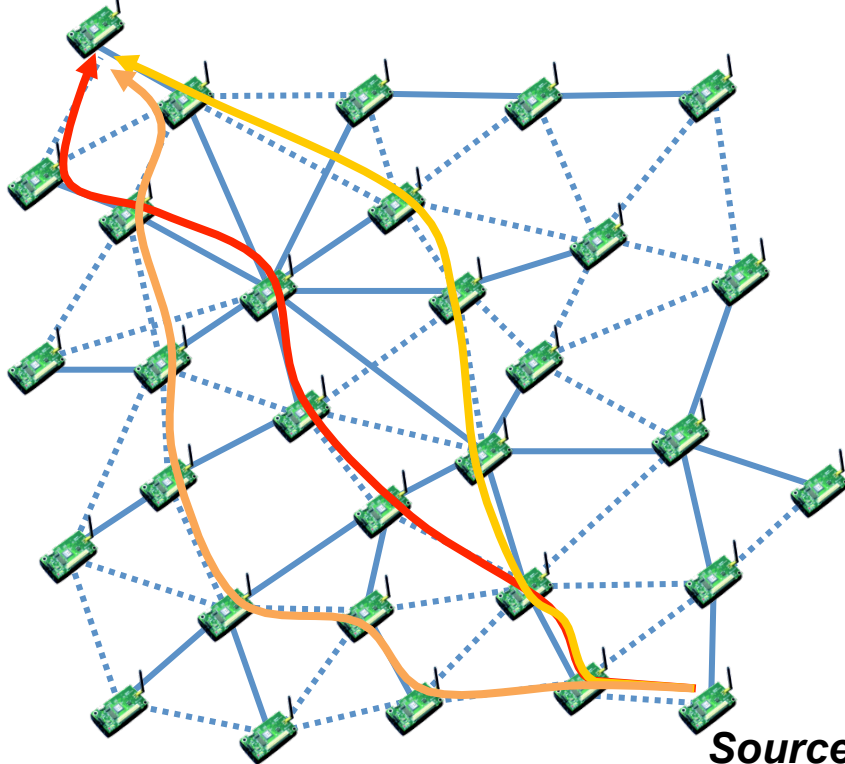
- Motivation
- IEEE 802.15.5
 - Mesh Network Formation
 - Asynchronous Energy Saving Mode
- Architecture and Implementation
- Performance Evaluation

Motivation

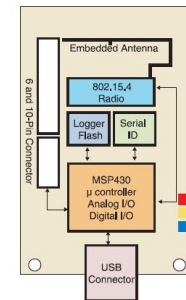
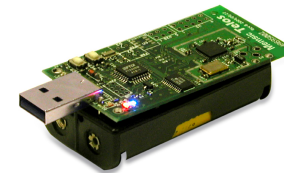
Wireless Mesh Sensor Networks (WMSNs)

Wireless Sensor Network (WSN) Wireless **Mesh** Sensor Network (WMSN)

Destination



Source



TPR2400CA Block Diagram

Wireless sensor platform: TelosB device provided by MEMSIC Inc.

Mesh capability

- Energy efficiency
- Link reliability
- Scalability
- Self-organization
- Interoperability
- Robustness
- Security
- ... Multi-hop mesh routing

Motivation

Wireless Mesh Sensor Networks (WMSNs)

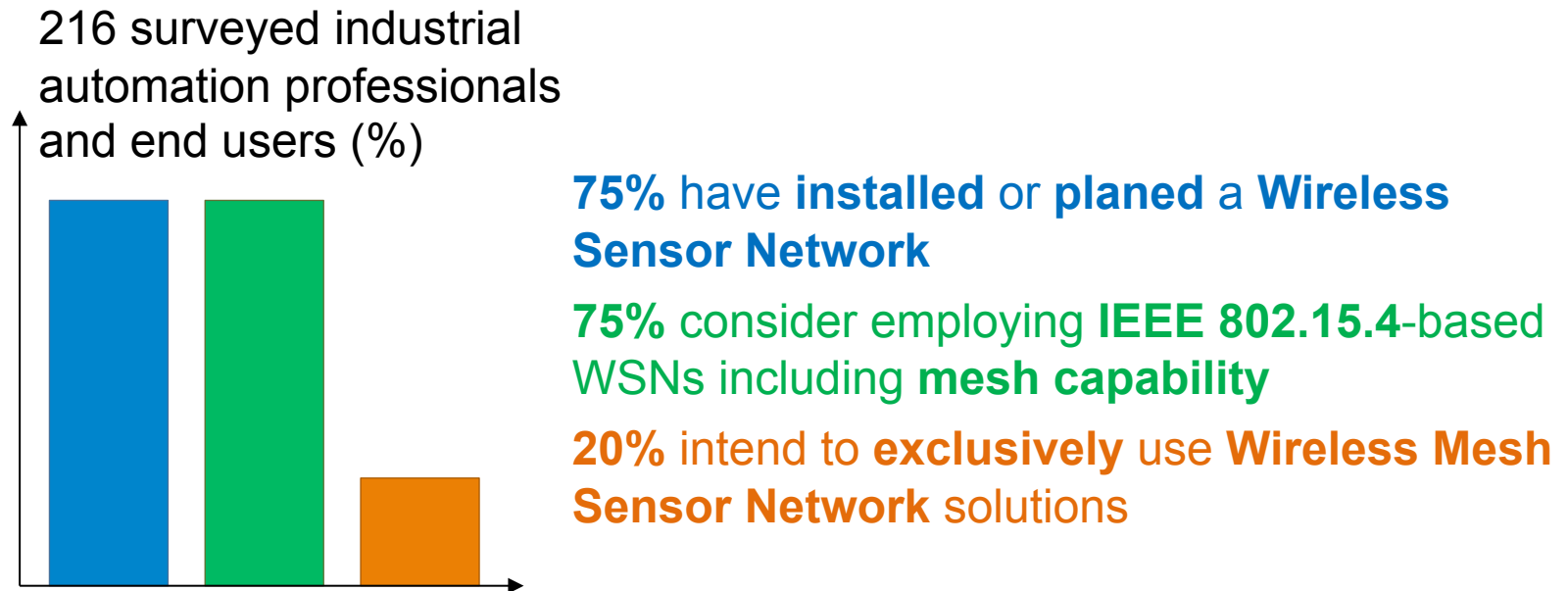


Fig. 1.3. Trend shown by the industrial automation market in the last few years. On World (Hatler *et al.*, 2012)

