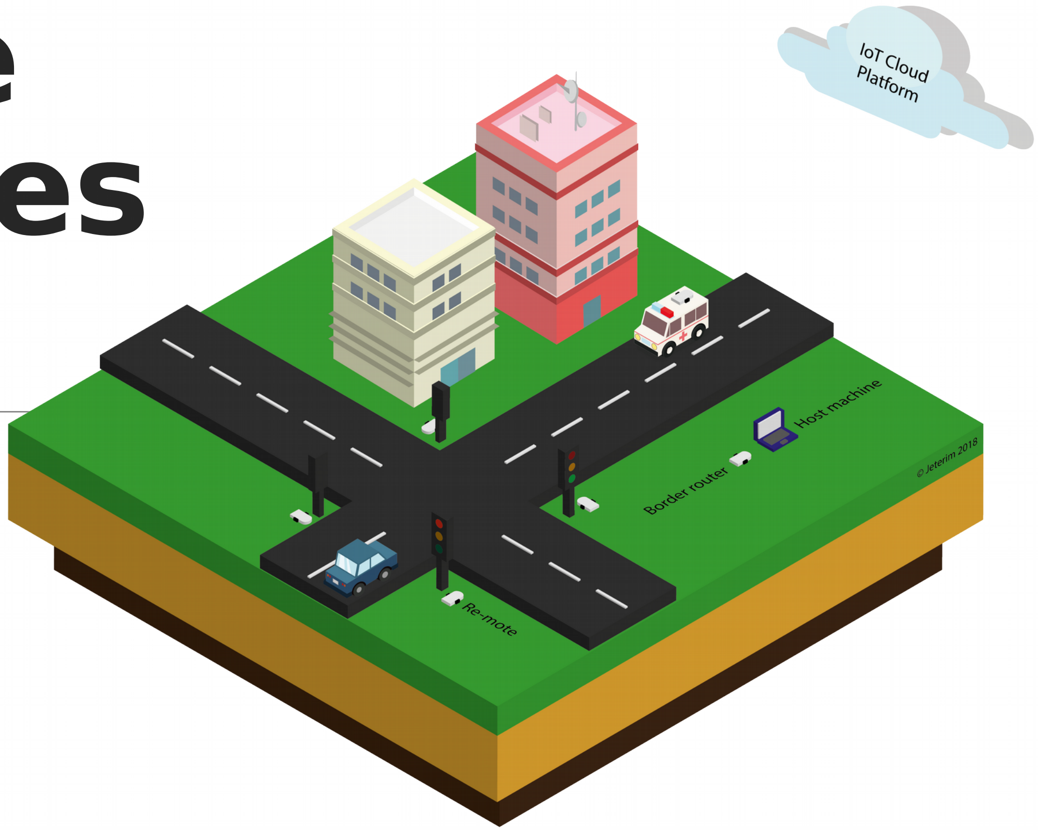
INSA INSTITUT NATIONAL DES SCIENCES APPLIQUÉES CENTRE VAL DE LOIRE

ECE PARIS ÉCOLE D'INGÉNIEURS

STAGE DE 4ÈME ANNÉE

Réseaux IoT pour le contrôle des feux de signalisation dans des villes Intelligentes



