Selecting Type of Communication for Wireless Sensor Network on Board of a Vessel

GEORGI ENCHEV[1], NIKOLAY DJAGAROV[1], ZHIVKO GROZDEV[1]
[1]Electrical Department, Nikola Vaptsarov Naval Academy,
Varna, BULGARIA
jagarov@ieee.bg, http://www.naval-acad.bg/en/

Abstract: - The need to move on to the next step in the automation and autonomy of ships requires improvement of the existing ones and the creating of new types of communication on board a ships. Like the top-trend in the shore industry – IOT (Industry Of Things) is increasingly spoken of by the need to create and implement the so-called IOS (Internet Of Ships). Shipping industry is currently in need of monitoring the technical parameters of mechanisms from remote workstations at the offshore office. For this, besides the measurement of parameters for machines on board, it is necessary to analyze and consider the communication possibilities. In this report we will look at the most commonly used IOT communications, whether they are appropriate and which is best for IOS.

Key-Words: Wireless, Monitoring, IOS, IOT, Smart Ship, Industry 4.0

1 Introduction

In recent years, it has been increasingly introduced the IOT. Industry Of Things is a group of sensors that drive or track certain devices and parameters via control points on the Internet. Several different communications and features are used to implement the interface.

The weakest and most critical link in this complex system is precisely the connection from an end-device, say some sensor and the rest of the system. This communication is mostly radio. For this it is necessary to choose the most correct method for the assigned task in a device, environment, etc. This article aims to examine the most popular and frequently used communication interfaces and to take the step towards introducing unified requirements for wireless communication in ship conditions and for its imposition into IOS.

The principle of IOT work is based on two main types of system structure. In one of the following (fig.1A) by making radio communication (exemplary communications) data are transmitted to the gateway, which in turn aims to convert information on an already-known route - Wi-Fi or broadband cable to transfer the information to an accessible location (cloud) end user. Another embodiment (Fig 1B) is, for example, the so-called M2M. After the measurement, by cellular communication or such a spectrum, the data is transmitted to another operator who already provides them to a user-friendly type.

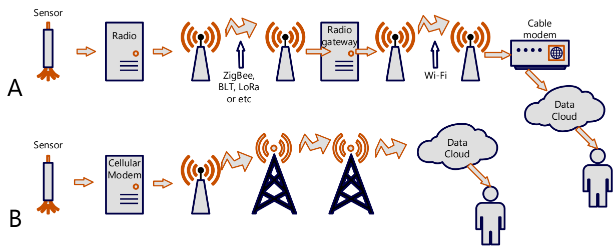

Fig.1. Example IOT and M2M system configurations

In order to choose the most appropriate communication for a highly aggressive environment such as vessel's will relied on a series of factors such as:

- Data rate of the device: What data rate is required? Video streaming type or just measuring several parameters like temperature, voltage or pressure. Or maybe something in between?
- Range or distance to the gateway: What is the area for which we will use it? Small 70 m^2 apartment or 400m long by 50m wide ship? Or maybe some agriculture area;
- The environment: One of more important requirement. Is this device stable of any hazardous sounding, weather, temperature, noise, vibrations of electrical equipment or etc.
- Need for encryption or authentication: By any means security is still a must do ability.
- Power consumption: For any stand alone devise the low power consumption is much needed. That`s why is included that one.
- Capacity: Maximum devices connected in one network.
- Quality of service and reliability;

• Network topology: As can be see in this paper, topology is one of most important thing to be adjusted before starting designing a wireless sensor network on board of a vessel;
• Simplex or duplex: One-way vs. two-way communications.
• Available ICs, modules, and equipment. Is this interface easy to get?
• Cost: Design, manufacturing, or Internet access service expense;
• Development platform: Is an OS needed? What other software is required?
• Internet access: What it need to operate? Cellular or maybe cable or satellite connection?

2 Specification

The purpose of this report is to help to choose the best and most appropriate option for performing the task - wireless sensor networks on board of a vessel like the one shown in Figure 2. There are two modules displayed. Module A is designed to measure the microcontroller on it is to convert the signal and to send it to Module B by using the Wireless Connection by selected from us interface. Module A has no precise location and can be located anywhere in the engine compartment. Part B, in turn, aims to obtain the data sent from A, process and provide it to the end user in an appropriate form. The place of this module is strictly specified and it is in Engine Control Room.

