SPE 112207

A Survey of Wireless Technology for the Oil and Gas Industry

Stig Petersen and Bård Myhre, SINTEF; Paula Doyle and Erik Mikkelsen, ABB; Simon Carlsen, Dag Sjong, and Amund Skavhaug, StatoilHydro; and Jan Hendrik van der Linden and Mark Sansom, SKF

This paper was prepared for presentation at the 2008 SPE Intelligent Energy Conference and Exhibition held in Amsterdam, The Netherlands, 25–27 February 2008.

Abstract

The IEEE 802.11/a/b/g specifications for wireless local area networks (WLAN), the IEEE 802.15.4 specification for low-rate wireless personal area networks, and radio-frequency identification (RFID) specifications have enabled a wide range of wireless applications such as wireless networking, wireless sensing, monitoring and control, and asset and personnel tracking. For the Oil & Gas industry, using this technology will lead to reduced operating costs as well as enable new applications.

This paper identifies the technical requirements for wireless technology within the boundaries of the Oil & Gas industry. Experiments have been performed on wireless solutions within three application areas in order to examine whether or not currently available technologies fulfill these requirements. The conclusion is that WLAN technology is ready for deployment in Oil & Gas installations, while there still is a need for an open industrial standard for wireless sensor networks. Regarding RFID, our experiments show that solutions with passive tags are not suitable for asset and personnel tracking applications.

Introduction

Recent advances in wireless technology have enabled the development of low-cost wireless solutions capable of robust and reliable communication. International standardization work within the fields of wireless local area networks (WLANs) [1] [2] [3] [4], wireless sensor networks (WSNs) [5] and radio-frequency identification (RFID) has become a foundation for the development of products within application areas such as wireless network access, wireless sensing, monitoring and control, and wireless asset and personnel tracking.

For the Oil & Gas industry, wireless technology has the potential to reduce operating costs as well as provide a wide new range of applications. However, a key limiting factor for the introduction of new wireless technology is the need for education and technical knowledge in both vendor and operator organizations.

The main contribution of this paper is the investigation of whether or not currently available wireless solutions fulfill the technical requirements for wireless technology within the confines of the Oil & Gas industry.

Wireless Technology in the Oil & Gas Industry

Motivation and Drivers.

StatoilHydro is a Norwegian based integrated Oil & Gas company with international activities in 40 countries. Its business covers exploration, drilling and operation of 39 oil and gas fields on the Norwegian continental shelf as well as substantial international operations. StatoilHydro is also operating hundreds of underwater installations in addition to logistics support activities (ships and helicopters). The potential use of wireless technology is especially related to the improvement of existing facilities. In addition the improved communication possibilities can enable the use of other state-of-the-art technologies in future investments/facilities.

In order for wireless technology to be adopted in the Oil & Gas industry, it needs to prove its contribution to the overall goal of the industry: improved health, security and environment (HSE) performance, increased production, reduced capital expenditure (CAPEX) and reduced operating costs (OPEX).

There are some concerns related to the use of wireless technology, e.g. security, reliability, user friendliness, power consumption, maintenance and support activities, integration with existing systems, standardization, scalability and development of internal wireless competence.

Typical application areas for wireless technology identified so far are: (1) wireless network access, (2) wireless sensing, monitoring and control, (3) asset and personnel tracking.

Technical Requirements.

A number of technical requirements for the deployment of wireless technology have been identified by the Oil & Gas industry.

Frequency Spectrum.

The license-free portion of the wireless spectrum varies by country and/or region. The use of the global unlicensed bands for radio communication allows for device consistency in installations, regardless of geographical location. Furthermore, the use of a single frequency and protocol validates testing and best practice guidelines, applicable in one region, for multiple regions. The 2.4 GHz unlicensed band is the most popular global unlicensed band for both WLAN and WSN networks. The downside to using the this is that it can become crowded, and network performance can be affected by coexisting systems.

Whereas WSN and WLAN solutions usually are confined to a single frequency band, RFID solutions can be found in almost all of the available license-free frequency bands. RFID characteristics such as antenna properties (inductive or electromagnetic), detection range and tags types (passive or active) are dictated by the solution’s frequency.

Open Standardized System.

The use of standardized, open communication protocols, over proprietary protocols, provides the industry with the freedom to choose between suppliers with guaranteed interoperability. It also allows a single wireless infrastructure to deliver a communications medium to many devices, and potentially many applications. In addition, standardized solutions usually have longer product availability than their proprietary counterparts. Main disadvantages with standardized solutions are that the standardization process itself delays the introduction of the products to the marked, and that the security mechanisms employed are published and available to all– this makes standardized protocols more vulnerable to attack than closed, proprietary systems.

Long battery Lifetime.

The Oil & Gas industry is pushing for battery lifetimes in excess of five years (at a one-minute update rate) for wireless sensors. A key driver for this requirement is the maintenance effort required to replace either the batteries, or the device itself if it is encapsulated or otherwise non-rechargeable. Otherwise, with the expectation that thousands of wireless sensors could be deployed in a single facility and will have to be replaced or re-engineered periodically, a tremendous effort would be necessary simply to maintain the network.

This requirement is not applicable for WLAN and RFID. The WLAN access points are mains powered, as are stationary RFID readers. The RFID tags investigated in this paper are passive (do not use batteries), and get their power from the electromagnetic field of the RFID readers.

Friendly Coexistence.

WLAN and WSN are both vital technologies within the Oil & Gas sector. The promotion of Integrated Operations models and the requirements to connect offshore facilities with onshore experts, is leading to requirements for mobility in the field. WLAN is the natural choice for this use. This combined with the desire for having wireless sensor monitoring and control in the very same facilities, means it is imperative that WLAN and WSN are able to peacefully coexist. I.e. there should be no critical degradation of WLAN or WSN performance when operating within the same area.

