IoT4D

Internet of Things for developping countries

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September 18, 2018

Objectives
Why

Foster Internet of Things technologies

- Developping technologies
  - developping countries
- Useful monitoring
  - environment, agriculture, safety
- Not expansive
  - sensors less 60 K CFA
- Easy to deploy
  - wireless communication

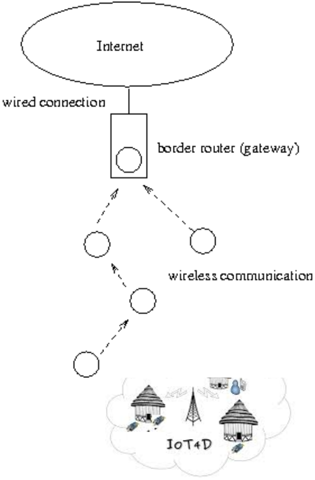
Context
Standardized Wireless Sensors Networks

- Sensor : physical device
  - sensing capability
    - temperature, humidity, motion. . .
  - CPU
    - low power, low memory
    - powerful enougth 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

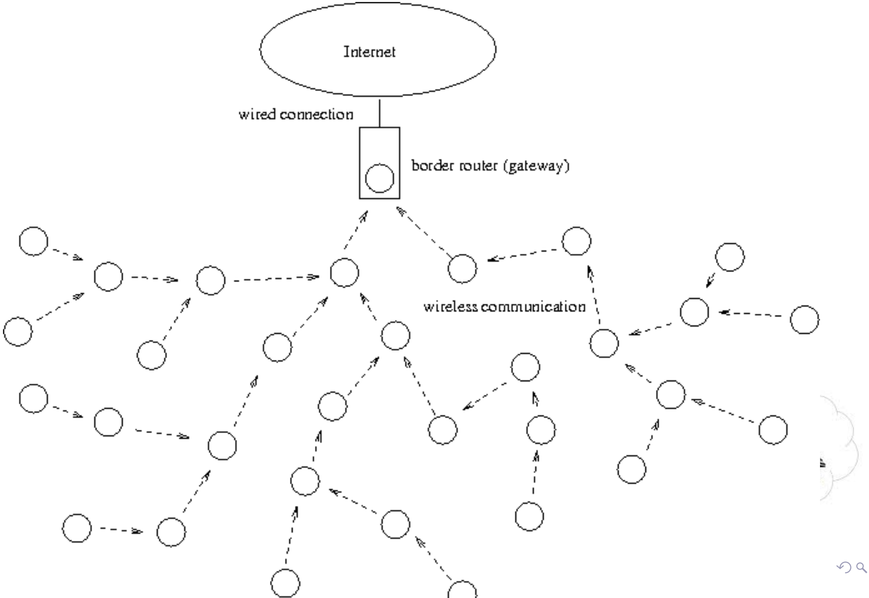


Wide Wireless Sensors Networks

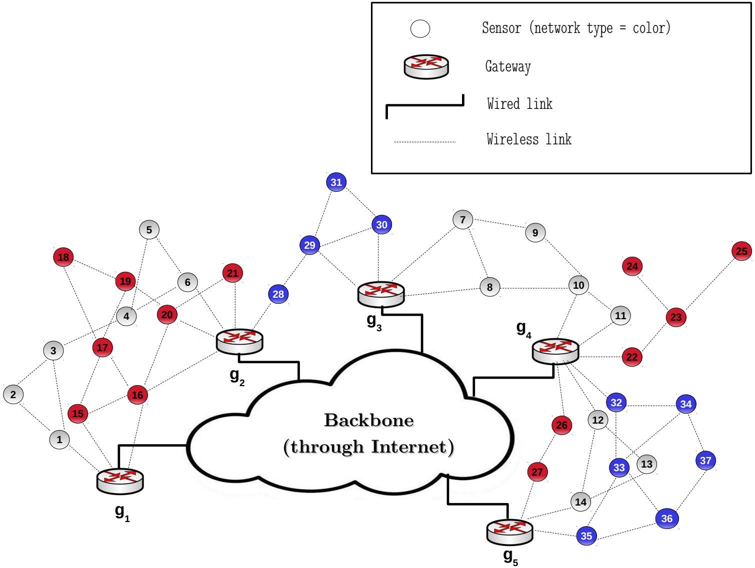
- $\approx$ 100 sensors and more
- Smart city, building, agriculture. . .
- Several WSN for each
  - smart city
    - temperature, pollution, trafic. . .
  - agriculture
    - humidity, motion. . .
- With differents constraints
  - end to end delay
  - lifetime
  - two ways communication

