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Integrating Industrial Network of Things (Inot), Fog and Cloud Computing into Condition Monitoring System (CMS) For Azimuth Thrusters

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Abstract
This paper focuses on integrating INoT, fog and cloud computing with equipment condition monitoring systems. The integration will help improve the current manual and time consuming system of carrying out azimuth thruster monitoring and maintenance. Equipment's monitoring is very important aspect if industries are to reduce down times and increase revenue especially in the oil and gas sector considering the low price of a barrel in recent times. The present method of equipment monitoring is not efficient and is prone to mistakes and data loss, at present the engineering department uses a USB drive to extract data from each thruster and send the data off to shore using a corporate PC. The entire six thrusters has to be interconnected into a closed network so that the industrial network of things (INoT) or industrial internet of things (IIoT) as industry experts call it are in one physical network, which is the first and data farm layer of the new redesigned system. The data gathered by the fog computing node is also sent off to thruster specialist onshore for further analysis and top management attention and decision making, this layer is the third in the multi-architecture and it's the Cloud. With the convergence of the three distinct networks and computing techniques information technology (IT) will bridge the gap between operations technology (OT) and decision maker to make hidden information more visible to those after fog layer (Engineer's) and at the cloud (Onshore). Operation technology has always being in use from time but those far away from the edge of the network just don't have a better technology and enough visibility until information technology is integrated into the operation technology. IT has made offshore OT visible to those onshore.

Keywords: *Azimuth Thruster, condition monitoring system, fog computing, Industrial Internet of Things (IIoT), Industrial Network of Things (INoT), Operations Technology (OT), Rig Area Network (RAN)*

1. Introduction

1.1. Background of the Study

Condition monitoring is a must for every equipment no matter the industry and where the equipment is located. Virtually every equipment has an in-built monitoring system to check condition and health status of the equipment. A simple monitoring devices we are all aware of are the voltage and fuel gauge on our home generators, the cars we drive has the dashboard to show and tell us what the condition of our car is. These are just but a few of where condition monitoring devices are applied in our everyday life. The main reasons for condition monitoring are for awareness and if required quick action to be taking in response of the alert received or displayed by the equipment. Condition monitoring saves time and resources and improves equipment performance if the right preventive and corrective actions are taken.

In general terms condition monitoring (CM) is preventive maintenance (PM) process which monitors the status or health condition of machineries or equipment's by taking note of parameters like vibration, temperature (oil and water), voltage, load, etc. This process can be done manually on a daily basis, semi-automated or fully automated. An azimuth thruster, figure 1 is a configuration of marine propellers placed in pods that can be rotated to any horizontal angle reason for the name azimuth, making a rudder unnecessary. These give ships better maneuverability than a fixed propeller and rudder system, figure 1. This OT can be better monitored and maintained by use of IT, where it does not have any means of communicating with other newer OT's information technology will bridge the gap.

In this paper I will focus on condition monitoring system for Azimuth Thruster, figure 1 and then look at integrate the different individual closed thruster networks and computing techniques. Bringing together Industrial Network of Things (INoT), Fog and Cloud Computing to come up with a workable solution for better equipment maintenance and performance. The combination of INoT, fog, and cloud computing will make life easy for engine room engineers who are thousands of miles away from shore where the analysis of these acquired thruster data are done. The boundary between information technology (IT) and operations technology (OT) is converging on a daily basis and its happening faster than we expected. Due to advances in information technology equipment we have seen organizations still make good use of their legacy OT using information technology equipment to make the legacy OT work in an environment with newer OT.

1.2. Statement of the Problem

The problem with the current setup is that Engineers have to physically go to each of the six thrusters which are very far apart to manually extra the data from the INoT device. The length of the ship is more 230 meters, a set of three are at the forward (Thrusters 1, 2, and 3) of the ship while another set of three are at the aft (being back) of the ship (Thrusters 4, 5, and 6). They are located in places where you have to climb up and down many stairs to the bottom of the ship.

Thruster data extraction is done manually using a USB stick this can be unreliable at times, there is no real-time data collection by our vendor in town and so preventive maintenance can be delayed while waiting on feedback from our thruster experts. The setup is time consuming and inefficient, and if for any reason we are in an emergency situation offshore no remote support connection to the thrusters systems for troubleshooting. Figure 1 shows the current standalone system in each of the thruster rooms.