PETIT JÉRÉMY

ANNÉE UNIVERSITAIRE 2017/2018

Problématique / Objectif du stage

Problématique / Objectifs du stage

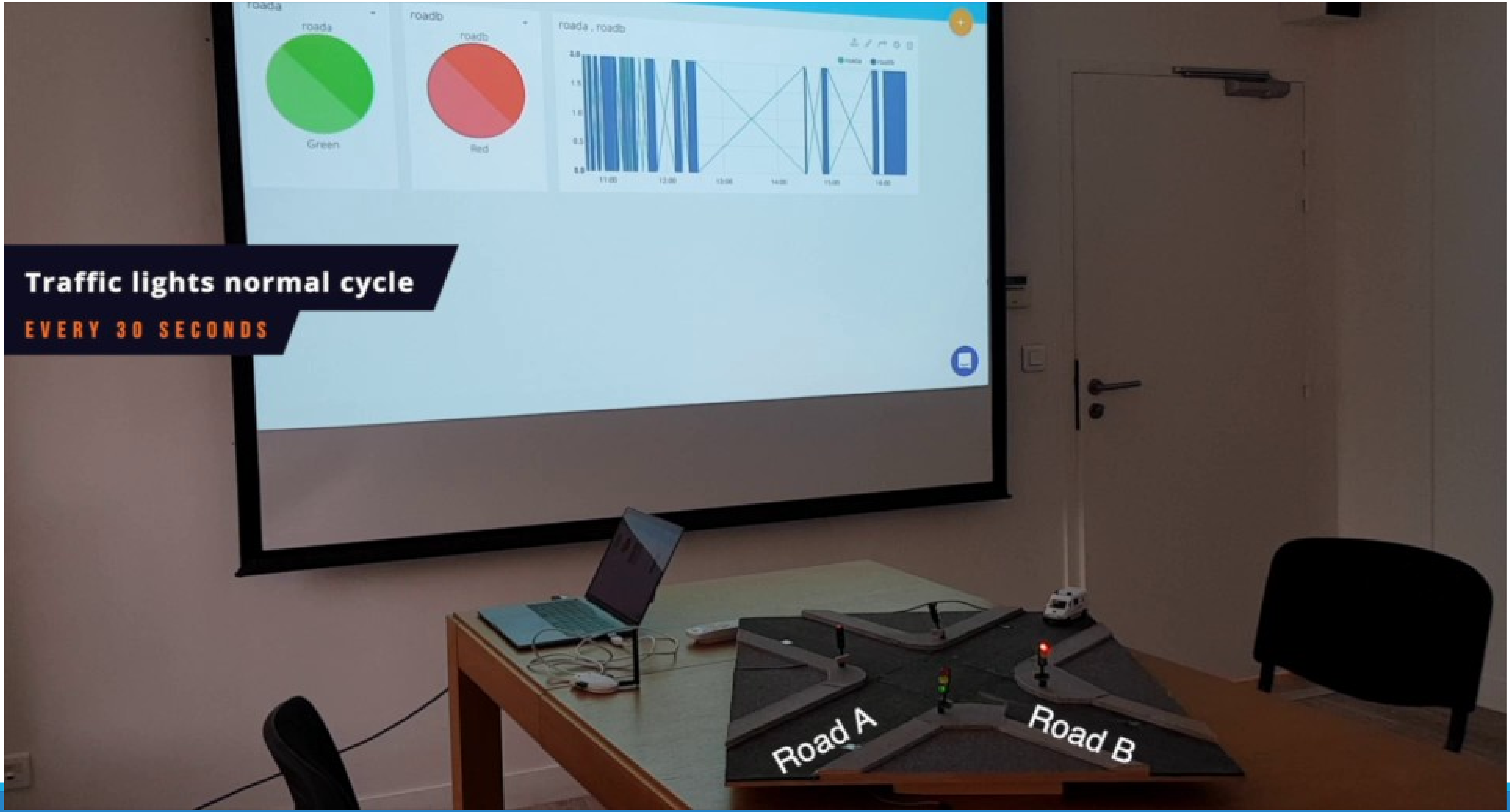
Trouver une solution en utilisant l'IoT pour des feux connectés et dynamiques

Objectifs :

- Reprendre le travail existant et l'améliorer pour s'approcher d'un fonctionnement normal de feux de signalisation
- Rendre ce projet plus autonome en supprimant un acteur de la chaîne
- Tests et évaluations d'un protocole de QoS (MQTT) dans un cas réel

Cas d'usage défini lors du travail existant : Interruption du cycle de feu pour laisser passer un véhicule prioritaire

Plan


Traffic lights normal cycle
EVERY 30 SECONDS
roada
Green
roadb
Red
roada , roadb
Road A
Road B

I Présentation de l’école et du laboratoire

I Présentation de l'école et du laboratoire

350 Enseignants

2100 étudiants

+17M d'€ de budget annuel

7 majeures (SI cyber sécurité & Big Data, SE, Objets connectés et réseaux, transports, santé, finance, énergie & environnement….)