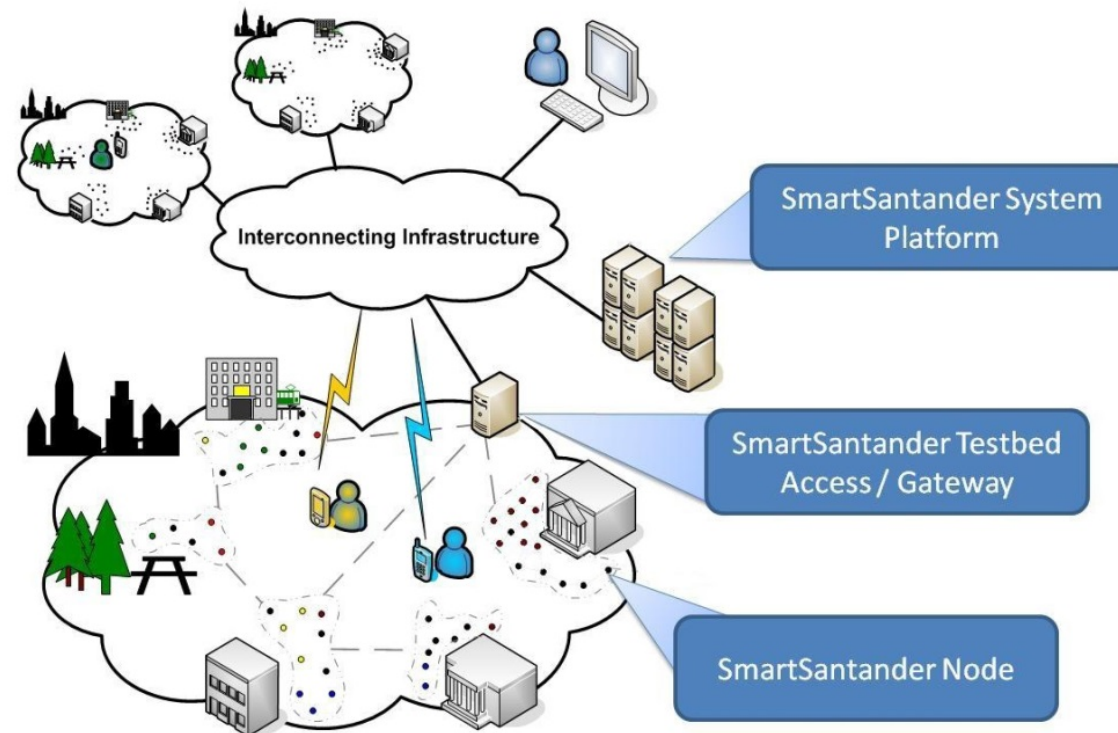
By 2016, 39% applications and services will be uniquely enabled by Low-Rate Wireless Personal Area Mesh Networks (LR-WPAN Mesh) (Hatler *et al.*, 2012)

Motivation

Wireless Mesh Sensor Networks (WMSNs)

Smart Santander City

Up to 12.000 nodes deployed in Santander (Spain) to create a Smart City

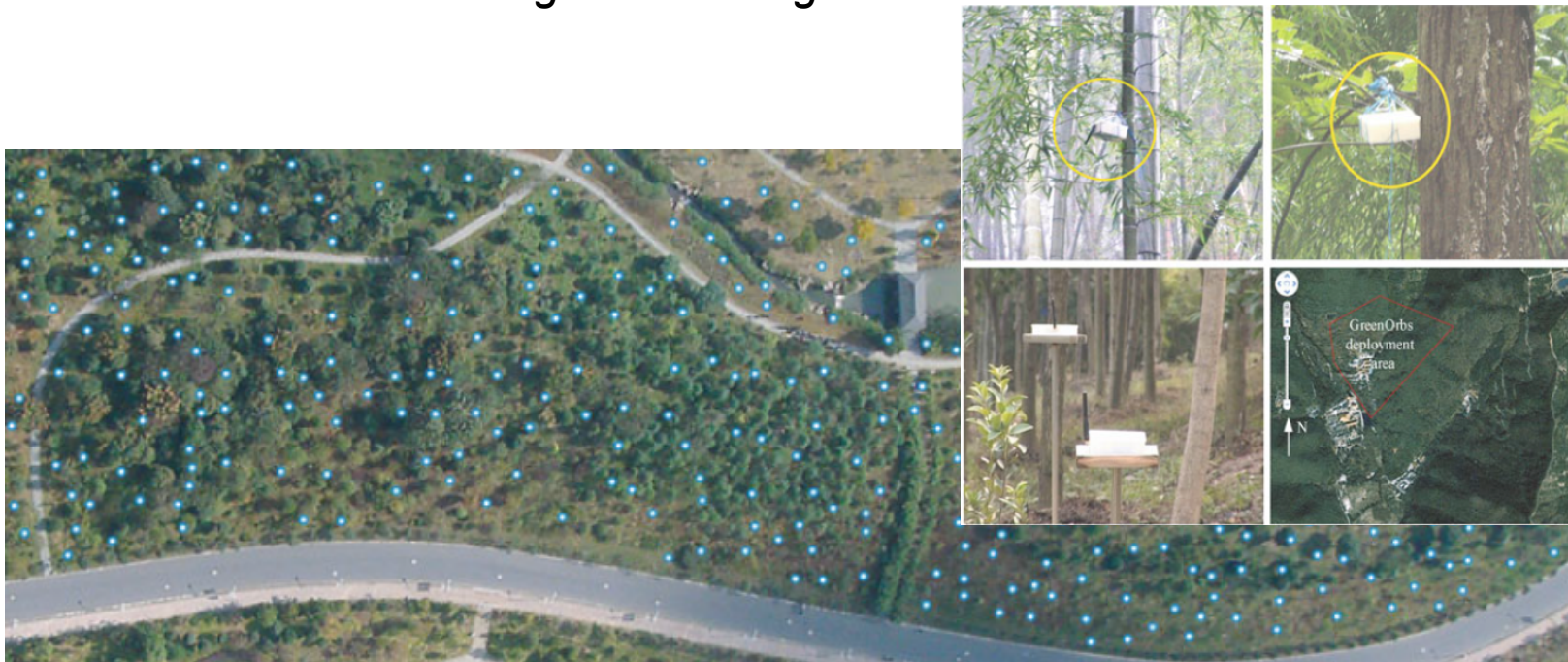


Motivation

Wireless Mesh Sensor Networks (WMSNs)

