SPE 112252

Industrial Wireless Technology for Oil Fields Connectivity "Wireless I-Field"

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

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Abstract
Wireless Technology is a potential cost-effective and efficient connectivity solution for several oil and gas explorations and producing applications. Remote oil wells, water injection plants, pump stations, pipelines operations can benefit from the first mile wireless access to connect to the corporate Process Automation Network (PAN). This would result in improving productivity, providing faster and more accurate data collection and reducing capital and operating expenditures.

In this paper, authors will provide an overview of industrial wireless technology for Oil Field Connectivity as well as the discussing key requirements and challenges for reliable and secure industrial wireless solution. Furthermore, emphasis will be on the use of industrial Fixed Broadband Wireless (BFW) for first mile field access. The successful field trial implementation of industrial BFW solution for microseismic field connectivity will be presented in this paper.

Introduction

Communications play a crucial role in process automation industry. They are the key enabler for successful overall functionality of extended and distributed systems. Effective communications provide plant operators the capabilities and tools to enhance operation productivity and minimize overall costs.

Wireless solutions have great potential in process automation applications since they enable flexible, quick and cost effective communications for various process machines, instruments and field devices. To ensure a reliable wireless connection, redundancy schemes and packet retransmission are added through the Wireless protocol. Generally, Wireless technology can be classified into two categories: Narrow-Band and Broad-Band.

Narrow band licensed radios have been the workhorse for wireless industrial communication for over thirty years. As the name would imply, narrow-band radio technology uses "Narrow" carrier/channel; usually 25 kHz channel in the Very High Frequency (VHF) range which would provide data rate up to 19,200 bps. These data rates are more suitable for serial communications (RS-232, RS 422, RS-485) which are the de-facto communication interfaces for most Remote Terminal Units (RTUs); Programmable Logic Controllers (PLCs) used in the Supervisory Control and Data Acquisition (SCADA) networks.

The major advantages of narrow-band radio systems are the propagation properties (less attenuation due to lower frequencies), higher output power and exclusive use of frequencies due to licensing. However, these systems are usually proprietary with limited bandwidth, suffers from noise, and limited in scalability.

Broadband radios which are based on spread spectrum technology can support much higher bandwidth (more than 1Mbps, usually 10s of Mbps) and have greater spectrum efficiency than the traditional narrow-band radio communications.

Spread spectrum radios spread the information across a wide bandwidth (usually more than 1MHz), reducing the signal power density so that it does not create interference. There are three key spreading technologies namely Frequency Hopping (FHSS) Fig. 1, Direct Sequence (DSSS) Fig.2, and Orthogonal Frequency Division Multiplexing (OFDM) Fig.3. The spreading of the frequencies makes the system immune to interference and noise. In addition, the wider bandwidth translates to higher data rates. However, because spread spectrum systems are limited to 0.1Watt output power, distances heavily depend on line-of-sight availability and antenna type and gain. Most spread spectrum devices operated at the license-free band (2.5GHz and 5.8GHz), it should be noted that higher frequency results into more bandwidth but with less wireless coverage (shorter distance).

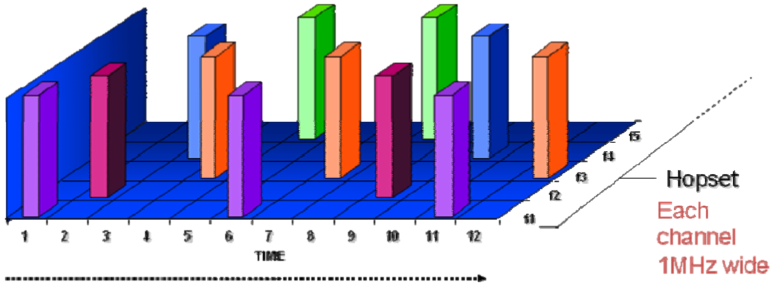

Fig.1: Frequency Hopping (FHSS)

