From Reactive to Predictive Flow Instantiation: An Artificial Neural Network Approach to the SD-IoT

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Problem Statement

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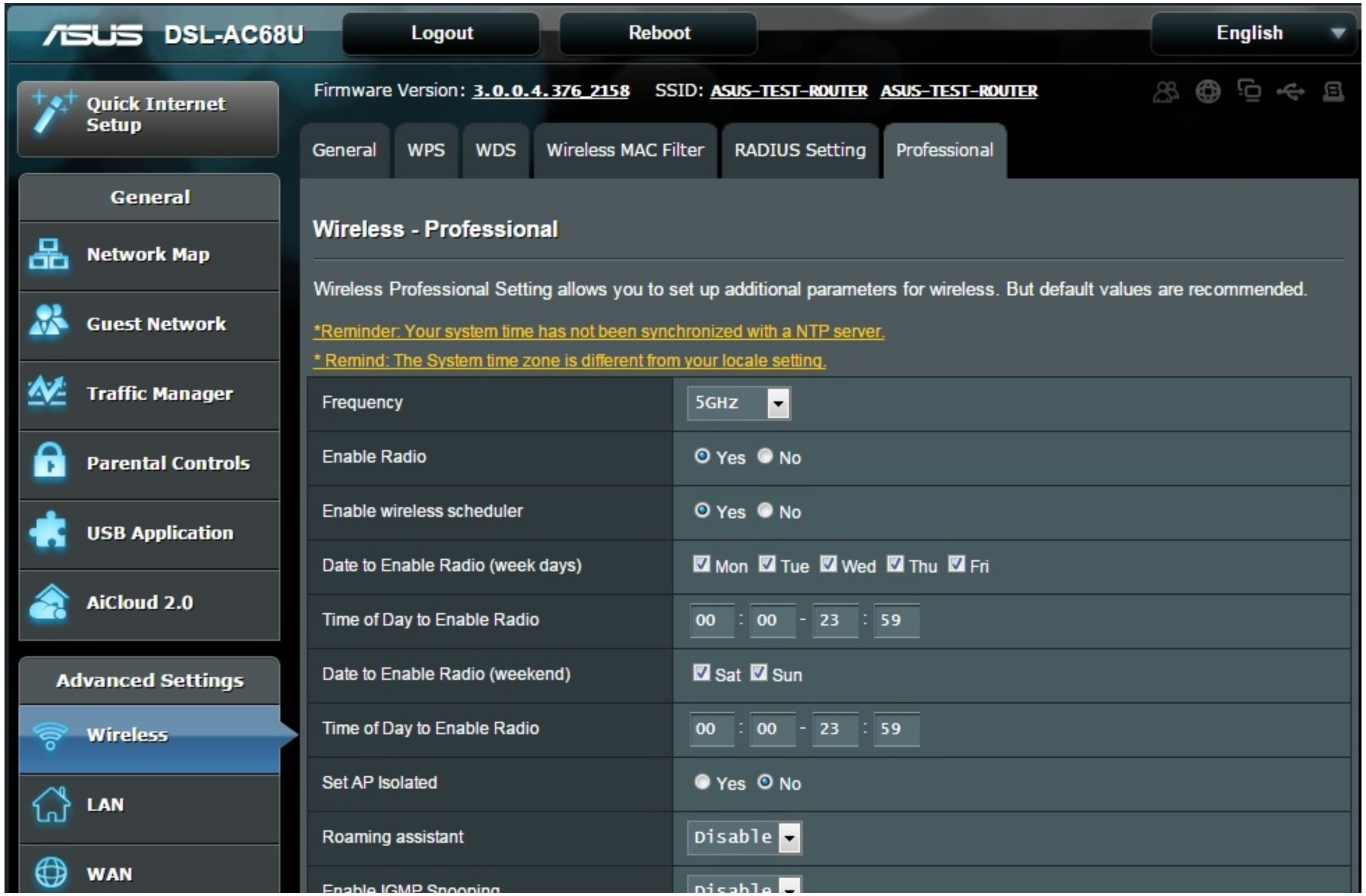
- IoT devices and in particular wireless sensor nodes, aim at achieving high efficiency with low power consumption.
- Is it possible to exploit tidal effects to increase the lifetime of a Wireless Sensor Network?
- Is there a simple way to implement such solution?

