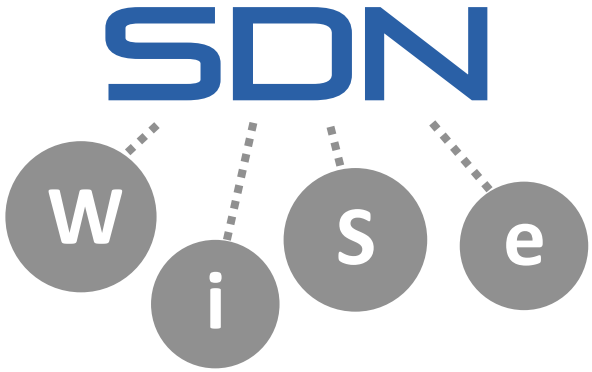
L. Galluccio, S. Milardo, G. Morabito, and S. Palazzo

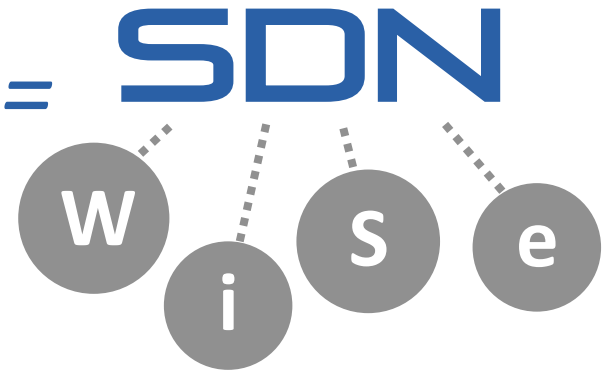


A “wise” choice for Wireless Sensor Networks Management, Experimentation, and Application Development

Presented by
Sebastiano Milardo
R&D Engineer @ CNIT-Catania

Cavalese, 15/01/2015

SDN + WIreless SEnsors =



- Requirements
  - Support nodes with scarce resources
  - Reduce energy consumption
  - Increase network flexibility
- Proposed solutions
  - Logically centralized approach
  - Flow rules, virtual sensor networks
  - Duty cycles, data aggregation, stateful SDN in WSN

SDN-WISE Statefulness

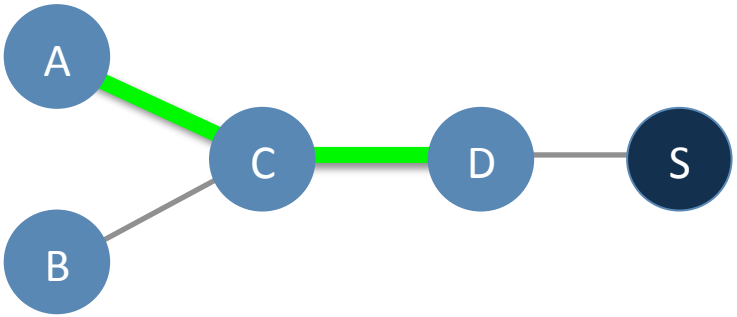


Fig.1: $Data_B \geq X_{thr}$

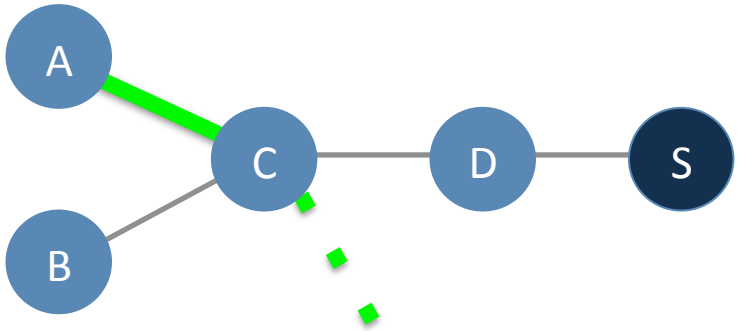


Fig.2: $Data_B < X_{thr}$

- Extremely hard to implement with traditional SDN solutions:
  - No packets handling depending on the content of another packet

G. Bianchi, M. Bonola, A. Capone, and C. Cascone.
OpenState: Programming Platform-independent Stateful OpenFlow Applications Inside the Switch.
ACM Computer Communication Review.
Vol. 44, No. 2, pp.: 45-51. April 2014.

SDN-WISE Simplicity

- Managing a WSN with SDN-WISE is simple
  - Firmware overhead ≈ 1000 lines of code ≈ 10kB Flash Memory
  - "C" + "Any other language that can handle UDP sockets or Web Services (SOAP, REST)"
  - The behaviour of each node is encoded in just three data structures:
    - WISE Flow Table
    - WISE State Array
    - Accepted IDs Array

Proposed Architecture: Control Plane

CONTROLLER

It controls network topology representation, routing and other parameters management

WISE-VISOR

It abstracts the network resources so different logical networks can be created

ADAPTATION

It formats packets received from the WSN (Real/Simulated) in such a way they can be handled by the upper layers and *vice versa*.

Proposed Architecture: Data Plane

TOPOLOGY DISCOVERY (TD)

