Panel

Challenges in Internet Sensors-based Systems ans Services

(energy, security, deployment, data collection, mangement, replacement, etc.)

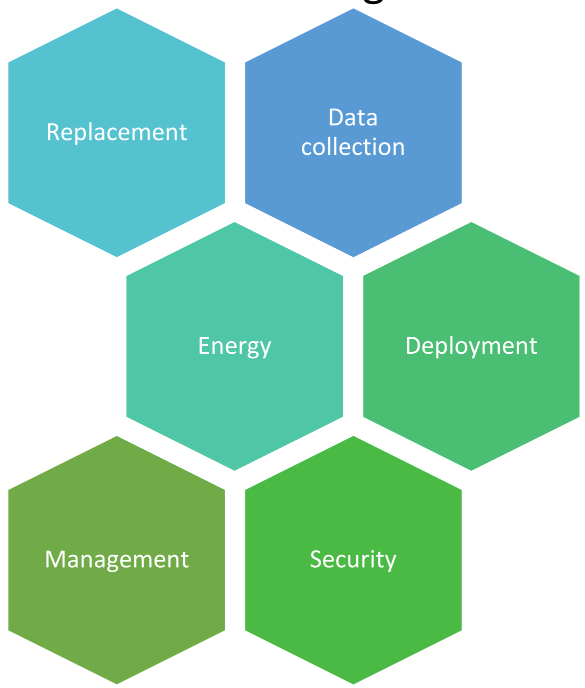
NetWare 2020

Chair

Pedro Vicente Mauri, Instituto Madrileño de Investigación y Desarrollo Rural, Agrario y Alimentario (IMIDRA), Spain

pedro.mauri@madrid.org

Which are the Current Challenges in Sensors-based Systems and Services?



Trade-off

Minimum requirements

Existing limitations

Panel

Challenges in Internet Sensors-based Systems ans Services

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Topics:

Energy consumption in WSN is a critical issue: how we will overcome the batteries limitations?

Indoor location of mobile devices: Is the acoustic indoor localization a solution?

From end devices to the cloud: how the edge constraints can be surpassed?

Chair
Pedro Vicente Mauri Ablanque, IMIDRA, España, pedro.mauri@madrid.org

Panelists
Anne-Lena Kampen, Western Norway University of Applied Sciences, Norway alk@hvl.no
Zhaobo Zhang, Futurewei Technologies Inc., USA zzhang1@futurewei.com
Masanari Nakamura, Hokkaido University, Japan masanari@ist.hokudai.ac.jp
Pedro Vicente Mauri Ablanque, IMIDRA, España, pedro.mauri@madrid.org

Panellist Position

Energy consumption – one of the most important issues in WSN

- **Anne-Lena Kampen,** Western Norway University of Applied Sciences, Norway alk@hvl.no

- Early depleting nodes violates collected information:
- May lead to wrong predictions,
- Increases management cost,
- Is a source of irritation and frustration

→ Reduce the energy consumption in the network

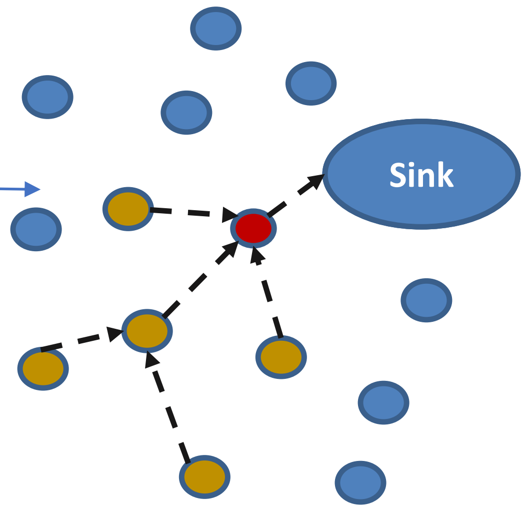
→ Focus on the most energy-intensive activities

→ Reduce the active periods of the nodes

→ Balance the energy consumption of the nodes to avoid early depletion of key-nodes

What is the consequences of a depleted node?

- **When nodes depletes: The dataset at the sink is incomplete**
  - May lead to wrong predictions about the monitored environment
  - The network may get partitioned



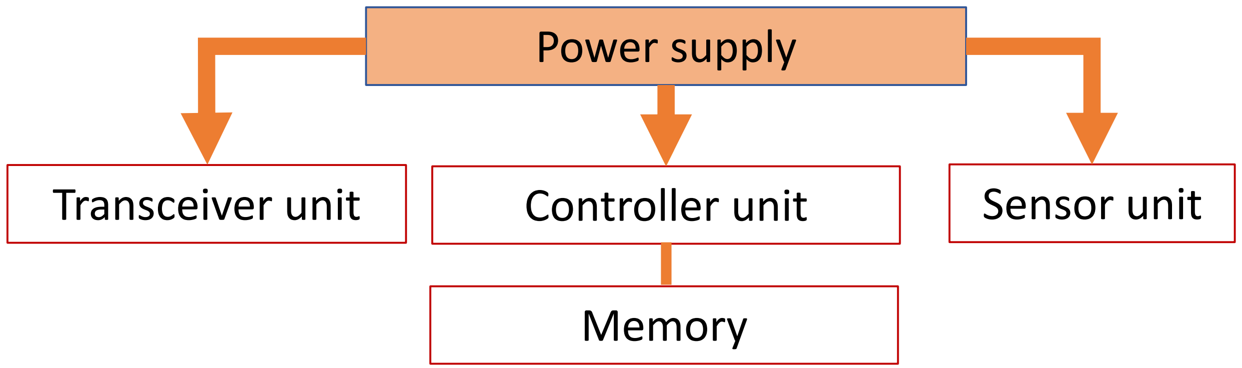
- **Early / frequently depleted nodes increases management cost**
  - Requires battery replacement
    - Cost manhour
    - May be difficult due to harsh environment

- **Early / frequently depleted nodes is a source of irritation and frustration**
  - Domestic applications
    - Battery replacement is challenging for some people (old, disabled, ..)
    - May not understand that something in the network is broken or the devastating consequences it may cause
  - Industrial application, manufacturing and smart grid
    - Processes may stop, go wrong,
  - Very inconvenient times for node depletion
    - In the middle of an military operation
    - During search for a person suffering from dementia
    - During landslide
    - ..

The red depleted node cannot provide any more data. Unless these yellow/ brown nodes find a new path toward the sink, their data are also lost.

Which processes in a node consume energy?

