Implementation and use of Software Defined Radio (SDR) technology for Public Safety, Traffic applications, and Highway Engineering

Topics of discussion

* Section 1. Wireless vs. Wired. Advantages and disadvantages of wireless and wireline networks.

* Section 2. Software Defined Radio technology overview. Introduction of Software Defined Radio technology and overview of how this technology addresses issues related to the use of wireless networks.

* Section 3. Innovative timing schema developed by Lexycom. Overview of well-known Point-to-Point, Point-to-Multipoint, Peer-to-Peer, and TDMA network topologies. Introduction of Lexycom's innovative timing schema, which takes these topologies to a completely new level of functionality.

Introduction

- About the company
  - Lexycom Technologies, Inc. is a manufacturer of Software Defined Radio transceivers; privately held; based in Longmont, Colorado;.
  - Contact information:
    - Web site: www.lexycominc.com
    - E-mail: info@lexycominc.com
    - Phone: (303) 774-7822
    - Fax: (303) 774-7828

- About the Speaker
  - Aleksey Pozhidaev, Lexycom Technologies, VP of Engineering
    - Education: MS in Communication and Control Systems from Academy of Communication And Control, Ukraine; BS in EE and CS from University of Colorado;
    - Publications: several technical publications in the field of spread spectrum signals;
    - Fundamental research: in the field of primary synchronization of demodulators of spread spectrum signals in the satellite communication systems.
  - Contact information:
    - E-mail: aleksey@lexycominc.com
    - Phone: (303) 774-7822, # 102

Purpose of the presentation

The purpose of this presentation is to discuss the benefits of wireless communications as an alternative to hardwired solutions. More specifically the advantages of a software defined radio when used in Traffic Control, Highway Engineering, and Public Safety applications. The SDR technology brings flexibility, ease of installation, robust, secure communication solutions to the traffic market.

Topics of discussion

- Section 1. Wireless vs. Wired.
- Section 2. Software Defined Radio technology overview.
- Section 3. Innovative timing schema developed by Lexycom.

Section 1. Wireless vs. Wired

In most of the cases the following motivations are used to choose between wired and wireless systems:

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

Section 1. Wireless vs. Wired

For the purposes of this presentation we would like to concentrate on the top three motivations in selecting a wireline network for a particular application:

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

Section 1.1. Reliability of wireless network

It is well-known and studied 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:

- Amount of available signal-to-noise ratio (SNR) at each receive site in the network vs. minimum SNR required by the communication equipment for its proper operation. *This parameter can be generally expressed in the form of available RF link budget.*

- Level of in- and out-of-band interference. *This parameter is less controllable by the system installer/user and is more a product of the environment in which the RF systems is installed.*

Let us see how SDR technology addresses these two concerns...

Section 1.1.1. 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 two main factors:

- receiver's sensitivity;
- type of modulation used in the RF channel.

Let's take a look at them…

Section 1.1.1. RF link budget

Receiver's Sensitivity

The receiver's sensitivity, usually, directly translates into the systems reliability and maximum achievable distances. However, the same receiver may require more or less input signal level 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.

Bandwidth occupied by the signal

Additionally, the receiver's sensitivity is inversely proportional to the bandwidth occupied by the signal. A wider signal bandwidth implies lower receiver sensitivity. Therefore, for longer communication links one would need to select a lower RF channel bit rate to take advantage of the higher receiver sensitivity.

Section 1.1.2. 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.

Section 1.1.2. In- and out-of-band interference

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.

Section 1.1.2. In- and out-of-band interference

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;
- Choosing between frequency hopping and direct sequence;
- Choosing between slow frequency hopping and fast frequency hopping.

Section 1.2. Security of RF links

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.

Section 1.3. 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.

Topics of discussion

- Section 1. Wireless vs. Wired.
- Section 2. Software Defined Radio technology overview.
- Section 3. Innovative timing schema developed by Lexycom.

Section 2. SDR technology overview

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."