It manages Parameters Configuration, Beaconing, Neighbours reporting

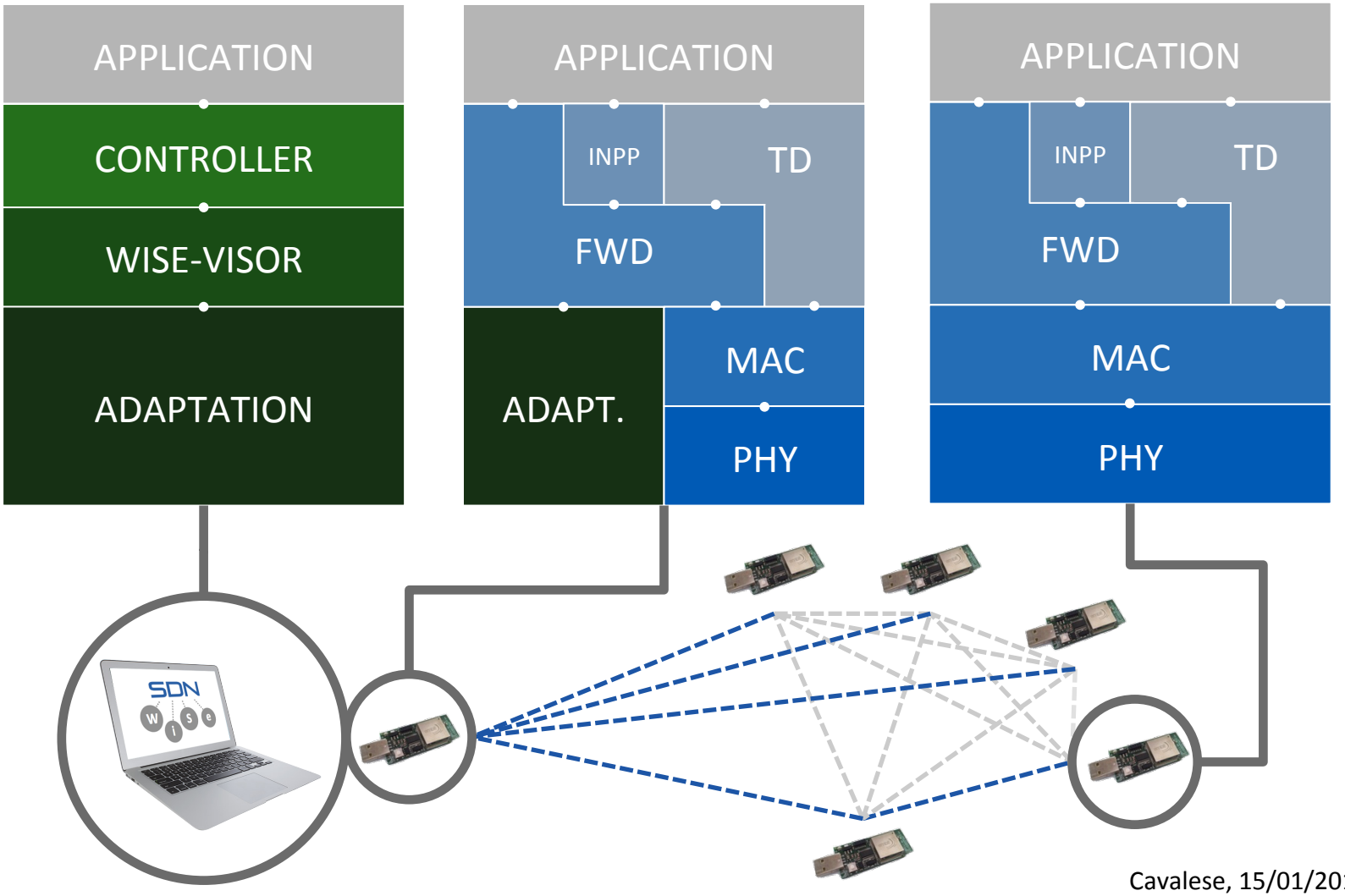
IN-NETWORK PACKET PROCESSING (INPP)

It is responsible for Data aggregation, *Network Coding, Compressive Sensing*

FORWARDING (FWD)

It handles incoming packets as specified in the WISE Flow Table

Example of SDN-WISE Network



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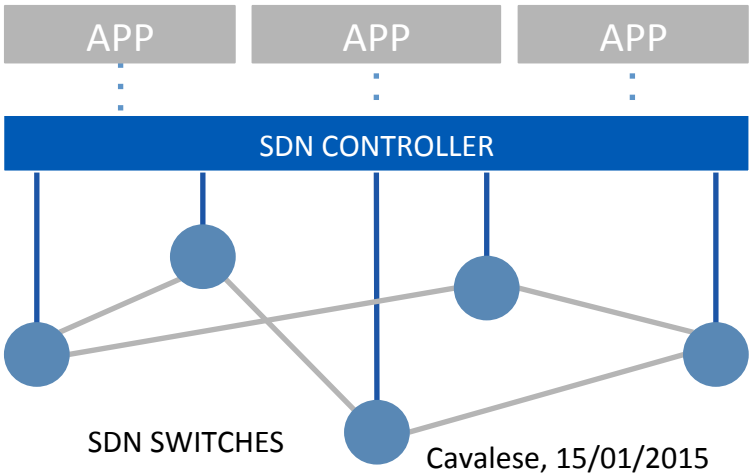
Setting up the network

- Targets
  - Nodes have to learn the best path to reach the Control Plane
  - The Control Plane has to create a representation of the network
- The protocol is based on
  - Beaconing
  - Periodic reporting of packets containing
    - Topological information
    - Battery level



WISE Flow Table

Matching Rule	
Operator	==,!=, >=, <=,>,<;
Size	0 - 2
Location	Packet, State Array
Offset	0 - 255;
Value	0x00 – 0xFF

