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Internet of Things based Architecture for Oil and Gas Industry

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ABSTRACT: The industry of oil and gas (O&G) suffers from delay to get enough information about equipment in case of maintenance and delay in communication between stakeholders. With the highly increasing of the data of oil and gas (O&G) industry, the concept of the Internet of Things (IoT) becomes a must to be applied to sense and monitor every area of O&G operations. This paper proposes architecture based on the Internet of Things for monitoring various operations of the oil and gas industry. Use of several Wireless Sensor Networks in management of oil and gas platforms is analyzed. New opportunities created by processing of data collected via sensors for improvement of safety of oil platforms (deposits), optimization of operations, prevention of problems, troubleshooting and reduction of exploitation costs in oil and gasindustry.

KEYWORDS: Internet of Things, Wireless Sensor Networks, monitoring, sensors, smart objects, network gateways, control center

I. INTRODUCTION

In the modern era, the oil and gas industry faces new production problems, especially against the background of a decline in oil prices. Finding new modernized ways to improve results and reduce costs in order to increase efficiency and competitiveness is an urgent and important task. Here a special role is assigned to collection of more detailed and accurate information about the production process and solution of the control problem. Directions such as increasing the speed of exploration and detection of oil, increasing oil production and reducing the risks to health, security of humans and the environment identified as a result of equipment malfunctions or operator errors are constantly developed with application of Internet of Things (IoT).

IoT is characterized as the next revolutionary development layer of information technologies fields after computer, Internet and mobile telephone communication. It is mainly used in medicine, agriculture, oil-gas industry and other fields in order to remotely control occurring changes, prevent fires and provision of other useful functionality.

Kevin Ashton, one of the developers of Radio Frequency Identification (RFID) technology notes that, IoT has a potential to change the world as much as Internet, may be even more [1].

Solution of several important social problems is expected with realization of IoT. Also, improvement issues of control development processes in oil and gas industry will besolved.

IoT will affect everything that surrounds us in nearest decades. Mentioned technology is mainly applied in following fields [2]:

- oil-gas industry: control of oil products exploration, production, processing, transportation and sale processes;
- in cities: transport control, lighting, stops, smart office buildings, wastecontrol;
- energy production and distribution: smart grid, microgrid, electrical stations controlsystems;
- agriculture: efficient production, situation based irrigation andfertilization;
- environment: pre-detection of forest fires, tracking animals that are becomingextinct;

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- medicine: remote diagnostics, monitoring of old and sickindividuals;

Oil-gas industry covers expedition, production, processing, transportation and sale processes of oil products. Fuel, oil and gasoline form the majority of products of this industry. Oil is also the raw material for many chemical products, including drug preparations, solutions, fertilizers, pesticides and plastic production. As demand for natural fuel is increasing daily, oil and gas companies must create new technologies and improve operations for increased productivity.

Application of IoT, which is based on sensors, can be taken as a topical issue as the way of implementing the right strategy in gathering information in the oil and gas sector. Application of this technology will enable to control efficiency, make efficient decisions, improve production and increase competitiveness. Oil-gas industry is the main industry controlling many other industries, important for worldwide energy production and significantly affecting world economy as a result [3].

Main results of IoT technologies for oil and gas industry are following:

- IoT has several significantly important potential applications in facility exploration, excavation and production operations, maintenance and overall facility control.
- works on application of IoT technologies in oil and gas field are on experimental level for now and performed works are focused on intensive processing of data and effective control of entrance/exit loadings.
- main objectives of IoT technologies' application are asfollowing:
- detection of more hydrocarbondeposits;
- safe, efficient production and transportation with minimal ecologicalimpact;
- planning of optimization;
- customer relations management;
- identification of new opportunities and markets.

II. RELATED WORK

In [2] authors used average residual battery level of the entire network and it was calculated by adding two fields to the RREQ packet header of a on-demand routing algorithm i) average residual battery energy of the nodes on the path ii) number of hops that the RREQ packet has passed through.According to their equation retransmission time is proportional to residual battery energy. Those nodes having more battery energy than the average energy will be selected because its retransmission time will be less. Small hop count is selected at the stage when most of the nodes have same retransmission time. Individual battery power of a node is considered as a metric to prolong the network lifetime in [3]. Authors used an optimization function which considers nature of the packet, size of the packet and distance between the nodes, number of hops and transmission time are also considered for optimization. In [4] initial population for Genetic Algorithm has been computed from the multicast group which has a set of paths from source to destination and the calculated lifetime of each path. Lifetime of the path is used as a fitness function. Fitness function will select the highest chromosomes which is having highest lifetime. Cross over and mutation operators are used to enhance the selection. In [5] authors improved AODV protocol by implementing a balanced energy consumption idea into route discovery process. RREQ message will be forwarded when the nodes have sufficient amount of energy to transmit the message otherwise message will be dropped. This condition will be checked with threshold value which is dynamically changing. It allows a node with over used battery to refuse to route the traffic in order to prolong the network life. In [6] Authors had modified the route table of AODV adding power factor field. Only active nodes can take part in rout selection and remaining nodes can be idle. The lifetime of a node is calculated and transmitted along with Hello packets. In [7] authors considered the individual battery power of the node and number of hops, as the large number of hops will help in reducing the range of the transmission power. Route discovery has been done in the same way as being done in on-demand routing algorithms. After packet has been reached to the destination, destination will wait for time δt and collects all the packets. After time δt it calls the optimization function to select the path and send RREP. Optimization function uses the individual node's battery energy; if node is having low energy level then optimization function will not use that node.