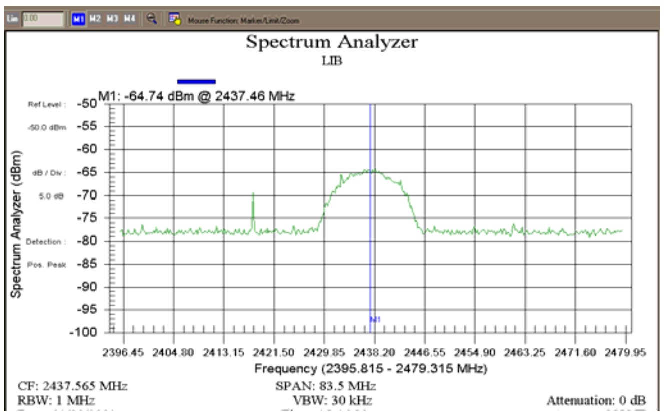

Fig.2: Direct Sequence (DSSS)

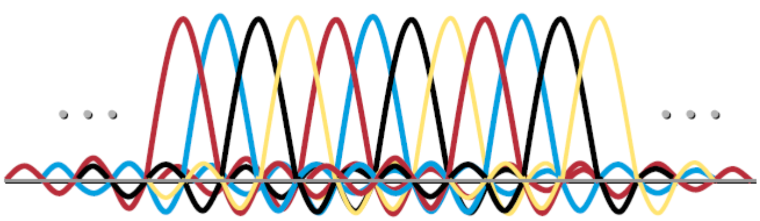

Fig.3: Orthogonal Frequency Division Multiplexing (OFDM)

The greatest amount of loss in your wireless system will be from Free Space Propagation. The Free Space Loss is predictable attribute and can be calculated by the formula:

$$P_r(d) = \frac{P_t G_t G_r \lambda^2}{16\pi^2 d^2 L}$$

Where $P_r(d)$ is the received power in Watt and is a function of the transmitter-receiver separation distance in meters (d), P_t is the transmitting power, G_t is the transmitting antenna gain, G_r is the receiver antenna gain. This formula can be simplified to provide the Free Space Loss in Decibel as a function of the distance between transmitter and receiver (D) and the operating frequency (F).

FSL (dB) = 32.45 + 20Log10F(MHz) + 20Log10D(km)

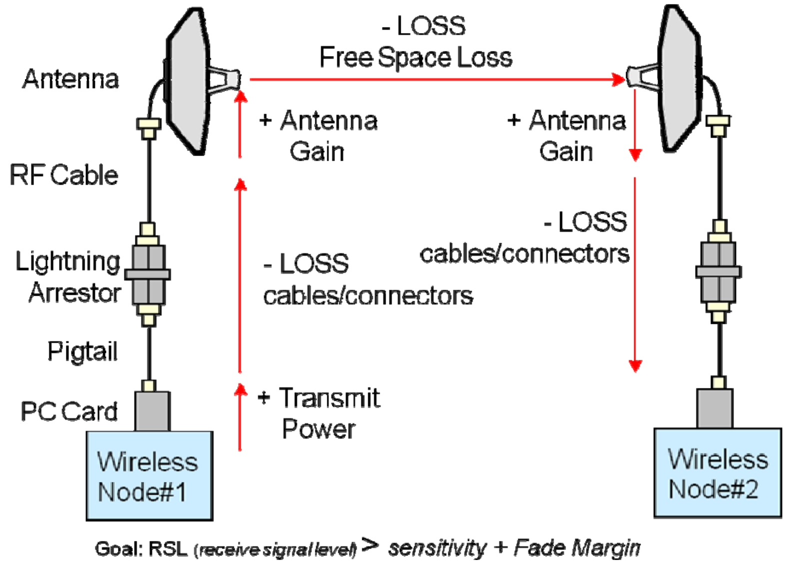

Fig.4: Wireless Link Budget

Wireless Technology Classification

Wireless technologies can be classified into four main categories based on their coverage area and bandwidth as follows:

- Wireless Personal Area Network (WPAN) – few meters – Zigbee, Wireless HART, SP100
- Wireless Local Area Network (WLAN) – few hundreds of meters up to few Kilometers, WiFi, HiperLAN
- Wireless Metropolitan Area Networks (WMAN) – tens of Kilometers, WiMAX, BFW
- Wireless Wide Area Networks (WWAN)– tens up to hundreds of Kilometers, VAST, GSM, UHF/VHF