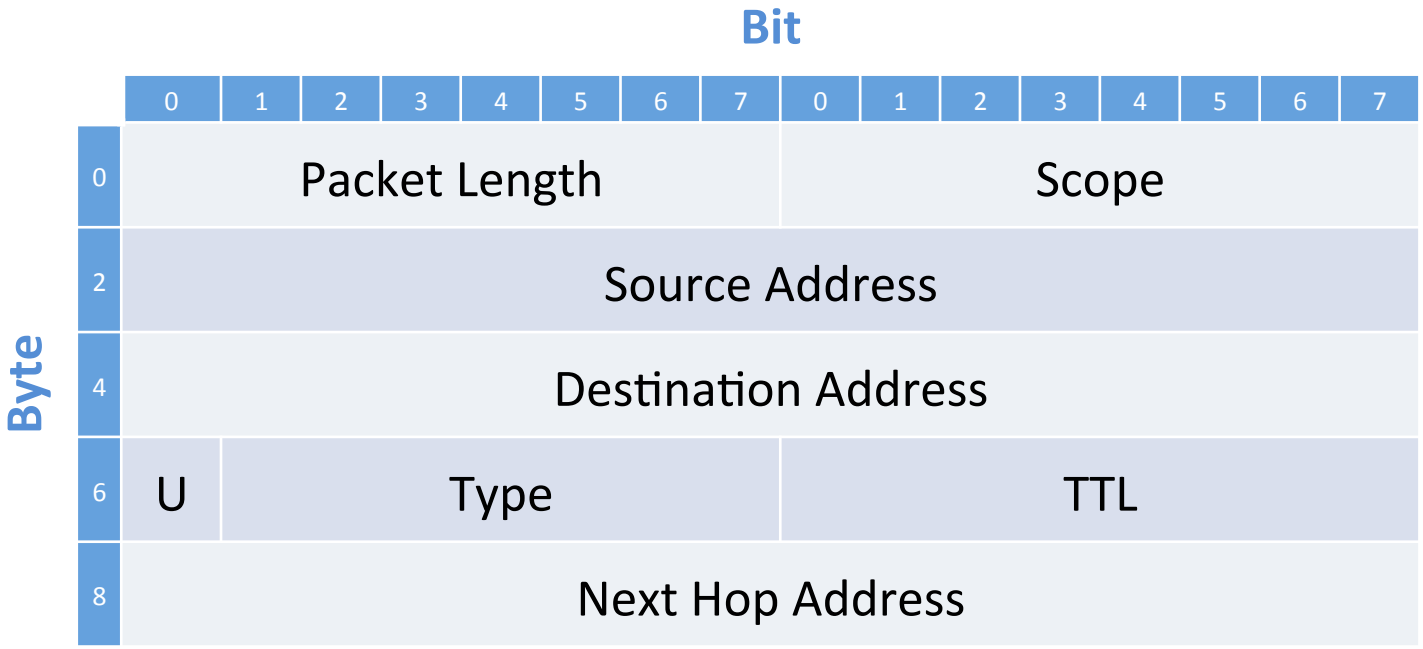
Action	
Type	Forward Unicast/Multicast, Drop, Modify, Send to INPP, Send to APP, Turn Off
Multimatch:	True/False
Location	Packet, State Array
Offset	0 - 255;
Value	0x00 – 0xFF

Statistics	
Time To Live	0 - 255
Counter	0 - 255

WISE Flow Table

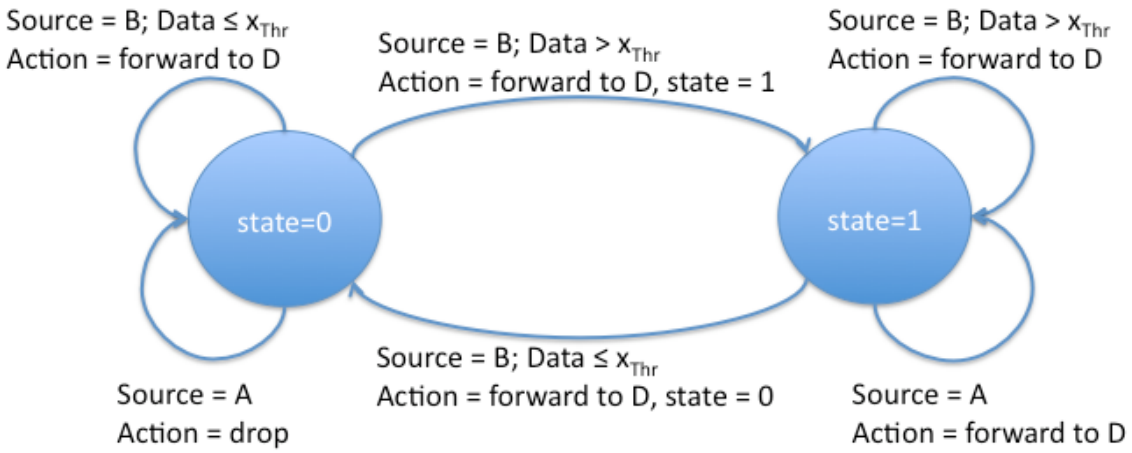
- If no rule matches a packet, the node asks the Control Plane
  - Rule Request
  - Rule Response
- The response is up to the Control Plane
  - Dijkstra's Algorithm
  - Static Routing
  - …

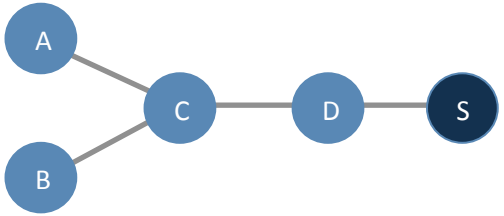
SDN-WISE: Packet Header



SDN-WISE Statefulness: Solution

Matching Rule					Matching Rule					Matching Rule					Action					Statistics	
Operator	Size	Location	Offset	Value	Operator	Size	Location	Offset	Value	Operator	Size	Location	Offset	Value	Type	Multimatch	Location	Offset	Value	TTL	Count
=	2	PACKET	SRC_ADDR	B	>=	2	PACKET	DATA	Xthr	=	1	STATE_ARR	0	0	MODIFY	TRUE	STATE_ARR	0	1	255	0
=	2	PACKET	SRC_ADDR	B	<	2	PACKET	DATA	Xthr	=	1	STATE_ARR	0	1	MODIFY	TRUE	STATE_ARR	0	0	255	0
=	2	PACKET	SRC_ADDR	B	-	-	-	-	-	-	-	-	-	-	FORWARD	FALSE	PACKET	0	D	255	0
=	2	PACKET	SRC_ADDR	A	=	1	STATE_ARR	0	0	-	-	-	-	-	DROP	FALSE	PACKET	0	100%	255	0
=	2	PACKET	SRC_ADDR	A	=	1	STATE_ARR	0	1	-	-	-	-	-	FORWARD	FALSE	PACKET	0	D	255	0





