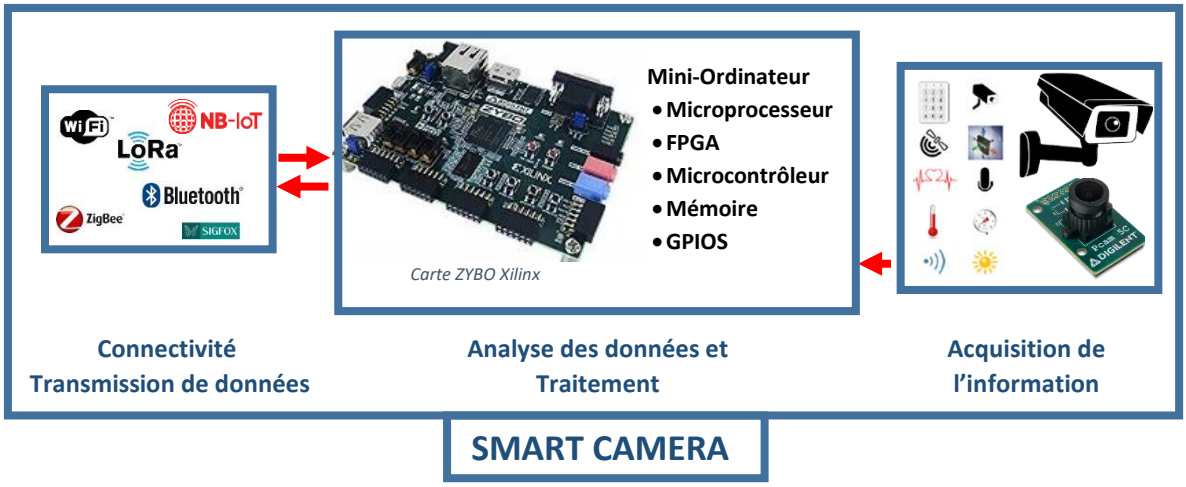
Study and conception of Smart Camera for the IoT LoRa Project

Introduction

Connected and smart objects have become an integral part of our daily lives, thanks to the evolution of the Internet of Things (IoT) domain. Experts from the world of technology, multinationals and startups, seek to make connected objects even smarter, smaller, multitasking and, above all, consuming the least amount of energy possible.

As part of research work carried out at LIRMM on IoT, an experimental platform consisting of connected objects, network gateways and servers for the processing of collected data. My project, part of this work, is to study and design a Smart Camera that ensures the acquisition, analysis and transmission of these data after treatment.



1. Smart Cameras

Smart Cameras are the new generation of normal cameras that only acquire images and transmit them in video format. The latter are able to process these data, analyze them according to video processing algorithms in order to derive information considered relevant by the user.

More and more companies that manufacture audiovisual devices decide to equip their camera with intelligence like the cameras offered by the American company NEST Labs, a subsidiary of Google and specializing in home automation. NEST cameras are smart cameras that can detect people and recognize familiar faces. These IP cameras transmit information (videos, images and notifications) via Wi-Fi or Bluetooth Low Energy (BLE), with a bandwidth required of at least 2Mbit / s, streaming and video recording as well as notifications on mobile devices require a broadband internet connection and a functional Wi-Fi network. NEST cameras are very demanding in terms of power, bandwidth and flow.

These types of connected cameras, although NESTs have AES encryption systems, but transmitting video data via IP itself increases the risk of hacking, especially with the integration of more and more objects connected the number of IP gateways also increases.

The LIRMM smart camera, connected to an intelligent network that consists of several other sensors, will use much less bandwidth to transmit information. These data are broadcast in the intelligent network and can be used by other connected objects or even by Smart Cameras fixed elsewhere.

Such systems can be used in many areas such as remote monitoring, road traffic and various applications in industrial and domestic environments such as smart homes …

1.1 Smart homes

During the last decade, the field of home automation and smart homes has undergone remarkable development. CCTV is one of the main concepts of Smart Homes, with the installation of surveillance devices for home security, tracking objects (furniture ...) and surveillance of pets.

Smart cameras made up of analysis and processing processors, cameras and communication modules offer intelligent monitoring. While normal cameras are used to capture what is happening in monitored locations, the purpose of smart surveillance is to effectively inform the user of events that may be of interest to them. Because with Smart cameras, the user will no longer have to view video recordings to find out what is going on in the house, but thanks to the processing algorithms that are implemented in the FPGA / Microprocessor, the Smart camera analyzes the information acquired. and warn the user of relevant events (depending on the algorithms used). Thanks to the communication modules, this information can be communicated to other cameras fixed in other corners of the house.