The main objective of using wireless in industrial application is to provide robust, reliable and secure communication connectivity between various devices, instruments, controllers and processes. (Fig.5)

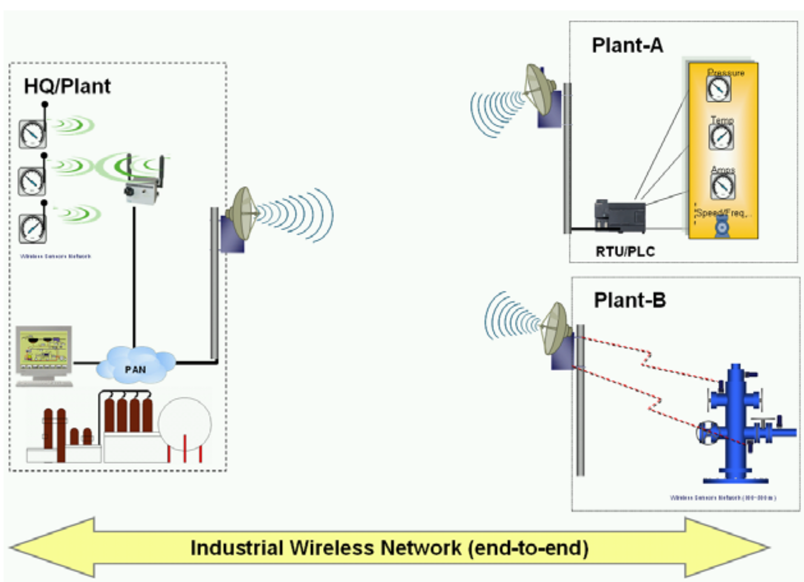

Fig.5: Industrial Wireless Network

Several wireless solutions have been implemented to provide process monitoring for remote facilities such as well head monitoring and pipeline applications such as traditional WiFi (IEEE802.11a,b,g), Zigbee, GSM (SMS/GPRS), VHF/UHF radios and VSAT satellite wireless solutions. However, these solutions were designed to provide “best effort” remote monitoring.

WPAN and WLAN solutions are appropriate for in-plant process connectivity such as connecting scattered sensors, controllers, instruments and machines wirelessly. On the other hand, Fixed Broadband Wireless (FBW) provides potential cost saving be eliminating the need to deploy physical cabling (optical fiber) between different facilities and plants. Moreover, FBW provides adequate throughput for point-to-pint and point-to-multi-point configuration that fulfills the requirement of current and future oil and gas process automation applications including:

- Oil/Gas well heads automation
- Cathodic protection monitoring and control
- Energy Management
- Waste water management
- Vibration monitoring
- Power Monitoring System
- Condition-Based maintenance
- Remote surveillance and alerting solution
- Power monitoring
- Micro-seismic sensing application

Key Requirements for Industrial FBW

Fig.6 shows key elements required in the industrial wireless solution such as FBW to be effectively utilized for process automation monitoring and control in oil and gas applications are summarized below:

- Support real-time applications (deterministic)
- Offer reliable radio channel "reliability"
- Use open standards interfaces and protocols "interoperability." This provides protection for investment (interoperability between different vendors)
- Be as secure as a wired network "security"
- Uses robust and certified industrial products

Fig.6: Industrial Wireless Link Performance Parameters

Deterministic and Shared Access

FBW solution shall provide deterministic access mechanism either by enabling the scheduling "cyclic" criteria or by reserving "bandwidth" to specific application(s) in order to guarantee air time access of process automation critical remote nodes as shown in Fig.7. This involves the remote nodes being cyclically triggered and thereby receiving a pre-defined "time-slot" for the data transfer.

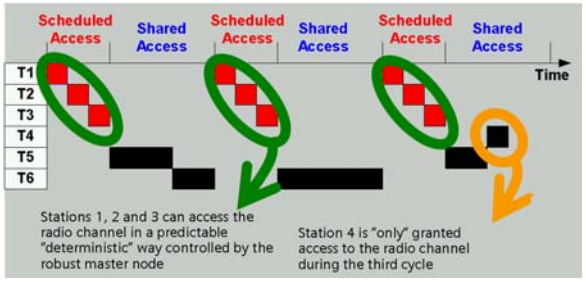

Fig.7: Wireless Deterministic Access for critical/time sensitive process applications

Redundant Radio Channels

It is crucial to use redundant wireless connection for oil and gas critical process automation applications. This could be achieved by having dual radio channels for the master and client nodes as shown in Fig.8. The 2.4GHz and 5GHz ISM bands are potential frequencies to be used as dual Radio access where both signals (2.4 GHz and 5 GHz) are transmitted simultaneously to achieve extremely high level of radio channel reliability and to provide minimal interference wireless connections.

