Wireless vs. Wired. How Software Define Radio technology addresses issues related to the use of wireless networks when compared to a wired solution.

White Paper

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May 2005

Revision history

Revision	Date	
A1	5/2005	DOWP0002A1
A2	8/2005	DOWP0002A2
A3	8/2005	DOWP0002A3

Printed in the United States of America.

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Abstract

Choosing between wireline and a wireless network for a specific application is often a challenging task. Wireline systems have a number of features, which until now made a hardwired solution a clear winner in some cases.

This paper intended to show how Software Defined Radio (SDR) technology addresses the most important concerns one may have when faced with the dilemma of choosing between wireline network and wireless solution.

Introduction

In general, all communication networks can be divided into several groups based on the type of media used to deliver messages from one communication node to another within a given network.

For the purposes of this paper, only two types of media will be considered: hardwired network (wireline infrastructure) and radio frequency (RF) channels (wireless links).

Additionally, this paper outlines and ranks motivations one would most likely use to choose between wireline and wireless networks for applications such as industrial control, traffic, public safety, and remote data gathering.

1. Quick look at Software Defined Radio technology

The concept of SDR has been around for some time while originally being discussed in the field of military research. With rapid improvements in semiconductor technology over the past several years, the implementation of SDR has become a reality even for low-cost commercial applications.

The FCC defines Software Defined Radio as follows:

> "A software defined radio is a radio that includes a transmitter in which the operating parameters of the transmitter, including the frequency range, modulation type or maximum radiated or conducted output power can be altered by making a change in software without making any hardware changes [1]."

A simplified structure of a SDR is shown in Figure 1 below. It consists of three main blocks: Base-Band Processing module, Digital Signal Processor module, and the RF section.

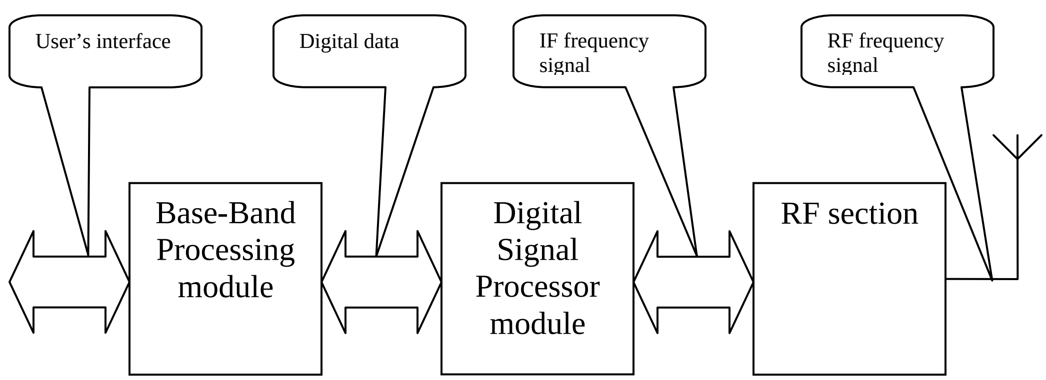

Figure 1. SDR structure.

The Base-Band Processing module provides user interface support and retains the software, which defines the protocol to be used in the RF channel (RF packets structure, algorithms of interaction between the nodes in the network, etc.).

The Digital Signal Processor (DSP) module provides interface between SDR's RF section and its Base-Band Processing unit. During the receive, the DSP module converts the intermediate frequency (IF) signals delivered to it from the RF section into a digital form and performs signal demodulation before reporting received data back to the Base-Band Processor. When the SDR needs to send data over the RF channel, the DSP module converts digital signal from the Base-Band Processing unit into IF signal and passes it to the RF section.

The RF section is responsible for the up- and down-conversion of the IF signals to the appropriate frequency band utilized by the SDR.

Please note, that the only analog part of the SDR is its RF section. All of the signal manipulations (modulation, demodulation, frequency channel determination, output power control, etc.) are done in digital form and performed by a DSP module.

2. Primary motivation in choosing networks

According to independent studies published by several marketing research firms, there are a number of factors that users consider when choosing a network type for their application. These factors and their appropriate rankings are summarized in the table below.

