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Usage of ZigBee and LoRa wireless technologies in IoT systems

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***Abstract*— IoT systems are based sensors and actuators to enable ubiquitous sensing to measure environment parameters from delicate ecologies and natural environments to urban environments. By connecting these sensors and actuators to a big network, like internet, an automatization can be performed, and repetitive actions can be done in background by the IoT ecosystem and save a lot of time. IoT can do such things in Home Automation, Smart Cities and even in Air Quality analysis. IoT solution are dependent on the way sensors are transmitting data to cloud or up to the internet. This paper will present the benefits of using Zig Bee instead of using traditional Wi-Fi sensor and present some of the characteristics of LoRa sensors. Cloud computing contributed to the expansion of the IoT systems by offloading local IoT devices of computation intensive tasks. Fog computing brings Cloud closer to the sensors and by doing this minimize communication latencies.**

Keywords—IoT, ZigBEE, LoRa

I. Introduction

In the last years, Internet of Things technology is booming, estimated connected devices number for 2020 will be 30.73 billion and for 2025 estimations are for 75.44 billion and according to a report made by Gartner, there will be around 8.4 billion connected things worldwide in 2020. This number is expected to grow to 20.4 billion by 2022 of connected devices through IoT technology [6], the estimation the estimations are very different but both of them are talking about billions of devices and tenth of billions of devices.

This concept of Internet of Things is an emerging technology which is getting widley accepted around the world. A definition of this concept is a network of connected embedded objects and devices, with a unique ID, capable to communicate and take actions without human interactions [5]. The main applications for Internet of Things systems are public services, smart commercial buildings, smart homes and transport services but this technology heads also for healthcare services, utilities, smart cities agriculture [5].

For setting up an IoT system the following stages should be fulfilled: should have sensors to collect data from the environment and actuators to take actions, a protocol to transfer data from sensors to gateways and over internet, an application that is used to collect and analyse data to infer knowledge from it and an interface to display, organize and decision making [5].

Data collected from sensorial devices are transmitted in IoT network using different protocols like 3G, Bluetooth, ZigBee, LoRa, etc. depending on the distance range, transmitting timing. For example, environment monitoring for agriculture often uses low data rates wireless protocols such as loRaWAN or 6LoWPAN because information of environments such as temperature and humity does not change rapidly [8][11].

Architecture of the IoT systems has introduced a new concept as Fog-Computing which is a convergence network of interconnected and distributed smart gateways, this network has being developed to reduce the transmission latency of the IoT network and to reduce the load for the embedded devices [6].

For low power application where data rates are not high and timing is relative low ZigBee and LoRa protocol can be used in IoT systems [9][11].

II. IoT Architecture

The Internet of Things will be the Internet of future, we have seen a huge increase in different technology areas like smart city, smart homes, smart transportation and smart grids. Due to the reduced computational power, battery life and bandwidth IoT devices are replaced by Cloud application, all the computing and storage tasks are being done in this section. In order to set-up an IoT system this should respect the general IoT architecture presented in Fig 1[10][5].

A. Sensing Layer

This layer is the bottom layer of the IoT technology, the place where data acquisition is made through sensors and actions are made through motors, actuators or any switching devices.

B. Network Layer

A mesh of different communication technologies put together, having the same purpose being to transmit data to the next layer. At this point or layer of the IoT architecture, communication protocols used to transfer information inside of the sensing layer have to converge to the same network this being the internet either through wired transmission or a wireless transmission.

C. Middleware Layer

Used for data conversions or to storage data and also for computing and mathematical calculation**.** Usually a Cloud server with unlimited computational resources or limited only by user and technology. Cloud servers can be configured to assure the