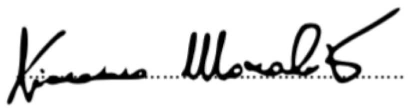
Problem Statement



Problem Statement

- Our goal:

"We want to make life easier for (network) developers"



SDN

SDN

- Control Plane: Forwarding Control logic
  - E.g. Routing protocols

- Data Plane: Forwards the packets/flows according to the specific rules imposed by the control plane
  - IP forwarding, lvl 2 Switching

↓

Network Programmability

SDN

```
# All the packets towards  192.168.101.101:80
should be sent on port 4

msg = of.ofp_flow_mod()
msg.match.nw_dst = IPAddr("192.168.101.101")
msg.match.tp_dst = 80
msg.actions.append(of.ofp_action_output(port = 4))
self.connection.send(msg)
```

Problem solved (?)

SDN: Towards Intelligent Control Planes

- Declarative Programming Languages

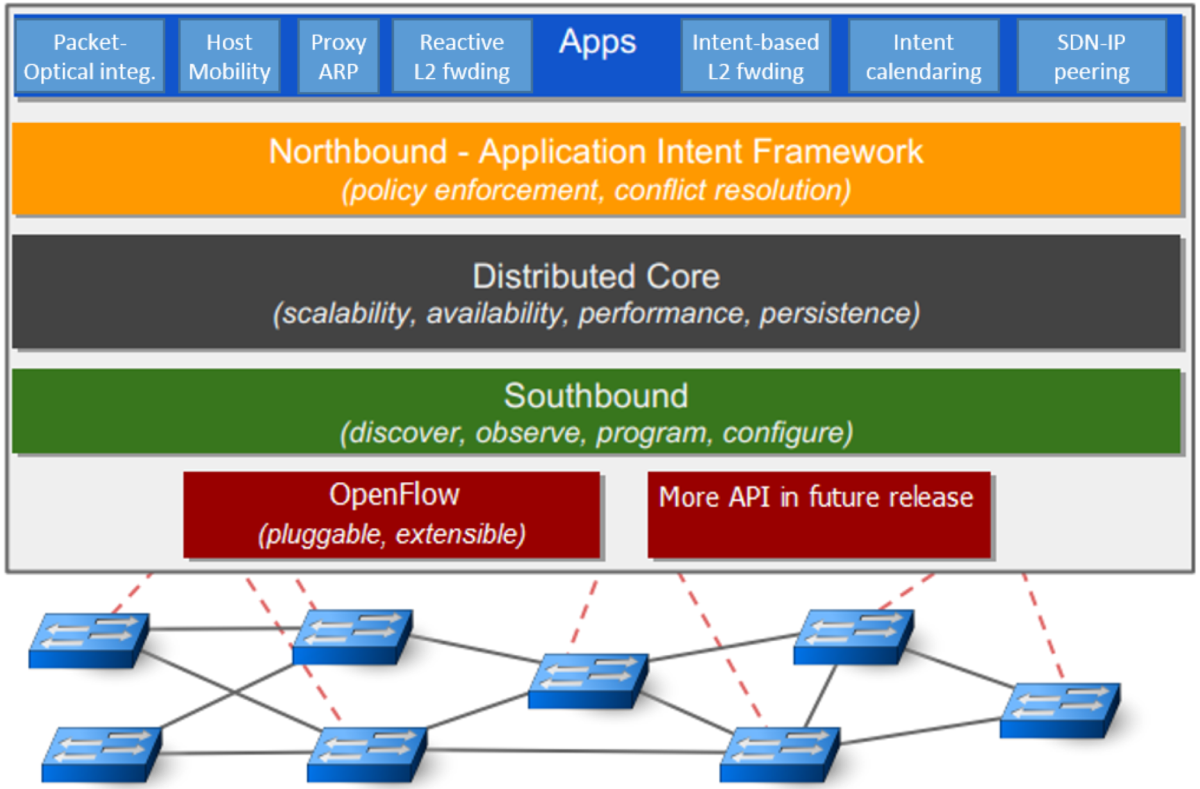
```
SELECT * from dogs
INNER JOIN owners
WHERE dogs.owner_id = owners.id
```