Ranking	For Wireline	For Wireless
1	High reliability	Need for mobile applications
2	High security	Flexibility/ease of expansion/relocation
3	Ease of Integration with existing networks world-wide	Provides long distance/remote coverage
4	Cost	Ease/fast installation
5	Establish/proven technology	Low cost installation
6	Availability of products for & To use with	Need where installing wireline would not be possible, or very costly

As shown, the top three motivations for choosing a wireline solution over wireless were high reliability, high security, and ease of integration with an existing network world-wide.

The following section of this paper will show how these issues are addressed by SDR technology implemented in products by Lexycom.

3. Reliability of the RF link

The issue of reliability, in the majority of the cases, was considered to be the most important factor in giving preference to a wireline technology.

It is well known that the reliability of a RF link depends on several factors. However, we will only consider two of them, which are found to have the most influence on system's overall performance:

1. Amount of available signal-to-noise ratio (SNR) at each receive site in the network vs. minimum SNR required by the communication equipment for proper operation.
2. Level of in- and out-of-band interference.

The first issue can be generally expressed in the form of available RF link budget. The more signal level above the noise floor the receiver has, the more reliable the communications link will be. Usually, this is something that can be pre-determined or acknowledged during the system's planning stage. However, sometimes one has to work with what is available or feasible to achieve – cannot put a repeater everywhere where it is desired, the FCC regulates the maximum output power, etc. These are the situations when the reliability of a wireless system becomes questionable. So, these are the cases that we will consider in the following section.

The second issue (level of in- and out-of-band interference) is less controllable by the system installer/user and is more a product of the environment in which the RF system is installed.

Let us see how SDR technology addresses these two concerns…

3.1. RF link budget

In simple terms, the RF link budget determines how much signal the receiver has to work with vs. how much it needs to be able to maintain the required bit error rate (BER) of the communication channel. We need to mention that the minimum amount of signal level required by different receivers typically depends upon the receiver's sensitivity and type of modulation used in the RF channel.[2]

The receiver's sensitivity, usually, directly translates into the systems reliability and maximum achievable distances.

However, the same receiver may require more input signal level or less for its proper functionality (suitable BER) depending on the type of modulation, which is used in the system. For example, the same receiver can deliver an additional 5-6 dB of sensitivity improvement if the modulation is switched from FSK to, say, BPSK[2]. In other words, with everything being equal, by selecting different type of modulation for the network one can gain as much as twice the communication distance.

Additionally, the receiver's sensitivity is inversely proportional to the bandwidth occupied by the signal. A wider signal bandwidth implies lower receiver sensitivity. Therefore, if the data bandwidth of the system needs to be high, the maximum achievable distances will be short. For longer communication links one would need to select a lower RF channel bit rate to take advantage of the higher receiver sensitivity.

In short, ideally, it is very desirable to adjust the modulation type and RF channel bit rate to better adopt the system to the requirements of a particular application. While it is relatively easy to implement in wireline network, to accomplish the same in the case of wireless network may present a series of technological challenges.

Fortunately, SDR technology allows wireless devices to be very flexible from the standpoint of RF link characteristics. As mentioned above, the SDR is a fully digital radio, which allows the user to select a waveform for the signal to be sent over the RF channel. The SDR provides the RF link to be adjusted in terms of modulation type used and RF channel bit rate selected. Therefore, the user can select between sending data at fast bit rates over relatively short distances or slow down the RF channel transmissions and gain the distance. Please, note that these options can all be done by simply selecting the appropriate option on the SDR's menu or by loading a different software to the device.

3.2. Interference in the RF link

The second most important characteristic of the RF link, which determines the reliability of the system, is the amount of in- and out-of band interference.

Most common sources of the interference are:

- Other wireless networks/devices operating in the vicinity (could be another network, which uses the same brand of transceivers, for example);

- A variety of human-made and natural sources of RF signals/noises (power lines, buildings, etc.);
- Multi-path disturbance due to reflection of the desired signal from walls, buildings, equipment, and metal structures.