A simplified SDR structure is shown below:

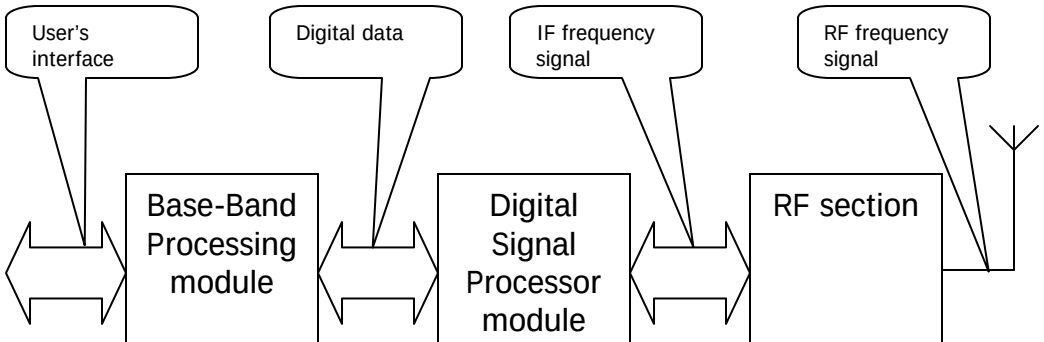

Figure 2.1. SDR structure.

Section 2. SDR technology overview

The SDR's structure and technological decisions allow one transceiver to fulfill the requirements of virtually any application:

- Possibility of re-using the same device in multiple applications;
- Adjusting RF link characteristics according to application requirements (modulation types, RF channel bit rates, etc.);
- 'Universal' data interface.

Section 2.1. Re-using the same device in multiple applications

Some of the applications may require implementation of a particular RF channel interface implemented. Because of the SDR devices' structure, most any RF protocol can be loaded into the device making it compliant with virtually any standard.

The limitations of possible RF channel interfaces supported by the SDR device are limited only by the hardware used on the SDR device (mostly its RF section).

Section 2.2. Adjusting RF link characteristics according to application requirements

Depending on the application, the following characteristics of the RF link need to be varied to best fit user's requirements:

- Modulation type used in the RF link
  - Choose to avoid/reduce in- or out-of-band interference;
  - Adjust to get more throughput or increase RF link distance;
  - Adjust to comply with certain standard within the United States or abroad.

- RF link bit rate/throughput
  - High data rates for relatively short communication links with high data bandwidth (Internet distribution, high quality video, etc.);
  - Low data rates for long communication distances (traffic controllers commands/configuration, GPS data, data from remote sensors, remote On/Off switches status control, etc.);
  - Adjust to stay in compliance with local frequency allocation/coordination agency.

Section 2.3. ‘Universal’ data interface

Properly designed and manufactured SDR transceiver may have an ‘universal’ data interface.

SDR technology is the best suitable to have multiple user data interfaces covered by one hardware.

Topics of discussion

- Section 1. Wireless vs. Wired.
- Section 2. Software Defined Radio technology overview.
- Section 3. Innovative timing schema developed by Lexycom.

Section 3. System topologies

The following are the most common system topologies used in wireless networks:

- Point-to-Point;
- Point-to-Multipoint;
- Peer-to-Peer;
- TDMA.

Each one of them has advantages and disadvantages. Let's consider them one at a time...