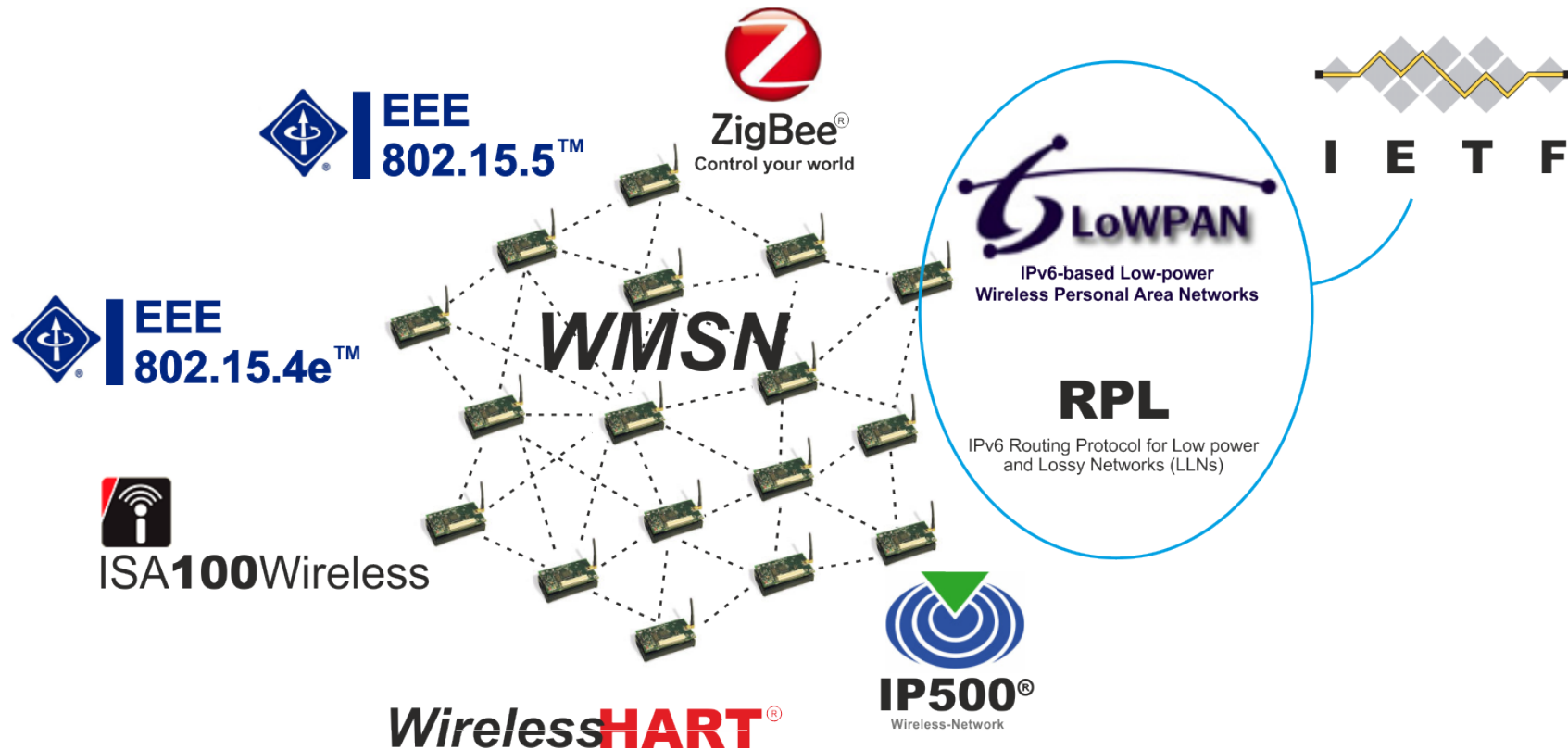
GreenOrbs

More than 1000 nodes deployed in TianMu Mountain, Zhejiang (China), for long-term ecological surveillance







Motivation

Wireless Mesh Sensor Networks (WMSNs)











Motivation

Wireless Mesh Sensor Networks (WMSNs)

Feature	 ZigBee® Control your world	 LoWPAN IPv6-based Low-power Wireless Personal Area Networks	 RPL IPv6 Routing Protocol for Low power and Lossy Networks (LLNs)	 IP500® Wireless-Network	 IEEE 802.15.4e™	 WirelessHART®	 ISA100Wireless	 IEEE 802.15.5™
Multi-hop mesh routing	✓	✗	NA	NA	✗	✗	✓	
Scalability	✗	✗	NA	NA	✓	✓	✓	
Energy efficiency	✗	✗	✗	✓	✓	✓	✓	
Link reliability	✗	✗	NA	✓	✗	✓	✓	
End-to-end reliability	✗	✗	NA	NA	✓	✓	✗	
Robustness	✗	✗	NA	✓	✓	✓	✗	
Interoperability	✓	✓	✓	✓	✗	✗	✓	
Self-organization	✓	✓	✓	✓	✓	✓	✓	
Security	✓	✗	NA	NA	✓	✓	NA	
Mobility support	✓	✓	NA	✗	✓	✓	✓	

Motivation

Wireless Mesh Sensor Networks (WMSNs)

Decisions	 ZigBee® Control your world	 LoWPAN IPv6-based Low-power Wireless Personal Area Networks	 RPL IPv6 Routing Protocol for Low power and Lossy Networks (LLNs)	 IP500® Wireless-Network	 IEEE 802.15.4e™	 WirelessHART®	 ISA100 Wireless	 IEEE 802.15.5™
Use of IPv6	✗	✓	✓	Compatible	✗	✓	Compatible	
In-network addressing scheme	16-bit	128-bit	16-bit	16-bit	16-bit	16-bit	16-bit	
Available source code	✓	✓	✗	Open issue	✗	✗	Open issue	
Free-payment contributions	✗	✓	✗	✓	✗	✗	✓	
Memory and CPU usage	✓	✓	✓	✗	✗	✗	✓	
Cost	✓	✓	✓	✓	✗	✗	✓	
Flexibility	✓	✓	✓	✓	✗	✗	✓	
Large-scale networks	✗	✗	✗	✗	✓	✓	✓	
Energy-saving support	✗	✗	✗	✓	✓	✓	✓	