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III. APPLICATION OF INTERNET OF THINGS TECHNOLOGIES IN OIL-GAS INDUSTRY

As in all sectors of the industry, application of IoT in the oil and gas industry promises great economic hopes. The application of this technology ensures the solution of a number of scientific-theoretical and technological problems [2]:

- controlling used equipment (engine, pumps, drilling rigs, etc.);
- optimization of drilling axis replacement;
- automatic production platform control;
- early detection of leaks;
- pipeline monitoring (for the safety of mechanical- physical condition);
- tracking staff through geolocation and monitoring of certain security factors (for example, based on immobility for a certain period of time to notify if the staff member has been injured or fallen by determining the user's pulse through smart helmets or anklets);
- reducing the need for man-made inspections, detecting leaks in real time, as well as measuring various parameters at the entrance of the oil well to optimize parameters through analytics and machine learning.

The technological process of the oil and gas industry can be conditionally divided into three major sectors [4]. The first sector covers exploration drilling and production processes. Here, primarily, potential underground or underwater crude oil, natural gas deposits and potential hydrocarbon reserves are researched and explored; exploration wells are drilled in the second stage and then hydrocarbon reserves are extracted from hydrocarbon reserves in oil or gas fields. These hydrocarbons allow the extraction of crude oil or crude natural gas to the surface. In the second sector, crude oil or oil products are transported.

Pipelines, rails, trucks, tanks and many other transportation systems are used to extract crude oil and extract hydrocarbons from production and wells to the processing areas where hydrocarbon and oil refining is performed. Later, various products are processed into the third sector. This sector covers crude oil processing and crude natural gas processing and purification. At this stage, petrol or fuel oil, kerosene, aircraft fuel, diesel fuel, heating supplies, oil, lubricants, wax, asphalt, natural gas and liquefied petroleum gas, as well ashundreds of petrochemical products are offered to consumers.

The article considers the application of IoT technologies to monitor the various operations of these sectors of oil and gas industry.

IV. PROPOSED IOT BASED ARCHITECTURE

Here we present an internet of things (IoT) based reliable architecture for monitoring various operations of the upstream, midstream and downstream sectors of the oil and gas industry. Figure. 1 illustrates a schematic representation of the proposed IoT based modular architectural design, comprising three modules, module of a smart object, module of a gateway and module of a control center (server). Each module is layered (including sensing, networking and application layers) and tackles specific functions to support monitoring of the interconnected oilfield environment.

The remaining section describes the three modules of the proposed IoT architecture, their functions and interactions in detail. In addition, possible technologies are suggested that can be applied to make the oilfield monitoring and other operations more reliable and efficient.

A. *Smart Object*:

Each smart object (SO) is a physical device and a plurality of these smart objects are deployed on various oilfield assets (equipment). Smart objects enable to sense and collect data and react to specific conditions. When a group of smart objects are installed on different equipment in an oil field environment it is referred to as a Smart Oilfield.

Thus, the data gathered by this smart oilfield has to be delivered to the server so as to process and analyze the data completely. The module of a smart object is comprised of three layers; sensing layer, network layer and application layer. The sensing layer involves data acquisition and collaboration between smart object(s) and gateway(s). Each

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smart object is equipped with different types of sensors, like acoustic, temperature, flow and pressure sensors to detect a leak. Networking layer is responsible for communication between smart objects, gateways and the control center. Each smart object may also include a radio transceiver at the network layer for short range communication with other smart objects and gateways.