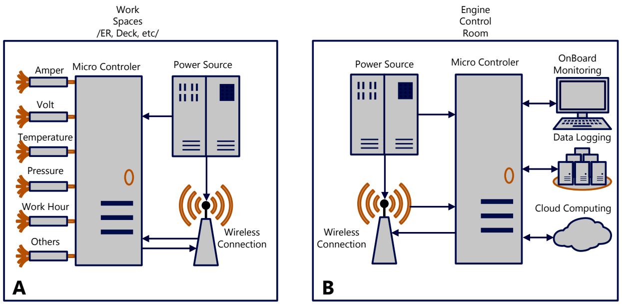

Fig. 2. Basic hardware diagram. Work Spaces and ECR

As already mentioned, we have shortened the scope of search and exploration of the possible options for our system to 4. They are as follows - Wi-Fi, Bluetooth, ZigBee and LoRaWAN. In this chapter is shown in detail with their exact specifications. Undoubtedly the most popular and known of them is Wi-Fi.

Wi-Fi (short for Wireless Fidelity) - Uses RF - radio frequency to communicate two devices to each other. We all know this technology from routing to computers and all sorts of other smart devices. In essence, the system allows two hardware modules to be connected to a local wireless network running on IEEE 802.11 standard. Also, Wi-Fi can also use the 2.4 GHz UHF or 5GHz SHF ISM radio band. It is also understood here that, like other technologies, there is standardization. Made by the Wi-Fi Alliance, it certifies the ability to connect to other certified devices. This communication is susceptible to Bluetooth interference, microwave and cell phones.

Bluetooth - Bluetooth and BLE - Low-power Bluetooth are technologies that provide the ability to distribute data over short distances. The most common use of this type of communications is when close communication and required when the end point is the end user's phone or tablet. BLE for its low power consumption is used in Wearable Smart Devices as smartwatches, fitness bracelet and so on. The standard uses UHF radio waves to transmit data. It was originally standardized as IEEE 802.15.1 but this standard is no longer supported. Interestingly, before a product you use this communication interface is put on the market must pass the Bluetooth Interest Group (SIG). This is to ensure and verify that this device will be able to work with everyone else.

ZigBee - Wireless communication gaining popularity in the LPWAN – Low Power Wireless Arena Network group. It is an open global standard that is intended for M2M networks (fig.1B). It has advantages of an engineering and economic nature - low cost and energy consumption. This makes it a great choice for Industry 4.0 applications. The low-latency and low duty cycles allow for a long battery life. ZigBee supports 128-bit AES encryption is great news if we need increased security. It supports Mesh topology, which means it allows multiple connection between devices (fig.5). Recently, a common standard has been created and approved by the ZigBee Alliance to unify the communication between all devices and to communicate with each other.

LoRaWan - Network with increasing popularity and used mainly for smart cities, homes or industry 4.0 - IOT. It is characterized by being a system using a centralized server whose data is encrypted and transmitted through different frequency channels at different data rates. What is interesting about it is that the security system offered has several layers of encryption, ensuring security at a good level. From another point of view, this is a low-energy, computerized network that is designed to perform specific tasks related to IOT. LoRaWAN's thermology has endpoint devices with many classes according to the receive mode.

Technology	Freq[hz]	Data rate[kb/s]	Range[m]	Power consumption	Cost
2G/3G	Cellular bands	10 Mb/s	Several km	High	High
802.15.4	2.4 G	250 kb/s	100m	Low	Low
Bluetooth	2.4 G	1,2 Mb/s	100m	Low	Low
LoRa	< 1 G	< 50 kb/s	2-5km	Low	Medium
LTE Cat 0/1	Cellular bands	1-10 Mb/s	Several km	Medium	High
NB-IoT	Cellular bands	< 1 Mb/s	Several km	Medium	High
SigFox	< 1 G	Very Low	Several km	Low	Medium
Weightless	< 1 G	< 24 Mb/s	Several km	Low	Low
Wi-Fi 11f/h	< 1, 2.4, 5 G	< 1 Mb/s	Several km	Medium	Low
WirelessHART	2.4 G	250 kb/s	100m	Medium	Medium
ZigBee	2.4 G	250 kb/s	100m	Low	Low
Z-Wave	908.42 M	40 kb/s	30m	Low	Medium

