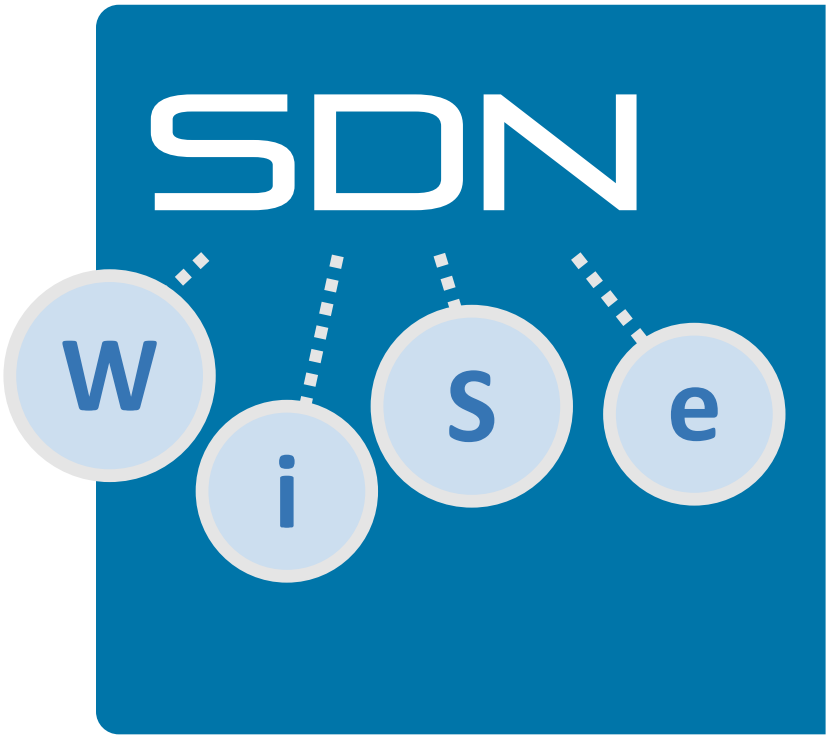


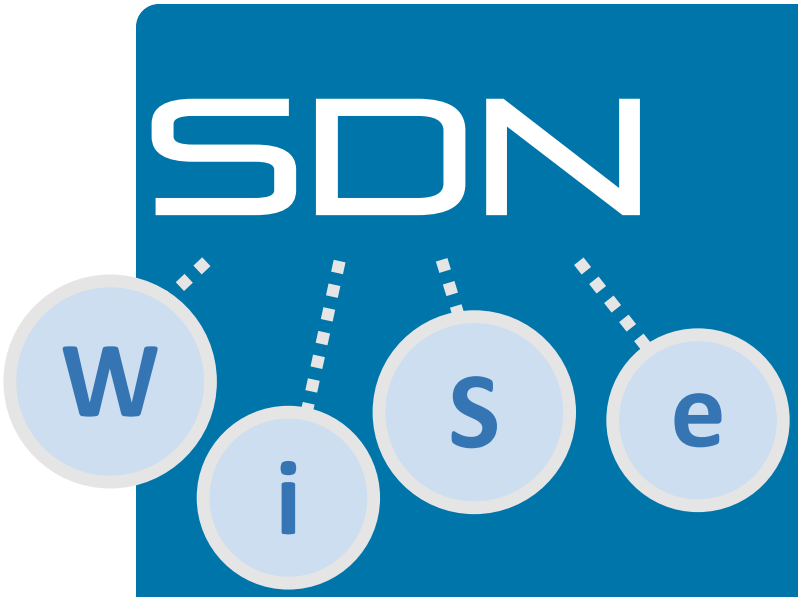
A SDN solution for Wireless Sensor Networks

DIEEI
University of Catania

http://sdn-wise.dieei.unict.it

Outline

- Motivations
- Related work
- SDN-WISE
- Prototype and testbed
- Performance evaluation
- Conclusions and future work



Motivations

A few facts about wireless sensor networks

- Mature technology since early 2000s
- Challenging communication & networking environment
- Requirements extremely application specific

The bottom-line...

There is nothing like a one-fits-all solution

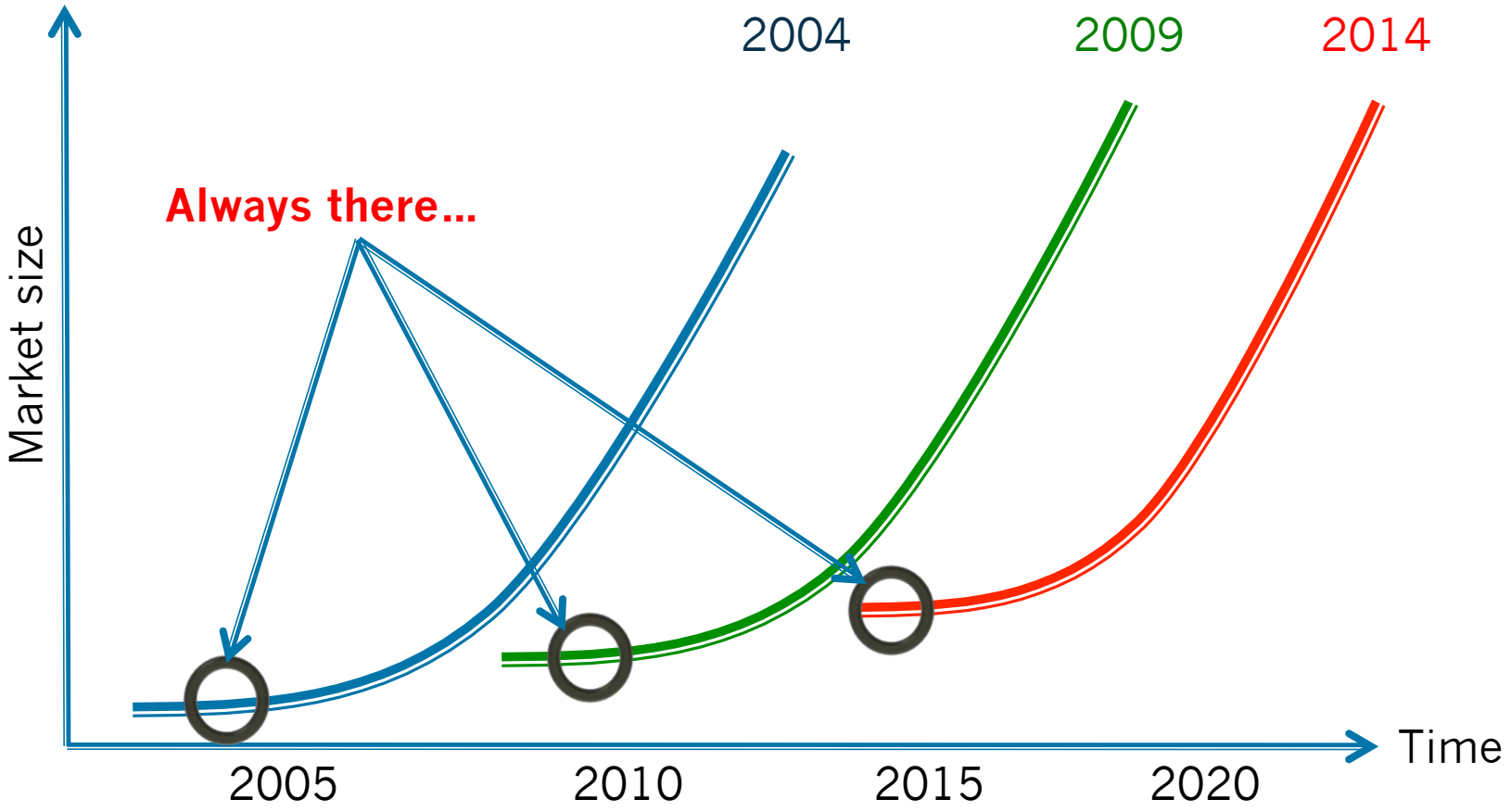
Upsides:

- Large number of solutions proposed
- Deep understanding of the WSN domain
- Zillions of papers, citations, academic promotions, projects

Downsides:

- High solution specialization
- Market fragmentation
- Burden on application developers
- Low reusability

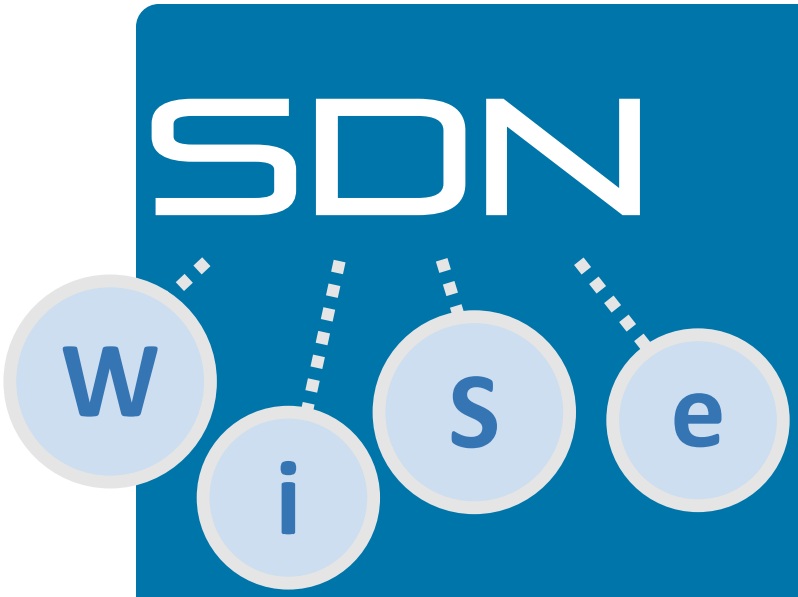
The consequence…



It's not taking off!

Our objectives

1. Overcome fragmentation
2. Ease life of developers



Related work

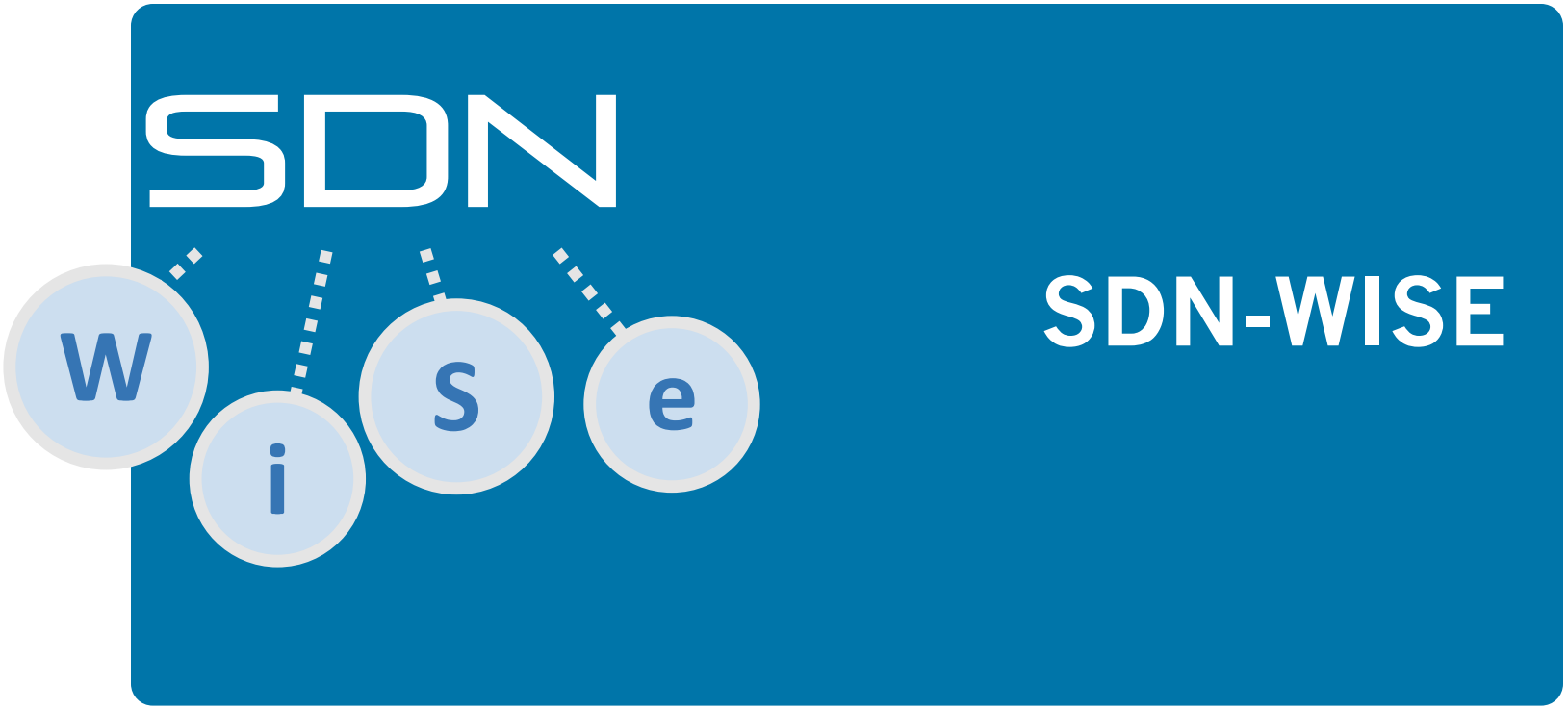
SDN & OpenFlow

- Software Defined Networking (SDN) clearly separates:
  - **Data plane:** run by network Switches
  - **Control plane:** implemented by a software program running on a server (the Controller)
- Modifying the behavior of the network as easy as it is installing a new piece of software on a PC
- **OpenFlow** is the most popular implementation of the SDN paradigm

