Data-centric Operations in Oil & Gas Industry by the Use of 5G Mobile Networks and Industrial Internet of Things (IIoT)

Spandonidis C. Christos
Prisma Electronics
Athens, Greece
email: c.spandonidis@prismael.com

Giordamlis Christos
Prisma Electronics
Athens, Greece
email: christos@prismael.com

Abstract **- For many years, the Oil & Gas Industry has been collecting huge amounts of data, turning thus slowly and gradually to "Data-centric Operations". Unfortunately, this data collection has typically happened via many independent pieces of equipment and systems – each with its own data and interfaces. The promising features of the forthcoming 5th generation (5G) mobile networks have enhanced the Industrial Internet of Things providing technology improving safety and optimizing performance. In this work a dedicated platform aiming at the continuous collection of critical information from multiple nearshore assets and transmission of the data through a 5G network is proposed. Important details and technology challenges that drive to a competitive proposal are discussed.**

Keywords - Offshore monitoring; Industrial Internet of Things; 5th Generation (5G).

I. INTRODUCTION

The ability to utilize data to obtain knowledge, predictions and insights gives today the tools for continuous process improvements and optimal performance throughout the lifetime of assets. According to World Economic Forum [1], the Oil & Gas industry is seeking to leverage new developments in digital technologies to unlock a value at $1.6 trillion by 2025. Major Energy companies like Aramco, BP and Statoil are leading the way in the "digitalization" of the oil field and recently presented their plans to invest in new digital technologies through 2020, in order to improve safety, security, and efficiency of their operations (see for example [2]). Based on the existing data flows from vessels, we are exploiting a unique business window opportunity for a platform architecture that allows the reliable and uninterrupted reception and management of data from a wide range of sensors within a near-shore offshore structure network.

The rest of the paper is structured as follows. In Section II, experience gained by shipping industry is provided in a critical way. Characteristic examples of data that lead to effective decision making and cost reduction are discussed. In Section III, the main challenges when it comes to Oil & Gas Industry are briefly described, while in Section IV a platform based on the development of the existing LAROS-based platform [3] that allows reliable and uninterrupted reception and management of data from a wide range of sensors within a wide range of offshore structures is proposed.

II. EXPERIENCE FROM SHIPPING

LAROS is a dedicated platform aiming at the continuous collection of critical information from the ship's inputs, the transmission of the data through a wireless network, centralization and homogenization of information in central computing, and analysis of measurements to support the decision-making mechanism of shipping companies. The system is using the vessel's communication systems (satellite) to transmit all collected & synchronized data to the Headquarters, in a very efficient manner in terms of cost, speed, and security. Transferred data are further processed using LAROS Data Analysis System.

A. System description

In more detail, the Data Collection process can be described as follows:

LAROS Smart Collectors are connected using the appropriate interface to analog or digital signals coming from different sensors and instruments of the vessel. Smart Collectors analyze the signals and calculate the required parameters. The sampling rate, as well as rate of the parameters calculations can be set from 100msec up to 30 minutes. Smart Collectors setup a wireless secure network inside the vessel to transmit the processed data to the Gateway with a user-defined sampling rate and ability to maintain and customize them remotely. The wireless protocol is based on IEEE 802.15.4 MESH [4] with additional layers and data format to cover the requirements of the vessel environment and increase the network Quality of Service. Through the Gateway, all the measured and processed parameters are stored in LAROS Server (onboard). All data are stored in LAROS server's database for a long period (up to 1 year depending on the number of sensors and on sampling rate). In addition, there are options to forward the data to any third party systems on board avoiding costly cabling or other infrastructure implications. LAROS On board Server periodically produces binary files and compresses them in order to reduce the size of the data to be sent via normal satellite broadband. The compressed files are transmitted through File Transfer Protocol (FTP) to the data center that will be selected by the operator. In the data center, there is a service that decompresses the incoming files and stores the new measurements in the main data base. In case the system is connected to a weather site, the weather data are stored in the main data base in the same format.