Table 1. Basic specification of wireless communications

3 Topology

Figure 3 shows an exemplary communication from tree topology. It clearly shows the different clusters of the tree. In this case there are 3. In cluster 1 we have two additional measuring devices. In the second cluster, however, a sub-cluster 2.1 was also implemented. The total number of devices in cluster 2 is seven, and in 2.1-3. In this topology, the disturbance problem is solved by taking measurements from one node by another device over the network to reach the coordinator. In this system, a device acts as a coordinator, that is, a device that sends commands, monitors their execution, and collects data from the measurement modules. Referring back to fig.2, the Type A modules are measurement modules, in Figure 3 denoted as (S). A module B of Figure 1 is exactly this coordinate (C). Topology of a tree type has one major disadvantage - let's say device 1.1 is damaged or stays powerless. This connection with devices 1.2 and 1.3 is interrupted. For a system with 10 branches, it is not such a big problem, but imagine a network of 200 devices and one of the 1st level devices of the tree refuses? Lost connection to many of the cluster's next devices.

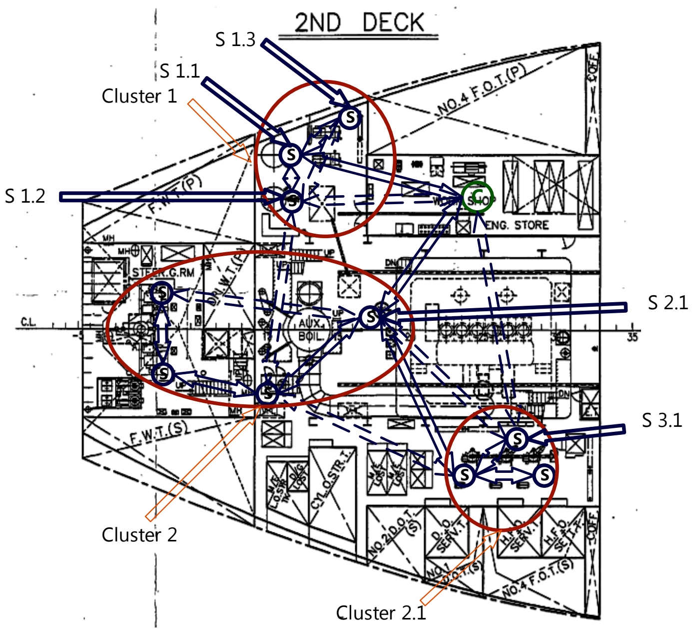

Fig.3. Example realization of three topology

Figure 4, similar to Figure 3, is a topology known and used in wireless communications. It may be the originator of topologies, namely star. It is used by cellular devices, Bluetooth, Wi-Fi, LoRa, and so on. Here we have a powerful central module, let's call it a coordinator/master, and the rest are simple executive devices/slave. Most communications, not just wireless, are built in this formation. The advantage and in front of the tree is that when one of the nodes/modules - modules A of fig.2 is dropped, only it disconnects. The rest continue to work. There is, however, a small problem with this topology - namely, that the slave devices must be powerful enough to communicate with the master. In a standard IOT implementation environment, this is not a problem, but we are still on board. In the last chapter of this article we will analyze the choice of the most appropriate topology.

