# WIRELESS SENSOR NETWORKS

## Applications in Oil & Gas

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# Introduction

As Machine to Machine (M2M), Internet of Things (IoT), and of course, Industrial Internet of Things (IIoT) makes the transition from technology magazines to corporate strategic initiatives, companies are recognizing a significant opportunity to enhance productivity, efficiency, and profitability through Wireless Sensor Networks (WSN). These Networks have emerged as a key technology for oil & gas exploration and production companies looking to gain a competitive advantage. Since initially being introduced, manufactures have enhanced product offerings to operate in the most inhospitable of environments while fortifying the technology with more robust communications architectures, hardening security, increasing reliability, and driving down power consumption. Through the entire oil & gas value chain (upstream, midstream, and downstream) as well as other industrial markets including Electric Power, Water/Waste Water, and Manufacturing, wireless sensor networks are increasingly being deployed where hardwiring was the De facto standard.

For many industrial applications, it has been well documented that wirelessly connected assets are up to 10X less expensive than wired alternatives. Driven by substantial and measurable cost savings in engineering, installation, and logistics as well as dramatic improvements in the frequency and reliability of data, wireless sensor networks offer much faster startups, and accelerated profits.

Wireless sensor networks fit within the context of Machine to Machine (M2M) Communications referring to direct communications between devices. More recently, the discussion is often via the Internet of Things (IoT). The concept of IoT was first introduced by Kevin Ashton in 1999[1] and refers to uniquely identifiable assets and their organizational "internet-like" structure. These assets can be anything but in the industrial automation world, it is specific to wireless sensors. While IoT does not define communication platforms or topologies, wireless sensor network communications architecture implementations allow for the proliferation of the technology across all markets and applications.

A wireless sensor network can be defined as a network of end nodes communicating information gathered from sensor locations through wireless links. Depending on the communications architecture, the data is either forwarded directly to a Gateway or perhaps through multiple end nodes back to a Gateway. The Gateway is then connected to other devices or networks such as a wired or wireless Ethernet backbone to relay sensor information to a control system. These networks are used to monitor a variety of conditions, covering all process control variables regardless of vertical market, including but not limed to Pressure, Flow, Temperature, and Level.

For the wireless communications piece, the sensor network end nodes are organized based on the topology implemented. By far, the two most common implementations

[1] ASHTON, K. That 'Internet of Things' Thing. In the real world, things matter more than ideas. RFID Journal, 22 June 2009. Available from: http://www.rfi djournal.com/articles/view?4986

are a Star topology and a Mesh topology (depicted in Figure 1). The Star topology is a single hop from the end node communicating directly to the gateway and the simplest wireless sensor network topology. Theoretically, these systems are considered the most reliable as there is but one single point of failure – the gateway. In a Mesh topology, the Gateways and end nodes work together to form a Mesh network where data from the sensor is relayed through the network to reach the gateway. A Mesh topology can be self-organizing and as a result, does not require manual configuration. For a wireless sensor network with closely located assets, this topology is inherently reliable and scalable.

