State of the art Smart Sensor

Industrial end project of studies

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Summary

1. Introduction

The place of study is the Laboratory of Informatics, Robotics and Microelectronics of Montpellier (LIRMM) which is a joint research unit jointly dependent on the University Montpellier (UM) and the National Center for Scientific Research (CNRS) [1].

The project is part of an industrial project of end of study which aims at putting the student in the situation of a project manager in charge of finding solutions to a concrete problem which is posed to him [2]

The Internet of Things (IOT) is the extension of the Internet to things and places in the physical world. The connected Internet of Things represents the exchange of information and data from real-world devices with the Internet.

The architecture of the device is shown in the chart below (Figure 1). The project aims to create the electronic board that will connect the sensors, the FPGA board and the communication modules as well as program them to work together. This is to help a thesis on microcontroller architecture exploration to lower energy consumption.

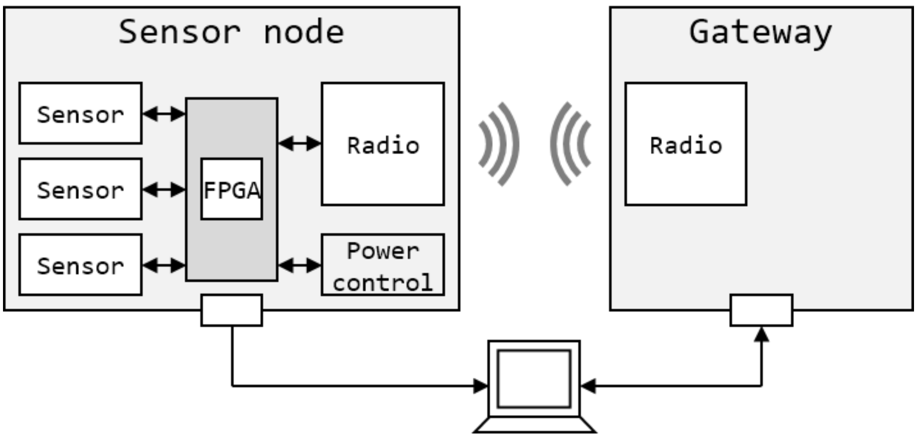


Figure 1 Smart Sensor architecture

2. Gantt

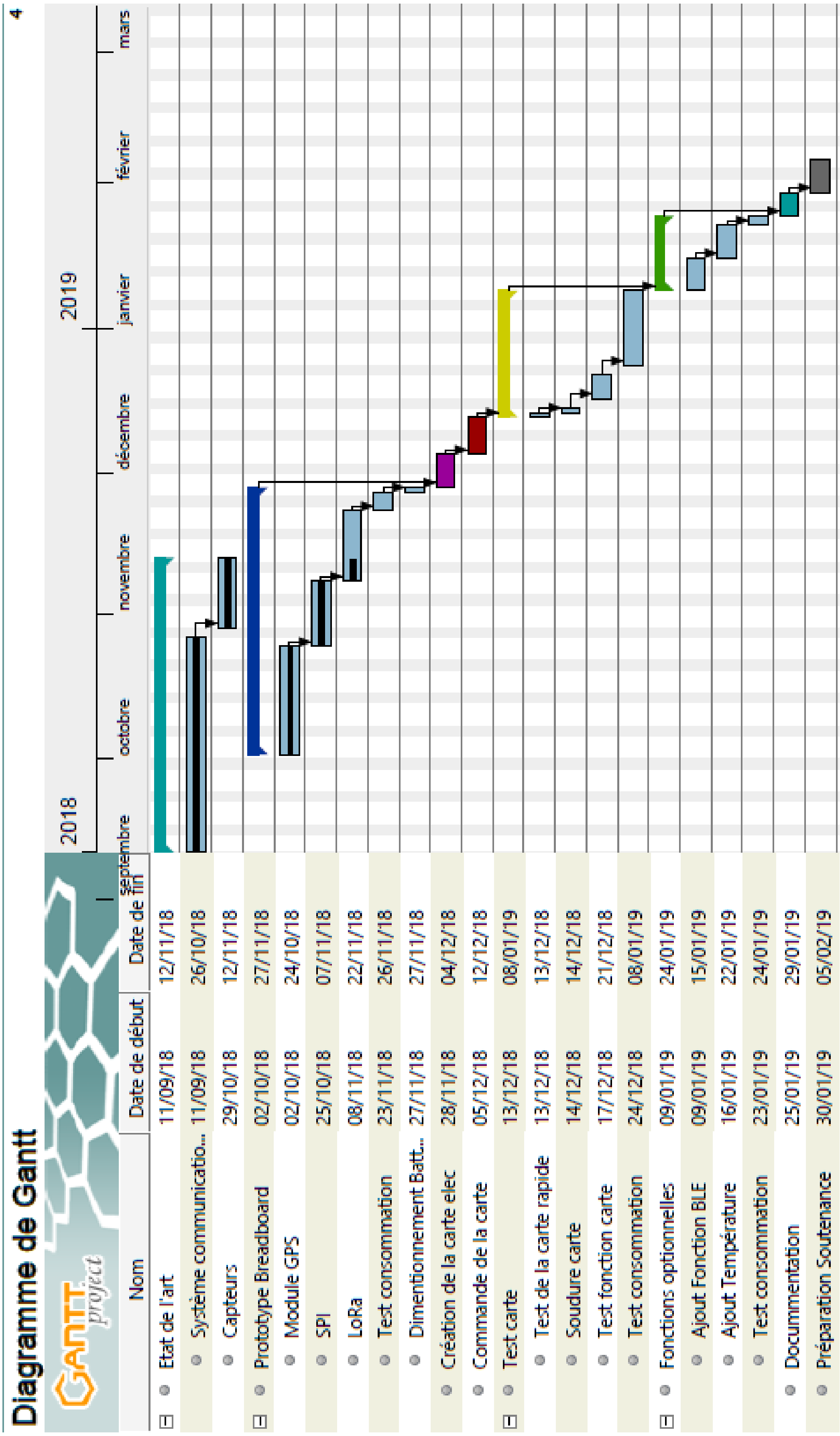


Diagramme de Gantt
GANTT project
2018
2019
septembre
octobre
novembre
décembre
janvier
février
mars
Nom
Date de début
Date de fin
Etat de l'art 11/09/18 12/11/18
Système communicatio... 11/09/18 26/10/18