- Imperative Programming Languages

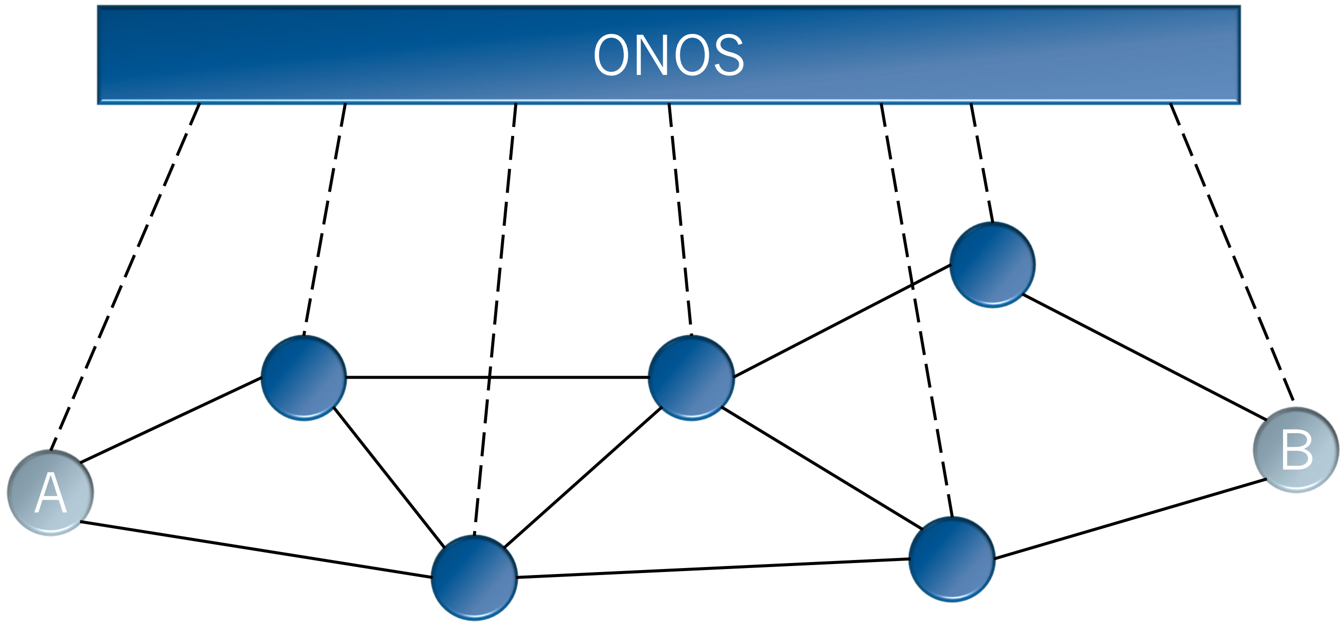
```
//dogs = [{name: 'Fido', owner_id: 1}, {...}, ... ]
//owners = [{id: 1, name: 'Bob'}, {...}, ...]

var dogsWithOwners = []
var dog, owner

for(var di=0; di < dogs.length; di++) {
  dog = dogs[di]

  for(var oi=0; oi < owners.length; oi++) {
    owner = owners[oi]
    if (owner && dog.owner_id == owner.id) {
      dogsWithOwners.push({
        dog: dog,
        owner: owner
      })
    }
  }}
}
```