SDN in WSNs

- Few attempts to extend SDN to WSNs:
  - Software Defined Wireless Networks (SDWN), 2012
  - Sensor OpenFlow, 2012
- Different requirements:

Traditional wired networks	WSNs
Velocity	Efficiency
	Flexibility
	Memory occupancy



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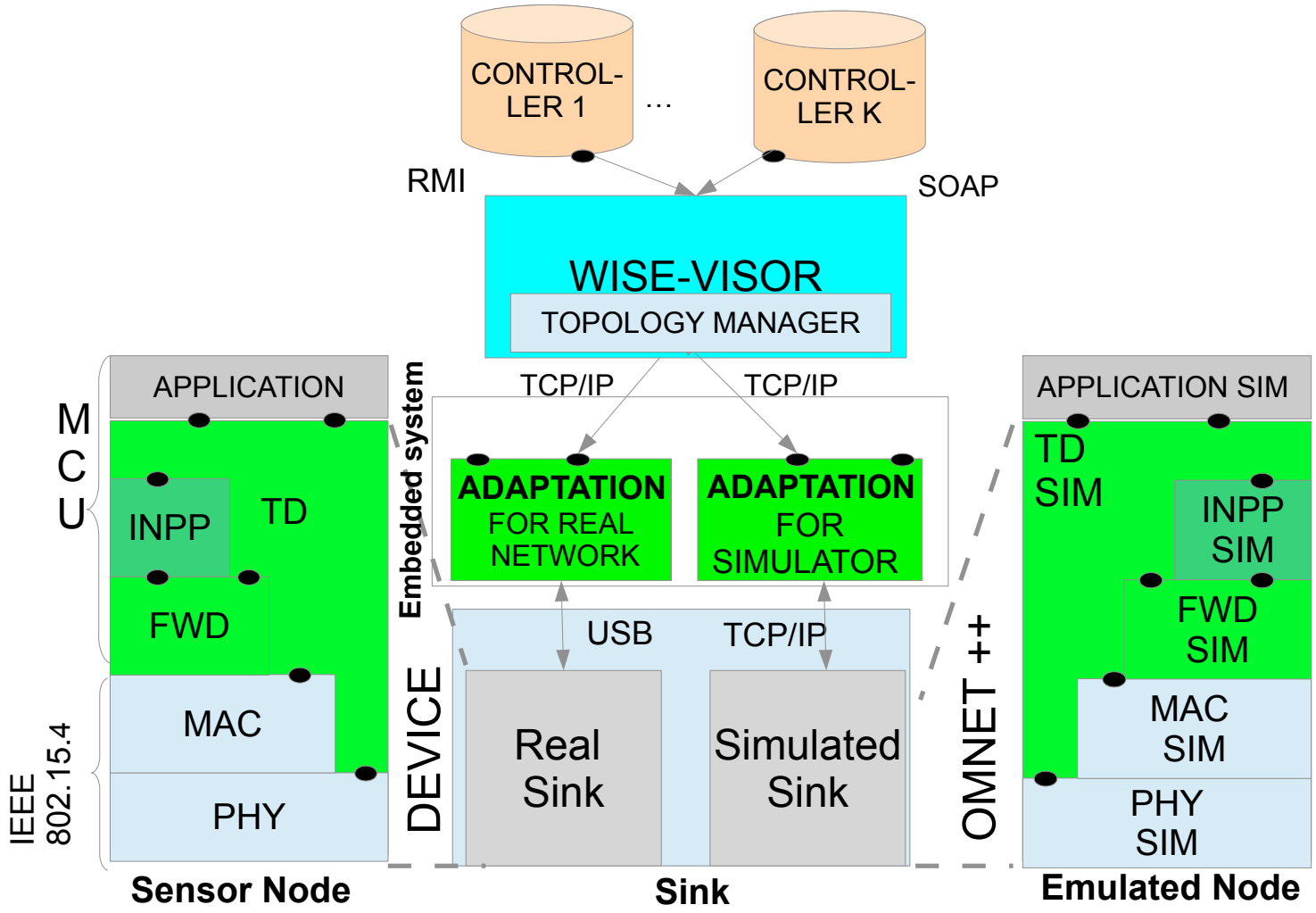
SDN-WISE: Basic concepts

- Directly derived by OpenFlow
- Separation between
  - **data plane** (executed by sensor nodes)
  - **control plane** (executed by the Controller)
- When an event (e.g., the arrival of a packet) occurs sensor nodes behave as specified in the WISE Table
- If there is no relevant information in the WISE Table → Ask the Controller
- The Controller replies sending a new entry for the WISE Table
- A simple protocol defined to allow nodes to:
  - Learn the shortest path towards the (closest) sink(s)
  - Discover the neighboring nodes
  - Periodically report local information to the Controller (through the sink)

WISE Table

Matching Rule					Matching Rule					Matching Rule					Action					Statistics	
Op.	Size	S	Offset	Value	Op.	Size	S	Offset	Value	Op.	Size	S	Offset	Value	Type	M	S	Offset	Value	TTL	Counter
=	2	0	2	B	>	2	0	10	x_{Thr}	=	1	1	0	0	Modify	1	1	0	1	122	23
=	2	0	2	B	≤	2	0	10	x_{Thr}	=	1	1	0	1	Modify	1	1	0	0	122	120
=	2	0	2	B	-	0	-	-	-	-	0	-	-	-	Forward	0	0	0	D	122	143
=	2	0	2	A	=	1	1	0	0	-	0	-	-	-	Drop	0	0	-	-	100	42
=	2	0	2	A	=	1	1	0	1	-	0	-	-	-	Forward	0	0	0	D	100	32

SDN-WISE Architecture



Major features (compared to OpenFlow)