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

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

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

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

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

Subject to :

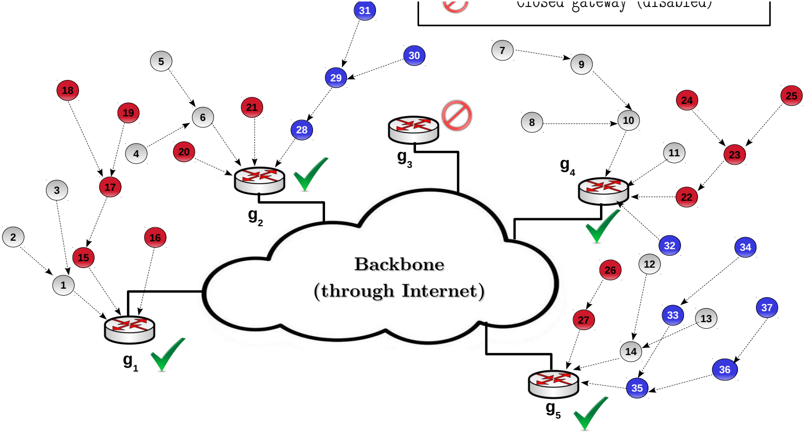
$$\begin{cases} \sum_{i=1}^{|V_g|} X_{ij} = 1, & \forall j \in V_n \\ \sum_{j=1}^{|V_n|} X_{ij} \leq \alpha_i, & \forall i \in V_g \\ X_{ij} \leq Y_i, & \forall i \in V_g, \forall j \in V_n \\ \sum_{i=1}^{|V_g|} c_{ij} X_{ij} \leq MAX_{Deep}, & \forall j \in V_n \\ 0 \leq X_{ij}, Y_i \leq 1, & \forall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

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

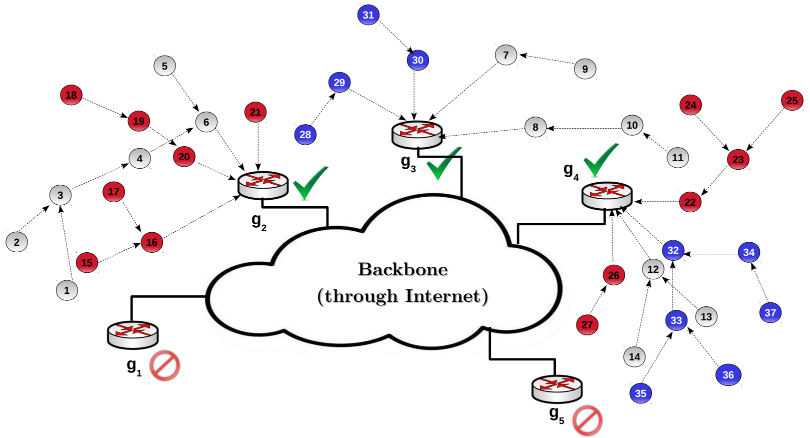
α_i : maximal capacity of a gateway i (number of sensors)
$MAXDeep$: maximal deep of a WSN