- The power supply provides energy for the various units
  - Senor
    - Generally, the operation of the sensor does not impact communication. Sensors' consumption is therefore generally not taken into account.
  - Controller and memory
  - Radio
- **Unless a node is switched off it consumes energy**
  - for sensing
  - for processing data
  - for transmitting and receiving data
  - to listen for activity..
  - ..and for sleeping



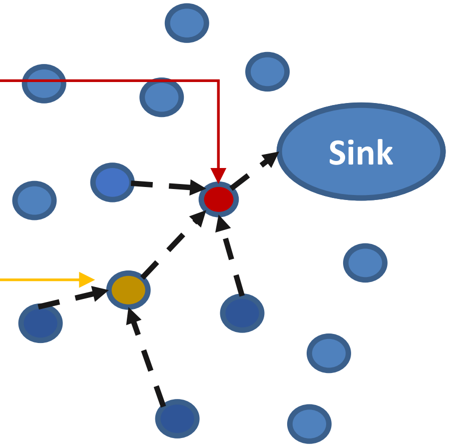
- Not unexpectedly, the least energy is consumed when the nodes are in sleep status.
- **The radio is generally the unit that consumes most energy.**
- **The radio switches between different states: transmitting, receiving, idle and sleep**

Reduce energy in Wireless Sensor Networks

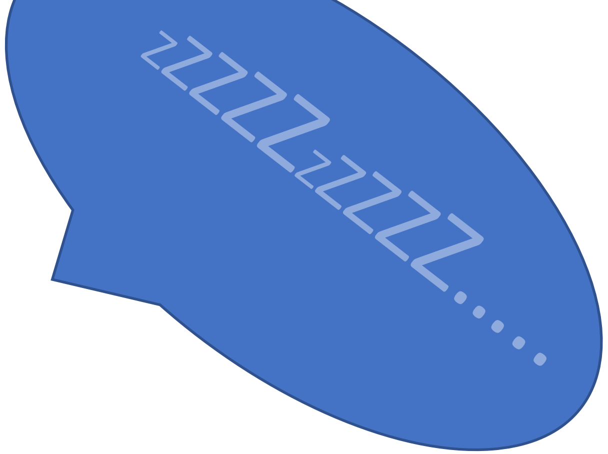
- Focus on the most energy-intensive activities
  - ➢Transmitting, receiving and listening

- Reduce the active periods of the nodes
  - ➢Make the nodes enter sleep mode whenever possible

➢Balance the energy consumption in the network to avoid early depletion of key-nodes



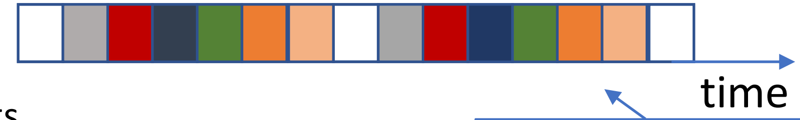
Duty cycle (sleep) protocols



- **So, it is energy efficient to switch node to sleep state since the power consumption in this state is much lower than the other states**

- Lowe Power Listening (LPL) is an efficient MAC layer sleep protocol
  - The nodes only periodically wake up to listen for activity
  - Nodes that have data to transmit must transmit a preamble to signal upcoming transmission
  - Low energy consumption and low management cost

  - However, the delay can be unpredictable



Each sender-receiver pair have their own timeslot, i.e., their own color

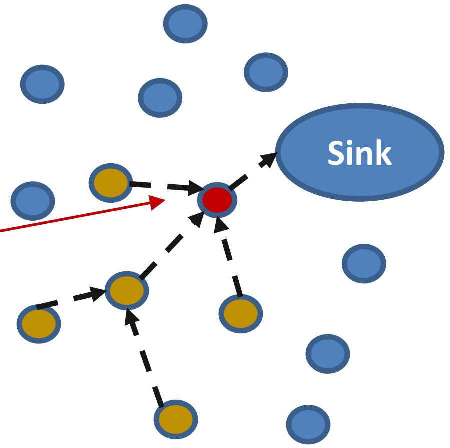
- Time Division Multiple Access (TDMA) can be used to save energy.
  - TDMA protocols share the medium by dividing the communication into consecutive timeslots.
  - Each sender-receiver pair communicates in their own predetermined timeslot, which is repeated periodically.
  - Each sender-receiver pair is assigned one or more individual timeslots in which they can transmit and receive data.
  - Thus, no collisions or overhearing occurs.

  - However, it is energy consuming to maintain firm synchronization and to manage the slot activity.
  - Slot management and assignment are particularly challenging when the network topology changes, such as when nodes are added or removed.

Which duty cycle approach ?

- Well, it depends, no solution fits all:
- Advanced LPL solutions (where the preamble is optimized to reduce receivers consumption, the wake-up periods is tuned to optimize energy consumption and so forth.) may be one of the most efficient solution to reduce network energy consumption
- However, TDMA is probably the best solution for networks with strict delay requirement

What about balancing the energy?



- The most important key-nodes in a WSN are usually the nodes that are located next to the sink

  - Data form all other nodes in the network must traverse these nodes to reach the sink

  - For network running LPL, we suggest to reduce the consumption of these important key-nodes by preventing them from transmitting preamble*
    - This is possible since the sink is always awake and ready to receive

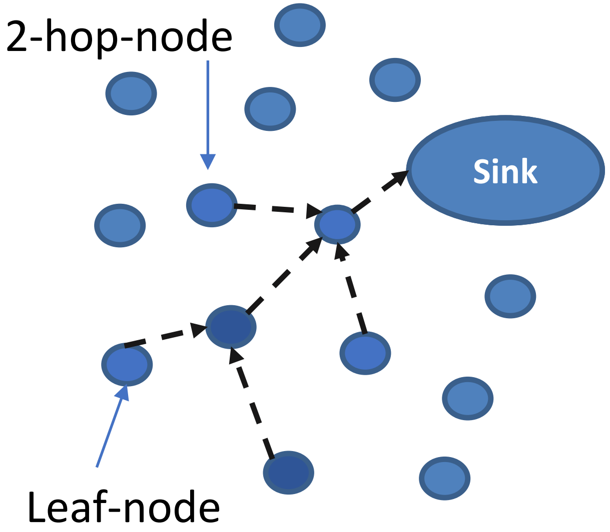
*[Anne-Lena Kampen and Knut Øvsthus,” Reducing The Energy Consumed During Multihop Transmissions in Wireless Sensor Networks”, SENSORCOMM’ 2020]