 ISBN: 978-1-61208-623-1

B. *Maintaining the Integrity of the Specifications*

Table 1 summarizes the main functionality modules, the needed signals and the collection points onboard:

TABLE I. INDICATIVE FUNCTIONAL MODULES - SHIPPING

Module	***Needed signals***	***Connection points***
Proppeler – Hull Performance	Vessel Speed, Shaft Revolutions per Minute (RPM), Shaft Power.	Speedlog, Torque-meter- RPM Indicator.
Engine Performance	Fuel Oil Consumption (FOC), Power (Specific Fuel Oil Consumption - SFOC), Diesel Generator (DG) Output	Flowmeters [Fuel Oil (FO) flow], FO temp, FO density, DG Power Analyzer
FO Consumption	FOC, Vessel Speed through water, Shaft RPM, Boiler Status	Flowmeters (FO flow), FO temp, FO density, Boiler status indicator
On-line bunkering	Tank level, FO temperature	Cargo Control Console, Engine Control Room (ECR)/ Cargo Control Room (CCR) Indicators.
Maintenance managementt	Pressures, Temperatures, Alarms from critical systems	Alarm Monitor System (AMS), ECR Indicators
Power management	DG Output, Reefers Power Consumption	DG/Reefer Power Analyzers
Environmental conditions	Wind speed & direction, Water depth, Ambient temperature & Pressure	Anemometer, Echo-Sounder, weather station
Operational profile	Ground Speed, Drafts, Trim, Rudder angle	GPS, strain gage, Inclinometer

Next, we present two characteristic examples of performance increase. In the first example, real time data were used to identify a problem in condition of crucial system, while the second is an example of using historical data to find a root cause on increased operational expenditure.

Example 1: The operator was unaware about any issues with the Diesel Generator. As shown in Figure 1, the visualization of data pointed increasing deviation in Lube Oil (LO) inlet pressure which normally is an indication of the main axis of Diesel Generator cracking. The crew inspected the axis and fixed the issue in the next stop. As a result, the operator saved thousands of Euros, and his liability in the case this issue caused a serious accident.

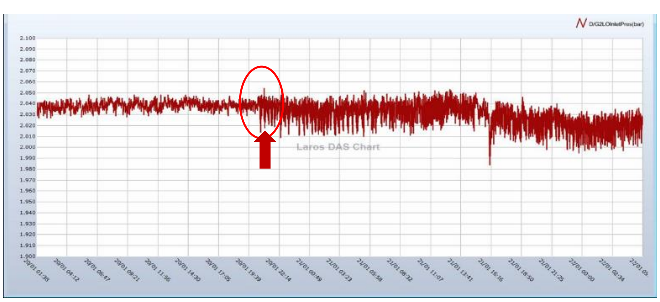

Figure 1. Observed increasing deviation in LO inlet pressure.

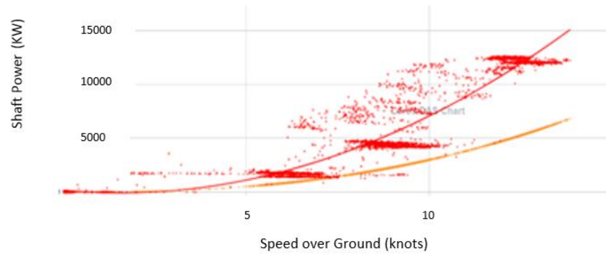

Figure 2. Shaft power vs vessel speed. With red dots are indicated the actual measurements. Sea trial baseline is indicated with yellow curve.