Passive RFID technologies operate in lower frequency bands than WLAN and WSN, and will not have any coexistence issues with these.

Security.

As wireless data is transmitted over the air, it is more susceptible to eavesdropping and security breaches than wired transmissions. The two most common threats are towards privacy and access. Encryption techniques are employed to protect the privacy of the data being communicated, while access threats are counteracted by using tools for transmitter authentication and data consistency validation.

Quantifiable Network Performance.

The performance of wireless technologies is more susceptible to environmental changes than their wired counterparts. Thus it is important to be able to quantify, within reasonable accuracy, the expected and operational reliability and availability of wireless communication links and networks. Moving equipment or personnel, antenna adjustments, even temperature and humidity, can influence the quality of a wireless link. However, there are a number of techniques that can be employed to increase the reliability and availability of a wireless network. The use of redundant paths, self-healing formations, and link quality-aware nodes can perform close to what is expected from a wired system.

Other requirements include:

- Predictable behavior when the system is scaled up or down.
- Easy commissioning and engineering.
- Fail safe operation in the presence of intentional (e.g. jamming) and unintentional (e.g. interference or propagation problems) loss of wireless links.

Required Changes in Work Processes.

Meeting the technical requirements is just one step towards the successful long-term implementation of wireless systems. A typical problem in the exploration for new technology areas is to overlook the human factors in technology adoption. In many cases, technologies *are* fit for deployment and will certainly add benefit in terms of cost savings or increased production, but without a study into how they can be incorporated into today's existing work processes – they are, in effect, un-implementable.

Today's work processes in relation to maintenance, inspection and operation typically involve a relatively large amount of manual labor – physical inspections of equipment, manual acquisitions of measurements, the entering of data into the backbone system, and analysis of the acquired data. Wireless technology, as described in this paper, can eliminate much of this manual load. For example, offline vibration monitoring systems typically require a monthly manual operation for data-acquisition. As an illustrative example, a system consisting of 1400 measurement points requires approximately 40 hours per month for measurement, collection and entry into the backbone system (analysis is additional). The elimination of this single manual work process, through the use of an autonomous wireless measurement and collection system, can save almost 500 man-hours / year.

However, not all wireless systems will simply eliminate existing work processes; some will require additional work processes in order for them to be successfully adopted into the plant life. This is particularly true with respect to installation, remote configuration, battery replacements and maintenance of wireless transducers and communication systems. A key requirement in this area is to 'hide' the complex RF issues related to security, infrastructure reliability as well as coexistence issues from the field worker. Systems which are self-configuring, dynamically adapt to frequency disturbances, and incorporate an easily-implementable (yet fully-functional) security suite are highly rated as they will reduce the complexity of the work.

Unique and novel work processes will be required to implement new applications that are directly enabled with wireless communication e.g. real-time mobile video and voice transmissions to support the mobile worker, personnel tracking to assist with HSE and asset tracking to help in device location.

Overview of Experiments

Experiments have been performed on current state-of-the-art solutions within three application areas: Wireless networking, wireless sensing, monitoring and control, and asset and personnel tracking. The solutions were deployed in the laboratory facilities at StatoilHydro's Research Centre in Trondheim, Norway. This laboratory provides a semi-industrial test environment, as it contains real-size replicas of equipment used in StatoilHydro's installations.

Wireless Networking

Often referred to as Wi-Fi, the IEEE 802.11 [1] is the family of standards for Wireless Local Area Networks (WLAN). The 802.11 family of standards began ratification in 1997, and are still continuing to improve in terms of power, bandwidth and security. Table 1 presents an overview of the most common WLAN standards.

Standard	Issue Date	Frequency Band	Practical Bandwidth (~50%)	Theoretical Maximum
802.11	1997	2.4 GHz	1 Mbps	2 Mbps
802.11a	1999	5 GHz	26 Mbps	54 Mbps
802.11b	1999	2.4 GHz	5.5Mbps	11 Mbps
802.11g	2003	2.4 GHz	26 Mbps	54 Mbps
802.11n	(2008)	2.4 GHz and 5 GHz	240 Mbps	300 Mbps

Table 1: Overview of IEEE 802.11 specifications

Technology.

The IEEE 802.11a specification [2] was ratified in 1999. This version of IEEE 802.11 uses the same core protocol as the others but operates in the license free 5 GHz band. Operating in this band offers the advantage of avoiding the already crowded license free 2.4 GHz band. On the other hand, the higher frequency makes it more sensitive to signal strength attenuation caused by walls and other architectural components. IEEE 802.11a uses a 52-subcarrier Orthogonal Frequency-Division Multiplexing (OFDM) modulation scheme with a maximum raw data rate of 54 Mbit/s, which yields a practical achievable data throughput in the mid-20 Mbit/s range.

The IEEE 802.11b specification [3] operates in the licence free 2.4GHz band, using frequencies from 2.400-2.4835 GHz. This frequency band is also used by other devices such as Bluetooth, Zigbee, microwave ovens, cordless phones etc. As the IEEE 802.11b was a close amendment to the IEEE 802.11 legacy protocol, products were quick to appear on the market. Like the legacy protocol, IEEE 802.11b uses Carrier Sense Multiple Access with Collision Avoidance (CSMA/CA) with Direct-Sequence Spread Spectrum (DSSS) modulation. Although IEEE 802.11b has a theoretical bandwidth of 11Mbps, practical data throughput is in the range of 6 Mbps.