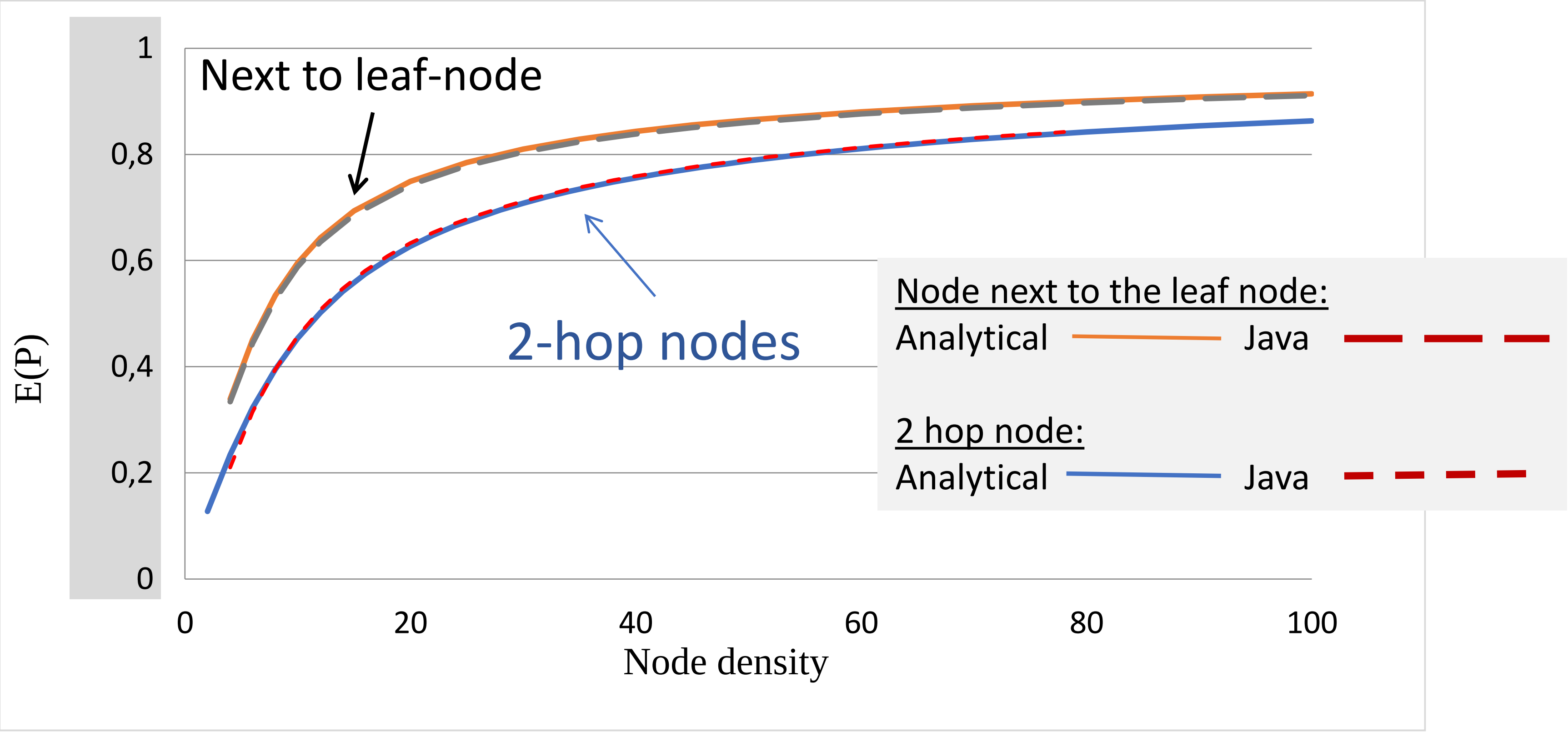
Is it important to balance the energy consumption in the network ?

We calculated and simulated the probability of disconnection of the paths in networks running RPL (Routing Protocol for Low Power and Lossy Networks) using hop-count as metric.*

The graphs show the expected value of the probability that a disconnected node are not able to find a new path toward sink when its current successor depletes

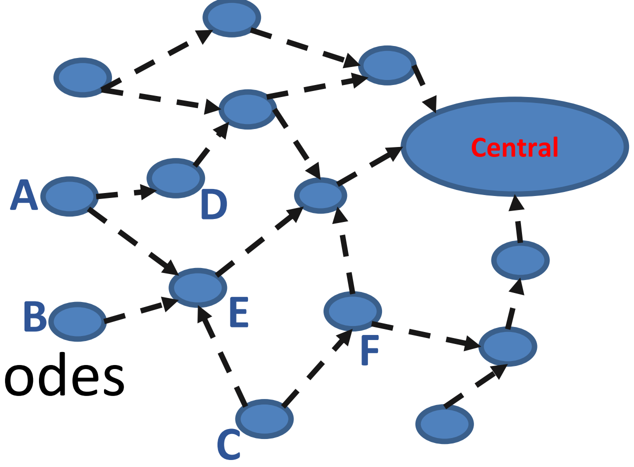
Lesson learned: Disconnections are likely to occur !





*[Anne-Lena Kampen, Knut Øvsthus and Øivind Kure," **An Analysis of the Need for Dedicated Recovery Methods and Their Applicability in Wireless Sensor Networks Running the Routing Protocol for Low-Power and Lossy Networks**", Proceedings of the 8th International Conference on Sensor Technologies and Applications (SENSORCOMM' 2014), pp. 121-129, 2014, ISBN: 978-1-61208-374-2]

Approaches to balance energy consumption in the network



- Routing protocols can contribute to balance the energy consumption throughout the whole network, and prevent early depletion of nodes

- Approaches includes:
  - Always use the node with the highest energy as successor
    - Found to be the most efficient solution*
  - Randomly select a successor among all the potential successors – one of our suggested solution*
    - Simple method to prevent that all nodes choose the same successor nodes
    - Node A in the figure randomly choose D or E, node C randomly chooses between E or F.
      - Less likely that both nodes A, B and C choose E as their successor
    - A solution that substantially reduces energy consumption, and is very simple to implement
  - Round-robin among all the successor nodes
  - Weighted round-robin among the potential successor nodes
  - Weighted round-robin, but avoid lowest-energy successor

*[Anne-Lena Kampen, Knut Øvsthus and Øivind Kure,” **Energy balancing algorithms in Wireless Sensor Networks**”, Proceedings of the 2015 Federated Conference on Computer Science and Information Systems (FedCSIS), Volume 5 , pp. 1223-1231, 2015, Electronic ISBN: 978-8-3608-1065-1, DOI: 10.15439/2015F67]

Conclusion

- **Reducing energy consumption in WSNs is important**
  - **Reduces management cost**
  - **Reduces stress, both among both users and managers of the WSNs**
- **Keeping the nodes in sleep state is efficient in reducing energy consumption**
- **Balancing energy consumption in the network is important in order to prevent early depletion of nodes and keep a connected network**

Panellist Summary

Challenges in Acoustic Indoor Localization for Mobile Devices

Masanari Nakamura, Hokkaido University, Japan masanari@ist.hokudai.ac.jp

- Introduction
- Acoustic indoor localization
- Challenges
- To deal with challenges

Challenges in Acoustic Indoor Localization for Mobile Devices

Masanari Nakamura

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Introduction

- Outside a building, mobile devices can precisely locate themselves using GNSS. However, inside a building, the GNSS could induce large errors due to shielding.
- To circumvent this, alternative methods for indoor environments have been widely researched.
  - E.g.) Camera, Wi-Fi, Bluetooth, PDR, Acoustic, etc.
- In this presentation, I will discuss about acoustic indoor localization

- Applications of indoor localization
  - Navigation
  - Monitoring patients in hospitals
  - Measuring flow lines of operators in factories
  - Virtual Reality and Augmented Reality

GNSS: Global navigation satellite system
PDR: Pedestrian dead reckoning

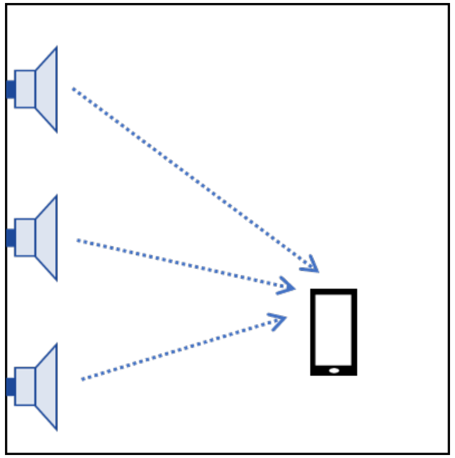
Acoustic indoor localization

Overview

- Acoustic signals, simultaneously transmitted by speakers installed in an indoor environment, are captured by an embedded microphone of a mobile device.
- The location of the microphone is estimated using the time difference of arrival (TDoA) of these signals.
  - The roles of speaker and microphone can be reversed;
  - To avoid causing inconvenience to a user, inaudible acoustic signals (> 15 kHz) are often used.

