

IoT4D

Internet of Things for developing countries

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Objectives

Why

Foster Internet of Things technologies

- Developing technologies
 - developing countries
- Useful monitoring
 - environment, agriculture, safety
- Not expensive
 - sensors less 60 K CFA
- Easy to deploy
 - wireless communication



Context

Standardized Wireless Sensors Networks

- Sensor : physical device
 - sensing capability
 - temperature, humidity, motion...
 - CPU
 - low power, low memory
 - powerful enough to be computational resource
 - OS : Contiki, TinyOS, Riot
 - wireless communication
 - low power (IEEE 802.15.4), low range
 - low throughput (250 Kbps, 127 bytes)
 - battery powered
 - communication is the most energy drain

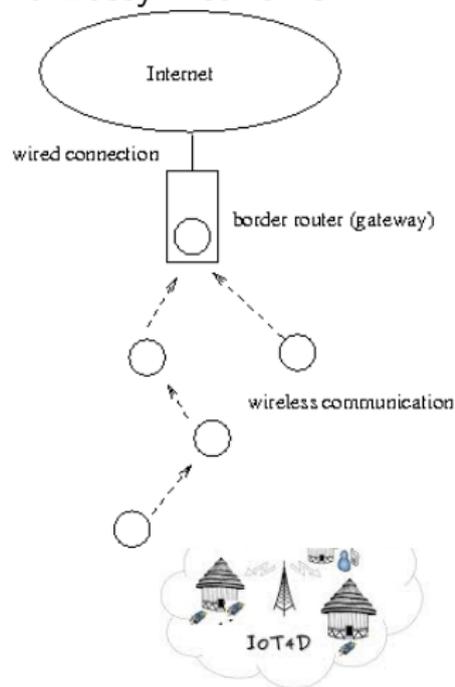


Context

Standardized Wireless Sensors Networks

RPL : IPv6 Routing Protocol for Low-Power and Lossy Networks

- Internet standard (RFC 6550 ...)
- Build an optimal communication network
 - between sensors
 - toward Internet acces point
- Contribution [IEEE SensAPP 2015]
 - optimal based on several metrics
 - QoS, battery, shortest path
 - fuzzy logic design