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SDN-WISE Statefulness: Solution

Matching Rule					Matching Rule					Matching Rule					Action					Statistics	
Operator	Size	Location	Offset	Value	Operator	Size	Location	Offset	Value	Operator	Size	Location	Offset	Value	Type	Multimatch	Location	Offset	Value	TTL	Count
=	2	PACKET	SRC_ADDR	B	>=	2	PACKET	DATA	Xthr	=	1	STATE_ARR	0	0	MODIFY	TRUE	STATE_ARR	0	1	255	0
=	2	PACKET	SRC_ADDR	B	<	2	PACKET	DATA	Xthr	=	1	STATE_ARR	0	1	MODIFY	TRUE	STATE_ARR	0	0	255	0
=	2	PACKET	SRC_ADDR	B	-	-	-	-	-	-	-	-	-	-	FORWARD	FALSE	PACKET	0	D	255	0
=	2	PACKET	SRC_ADDR	A	=	1	STATE_ARR	0	0	-	-	-	-	-	DROP	FALSE	PACKET	0	100%	255	0
=	2	PACKET	SRC_ADDR	A	=	1	STATE_ARR	0	1	-	-	-	-	-	FORWARD	FALSE	PACKET	0	D	255	0

Operator	Size	Location	Offset	Value	Operator	Size	Location	Offset	Value	Operator	Size	Location	Offset	Value
=	2	PACKET	SRC_ADDR	B	>=	2	PACKET	DATA	Xthr	=	1	STATE_ARR	0	0
=	2	PACKET	SRC_ADDR	B	<	2	PACKET	DATA	Xthr	=	1	STATE_ARR	0	1

SDN-WISE Statefulness: Solution

Matching Rule					Matching Rule					Matching Rule					Action					Statistics	
Operator	Size	Location	Offset	Value	Operator	Size	Location	Offset	Value	Operator	Size	Location	Offset	Value	Type	Multimatch	Location	Offset	Value	TTL	Count
=	2	PACKET	SRC_ADDR	B	>=	2	PACKET	DATA	Xthr	=	1	STATE_ARR	0	0	MODIFY	TRUE	STATE_ARR	0	1	255	0
=	2	PACKET	SRC_ADDR	B	<	2	PACKET	DATA	Xthr	=	1	STATE_ARR	0	1	MODIFY	TRUE	STATE_ARR	0	0	255	0
=	2	PACKET	SRC_ADDR	B	-	-	-	-	-	-	-	-	-	-	FORWARD	FALSE	PACKET	0	D	255	0
=	2	PACKET	SRC_ADDR	A	=	1	STATE_ARR	0	0	-	-	-	-	-	DROP	FALSE	PACKET	0	100%	255	0
=	2	PACKET	SRC_ADDR	A	=	1	STATE_ARR	0	1	-	-	-	-	-	FORWARD	FALSE	PACKET	0	D	255	0

Type	Multimatch	Location	Offset	Value
MODIFY	TRUE	STATE_ARR	0	1
MODIFY	TRUE	STATE_ARR	0	0

SDN-WISE Statefulness: Solution

Matching Rule					Matching Rule					Matching Rule					Action					Statistics	
Operator	Size	Location	Offset	Value	Operator	Size	Location	Offset	Value	Operator	Size	Location	Offset	Value	Type	Multimatch	Location	Offset	Value	TTL	Count
=	2	PACKET	SRC_ADDR	B	>=	2	PACKET	DATA	Xthr	=	1	STATE_ARR	0	0	MODIFY	TRUE	STATE_ARR	0	1	255	0
=	2	PACKET	SRC_ADDR	B	<	2	PACKET	DATA	Xthr	=	1	STATE_ARR	0	1	MODIFY	TRUE	STATE_ARR	0	0	255	0
=	2	PACKET	SRC_ADDR	B	-	-	-	-	-	-	-	-	-	-	FORWARD	FALSE	PACKET	0	D	255	0
=	2	PACKET	SRC_ADDR	A	=	1	STATE_ARR	0	0	-	-	-	-	-	DROP	FALSE	PACKET	0	100%	255	0
=	2	PACKET	SRC_ADDR	A	=	1	STATE_ARR	0	1	-	-	-	-	-	FORWARD	FALSE	PACKET	0	D	255	0

Operator	Size	Location	Offset	Value
=	2	PACKET	SRC_ADDR	B

Type	Multimatch	Location	Offset	Value
FORWARD	FALSE	PACKET	0	D

SDN-WISE Statefulness: Solution

Matching Rule					Matching Rule					Matching Rule					Action					Statistics	
Operator	Size	Location	Offset	Value	Operator	Size	Location	Offset	Value	Operator	Size	Location	Offset	Value	Type	Multimatch	Location	Offset	Value	TTL	Count
=	2	PACKET	SRC_ADDR	B	>=	2	PACKET	DATA	Xthr	=	1	STATE_ARR	0	0	MODIFY	TRUE	STATE_ARR	0	1	255	0
=	2	PACKET	SRC_ADDR	B	<	2	PACKET	DATA	Xthr	=	1	STATE_ARR	0	1	MODIFY	TRUE	STATE_ARR	0	0	255	0
=	2	PACKET	SRC_ADDR	B	-	-	-	-	-	-	-	-	-	-	FORWARD	FALSE	PACKET	0	D	255	0
=	2	PACKET	SRC_ADDR	A	=	1	STATE_ARR	0	0	-	-	-	-	-	DROP	FALSE	PACKET	0	100%	255	0
=	2	PACKET	SRC_ADDR	A	=	1	STATE_ARR	0	1	-	-	-	-	-	FORWARD	FALSE	PACKET	0	D	255	0