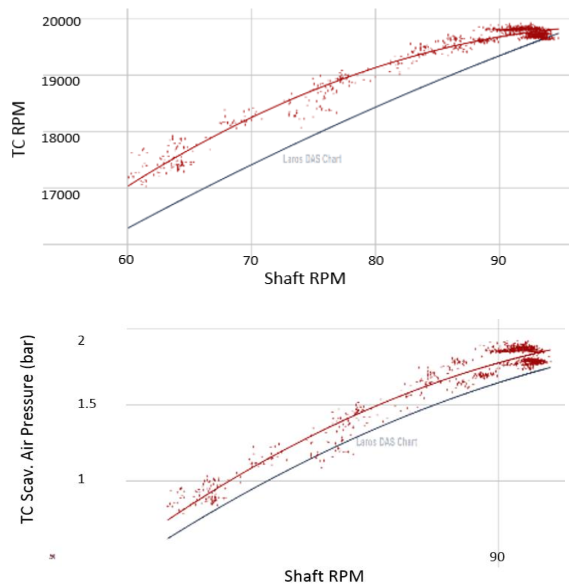

Figure 3. Turbo Charger (TC) Rounds per Minute (RPM) vs Shaft RPM (up) and TC Scav. Air Pressure vs Shaft RPM (down).

Example 2: Often dry-docking is a scheduled event and it is a costly one. However, a persistent problem may be much more costly if it is not addressed as soon as possible. Operator had the insights of very accurate data, proving that loss was greater than gain to keep operating. By using historical data, it was able to find out the propulsion performance and power analysis on the main engine's performance, influence of wind, waves, swell, current, shallow water, trim, use of rudder, possible drift, resulting in 73% deviation from Sea Trials/Model test report (Figure 2). Further analysis on engine performance (Figure 3) identified a well operating engine with no deviation, which was indicative of a clear hull fouling problem. This results in estimated 65% excess FOC.

III. OIL & GAS CHALLENGES

For many years, the Oil & Gas Industry has been collecting huge amounts of data (e.g., one rig can generate 1 terabyte of data per day), turning thus slowly and gradually to "Data-centric Operations". Wang et al. [5] provide a comprehensive review of the recent developments in field monitoring for offshore structures. In their work, the authors present a detailed list with typical monitoring projects of offshore platforms for the last 3 decades. Table II summarizes the main monitoring scopes and related sensing technologies. Unfortunately, this data collection has typically happened via many independent pieces of equipment and systems – each with its own data and interfaces. Integrated Marine Monitoring Systems (IMMS) have been developed to overcome such problems. A review of IMMS systems that enable the synchronization of collected data is presented by Yuan [6], while Wu [7] described the aspects of software and hardware to ensure the long term operation of such systems. Von Aschwege [8] presented the principles of design as well operational and technical considerations an Independent Remote Monitoring System (en entirely independent back up system used to transit critical data during hurricane conditions) should follow.

Despite the significant number of offshore platform monitoring related projects conducted all over the world, they are almost entirely limited to single offshore platforms. Data exchange between long-distance remote located offshore structures (e.g. between offshore platform and hurricane prediction stations, pipeline /reservoir monitoring systems, ocean ecological environment monitoring) or even between platform and support vessels or on-shore low-coverage areas, is a difficult to solve the problem.

Through our experience implementing LAROS on ships, we have highlighted several issues in the transmission of information, when it comes to multi structure network architectures, mainly due to (a) adverse conditions within specific offshore environments, (b) long distances between the nodes and (c) dependence of the system on the main power supply network (d) latency/bandwidth limitation on communication network, (e) cybersecurity issues. The promising features of the forthcoming 5th generation (5G) mobile networks assisting the aim of integrating multiple offshore structures into a wider ecosystem for the exchange of *large dimensional structured information* leading to an efficient and comprehensive operation of the offshore assets through Information Intelligence.

IV. INTEGRATED 5G BASED PROPOSAL

The proposed platform is based on the development of the existing LAROS-based platform to allow the reliable and uninterrupted reception and management of data from a wide range of sensors within a wide range of offshore structures (e.g. platform, Support Vessel, floating buoy) with emphasis on the requirements described by Wang et al. [1]:

(a) Need for smart monitoring instruments with less power requirement, higher accuracy, ability for synchronization, and applicable in a variety of sensor types (Table II) and ideally on fiber-optic sensors.

(b) Need for efficient wireless communication network that allows multi-measurement acquisition and real time data exchange between different offshore structures and between offshore structures and third parties (e.g., port authorities).