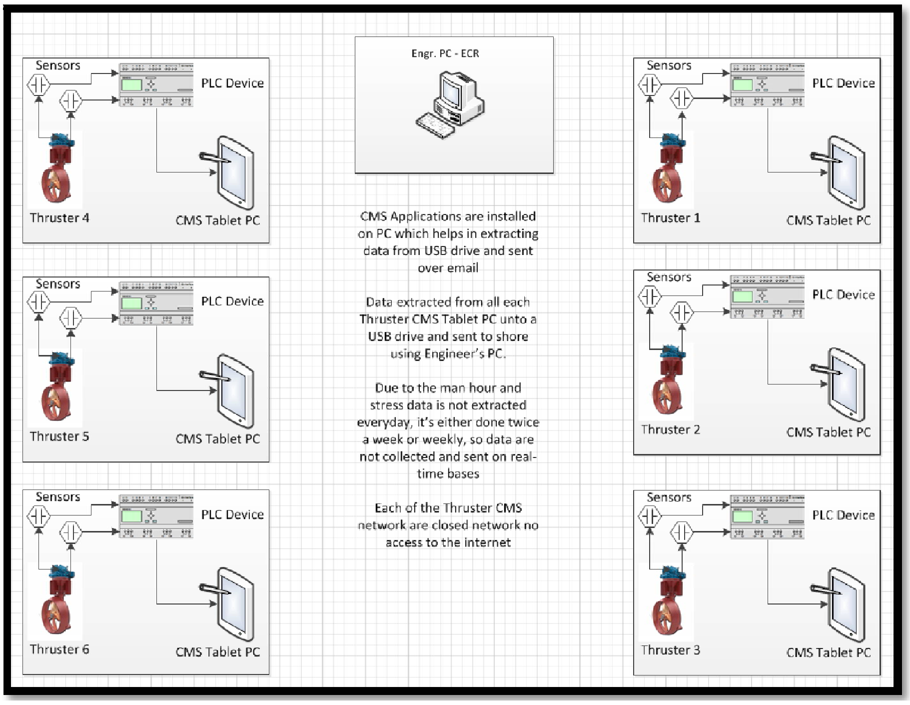

Figure 1: Current Standalone System

1.3. Aim and Objective of the Study

The aim of the study is design a better solution and architecture that will automate the extraction and transmission of thruster data onshore. The specific objectives are to:

- Understand how thruster data are collected from INoT
- Identify hardware's and software's need of the need new architecture
- Design network architecture to automate data extraction and transmission

1.4. Scope of the Study

This work focuses on improving on the condition monitoring system to make the work of those who work legacy operational technology easy. It also focuses on interconnecting all standalone thruster condition monitoring system for seamless data collection and transmission. The work focuses on helping the company management onshore have easy and quick access to maintenance information, to enable them respond faster, to help improve equipment performance and cost saving in the long run.

1.5. Limitation of the Study

This study at this stage is to propose a design of the new architecture and systems that will be needed to improve on the existing manual and time consuming system. This is study will not implement the proposed new design and systems so there will be no details of software system configurations.

1.6. Significance of the Study

This study is of great importance to the ship marine and engineering department, it will save them man hours and resource in getting the data and manually send them through their personal PCs. On the other hand the shore base personnel's will have quick access to maintenance information that usually have to be giving to them by the engineers. It will provide more reliable and consistent data as there will be no manual operation involved. Equipment's will get the maintenance attention they require and perform better and longer hours too.

1.7. Definition of Terms

- OT: Operation Technology, equipment's like thrusters
- INoT: Industrial Network of Things like sensors, PLC, industrial PC's, Tablets, etc.
- IIoT: Industrial Internet of Things where every device has access to the internet
- RAN: Rig Area Network
- CMS: Condition Monitoring System

2. Literature Review

2.1. Overview

A lot of literatures reviewed did well in exploring and applying the new trend industrial internet of things (IIoT) to industries and coming up with different architectures that suits the particular brand they are promoting or needs. The literature also did well in coming up with good business guide for those looking at integrating IIoT into their existing architecture and a review of the market share of IIoT in the years to come (www.i-scoop.eu, 2019). Some research apply IIoT to the unique industry thereby developing more of a customer built system which will not work well for other industries this pretty much how IIoT is implemented. Since every manufacturer or industry is unique even though there are in the same sector their machines, or INoT are not all going to of the version or model and will need some customization to make IIoT work (Murphy, B., Lin, S.W., and Burger, B., 2016).

However as regards integrating the manual condition monitoring systems with INoT, fog, and cloud computing for easy management of azimuth thruster maintenance there seem to be little or no literature in this area. Many of the literatures are focused on IoT, and industrial internet of things (IIoT) which is the trending thing in the industry today and are more of vendors who are marketing their different control network products. Not one literature is written on INoT for thrusters monitoring.