Capteurs 29/10/18 12/11/18
Prototype Breadboard 02/10/18 27/11/18
Module GPS 02/10/18 24/10/18
SPI 25/10/18 07/11/18
LoRa 08/11/18 22/11/18
Test consommation 23/11/18 26/11/18
Dimentionnement Batt... 27/11/18 27/11/18
Création de la carte elec 28/11/18 04/12/18
Commande de la carte 05/12/18 12/12/18
Test carte 13/12/18 08/01/19
Test de la carte rapide 13/12/18 13/12/18
Soudure carte 14/12/18 14/12/18
Test fonction carte 17/12/18 21/12/18
Test consommation 24/12/18 08/01/19
Fonctions optionnelles 09/01/19 24/01/19
Ajout Fonction BLE 09/01/19 15/01/19
Ajout Température 16/01/19 22/01/19
Test consommation 23/01/19 24/01/19
Documentation 25/01/19 29/01/19
Préparation Soutenance 30/01/19 05/02/19

3. Sensors

3.1. Definition, types of sensors

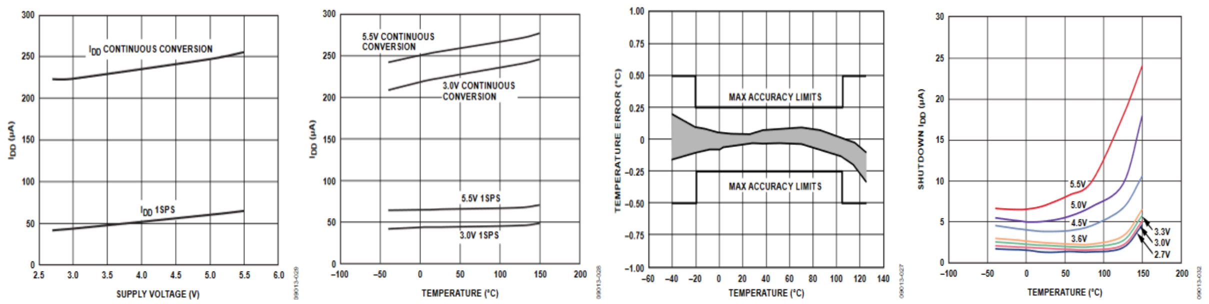
A sensor is a device that provides from a physical quantity taken, another physical quantity of different nature (often electrical) [3].

There are two different types of sensors. The active sensors under the action of the measurand, generates an electrical signal (current or voltage), we can call it generator. Passive sensors under the action of the measurand show a variation of impedance. The passive sensor does not directly produce an electrical signal, it will be essential to use an external electrical circuit to determine the value of the measurand.

Some examples of passive sensors: temperature, optical flow, deformation, humidity ...

Some examples of active sensors: optical flow, force, pressure, speed ...

