

“IoT”

The Internet of Things

“Billions” of wireless sensors.....

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Abstract

A market of billions of wireless connected devices is opening up. These considerations are written by those especially interested in being present in this huge market as a manufacturer of wireless sensors, alarms, tags, etc. etc. And of course to all the induced Gateways, Repeaters, Routers and all the related operational "SW". The problem is not to fail the target.

Some "flops" have already been there

A necessary premise for reading this White Paper.

Please note that this document dates back to 2018 (currently its first draft is from 2016): in the meantime, many things have changed, progress in this telecommunications sector is truly impressive. However, the technique and the legal bases on which the use of "Unlicensed" frequencies is based remain valid and therefore the reading of this document can also be useful to remember the subsequent phases of progress in the "IoT" sector. Other possible techniques have been added, such as NB-IoT.

The Internet of Things

The vision that is emerging of what is and will be the "IoT" is that in the future, homes, offices, industries and entire cities will be increasingly interconnected. It seems that we are at the beginning of a technological revolution and at the beginning of a large market in the "Wireless Sensor Network" (WSN) sector. This report is an investigation made and seen from the side of a "Wireless" device factory and therefore made by those interested in understanding how to move to capture at least a part of this promising colossal market

The aforementioned interest, however, is also accompanied by strong concerns about the development and implementation of these networks and the doubts that arise when observing the remarkable variety of solutions, studies and proposals. Solutions proposed for "Wireless Devices" and also for the part concerning the "Networks", that is the part of the devices most appropriately responsible for data collection and its connection to the control and data processing centers and therefore to the Internet.

Some of the many solutions proposed to network "billions of sensors" seem to be very weak from a technical point of view and some are not very feasible from a regulatory / legal point of view

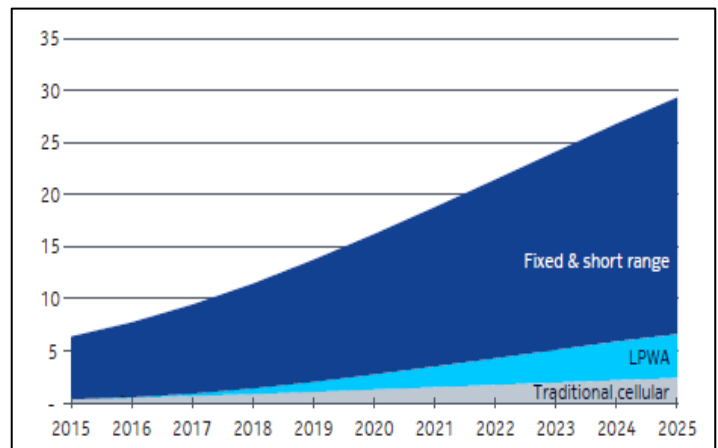


Figure 1: Billion global connections (Machina Research, May 2015)

1) "IoT" - Billions of Sensors

Words that prelude the beginning of a colossal market of "Wireless" products (see Fig. 1).

But will it be like that? Are we sure we understand what it is? And, each for its specific sector, which roads should we take to face this market? Naturally, the press, the magazines, the meetings and the congresses, everything is practically and every day a great speech on this "IoT". The manufacturers of integrated circuits and electronics are competing with each other to offer new products, each of which is the guaranteed solution that solves all problems. We are certainly facing a new "wave" of applications (in particular "Wireless"): care must be taken to avoid errors.

Speaking of "wave": for those who lived it, we remember well the "dot.com" years (1994-2000), the first speculative Internet "Bubble" : an excess of initial enthusiasm, both technological and financial, was partly caused by an incorrect technical evaluation. Surely the technological development was there and it was remarkable, but not with the times and not with the modalities that had been anticipated, foreseen and guaranteed by "talented" experts and prestigious market analysts.

Billions of Sensors - # 1

There will be many things on the Internet, but in this report we are interested in "Billions".

Here "Billions" means billions of wireless devices, or sensors of physical parameters, but also of various alarms and commands, actuators, tags, etc. Already on the Internet we have "Millions" of devices: the entire "M2M" sector, the "Metering" sector, GPRS modems, etc. etc. In fact, even the entire "IT" sector with WiFi and Bluetooth devices can be partly considered "IoT" and, in any case, uses the "Unlicensed" frequency bands. What is certain is that what arouses great expectations are the "Billions".

"Billions" within "WSN" - Wireless Sensor Network - composed of low-power, low-cost and extremely low-energy wireless devices. We are talking about increasing quantities in homes, offices, buildings, shops, factories, etc. In each of which there will be 100-500-1000 or more wireless sensors. For many years there have been "wireless" automation and control applications, home automation (for example chronothermostats or burglar alarms), but now we obviously think of an evolution of these devices and their integration into "WSN" networks and finally to the Internet.