TABLE II. INDICATIVE MONITORING SCOPES – OIL & GAS

Scope	***Needed signals***	***Sensing technologies***
Metocean	Wind	Anemometer
	Sea Waves	Remote wave buoys X-band Radar
	Current	Acoustic Doppler Current Profiler (ADCP)
	Internal waves	SAR
	Ice	Moored Upward Looking Sonar (ULS)
	Environmental conditions	Humidity, pressure, Ambient Temperature
	Tide	Pressure & Water Density sensor
Structural Motions	Positioning	Differential Global Positioning Systems (DGPS), Inertial Navigation System (INS)
Structural operational status	Platform Hull	Altering Current Field Method (ACFM), Field Signature Method (FSM), underwater robot probe, Remoted Operated Vehicle (ROV)
	Riser	Tension riser Monitoring system
	Mooring line	Load cells, inclinometers
	Submarine pipelines	Visual inspection Tension sensors, Echo sounder, contour sonar

A. *Smart monitoring instruments*

The viability of the LAROS-based smart sensing platform in wireless-based systems for predictive maintenance and management in a harsh industrial environment was demonstrated by Sachat et al. [3]. The outcome of that work was a sensing platform that was viable, low cost and of low complexity, able to be efficiently integrated in autonomous fiber-optic sensing units and capable of forming a distributed monitoring network. The selection of large core optical fibers additionally allows the use of low power light sources and photodetectors that could be integrated in the sensing unit with low power requirements (Figure 4).

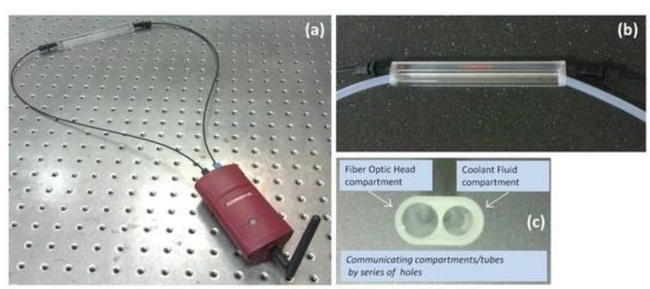

Figure 4. (a) Measuring apparatus with the sensing head connected to the wireless sensing node unit; (b) Photograph of the glass measuring cell (c) Photograph showing in detail the dual tube glass cell. [3]