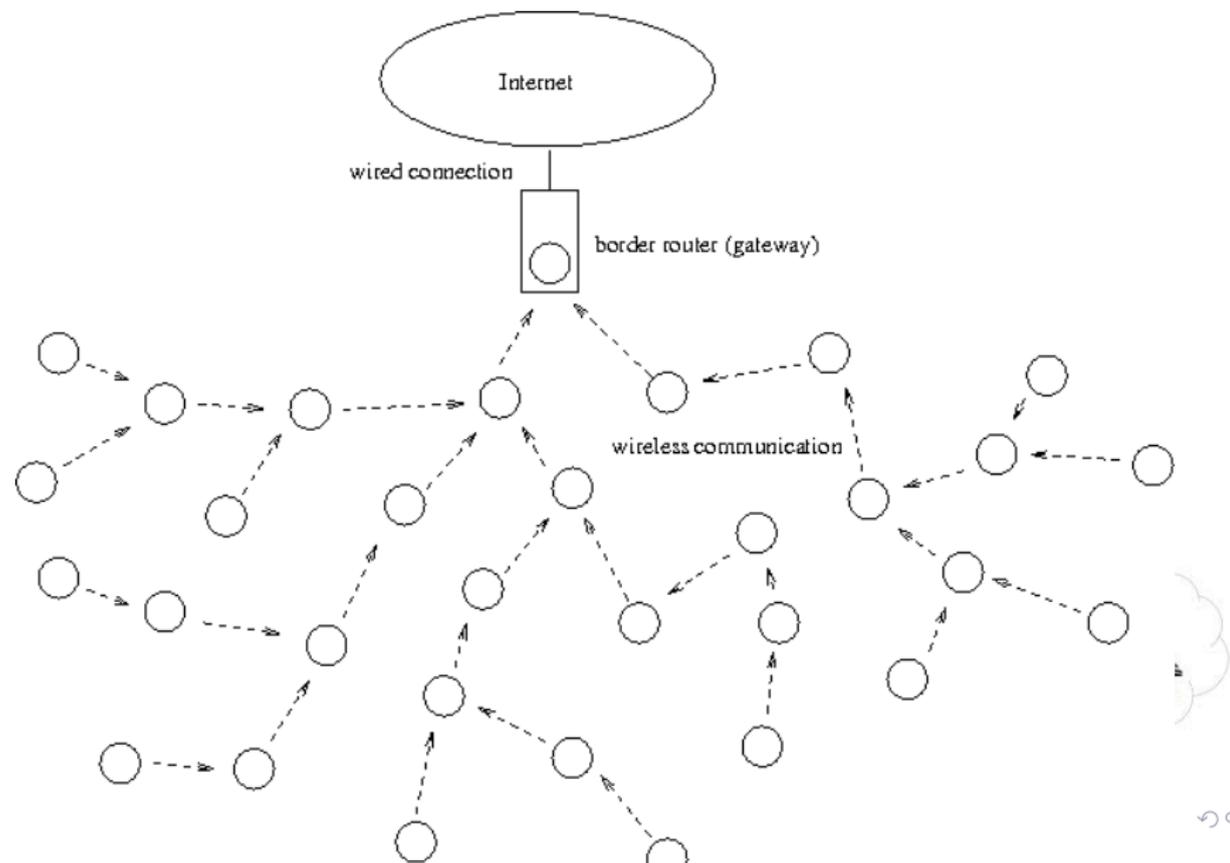
Wide Wireless Sensors Networks

- ≈ 100 sensors and more
- Smart city, building, agriculture. . .
- Several WSN for each
 - smart city
 - temperature, pollution, traffic. . .
 - agriculture
 - humidity, motion. . .
- With different constraints
 - end to end delay
 - lifetime
 - two ways communication



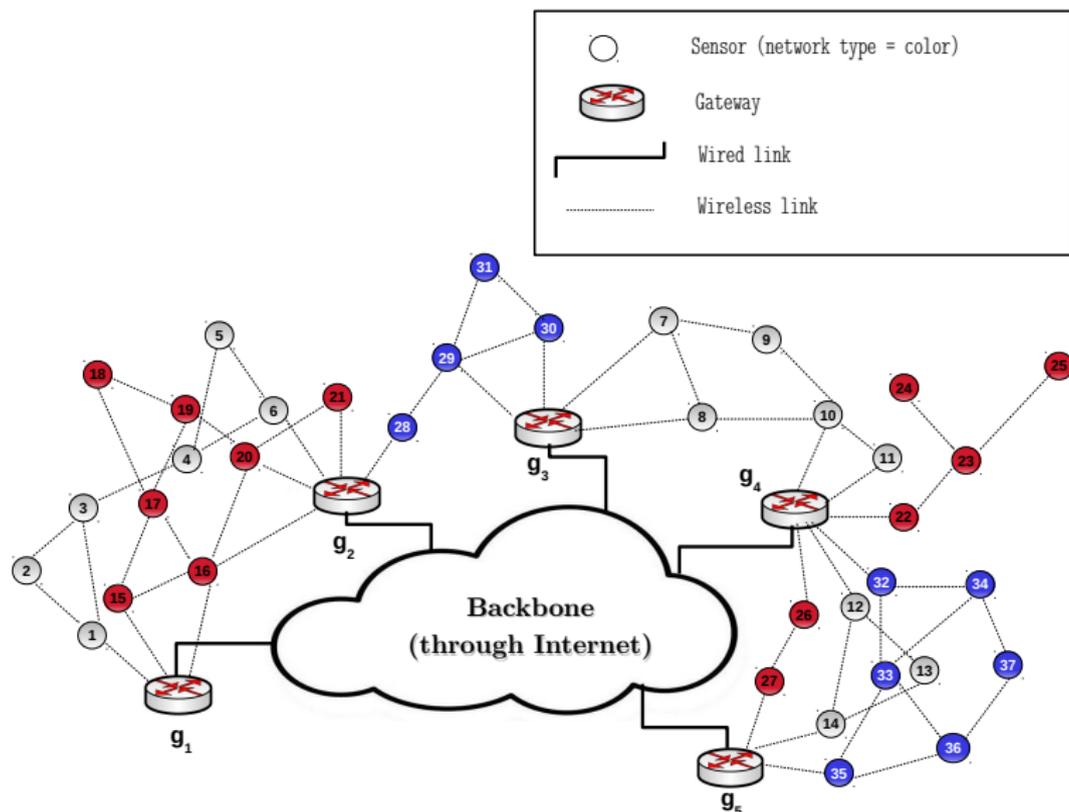
Wide wireless sensors network

Too much for one gateway



Multiple gateways

to multiple wireless sensors networks



WSN vs Gateways

A Capacitated Facility Location Problem

- Each gateway
 - provides Internet access point
 - to several WSN
 - should be available
 - is limited
- Each WSN
 - needs gateways
 - avoid bottleneck
 - could be splitted