Billions of Sensors - # 2

These hundreds or thousands of sensors per house, production unit or other, but to whom or what do they transmit the data, how and what kind of data ?

There is a great offer of universal "Protocols", able to solve all problems: really a great confusion around with many proposed solutions, but at the same time there is no clear idea of how data exchange should work between a wireless device (in many cases, unidirectional) and the receiving station, using the "Unlicensed" frequencies.

Frequencies already used by current systems in the ICT sector such as Zigbee, Bluetooth or WiFi. And frequencies (especially the sub-GHz) where there are very restrictive regulations both with precise technical limits and with legal limitations. It is obvious that, as an example, on Ethernet it is necessary to have a "Standard" protocol, it is less easy to understand how standard protocols can be thought on "not licensed" radio channels with network structures and needs that can be very different from each other and where the requirement of a sensor is that of consuming as little battery as possible and perhaps costing just a few dollars.

Note that a distinction must be made in the RF sector between "Standard" communication and "Protocols".

Bluetooth, Zigbee, WiFi etc. they use the ISM or SRD band frequencies and this solves the license problem, they are "license-free" frequencies. Surely it is true that these systems solve many applications well, but not all or at least not the "Billions". These systems are suitable and designed for "IT" applications, for "Information Technology", they have a high bit rate, but they consume energy and generally have insufficient range. The "Billions" will probably have different and perhaps a little more modest needs, but to transmit a temperature, an alarm or if a door is closed or open it is not necessary to go to 1 Mbps.

There are several features that will serve most of the "Billions": for example, a good range, even indoor, a low price and extremely low consumption. A lifetime (if powered by batteries) of years without maintenance: a 10/15 or better 20/25 years is now a possibility with modern lithium batteries. I want to see how it is possible to maintain a building equipped with hundreds of sensors if it is necessary to change the batteries every few years. And please don't take out the "Energy Harvesters" which is an excellent technology, but complicated and expensive and which however only solves a small part of the "Billions": a temperature sensor or a contact on a door in a cellar from where it can extract energy?

Billions of sensors - # 3

A necessary clarification: we are describing the situation for the "Billions" with particular attention to WSN, the "Wireless Sensor" Networks. But they are not the only ones: there are also other transmission media and other types of devices and networks, but at least for the part of the electronic industry (Manufacturing Industries) that are preparing for this promising sector, the "wireless" is certainly the most interesting part.

Then there is the whole part of receiving, decoding and addressing of the data, there are the Base Stations, the Concentrators, the Repeaters, the Gateways and the Routers etc. And then there is the whole part, considered by many to be the most complex and also the most difficult to implement, given the enormous variety of possible applications, the collection and decryption and management of data (ie "SW", "App", "Cloud" etc. etc.).

But even the most profitable as a species with the help of the Internet can open a wide field in the service sector.

Billions of sensors - # 4

To clarify the above, you can consult a Nokia White Paper "LTE-M-Optimizing LTE for the Internet of Things".

Here Nokia, which is a mobile phone factory and which is therefore interested in the deployment of LTE-based (LTE-M and NB LTE-M) systems, commenting on the development of the IoT sector (Figure 1) talks about 7 Billions within 2025 of "LTE" cellular and "LPWA" devices. But the estimated total of the IoT sector is 25-30 Billions of which precisely 18-23 Billions are wireless short range "SRD" sensors.

2) “IoT” - the Internet of Things

“IoT” - # 1

It will be good not to confuse what "Internet" is and what it can do and what the "WSNs", the "Wireless Sensors Networks" are. And all the different applications and configurations that "WSNs" can take.

The term "IoT" is very suggestive and of immediate media impact, but in reality it is more suitable to represent an idea of how, with the evolution of the current technology, it is and it will be possible to realize "smart" cities or buildings or to monitor vast areas in the agricultural sector, etc. but also to solve monitoring and security problems of small and medium entities. With all the advantages and comforts that this entails. In practice, an evolution of communication systems, in this case of data transmission, between "things" and the world. Research centers and regulatory bodies are also involved in IoT: for example, ETSI (European Telecommunications Standard Institute) (www.etsi.org) with GS documents LTN 001 - 002 - 003 v1.1.1 (2014-09).

Take for example the terms "Smart City", "Smart Grid", "Smart Metering" and so on. "Smart" is a very general term, linked more than anything to the concept of technological progress. In this sense, "Smart City" generally means all the technologies applied to make a city more "intelligent": among these technologies there are also "Wireless sensors and alarms".