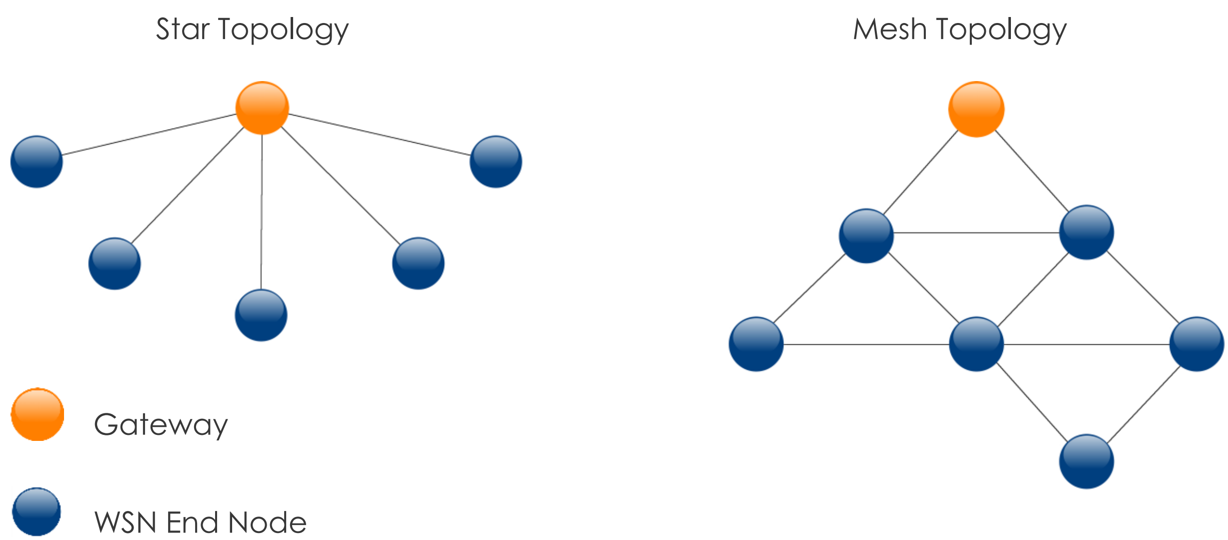


**Figure 1. Wireless Sensor Network Topologies**

The power of the sensor network nodes is typically provided by batteries. Given that these sensors are most often installed in hazardous areas where explosive vapors, gases, and fluids are always present (National Electrical Code, Class 1, Div. 1)[2] and may incorporate intrinsically safe designs, the range of the end nodes is relatively short as compared to other Supervisory Control and Data Acquisition (SCADA) wireless modems. For Mesh Topologies, a few hundred yards can be achieved where assets in a Start topology can achieve robust links of over a mile. Obviously, as with any Radio Frequency (RF) device, clear line of sight is preferred with no Fresnel Zone impact.

# Applications

The oil & gas Industry is perhaps one of the most prevalent industries for the application of wireless sensor networks. However, these applications are usually located in remote

[2] "NFPA 70, National Electric Code". National Fire Protection Association.

areas with rough terrain and elevation challenges, not to mention extreme ambient environmental demands. Regardless, wireless sensor networks are deployed to monitor, manage and control everything from tanks and compressors to generators, separators and wellheads. As costs are continuing to rise while the price of oil experiences 8-year lows, wireless sensor networks offer advantages over the traditional wired technology where wired options are either too expensive or not even an option.

Wireless technology continues to make advances in terms of applications, thus, eliminating the need for cables, allowing for cost efficient network deployments. Wireless sensor networks may consist of many different types of sensors, covering a wide variety of applications consisting of Pressure, Temperature, Flow, Level or simply relaying a contact closure through a Discrete Transmitter. Figure 2 provides some of the options users have when deciding on the right transmitter for a given application.


**Figure 2. Wireless Sensor End Nodes**

Wireless sensor network applications most commonly cover monitoring of near real-time process control, safety, regulatory, and production performance. Within the upstream oil & gas market, as depicted in Figure 3 (page 5), the core applications center around:

- Tank Levels – The wireless transmitter head is paired with a level sensor based on the application requirements, process fluid, and whether or not a water interface level is required. Based on these application requirements, the sensor technology can range from resistive and magnetostrictive type sensors to a variety of other technologies including radar and ultrasonic. If cost is an issue, hydrostatic pressure sensors can be used or if only a level alarm is needed, just a simple level switch can be used tied to a transmitter.

- Pressures – Most commonly, wellhead casing and tubing pressures are monitored by pairing a wireless transmitter with a pressure transducer. The main components of all wells drilled for oil or gas are casing and tubing. While the casing and tubing used in the oil and gas industry are made of special alloys based on their strength and performance under pressure, every metal reaches a point that the pressure exerted exceeds its ability to contain it. Therefore, monitoring these pressures and taking proactive action can prevent blowouts, potential safety and environmental consequences as well as lost resources.