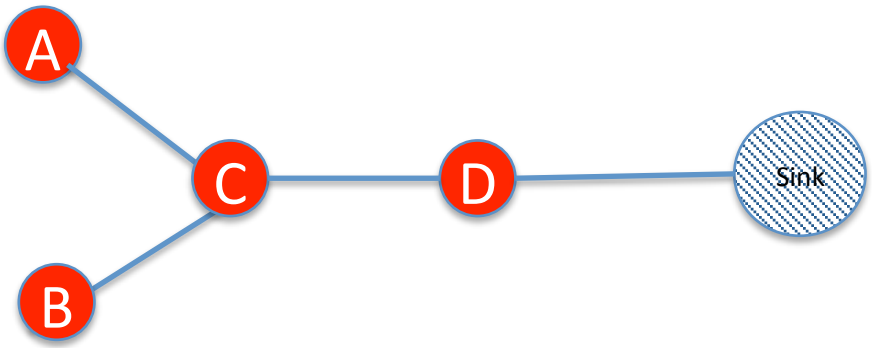
1. Statefulness
2. Flexible definition of rules
3. Support of duty cycles
4. Support of multitenancy (beyond *slicing*)
5. Lots of deployment options and programming languages
6. Integration with simulation environments (OMNET++ & OPNET)

Statefulness

- OpenFlow is stateless
- SDN-WISE is stateful: a buffer of memory is reserved for state information
  - Rules can state info to classify packets in flows
  - Actions can modify state info
- **Why?** Reduce the number of interactions with the Controller if local policies must be applied
- 3 exemplary uses of the state...

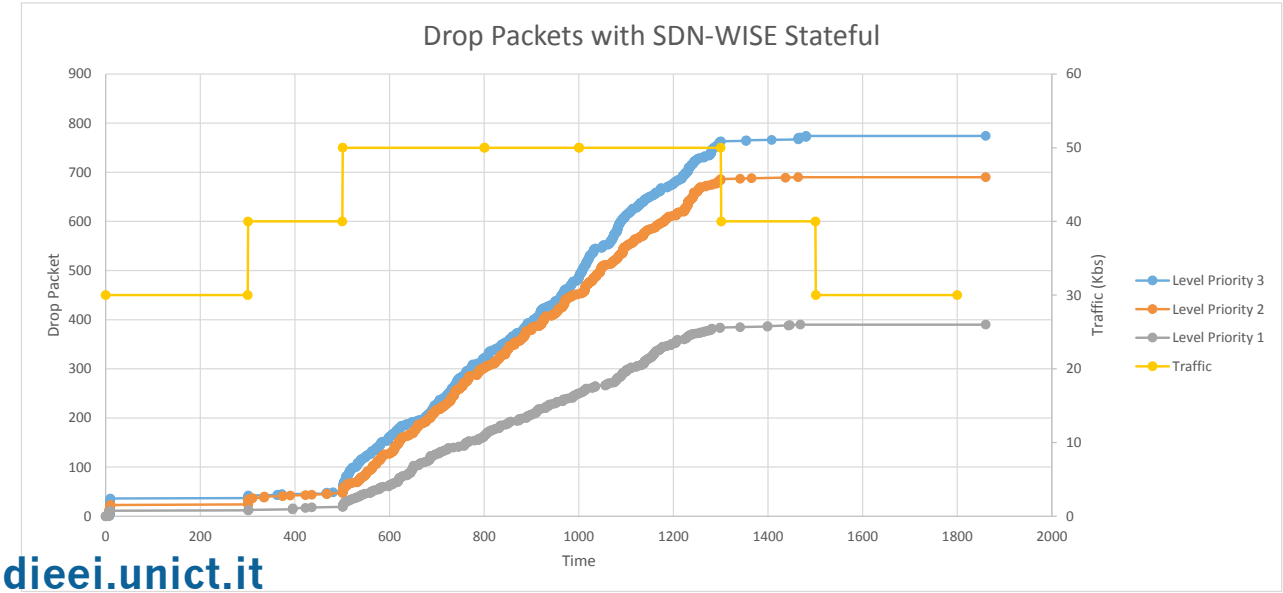
Exemplary use of the state (1)

- Conditional forwarding:
  - C must forward packets from A only, if the values coming from B are higher than a threshold



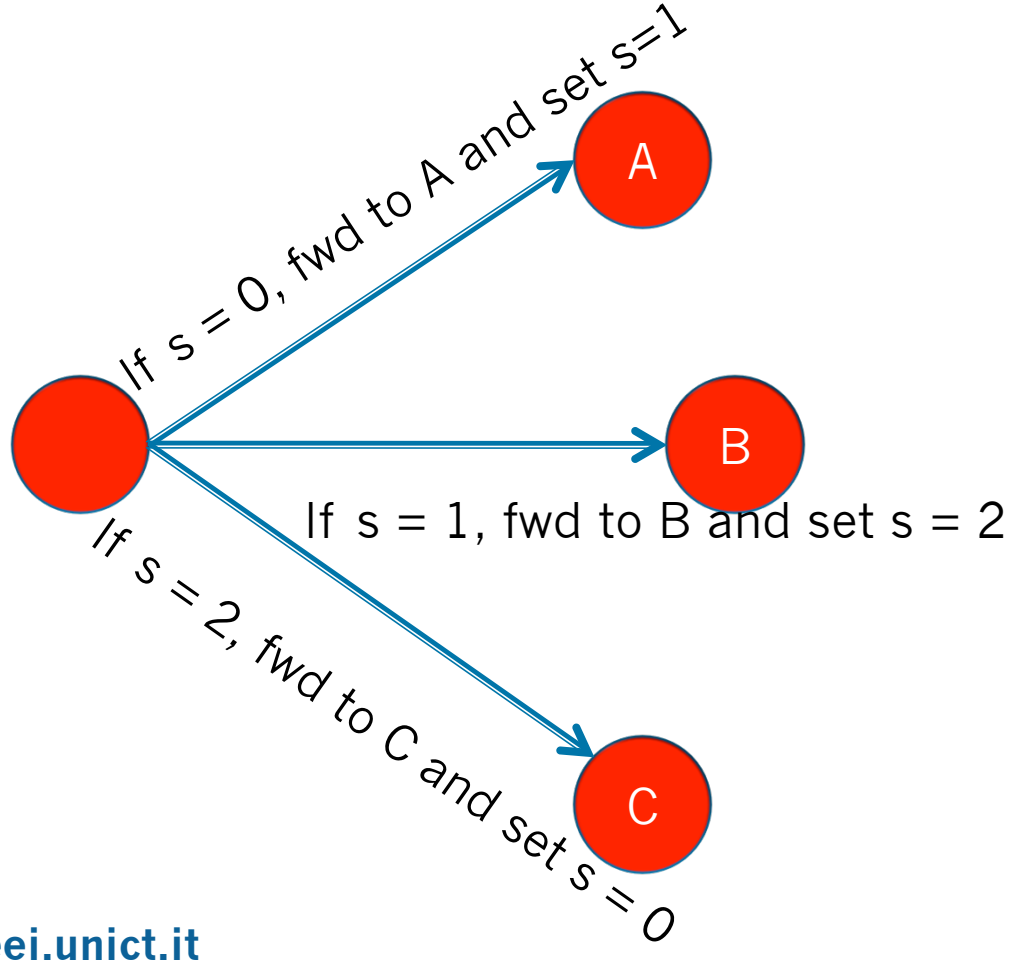
Exemplary use of the state (2)