Characteristic

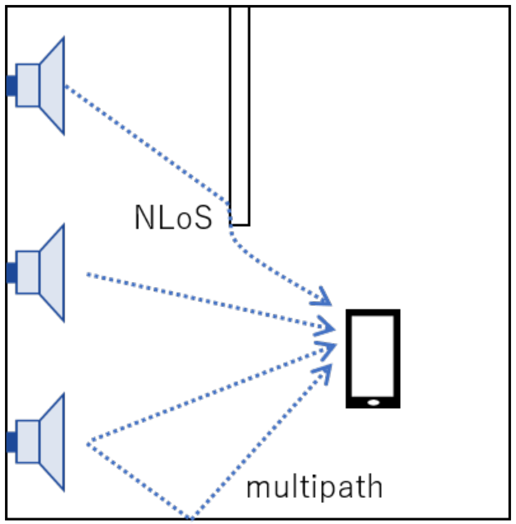
- Commercial speaker and microphone can be utilised.
  - No need to add specific devices to the mobile device.
- Precise localization performance (centimeter-level) can be achieved.
  - Due to the relatively slow propagation speed
    - Acoustic: 3.4×10^{2} m/s, Radio: 3×10^{8} m/s



Acoustic indoor localization

Challenges

- Deterioration of localization due to interference between the direct and multipath signals.
  - Depends on the surrounding environment
- Deterioration due to non line-of-sight (NLoS)
  - Acoustic signals could be shield by a wall, pillar, etc.
  - Mobile devices could be placed inside a pocket or bag.
- Installation and maintenance costs
  - It seems that the cost is still too expensive for localization.
- Energy consumption of mobile devices because of continuous localization



Multipath and NLoS

To deal with the challenges

- Information fusion could be a suitable choice.
  - Fusion with the location information estimated by other sensors.
  - Fusion with the prior information
    - E.g.) map information, motion model of users
  - Fusion with the logs of stationary equipment
    - E.g.) home appliances
    - Equipment are used as proximity sensors

- It is desirable to integrate the information adaptively according to the present environment.
  - For this, it is necessary to determine the reliable information in the surrounding environment.

Panellist Summary

Overcoming the Edge Constraints with Scheduling Optimization between Edge and Cloud

Zhaobo Zhang, Futurewei Technologies, USA zzhang1@futurewei.com

- Intelligent Edge Computing
- Unified Orchestration between Edge and Cloud
- Scheduling Optimization

→ Fast-growing Internet sensor-based systems and services drive computing to the edge.

→ Edge computing can leverage cloud resources to overcome its resource constraints.

→ Dynamic scheduling among different locations optimizes performance and resource utilization.

NetWare 2020 Congress, Panel: Challenges in Internet Sensor-based Systems and Services

Overcoming the Edge Constraints with Scheduling Optimization between Edge and Cloud

Zhaobo Zhang
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Nov. 2020

IARIA

FUTUREWEI Technologies

Booming of Internet Sensor-based Systems

- **Fast-growing Internet of Things (IoT) market**
  - Field: Industrial 4.0, Smart City (meter, lights, video), Smart farming (irrigation, animal tracking), Autonomous Vehicle
  - Industrial edge computing market: $11B 2020 → $30B 2025 *
- **5G enables massive machine type communication**
  - High device density: 1 million devices per km^2
  - Low power: up to 10-year battery life for low power IoT devices
- **Intelligent edge enables new set of opportunities**
  - Elastic infrastructure with edge computing and cloud computing
  - Distributed software applications

*https://iot-analytics.com/iot-edge-computing-what-it-is-and-how-it-is-becoming-more-intelligent/

Edge Computing Definition

- **Where is the edge?**

	End Devices (sensors)	⟺ Small Edge (MEC, far edge)	⟺ Medium/Large Edge (edge site, PoP, near edge)	⟺ Cloud Data Center
Example	car, cellphone	mobile tower, stadium, factory	CDN site, central office	public cloud
Latency	0.1ms	1ms	10ms	100ms
Count	Millions	Thousands	Hundreds	Tens

- **Edge Computing:** a distributed computing paradigm, brings computation and data storage closer to users, to improve response times and save bandwidth.

Edge Computing Challenges

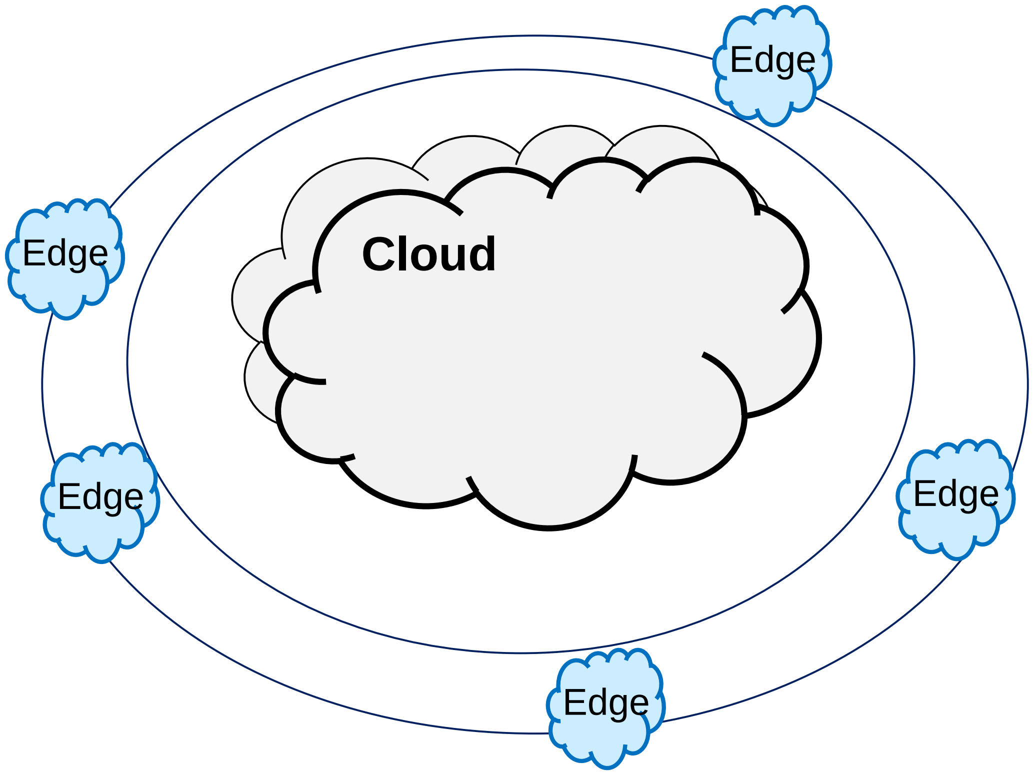
- Open architecture, various communication protocols
- Large volume of data (hard to transport back to cloud)
- Require real-time decision
- Dynamic scenarios, static rule-based solutions not enough
- Resource constraints, limited compute and storage resource
- Limited network connectivity

What operational models and technologies will be able to effectively unlock the edge potential?