Operator	Size	Location	Offset	Value	Operator	Size	Location	Offset	Value
=	2	PACKET	SRC_ADDR	A	=	1	STATE_ARR	0	0
=	2	PACKET	SRC_ADDR	A	=	1	STATE_ARR	0	1

SDN-WISE Statefulness: Solution

Matching Rule					Matching Rule					Matching Rule					Action					Statistics	
Operator	Size	Location	Offset	Value	Operator	Size	Location	Offset	Value	Operator	Size	Location	Offset	Value	Type	Multimatch	Location	Offset	Value	TTL	Count
=	2	PACKET	SRC_ADDR	B	>=	2	PACKET	DATA	Xthr	=	1	STATE_ARR	0	0	MODIFY	TRUE	STATE_ARR	0	1	255	0
=	2	PACKET	SRC_ADDR	B	<	2	PACKET	DATA	Xthr	=	1	STATE_ARR	0	1	MODIFY	TRUE	STATE_ARR	0	0	255	0
=	2	PACKET	SRC_ADDR	B	-	-	-	-	-	-	-	-	-	-	FORWARD	FALSE	PACKET	0	D	255	0
=	2	PACKET	SRC_ADDR	A	=	1	STATE_ARR	0	0	-	-	-	-	-	DROP	FALSE	PACKET	0	100%	255	0
=	2	PACKET	SRC_ADDR	A	=	1	STATE_ARR	0	1	-	-	-	-	-	FORWARD	FALSE	PACKET	0	D	255	0

Type	Multimatch	Location	Offset	Value
DROP	FALSE	PACKET	0	100%
FORWARD	FALSE	PACKET	0	D

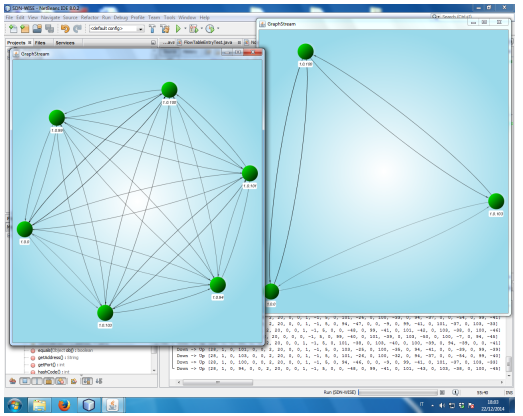
Cavalese, 15/01/2015

SDN-WISE: Prototype and Testbeds

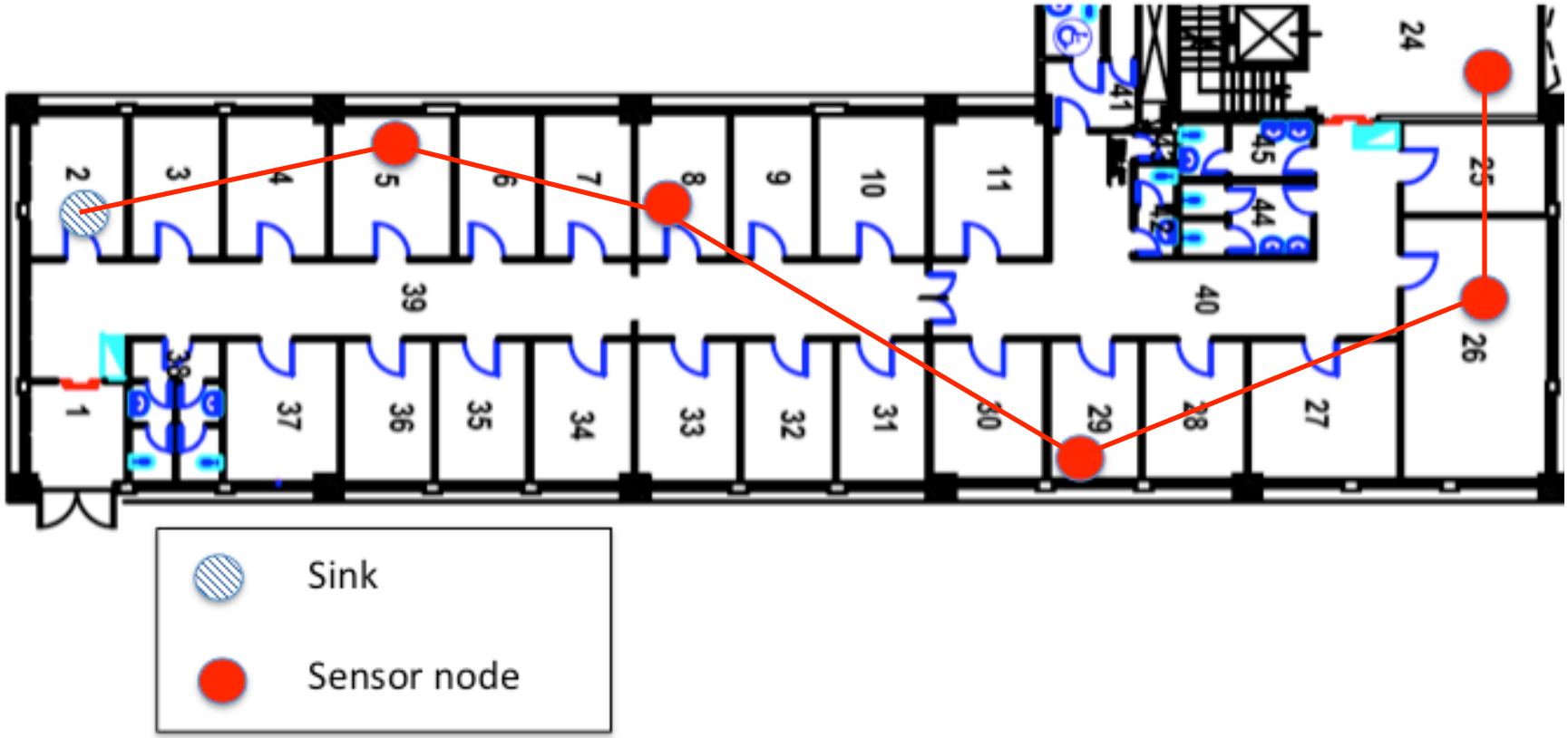
- Simulated Testbed
  - OMNeT++

- Real Testbed
  - 6 Embit EMB-Z2530PA
  - IEEE 802.15.4
  - TI CC2530 single chip device - 8051 8-bit controller
  - 8kB of RAM and 256kB of Flash memory