The temperature sensor used is Digilent's PmodTMP2 [4] (Figure 3) which will operate under the following conditions: Vdd = 3.3V, periodic reading. The advantages are:



(a) Courant moyen de fonctionnement en fonction de la tension d'alimentation

(b) Courant de fonctionnement en fonction de la température

(c) Erreur en fonction de la température

(d) Courant en mode Sleep en fonction de la température pour différentes tensions d'alimentations

Figure 2 Specifications of the PmodTMP2 by Digilent

The average current consumed is 225µA in continuous operation (Figure 2 (a)), but it is slightly variable depending on the temperature (Figure 2 (b)). The sensor is very accurate because it has a maximum error of 0.5 ° C between -20 ° C and 105 ° C (Figure 2 (c)). Sleep mode consumes only 5µA maximum (Figure 2 (d)) and saves energy which is very important in our application [5].

3.2. Analog / Digital

You have to transform this analog data into digital data. We will create electrical circuits to receive digital values or use, as in most cases, a microcontroller. There are many sensors in the form of modules that deliver the digital data. Sensors used:

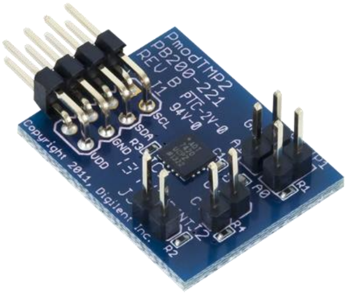


Figure 3 PmodTMP2 sensor by Digilent

Figure 4 PmodGPS sensor by Digilent

To interface between the module and the central microcontroller, it is necessary to communicate by cables. We will use communication interfaces such as UART, I2C, SPI and others.

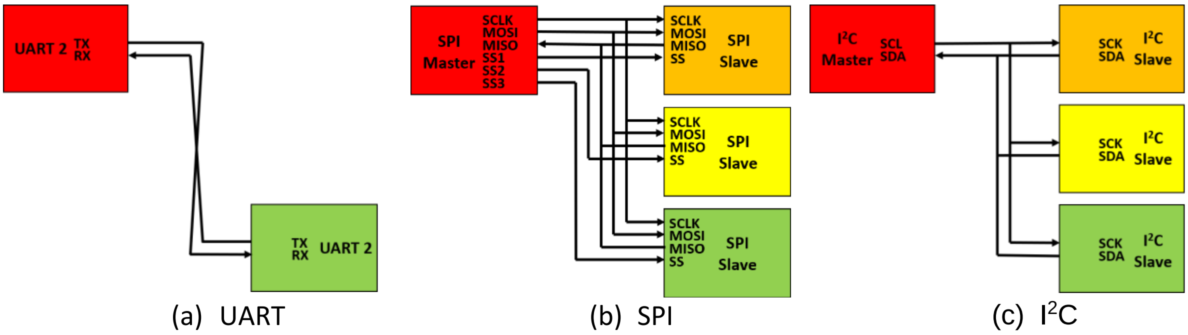


Figure 5 Communications Interfaces

A UART (Figure 5 (a)), for Universal Asynchronous Receiver Transmitter, is a universal asynchronous transceiver.

An SPI link (Figure 5 (b)) (for Serial Peripheral Interface) is a synchronous serial data bus. The circuits communicate according to a master-slave scheme, where the master controls the communication. Several slaves can coexist on the same bus, in this case, the selection of the recipient is done by a dedicated line between the master and the slave called Slave Select.

I2C (Figure 5 (c)) is a half-duplex bidirectional synchronous serial bus, where multiple devices, masters or slaves, can be connected to the bus.

UARTs, SPIs, and I2Cs are usually integrated into components like microcontrollers. In this case they are no longer a component per se, but a peripheral function of the central component.

4. Communication

4.1. Wireless for IoT

For the IOT it is important that the more devices are connected to have more information and act in the best way possible. The interest of the wireless network is that it is convenient (no wire) and that the installation of a new device will be fast and simple. Here are some wireless networks adapted to IOT that will be compared at the level of energy consumption:

The **SIGFOX** is a UNB (Ultra Narrow Band) technology that operates at 868 MHz with a rate of 1000 b / s for a bandwidth of 1 KHz and a sensitivity of -140 dBm with a reported range of 40 km. Devices using this technology can send 140 messages a day to a station. It's asynchronous technology, so nodes do not wake up to sync. It is therefore simpler to calculate the consumption [6].

LoRa is made for long-range IOT applications. LoRa Alliance offers a station that receives packets from a device and retransmits data to a server over a TCP connection. The LoRa uses mainly CSS (Chirp Spread Spectrum) based modulation which allows a bandwidth of 0.25 to 11 kb / s with a bandwidth of 7 to 250 KHz. In this comparison only LoRa class A will be taken into account [6].