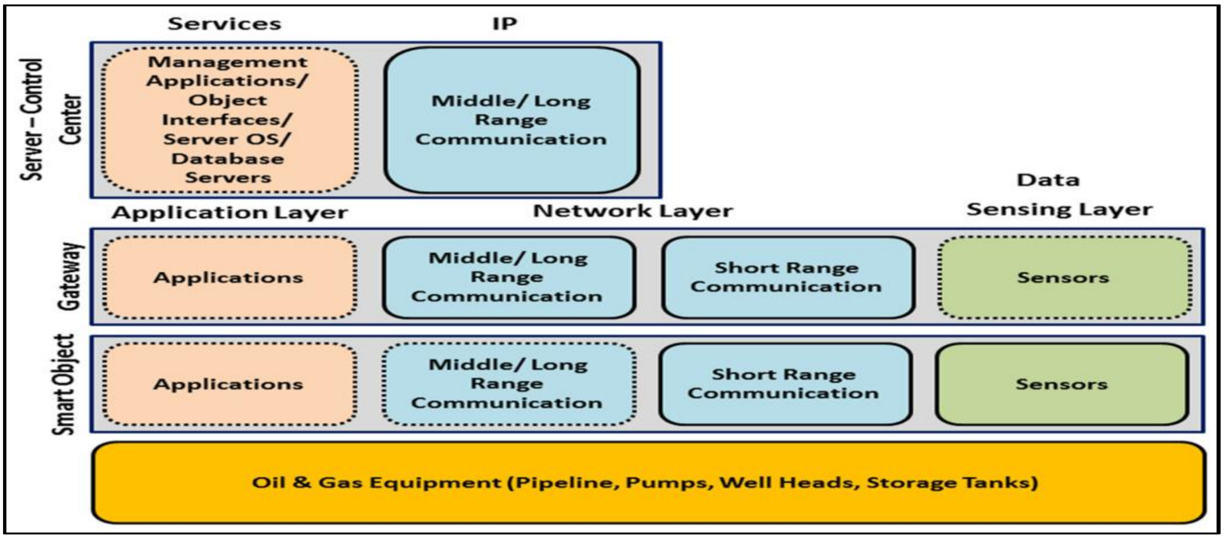

Figure 1. Proposed IoT based Architecture for Oil and Gas Industries

B. *Gateway:*

The gateway module is a bridge between smart objects and the control center. On the other hand, in the case when smart objects have no direct link available for direct communication with the control center through long range communication technologies; gateways will connect these smart objects to the control center. Also the gateway module will perform the responsibilities of the application layer in the absence of an application layer in the smart object module. A plurality of smart objects will be connected to the gateway module through short range communications. Sensing layer in the gateway module is optional but each gateway may also be equipped with different types of sensors, like acoustic, temperature, flow and pressure sensors. Each gateway may also include a radio transceiver at the network layer for short range communication with other gateways and smart objects. The communication between the smart objects and gateways can be achieved by employing RPL (Routing Protocol for Lossy networks) [6]. The applications running on the smart object and gateway modules will perform real time actions (fire alerts, shut down of different equipment, evacuation of the staff, and localization of faults) against anomalous events like oil and gas leakage, fire etc.

C. *Control Center:*

The control center (server) module is responsible for management of applications and the analysis of the data gathered from the smart object modules, generating the information and taking important decisions against anomalous events, providing the dashboard to support the decision making process. The control center is comprised of only two layers the network and the application layer. The network layer is responsible for communication between the gateways and in some scenarios directly with the smart objects through long range communication technologies. The Application layer is basically responsible for management processes and includes the object interfaces, IoT applications, databases and service APIs, Visualization tools etc. When thecollected data is analyzed using algorithms [4] and problems are sorted out, actuation is performed by controlling the functions without human intervention. The control center will perform data analysis for two main purposes, first for the predictive maintenance of the equipment by analyzing the equipment condition data delivered by the smart objects to the control center and various parameters (sensed data) and detecting failure modes either before they are going to take place or when the equipment will likely to fail or need service. Thus

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the control center will perform preventive maintenance for maximizing production uptime and minimizing disruptions, thus to better control and maintain various assets with reduced health and safety risks. Second, the control center will analyze the data for the production performance by analyzing the daily usage and production of oil and gas.

IV.DEVELOPMENT OF THE ARCHITECTURE BASED ON INTERNET OF THINGS FORMONITORING OF OIL-GAS INDUSTRY

This section presents the IoT based architecture for monitoring various operations of the upper, middle and sub-sectors of the oil and gas industry (Figure2).

The proposed architecture consists of three modules - sensors (smart object modules), network module (gateways) and application (control center)modules [4, 5].