Further reading and search for INoT only found a paper written by Jeffrey Voas of the National Institute of Standard and Technology (NSIT) of the US Department of Commerce, where he also rightly observed in his paper on "Network of Things" -NIST special publication 800-183 that the name should be Network of Things (NoT) and not IIoT as is being echoed by industry experts According to Voas, J., (2016) "The relationship between NoT and IoT is subtle. IoT is an instantiation of a NoT that is resemblance of IoT in a closed LAN, more specifically IoT has its things (devices) tethered to the Internet. A different type of NoT could be a Local Area Network (LAN), with none of its things (devices) connected to the Internet. Sensor networks, and the Industrial network are all variants of NoTs".

2.2. Condition Monitoring System

By definition "Condition monitoring is the process of monitoring conditional parameter of a machinery (vibration, temperature, etc.), in order to identify significant change which is indicative of a developing fault" (Wikipedia, 2019)

In the early years condition monitoring was not used to monitor and carryout predictive and prevent maintenance because industries were kind of simple and people were able to do most of the preventive maintenance manually. During the 1930's and 1940's most of the factory were pretty basic and there was no attention given to equipment downtime reason been that the tools were less complex, and repairs were relatively easy (Scanmetrics, 2019). But as time went passed organization has come to rely more on systems and equipment's that have become more technically advance and has become increasingly vital to achieve optimal uptime. This change started in the 1950's to the 80's when organization started seeing the need of equipment condition monitoring and placed high priority on it so as to reduce downtimes for increased revenue. (Scanmetrics, 2019).

In the marine industry where oil and gas drilling ships operates of recent international maritime organization (IMO) has made it mandatory for condition monitoring system to be installed for proper critical marine equipment monitoring through environmental and human laws like the "Sulphur 2020 Implementation" which was confirmed 2016, and adopted in 2018, states that beginning from January 1, 2020 it will become mandatory for all ships to have 0.50% sulphur limit, (IMO, 2019). What this guide says is that companies must monitor the kind of fuel oil they buy and always monitor the fuel oil condition of their machine.

When the ships left shipyard the azimuth thruster had no CMS installed the engineers were carrying out the monitoring of the thruster the old fashioned way, they do a daily round to all six thruster rooms located at long distance, up and down the stairs and far from each other. To get the readings can take up one to two hours to complete, this was time consuming being that there are other equipment's that are also monitored manually. The reading they get using manual method is only the bearing and oil lube temperature, they are not able to capture the vibration, and oil particles reading properly as they use visual and hearing inspection to check for both readings. Figure 2 show the general condition monitoring concept