Motivation

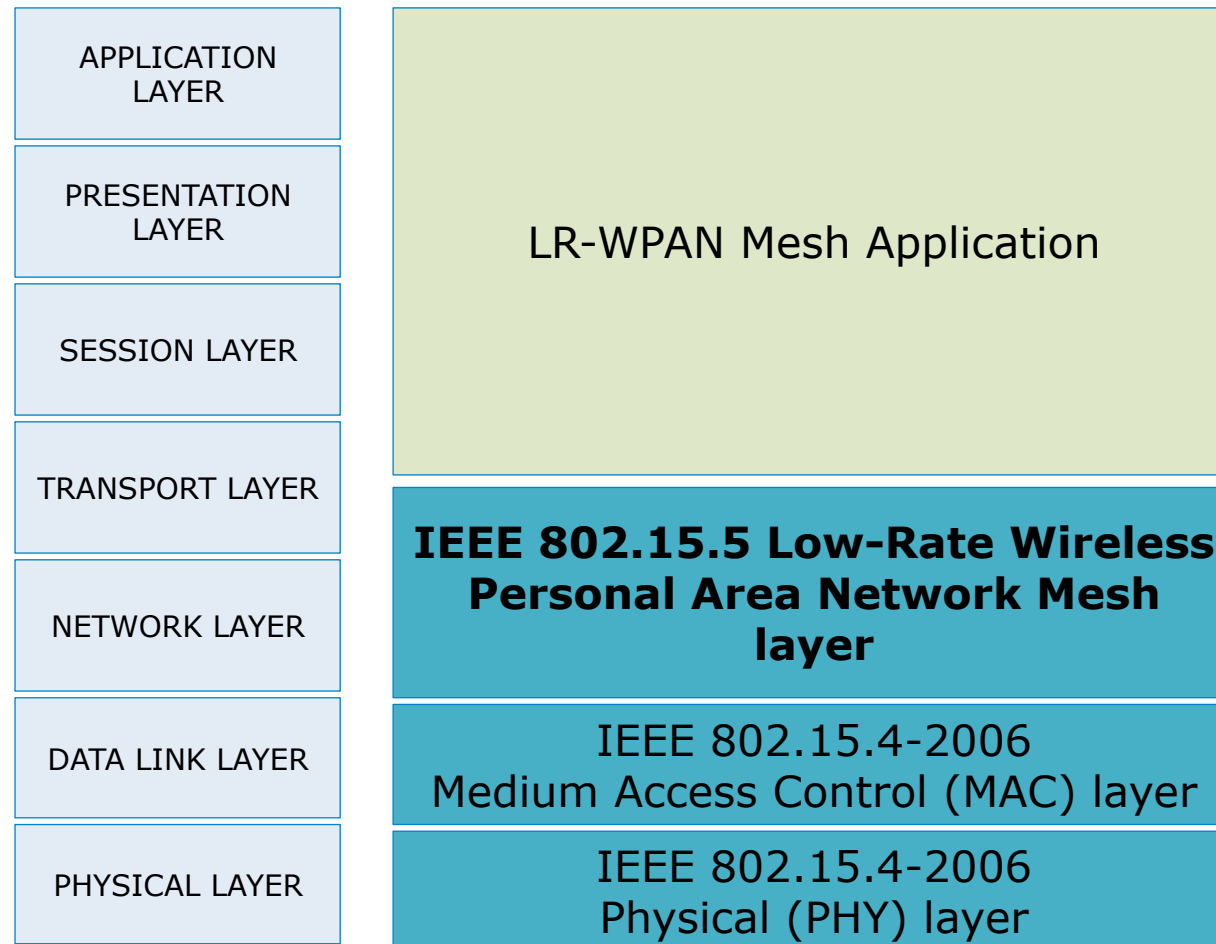
Wireless Mesh Sensor Networks (WMSNs)

- The IEEE released in 2009 the IEEE 802.15.5 standard to extend traditional Low-Rate Wireless Personal Area Networks (LR-WPANs) to scalable, robust, energy-efficient and interoperable WMSNs
- Despite the sought after features already offered by this standard, there is still very few experimental work accessing the performance of IEEE 802.15.5 networks
- Lack of an open-source implementation available to the scientific and development communities

The IEEE 802.15.5 LR-WPAN Mesh standard

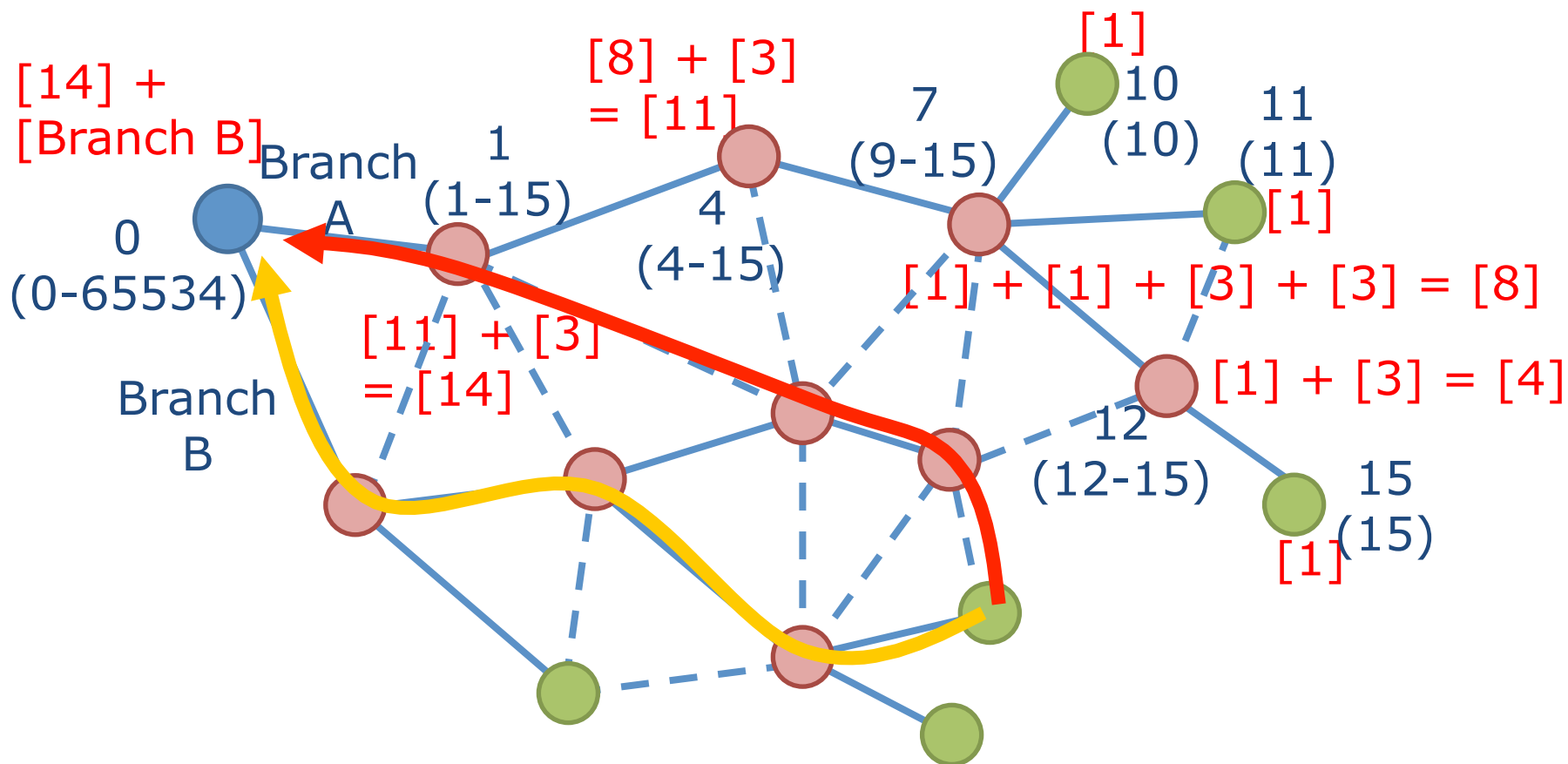
Anatomy of the current communication stack