3 axes de recherche (Stage réalisé dans l'axe Systèmes Intelligents Communicants - SIC)

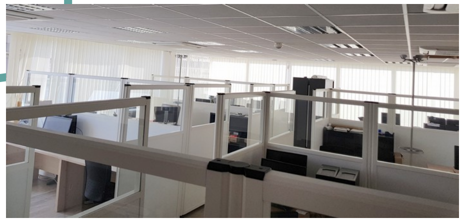
15 enseignants-chercheurs

9 doctorants

1 ingénieur de recherche

Près de **150K€** de budget (équipements, stages, doctorants…)

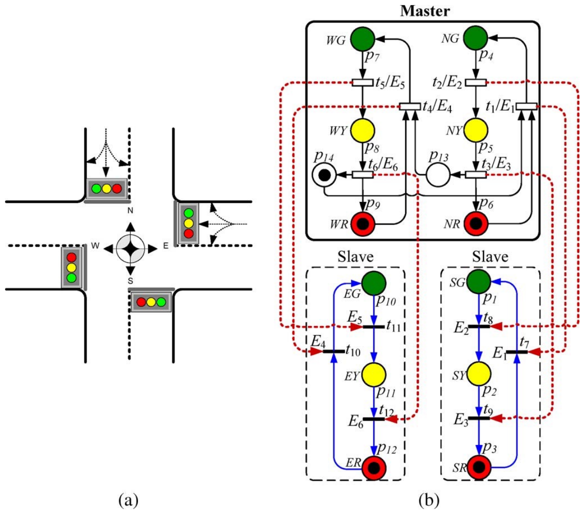
Laboratoire

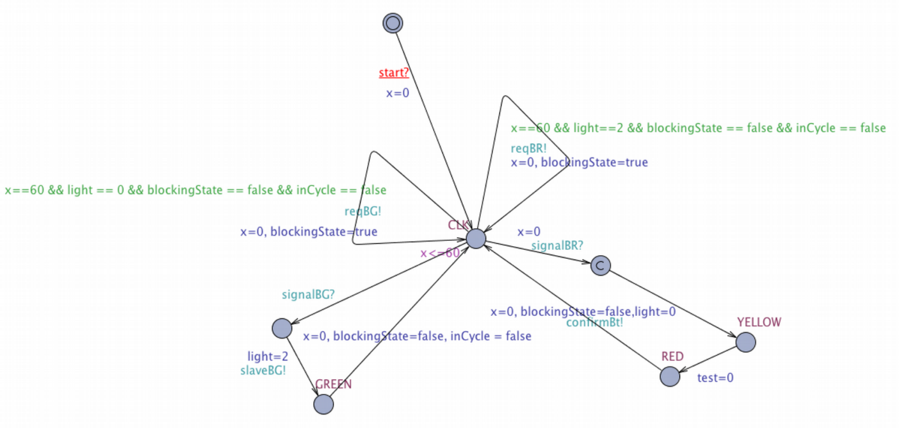


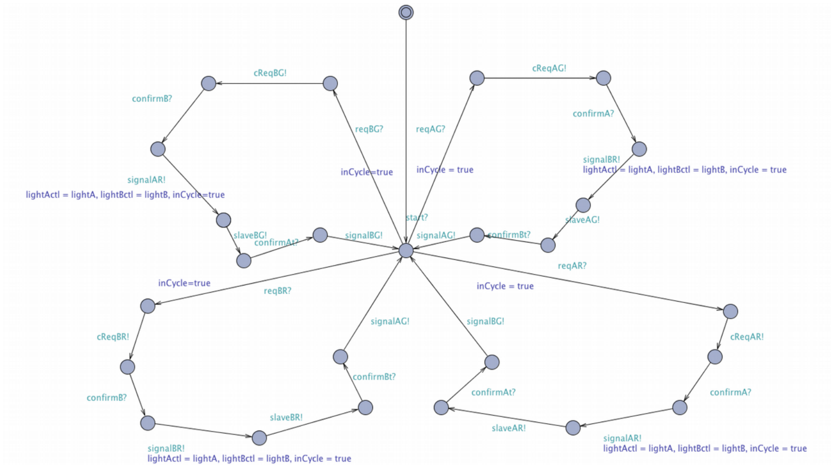
II Conception

II Conception

Développer notre modèle et définir que des points de contrôle sont nécessaires pour notre système