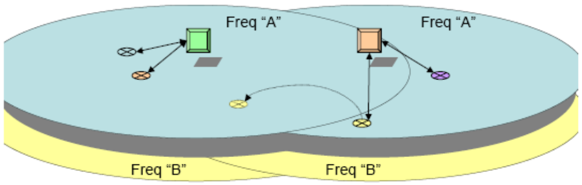

Fig.8: Redundant Radio Access for critical/time sensitive processes applications

Robust and Classified Materials

Wireless device used inside the classified area (zone) of a hydrocarbon facilities must adhere (and be certified) to the area classifications requirements to insure safe operation of wireless systems inside any classified areas of hydrocarbon facilities that comply with IP67. (6=No ingress of dust; complete protection against contact, 7=Ingress of water in harmful quantity shall not be possible when the enclosure is immersed in water under defined conditions of pressure and time (up to 1 m of submersion))

Secure Wireless Communication

Basic security settings and factory default settings for "operating" industrial wireless networks shall not be allowed under any circumstances. The use of Advanced Encryption Algorithm (AES) [2] can ensure fully secured data transfer over wireless channel. The AES encryption algorithm cannot be "cracked" with current technology. Moreover, proper Radio Frequency (RF) planning is needed to optimize wireless coverage and limits wireless signals propagation outside plants or facilities

Wireless Field Trial

A point-to-point FBW (Fixed Broadband Wireless) solution was deployed to provide real-time network connectivity for the oil reservoir microseismic analysis and monitoring system. The network connectivity, shown in Fig.9, is used to link two sites that are 7 Kilometers a part from each others. At the oil field data is captured on continuous basis and is stored locally in an industrial server. The data is also sent real time concurrently to the centralized server which is linked by a high speed Wireline IP network to the corporate databases and simulation systems. This connectivity enabled engineers to analyze and optimize recovery of hydrocarbons and provide fluid flow path monitoring between wells.

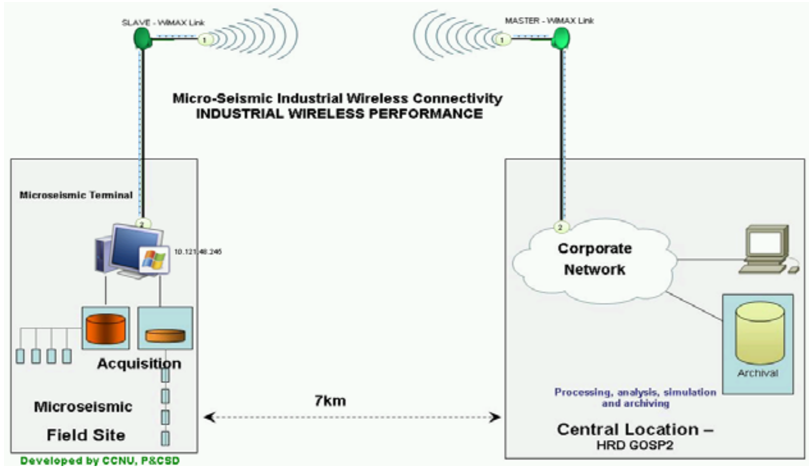

Fig.9: Broadband Fixed Wireless Network Trial

As part of this trial, test cases were developed to test the performance of the deployed wireless system. The key parameters that were used in the test cases are:

- Link budget verification
- Throughput measurement
- Integrity test
- Wireless link survival test

Field results were very close to the calculated values as shown below:

- Transmit Power for primary link = 18dBm Received Power for primary link = -61dBm
- Transmit Power for secondary link = 18dBm
- Received Power for secondary link = -60dBm
- Avg. Throughput for Primary Link = 76Mbps “shown in Fig.12”
- Avg. Throughput for Secondary Link = 80Mbps

Online performance testing and benchmarking was developed to evaluate and validate the performance of industrial wireless systems. Key performance parameters such as Availability, Packet Error Rates (PER), Latency, Throughput and Utilization have been identified and monitored for the planned evaluation phase (Fig.10, 11).