OSI Reference
Model



The IEEE 802.15.5 LR-WPAN Mesh standard

Mesh network formation

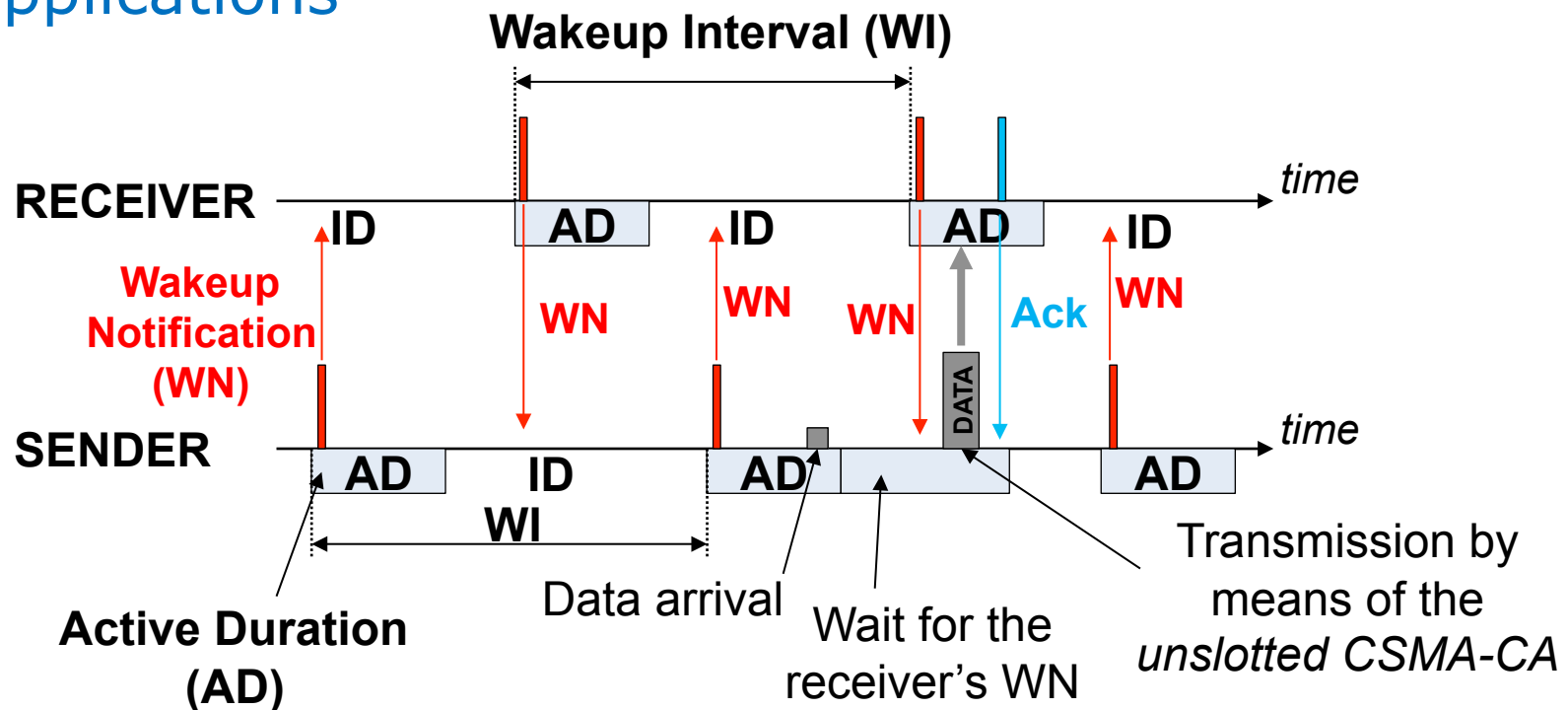


● Mesh Coordinator
 ● Mesh device
 ● End device

The IEEE 802.15.5 LR-WPAN Mesh standard

Asynchronous Energy Saving (ASES) mode

- Conceived for the majority of traditional WSN applications

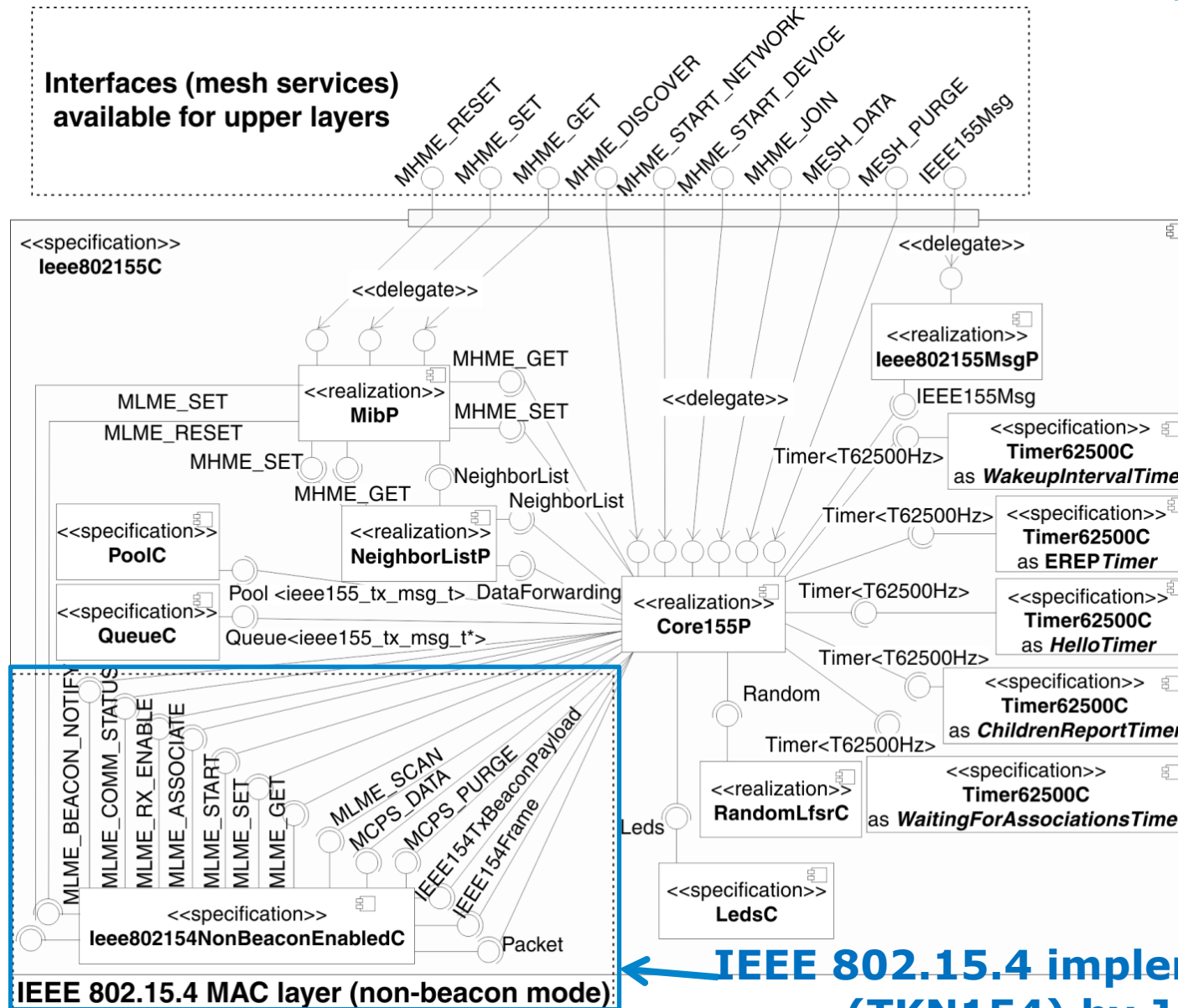


$$WI = meshBaseActiveDuration \cdot 2^{WO} \text{ [ms]}$$

$$AD = meshBaseActiveDuration \cdot 2^{AO} \text{ [ms]}$$