Bluetooth Low Energy is a version of standard Bluetooth. It is most often used for applications such as heart rate monitors or remote room temperature controls. The advantage of this technology is that it is very popular (in most smartphones) and that the latest versions (4.2, 5.0) allow to have several nodes. BLE has a frequency of use of 2.4 GHz, the maximum bit rate is 2 Mb / s. In the last version 5.0, it is possible to use 4 different diagrams which make it possible to have several bitrates (125 kb / s, 500 kb / s, 1 Mb / s and 2 Mb / s) to consume less depending on the applications [6].

NB-IoT (Narrowband Internet of Things) technology is a wireless communication technology that operates at 180KHz with a data rate of 250 kb / s. Applied to date mainly to the industry sector, the NB-IoT, led by China, now wants to conquer that of the Smart Home, Smart Building and Smart City. The advantages of this technology are numerous: low energy consumption, extensive coverage and low cost of production and use [7].

4.2. Energy

The IOT is interesting because of its autonomy and its source of wireless energy. The results presented are based on a scientific article: Comparison of the Device Lifetime in Wireless Networks for the Internet of Things [6].

Calculations of the lifetime of connected objects are made from the values of the variables in this diagram (Figure 6).

t_a means the period of application

t_{on} means the period of issue

t_{ci} means the period of synchronization

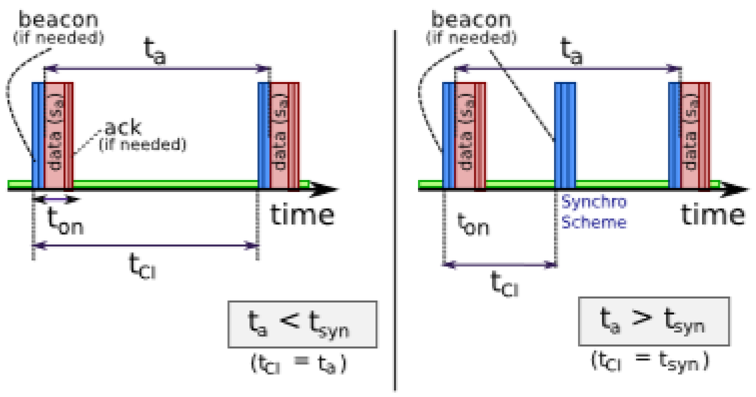


Figure 6 Calcul de consommation

The authors of the article have created the algorithm that will treat these values and give us consumption.

Here is the consumption of each mode (Figure 7) (it is not necessary to take into account only this table because each protocol will use during more or less long time these modes):

Power	P_Tx	P_Rx	P_Idle	P_Sleep
SIGFOX	147mW	39mW	Ø	4.32uW
LoRa	419.6mW	44mW	Ø	4.32uW
BLE	24.11mW	9.26mW	4.67mW	3.24uW
NB-IOT	Ø	Ø	Ø	Ø

Figure 7 Consumption

NB-IOT has no value in the table because this communication system was not in the article studied and taking values from other studies would not be objective since the test conditions would not be the same .

There is another algorithm that calculates the consumption based on the lost packet probability that must be returned.

5. Conclusion

The major challenge of the IOT is autonomy, hence the preference to use active sensors (which generate a voltage or a current). The interest is to make architecture exploration on FPGA microcontroller to lower the consumption.

Here are the results of my research on the consumption of the radio protocols (recall: except NB-IOT):

- When the packets are not lost:

For an emission every day, every 100s, every second and milliseconds the BLE is the most efficient in terms of energy saving.

- When 20% of packets are lost:

The BLE remains more energy efficient but the service life decreases by about 10%.*

- The clock drift:

It only slightly reduces the life of LoRa and SIGFOX at low traffic levels, unlike BLE.

For our application we will therefore prefer the LoRa because it ultimately consumes very little but has a much larger scope than the BLE. We will prefer to use Pmod sensors to facilitate the testing of different sensors when the card is completed. Sensors such as temperature, location will be used to have relevant data to transmit.

The use of LoRa is attractive for LIRMM as it will provide data on this recent technology.

Références

[1] http://www.lirmm.fr/

[2] https://moodle.umontpellier.fr/

[3] Alain Foucaran, Cours Capteur, 2017

[4] https://fr.farnell.com/

[5] Datasheet ADT7420

[6] Elodie Morin, Mickael Maman, Roberto Guizzetti et Andrzej Duda, Comparison of the Device Lifetime in Wireless Networks for the Internet of Things, Received January 24, 2017, accepted March 1, 2017, date of publication April 7, 2017, date of current version June 7, 2017.

[7] https://www.abavala.com/qu-technologie-nb-iot/