- Flow – Flow measurement in the oil and gas industry covers everything from well injection to custody transfer. In all cases, the wireless transmitter is paired with the flow measurement instrumentation. This instrumentation includes but is not limited to different types of flowmeters that utilize differential pressures, positive displacement, ultrasonic, and Coriolis.

- Temperature – In the oil and gas industry, temperature is typically measured with a Resistance Temperature Detector (RTD) or a Thermocouple. The RTD or Thermocouple is paired with a wireless transmitter and monitors process temperatures including fluid and gases, chemicals, engines, compressors and flare stacks.

- Valve Actuation – Valves play a key role in oil & gas production and are vital in providing safety to personnel and mitigating risk from any environmental impact. Emergency Shutdown (ESD) valves can be wirelessly automated to shut-in a well in the event of abnormal process conditions preventing a spill or catastrophic environmental incident.

- Environmental Regulations – In order to conform to more and more regulatory initiatives regarding greenhouse gas emissions, a wide range of wireless sensors are being utilized. In fact, in June of 2015, the Environmental Protection Agency (EPA) proposed a suite of requirements under President Obama's Climate Action Plan[3] to reduce methane and VOC emissions from oil and gas production, processing, and transportation activities. Wireless sensor networks are being leveraged to provide condition based monitoring and as a result, advanced analytics can be used from sensor data for predictive maintenance. From leak detection systems to thief hatch monitoring solutions, the oil and gas industry will be harnessing the power of wireless sensors networks to stay compliant with the new regulations.

[3] Environmental Protection Agency, "President Obama's Climate Action Plan", June 2015. Available from: https://www.whitehouse.gov/sites/default/files/docs/cap_progress_report_final_w_cover.pdf