$$0 \leq \text{Active Order (AO)} \leq \text{Wakeup Order (WO)} \leq 14$$

IEEE 802.15.5 Architecture for TinyOS

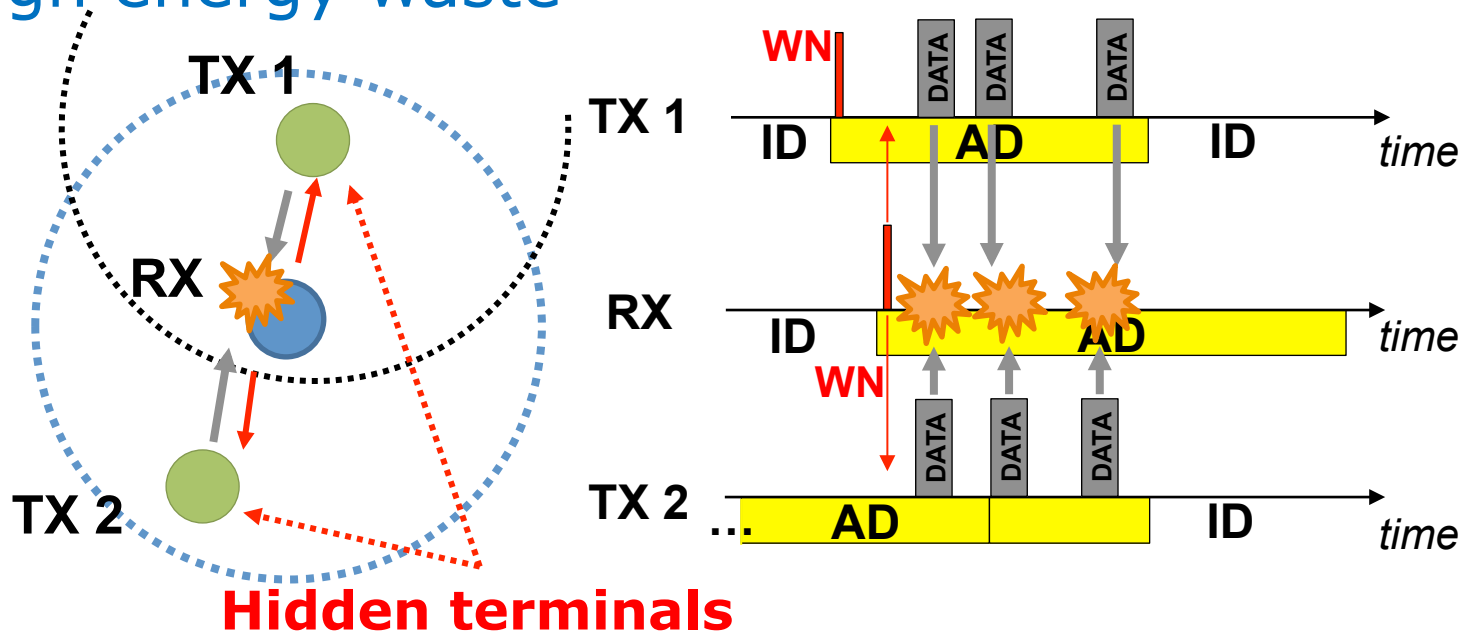


IEEE 802.15.4 implementation (TKN154) by J.-H. Hauer

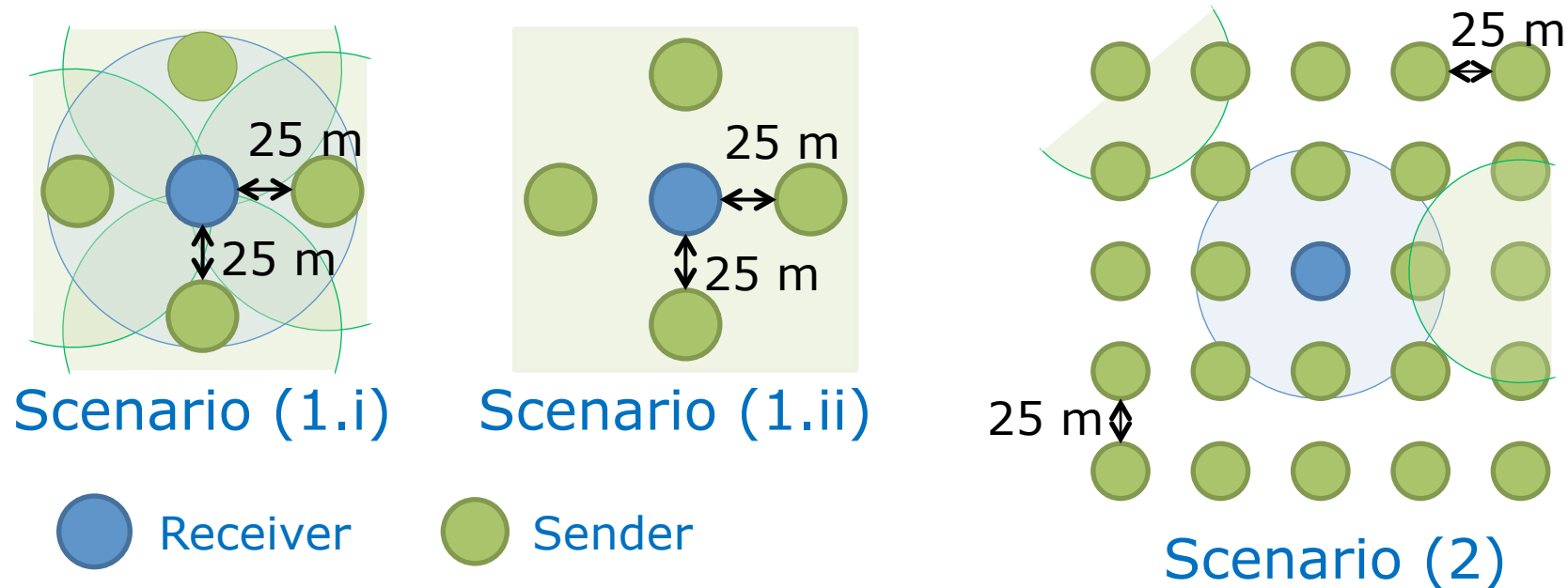
Performance Evaluation

The hidden terminal problem

- The HT problem gives rise to message collisions, leading to further retransmissions and messages lost
- High energy waste