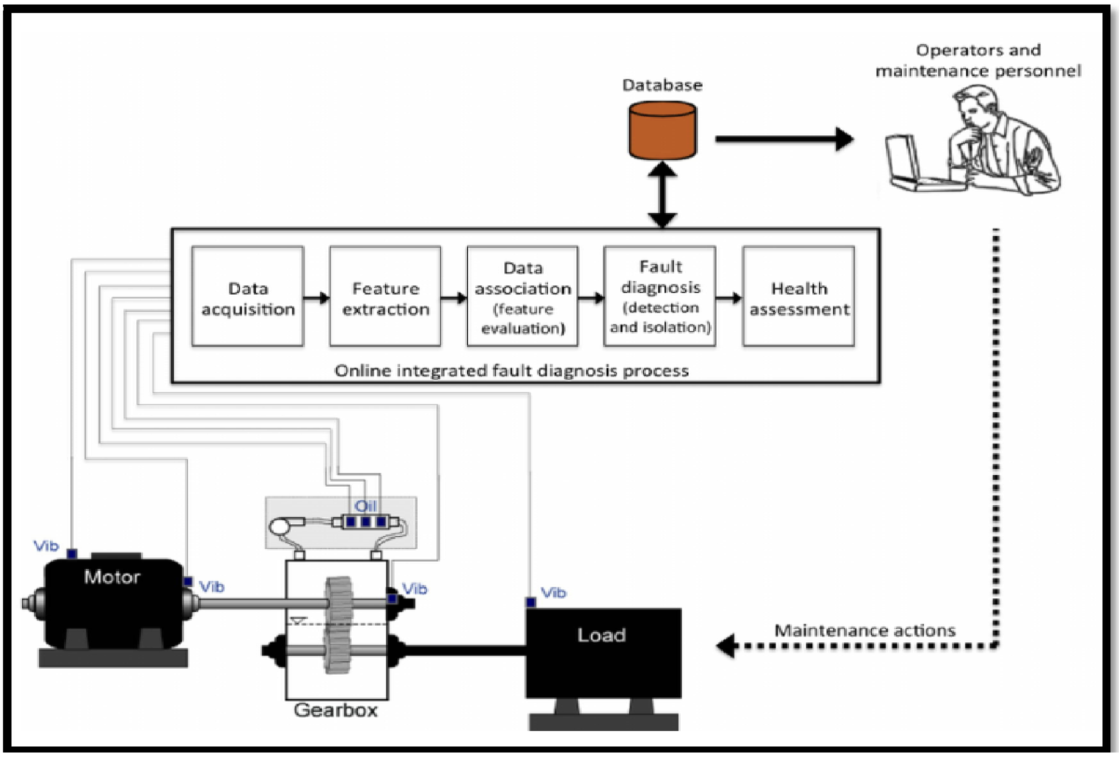

Figure 2: Condition Monitoring Concept
Source: (Persin, G., and Vizintin, Joze, 2014)

2.3. Industrial Network of Things (INoT)

To put the record straight devices before the fog computing layer should be Industrial Network of Things (INoT) not IIoT especially for those who have not being opportune to see or work in an industry where heavy equipment's are interconnected in a rig area network (RAN). Another reason is for people not to be confuse with the industrial version of IoT called Industrial Internet of Things (IIoT). INoT has always being there for heavy industries with closed rig area network (RAN). For instance in the oil and gas industry especially offshore, drilling control, navigation or vessel control networks consist of Industrial Network of Things (INoT), with no internet access, a lot of drilling equipment's from time has always being interconnected with both universal and proprietary connectors like RJ45, SC, ST, RS232/485, Amphenol communication connectors, etc. forming closed rig area network (RAN). Just that it is not talked about frequently or universally and not given the needed attention like IoT or IIoT.

The industrial version of NoT should be Industrial Network of Things (INoT), the (things) devices be it sensor, PLC controller, terminal stations and of recent mobile devices are able to communicate with each other exchanging very critical and important data at high speed that helps with decision making. INoT is the foundation of IIoT, in reality equipment's like Hydraracker, Topdrive, and other drilling equipment's or tools have no direct access to the internet but are interconnected on same network. To further make some clarification, it should be explained that IIoT applies to devices in the cloud section of the architecture like data center servers, personal mobiles devices, PC's, etc. while INoT applies to devices before edge or fog computing like I/O Signals, temperature, current and voltage sensor's, PLC, machines, etc., figure 3

We are only able to move data to IIoT if INoT is integrated and redesigned with fog and cloud computing each playing its part, this is converging point between information technology (IT) and operations technology (OT), see figure 3.The integration or architecture created depends on the organizational need and what they want to achieve but it's all same ideology where closed network with OT is integrated with another architecture with IT to either send data straight to the cloud for onshore analysis and visualization or data is analyzed both offshore and onshore with each geographically apart locations taking the required action to deal with a situation.

In the proposed used case of thruster condition monitoring system the data analysis and visualization if done onboard the ship using fog computing will prompt the Engineers to start taking necessary steps to change whatever parts, e.g. oil that has water content above the threshold will be changed immediately not waiting for onshore decision while on the other hand a cloud a bearing that is showing sign of failure will prompt those onshore to start making plans to order new bearing and send offshore since those offshore cannot just leave the ship and go shop for a new bearing that is the job of procurement in town after getting the necessary approval.