Réseau de Petri

UPPAAL

III Réalisation

III Réalisation

6LoWPAN

Contiki Os

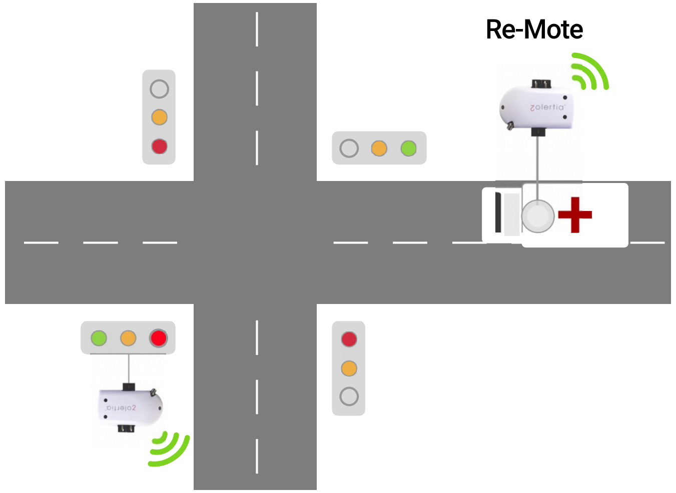
Zolertia Re-mote

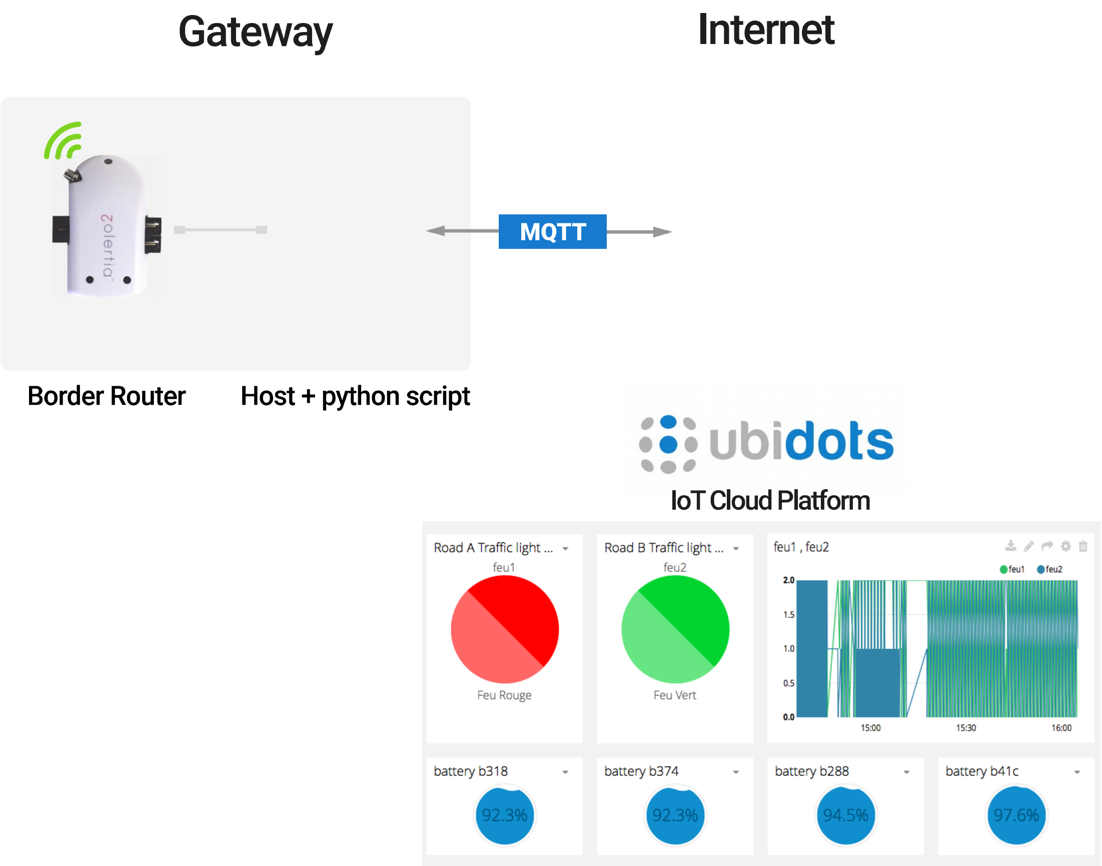
Border Router

Paho Python

MQTT & QoS

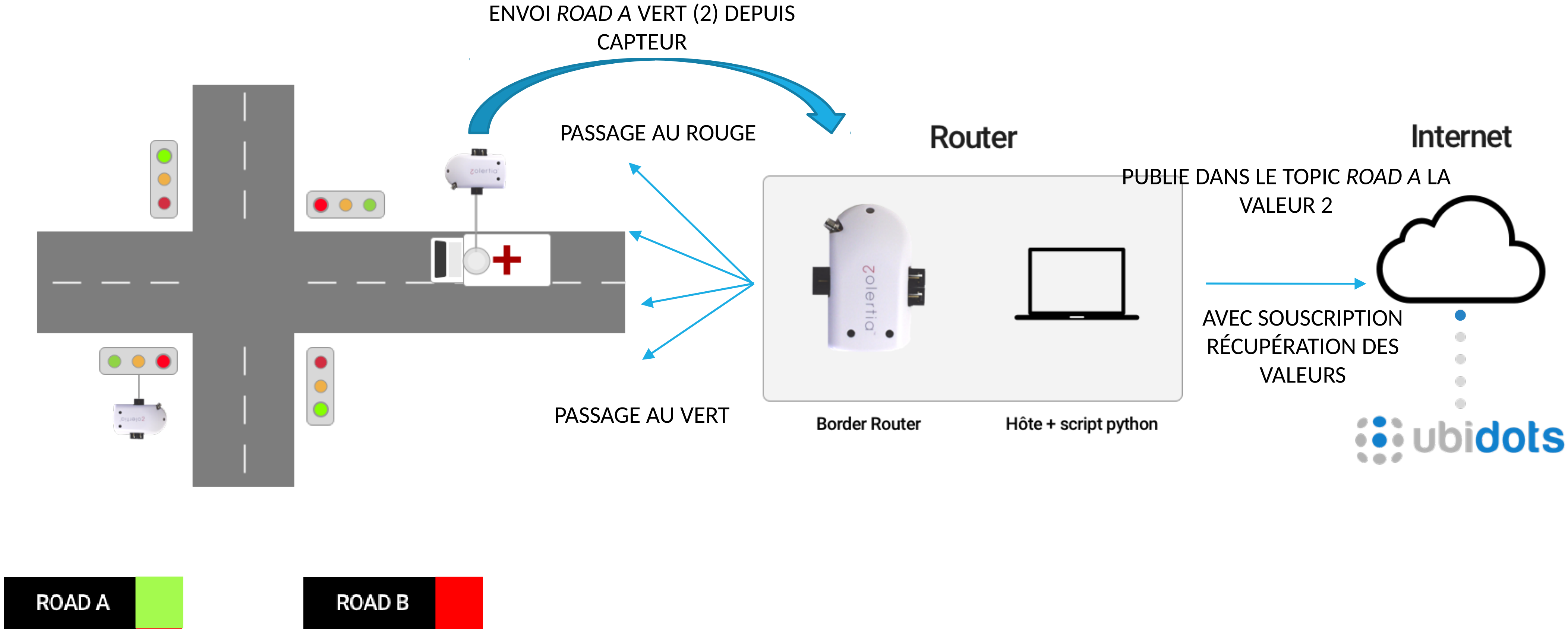
Ubidots