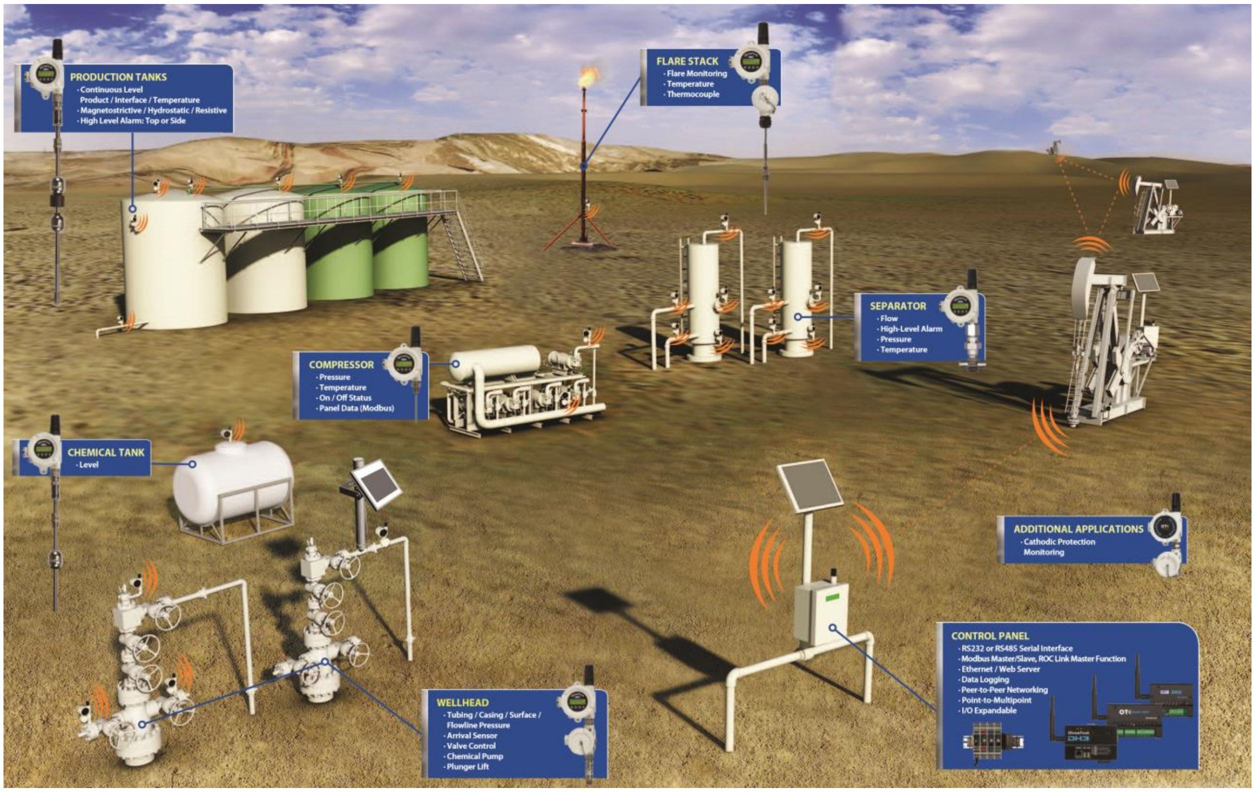


**Figure 3. Wireless Sensor Network Applications**

# Energy Harvesting

Obviously, for any wireless sensor end node to operate, power is required. For many industrial applications, the existing non-rechargeable battery powered solutions are more than capable of serving the market's needs in terms of performance with an acceptable battery life. At the end of the day, the battery does become the limiting factor as in order to optimize battery life, a tradeoff is required to lower the duty cycle and therefore minimize power consumption. However, for specific IoT applications, wireless sensors need to operate and communicate continuously which certainly creates a challenge for the existing solutions as non-rechargeable batteries are not a feasible option for the power requirements, high duty cycles, and faster data rates.

While the utilization and functionality of wireless sensors networks has increased dramatically over the years, battery technology has not improved at the same rate. Thanks to energy harvesting and rechargeable batteries, this constraint has largely been eliminated, allowing for continuous, autonomous operation.

Energy Harvesting is the process of using ambient environmental sources of energy like sun, wind and vibration and converting them into usable electrical energy to power sensor nodes. It is an attractive option as it supplements existing battery power and can lead to perpetual operations of end nodes. As mentioned above, the objective is to achieve a proper balance between power management and performance of the applications. For example, it is not necessary for nodes to be operated at the lowest possible duty cycle in order to maximize battery life. The duty cycle can be increased based on the amount of energy harvested so that the application performance can be increased.

With the global market for Industrial wireless sensor networks expected to grow at a Compound Annual Growth Rate (CAGR) of 12.96% from 2014 to 2020[4], much needed innovation is required. Energy harvesting is seen as one the of the key areas that advancements need to be made simply because replacing batteries is not feasible. In fact, according to ON World[5], Energy harvesting is a growing consideration because changing batteries for thousands of remotely deployed wireless sensor nodes could become an expensive logistical headache. Based on ON World's 2012 research, Energy Harvesting was identified as the most needed innovation for wireless sensor networks as shown in Figure 4.