- Controller Plane + Application
  - Intel Core 2 CPU @ 2.40 GHz
  - 4GB of RAM
  - Windows 7 - 32 bit + Java 7

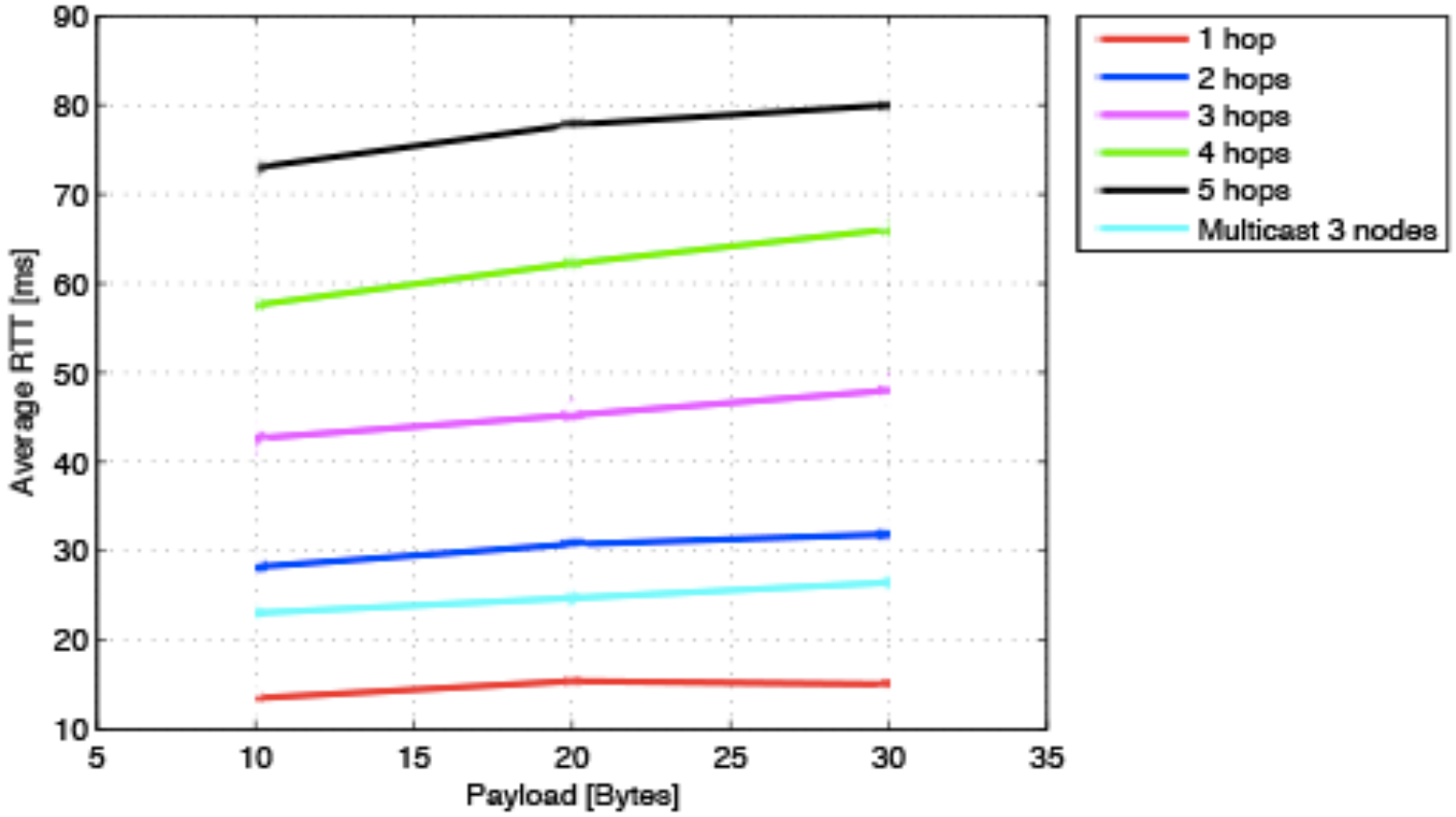


Physical Testbed



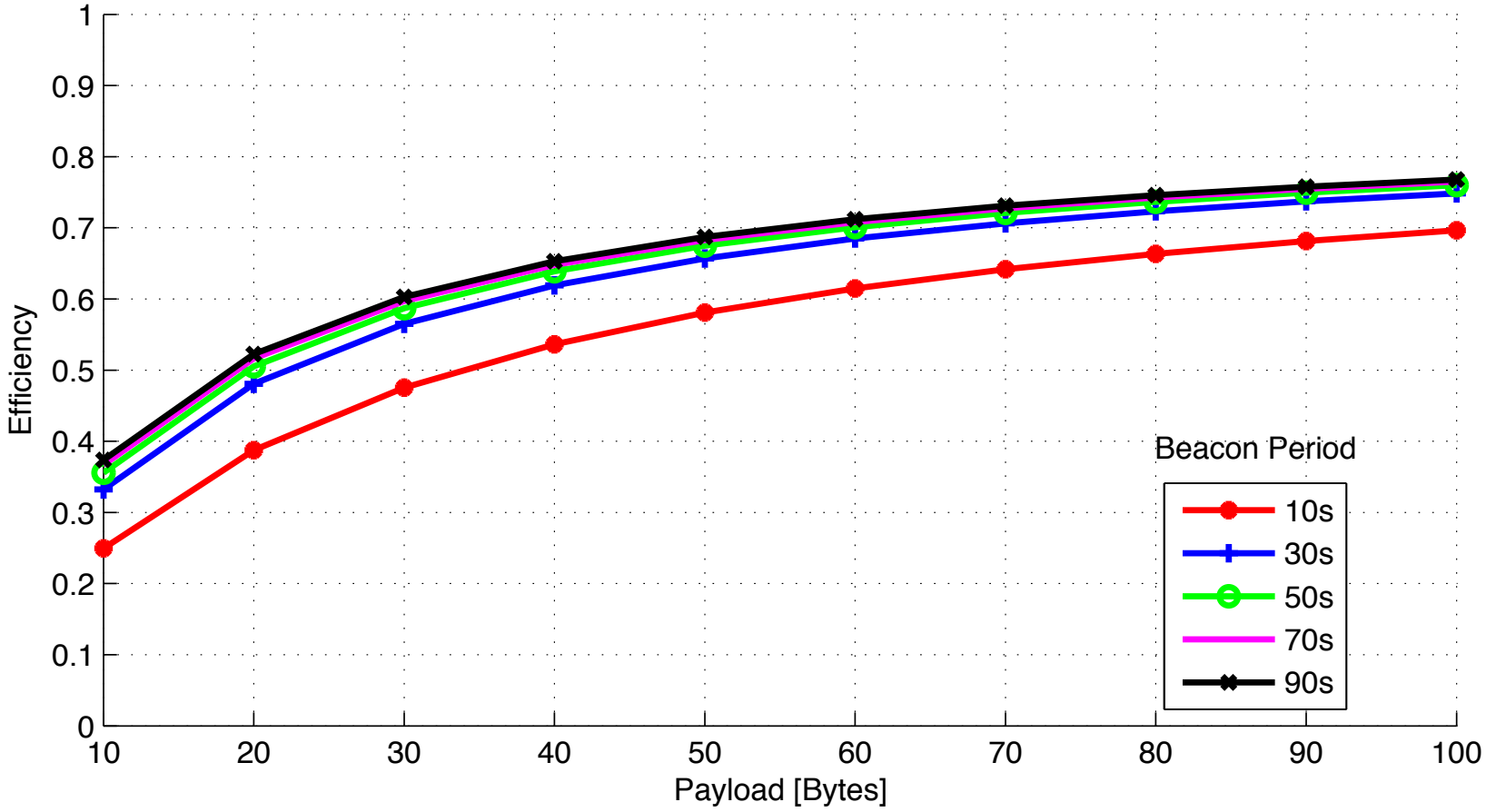
Performance Evaluation

Average RTT vs. payload size for different values of number of hops