- Support of QoS:
  - A congested node must give different priorities to different flows
  - Level of congestion stored as state information
  - Different drop probabilities given to different flows in the WISE-table in case of congestion



Exemplary use of the state (3)

- Multipath routing



Flexible definition of rules

- Rules consider:
  - <= 3 windows (<= 2 byte) in the packet (in any position), or
  - any portion (<= 2 byte) of the memory for state
  - any relational operator (=, <, >, <=, >=, !=, Kalman filters)
- Slower than OpenFlow but higher efficiency and more sophisticated programmability

Support of duty cycle

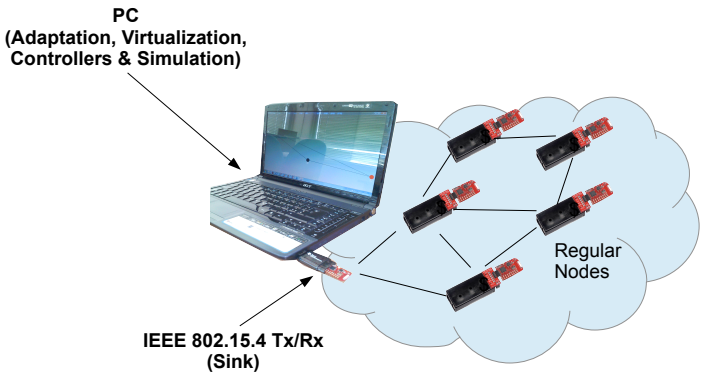
- The set of actions has been enlarged to support duty cycle
- It is possible to turn the radio off for a certain time interval

Multitenancy (beyond *slicing*)

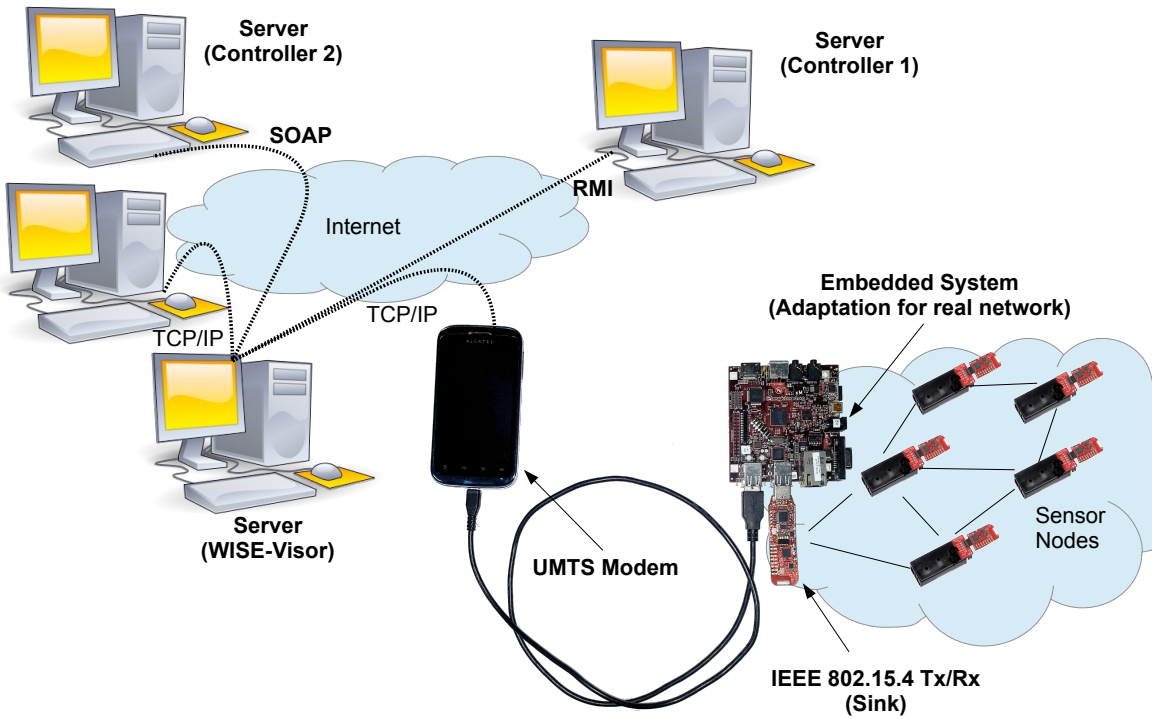
- Slicing assigns each packet to **only** one tenant
- In WSN the same piece of data can be of interest of several applications
- **WISE-Visor** a new layer which abstracts the real network and creates (different) views for different tenants
- At each node a packet belongs to all tenants that agree on its treatment
- When there is a disagreement, a new copy of the packet is created

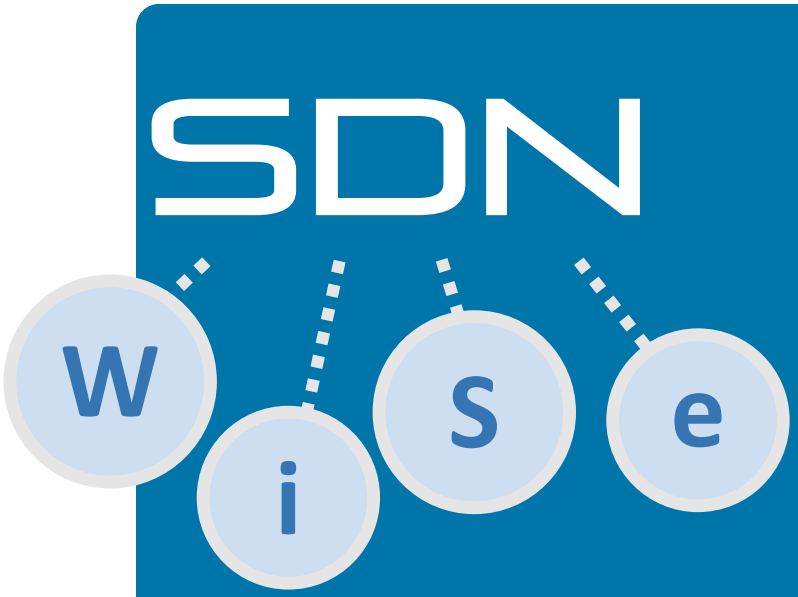
Lots of deployment options and programming languages