Depending on the frequency band of operation and specifics of a particular installation location, one of the listed above interference sources will dominate others. More specifically, license-free transceivers operating in the 900 MHz ISM band, for example, usually experience far more in-band interference from other ISM transceivers located in the vicinity than from any other noise sources. Yet, the natural and human-made noise sources will most likely dominate in the 400 MHz frequency range and lower.

The most common ways to reduce the influence of the in-band interference are:

- Add communication nodes and repeaters to the system to provide better coverage;
- Careful choice of types and sizes of antennas in the network;
- Channel selection to minimize overlapping with interfering signals in the frequency domain;
- Conduct antenna site surveys to insure good signal reception coverage;
- Select antenna polarization and location, which provides highest interfering signal rejection;
- Limit transmission distances where signals are creating problems for other equipment.

Please note that most of the steps to reduce the interference listed above do not depend on the characteristics of the wireless equipment used in the system. However, additional measures can be used to fight the interference if the wireless equipment utilizes SDR technology:

- Selectable type of RF signal modulation, which provides better rejection of interfering noise sources. For example, most of the license-free wireless equipment available for 900 MHz ISM band operation uses FSK type of modulation and its derivatives (CPFSK, MSK, TFM, etc.). Thus, selecting a type of modulation based on modulating amplitude of the transmitted signal (AM and its derivatives) or its phase (PSK and its derivatives) will provide higher interference rejection even in the case when the interfering signal completely overlaps the desired message [2,3].
- Choosing between frequency hopping and direct sequence. It is shown in a number of published studies that each of these signal spreading techniques provide advantages in certain cases [3,4,5].

- Choosing between slow frequency hopping and fast frequency hopping. The less time a wireless network spends time on each frequency channel, the lower the chance that the interfering signal will 'step on top of it'.

Once again, all of these steps are possible only if the wireless equipment is fully digital and capable of being programmed in appropriate way.

4. Security of the RF link

The security of wireless transmissions is a concern in terms of unauthorized access to the data transferred within the network. The security issues are especially pronounced when wireless devices are built per specific standard such as 802.11, for example. The standardization is big benefit from the stand-point of interoperability of the devices, but it also presents a set of security concerns to the user.

The most common ways to provide secure wireless connectivity are:

- Use of proprietary protocols for RF transfers;
- Make wireless equipment to have a variety of user-selectable features/options so the overall number of selections required to be known/matched by the third-party listening devices is very large.

However, even with the steps taken above, some users of wireless devices are still not completely satisfied. The answer is in encrypting every bit of the user's data sent over the RF channel.

Currently, the most commonly used data encryption protocols are AES and DES. But, the real time encryption of user's data requires additional processing power from the wireless transceivers. Being fully digital and by definition designed to handle a lot of processing, the SDRs are the best fit for it. An SDR, which uses a proprietary RF channel communication protocol in addition to supporting data encryption protocols such as AES or DES, is capable of making the RF channel even more secure than the majority of wireline systems.

5. World-wide deployment

While wireline systems can be installed in virtually any country around the world, the deployment of a wireless network in most cases is followed by a line of regulatory issues related to obtaining licenses for system operation in the region of interest.

Being an issue for conventional wireless transceivers, for an SDR it is only a matter of being re-programmed to comply with the local frequency allocation requirements.

Summary

The SDR is an innovative technology, which represents the next generation of wireless devices. Because of its extreme flexibility, the SDR presents solutions to the most important concerns one may have when selecting between wireline and wireless media.

[1] FCC, *CFR Title 47. Part 2.1(c).*
[2] S. Haykin, *Communication Systems*, 2nd ed, John Wiley & Sons, New York, 1983
[3] R. C. Dixon, *Spread spectrum Systems with Commercial Applications*, 3ed, John Wiley & Sons, New York, 1994
[4] M. K. Simon, J. K. Omura, R. A. Scholtz, B. K. Levitt, *Spread Spectrum Communications Handbook*, McGraw-Hill, New York, 1994
[5] H. Taub, D. L. Schilling, *Principles of Communication Systems*, 2ed, McGraw-Hill, New York, 1986