SDN: NOS

Open Network Operating System



SDN: NOS - Intent



SDN: Intelligent Control Plane – Baby Steps

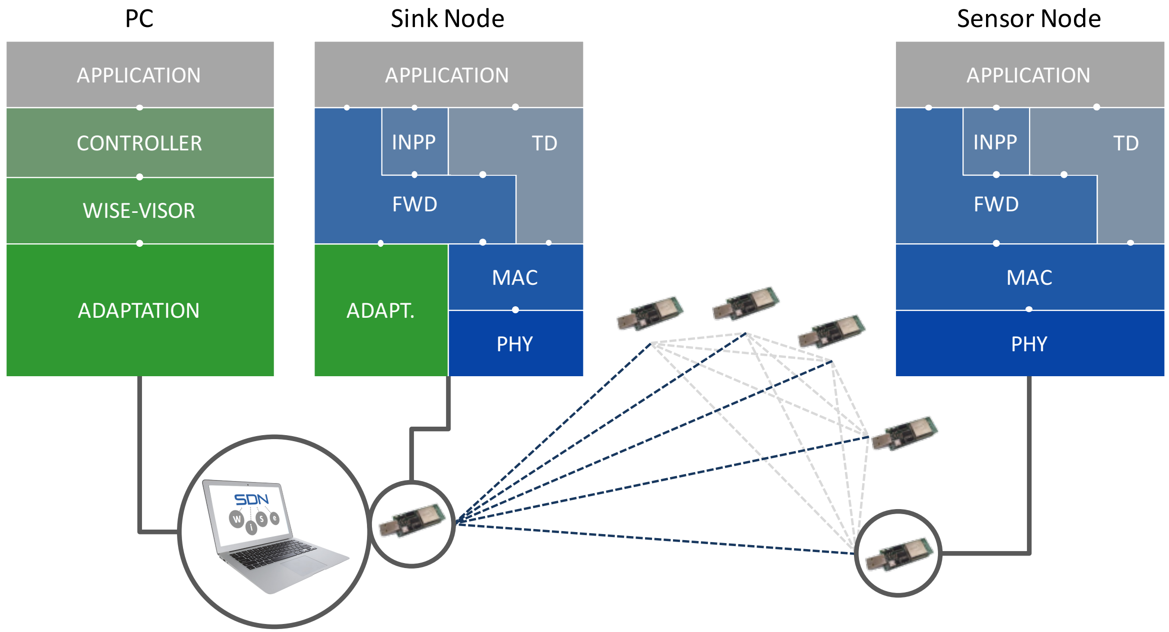
- Ask the NOS to implement a certain property in the controlled network
- Let the NOS install all the required rules to achieve such goal

Proposed Solution

Proposed Architecture – SDN-WISE

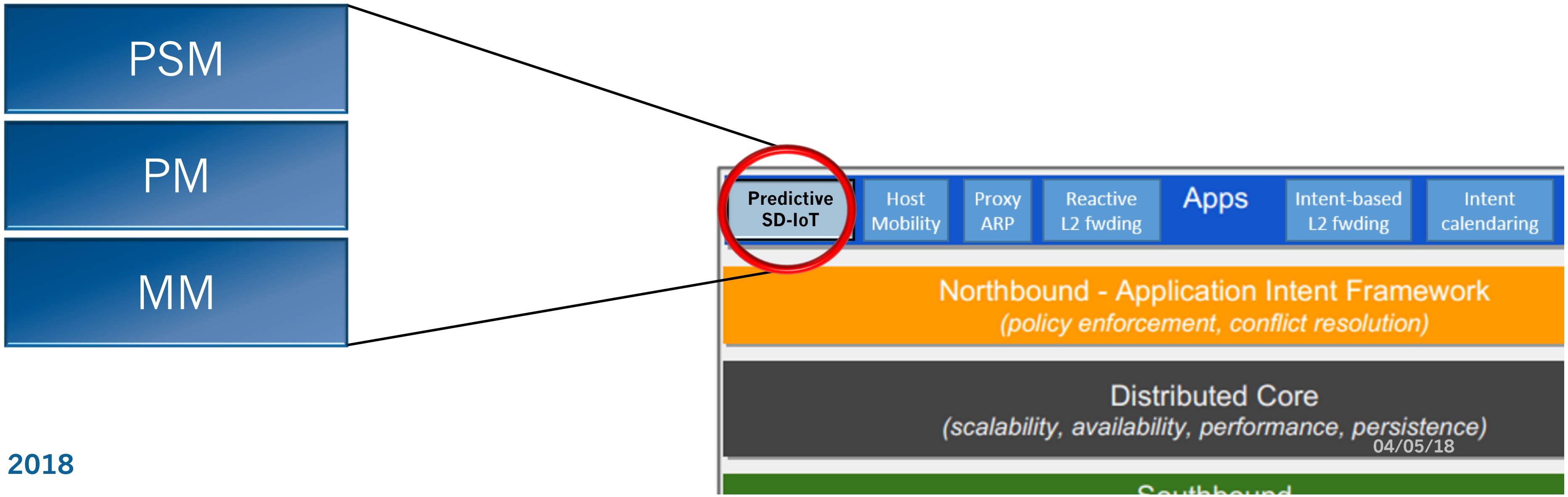
- L. Galluccio, S. Milardo, G. Morabito, and S. Palazzo. SDN-WISE: Design, prototyping and experimentation of a stateful SDN solution for WIreless SEnsor networks. Proc. of IEEE INFOCOM 2015. April 2015.