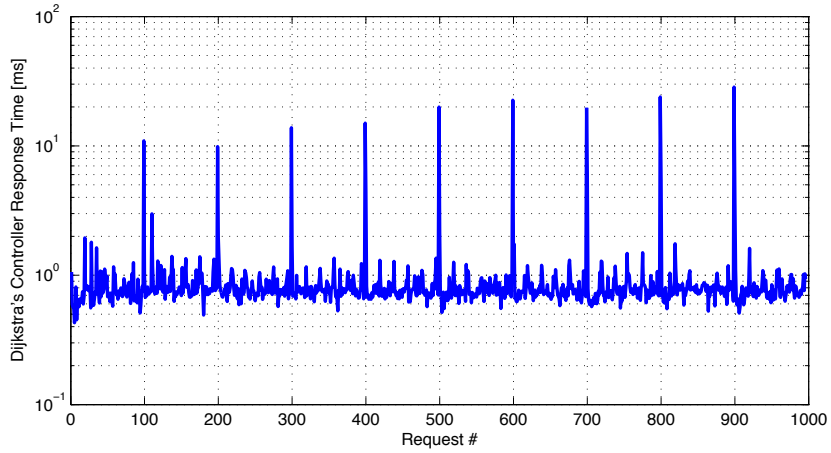
Performance Evaluation

Efficiency for different values of beacon sending period

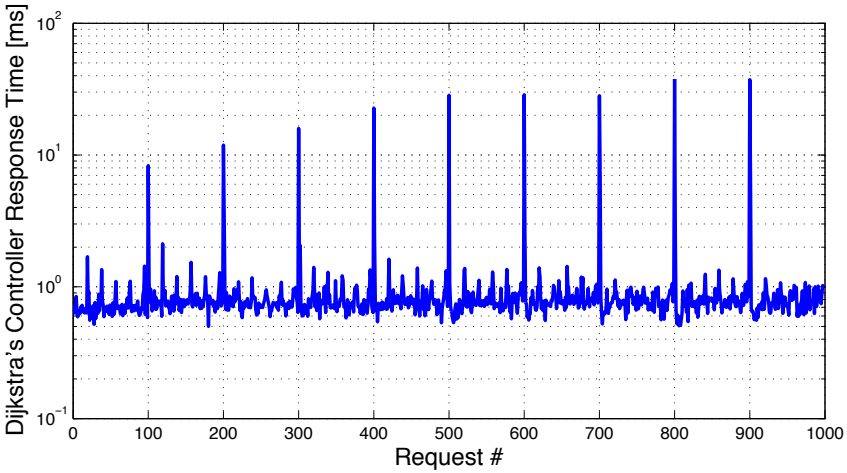


Performance Evaluation

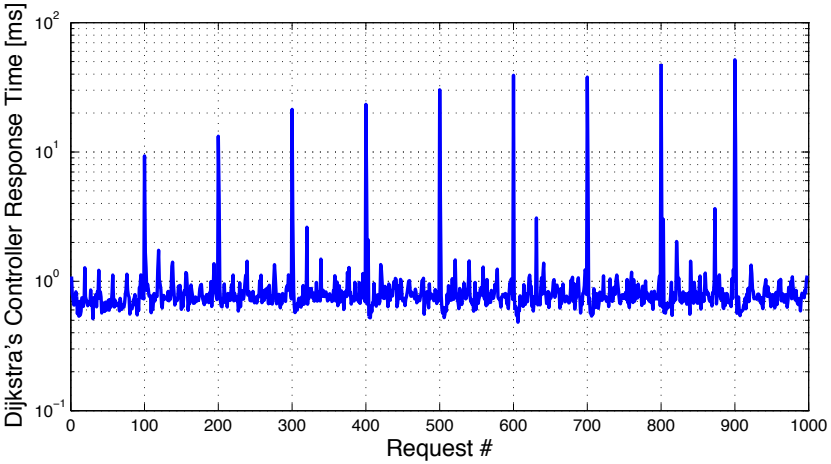
Controller response time for different topologies