Section 3.1. Point-to-Point network

Structure

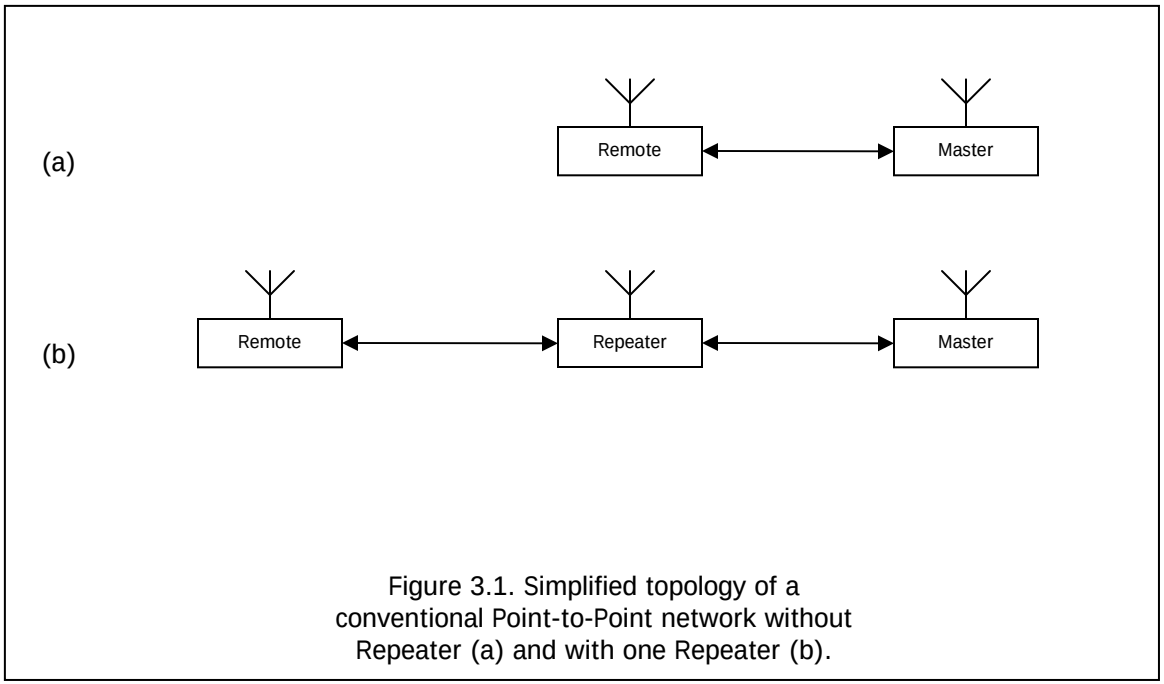

Figure 3.1. Simplified topology of a conventional Point-to-Point network without Repeater (a) and with one Repeater (b).

Section 3.1. Point-to-Point network

Advantages:

- Higher security of the RF link can be accomplished;
- Directional antennas can be used = higher immunity of the network to the noises/interference;
- All of the uplink and downlink messages can be acknowledged = usually higher efficiency in using the available RF link throughput (for example, only the packets corrupted in the RF link can be re-sent by the transmitting site);
- No RF packets collisions.

Disadvantages:

- Need a Master to provide network synchronization;
- Only point A to point B communications are possible;
- Not scalable in its original form.

Section 3.2. Point-to-Multipoint network

Structure

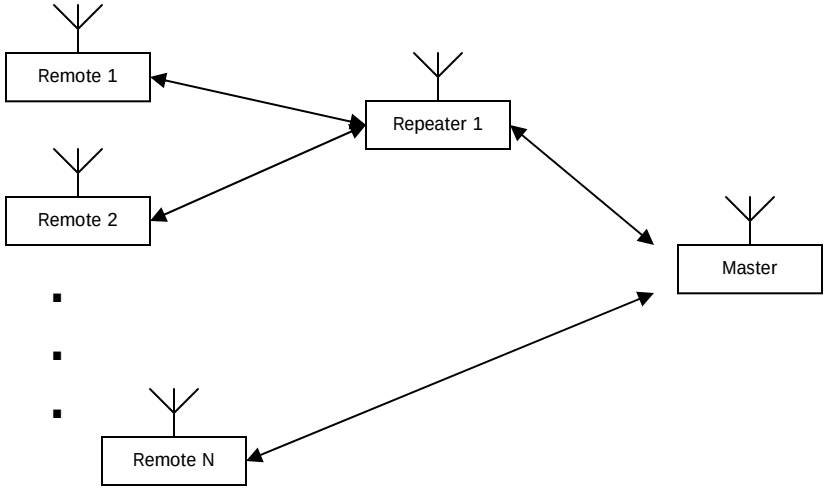

Figure 3.2. Simplified topology of a conventional Point-to-Multipoint network with one Repeater.

Section 3.2. Point-to-Multipoint network

Advantages:

- Multiple sites in the system can be linked to the central site;
- Each message going from the central site can be addressed to a specific remote or broadcast;
- Easily scalable.

Disadvantages:

- Need a Master unit to provide network synchronization;
- Lower security of the RF system compare to the Point-to-Point system;
- The remote sites need to share with each other the access to the Master (usually, the Master can 'serve' one remote at a time);
- Possibility of RF packet collisions = remotes may need to hold user's data in their buffers until they have a chance to talk to the Master = possibility of increased delays;
- All remotes can communicate with the Master only and not with each other (at least not directly).