III Réalisation

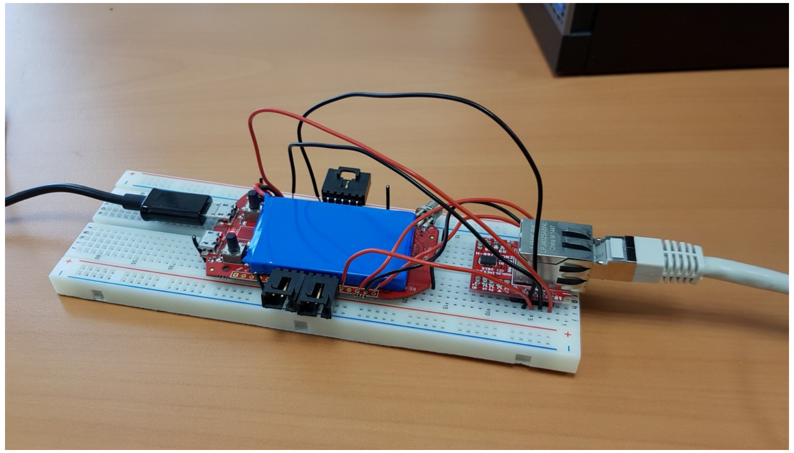
SITUATION D’UN VÉHICULE PRIORITAIRE



III Réalisation

Réalisation d’un second projet pour apporter plus d’autonomie au système

- Suppression du middleware
- Connexion MQTT depuis chaque Re-mote



Problèmes