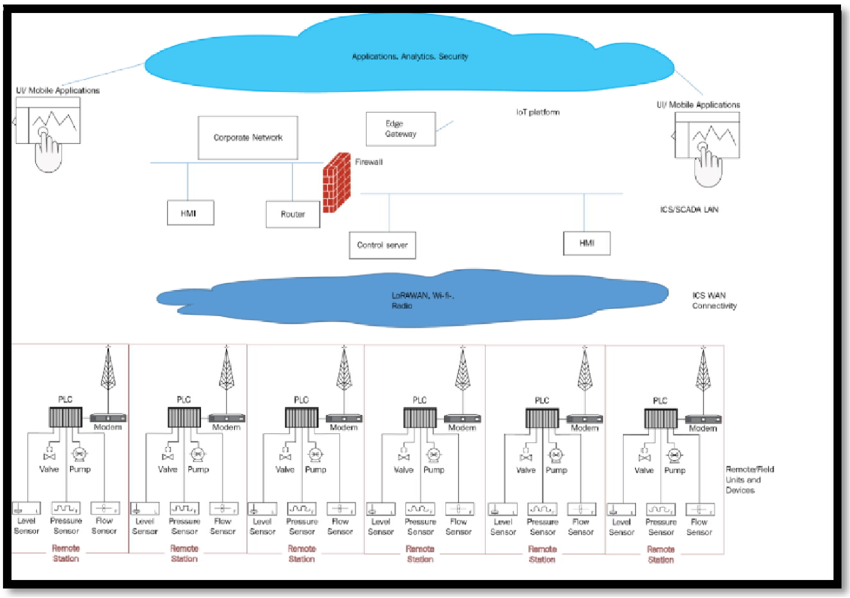

Figure 3: Typical Inot Architecture
Source: (Bhattacharjee, S., 2018)

3. Methodology

In this study the methodology to be used is systems integration of operation technology using information technology. Operation technology like ship azimuth thruster and many more marine equipment's are very critical to the performance of the ship's movement and for these OT's to perform at optimal capacity and reduce downtime there has to be proper equipment condition monitory system which help in predictive (PdM) and preventive maintenance (PM).
This is where companies leverage on information technology to interconnected and integrate these equipment's for proper monitoring. Figure 1 architecture will be improved upon, in the new system all thruster rooms will be connected into one network through help of fiber and Moxa media converter.

3.1. Sensor and Actuator Network

Sensor networks are one of the major source of data acquisition in the heavy industry oil and gas inclusive, the amount of data that gets collected through the help of sensors are unending ranging from tank levels, to gas (H2S, Hydrocarbon) levels to I/O signal, temperature, pressure level, to thrusters vibration, virtually every equipment can be integrated to a sensor for monitoring and data collection. A sensor network is made of a group of tiny, typically battery or AC current powered devices both wired or wireless infrastructure that monitor and record conditions in any number of environments from the factory floor to the data center to a hospital lab and even out in the wild, and offshore (Shultz, B., 2010). The sensor network maybe connects to the Internet, or an enterprise WAN or LAN, or RAN, or a specialized industrial network so that collected data can be transmitted to back-end systems for analysis and used in applications".
Sensor can be installed where humans can't get to and collect the needed data that help in critical decision making for operational excellence and efficiency, sensors are the sensing organs of any industry included offshore operations. They sense the physical environment and many other things there are the traditional wired and wireless sensor network just as there are different types of sensor for different applications.

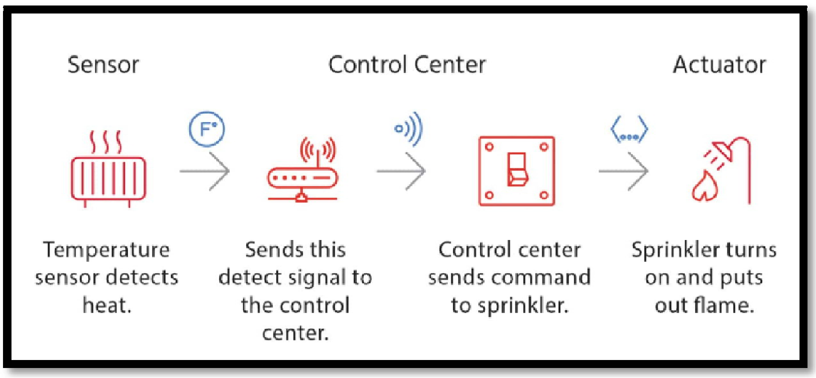

Figure 4: Sensor to Actuator Flow
Source: (Www.Bridgera.Com, 2019)

Sensor is like transducers which are physical device that converts one form of energy into another. In the case of sensor a physical effect or phenomenon is converted into an electrical impulse which is interpreted to determine a reading. Figure 4explains the actions from sensor to actuator, so in INoT setting sensor collects information the physical environment (Equipment's) and sends it to a control system which is the fog node within INoT network which analyzes the data and decision is made to actualize the result of the data analysis.

3.2. Fog and Cloud Computing

In 2014 Cisco came up with fog computing concept which is very similar to edge computing. They defined fog computing as a computational architecture that is dense and located at the edge of the networkthat is close to the sensors, actuators, PLC, and other INoT devices, with low latency, location awareness and able to retrieve data from anetwork (Cisco, 2014). In edge computing the data to be processed are not too large and complex so can be handle by an edge node just like traffic light decision making, it is not too complex for the microcomputer to handle at the traffic point so it switches the light between RED, YELLOW, and GREEN, so if we take figure 5 for instance data analysis and decision will be done at the fog node alone while in fog computing butif the data becomes bigger, more complex, and requires inputs from people outside of the place where the activity is taking place like more traffic lights, videos, pictures, GPS trackers then a device with more computational power will be required, this is where fog computing comes in,where data analysis is done both closer to the network and at the center of the network being the cloud, making analyzed data available to both those in this case offshore and onshore.