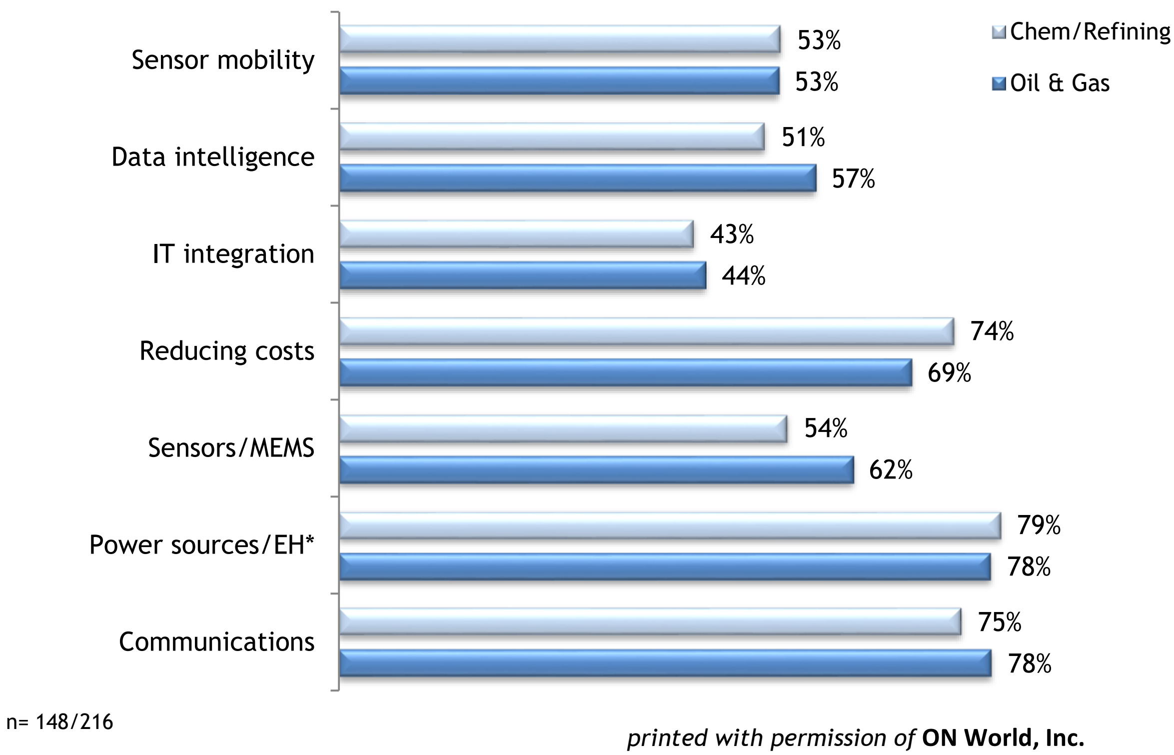


**Figure 4. Most Needed Wireless Sensor Network Innovations**

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[4] Markets and Market, "Industrial Wireless Sensor Networks Market worth $944.92 Million by 2020" press release. Available from http://www.marketsandmarkets.com/PressReleases/wireless-sensor-network.asp

[5] Mareca Hatler, Darryl Gurganious, and Charlie Chi Ph.D. "Oil & Gas WSN, Global Market 2012" June 2012

Since batteries have finite energy and battery replacement is not feasible in most applications, energy harvesting from ambient sources is a practical solution to alleviate this problem. Using various energy harvesting methods, wireless sensor end nodes can simultaneously address the power management and performance criteria mentioned above. Some of the most viable Energy harvesting methods include:

- Photovoltaic: Harvesting Energy from Light
- Electrodynamic: Harvesting Energy from Vibration
- Piezoelectric: Harvesting Energy from Pressure (mechanical stress)
- Thermovoltaic: Harvesting Energy from Heat

Of the methods mentioned above, Photovoltaic energy harvesting offers the most significant advantages as we have a virtually inexhaustible source of power with little to no adverse environmental impact. In addition, of the solutions that are commercially available, solar energy harvesting devices based on Photovoltaic modules provide the highest power density, making it the best choice to power wireless sensor end nodes.

Solar is a convenient energy harvesting source and is a proven technology.  However, it is difficult to power wireless sensor nodes directly from solar panels, since supply voltage depends on the time varying load impedance. Therefore, when photovoltaic methods are used, a secondary energy storage element such as a rechargeable battery is used to provide a stable voltage to the end node.