For example, parking sensors, traffic sensors, lighting control, pollution sensors, building control, schools, etc.

The same applies to "Smart Grid", "AMR", "Water Management", "M2M" etc. whereas each of these "wireless" sectors was born on its own and has developed for years in ways that are often incompatible with each other, with different protocols and very different transmission methods even in the face of very different regulations in the world. So we are thinking about how to integrate these "IoT" systems and about the function that "Internet" can take in order to make everything more and more interconnected.

If we want to remain in the implications of the "IoT" that most closely concerns the wireless manufacturing industry, which is what interests us, it will be good to understand how wireless and non-wireless sensor networks will require devices such as sensors, alarms, controls, actuators, tags, etc.

And their interaction with local networks already existing or to be created.

"Local Network" is a very general term, can mean a small housing unit, but also large buildings, factories even entire cities: however, even a "Smart City" will be reduced, for a proper and efficient management and collection of wireless data, in single homogeneous smaller networks. After all, this is the tendency of the whole Telecom cellular sector (Picocells). Then you can discuss the Internet.

“IoT” - # 2

It is interesting to note (see what has already been said at the beginning - fig. 1) as in the media and in the magazines of the sector there is a great enthusiasm for the "Billions". CRN, a well-known publication specializing in "Information Technology" (www.crn.com), reports a ranking of the 50 most quoted companies specializing in "IoT" (CRN - The Internet of Things 2015 50). Of these "50" most are producers of semiconductors or companies specialized in "Platforms", in "Database", in short in "SW" for "Information Technology" (IT and ICT).

But actually, when we talk about "Billions" we refer to "Wireless Devices": well, only very few of the "50s" are producers of "Sensors" or "Wireless Sensors" and propose or describe "WSN" in particular on sub-GHz Bands. Some of the "50" companies offer the usual Bluetooth or WiFi admitting, however, that there are problems. Finally, just to give an example, but only in 31st place, there is Monnit (www.monnit.com) which is among the very few to have understood (in my opinion) how to deal with the "IoT" sector (the "Billions") proposing for direct sales a high number of "Wireless Sensors" operating in the 868 or 915 MHz bands and also offering Access Point, Gateway and Routers plus the relative "SW" to create and manage a "WSN" directly or via the Internet.

3) WSN - “Wireless Sensor Networks”

There are various approaches to the problem of creating a global network suitable for data collection from "Wireless Devices". Some systems are currently operational: NWave (Weightless-N), Clean-Slate, LoRa, Sigfox, and many others. All tend to increase the range, in practice by adopting modulation modes for data transmission with a low or very low bit rate in order to increase the sensitivity of the receiving system (up to -135 and even -140 dBm) and also to reduce consumption and cost. Surely they are valid systems for many cases of remote (very remote) sensors, but they are also systems that have technical and regulatory problems: this will be discussed later.

“WSN” - # 1

The wireless systems to which we explicitly or indirectly refer, generally operate on the "License-free" bands: 2.4GHz, 5GHz, 915/868MHz and then also 315/434 MHz and this also applies to all the wireless non-regulated frequencies applications.

There are also other "free" frequency bands, such as in the USA the MURS band at 154 MHz or in Europe the 169 MHz, but they are not global and practically has only local applications. The "free" frequencies used are therefore the "ISM" (Industrial, Scientific and Medical) and the "SRD" (Short Range Devices). The ISMs, to which as an example the 2.4 GHz belongs, are in any case "Unlicensed", but they are not a "Radio Service": see for example what REC 70-03 (October 2017 edition, page 4) reports : "Short Range Devices are not considered a" Radio Service " pursuant to the ITU regulation (article 1)".

If the International "Recommendations" wrote about the "SRD" (and this, in a little different version, it is written also for all the "Rules") there will be a reason. One of the reasons is surely that "Short" should not be intended as a precise limit in the range, but rather that "SRD" and "ISM" frequencies are "free" because they are tolerated for personal or private use, they are not a "Radio Service" (and are not protected) and are equipped with specific rules (RF power, Duty-cycle, etc.) to mitigate the possibility of disturbing other services or other free users. Limitations on the use of SRD "Unlicensed" frequencies can also be found on the ECC Report 11 (Strategic Plans for the Future Use of the frequency bands 862-870 MHz and 2400-2483.5 MHz for Short Range Devices - Pag.3 and Page 8, Annex 3) :

"It is therefore suggested that any networking and use of repeaters within the SRD band 862-870 MHz should be limited to single owned use". It is the old concept of the "closed-private fund" and Annex 3 is entitled "Networks and third party traffic in SRD bands".