Formal description

V_g : set of gateways, V_n : set of all WSN sensors

c_{ij} : hops count between gateway i and sensor j

$$X_{ij} = \begin{cases} 1 & \text{if gateway } i \text{ is connected to sensor } j \\ 0 & \text{otherwise} \end{cases}$$

$$Y_i = \begin{cases} 1 & \text{if gateway } i \text{ is open} \\ 0 & \text{otherwise} \end{cases}$$

$$\text{minimize} \left[\sum_{i=1}^{|V_g|} \sum_{j=1}^{|V_n|} c_{ij} X_{ij} + \sum_{i=1}^{|V_g|} Y_i + \sigma \left(\sum_{i \in V_g} X_{ij} \right) \right]$$

- number of hops
- number of open gateways
- disparity sensors per gateway



Subject to :

$$\left\{ \begin{array}{ll} \sum_{i=1}^{|V_g|} X_{ij} = 1, & \forall j \in V_n \\ \sum_{j=1}^{|V_n|} X_{ij} \leq \alpha_i, & \forall i \in V_g \\ X_{ij} \leq Y_i, & \forall i \in V_g, \forall j \in V_n \\ \sum_{i=1}^{|V_g|} c_{ij} X_{ij} \leq MAX_{Deep}, & \forall j \in V_n \\ 0 \leq X_{ij}, Y_i \leq 1, & \forall i \in V_g, \forall j \in V_n \end{array} \right.$$

- all sensors connected
- gateways not overloaded
- sensors connected to open gateway
- limits network deep

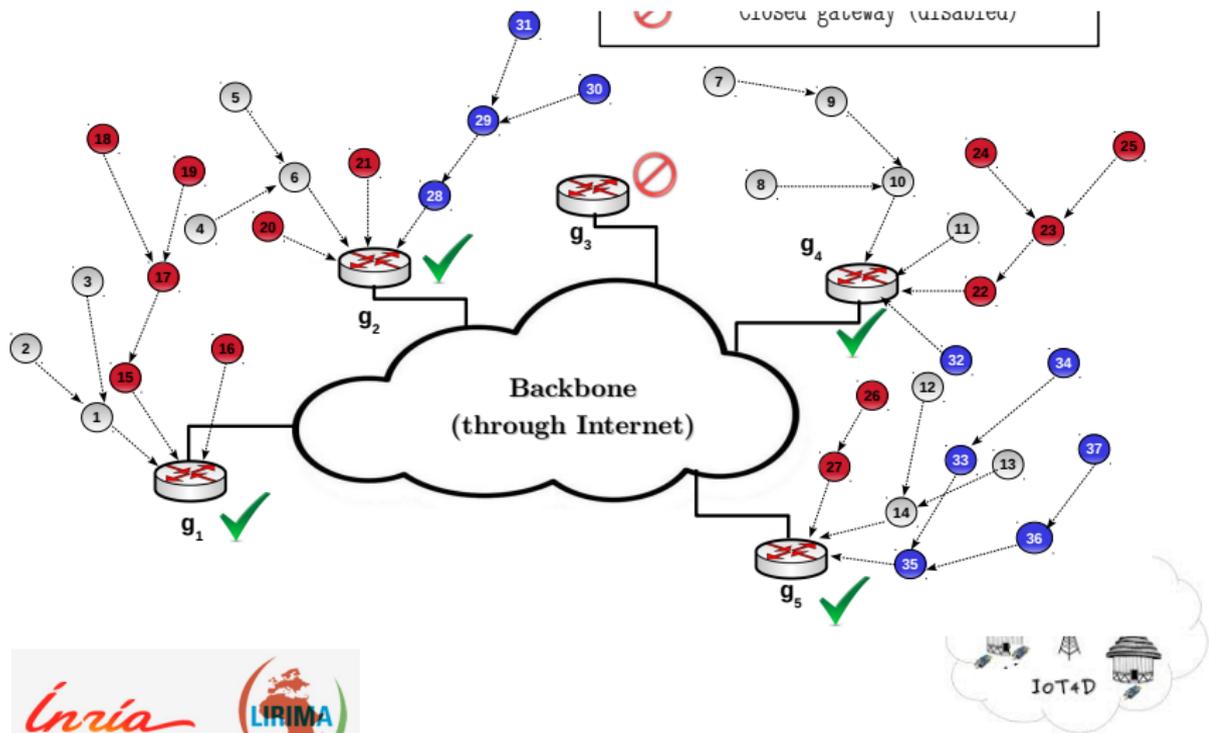
α_i : maximal capacity of a gateway i (number of sensors)