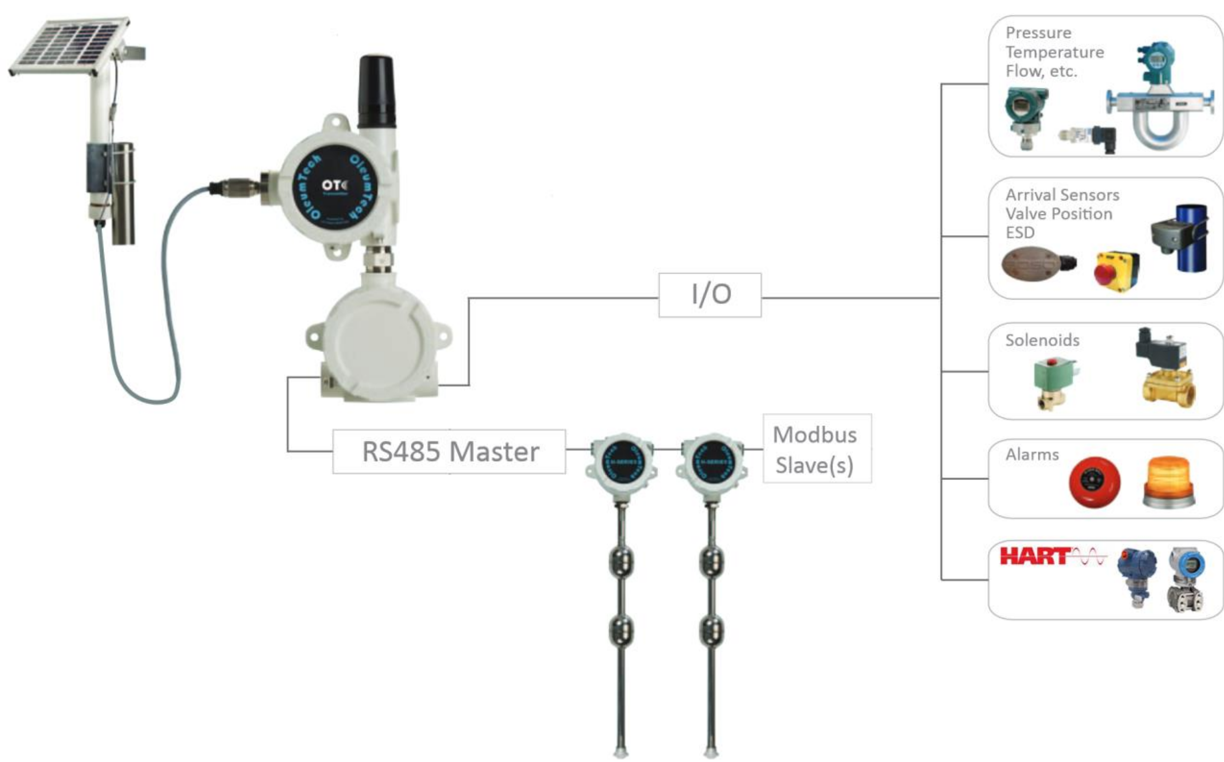


**Figure 5. Wireless Multi-I/O Solution with Photovoltaic Energy Harvesting**

# Summary

Global economic drivers and external forces are driving the need to continually improve performance and operational efficiency. Driven by the growing demand for advanced technology solutions to enhance productivity, efficiency, and profitability, all industrial sectors are harnessing the power of wireless sensor networks. Innovation is being driven by data in order to make decisions, improve processes, and understand our customers. Connected assets through wireless sensor networks leads to lower costs, optimized processes, and the ability to make better decisions.

A variety of energy sources can be utilized to power wireless sensor end nodes. Solar, mechanical, and thermal energy are the primary sources. Given these options, harnessing solar power is the most used and mature energy harvesting technique. Power consumption is driven by the frequency of transmissions. For certain condition monitoring applications such as monitoring Tank level, latency in duty cycle is less important. However, reliability remains vital.

Depending on the application and the availability of potential ambient energy sources, energy harvesting makes sense in order to maximize useful life of the sensor. It will certainly be interesting to see the outcome of the developments being made in this space as energy harvesting will be a central part wireless sensor network design for years to come.