As an example, this is not the case of Sigfox, at least of the "first" Sigfox version, for the part on which they focus very much on the so-called "SNO" (Sigfox Network Operator) that is a global Network Operator for collecting and managing paid data, albeit with a low or very low cost/bit (in October 2017 the figure of the SNO disappeared....)

“WSN” - # 2

We can consider some typical examples of "WSN" configuration.

This study on the possible "IoT" network solutions is seen by those who think of the "Billions".

As mentioned above, "Billions" of "Wireless Sensors".

So keep in mind :

- (a) The "IoT" sector is viewed from the side of a "Wireless Sensors" manufacturer.
- (b) Always remember the exceptional variety of possible applications in the "IoT" sector.
- (c) "Smart Grid", "Smart Metering", "M2M", etc. they are always "IoT" applications, but have very different and normative technical and regulatory problems and may require a different type of network....

In particular, we can think of two typical and rather typical situations.

- (1) - **Network A**: a network comprising the sensors installed in a small residential unit.
 - (2) - **Network B**: a much more complex network including the management of sensors in an entire city.
- In between all other Network configurations.

A - Network

Two typical network implementation :

First case (Fig. 2)

Internet access is provided by the "Devices".

Second case (Fig. 3)

Internet access takes place directly from the Gateway (via Modem GPRS or NB-IoT)

The management and control of the data can be local in the "Devices" or it can also partially be in the Gateway itself or it can be remote in a remote (cloud) control center or platform

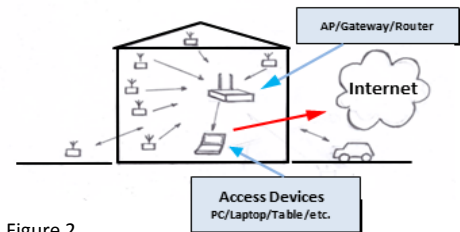


Figure 2

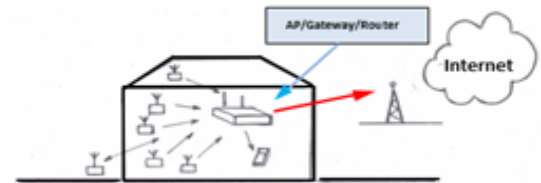
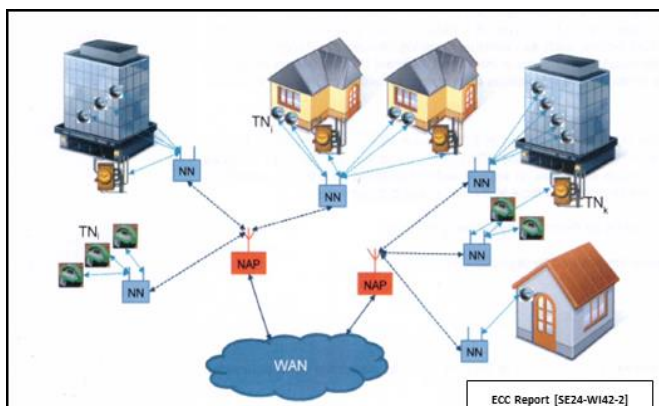


Figure 3

B - Network - Smart-City

The case represented here of a "Smart City" (as in the case of other large coverage networks) configures the construction of local WSN, Terminal Nodes (TN) with concentrating stations (NN), connected directly to the WAN or through other Concentrators (NAP) : the terminology used is that reported on the ECC Report SE24-WI 42-2.



TN - Terminal Nodes
Sensors - Alarms - etc.
NN - Network Nodes
Gateways - Routers
NAP - Network Access Points

Network Element	DC, %		Density, 1/km ²
	Max	Average	
NAP	10	2.5	10
NN	2.5	0.7	90
TN	0.1	0.1	1900

Figure 4



It should be noted that the above drawing of a possible configuration of a "WAN" network is taken from a study / document of the CEPT (ECC Report WI 42-2) of 2015 and studies are underway to develop standards related to M2M networks. and "Internet of Everything" with a particular effort to find sub-GHz bands and free frequencies for both "Licensed" and "Unlicensed" applications