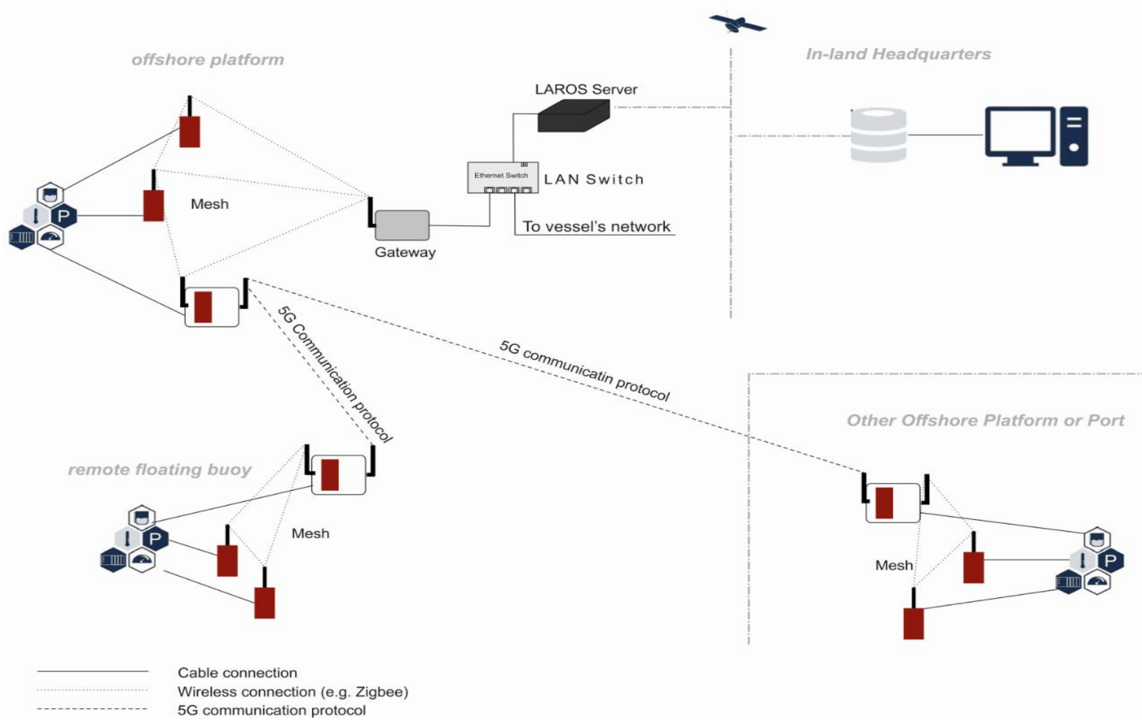

Figure 5. Decsriptive example of proposed system architecture

B. *Smart communication network*

Mesh networking combined with low power consumption (e.g., Zigbee [9]) is proposed be used for exchange of data between nodes at short distances. For communication between remote nodes or an external network, 5G protocol will be used that allows communication at long distances in an efficient and energy-efficient way.

Use of 5G mobile network has been proposed instead of other communication technologies, such as Wifi, 4G, etc, mainly due to rate (b) lower End-to-end latency, (c) large number of connection points, (d) reduced Capital and Operational Expenditures, (e) consistent Quality of Experience and (f) reduced demand for energy [10].

Following Mugen et al. [11], in order to achieve these goals, we propose a heterogeneous cloud radio access network (H-CRAN), where cloud computing is used to fulfil the centralized large-scale cooperative processing for suppressing co-channel interferences. As shown in Figure 5, central stations (on offshore platform) (Node C in [11]) act as the Base Band Unit (BBU) pool to manage all accessed Remote Radio Heads (RRHs), and the software-defined H-CRAN system architecture is presented to be compatible with Software Defined Networks (SDN). This architecture will eliminate issues of path loss and the need for line of sight due to the high operating frequency of such networks.

The development of 5G-based Low Earth Orbit (LEO) satellites will further enhance the integration of satellite and terrestrial networks in 5G [12], enabling thus even larger or distant located eco-systems (e.g., deep water oil platforms). Figure 6 schematically presents such an integrated architecture.

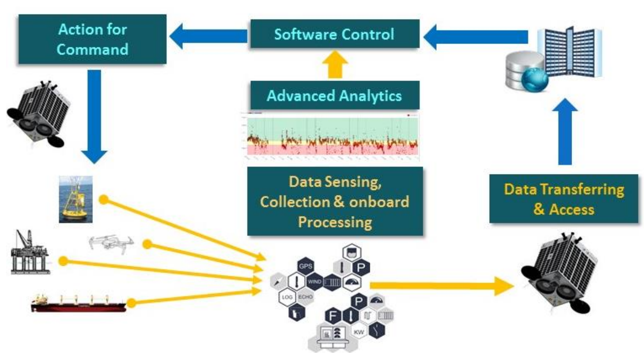

Figure 6. Schematic view of 5G Low Earth Orbit LAROS architecture

C. *Benefits of proposed monitoring platform*

An advanced monitoring system, as the one described above, enables the following core functionalities:

<u>Efficiency control</u>

The platform provides the necessary tools that allow managers and operators to measure in detail the efficiency of every asset on board. Further OPEX reduction is possible as a result of performance analysis of the facilities and corrective action plans, e.g., effective power system management, rational usage of equipment, isolation and replacement of heavy energy consumers, etc.

 ISBN: 978-1-61208-623-1

Condition Monitoring and Event Detection

Continuous monitoring of an asset or of a condition can only be performed by an online system onboard. The more parameters examined and analyzed simultaneously the better the monitoring performance. The platform provides alarms triggered in real time when anomalies get detected.