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



Proposed Architecture – Predictive SD-IoT

- Performance Specification module (PSM)
- Measurement module (MM)
- Prediction module (PM)



Proposed Architecture – Predictive SD-IoT

- Performance Specification module: it accepts the requirements from the user and translates such requirements into an objective function (e.g. fairness).

- Measurement module: it is based on the ONOS REST APIs which are used to collect the amount of traffic traversing each link of the network

- Prediction module: it includes the LSTM-ANNs used for predicting network patterns

Proposed Architecture – ANN

- We used Long Short-Term Memory ANN in the prediction module as it is regarded as the State of the Art for time series prediction.

- In our case we used LSTM-ANNs with 3 layers: 4 neurons in the input layer (one for each variable considered: day of the week, hour of the day, holiday, no. of generated packets) 50 neurons in the hidden layer, and one neuron in the output layer.

Routing Strategy

$$w'(x,y) = a \cdot w(x,y) + (1-a) \cdot p(y)$$

- where ***w*** is the weight of the edge between nodes *x* and *y*,
- ***p(y)*** is the amount of packets sent by the node *y*, as predicted by the LSTM-ANN,
- ***a*** is the tuning parameter imposed by the performance specification module based on the user's preferences.

Testbed

Testbed


CERTIFICATE *of* ACHIEVEMENT

THIS ACKNOWLEDGES THAT

Akhilesh Venkatasubramanian (SSN College of Engineering), **Sebastiano Milardo** (University of Catania), **Krithika Vijayan** (SSN College of Engineering) and **Giacomo Morabito** (University of Catania)

HAVE EARNED THE FESTIVAL AWARD FOR "BEST EUROPEAN FESTIVAL EXPERIMENT"

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FESTIVAL

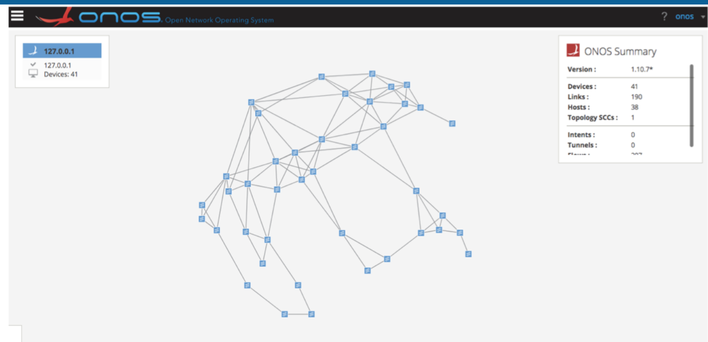
Levent Gürgen
FESTIVAL Project Coordinator