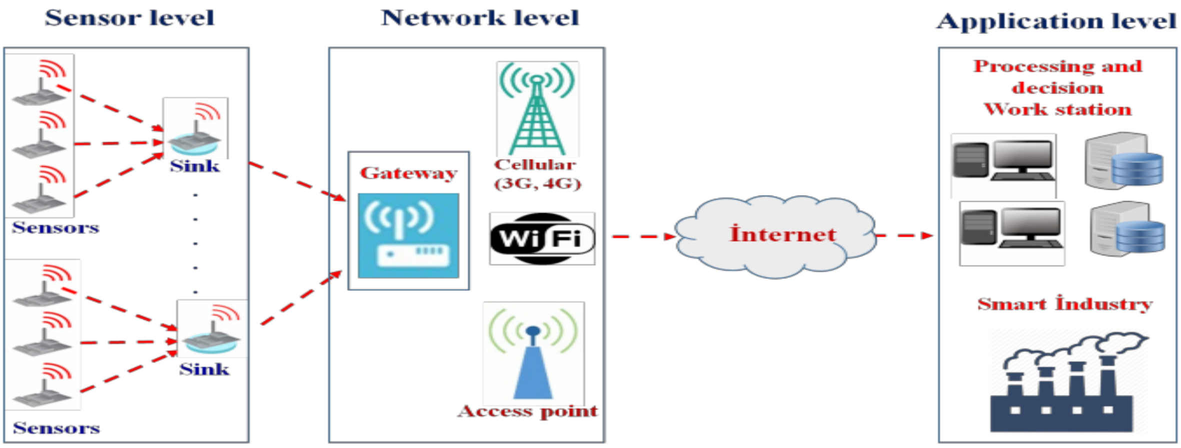

Figure 2. Architecture of Internet of Things Technology

Each module carries out monitoring of various oil field environments related to each other. Three sections of the IoT architecture offered in other sections of the article are explained in detail in their function and interaction. Additionally, possible technologies are proposed that can be applied to ensure the reliability and efficiency of monitoring and other operations in the oil field.

Sensor layer (smart object). Sensor layers consist of sensors installed on different equipment of oil wells and wireless network technologies (3G, 4G, Wi-Fi, ZigBee, etc.) that connect them. Each smart object (sensors) is a physical device, and most of themare placed in different oil equipment. Smart objects allowyou to measure and collect data. Installation of a group of Smart objects on different equipment in oilfield environment is called Smart Oilfield. Signals received from sensors installed for monitoring of oil field pumps (pressure and temperature of pumps, pump outlet, etc.) mainly assists the control process [6].

Network layer (gateways). The network layer is also known as a transmitter layer and is used as an intermediate layer in the Internet architecture of items [7]. The gateway layer basically assures that the data collected on the oil platform is conveyed to the IoT control center or vice versa provides safe transmission of received signals from control center to the sensor layer. Created network controls the installed oil wells devices in several areas, based on the WLAN (Wireless Local Area Network) protocol. In this layer, data is received from the sensor node and if necessary, is encrypted and transmitted to the control center. Because the wells in the oil industry are located far from the center, there is usually no 4G network in these areas and therefore it is important to set up a dedicated wireless network to support the system's service [6].

Application layer (control center). The application layer is implemented as the top layer of the Internet of Things. The Control Center (server) module responds to application control and analysis of data collected from smart object

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modules. At this layer, automated control of oil pump monitoring is carried out on the basis of the data control and analysis on each well. It collects data and makes important decisions for anomaly events and supports the decision-making process of the control panel. The control center consists of only two layers - network and application layers. The network layer is responsible for the communication between the smart object and control center through communication technologies. The application layer is largely responsible for managing processes and consists of object interfaces, central IoT control servers, IoT applications, databases, visualization tools etc.

The IoT control center receives data from sensors installed on pumps in real time. The collected data (oil well temperature, pressure, flow, etc.) is analyzed through a smart application and management is performed without human intervention after grouping according to types [6]. The Control Center has two primary goals: to analyze information transmitted to the control center from smart objects through different sensors on the state of equipment, detect malfunctions or predict the possibility of their occurrence. Thus, the control center will assist in the implementation of preventive measures to increase productivity and minimize malfunctions, thereby facilitating better control and maintenance of equipment with lower health and safety risks. The second is to analyze data on production performance based on the daily use and production of oil and gas in the control center [4].

V.APPLICATION OF WIRELESS SENSOR NETWORKS IN OIL- GAS INDUSTRY

WSN technology is a new alternative that significantly reduces costs, facilitates exploitation, flexibility and convenience.During the above processes, there is a need for a wide range of monitoring of various parameters with the help of a large number of sensors. These sensors are installed in different locations for measuring various information about the operation process and operating environment. This is very important for the safety of the production process, production, maintenance plan, optimization of erosion and recovery processes. Sensors, which have been used for many years, have been effectively utilized by cable cables. WSN technology offers faster, less costly, more flexible, and more convenient choices for monitoring systems. Improvements in the Internet, communication and information technology have also contributed to the development of WSN .

VI. CONCLUSION

The article recommends a monitoring system based Internet of Things technology to improve the safety of oil platforms (deposits), optimization of operations, preventing emerging problems, eliminating errors and reducing operational costs based on data collected through sensors in the oil and gas industry. It has been noted that the use of wireless Internet of Things technologies in the sensory network technology has a significant impact on costs' reduction, simplification of exploitation, flexibility and convenience. The issues of ensuring the solution of a number of scientific-theoretical and technological problems in the oil and gas industry through the application of the Internet technologies of items have been analyzed.

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