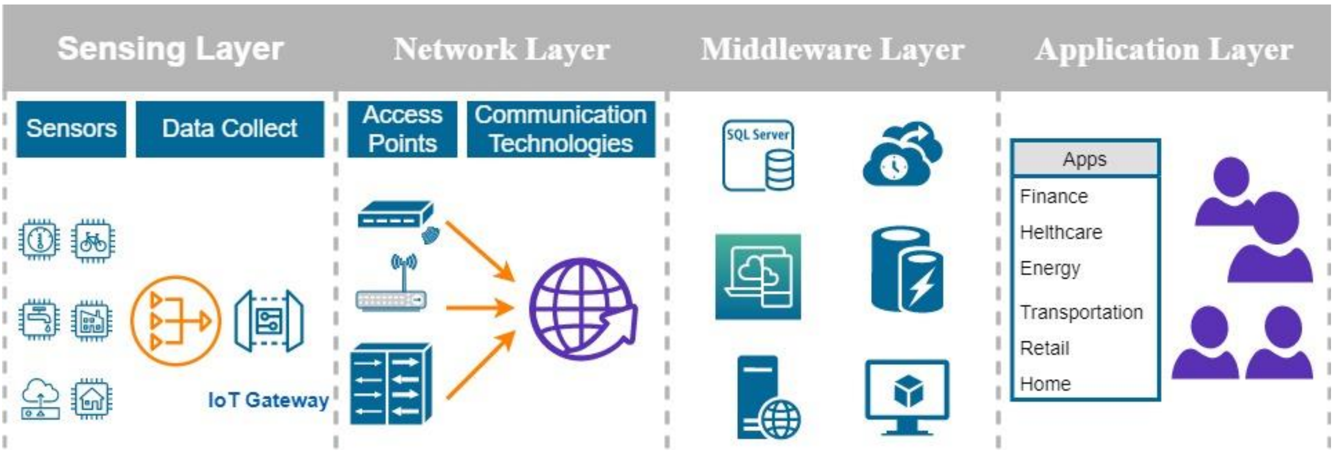

Fig. 1 Basic four-layer IoT Architecture

resources necessary for the IoT functionality application and can be reconfigured if the functionality is growing or is reduced offering scalability for IoT ecosystem.

D. Network Layer

A mesh of different communication technologies put together, having the same purpose being to transmit data to the next layer. At this point or layer of the IoT architecture, communication protocols used to transfer information inside of the sensing layer have to converge to the same network this being the internet either through wired transmission or a wireless transmission.

E. Application Layer

Application Layer is used in order to create a user-friendly platform where users can login and create an easier way to manipulate data.

These applications give the user access to the data from the field in a more orderly way and within its meaning. Graphs can be drawn based on data already stored and transformed, helping in decisions taking or for trend identifiers.

III. Fog and Edge Computing

In term of functionality Edge and Fog computing are doing the same thing, both of those technologies are pushing data to the analytic platforms which are located near the sensing devices and actuators [6]. Edge computing technology is implemented usually on the sensing devices or gateways that are close to the sensing devices. Fog technology moves Edge computing to wired devices like gateways but in this case, devices are far away from sensing layer.

With Fog computing, data processing is made by a node or a gateway from the same network while with Edge computing data is processed on the sensing nodes, data not being moved [6].

An advantage of the edge computing is by not transferring data in the network which assure security and discretion for that data, by processing the data on the device that created it, like sensorial devices. Besides security advantages of the Edge technology, this offer also time and resources in the maintenance of operation by collecting and analyzing data in real time. Of course, Edge computing has also disadvantages. For some applications is very hard to balance the sensing processing and cloud processing. Speaking from costs point of view sometimes is more effective to analyze data in Cloud than on the sensing device [7].

Fog computing present some advantages too, by transferring and manipulating data in the same network, aggregate data form multi-devices into local storage devices. Fog computing architecture allow system scalability despite edge computing from the larger capability of data processing [6].

IV. ZigBee Protocol

In order to extend the functionality of an IoT system the big challenge is to embed more wireless communication technologies in one gateway or in the Network Layer. Based on this ZigBee is permissive by allowing multiple routers and end devices, WiFi protocol allows connection to the big network which is the Internet [2][9].

A. ZigBee Alliance

Founded in 2002 and composed by a group of companies that maintain and define the ZigBee protocol. The name ZigBee is a trademark registered for this group. The main activity of this group is not only the definition and publications for this standard but also applications profile for OEM vendors in order to create interoperable products. Over past years members number of the alliance has increased to over 500 between we can see Comcast, IKEA, Legrand, Samsung SmartThing and Amazon [2].

B. IEEE 802.15.4 Standard

This standard has been released in 2003 and was developed by IEEE 802 standard committee. IEEE 802.15.4 defines specifications for PHY and MAC layers of wireless networking, but it does not specify any requirements for higher network layers. It is developed for applications with low transmitting rate and which power capabilities are limited and can't stand a heavy protocol stack [3][4].

C. ZigBee devices

ZigBe devices are providing low-cost solutions, low bit-rate and reduced power consumption capable for running on battery for wireless sensor networks. Zigbee protocol, based on IEEE 802.15.4 wich are operating on 2.4GHz frequency range are very efficient from power consumption point of view.

ZigBee stack is defined by four layers, fisrt two layers being used from IEEE 802.15.4 standard, meaning PHY (Physical) layer and MAC (Medium Access Control) Layer responsible for data transmission and last two layers, Network layer and Application layer which are ZigBee specific. The layers of ZigBee stack are presented in Fig 2[3][4].

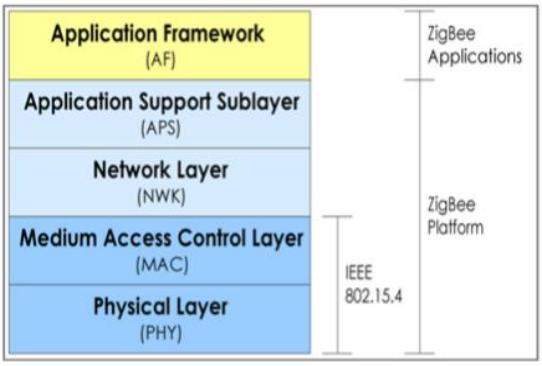

Fig. 2 ZigBee stack layers

Besides low-cost and low energy consumption ZigBee modules bring other advantages like bit-rate up to 250kbps at a 2.4 GHz band, 128-Bit AES security, multiple network topologies modes (Cluster Tree, Mesh and Star) and two mod operation modes in the network as beacon mode or non-beacon mode. Related to the operation modes, in beacon mode the topology of the network is cluster tree or mesh, but data is transmitted cyclical from a network coordinator to the network nodes, in this way consumed energy is controlled. In non-beacon mode, network topology is configured in Peer-to-Peer mode and communication is dual, from coordinator to nodes and vice-versa but in this mode power is not controlled [9].

