The Microsoft Research Software Radio (Sora) Project is an initiative from the Wireless and Network Group, Microsoft Research Asia.
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Chapter 1.
Introduction

The Sora manual provides reference documentation for Microsoft Research Software Radio, also known as Sora, which is a research project initiated in the Wireless and Networking Group (WNG) at Microsoft Research Asia. Sora is a high-performance fully programmable software radio based on general purpose processors (i.e., CPU) in commodity PC architecture. Sora contains both hardware and software components. The hardware component is a high-speed, low latency Radio Control Board (RCB) that interconnects the RF frontend and the PC memory. RCB is based on PCI-Express interface and is capable of transferring large amounts of digital samples in high speed. All these digital samples are processed by software running on the host CPU. The software component is an SDK, containing critical drivers and libraries for programming and running highly-efficient baseband in real-time on modern multi-core PCs.

The first Sora SDK (Microsoft Research Software Radio Academic Kit), version 1.02, was released to academia in June 2010. An update, version 1.1, was released in November 2010. Sora version 1.5 was released in Sept 2011. This document contains updated information for the latest Sora release.

More information on Sora is available online:

http://social.microsoft.com/Forums/en-us/sora

If you want to obtain Sora hardware, please find more information at


1.1 What is new in Sora SDK ver 1.5?

Sora SDK ver 1.5 substantially changes the implementation of the Sora core library and drivers, providing programmers with a more flexible, robust, and friendly developing environment to
build powerful SDR applications. It also fixes almost all known bugs in the previous versions. The key features of Sora SDK ver 1.5 includes:

- **Full compatible with Windows XP.** Previous Sora versions have several compatibility issues across different variants of Windows XP due to an implementation limitation. Sora SDK ver 1.5 has removed this limitation and is compatible to all Win XP versions by implementing a new scheduler that dynamically assigns best cores to the time-critical threads. While a real-time thread may run on different cores, its execution is not interrupted. The new scheduler also greatly improves the responsiveness of the system compared to previous versions.

- **Full-fledged User-Mode Extension (UMX) API.** The UMX API is first introduced in Sora SDK ver 1.1. The new Sora SDK ver 1.5 has completed a full-fledged UMX API to build powerful SDR applications. A new resource isolation and collection mechanism has been implemented to protect the system against unsafe applications. Zero-copy mechanisms are deployed when accessing both hardware Tx and Rx buffers. Therefore, the overhead and latency of sending/receiving signals in user-mode are reduced to minimum. A new UMX-based 802.11a/b/g decoder is included in the SDK to illustrate the usage of the new UMX API.

- **Enriched tools.** Sora SDK ver 1.5 comes with a set of useful tools for SDR development. The package contains software oscilloscopes for both 802.11b DSSS and 802.11a/g OFDM. It also includes a handy Hardware Verification Tool to test your hardware and also help you find the best parameter settings.

### 1.2 Target Operating Systems

Sora works on Microsoft Windows Operating System. All current versions of Sora require Microsoft Windows XP with Service Pack 3.

Sora also requires Microsoft Windows Driver Kit (WDK) to be compiled. You can download WDK from Microsoft downloads ([http://www.microsoft.com/whdc/DevTools/WDK/WDKpkg.mspx](http://www.microsoft.com/whdc/DevTools/WDK/WDKpkg.mspx)).

### 1.3 Target Hardware

In theory, Sora should work with any modern commodity multi-core PC with one spare PCIe-x8 or PCIe-x16 slot. Since Sora performs all Digital Signal Processing (DSP) in software, you may
want to equip the PC with the latest CPU and as many cores as affordable. As a general guidance, a quad-core CPU clocked at 2.66GHz or higher is recommended to run real-time software radio applications like WiFi. Most Sora DSP software requires Intel SSE3 and above. Therefore, you should double-check your CPU data-sheet to verify that SSE3 instructions are supported (most Intel CPUs in the market should already support it).

Sora requires a compatible Radio Frequency (RF) Front-end to communicate over the air. Currently, two RF boards are supported: RICE WARP RF daughter board and USRP XCVR2450 daughter board. Both are 2.4G/5GHz radios. In the future, we hope to support more and more compatible RF front-ends. Please visit the Sora web site and forums for updated information.