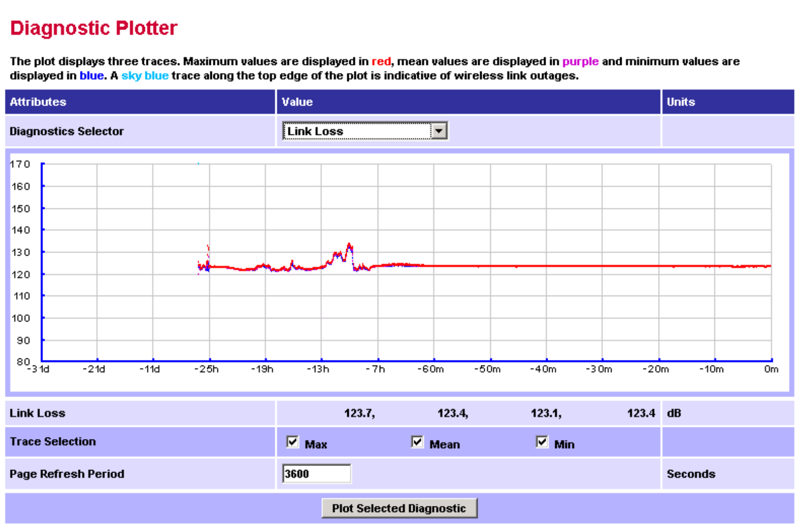

Fig.10: Broadband Fixed Wireless Network Trial

Fig.11 depicts the throughput performance as it relates to the traffic load. The achieved wireless link throughput is 76.09 Mbps as it related to a maximum load input testing. It must be noted that the throughput depends on signal quality and distance.

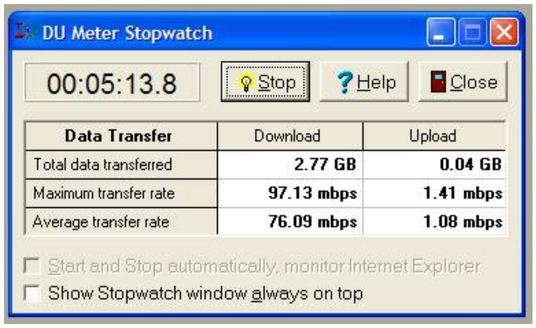

Fig.11: Broadband Fixed Wireless Network Trial

The system reliability was demonstrated during various weather conditions. This includes high temperature and major winds and stand storms. The performance has showed that this wireless technology can endure harsh weather environment as shown in Fig. 12.