Industry Movements

- **Cloud Providers**
  - Extend cloud to edge, with the same cloud services on at the edge, uniformly manage edge computing as part of a broader cloud footprint
  - AWS Outposts; Azure Arc, Stack Edge; Google Anthos
- **Challengers**
  - CDN (content delivery networks), colocation and telecom providers challenge from the edge with their global network locations and experience
  - Akami, Equinix, AT&T place edge sites near customers and offer cloud-like services

Intelligent Edge with Cloud Computing



Continuous Optimization, Federation and Collaboration

- **Elastic Infrastructure**, workloads move seamlessly between Cloud and Edge, and Edge to Edge
- **Edge Intelligence**, data preprocessing and compression, time/location/context aware
- **Global Optimization**, scheduler, scaler, continuous resource allocation optimization
- **Resource-aware Application Design**, split into microservices based on the requirements of latency, computation complexity, state, etc.

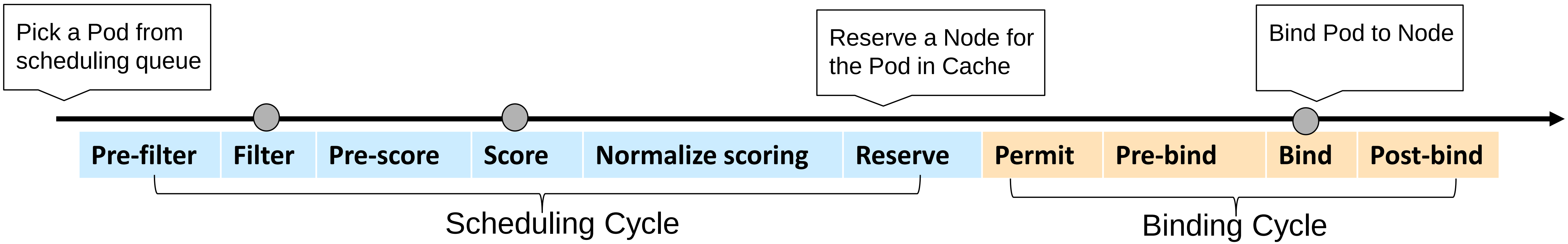
Scheduling Optimization between Edge and Cloud

Application Type	Schedule Requirements	Optimization Goal	Algorithms
• Scientific workflow • Large-scale data • Real-time • Cloud storage • Throughput intensive • Delay sensitive • Network services	• Workload dependency • Resource affinity • Resource quota • Latency, geo-proximity • Throughput	• Deployment cost • Service reliability • Resource utilization • Response time • Energy cost • Operation cost	• Decision tree • ILP (Integer Linear Programming) • Graph neural network • Greedy algorithm • Dynamic programming • Genetic algorithm • Particle swarm optimization

- Find a tradeoff between cost and performance
- Scheduled jobs could be dynamically rescheduled for optimization purpose

Kubernetes-based Scheduling Example

- Kubernetes is a popular container orchestration platform, considered as Cloud OS
- Scheduling framework: filter (by predicate) and score (by priority) with rich extension



- Scheduling Framework Optimization:
  - **Co-scheduling**, schedule a group of pods instead of one considering workload dependency
  - **Multi-profile scheduling**, combine different filter and score function for different workload
  - **Priority function extension**, add customized functions to be location/latency/energy aware
  - **De-scheduling**, periodically audit scheduling requirements, evict unsatisfied pods

Takeaways

- Edge is the next computing frontier after Cloud
- Edge computing strategies are critical for unleashing the full potential of Internet Sensor-based Systems and Services
- Global scheduling optimization can bring the best out of Edge and Cloud
- Resource-aware applications are easy to deploy and achieve better performance

Panel

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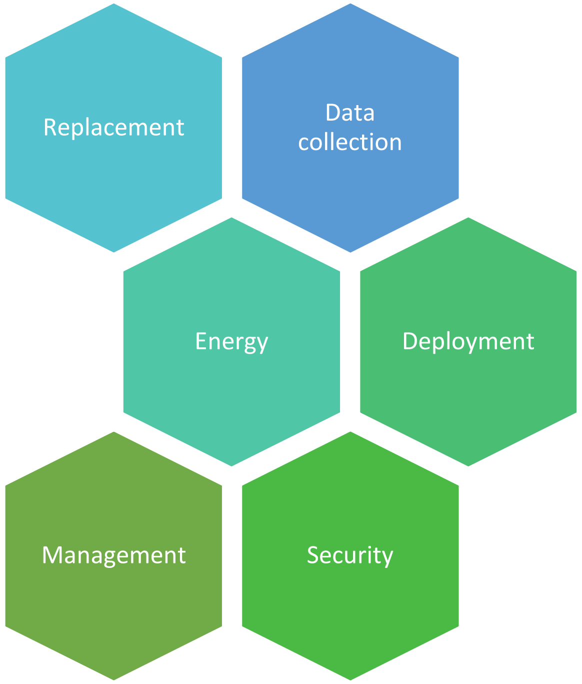
Which are the Current Challenges in Sensors-based Systems and Services?



Trade-off

Minimum requirements

Existing limitations

Topics:

Coverage problems in the deployments in rural areas: How the vegetation and soil affects to the coverage?

Energy consumption in WSN is a critical issue: how we will overcome the batteries limitations?

Indoor location of mobile devices: Is the acoustic indoor localization a solution?

From end devices to the cloud: how the edge constraints can be surpassed?

Why do we have coverage problems in rural areas?

In rural areas, wireless sensor networks are preferred to wired networks.

Generally, rural areas have dense vegetation that causes a reduction of the received signal.

In some cases, due to till actions, it is necessary to deploy the nodes underground.