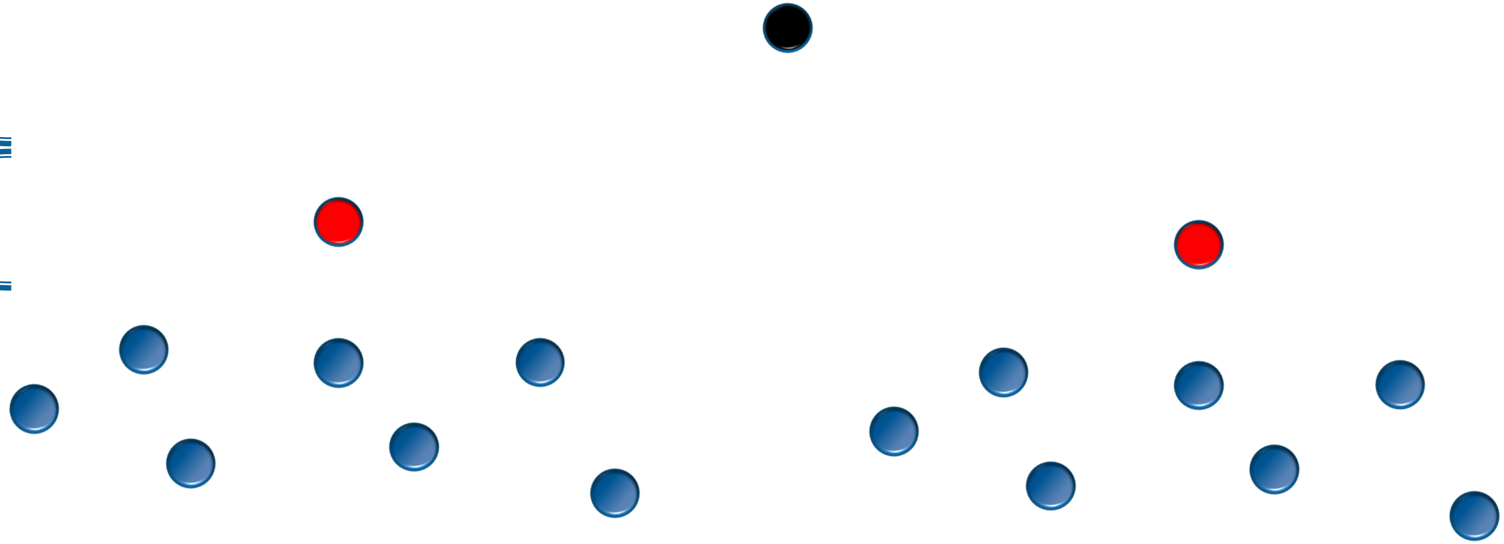
November 10th, 2017

- 309 wireless sensor nodes
- 37 wireless relay nodes
- 3 gateways
- 1,580,807 messages
- from January 1, 2016 to December 31, 2016