MAX_{Deep} : maximal deep of a WSN



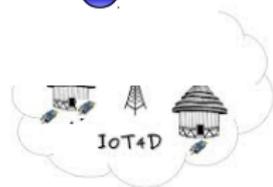
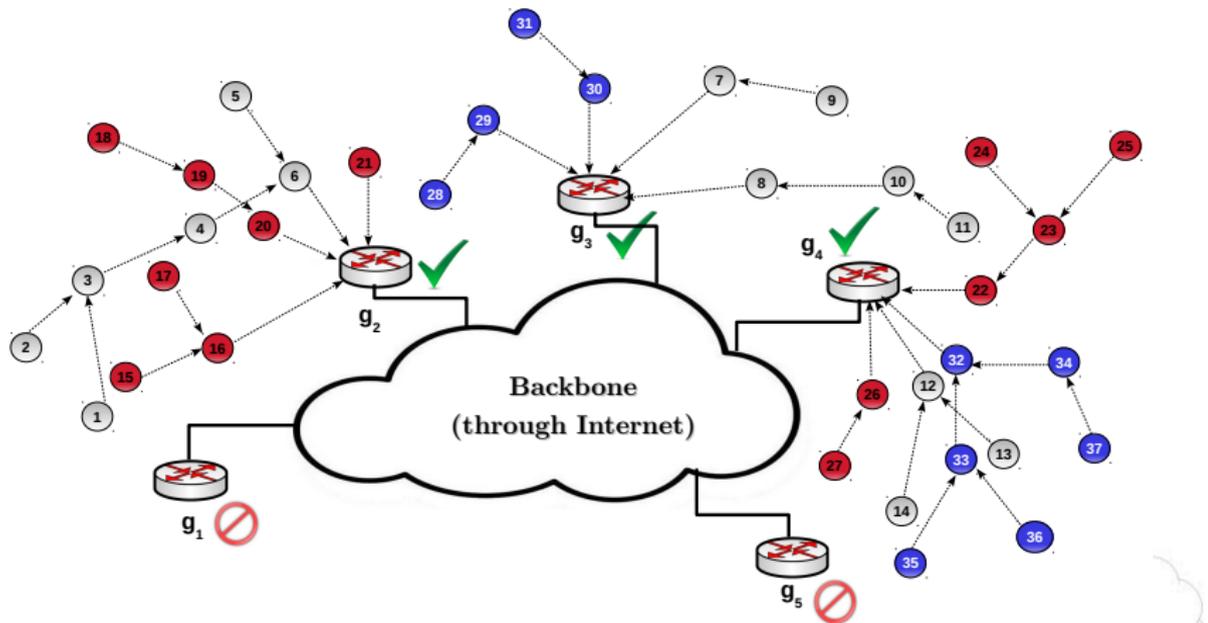
One solution