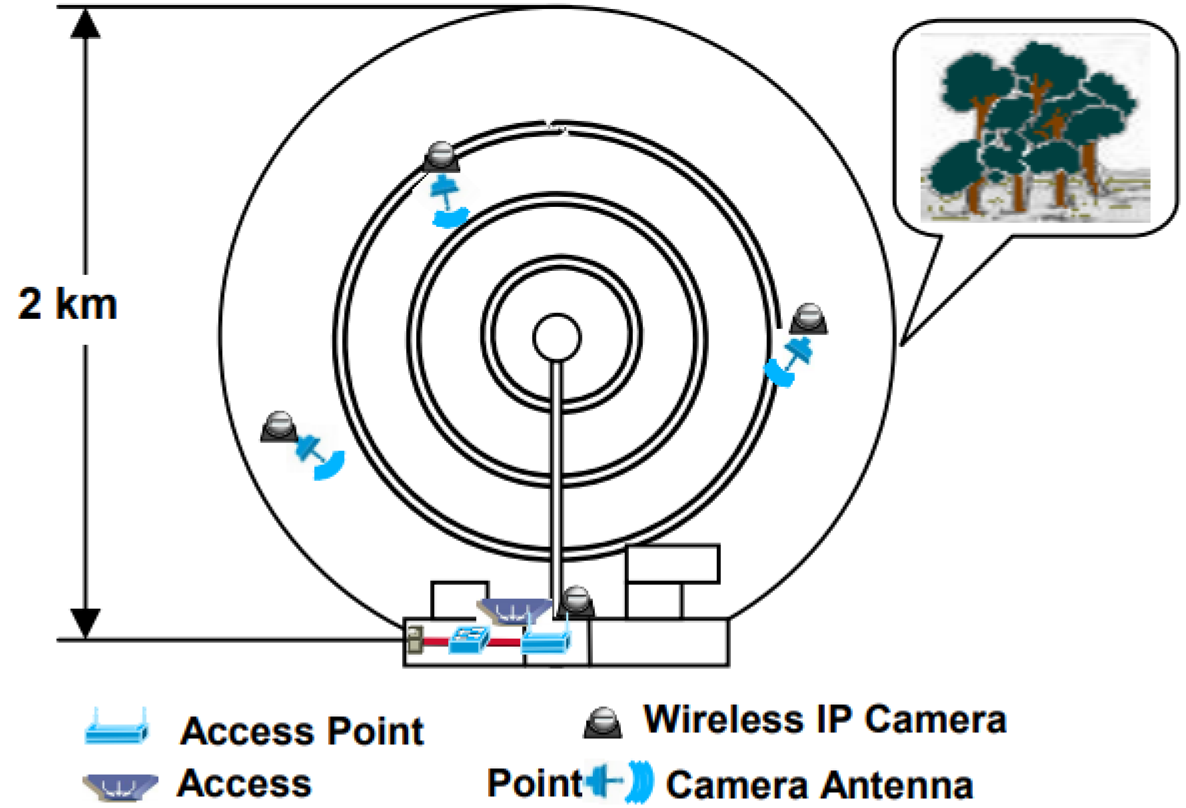
Effect of vegetation over the coverage

Motivation: Fire detection

Task: Real deployment of IP cameras

Objectives:

1. Estimate the effect of vegetation on signal
2. Consumed bandwidth by IP cameras



Lloret, J., Bri, D., Garcia, M., & Mauri, P. V. (2008, June). A content distribution network deployment over WLANs for fire detection in rural environments. In *Proceedings of the third international workshop on Use of P2P, grid and agents for the development of content networks* (pp. 55-62).

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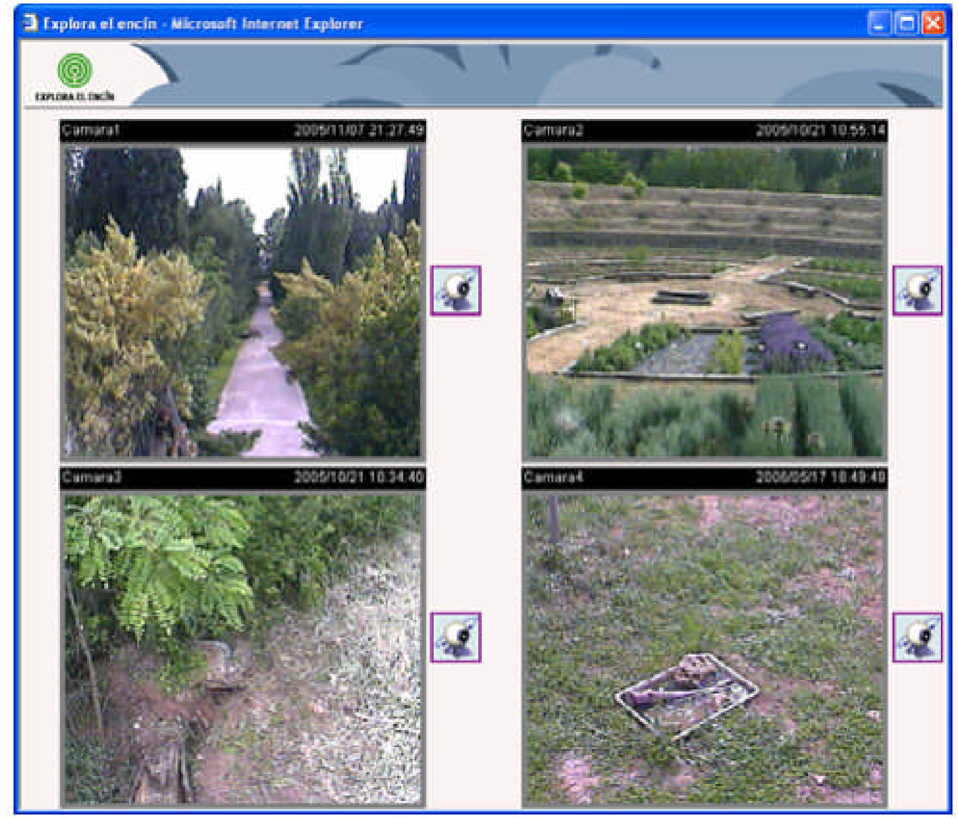
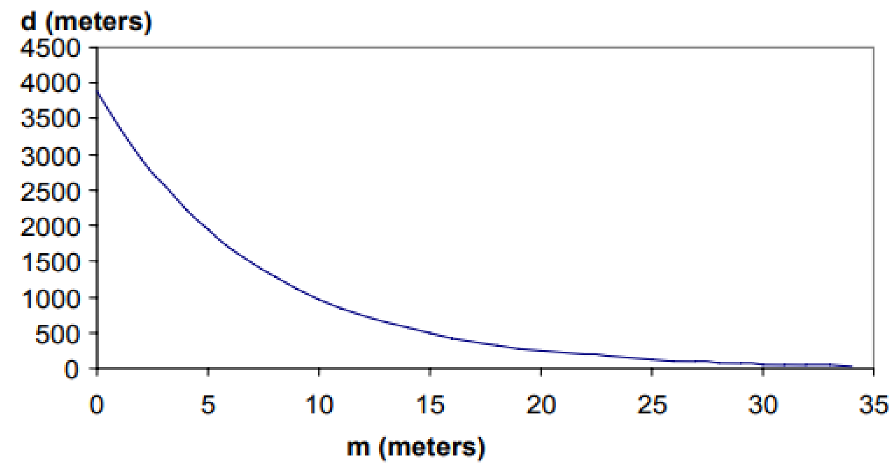
1. Estimate the effect of vegetation on signal