Section 3.3. Peer-to-Peer network

Structure

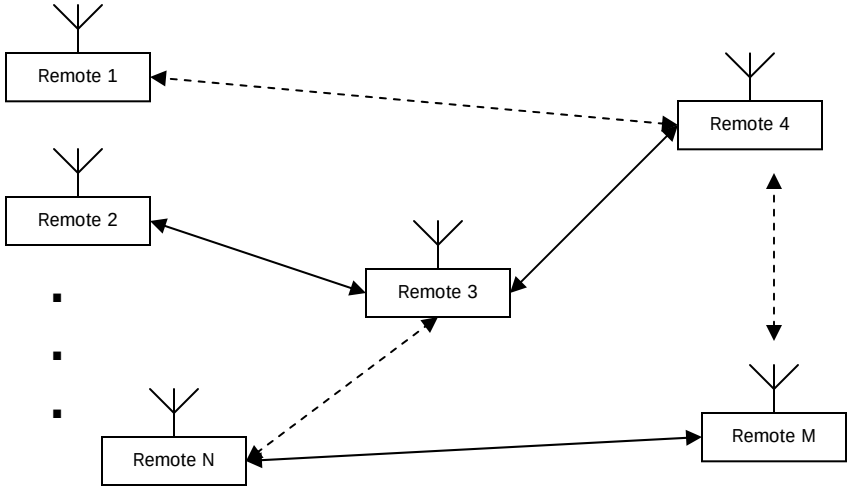

Figure 3.3. Simplified topology of a Peer-to-Peer network.

Section 3.3. Peer-to-Peer network

Advantages:

- More flexible in terms of sending RF packets to/via the neighbor sites;
- Anybody-to-anybody links are possible;
- Every communication site has equal capabilities and responsibilities;
- No need to have a dedicated Master unit = at every given moment the network can be considered as a combination of individual Point-to-Point or Point-to-Multipoint networks;
- Easily scalable.

Disadvantages:

- Lower security of the RF system compare to the Point-to-Point system;
- Higher chances of the in-band interference especially if the sites are mobile.

Section 3.4. TDMA network

Structure

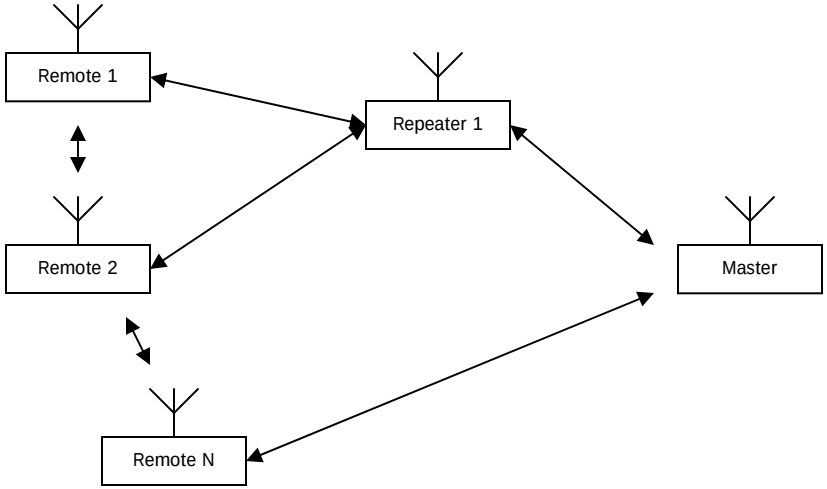

Figure 3.4. Simplified topology of a TDMA network.

Section 3.4. TDMA network

Advantages:

- Multiple nodes in the system can communicate with each other without going through the Master;
- No RF packets collisions = better management of the system's performance;
- Easily scalable.

Disadvantages:

- Lower security of the RF system compare to the Point-to-Point system;
- Any given site in the system needs to sync to the Master before it is ready to communicate with anybody in the network.

Section 3.5. Innovative network topology proposed by Lexycom Technologies

Lexycom's innovative network topology supports the features such as:

- RF links are secure;
- Dedicated time slots for transmissions of some of the remote sites in the system while allocating time slots that are shared by multiple remotes;
- Possibility of anybody-to-anybody communication without going through the central site (Master).

The network topology by Lexycom introduced a set of new options, which bring the conventional Point-to-Point and Point-to-Multipoint networks to a completely new level of functionality.

Summary

Section 1.

- There are several reasons why a wireline technology is selected over a wireless solution for a specific application. The SDR technology addresses these motivations making wireless devices much more suitable for applications in which wires used to be a clear winner for a long time.

Section 2.

- The SDR is one of the most robust/flexible wireless technologies available today. The SDR transceivers are capable of fulfilling most any application requirements in the fields of Highway Engineering, Traffic Control, Remote Data Gathering, and Public Safety.

Section 3.

- Several wireless network topologies were considered during this presentation. Each one of them has been found to be more suitable for a particular application than others. However, Lexycom Technologies proposed a way of combining these topologies into one innovating timing schema. Such a solution combines the advantages of reviewed networks and adds to them a set of valuable unique features and capabilities.