$\alpha_i = 10$

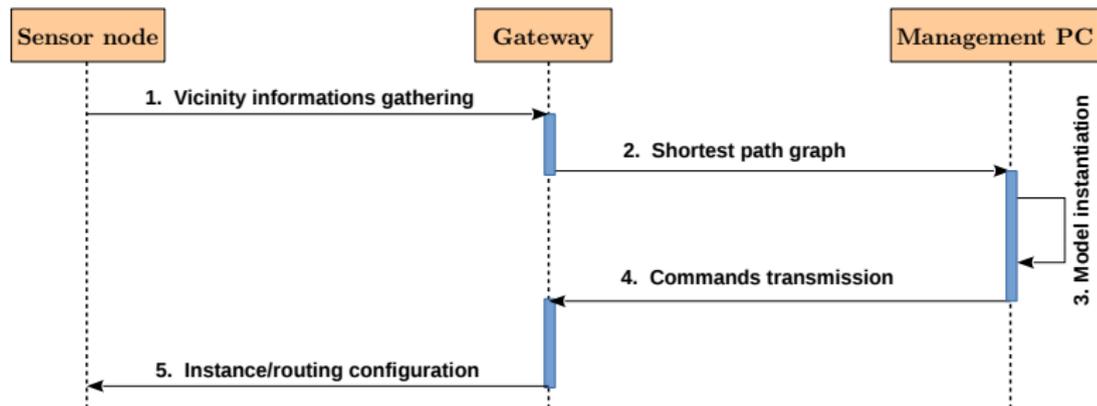
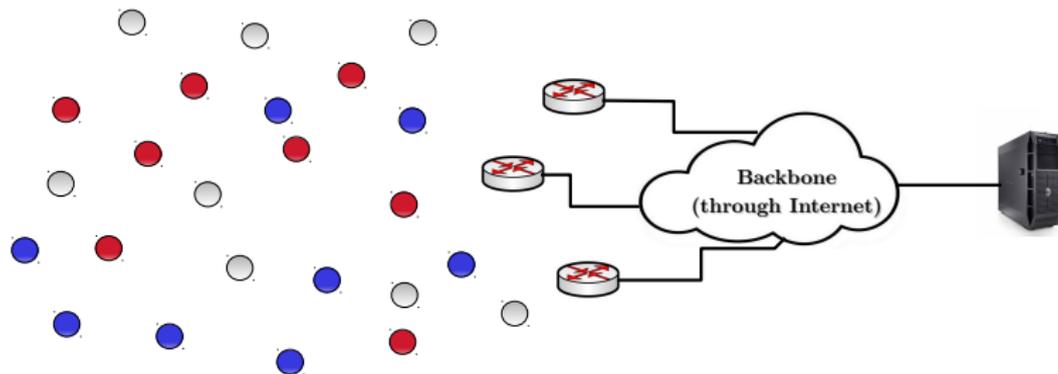


An other solution

$\alpha_i = 15$



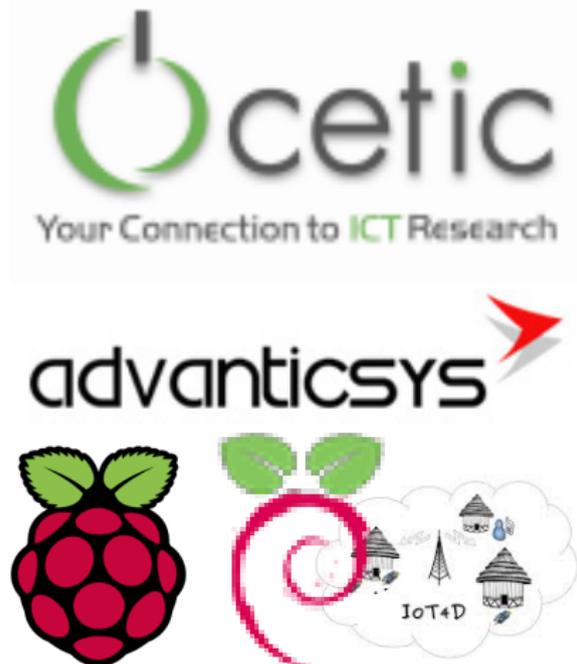
System Architecture



Implementation

6lbr & Raspberry Pi

- Fork from CETIC 6lbr open source
- Multiple 6lbr : m6lbr
- Gateway on Raspberry Pi and Sky mote
- Os: Raspbian and Contiki
- Simulation 100 nodes in 3 WSN
- Real deployment with 2 gateways, 5 nodes and 2



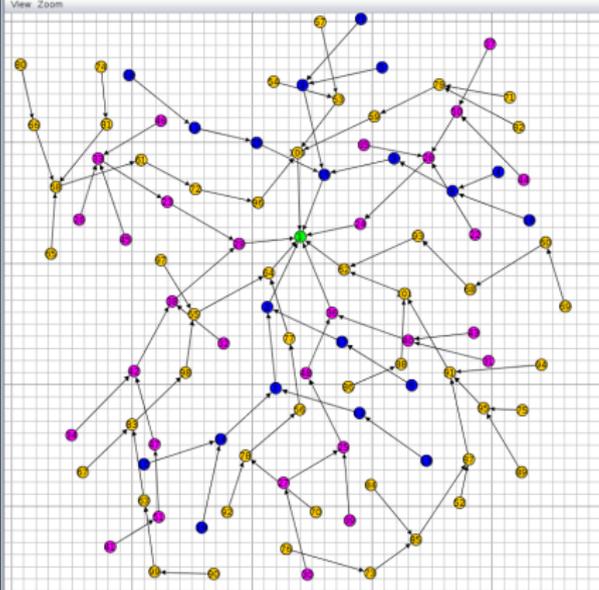
3 separate WSN

Large Scale Simulation - Cooja: The Contiki Network Simulator

File Simulation Notes Tools Settings Help

Network

View Zoom



Serial Socket (SERVER) (Key 1)

Listen port: 60001 Stop

socket -> mote: 1003622 bytes
mote -> socket: 832691 bytes

Status: Client /127.0.0.1:36704 connected.