Fog computing can be applied virtually in a lot of areas ranging from oil and gas, transportation, health care, etc. In oil and gas where heavy equipment's are used and real-time data is required for analysis at the edge of the network for quick decisions on preventive maintenance to be carried out on critical equipment's, and the cloud for top management visibility and decision making. Fog nodes communicates with industrial network of things (INoT) devices and collect data needed for analysis, the devices are unlimited as long as they are connected to the network. Some of the benefits of fog computing are deeper insights with internal control of sensitive data inside the local network, lower operational expense by saving on bandwidth usage if analysis it to be at the cloud, and better security, fog nodes can be protected using same security policy as other IT environment.

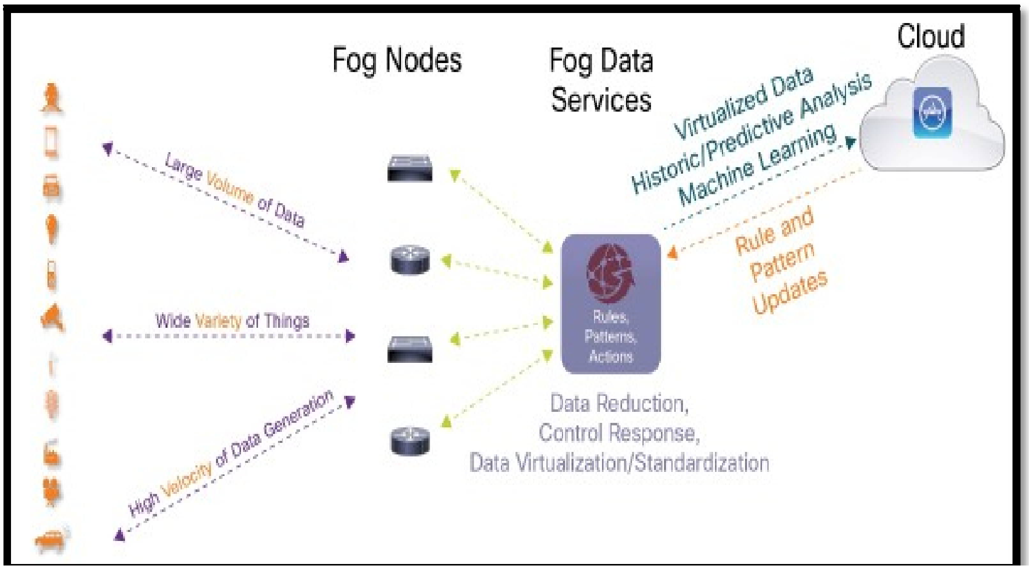

Figure 5: Fog Computing Architecture
Sources: (Mckendrick, J., 2016)

3.3. CMS Hybrid Network Architecture

The proposed network solution to achieve the goal at hand is to have a hybridized network architecture that serves our purpose. The architecture should meet the expectations of both offshore and onshore need for real-time data and extraction and analysis for prompt decision making at every stage of operation especially when we are drilling, deep water drilling operation depends on the stability and easy maneuvering of the ship and this is one of the important functions of the thruster and the Engineers. Figure 6shows the different layers of the hybrid architecture with the different physical components on the left side of the pyramid and virtual activities that takes place at the background on the right side of the pyramid.