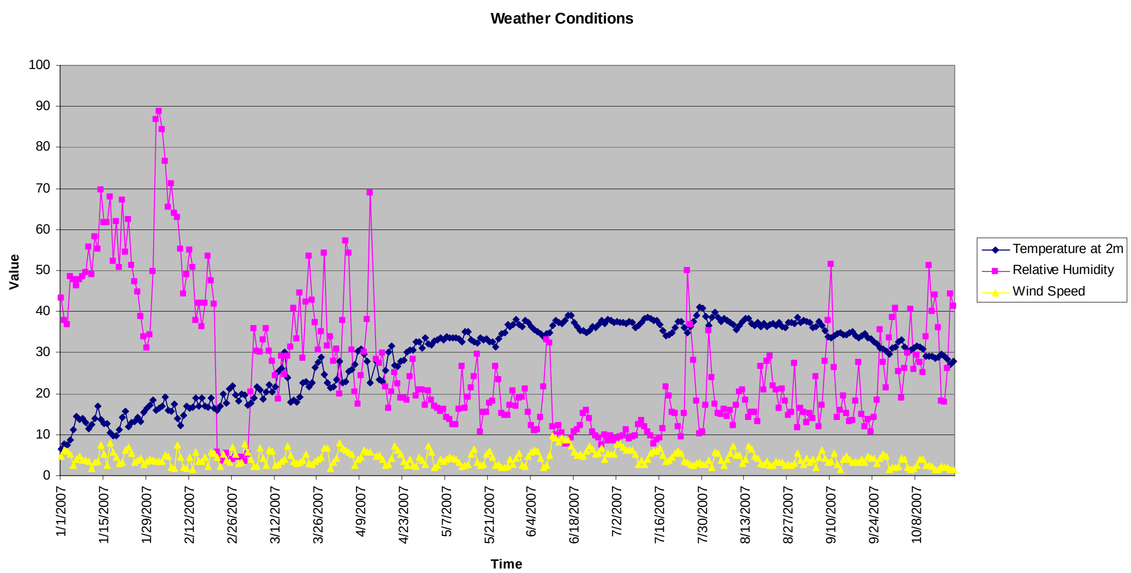

Fig.12: Weather Conditions

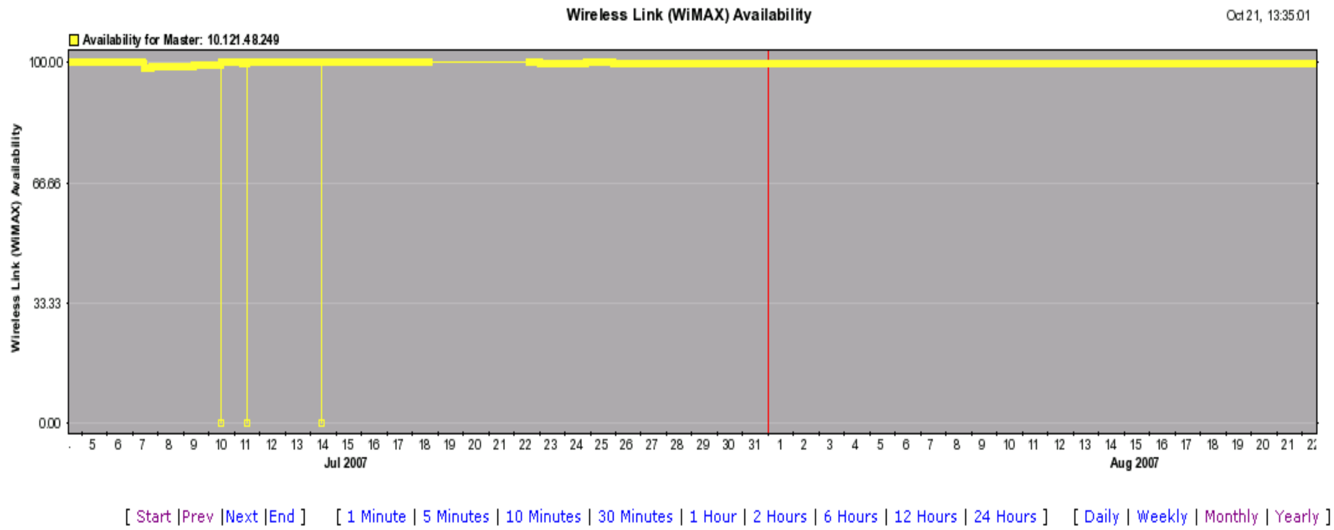

Fig.13: Broadband Fixed Wireless Reliability

Conclusion:

Industrial Wireless solution provides rapid network connectivity deployment that is cost effective and efficient for various oil and gas applications. It is very crucial to ensure reliable guaranteed access for time critical applications in a point-to-point and point-to-multi-point /mesh architecture. Moreover, providing redundant links "radio" and complying with hazardous area's classifications is necessary to ensure the reliability of wireless connectivity and safety of hydrocarbon operation.
The field trial has confirmed the flexibility of utilizing Fixed Broadband Wireless as a potential first mile network access for plant and process operations such as Intelligent Field "I-Field", SCADA, and other remote process monitoring applications (e.g., microseismic application). FBW solution showed reliable and secure communication solution for field connectivity with sufficient throughput capability (70+ Mbps) for advanced microseismic applications. Furthermore, open standard Industrial wireless solution (IP based) can easily be integrated and interfaced with the wired solution "corporate LAN/WAN" thus providing seamless end-to-end connectivity.