"WSN" - # 3

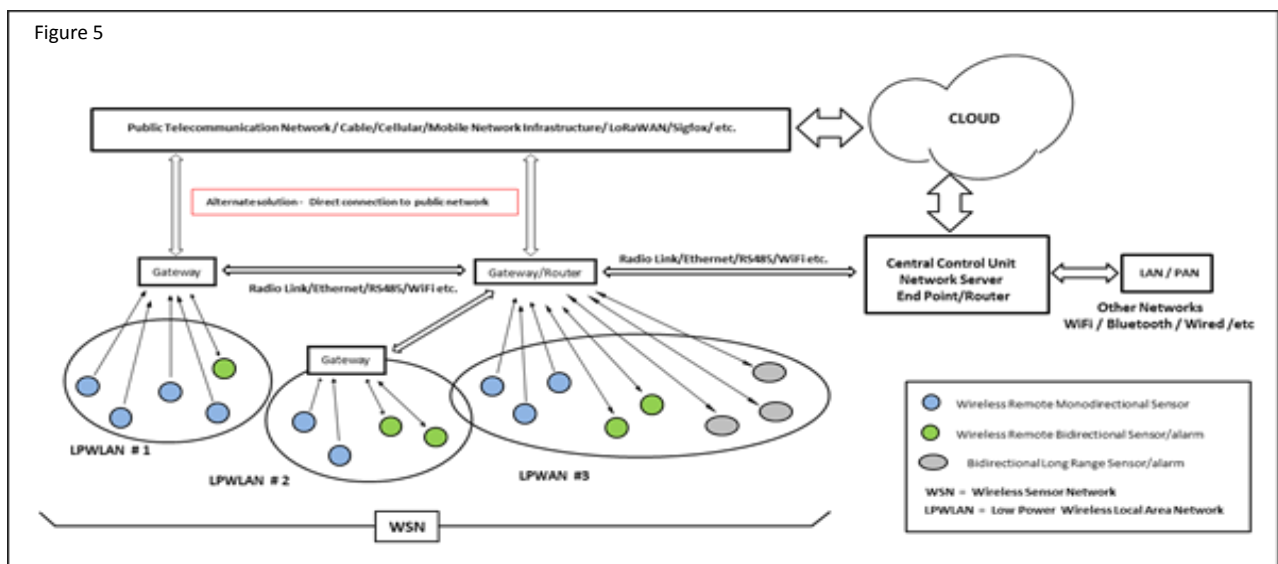
Another typical application that requires the installation of hundreds of sensors may involve large commercial businesses (such as "Supermarket") where measurement and alarm sensors can be used for air conditioning (HVAC), goods control, temperature control systems, refrigerated counters, control over the movement of the public, lighting, entrances and alarmed gates and also with more far-reaching sensors on underground or outdoor car parks, external perimeter alarm sensors, etc. etc.

In all these applications it is evident the convenience of creating small local areas (especially in "In-building" applications) that require the use of simple, low-cost sensors, equipped with autonomous power supply, but designed to be easy to install and do not require maintenance for 10/20 years. More complex cases, such as fire alarms or critical measures of levels, pressures, metering, etc. they may require other more complex and higher bidirectional "Wireless" systems, but it is clear that the "Billions" will be of the first type.

These local networks are referred to as "Gateway" or "Router / Repeater" etc. then flowing through other radio links (SRD) or connecting to fixed networks (Ethernet) or even to existing wireless networks (WiFi) or cellular networks (GPRS) to control centers and data management. Then the Internet can intervene by connecting everything with the rest of the world, with methods and criteria depending on the type of application.

"WSN" - # 4

So without the claim to consider exhaustively the description below of how will the wireless remote sensor networks that is the "WSN", at least in the "IoT" world, it seems logical to think that the structure of this "Network" will be represented as in fig. 5.



The networks of sensors in the greatest number of cases, both in the case of a small housing unit, and in the case of large and complex networks extended to entire urban areas, can be conveniently realized as many small or relatively small areas served by a Gateway / Router . This for reasons of regulations certainly (they are "SRD" devices, must respect for example the constraint of low "Duty Cycle"), but also for problems of cost, energy and operational autonomy, and to solve problems of interference and collisions between the various "Billions".

These "LPWAN" managed locally by the "Gateway" (which in many cases will contribute to a first data check, when necessary or convenient) are then interconnected to the control center for data processing and alarms collected or sent. In the interconnection of the "Gateways", in particular cases or in particularly large areas, the passage can be made through public or other networks.

4) CONCLUSION

The "Billions" are "Remote Wireless Sensors": the bulk of the "IoT" market is played on these, at least for what concerns the manufacturing industry of "wireless Sensors". Then there are the Concentrators, Gateways, Access Points, etc. and all the complicated world of "SW" programs that must run them without forgetting that a significant part of the whole is installation, programming and maintenance.

The "Wireless Networks", at least for the part most properly related to the automation of homes, buildings, commercial or manufacturing activities and gradually to the Smart Cities, etc. will be "WSN" local networks. Where "local" is not so much understood in the sense of more or less large area, but in the sense of a homogeneous network that performs a specific function.