Simulations

- Onos
- Mininet
- Cooja





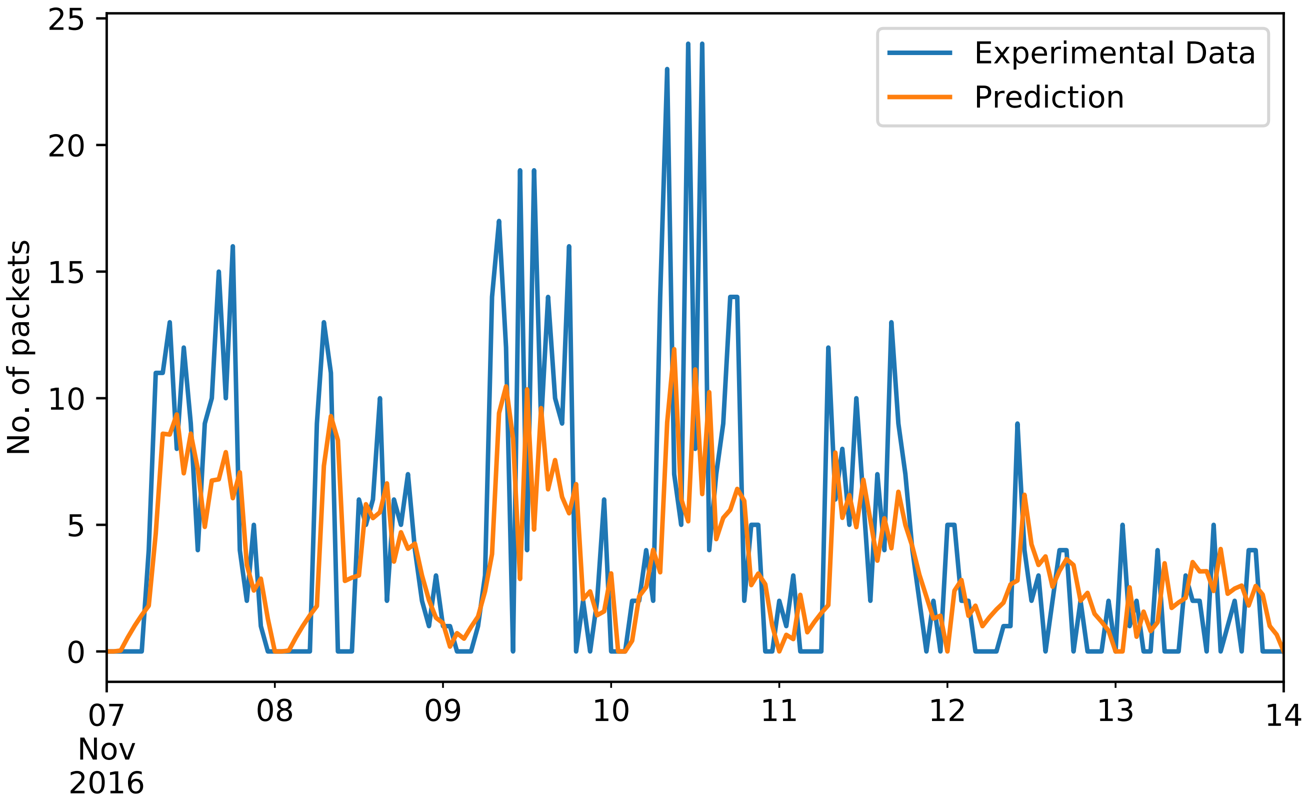
Predictive Flow Instantiation

Algorithm 1 Prediction Algorithm

```
traffic = []
topo = getNetworkTopology()
weightedTopo = setWeights(a=1, b=0, topo)
pThreshold = getThreshold()
while (1) do
    currentTraffic = getTrafficData()
    traffic.append(currentTraffic)
    prediction = predictTraffic(traffic)
    pCurrent = getPacketsToBeSent(weightedTopo)
    newWeightedTopo = setWeights(a, b, topo, traffic)
    pPredicted = getPacketsToBeSent(newWeightedTopo)
    pRules = getUpdateCost(weightedTopo)
    if (pCurrent >pPredicted + pThreshold + pRules) then
        paths = Dijkstra(newWeightedTopology)
        updateFlowRules(paths)
        weightedTopo = newWeightedTopo
    end if
    waitForNextSlot()
end while
```