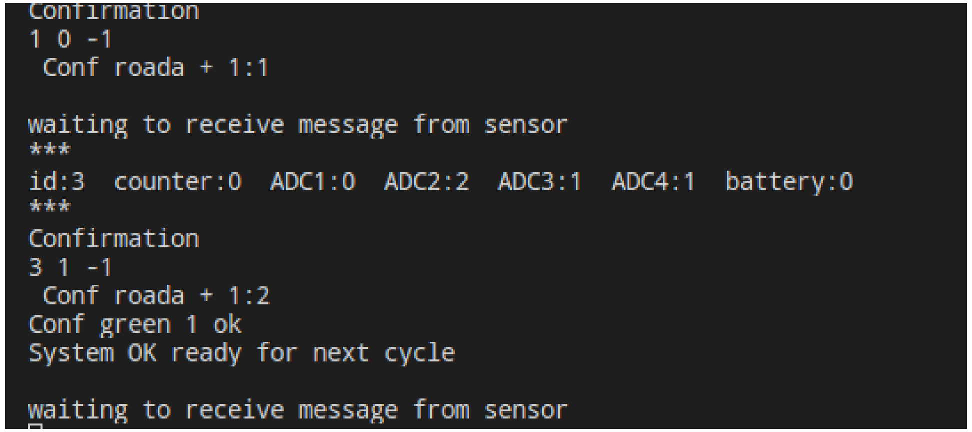
- Limitation matérielle de l’Ethernet Router
- Limitation logicielle du moteur MQTT de la solution

IV Résultats

II Résultats

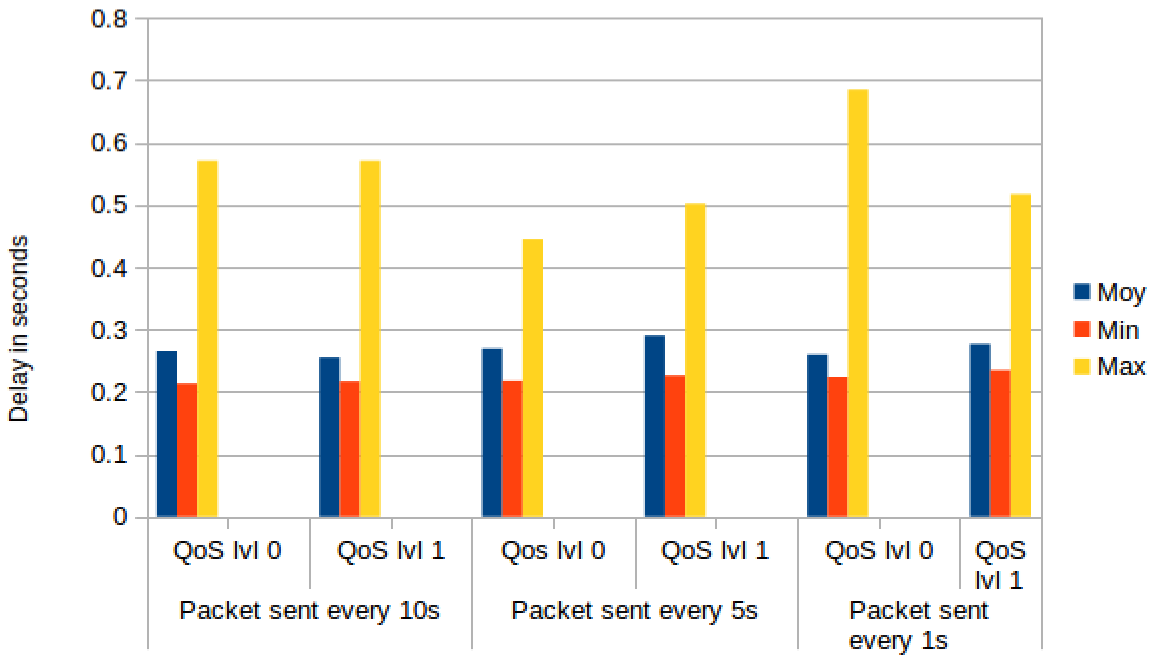
Projet fonctionnel mais avec des sécurités mises en place (contraintes)