1.2 Trafic Road Surveillance

After the integration of smart cameras in homes and industrial settings, their use for traffic monitoring has a lot of benefit for traffic control, accident detection and car tracking.

Roads equipped with these new generation cameras will have the ability to monitor and alert the right people according to the event produced.

Several analysis algorithms are developed and implemented in smart cameras to perform different tasks [2]. We can then detect vehicles [2], determine their speeds, analyze the behavior of cars to detect accidents as soon as they occur, and also track and predict car travel [2].

With these smart cameras, people who monitor the road will be quickly notified of accidents and their location will be even easier. Because to monitor a road, it is necessary to be attentive to a hundred screens at the same time, something which is impossible, whereas with such cameras, the qualified agents will have to be attentive to the flow of messages sent by the smart cameras containing the information on the occurrent event (vehicle traveling at high speed, sudden movement of the vehicle or accident ...).

Smart cameras have a lot of benefit for road monitoring, they will detect accidents as soon as they happen, locate them to act as soon as possible, as they can track cars and plan their trips to control the traffic. traffic and even avoid traffic jams.

1.3 Synthèse

Thanks to the modules that make up Smart Cameras, they can ensure maximum surveillance in different environments (houses, industries, roads ...) and with low bandwidth consumption.

Smart cameras transmit messages via low bit rate networks and low power wide area network (LPWAN) scopes [3], which are widely used to connect applications in the IoT domain.

They thus ensure the surveillance of an environment by keeping a confidential nature because they make it possible to warn the user of the relevant events (human presence in a place, to count the number of people entering / leaving ...) without revealing totally what happens in the middle. This guarantee of confidentiality is a very important asset that may interest several infrastructures that rely on camera surveillance to ensure security, event inspection...

2. Hardware and Software Architecture

The Smart Camera consists of three main elements: the camera, the development board and the message transmission module. These allow successively acquisition, analysis / processing and the transmission and reception of data.

The hardware part designates the architecture of the Smart camera system with the IPs (Intelectual propertys) which compose it: Zynq Processing Synstem, GPIOs, AXI QUAD SPI ... While the software part concerns rather the distribution linux, the programming of the gpios, module of communication…

2.1 Caméra

Unlike IP cameras that are connected to computer networks, via optical cable or copper or even WIFI connection, the risks of saturation are reduced. In fact, to transmit the data captured by IP cameras, a large bandwidth is required which can vary considerably according to several parameters (type of video compression, image resolution, quality, number of cameras, images per second, etc.). This type of camera is therefore not suitable for the system to which we want to integrate our Smart Camera, which in reality is an intelligent gateway that contains several other sensors.

We therefore chose a Digilent PCam 5C camera designed to be connected to a development platform with FPGA.

2.2 LPWAN Networks

The concept of our smart camera is based on the fact that the information published in the network is small, so we choose LPWAN (Low Power Wide Area Network) wireless modules. The LPWAN communication modules allow the integration of a very large number of sensors and other connected objects (IoT) since these are used only for data services that require very few flows.

Several networks have managed to win in the world of IoT and have sparked our interest in the Smart Camera system and its applications, among them we find the LoRa, SigFox and NB-IoT.

The use of a LPWAN module for communication is a major asset for the privacy of environments equipped with Smart Cameras. Indeed, the latter have a capacity of data transmission retreinte between 22 and 256 bytes, which makes impossible the transmission of videos captured by the camera.

Each of the three networks offers different benefits and has its limits. QoS quality of service means that NB-IoT is favored for applications that require the guarantee of high QoS, it also offers a maximum data transmission compared to all other LPWANs with a higher QoS. transmission capacity of 1600o against 243o for LoRa and 12o for Sigfox. However, NB-IoT has higher energy consumption and higher cost (Figure 2).

Depending on the type of application of the Smart Camera, the LoRa proves to be the most suitable, especially since it is less restrictive in terms of the size of the data to be transmitted while having a large reach and a low consumption, without forgetting the security of communications with AES encryption not found in Sigfox

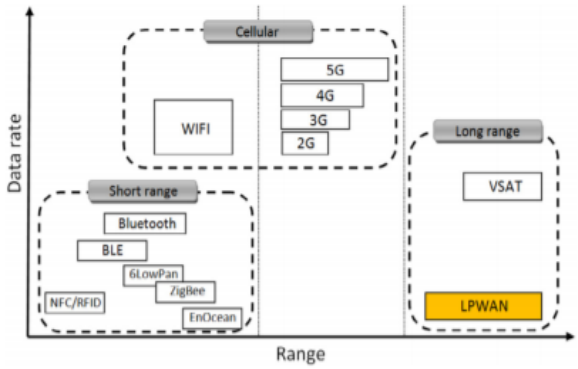


Figure 1 Positionnement réseaux LPWAN selon Taille de données/Portée [4]