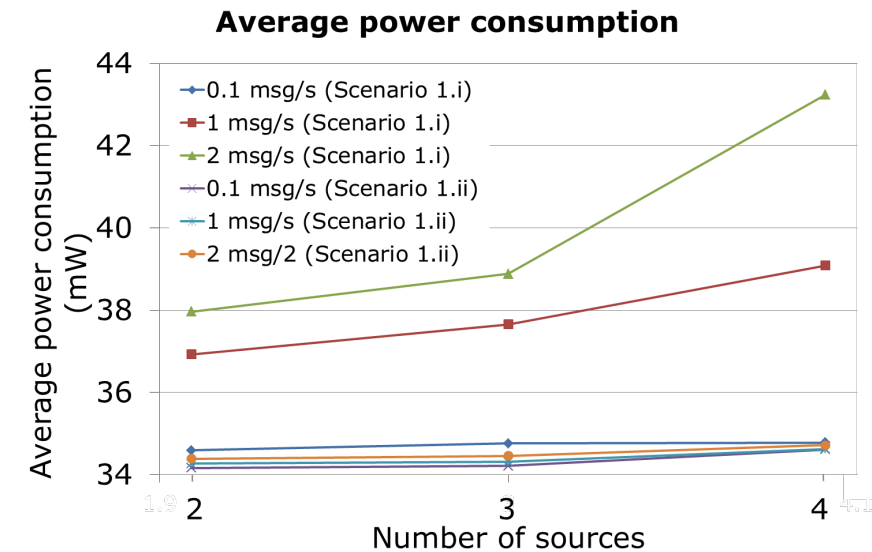
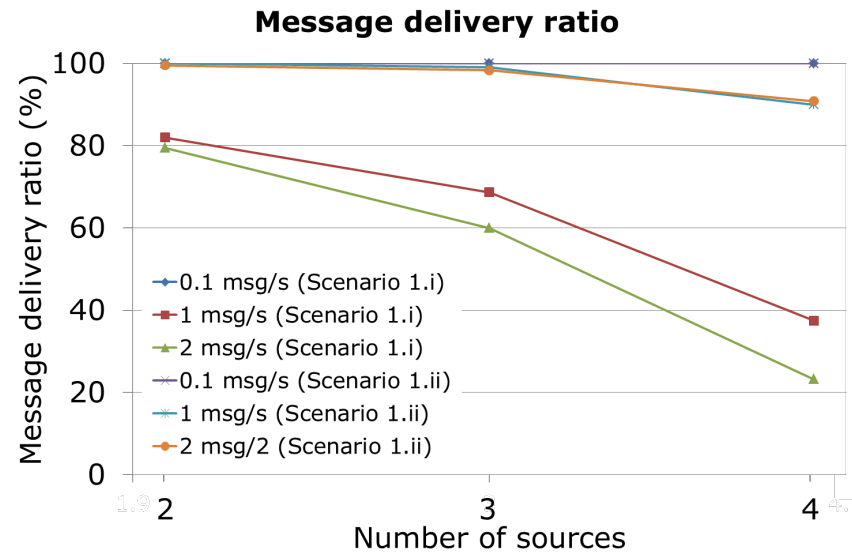
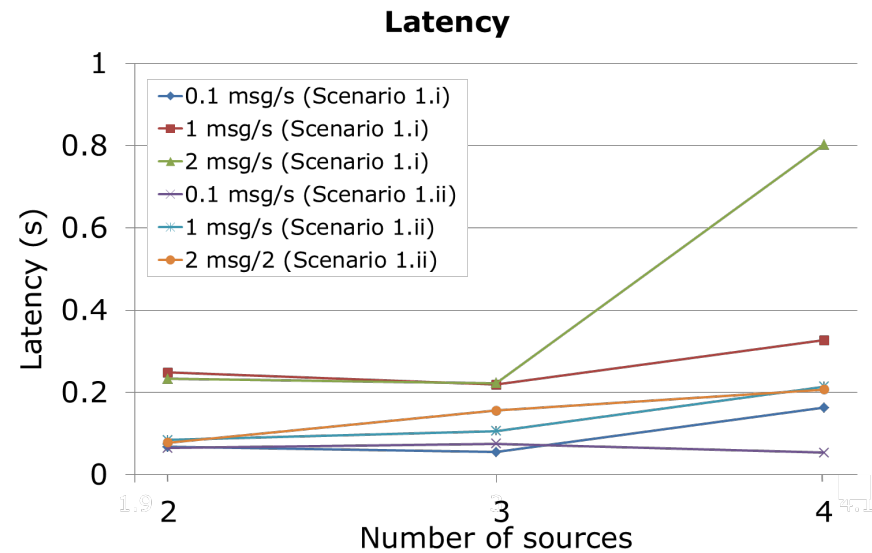
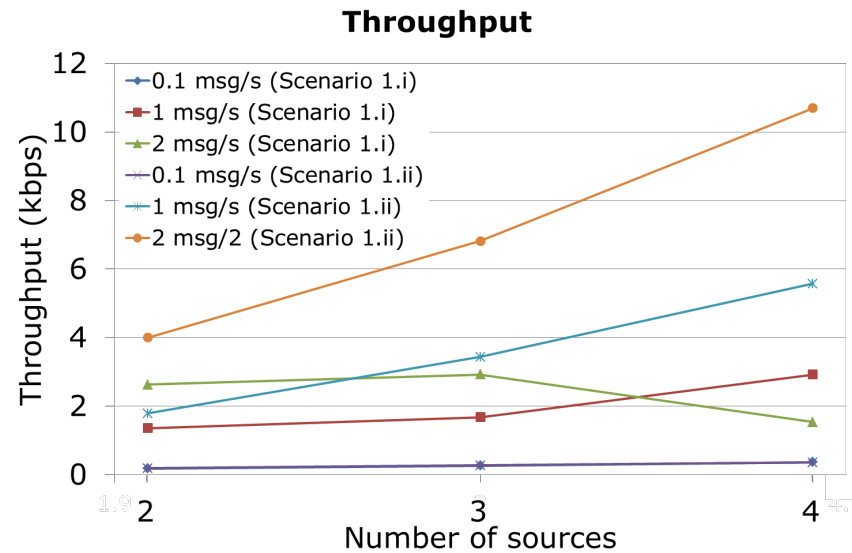