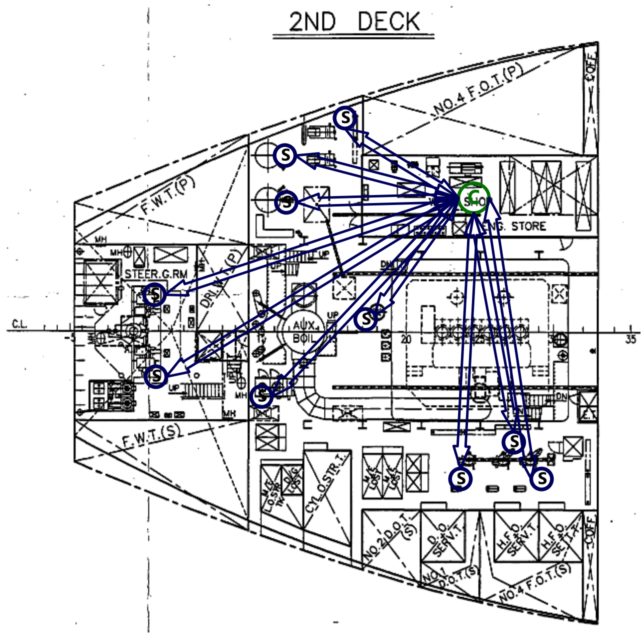

Fig.3. Example realization of three topology

The last topology that we will look at today is mesh, and more-precisely the self-healing subtype, has also come to pass. We can guess what it differs from its name, it is a real maize - everything communicates with everything, at one point, the device can be a sensor, in another - a router. The goal is only one - the date of each module connected to the network reaches the control module / coordinator /. Like the tree structure, we also have clusters here. But let's look at the script from the tree structure? When Module 1.1 is dropped for unknown reasons, the link to 1.2 and 1.3 will not be dropped. Module 1.3 will pass on 1.2 that will pass to 2.1 and then to the Coordinator, and the communication safety issue is cleared. We know that 30% of the sensors should be dropped to break a cluster connection. The percentage depends on the pre-fabrication structure and the layout of the modules. Let us consider the case where 2.1 is dropped out? Then the signal from the other modules can go through 1.2 or 3.1 and we have a connection again. The other problem we have mentioned, namely that of star-topology, is also resolved. Here, the modules relay the signal and it is enough to have only 1 in the cloud to maintain normal network operation and maintain communication. Like everything, there are also minuses. Proper routing and location selection during installation are the most popular issues. The most serious of them, however, is that not all communications support this topology. It requires a serious CPU power to be able to crawl the routes and look for a new one in case of a problem. Another problem is that the modules supporting this structure are in the middle category price range, for the difference from the modules that support only tree or star.

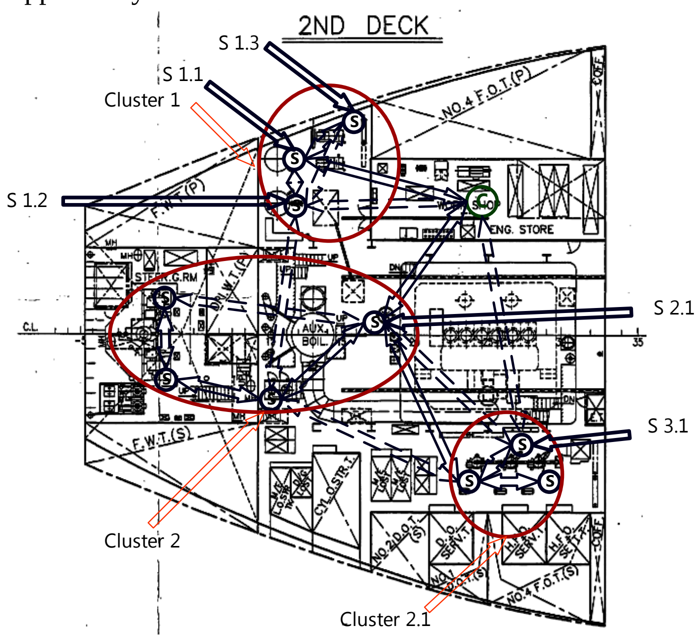

Fig.5. Example realization of self-healing mesh topology

4 Conclusion for selection a wireless communication for on board use

For the selection of technology to build a wireless sensor network on board a ship have been пре-selected the most appropriate communications. They are as follows - Wi-Fi, Bluetooth, ZigBee and LoRaWAN. Factors such as data rate and maximum distance for stable communication are taken into account during the assessment. Maximum number of devices per network. Does the network support encryption or not, cost, service quality, topology etc? All criteria can be found in Table 2.All possible disturbances are simulated whereby the main attention is on the work of electrical propulsion system and its impact on the electricity's quality.

Below is presented part of the received as a result of the simulation characteristics.

For work on board a ship we need a device that is influenced as little as possible by electromagnetic noise, because as we know in the ER, there are dozens of mechanisms creating them. Wi-Fi is a great choice for WSN but for coastal ones. When there is a surface projection and high noise levels there will be a lot of gaps and a bad connection. The same goes for full force, even more for Bluetooth. The other two technologies are less sensitive. Another important aspect to be addressed is the indoor scope. This parameter corresponds to all the selected systems. The ER ranges are expected to be no larger than 100 m without any line of sight. The system must also support bidirectional communication for forced measurements, so one more minus for BT.