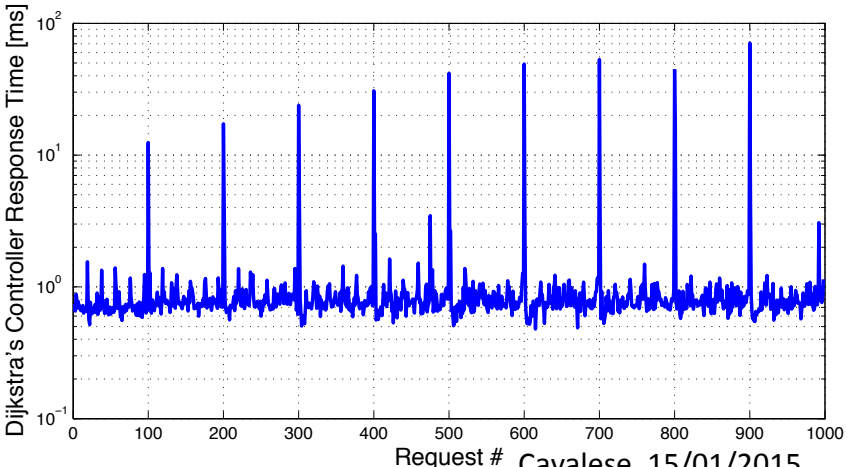
40 Nodes



50 Nodes



60 Nodes

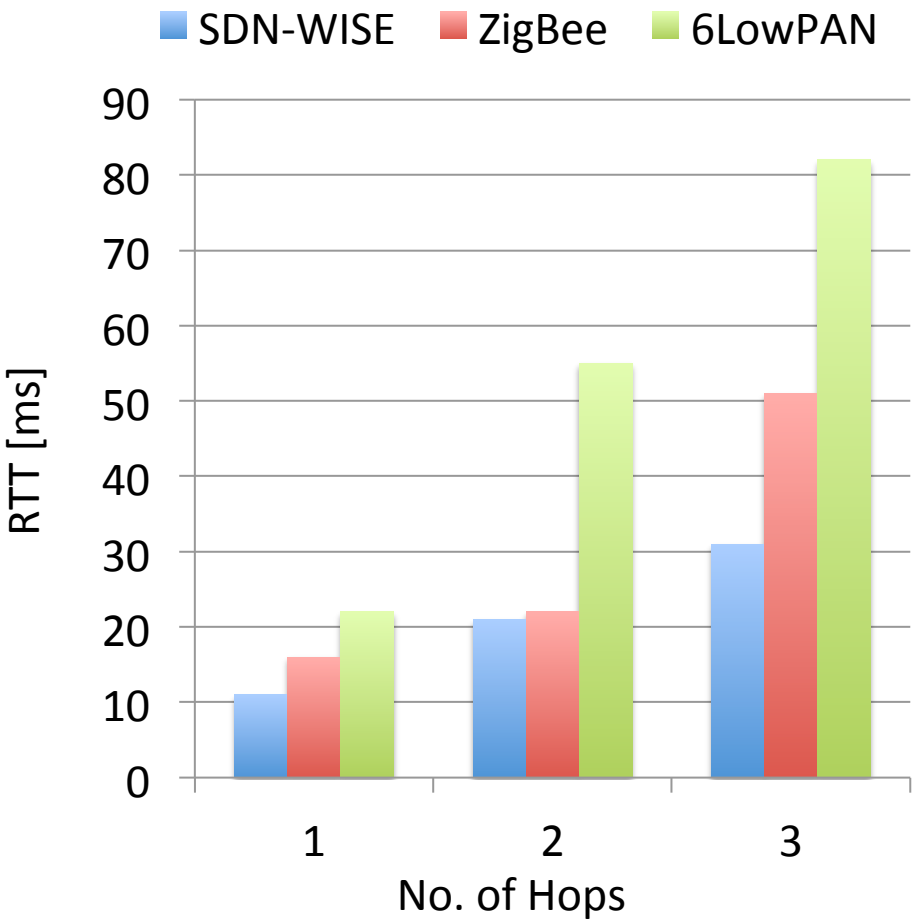


70 Nodes

Performance Evaluation

Unicast traffic: RTT as a function of the number of hops when transmitting 20 bytes of payload

SDN-WISE vs ZigBee vs 6LowPan



C. Buratti, G. Gardasevic, S. Milardo, M. D. Abrignani, S. Mijovic, A. Stajkic, G. Morabito, and R. Verdone.
Testing Protocols for The Internet of Things on The EuWIn Platform
Submitted to IEEE Internet of Things Journal

Conclusions and Future Work

- We presented a stateful SDN solution for WSN
- We highlighted how this approach can simplify management and increase flexibility
- Open Issues: Security, INPP, QoS
- http://www.diit.unict.it/users/gmorabi/

Further details can be found in our paper:

L. Galluccio, S. Milardo, G. Morabito, and S. Palazzo.

SDN-WISE: design, prototyping and experimentation of a stateful SDN solution for WIreless SEnsor networks

In *The 34th Annual IEEE International Conference on Computer Communications (INFOCOM 2015)*,

Hong Kong, P.R. China, April 2015

Questions?