- Filtrage des messages
- Demande de passage à un nouvel état d’un feu
- Demande de confirmation de ces états
- Ordre d’envoi défini
- Reprise du cycle de feu normal



II Résultats

Statistiques effectués sur notre niveau de Qualité de Service



V Perspective d’avenir du projet

V Perspectives d’avenir du projet

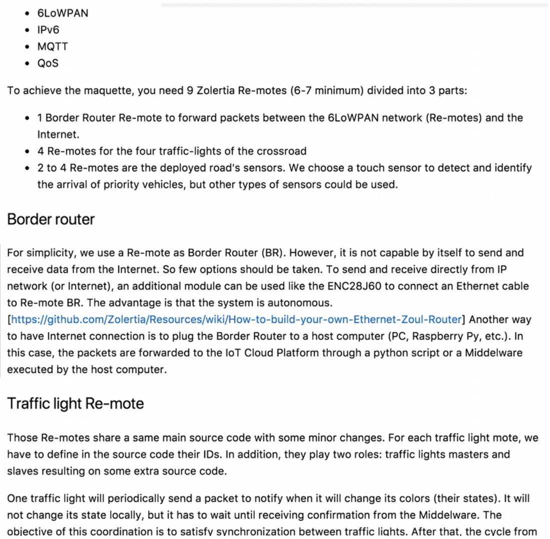
- Basé sur un cas d’usage, il peut être développé pour d’autres domaines
- Nouveaux capteurs => nouveaux usages
- Développer le projet avec l’Ethernet Router (pallier ses problèmes)
- Être maître de tous les aspects du projet
- Projet Open Source

VI Aspect recherche

VI Aspect recherche

- Documenter son travail, comment mettre en place son projet

Github, Wiki, PDF, LaTeX



- 6LoWPAN
- IPv6
- MQTT
- QoS

To achieve the maquette, you need 9 Zolertia Re-motes (6-7 minimum) divided into 3 parts:

- 1 Border Router Re-mote to forward packets between the 6LoWPAN network (Re-motes) and the Internet.
- 4 Re-motes for the four traffic-lights of the crossroad
- 2 to 4 Re-motes are the deployed road's sensors. We choose a touch sensor to detect and identify the arrival of priority vehicles, but other types of sensors could be used.

Border router

For simplicity, we use a Re-mote as Border Router (BR). However, it is not capable by itself to send and receive data from the Internet. So few options should be taken. To send and receive directly from IP network (or Internet), an additional module can be used like the ENC28J60 to connect an Ethernet cable to Re-mote BR. The advantage is that the system is autonomous. [https://github.com/Zolertia/Resources/wiki/How-to-build-your-own-Ethernet-Zoul-Router] Another way to have Internet connection is to plug the Border Router to a host computer (PC, Raspberry Py, etc.). In this case, the packets are forwarded to the IoT Cloud Platform through a python script or a Middelware executed by the host computer.

Traffic light Re-mote

Those Re-motes share a same main source code with some minor changes. For each traffic light mote, we have to define in the source code their IDs. In addition, they play two roles: traffic lights masters and slaves resulting on some extra source code.

One traffic light will periodically send a packet to notify when it will change its colors (their states). It will not change its state locally, but it has to wait until receiving confirmation from the Middelware. The objective of this coordination is to satisfy synchronization between traffic lights. After that, the cycle from

Prototyping of Urban Traffic-Light Control in IoT

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***Abstract*—In this work, we propose a demonstration of Urban Traffic Light Control based on an IoT network (IoT-UTLC) for smart cities. We mocked up a real crossroad by integrating a 6LoWPAN Wireless Sensor Network (WSN) to control mini traffic light panels. The network's nodes are wireless sensors and actuators interacting with an IoT Cloud Platform. MQTT Quality of Service (QoS) protocol has been implemented to manage the priority levels of exchanged data between the Cloud and WSN. Our IoT-UTLC has been found functional after verification and validation using the UPPAAL model checker.**