Simple



Complex





Prototype and testbed

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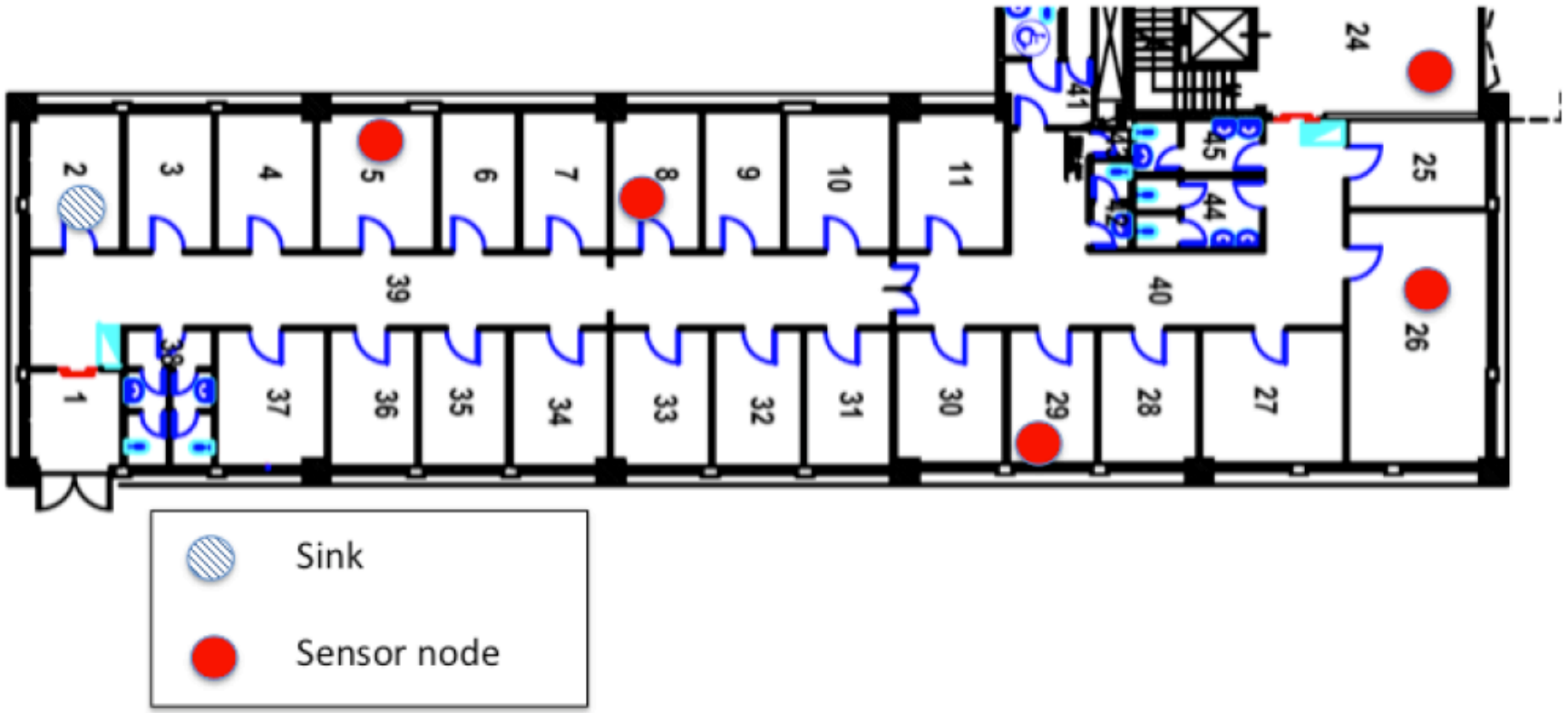
Prototype

- **Sensor nodes:** Embit IEEE 802.15.4 boards (EMB-Z2530PA)
  - 2.4 GHz ISM
  - Texas Instruments CC2530
  - Memory: 8 kB RAM + 256 kB Flash memory
  - 40 kB of memory used for MAC (TIMAC v.1.4.0)
  - 10 kB of memory used for SDN-WiSe
- **Control plane:** WISEVisor + Controllers hosted in the same PC
  - Intel(R) Core(TM) 2 CPU, 2.40 GHz
  - 4GB of RAM
  - Windows 7, 32 bit
  - Controllers implemented Java 7

Testbed



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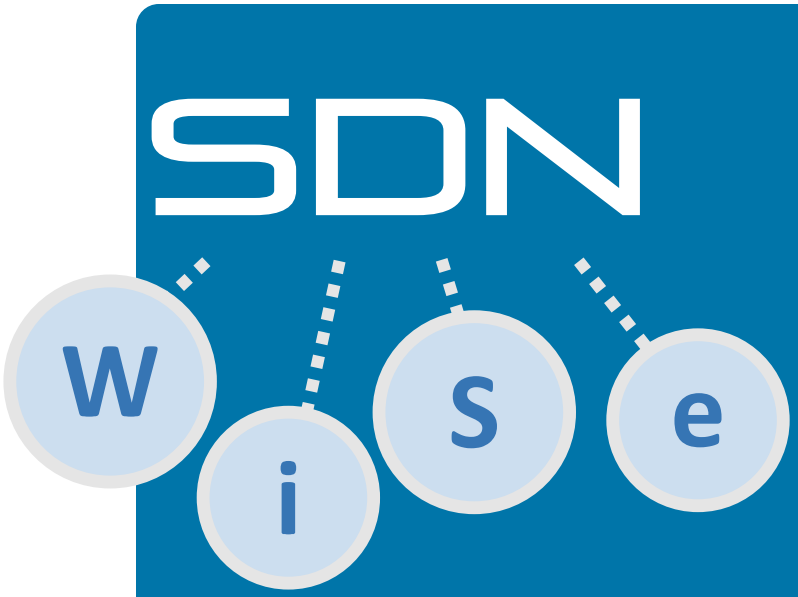