One solution

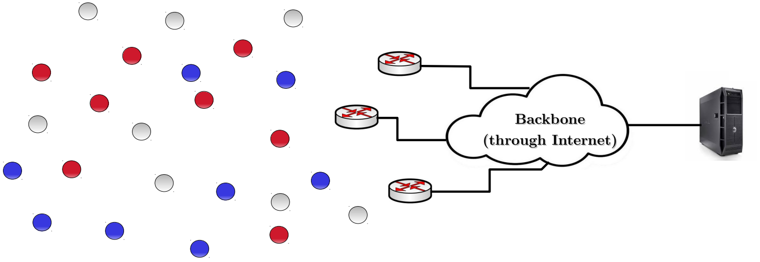
$\alpha_i = 10$

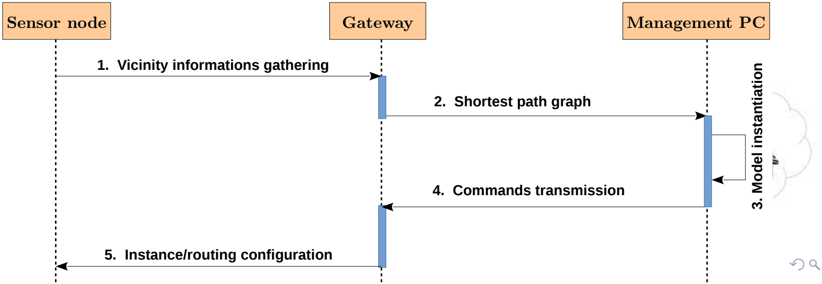


An other solution
$\alpha_i = 15$



System Architecture



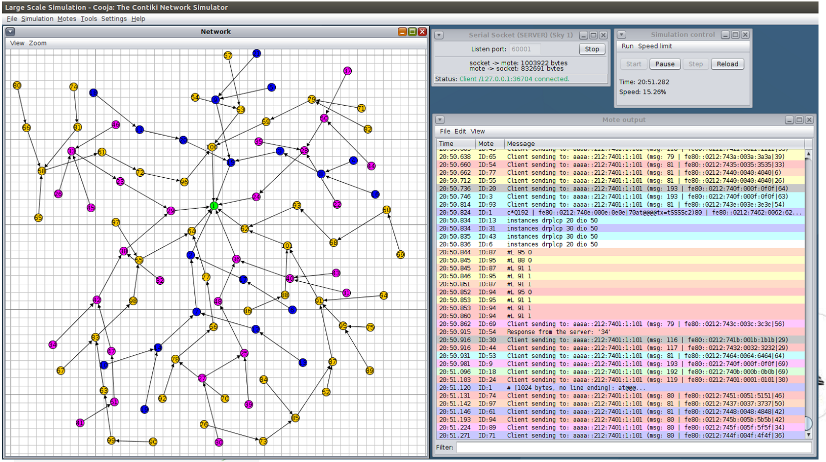


Implementation
6lbr & Raspberry Pi

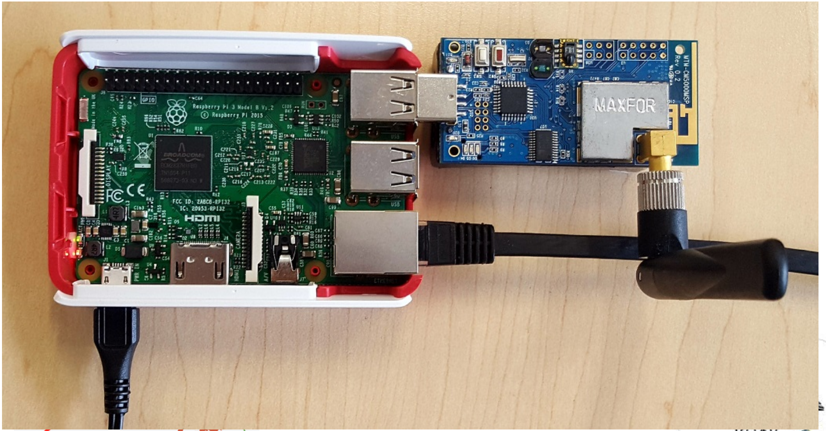
- Fork from CETIC 6lbr open source
- Multiple 6lbr : m6lbr
- Gateway on Raspberry Pi and Sky mote
- Os: Raspbian and Contiki
- Simulation 100 nodes in 3 WSN
- Real deployment with 2 gateways, 5 nodes and 2 WSN

Simulation
Cooja

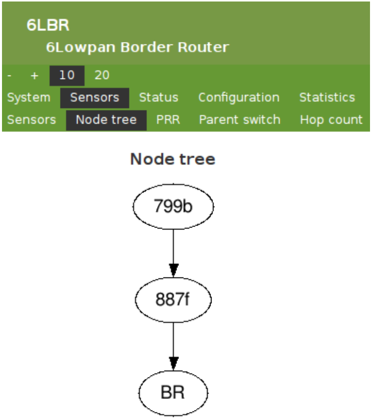
3 separate WSN

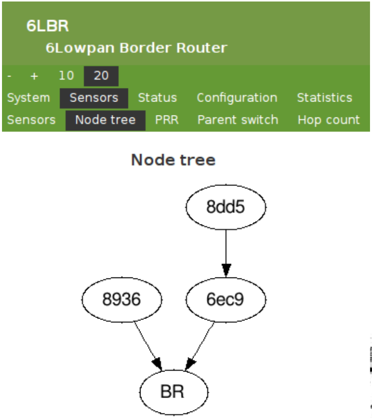


Gateway
Raspberry + Sky



Multiple 6lbr
Web interface





Results

- 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)