Simulation control

Run Speed limit

Start Pause Stop Reload

Time: 20:51.282
Speed: 15.26%

File Edit View

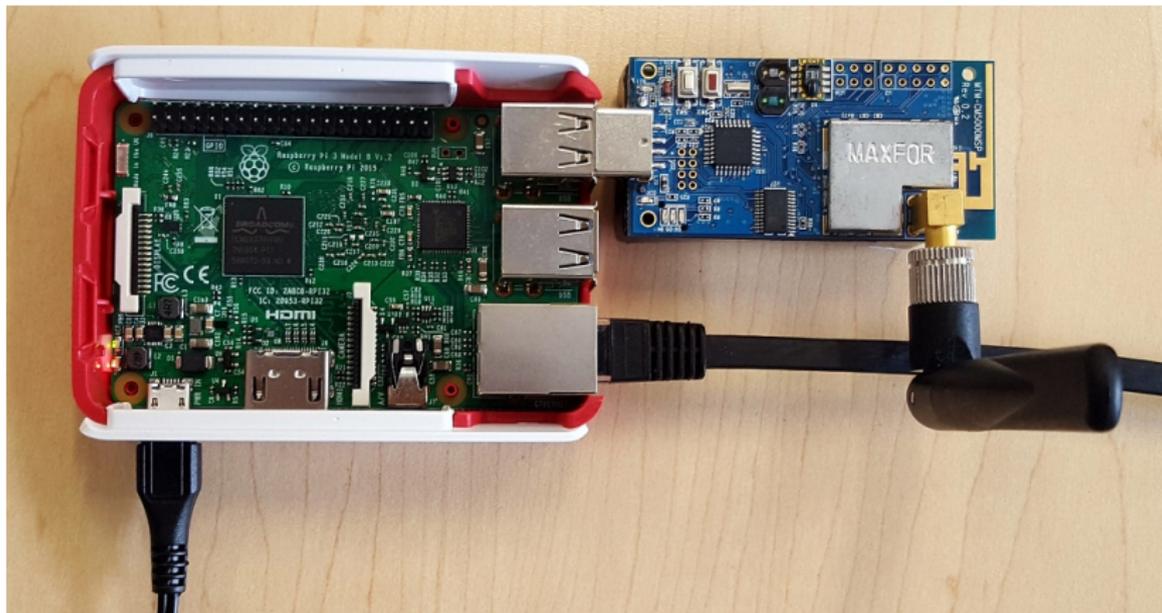
Time Mote Message

```
20:50:638 ID:05 Client sending to: aaaa::212:7400::1:101 (esp: 79 | fe80::0212:743a:003a:3a3a) 39)
20:50:660 ID:54 Client sending to: aaaa::212:7400::1:101 (esp: 81 | fe80::0212:7425:0025:3535) 33)
20:50:662 ID:77 Client sending to: aaaa::212:7400::1:101 (esp: 81 | fe80::0212:7440:0040:4040) 61)
20:50:712 ID:55 Client sending to: aaaa::212:7400::1:101 (esp: 81 | fe80::0212:7440:0040:4040) 26)
20:50:736 ID:20 Client sending to: aaaa::212:7400::1:101 (esp: 193 | fe80::0212:740f:000f:0f0f) 64)
20:50:746 ID:3 Client sending to: aaaa::212:7400::1:101 (esp: 193 | fe80::0212:740f:000f:0f0f) 63)
20:50:814 ID:03 Client sending to: aaaa::212:7400::1:101 (esp: 81 | fe80::0212:743a:003a:3a3a) 54)
20:50:824 ID:1 cM092 | fe80::0212:740e:000e:0e0e|70ateeeeet+SSSSc2180 | fe80::0212:7462:0062:62..
20:50:834 ID:13 instances drplc 30 die 50
20:50:835 ID:43 instances drplc 30 die 50
20:50:836 ID:6 instances drplc 20 die 50
20:50:844 ID:87 #L 95 0
20:50:845 ID:95 #L 88 0
20:50:845 ID:87 #L 91 1
20:50:846 ID:95 #L 91 1
20:50:851 ID:87 #L 91 1
20:50:852 ID:94 #L 95 0
20:50:853 ID:95 #L 91 1
20:50:853 ID:94 #L 91 1
20:50:860 ID:94 #L 91 1
20:50:862 ID:69 Client sending to: aaaa::212:7400::1:101 (esp: 79 | fe80::0212:743c:003c:3c3c) 56)
20:50:915 ID:04 Response from the server: '34'
20:50:916 ID:30 Client sending to: aaaa::212:7400::1:101 (esp: 116 | fe80::0212:741b:001b:1b1b) 29)
20:50:916 ID:44 Client sending to: aaaa::212:7400::1:101 (esp: 117 | fe80::0212:7432:0032:3232) 29)
20:50:921 ID:53 Client sending to: aaaa::212:7400::1:101 (esp: 81 | fe80::0212:745a:005a:4a4a) 64)
20:50:961 ID:9 Client sending to: aaaa::212:7400::1:101 (esp: 193 | fe80::0212:740f:000f:0f0f) 69)
20:51:096 ID:18 Client sending to: aaaa::212:7400::1:101 (esp: 192 | fe80::0212:740b:000b:0b0b) 69)
20:51:103 ID:24 Client sending to: aaaa::212:7400::1:101 (esp: 119 | fe80::0212:7401:0001:0101) 30)
20:51:120 ID:1 # [1024 bytes, no line ending]: at9000...
20:51:131 ID:74 Client sending to: aaaa::212:7400::1:101 (esp: 80 | fe80::0212:7451:0051:5151) 46)
20:51:142 ID:67 Client sending to: aaaa::212:7400::1:101 (esp: 81 | fe80::0212:7437:0037:3737) 58)
20:51:146 ID:61 Client sending to: aaaa::212:7400::1:101 (esp: 81 | fe80::0212:7446:0046:4646) 42)
20:51:193 ID:94 Client sending to: aaaa::212:7400::1:101 (esp: 80 | fe80::0212:745b:005b:5b5b) 42)
20:51:224 ID:89 Client sending to: aaaa::212:7400::1:101 (esp: 80 | fe80::0212:745f:005f:5f5f) 34)
20:51:271 ID:71 Client sending to: aaaa::212:7400::1:101 (esp: 80 | fe80::0212:744f:004f:4f4f) 36)
```