$$d = 10^{\frac{P_{tx}+G_{tx}+G_{rx}-L_{rain}-L_{vegetation}-P_{rx}}{20}}$$

$$d = 10^{\frac{71,77-1,2\bullet m}{20}}$$





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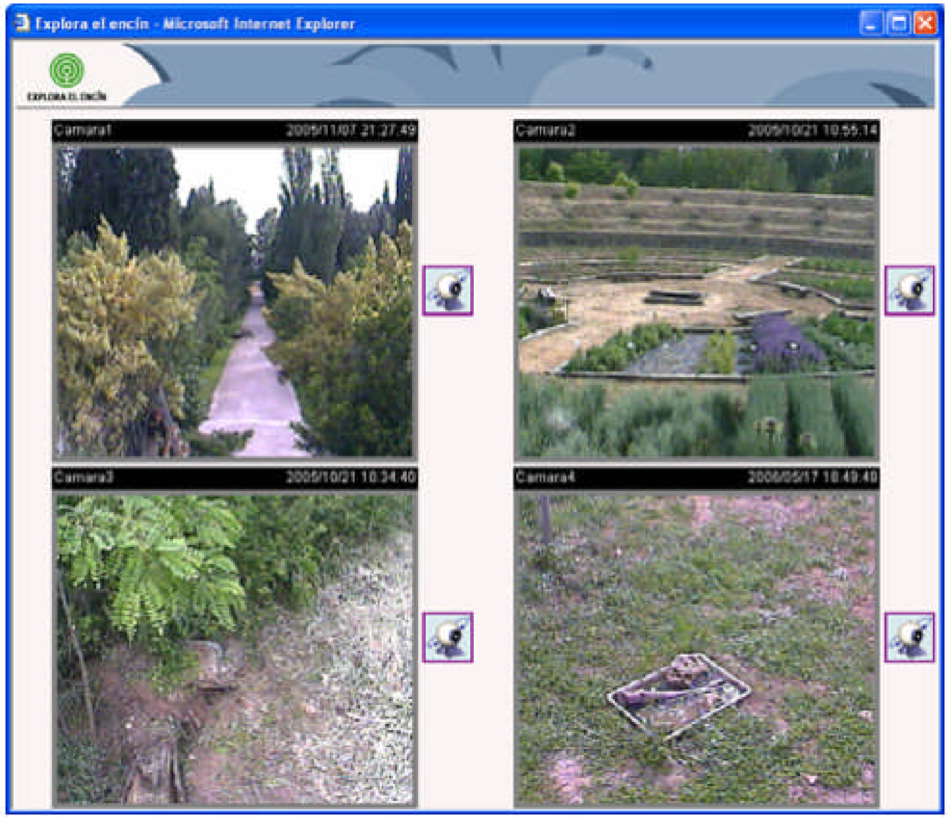

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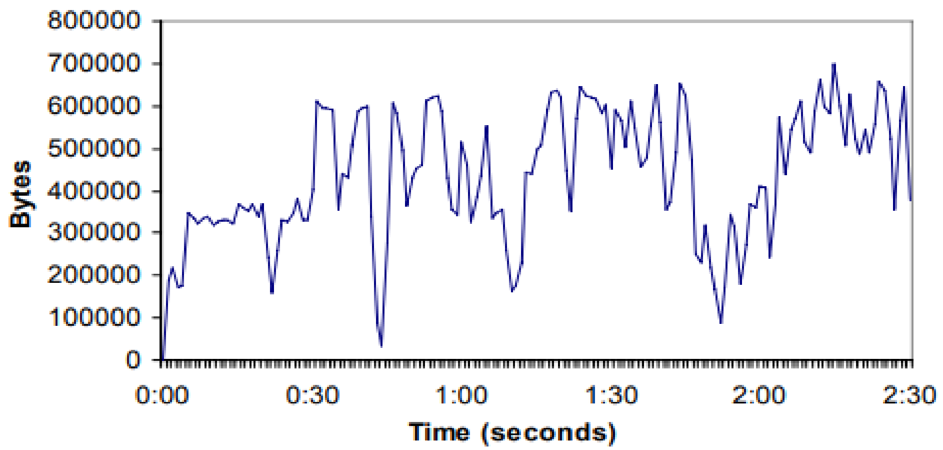

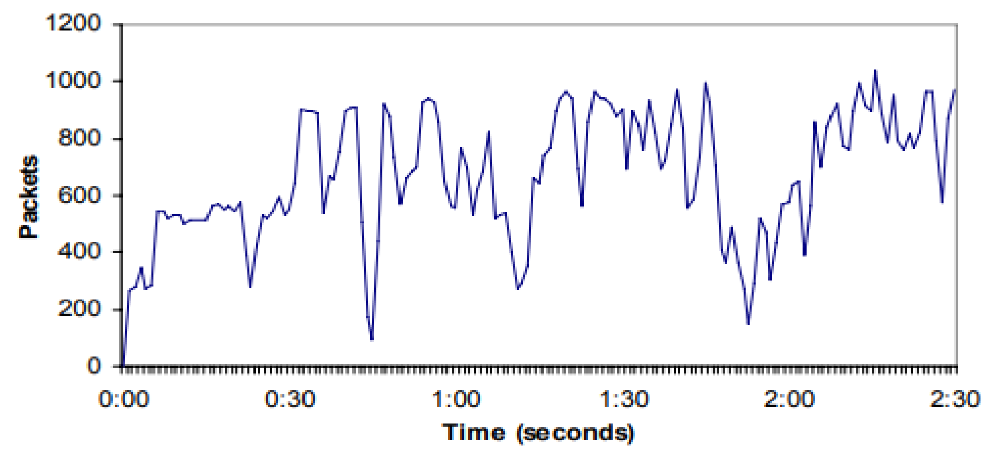

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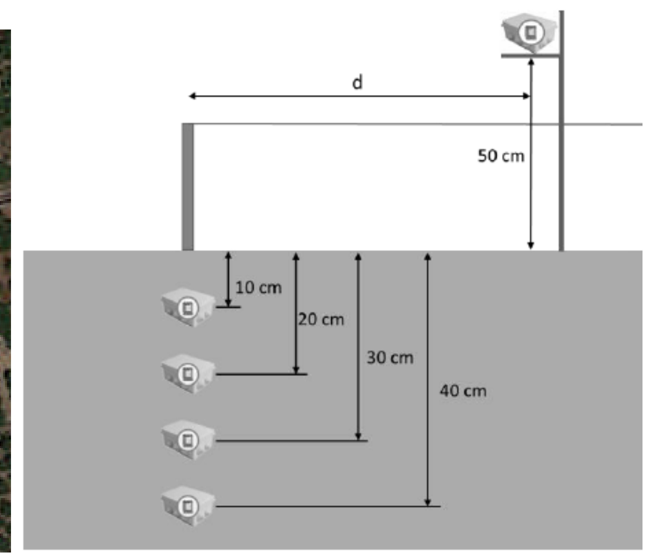
Effect of soil over the coverage

Motivation: Ensure connectivity of underground nodes

Task: Real deployment of underground nodes

Objectives:

1. Measure the RSSI of nodes deployed at variable depth in an orchard area



L. García, L. Parra, J. M. Jimenez, J. Lloret, A. Abouaissa, P. Lorenz (2019, November). Internet of Underground Things ESP8266 WiFi Coverage Study. The Eighth International Conference on Communications, Computation, Networks and Technologies, Valencia, Spain, 24-28 Nov. 2019, p. 55-62.