The increase in throughput of IEEE 802.11b (compared to the legacy standard) coupled with ability to re-use much of existing chipsets led to IEEE 802.11b's acceptance as the definitive WLAN technology. However, operating in the already crowded 2.4 GHz band can have a negative impact on network performance.

The IEEE 802.11g [4] specification which was ratified in 2003, and it offers the higher data rate of 54 Mbit/s. IEEE 802.11g uses a either OFDM or DSSS modulation schemes depending on the data rate. IEEE 802.11g is backwards compatible with 802.11b, but the existence of an 802.11b device within a network will reduce the speed of the 802.11g network. The maximum range of 802.11g devices is slightly greater than that of 802.11b devices, but the range in which a client can achieve the full data rate is much shorter than that of 802.11b.

The IEEE 802.11n specification is a work in progress, expected to be ratified in Q2 2008. Currently, an interim 2.0 Draft specification is used as the baseline for initial rounds of equipment certification and compatibility testing that started in summer 2007.

New in the IEEE 802.11n specification is, among other things, multiple-input multiple-output (MIMO) functionality where multiple transmitter and receiver antennaes are used to improve performance, in addition to channel bonding and packet aggregation. This allows for extended range and a maximum raw data rate of up to 300 Mbit/s.

The IEEE 802.11n is able to operate in both the 2.4 and 5 GHz bands simoultaneously, and it is backwards compatible with all three IEEE 802.11a/b/g specifications. The channel bonding funcionality of the IEEE 802.11n is used to combine two non-overlapping channels into a single channel. As the 2.4 GHz band only has three available non-overlapping channels (channel 1, 6 and 11), this means that IEEE 802.11n equipment may occupy 2/3 of the available spectrum.

Although 802.11a offers an increased bandwidth capacity over 802.11b, it is not as widely accepted. Today, it is difficult to acquire 802.11a Access Points or Network cards as 802.11b and 802.11g have developed as the de-facto standard for both the consumer and industrial markets.

Laboratory Experiments.

To evaluate their practical usability in the Oil & Gas industry, signal strength and throughput of IEEE 802.11a and IEEE 802.11b wireless networks have been studied in a series of experiments conducted in a semi-industrial environment. Even though the IEEE 802.11g specification offers higher data rate than the IEEE 802.11b, the backwards compatibility of the IEEE 802.11g dictates that the presence of an IEEE 802.11b client in the network will reduce the network data rates to that of IEEE 802.11b. As "older" clients only using IEEE 802.11b have to be supported, the experiments were performed on IEEE 802.11b, even though it is clearly inferior in terms of data rate compared to IEEE 8022.11a.

Signal Strength Measurements.

In a first series of experiments residual signal strength was measured at several different positions, some in direct line of sight with the access point, others with heavy metal objects obstructing the direct line of sight. Table 2 shows that when not in direct line of sight, 802.11b equipment consistently reports a higher received signal strength than the 802.11a equipment. Also, the stronger attenuation of the higher frequent 802.11a signals can be seen; where at 13 meters distance the 802.11a equipment still reports higher signal strength than its 11b counterpart, the situation is reversed at 20 meters distance.

Distance from AP [m]	Signal Strength [dBm]			
	IEEE 802.11a		IEEE 802.11b	
	Line of Sight	No Line of Sight	Line of Sight	No Line of Sight
1	-50	-	-39	-
10	-69	-66	-59	-63
13	-56	-66	-60	-56
20	-66	-71	-62	-57

Table 2: IEEE 802.11a and IEEE 802.11b signal strength measurements

Throughput Measurements.

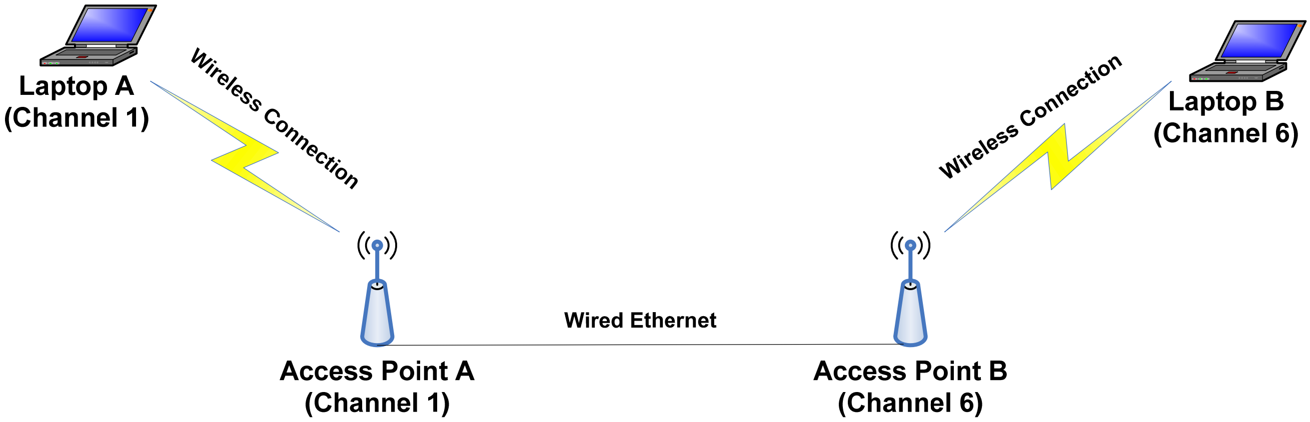

Figure 1: Configuration of IEEE 802.11a and IEEE 802.11b throughput measurements

Figure 1 shows the network configuration used for the throughput measurements. Two access points were used; one remained at a fixed location as the other was positioned at increasing distances from the first. The access points were configured to use the non-overlapping channels 1 and 6. Data was transferred wirelessly from client A to Access Point A, then by wire (Ethernet) to Access Point B, and finally wirelessly to client B.