ZigBee modules can sustain multiple application profiles for different operation like: ZigBee Home Automation, ZigBee Health Care, ZigBee Smart Meters, Weather Stations or Irrigation systems.

ZigBee resembles with Bluetooth but simpler, lower data rate and most of the time the device is snoozing which leads to a very efficient device that can run on an AA battery up to 2 years. In term of data rates ZigBee devices can go up to 250kbps while Bluetooth can go even to 1mbps. When we talk about a master-slave network ZigBee allows up to 254 nodes despite Bluetooth which allows 8 slave nodes [4][9].

V. LoRa Network

LoRa, right now, is a growing technology in the market with the operational field in a non-licensed band below 1 GHz for long-range communication link operation. The technology that it is used by LoRa was derived from chirp spread spectrum modulation (CSS) which was made in 1940 for military application. The CSS implementation trades data rate for sensitivity within a fixed channel bandwidth, with this the data transmission long distances transfer and interference robustness can be achieved. Lora it's the first low-cost implementation for commercial usage [11][12].

Those advantages are achieved by using an adaptive modulation technique with multichannel multi-modem transceiver for receiving multiple number of messages from the channels. This method provides advantages in managing the data rate [12].

Other benefits of LoRa are [11][12][13]:

- Quality of Service – unlicensed spectrum and asynchronous protocol, can handle interference, multipath, and fading.
- Battery life & latency – The sleep functionality is possible with LoRa devices and it can stay in this state for as little or as long as the application desire, in this way making the device very efficient with the energy used. For the application that are insensitive to the latency and do not have large amounts of data to send LoRa is a very good choice.
- Network coverage & range – This is a major advantage of LoRa because the whole city could be covered by one gateway or base station.

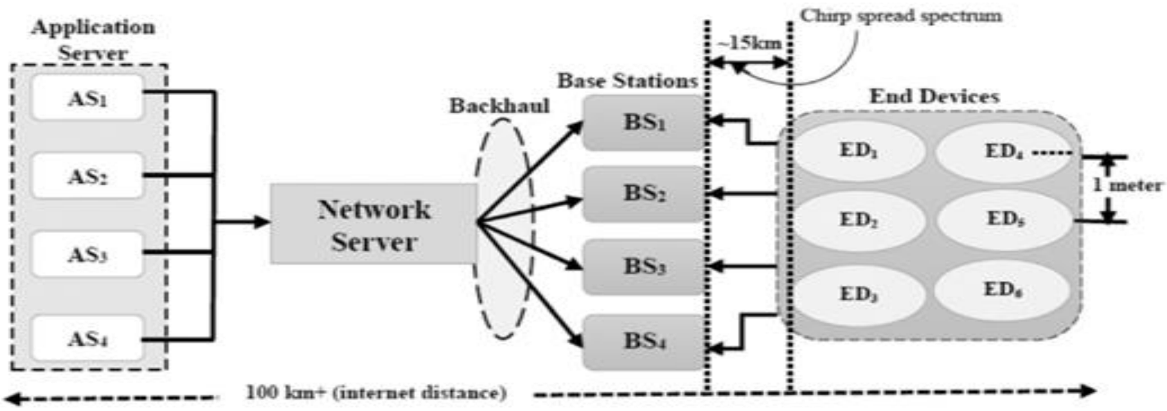

Fig. 3 LoRa WAN Network achitecture with application server and network server, connected with base station and EDs

- Deployment model – LoRa ecosystem is very mature and production-ready.

- Cost – The Spectrum cost is free and the network & Deployment cost varies from 100-1000$/gateway, which is very cost friendly.

VI. RESULTS

In order to extend the functionality of an IoT system the big challenge is to embed more wireless communication technologies in one gateway or in the Network Layer. Based on this ZigBee is permissive by allowing multiple routers and end devices, WiFi protocol allows connection to the big network which is the Internet [2]. Some research from the last few years in sensor networks from IoT systems tried to implement hybrid wireless communication by putting together two or more wireless communication technologies. One of these papers tried to put together ZigBee and WiFi protocols using the same band, 2.4 GHz, by making gateways that can transmit concurrently ZigBee radio signals and Wi-Fi radio signals. [4]. As ZigBee, LoRa is a low power and low-bit rate wireless communication technology but with a larger distance range which can be used to connect the Sensing Layer of an IoT system to connect to Internet.

VII. CONCLUSIONS

As a conclusion, ZigBee technology provide a low power device with a standardized communication protocol, IEEE 802.15.4, capable of embedded application due to ZigBee Alliance Network and Application Layer specification and extending IoT functionality by hybrid communication between ZigBee and other wireless technologies as Wi-Fi or LoRa which brings a lot of advantages to IoT systems.

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