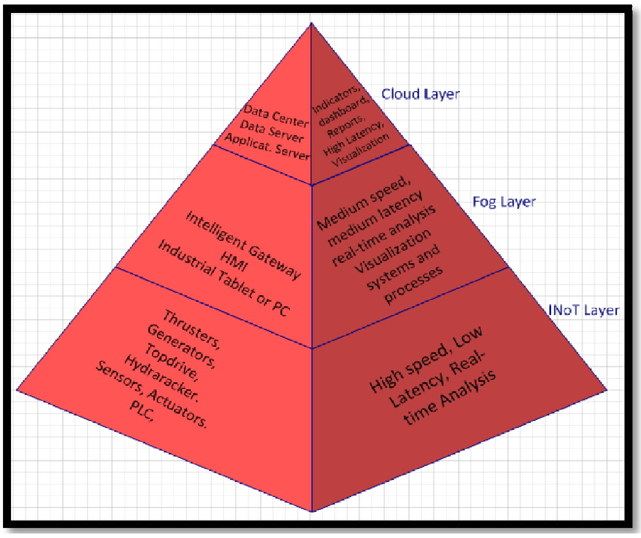

Figure 6: CMS Hybrid Network Architecture

3.4. Information Technology (IT) and Operations Technology (OT) Convergence

In this section I will look at how the different technologies can be integrated and applied in the engineering department of a drilling ship in particular the azimuth thruster's condition monitoring system (CMS) in the various thruster rooms. Bringing them into one closed networked and using INoT, fog and cloud computing to collect, store, analyze, and transmit data both at the edge of the network and to shore base for further analysis if need be. The shore base represents the cloud section of the architecture. Figure 1 is the current and manual setup, the Engineer's uses a USB stick to extract the data from all six thrusters, and then sends the information to our thruster specialist in Finland through their normal office PC using Microsoft outlook email. The system of collecting and sending thruster data for analysis has a lot issues which has being stated in the problem statement in introduction.

If figure 1 is to be re-designed to figure 8 without fog computing then we will still experience some of the known issues discovered with INoT, IIoT, or IoT to cloud using IoT gateways which are; the time it takes to send data to the cloud and receive the processed data is too long, the latency is high. It's even worse if applied for instance in the oil and gas industry where drilling operations take place thousands of miles away from shore base office. The cost of satellite communication bandwidth is too expensive to allow moving data in and out between the INoT network and the cloud in real-time, if decision needs to be made on a particular equipment or machinery then the operation will be on down time and revenue will be lost.

Bringing fog computing into the equation will help to reduce the latency, increase the response time in getting feedback from the data analysis done at the edge of the network by a rugged industrial computer figure 7 which will be at the fog end of the architecture, the industrial computer has two LAN ports, one connects to the closed thruster CMS network and the other is the only source of outside communication for sending data to the cloud for further analysis. A fog node has the capability to store data from INoT devices, analyze the data at the edge of the network saving bandwidth and then a visual report of critical preventive maintenance needs to be done so the onsite Engineers can start taking urgent action, by this the fog node has being able to save the company a lot of time in responding to critical maintenance, and revenue is save from not going on down time, while data is later sent to cloud during off peak period for further analysis.

Figure 7: Rugged Industrial Computer
Source: (www.ruggedpcreview.com, 2019)

To be able to transport the huge data from all thrusters we have to interconnected all six thruster rooms with a fiber backbone that runs from the thruster rooms to the engine control room (ECR), at the moment they are standalone systems in each thruster room and the Engineer's use USB stick to extract data from each thruster as stated earlier. In Figure 8, I came up with a new network diagram showing how the fibers are to be interconnected, the Sensors an INoT device,collects the needed data from the thruster components e.g. gear, bearing, oil, shaft, etc. (being the environments data are collected) and sends the data to the PLC's, then the Tablets in the thruster space also an INoT device, connects to the PLC through the LAN cable gets the data and store in its database for processing, with its second LAN portwhich is on the fog network with the fog node (industrial PC) figure 7 to send it to the cloud for further analysis. The red lines in figure 8 represents fiber cables that interconnects each thruster rooms with engine control room and every location has a fiber patch cabinet and a Moxa media converter all shown in figure 8.