Figure 2 shows that if the two access points are situated too close together the effective throughput is negatively affected and may deteriorate by as much as 50%. This proves that although channel 1 and 6 of 802.11b are said to be non-overlapping, they do in fact interfere with each other. As the access points are placed further apart the cross-channel interference decreases, which results in a higher throughput. Maximum throughput is achieved when the 802.11b access points are placed 15 meters or more apart. For 802.11a equipment, a mere separation of more than 5 meters suffices to achieve maximum throughput.

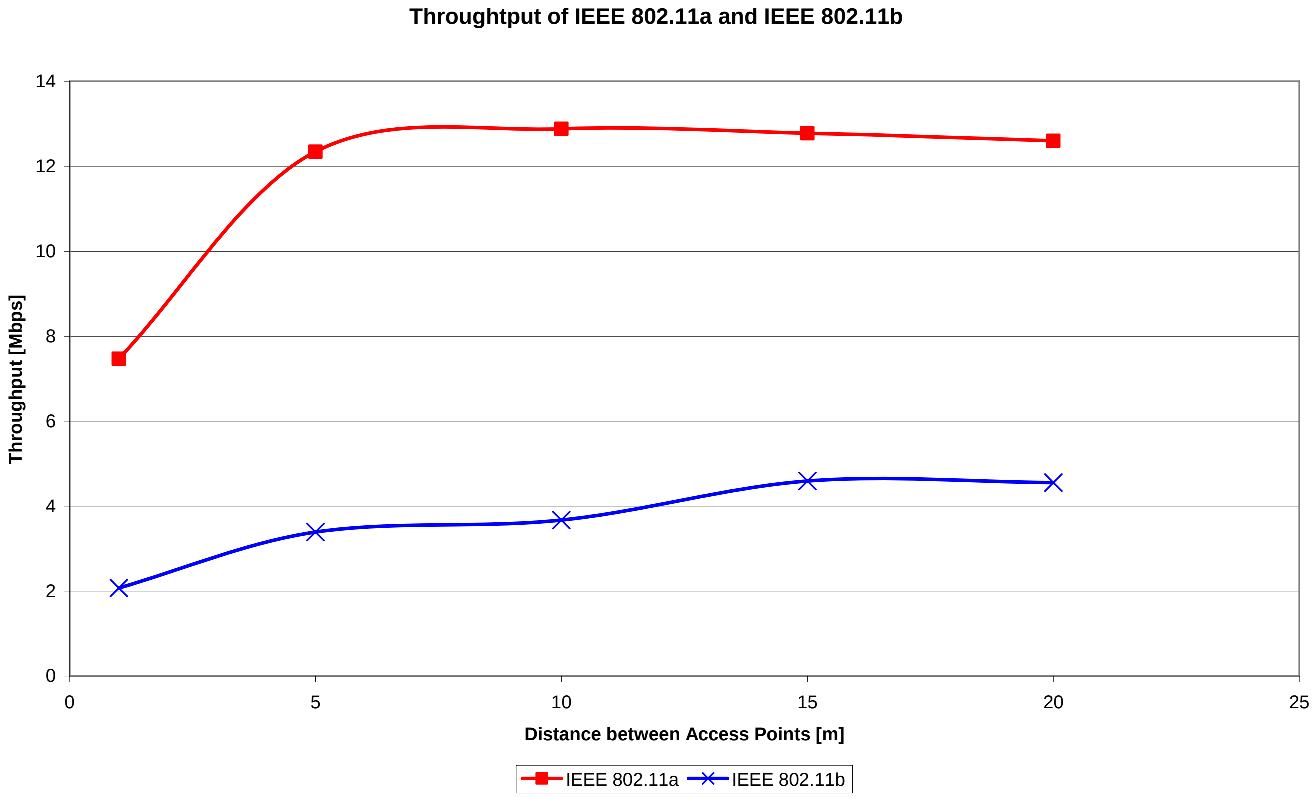

Figure 2: IEEE 802.11a and IEEE 802.11b data throughput measurements

WLAN-discussion.

The experiments show that IEEE 802.11a and 802.11b wireless communications can be used reliably in industrial environments provided that correct decisions are made about placement of access points and the channels used. Absorbing and reflecting surfaces encountered in an industrial environment do affect the data rate of a wireless connection, but careful positioning of access points and configuration of wireless channels can still ensure good data throughput.

Positioning access points with at least 15-20m distance between them, followed by a survey of signal strength will ensure that the network will function in an efficient manner. Adjacent access points should have their channels set to be non-overlapping. e. g. channels 1, 6 and 11 for IEEE 802.11b.

Where possible, line of sight should be maintained between access points and wireless clients. This will minimise the effect of the environment on the signal quality. Multi-path reflections usually decrease the performance of a wireless connection, but in cases where there is no line-of-sight between the client and the access point, reflections actually help provide coverage.

For IEEE 802.11a equipment, a higher density of access points will be required due to its shorter signal propagation distance. However, the shorter range can also be an advantage in cases where the network coverage needs to stay confined within a certain area.

As IEEE 802.11b and IEEE 802.11g have turned into the de-facto standard for both the consumer and industrial markets these devices are more readily available and much cheaper than their IEEE 802.11a counterparts, which mean that in order to provide coverage in a given area an IEEE 802.11a deployment could be significantly more expensive than an equivalent IEEE 802.11b deployment. In turn, IEEE 802.11a equipment provides benefits in terms of less interference and a higher relative throughput at close range.