Performance Evaluation

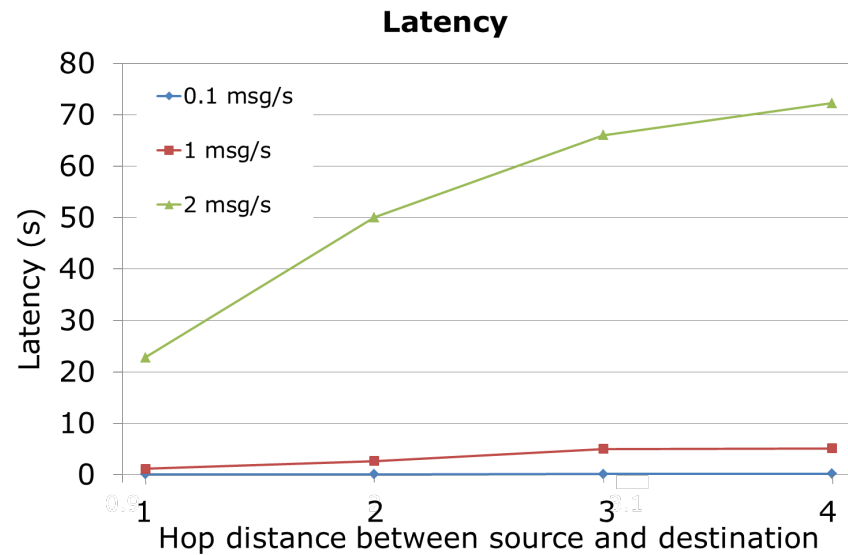
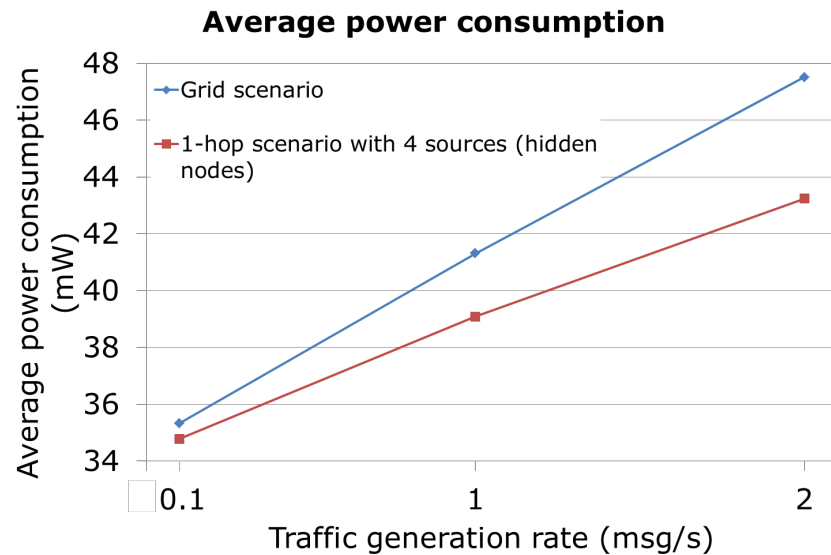
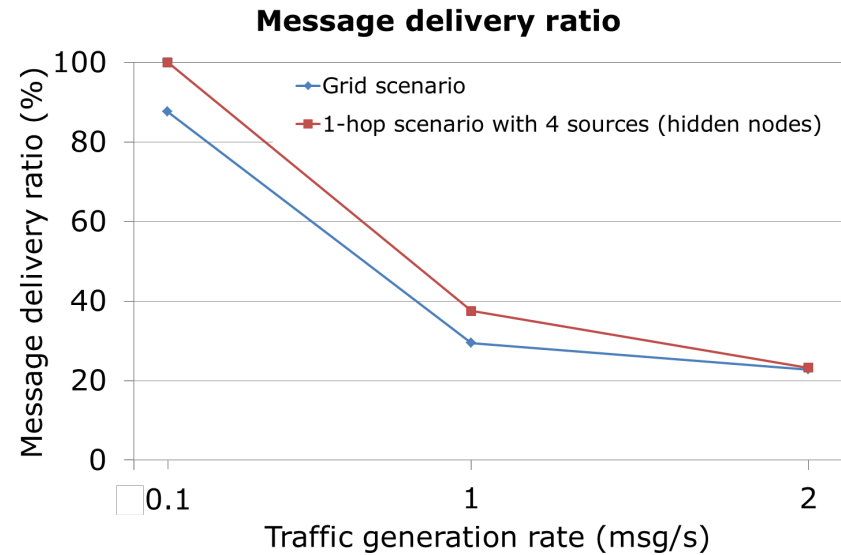
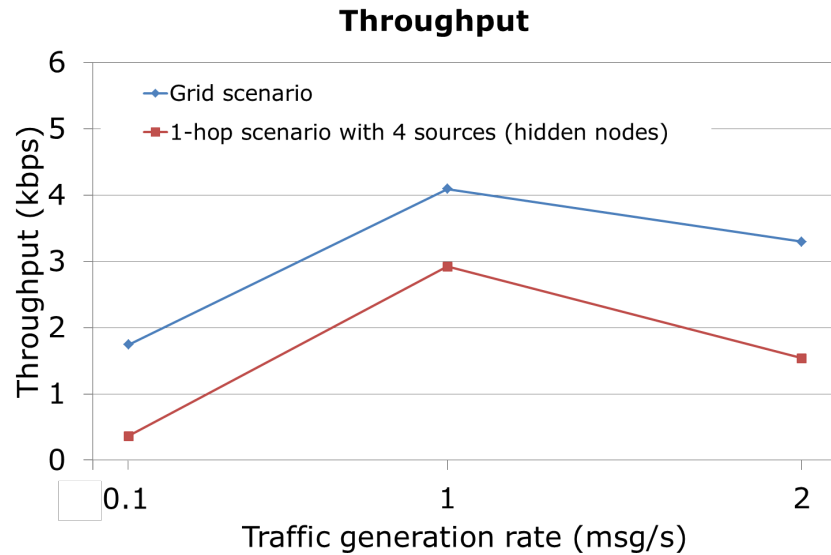


- Deployed TelosB devices in an indoor scenario
- Traffic generation rate: 0.1, 1 and 2 messages per second (127 bytes at the IEEE 802.15.4 PHY layer)
- All nodes configured with $WO = 4$ ($WI = 80$ ms) and $AO = 3$ ($AD = 40$ ms)

Results: Single-hop scenario



Results: Mesh scenario



Conclusions and Future Work

- Developed first open-source implementation of the IEEE 802.15.5 LR-WPAN Mesh standard for TinyOS
- Assessed WMSN operation considering HT problems
- HT problems degrade significantly the WMSN performance
- Complete the implementation of the IEEE 802.15.5 standard
- Investigate and evaluate solutions to alleviate the HT problems in an IEEE 802.15.5 networks

**The complete software can be found in the following repository:
<https://github.com/upct/mesh802155.git>**

Thanks!

antoniojavier.garcia@upct.es