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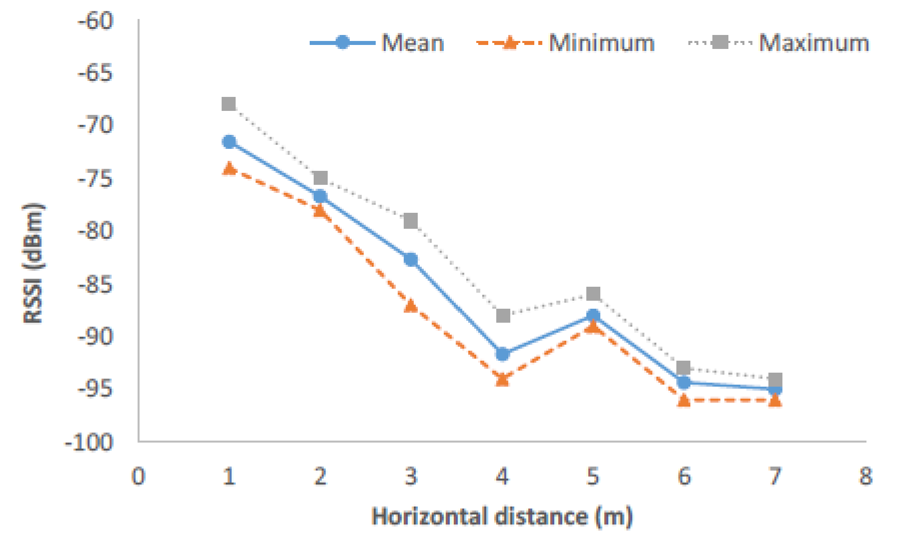
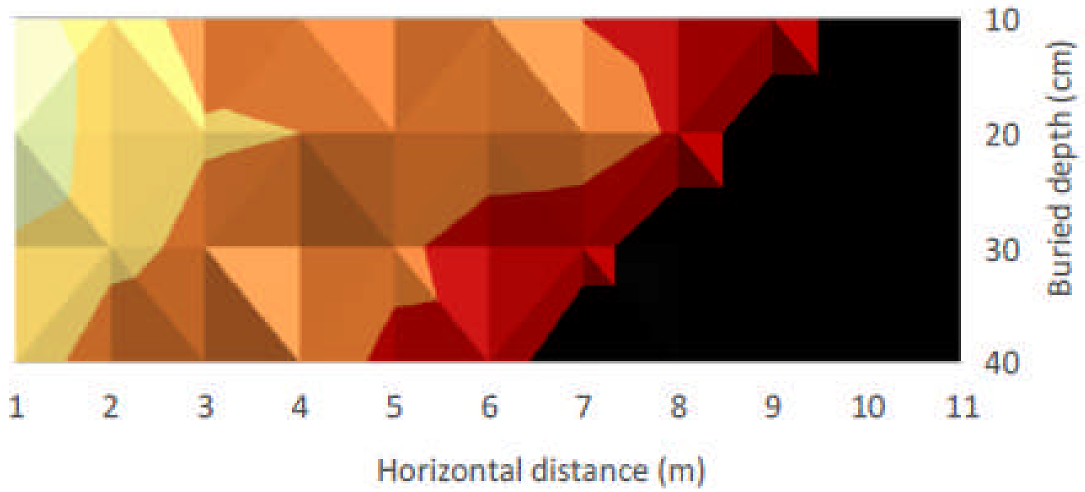


Node deployed at 30 cm



Summary of measured RSSI

L. García, L. Parra, J. M. Jimenez, J. Lloret, A. Abouaissa, P. Lorenz (2019, November). Internet of Underground Things ESP8266 WiFi Coverage Study. The Eighth International Conference on Communications, Computation, Networks and Technologies, Valencia, Spain, 24-28 Nov. 2019, p. 55-62.

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A model was created to obtaine the losses of the soil (Lsoil):

$$L_{soil} = L_m + L_\alpha \quad (3)$$

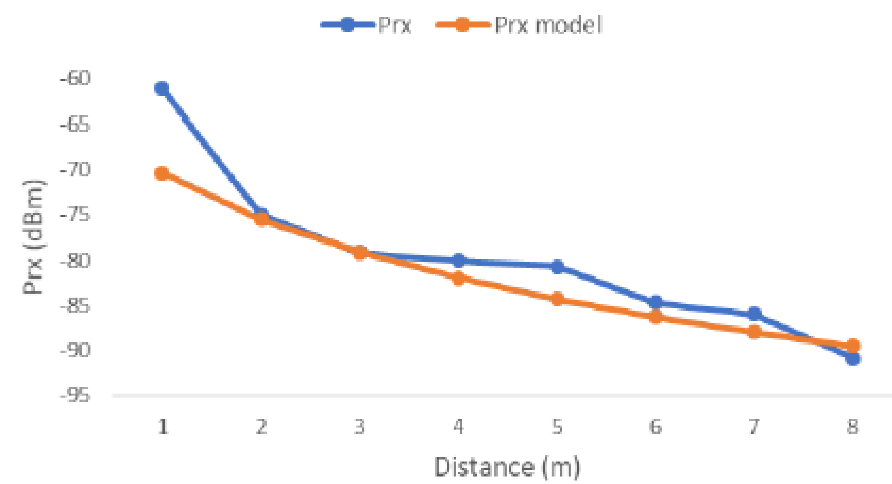
Where L_m is the attenuation caused by the variation in wavelengths and L_α corresponds to the losses due to the attenuation constant. Each of them is presented in (4) and (5) respectively.

$$L_m = 20\log\left(\frac{\lambda_0}{\lambda}\right) = 20\log\left(\frac{\frac{c_0}{f}}{\frac{c}{f}}\right) = 20\log(\sqrt{\mu_r \varepsilon_r}) \quad (4)$$

$$L_\alpha = 8.69\alpha d_{soil} \quad (5)$$

The attenuation constant is given by (6).

$$\alpha = \frac{1}{5.31 * 10^{-3} * \frac{\sqrt{\varepsilon'}}{\sigma}} \quad (6)$$



Model and real measures for node deployed at 20 cm

L. García, L. Parra, J. M. Jimenez, J. Lloret, A. Abouaissa, P. Lorenz (2019, November). Internet of Underground Things ESP8266 WiFi Coverage Study. The Eighth International Conference on Communications, Computation, Networks and Technologies, Valencia, Spain, 24-28 Nov. 2019, p. 55-62.

Conclusions

- The correct location of nodes in the deployment must be carefully planned in rural environments, and the losses due to vegetation and soil have to be considered.
- Rural areas are a complex environment with multiple and variable problems for the deployment of wireless networks (rain, the variation of vegetation density, the variation of soil moisture…).
- More studies to evaluate the effect of vegetation and soil in other technologies such as LoRa will appear.