Wireless Sensing, Monitoring and Control

It is expected that WSN technology will provide low-cost, low-power sensors and actuators which in turn will enable wireless sensing, monitoring and control applications such as: (1) condition and performance monitoring, (2) surveillance and monitoring, (3) environmental monitoring, (4) process control, and (5) emergency management. In addition, it will be cost efficient to monitor more parameters than is financially viable today. The new measurement points can either be of a temporary nature, or they can be located in previously unreachable remote or hostile areas. More measurement points will make it possible to optimize production in a safer and more reliable way.

Technology.

The IEEE 802.15.4-specification [5] for a low-rate wireless personal area network, with features such as ultra-low complexity, cost and power, is a suitable communication standard for WSNs [6]. A growing number of solutions, both standardized and proprietary, using the IEEE 802.15.4 physical (PHY) and medium access control (MAC) layers are emerging:

ZigBee.

The ZigBee specification, released in 2004, defines a network and application layer based on the IEEE 802.15.4 PHY and MAC [7]. A second version of the ZigBee specification was released in December 2006 [8], - dealing primarily with scalability and performance issues found in the 2004-edition. In October 2007, the ZigBee Alliance released the ZigBee PRO specification [9] which is a version of ZigBee aimed at the industrial market. It offers, among other things, enhanced security features, a stochastic addressing scheme which allows for larger networks, and frequency agility which enables networks to change channels when faced with noise and/or interference.

WirelessHART.

*Wireless*HART, released in September 2007 as a part of the HART 7 specification [10] from the HART Communication Foundation, is the first open wireless communication standard specifically designed for industrial process and control applications. *Wireless*HART allows for the transmission of HART messages over a wireless medium. The *Wireless*HART specification uses the IEEE 802.15.4 PHY with a modified MAC-layer, and it implements frequency hopping in a multi-hop mesh network topology. Time Division Multiple Access (TDMA) is used for communication between network devices, specifying both which timeslot and frequency to use for each link.

ISA100.

The ISA100 standards committee aims to deliver wireless systems for industrial automation by developing a universal family of wireless standards. The first standard to emerge from the ISA100 family is the ISA100.11a Release 1 [11], which will provide secure and reliable wireless connectivity for fixed, portable and moving devices for non-critical monitoring and control applications. Much like *Wireless*HART, the ISA100.11a will use the IEEE 802.15.4 PHY with a modified MAC-layer to provide a frequency hopping, multi-hop mesh network capable of inter-network routing.

In October 2007, the ISA100 committee announced that it will try to accommodate *Wireless*HART in the ISA100.11a Release 1 through a dual-gateway architecture. A more integrated approach is planned for Release 2 of the ISA100.11a.

The ratification of ISA100.11a is expected to happen in Q2 2008.

WSN-discussion.

As mentioned in the "*Technical Requirements*" section, the Oil & Gas industry needs wireless solutions which are based on open international standards. ZigBee PRO, WirelessHART and ISA100.11a are all potential candidates for becoming the wireless sensor network solution for the Oil & Gas industry, but due to their very recent release and ratification, there are no available platforms for testing. However, tests performed on two state-of-the-art proprietary solutions [12], indicate that WSN technologies are able to offer adequate network performance in an industrial environment, even when coexisting with IEEE 802.11b networks. The main challenge is to achieve a battery lifetime in excess of 5 years.

Coexistence of Wireless Sensor Networks and Wireless Local Area Networks

The IEEE 802.11b/g specifications for wireless local area networks (WLAN) and the IEEE 802.15.4 specification for wireless sensor networks (WSN) both define operation in the 2.4 GHz band. For the Oil & Gas industry, it is important that these two technologies are able to coexist, as future plants and installations will probably have full WLAN and WSN coverage.

IEEE 802.11b/g divides the 2.4 GHz channel into 14[1] overlapping channels, each with a bandwidth of 20 MHz. Only a few of these channels can be used simultaneously in one area if cross-channel interference between networks is to be avoided. For the U.S. and Canada, this can be achieved using channel 1, 6 and 11 – the only possible configuration that allows three non-overlapping channels in one area. In Europe, channels 12 and 13 are also available, so a configuration with four non-overlapping channels can be achieved using channels 1, 5, 9, 13. Globally, when planning the deployment of a large WLAN network consisting of many access points, it is an advantage to utilize the three non-overlapping channels 1, 6 and 11, letting adjacent access point use different channels.

As mentioned in the "*Technology*"-part of the "*Wireless Sensing, Monitoring and Control*"-section, the three major industrial WSN standards (ZigBee PRO, *Wireless*HART and ISA100.11a) all utilize the Physical Layer of the IEEE 802.15.4 specification. IEEE 802.15.4 divides the 2.4 GHz band into 16 non-overlapping channels (numbered 11-26), each having a bandwidth of 3 MHz.

Figure 3 shows a comparison of the channel distribution of IEEE 802.15.4 and the non-overlapping channels 1, 6 and 11 of IEEE 802.11b/g. As can be seen, IEEE 802.15.4 channels number 15, 20, 25 and 26 are positioned such that they will not suffer major interference from IEEE 802.11b/g channels 1, 6 and 11, thus enabling the possibility of friendly coexistence between WLAN and WSN.

*Wireless*HART and ISA100.11a utilizes adaptive frequency hopping, which means that they alternate communication between all 16 available channels, in addition to blacklisting channels with high interference and/or noise. This means that a WirelessHART or ISA100.11a sensor network which is deployed on a site with a IEEE 802.11b/g network that uses channels 1, 6 and 11, will over time end up using only channels 15, 20, 25 and 26.