Performance results

Unicast RTT

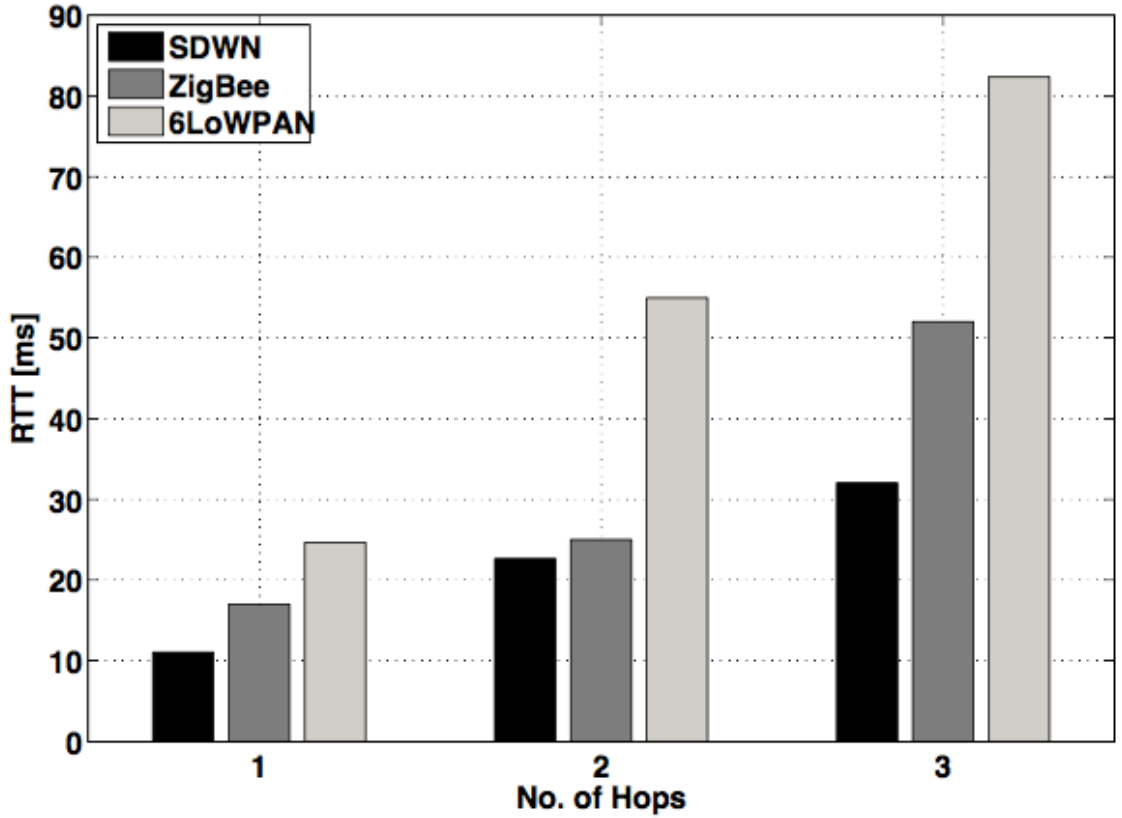


Fig. 4. Unicast traffic: RTT as a function of the number of hops when transmitting 20 bytes of payload in static conditions.

Unicast RTT

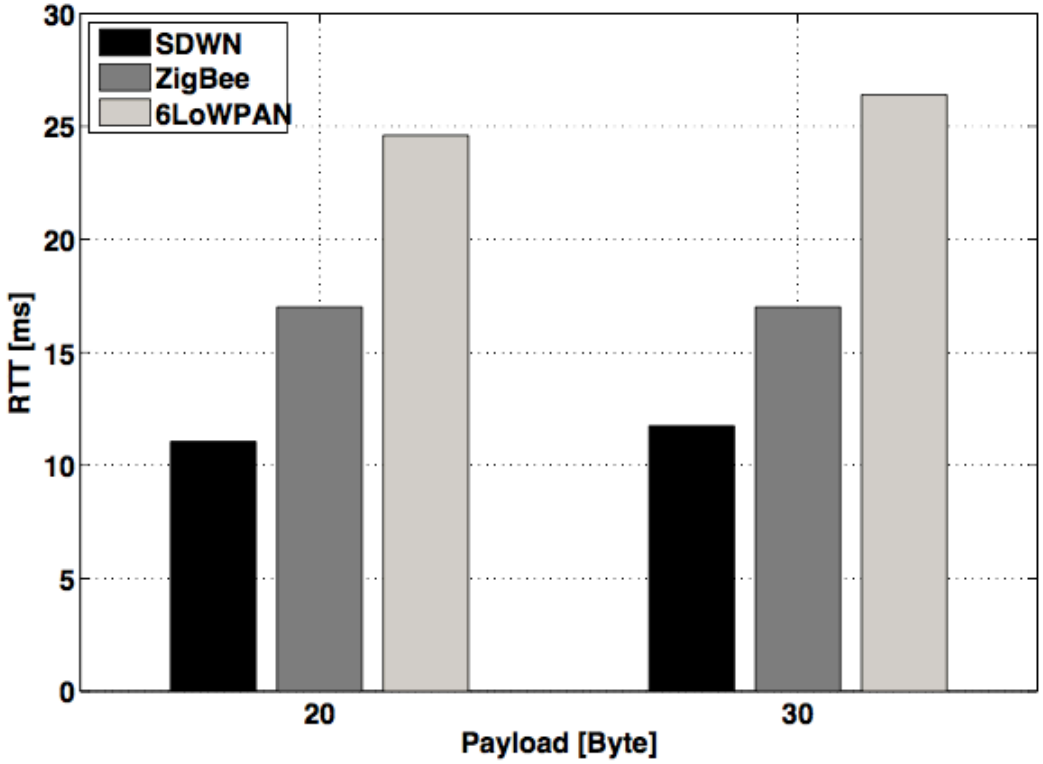


Fig. 5. Unicast traffic: RTT as a function of the payload size in the case of one hop and static conditions.