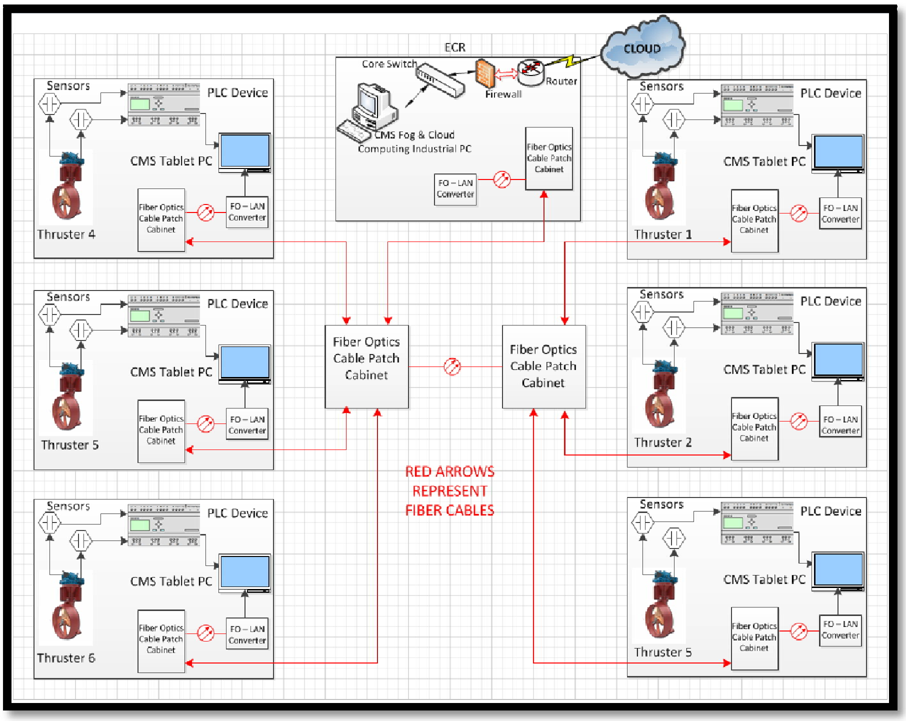

Figure 8: After Inot, Fog & Cloud Computing Integration

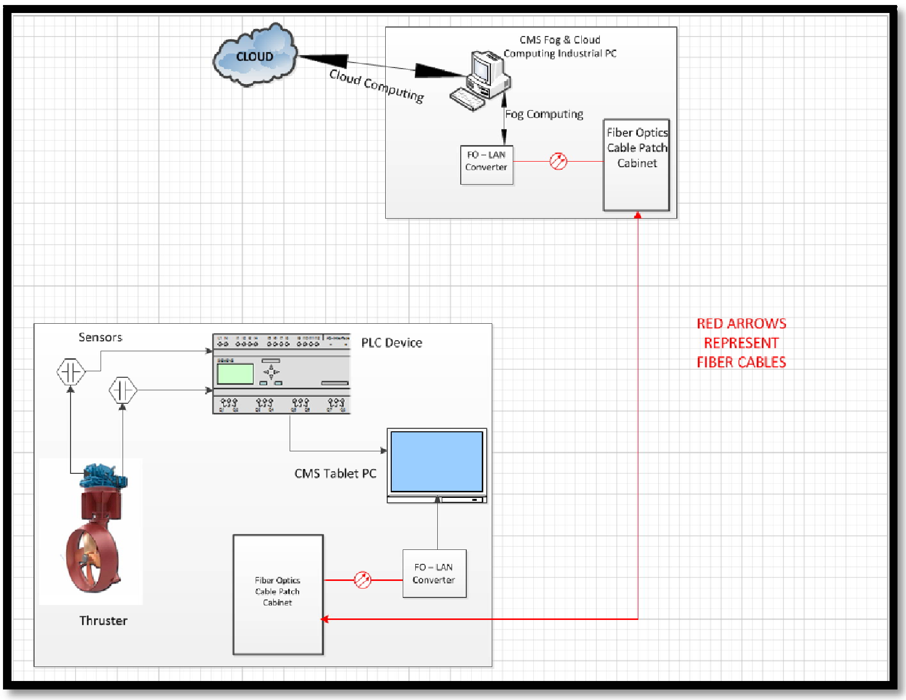

Figure 9: After Inot, Fog & Cloud Computing Integration (Enlarged)

Figure 9 is an enlarged diagram of figure 8 showing only one thruster room for better viewing

4. Conclusion

In conclusion, in this paper I have looked at condition monitoring system for azimuth thruster, the manual process of collecting data from the thrusters and the challenges the Engineers are facing with this system. I identified the feasible and possible network architecture, and information technology (IT) to be integrated into our old operation technology (OT) for the required solution that suits our need.

Fog computing was talked about, it islike the middle man who takes data collected from INoT devices readily usable by the people who are close to the edge of the network (offshore) or far away from the office (onshore) that really need it for quick action. Fog layer also is able to give upper management more detailed understanding of what is happening offshore. This paper has also shown that IoT is not easily applicable everywhere especially at offshore locations where bandwidth is a bottleneck for operational data rather a combination of INoT, Fog and Cloud computing will very well be a better option of organization's with remote location operations like offshore drilling.

Also giving the increasing popularity of IIoT, and the way and manner it is used and talked about is some worth misleading as the word INTERNET in the acronym would give the manon the street or out there in industries like offshore locations the impression that equipment's are practically allowed or open to connect or communicate with the outside world using IoT or IIoT, rather they are in this case just Industrial Network of Things (NoT) that is not connected to the internet. My hope is that this paper will prompt people in the industry to take another look at IIoT and beginning to make a change suggested in this paper and just as Jeffrey Voas had also suggested too.

This research did not implement the new design and integration suggested here, it is hoped that in the future it will be improved on and implemented.

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