***Keywords*—Internet of Things, Smart Cities, Wireless Sensor Networks, IoT Cloud Platform, 6LoWPAN, QoS, MQTT, UPPAAL**

I. Introduction

The development of Wireless Sensor Networks (WSNs) and the Internet of Things (IoT) leads to new opportunities. Smart city's projects are rising, responding to the intent of interconnecting users to their environment. The aim of IoT is to make the Internet more immersive on everyday life by using Hardware and Software components to interconnect things through the Internet. In this smart city context, we prototyped an Urban Traffic Light Control based on an IoT network architecture (IoT-UTLC). Our traffic light system would be interactive and able to connect indirectly, via Internet, traffic lights and vehicles. Our objective is to propose and demonstrate a solution for actual traffic lights, which have a static behavior. By using IoT, traffic light control would be dynamic, bringing new services and becoming application scalable, *i.e.* not limited to a simple traffic light management system. For example, we can imagine noise or air pollution measurements through panels or road's sensors.

Solutions have been proposed to make Urban Traffic Light Control (UTLC) smart and dynamic. The first idea is to use a wired installation on every crossroad with cameras to detect vehicles [1]. It involves expensive means to implement it on various intersections and cannot be deployed throughout an entire city. Moreover, research works, such as in [2], deal with only a local control of traffic lights and vehicles at intersections. Intelligent solution needs a global interconnection between road's users and infrastructure. However, we propose a wireless sensor/actuator network remotely controlled via a dedicated QoS protocol for IoT. We also set up a Cloud Interface to collect sensed data and interact with the network.

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Fig. 1. Architecture of IoT-UTLC

Our solution has been developed with a simple use case in mind, which is the ability to interrupt the classic cycle of traffic lights to adjust the traffic flow for certain types of vehicles. For instance, emergency vehicles or public transportation services could use an IoT based system like IoT-UTLC to avoid congestion and "claim" a prioritized access. However, several technologies can co-exist for communicating between infrastructure, *e.g.* Zigbee, LoRa, SigFox, ITS-G5. Consequently, the only thing that binds them together is the Internet, which is a natural mean for heterogeneous networks inter-communications. Thus, our prototype proposes an IoT Cloud Platform in order to collect information about the traffic lights' sensors and actuators. Thanks to the IPv6 over Low power Wireless Personal AreaNetwork (6LoWPAN) [3], our WSN would be energy-efficient and IPv6 accessible.

For prototyping, students from ECE Paris engineering school [1] have built a demonstration maquette. They connect sensors, mini traffic lights panels and IEEE 802.15.4 transceivers via middleware establishing the connection to the IoT Cloud Platform. We improve the achievements of this project by integrating Message Queuing Telemetry Transport (MQTT), which is a light transport protocol, capable of doing Quality of Service (QoS). Mainly, we specified the levels of QoS managing a reliable network communication. When messages are sent without acknowledgement, our system defines the priority for crossing packets, which could have the highest level to guarantee an efficient and reliable communication.

II. Architecture and Prototype

Fig. 1 shows the architecture of our IoT-UTLC composed of three parts. From left to right, we have the WSN part with connected traffic lights' actuators, sensors and transceivers.

[1] Video of students' project: https://youtu.be/QottWpnE1zk

- Rédaction de papiers techniques
  - Extended abstract
  - Short Paper

VI Aspect recherche

Participation à des événements :

- Journée doctorale de l'ECE Paris, mai 2018
- Participer à l'organisation de la conférence IEEE ICACCE 2018 à l'ECE Paris, juin 2018
- Présenter un démonstration et un poster acceptés dans la conférence IEEE ICS2 2018, Kansas City, US, septembre 2018

VII Bilan

- Développer mes compétences en IoT (plus programmation C/Python) et Réseaux

- En accord avec ma formation (option 4A Mobilité)

- Mener un projet de A à Z, réfléchir à chaque étape du développement du projet

- Chercher des solutions et comprendre les problèmes

- Découverte de la recherche (méthode de travail, rédaction de papiers, et pouvoir avoir la chance de participer à des conférences pour échanger et présenter son travail)

Des questions ?