Filter:

Gateway

Raspberry + Sky



Inria
INVENTORS FOR THE DIGITAL WORLD



Multiple 6lbr

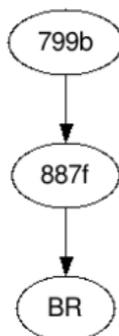
Web interface

6LBR
6Lowpan Border Router

- + 10 20

System **Sensors** Status Configuration Statistics
Sensors **Node tree** PRR Parent switch Hop count

Node tree

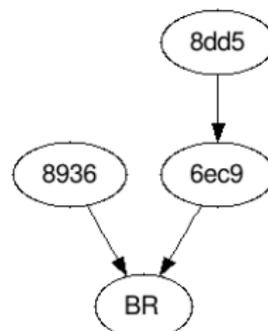


6LBR
6Lowpan Border Router

- + 10 20

System **Sensors** Status Configuration Statistics
Sensors **Node tree** PRR Parent switch Hop count

Node tree



- 2017
 - "Architecture for an efficient integration of wireless sensor networks to the Internet through Internet of Things gateways" *International Journal of Distributed Sensor Networks* 11-2017
 - "Configuration Dynamique et Routage pour l'Internet des Objets" *PhD defense of Patrick Olivier Kamgueu (Yaoundé - Université de Lorraine)* 12-2017
- 2018
 - "Survey on RPL enhancements: A focus on topology, security and mobility" *Computer communication* 2-2018



Ongoing & Future Work

- 1 week in Yaoundé (june 2018)
- Smart agriculture
 - Master and PhD
 - WSN for specific crop
- WSN long range communication
 - Mesh network LoRA, WiMax
- Groupe de Recherche International (GDRI) "Sense-Sud"
 - Institut pour la Recheche et le Développement (IRD) project
 - WSN for environment (cities)