ZigBee PRO does not support frequency hopping, but uses what the standard specifies as frequency agility, meaning that a network will change its operating channel if faced with interference and/or noise. Therefore a ZigBee PRO network will also be able to friendly coexist with an IEEE 802.11b/g installation.

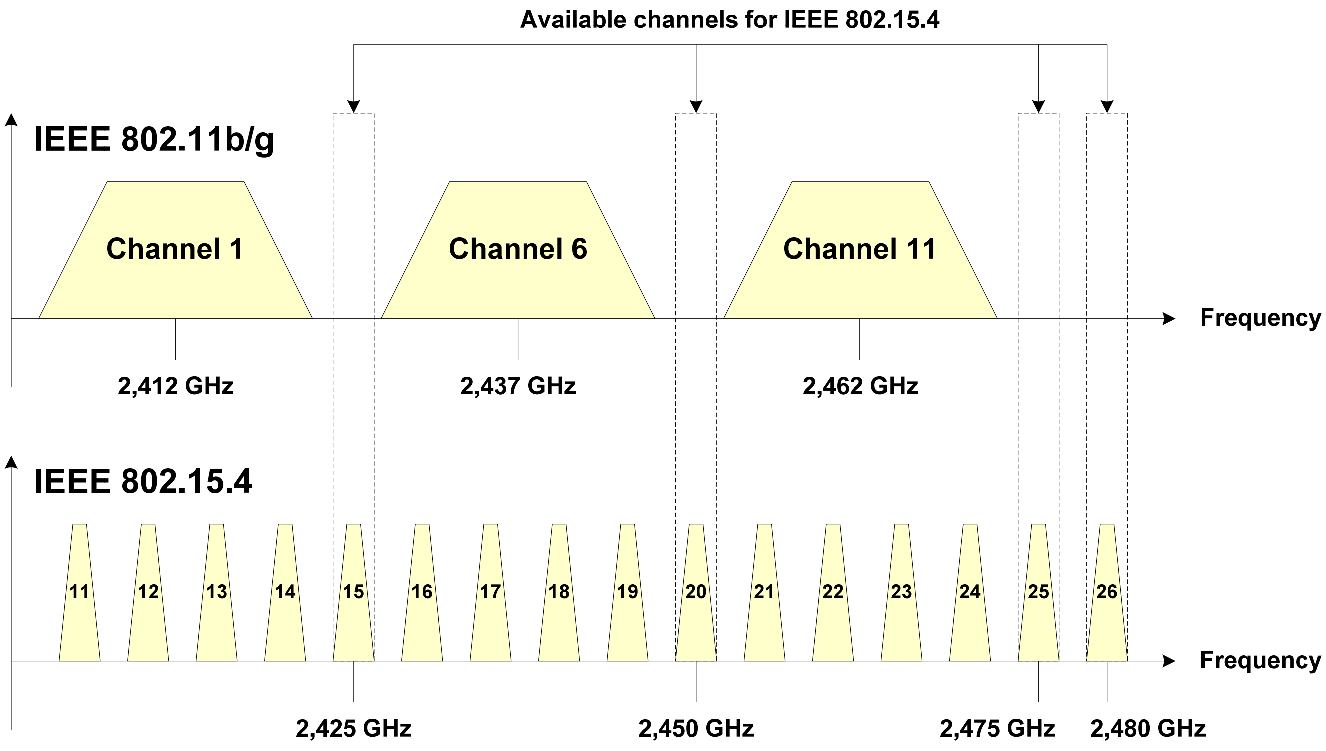

Figure 3: IEEE 802.11b/g and IEEE 802.15.4 channel distribution

[1] Following national regulations, only channels 1 through 11 are available in the U.S. and Canada; channels 1 through 13 are available in Europe; and in Japan, only channel 14.

Asset and Personnel Tracking

Keeping track of objects is increasingly important as industrial operations become more and more complex. Within this paper, the focus will be on battery-less (passive) RFID solutions, or more specifically, solutions complying with the following two ISO standards for contact-less identification:

- ISO 15693[2] – *Identification cards - Contactless integrated circuit(s) cards - Vicinity cards (13.56 MHz)*
- ISO 18000-6 – *Radio frequency identification for item management - Parameters for air interface communications at 860 MHz to 960 MHz*

The reason for the wide frequency range defined for ISO 18000-6 is that different countries allow using different frequencies, and that only parts of the total frequency band is allowed for RFID purposes in each area. As an example, UHF RFID equipment in Europe may only operate at 865-870 MHz, while the same equipment in the US is only approved for use between 902 and 928 MHz.

Technology.

The basic difference between the two selected solutions lies in the operating frequencies, which are 13.56 MHz (high frequency / HF) and 860-960 MHz (ultra-high frequency / UHF). Another difference, directly linked to the frequencies in use, is that the 13.56 MHz solution is based on inductive (magnetic) communication, while the 860-960 MHz solution is based on electromagnetic (radio) communication. Due to fundamental properties of magnetic fields, inductive communication is limited to a maximum distance of 0.16 times the signal wavelength [13]. These fundamental limits do not apply to RFID systems based on electromagnetic waves (such as the UHF solution), which may thus provide longer read ranges than their inductive equivalents.

Laboratory Experiments.

The performance of two RFID solutions, a short range solution operating in the 13.56 MHz band and a long range solution operating in the 865 MHz band, were examined when deployed in a semi-industrial environment.

Short range RFID (13.56 MHz).

The objective of the tests was to determine read ranges of various transponders as a function of their relative orientation to the receiver, as well as testing an RFID reader's capability of detecting multiple transponders at once. The RFID reader consisted of an antenna (coil) and a processing unit, the latter being connected to and controlled by a PC. The reader antenna dimensions were 337 mm x 238 mm x 8.3 mm.