Centralized monitoring

Monitoring of multiple assets can be achieved using a unified dedicated dashboard that allows centralized monitoring and reporting. The operational and performance parameters of each asset can be individually tracked and analyzed using a single reporting system accessed from anywhere in the world using simple Web services.

Expandable

The platform is expandable and adaptable in order to cover any future needs and required measurements. This is easily done by connecting additional sensors to the installed LAROS Collectors or by adding extra Collectors in the existing 5G network.

V. CONCLUSION AND FUTURE WORK

To gain reliable and comparable data at low cost and in energy efficient method from a wide network of offshore assets, mesh networking combined with 5^{th} generation network architecture is proposed. Examples from experience on vessels, for the exchange of data between nodes at short distances is presented and existing challenges for 5G mobile network are drafted for communication between remote nodes and the external network. Technology barriers and challenges for a robust operational model that drives to a competitive and integrated 5G based proposal that will make an impact in the field of Offshore “Data-Centric Operations” were further discussed. It was shown that State-of-the-art technology trends in various sectors including M2M, intelligent processing, machine learning, data agents, cyber-safe datasets, telco etc., should be part of new generation platforms to secure data science in a level that allows the Oil & Gas Industry to enter the IIOT – 5G area dynamically and support effectively decisions, safety, efficiency and interoperability. The goal for the next step would be to define the important details in order the designed platform architecture to offer a reliable and usable monitoring system even in harsh and non-accessible until now environments.

REFERENCES

[1] D. Paganie, “Assesing the digital transformation,” Offshore Magazine, vol 17:10, pp 3-5, 2018.

[2] Fugro. Fugro Complete Wellhead Monitoring Project for BP in Gulf of Mexico, 2015. (source: https://www.fugro.com/media-centre/news/fulldetails/2015/10/01/fugro-complete-wellhead-monitoring-project-for-bp-in-gulf-of-mexico).

[3] A. El Sachat et al., "Characterization of industrial coolant fluids and continuous ageing monitoring by wireless node-enabled fiber optic sensors", Sensors MDPI 17, 568, pp. 568-588,2017. doi:10.3390/s17030568.

[4] J. T. Adams, “An Introduction to IEEE 802.15.4”, IEEE Press, vol. 2, pp. 1-8, 2006.

[5] W. Peng, T. Xinliang, P. Tao, and L. Yong, A review of the state-of-the-art developments in the field monitoring of offshore structures, Ocean Engineering, Volume 147, pp 148-164, 2018.

[6] S. Yuan,“Prototype Measurement and Monitoring Technology Research of Floating Offshore Platform (Master's thesis). Da Lian Engineering University, 2013.

[7] W. Wu et al., “Design, implementation and analysis of full coupled monitoring system of FPSO with soft yoke mooring system”. Ocean. Eng. 113, pp. 255–263, 2016.

[8] J. Von Aschwege, K. Jassal, and R. Barker, “An independent remote monitoring system for Gulf of Mexico deepwater floating production systems”, Offshore Technology Conference,pp. 2007.

[9] K. Pantelaki et al., “Survey of the IEEE 802.15.4 Standard’s Developments for Wireless Sensor Networking”, American Journal of Mobile Systems, Applications and Services vol. 2, No. 1, pp. 13-31, 2016.

[10] J. G. Andrews et al., “What will 5G be?”, IEEE Journal on Selected Areas in Communications, vol. 32, no. 6, pp. 1065–1082, 2014.

[11] M. Peng,Y. Li, Z. Zhao, and C. Wang, “System architecture and key technologies for 5G heterogeneousc loud radio access networks,” IEEE Netw., vol. 29, no. 2, pp. 6–14, Mar. 2015.

[12] M. D. Sanctis, E. Cianca, G. Araniti, I. Bisio, and R. Prasad, “Satellite communications supporting internet of remote things,” IEEE Internet of Things Journal, vol. 3, no. 1, pp. 113–123, 2016.