Multicast RTT

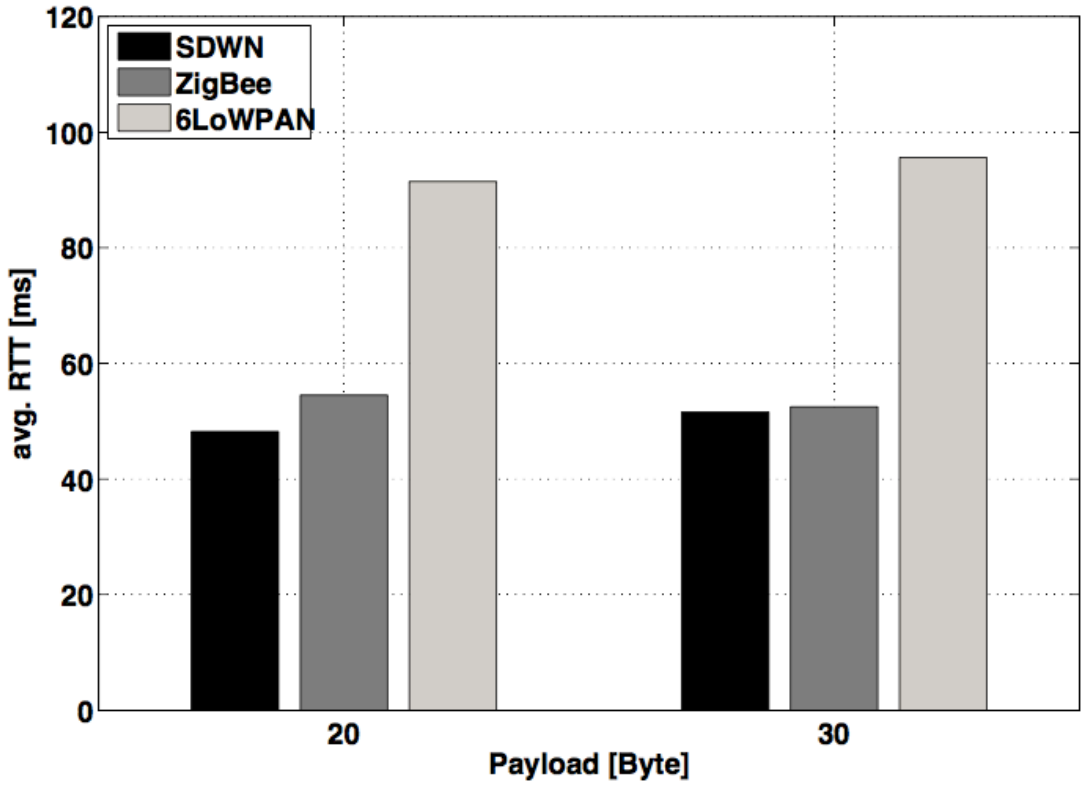


Fig. 7. Multicast traffic: Average RTT as a function of the payload size.

Multicast RTT

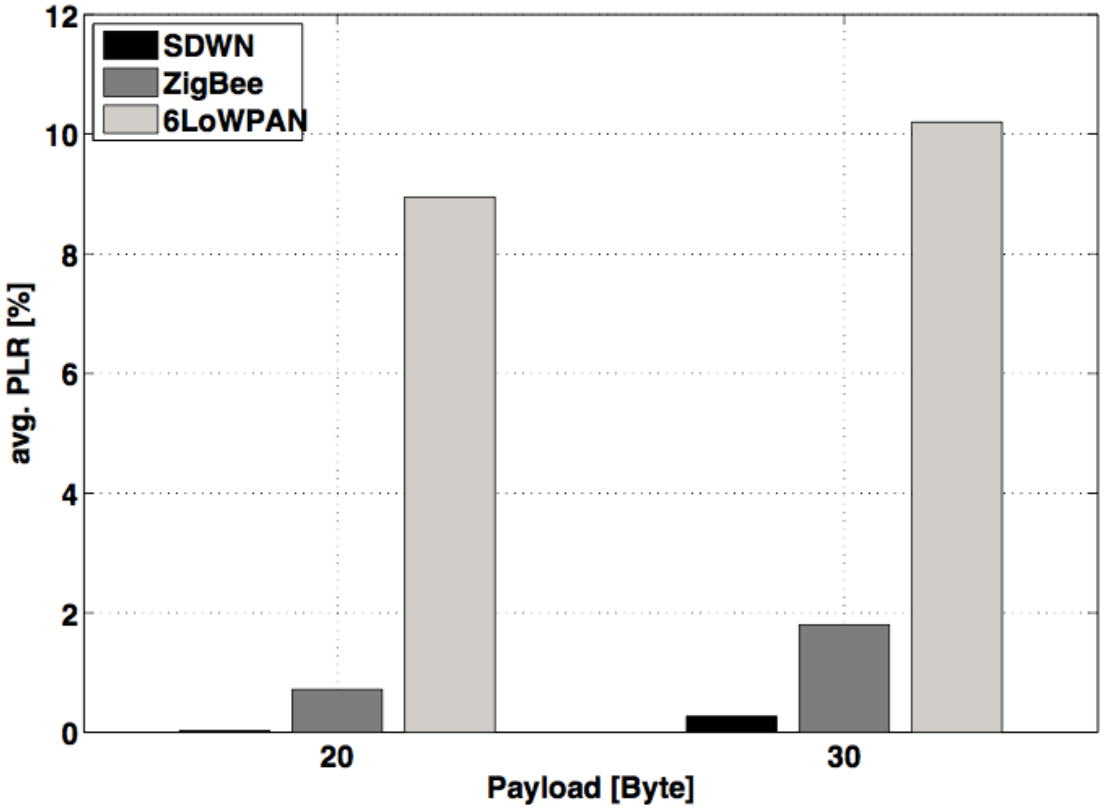
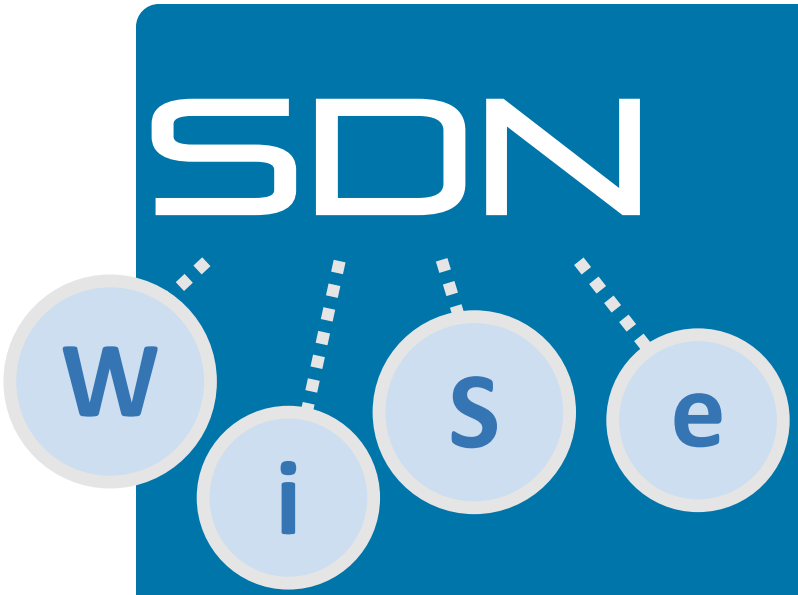


Fig. 8. Multicast traffic: Average PLR as a function of the payload size.



Conclusions and future work

Conclusions

- SDN-WISE is a SDN solution for WSNs
- SDN-WISE has several specific features designed to achieve efficiency in WSNs
- A prototype of SDN-WISE has been implemented and is **available for download:**

http://sdn-wise.dieei.unict.it

- EuWIN facility (Newcom#) has been exploited to run experimentation
- Performance comparison has been carried out with respect to ZigBee and 6LOWPAN

Current work

- Implement a framework for in-network processing in SDN-WISE
  - MapReduce approach
- Implementation in Contiki
- Integration with Open Network Operating System (ONOS)

Q&A

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