Transponder type	Maximum read range	
	Ideal orientation	Non-ideal orientation
Circular, white tag, diameter approx. 20 mm	17 cm	Not detectable
Circular, black tag, diameter approx 25 mm	20 cm	Not detectable
ID card, approx. 80 mm x 55 mm	25 cm	Not detectable
Circular, red tag, diameter approx. 80 mm	27 cm	Not detectable
Square, white sticker, approx. 55 mm x 55 mm	30 cm	Not detectable
Rectangular, transparent, approx. 140 mm x 90 mm	54 cm	Not detectable

Table 3: Maximum read ranges of various HF RFID transponders (ISO 15693)

The results showed a maximum read range from 17 to 54 cm depending on the transponder type. However, for all the transponders the orientation influenced the read ranges, and at certain orientations the RFID reader was not able to detect the transponders at all.

When it came to detection of several collocated transponders, the reader proved able to report at least 20, as long as they were not physically overlapping.

Long range RFID (865 MHz).

The objectives of the tests were to determine the read ranges and anti-collision properties of an ISO 18000-6 compatible reader and the two different transponders (one with linear polarization, and one with dual-linear polarization). The reader operated on 865 MHz with 2W e.r.p.[3], which is the maximum power allowed in Europe for UHF RFID applications.

The transponder with linear polarization was a so-called "rigid" transponder, enclosed in a plastic case. Its maximum read range was tested to 8.0 meters under optimal conditions. If the transponder was rotated or located outside the reader's main

[2] Also known as ISO 18000-3 (Radio frequency identification for item management -- Part 3: Parameters for air interface communications at 13,56 MHz)
[3] Effective radiated power

lobe the read range was reduced. This was expected, as both the reader and the transponders were linearly polarized, meaning that they should be parallel in order to work optimally. Mounting the transponders to other materials such as a wooden board or a metallic foil reduced the optimal read range to 5.5 meters and 1.5 meters respectively.

The transponders with dual-linear polarization were flexible, stick-on labels coming in rolls made for label printers. Compared to the linearly polarized transponder, they had a somewhat shorter maximum read range (5.1 meters), but due to their dual-linear polarization the read-range was in return somewhat less susceptible to variations in transponder orientation. Laboratory tests showed that these transponders became more linearly polarized when connected to a wooden board, but they were still readable. The resulting read ranges were between 1.0 and 4.1 meters, depending on the transponder orientation. When attaching the transponders to a metallic foil, the dual-linearly polarized transponders were not detectable. Regarding anti-collision, the reader was able to detect several collocated ISO 18000-6 compatible transponders, although there seemed to be some stability issues, as not all the present tags were discovered during every read attempt.

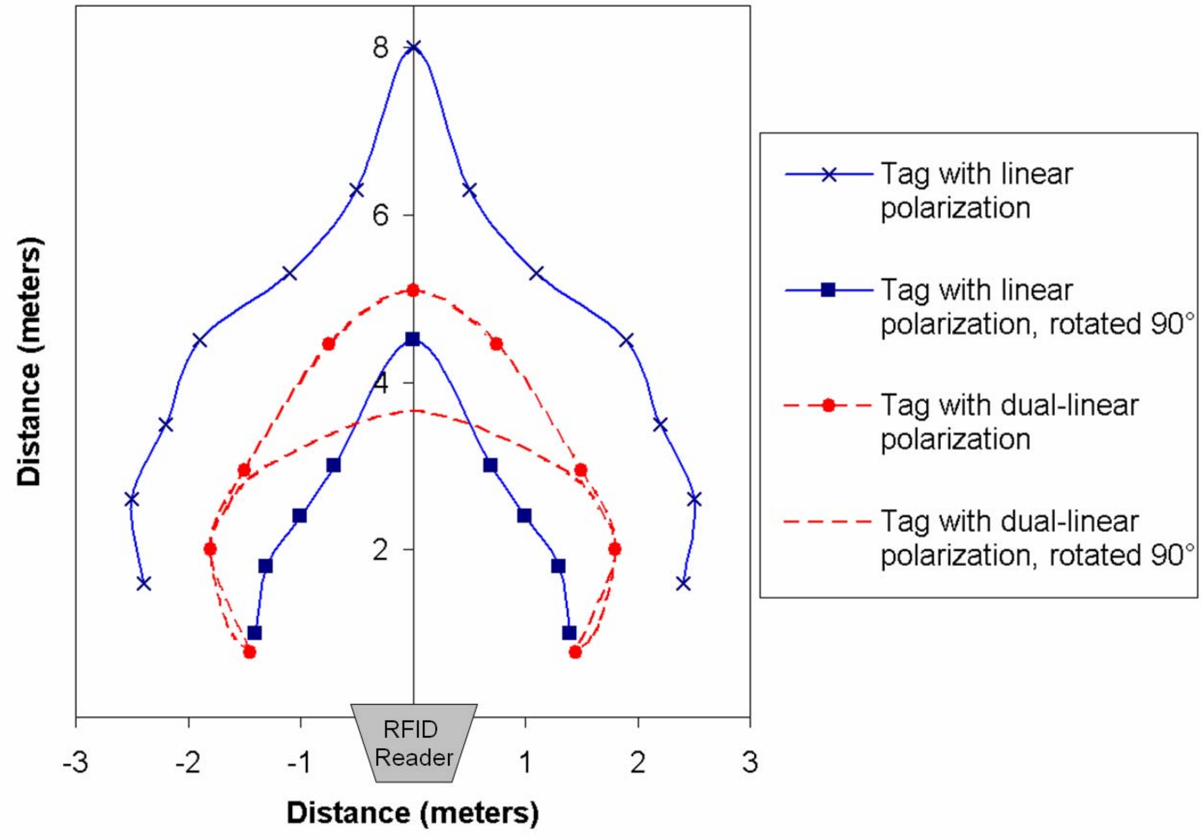

Figure 4 – Maximum read ranges for two transponder types conforming to ISO18000-6

RFID-discussion.