Devices→ ***Conditions ↓***	**Wi-Fi**	***Bluetooth***	***ZigBee***	***LoRa WAN***
Data rate of the device	< 1 Mb/s	1,2 Mb/s	250 kb/s	< 50 kb/s
Range or distance to the gateway	Several km outdoor	100m outdoor	120m indoor	2-5km outdoor
The environment	Sensitive	Sensitive	Not Sensitive	Not-Sensitive
Need for encryption or authentication	WEP, WPA, WPA2	56/128-bit	128-bit AES	128-bit AES
Power consumption	Med	Low	Low	Med
Capacity	255	255	65000	120
Quality of service and reliability	Good	Good	Good	Good
Network topology	Varies	Point-to-point	Mesh	Varies
Simplex or duplex	Duplex	Simplex	Duplex	Duplex
Available ICs, modules, and equipment	Yes	Yes	Yes	No
Cost	Low	Low	Low	Med
Development platform	Good	Good	Good	Good
Internet access	No	No	No	No

Table 2. Criteria for selecting a wireless technology for sensor network on board a vessel

The price is of course important. Here the minus is for LoRa. The cost of this interface is still high, as well as development and development platforms. All devices offer a sufficient number of maximum connections in one network. Even LoRa supports 120 which is enough. But still, more is always better! The least encryption is offered by BT, and most secure than Wi-Fi. The last and maybe a determining point is the maintenance of the "right" topology. Mesh is undoubtedly the best choice for networks where there is no direct line of sight, high noise, and a high level of security in data transmission. Under high security, you do not understand encryption, but sure that measurements will reach the end device. In view of this and all these criteria, we conclude that the most suitable technology for Wireless sensor networks on board is ZigBee. It meets all the conditions as someone even goes beyond expectations a few times.

ACKNOWLEDGEMENT

This document is under project BG05M2OP001-2.009-0037-C01 "Support for the development of PhD students, post-doctoral students, young scientists and lecturers in the Nikola Vaptsarov Naval Academy", with the beneficiary of the Nikola Vaptsarov Naval Academy, Varna funded by the Intelligent Growth Science and Education Operational Program, co-financed by the European Union through the European structural and investment funds.

References:

1. R. King, Cloud Computing Gains Traction in Cargo Shipping Industry, *The wall street journal*, May 5, 2015
2. *Condition Monitoring and Diagnostic Engineering Management*, Edited by A.C. Starr, R.B.K.N. Rao, Proceedings of the 14th International Congress, COMADEM 2001, 4-6 September 2001, Manchester, UK, Elsevier, 1021 p.
3. M.S. Thomas, J.D. McDonald, *Power System SCADA and Smart Grids*, CRC Press, Taylor & Francis, 2015, 336 p.
4. *Guide to Wireless Sensor Networks*, Edited by S.B. Misra, I.Woungang, S.C.Misra, Springer, 2009, 725 p.
5. K. Romer, F. Mattern, The Design Space of Wireless Sensor Networks, *IEEE Wireless Communications*, Vol.11, No.6, Dec. 2004, pp.54-61.
6. J. Hill, M. Horton, R. Kling, L. Krishnamurthy, The Platforms Enabling Wireless Sensor Networks, *Communications of the ACM*, Vol.47, No.6, June 2004, pp.41–46.
7. A.A. Ahmed, H. Shi, Y. Shang, A Survey on Network Protocols for Wireless Sensor Networks, *International Conference on , Information Technology Research and Education* (ITRE), 11-13 Aug 2003, Newark, USA.
8. M. Srivastava, Sensor Node Platforms and Energy Issues, *8th ACM International Conference on Mobile Computing and Networking* (MobiCom'02), Atlanta, GA, Sept. 2002, Tutorial 2.

9. C.F. Chiasserini, M. Garetto, Modeling the Performance of Wireless Sensor Networks, *23rd Annual Joint Conference of the IEEE Computer and Communications Societies* (InfoCom'04), 7-11 March 2004, Hong Kong, China, pp.220-231.

10. N. Bulusu, S. Jha., Wireless Sensor Networks, Vol.1, 2005

11. N. Mukherjee, S. Neogy, S. Roy, Building wireless sensor networks, *Theoretical and practical perspectives*, Vol.1, 2016

12. S. Capkun and J.-P. Hubaux, Secure positioning of wireless devices with application to sensor networks. *In Infocom'05*, Miami, March 2005, pp.1917–1928.

13. A. Boukerche. *Handbook of Algorithms for Wireless Networking and Mobile Computing*, (Chapman & Hall/Crc Computer & Information Science), Chapman & Hall/CRC, Boca Raton, FL, 2005.

14. H.A.B.F. Oliveira, E.F.Nakamura, A.A.F. Loureiro, and A. Boukerche, Directed position estimation: A recursive localization approach for wireless sensor networks. *14th IEEE International Conference on Computer Communications and Networks*, San Diego, 17-19 Oct 2005, San Diego, USA pp.557–562.

.