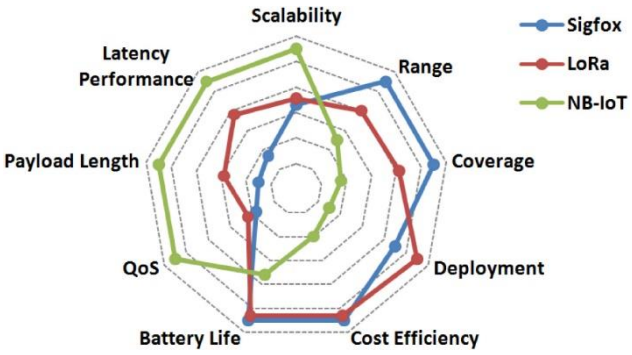


Figure 2 Positionnement des caractéristiques de Sigfox, LoRa et NB-IoT respectivement

2.3 Data Processing

The Smart Camera processes the images acquired through the two parts of the development platform: Programmable System with an ARM dual core and Programmable Logic representing the FPGA. The treatment consists in recognizing the objects visualized via the camera and to do this, we use image processing algorithms.

There are many image processing algorithms based on openCV library [...] tools to develop different programs such as motion detection and tracking [5]. We can realize and implement several processing algorithms for different tasks in order to allow the Smart camera to inform us of several events such as object recognition, presence detection, know if a person comes in or out ...

In order to synthesize algorithms designed with C / C ++, SystemC or even OpenCL programming languages, the VIVADO High Level Synthesis (HLS) tool is used. The latter provides an integrated graphical environment for rapid production of IP and systems-on-a-chip assembly [6], these IPs can include logic circuits, signal processing modules and algorithmic descriptions written in C [7].

These systems will be the elements that will be of particular interest after the validation of the first version of the Smart Camera (Acquisition, Processing and Transmission messages). Because they can be equipped with artificial intelligence with the use of neural networks.

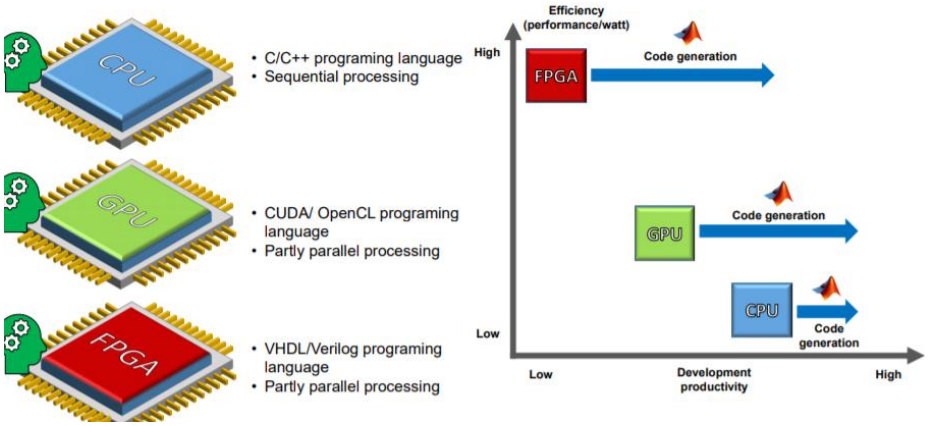


Figure 3 Embarquer de l'intelligence artificielle sur CPY, GPU et FPGA - Comparaison [8]

Machine Learning techniques can be implemented on several embedded targets for IoT. Compared to CPUs and GPUs, FPGAs offer an architecture better suited to the implementation of AI algorithms (Artificial Intelligence) as well as better energy efficiency [8].

FPGAs therefore offer a lot of advantages in the development of machine learning. It is therefore wise to rely on a development platform with FPGA for the evolution of the Smart Camera and here we talk about the scalability of the system.

Conclusion

This project, led by the LIRMM, is making a significant contribution to the development of smart grid gateways in the IoT domain. It will therefore encourage the integration of cameras in embedded systems networks with several sensors and actuators.

Indeed, the modules of the Smart camera that perform the image processing acquired (FPGA + ARM processor) and broadcast messages (LoRa), allow a minimal occupation of the network and bandwidth. In addition to these advantages, the Smart Camera guarantees a confidential appearance that makes it preferable for certain applications and areas of use.

The first version of the Smart Camera requires the use of two ZYBO cards, in order to use both parts to perform the tasks of processing and dissemination of information. The next step is to validate the LoRa transmission module and then abandon the second card to keep only one and use its two parts (Programmable System and Programmable Logic).

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