The experiments showed that all the technologies in question were reliable with regard to detection (and anti-collision, when applicable) as long as the test situations were controlled and optimal. However, upon altering the conditions, the performance was consistently reduced. Thus, if these technologies should be used with any degree of reliability, it seems necessary to maintain a high degree of control over the usage situation. For automatic tracking situations where the objects neither follow a specific path nor are transported in a specific orientation, the tested RFID solutions seem unsuitable. Letting several readers cover the same area will increase the system reliability, but not to a sufficient level. For these situations, solutions with active transponders (that is, battery-based transponders) is a more appropriate choice, as these both have longer communication ranges and are less susceptible to transponder orientation.

Conclusion

This paper has examined the possible use of wireless technology in the Oil & Gas industry. Technical requirements have been identified and the effects the introduction of wireless technologies can have on work processes have been investigated. In addition, the performance of state-of-the-art solutions within the three identified application areas, wireless networking, wireless sensing, monitoring and control, and personnel and asset tracking, have been tested when deployed in the semi-industrial environment of the laboratory facilities at StatoilHydro’s Research Centre in Trondheim, Norway.

For wireless networking, the conclusion is that the WLAN technology is ready for deployment in Oil & Gas facilities. Although an industrial environment with metal structures and heavy machinery will degrade the performance of a wireless network, it is still possible to provide wireless clients with network access of adequate connectivity and data rate.

Within the area of wireless sensing, monitoring and control, currently available solutions *do not* fulfill the Oil & Gas industries requirement of being based on an international standard. However, experiments performed on state-of-the-art proprietary solutions suggest that the ZigBee PRO, *Wireless*HART and ISA100.11a industrial WSN standards will probably fulfill the technical requirements of the Oil & Gas industry. The main challenge for these technologies is to meet the Oil & Gas industry's demand for a battery lifetime in excess of 5 years for the wireless sensors.

Experiments performed on two passive RFID solutions have shown that this technology is reliable in scenarios where a high degree of control of the usage situation is maintained. For automatic tracking of assets and personnel in situations where it is difficult or impossible to control the movement path of the object or person, the tested RFID solutions are unsuitable.

Future work within the area of wireless technology for the Oil & Gas industry will be to perform experiments with equipment adhering to the future IEEE 802.11n standard which is expected to be ratified in 2008, to examine and compare the three industrial WSN standards (ZigBee PRO, *Wireless*HART and ISA100.11a), and to evaluate the performance of active RFID solutions for asset and personnel tracking.

Acknowledgement

The authors would like to thank the following for their contributions, comments and feedback on our work: Kai Hansen from ABB Strategic R&D for Oil & Gas and Knut-Olav Fjell and Pål Johansen from StatoilHydro R&D. In addition we would like to thank the other members in the TAIL IO project for their support.

References

1. IEEE Computer Society, "*IEEE 802.11-1999: Wireless LAN Medium Access Control (MAC) and Physical Layer (PHY) specifications*", *IEEE Computer Society* (July 1999).
2. IEEE Computer Society, "*IEEE 802.11a-1999: High-speed Physical Layer in the 5 GHz Band*", *IEEE Computer Society* (Feb. 1999).
3. IEEE Computer Society, "*IEEE 802.11b-1999: Wireless LAN Medium Access Control (MAC) and Physical Layer (PHY) specifications: Higher-Speed Physical Layer Extension in the 2.4 GHz Band*", *IEEE Computer Society* (Oct. 1999).
4. IEEE Computer Society, *"IEEE 802.11g-2003: Wireless LAN Medium Access Control (MAC) and Physical Layer (PHY) specifications: Further Higher Data Rate Extension in the 2.4 GHz Band", IEEE Computer Society* (June 2003).
5. IEEE Computer Society, "*IEEE 802.15.4-2006: Wireless Medium Access Control (MAC) and Physical Layer (PHY) Specifications for Low-Rate Wireless Personal Area Networks (LR_WPANs)*", *IEEE Computer Society* (Dec. 2006).
6. I. F. Akyildiz, W. Su, Y. Sankarasubramaniam and E. Cayirci, "*A Survey on Sensor Networks*", *IEEE Communications Magazine* (Aug. 2002), pp. 102-114.
7. ZigBee Alliance, "*ZigBee Specification Version 1.0*", *ZigBee Alliance* (Dec. 2004).
8. ZigBee Alliance, "*ZigBee-2006 Specification*", *ZigBee Alliance* (Dec. 2006).
9. ZigBee Alliance, "*ZigBee PRO Specification*", *ZigBee Alliance* (Oct. 2007).
10. HART Communication Foundation, *"HART Field Communication Protocol Specification, Revision 7.0", HART Communication Foundation* (Sept. 2007).
11. ISA100 Standards Committee, "*ISA100.11a, Release 1 – An Update on the First Wireless Standard Emerging from the Industry for the Industry*", *ISA EXPO 2007* (Oct. 2007)
12. Petersen, S et al., "*Requirements, Drivers and Analysis of Wireless Sensor Network Solutions for the Oil & Gas Industry*", *Proceedings of the 12th IEEE International Conference on Emerging Technologies and Factory Automation* (Sept. 2007), pp. 219-226.
13. Finkenzeller, K., *"RFID Handbook", Wiley* (2003), p. 114