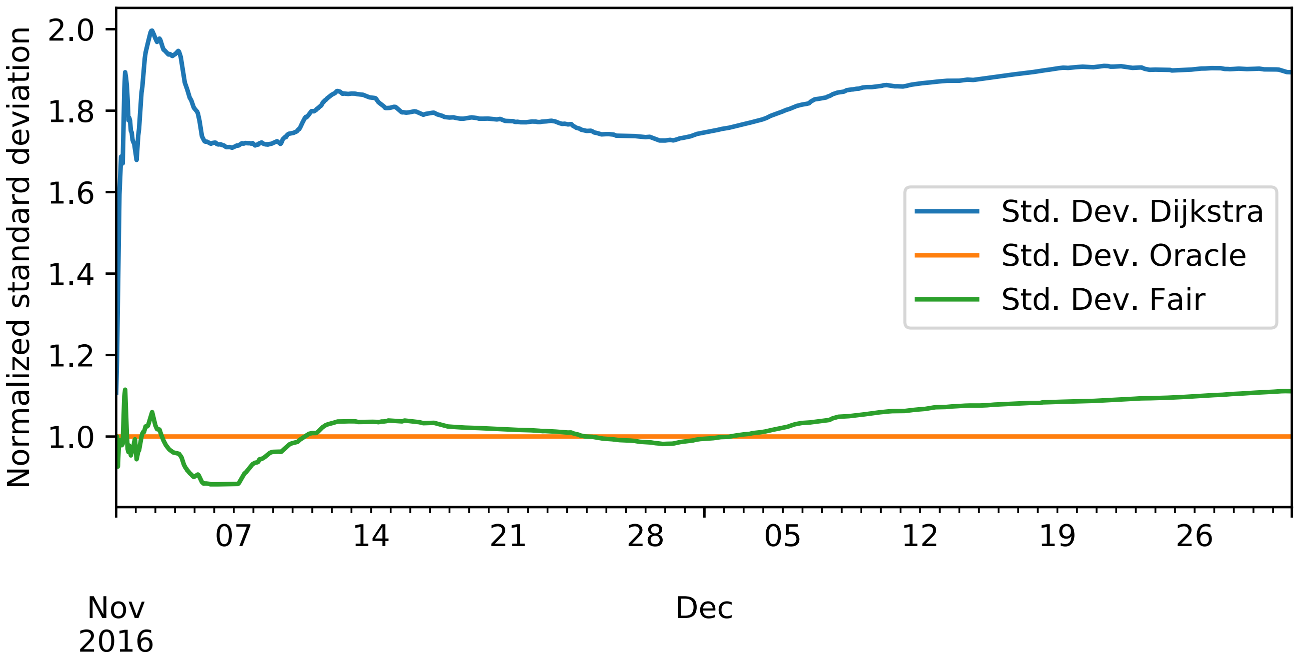
Results

Results



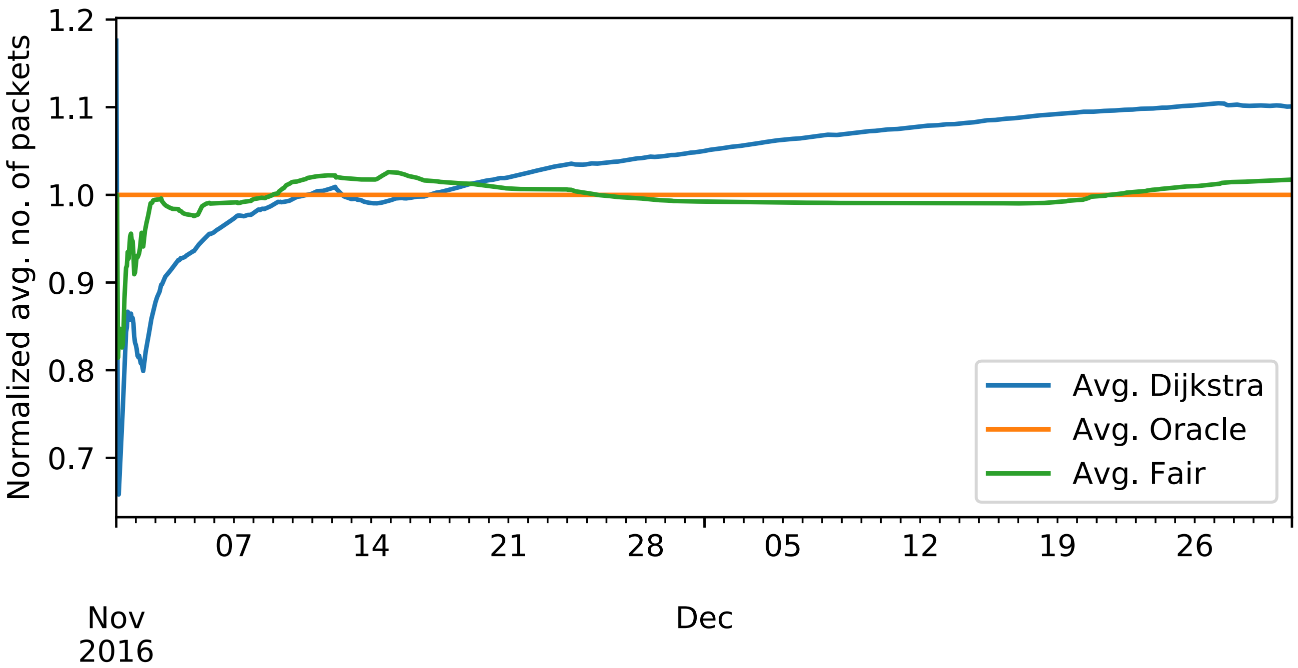
Experimental Data
Prediction
No. of packets
0
5
10
15
20
25
07
Nov
2016
08
09
10
11
12
13
14

Results



Normalized standard deviation
2.0
1.8
1.6
1.4
1.2
1.0
07
14
21
28
05
12
19
26
Nov
2016
Dec
Std. Dev. Dijkstra
Std. Dev. Oracle
Std. Dev. Fair

Results



1.2
1.1
1.0
0.9
0.8
0.7
Normalized avg. no. of packets
07
14
21
28
05
12
19
26
Nov
2016
Dec
Avg. Dijkstra
Avg. Oracle
Avg. Fair

Conclusions

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- We have presented a general architecture for an SD-IoT management system based on a LSTM-ANN. We tested our approach on a real dataset inside a simulated environment.
- The proposed solution aims at providing the starting point for a wider declarative, SDN-based, predictive flow rule instantiation system

Thanks