Sora also requires an RF-specific Adaptor Board (RAB) to connect either USRP or WARP daughter board to the RCB. You can find their order information on the Sora web site. The USRP RAB further comes pre-clocked with two different rates: 40MHz or 44MHz, providing a sampling rate of 40MSps or 44MSps respectively. Choosing which clock rate depends on your application. If you mainly work with OFDM like 802.11a/g, you may find it handy to use 40MHz RAB. Otherwise, if you want to work with 802.11b-like system, you can choose 44MHz RAB. WARP daughter board only comes with 40MSps sampling rate.

Table 1 summarizes the hardware requirements for Sora.

Table 1. Hardware requirements for the Microsoft research Software Radio

<table>
<thead>
<tr>
<th>CPU/Freq</th>
<th>quad-core/2.66GHz (or above)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Memory</td>
<td>1GB or above</td>
</tr>
<tr>
<td>PCIe-x8/x16 slot</td>
<td>1</td>
</tr>
<tr>
<td>Hard Disk</td>
<td>100M of free space</td>
</tr>
<tr>
<td>Radio hardware</td>
<td>Microsoft Research Software Radio Control Board (RCB)</td>
</tr>
<tr>
<td></td>
<td>Compatible RF front-end boards (currently, WARP RF daughter board or USRP XCVR2450 board with respective RF Adaptor Board)</td>
</tr>
</tbody>
</table>
Chapter 2.
Getting Started

2.1 Install Sora SDK

After you download the Sora SDK package, you can simply run SoraSDK.msi and follow the on-screen instructions to install software. The Sora SDK package contains the following components:

- The Sora core driver for the RCB.
- The HwTest driver - implementing user-mode extension.
- The sample SoftWiFi driver – a kernel-mode miniport driver implementing full functional IEEE 802.11a/b/g.
- Hardware Verification Tool – helping to test and configure the hardware.
- Software oscilloscopes for 802.11a/b/g.
- Other samples and tools.

Section 2.5 shows a complete directory tree of the Sora SDK ver 1.5.

2.2 Install RCB Driver and HwTest Driver

Before you install the RCB driver, please make sure that the RCB board is firmly plugged into your motherboard and a RF front-end is properly connected to the RCB. Please follow the instructions in "Sora Device Drivers Installation.pdf" to install and configure the RCB driver.

Then, you can install the HwTest driver. HwTest implements user-mode extension API that allows applications to access the Sora radio resource. You can use Windows Device Manager “Add Hardware Wizard” to install them. You should choose ‘manually add a new driver’ and specify the driver files location. The binary of the HwTest driver is located at %SORA_ROOT%\bin\hwtest\.
Any time if you want to reset the RCB driver, you should reset the RCB hardware as well. After disabling the RCB driver, you should press the reset buttons on both RCB and the RAB (if you use USRP RF daughter boards) before you re-enable the RCB driver again. These reset buttons are shown in the following Figure 1.

![Reset buttons on USRP RAB (left) and RCB (right).](image)

**Figure 1.** Reset buttons on USRP RAB (left) and RCB (right).

### 2.3 Test Hardware

#### 2.3.1 Hardware Verification Tool

Sora SDK ver1.5 includes a new handy tool for testing your hardware: the Hardware Verification Tool (HVT). HVT allows you to visually verify your RF hardware and tune proper parameter settings (like central frequency offset and Tx/Rx gains).

You need two Sora boxes to run HVT, one as the sender and the other as the receiver. Before starting HVT, you should make sure both the RCB driver and the HwTest driver are enabled. Once you start HVT (you can find a short-cut at “Start Menu->Sora->Tools->Hardware Verification Tool”), you will see the following window, as shown in Figure 2. Table 2 provides a reference to each element on the HVT main window.
Figure 2. The main window of HVT.

Table 2. HVT Reference.

<table>
<thead>
<tr>
<th>Label</th>
<th>Name</th>
<th>Remark</th>
</tr>
</thead>
<tbody>
<tr>
<td>a</td>
<td>Test method selection</td>
<td>Select test type (sine test/SNR test).</td>
</tr>
<tr>
<td>b</td>
<td>Start button</td>
<td>Start/stop a test.</td>
</tr>
<tr>
<td>c</td>
<td>Dump button</td>
<td>Take a snapshot of the received signal and save it to a dump file. It</td>
</tr>
<tr>
<td></td>
<td></td>
<td>is only available when HVT is working in the receiver mode.</td>
</tr>
<tr>
<td>d</td>
<td>Suggestion button</td>
<td>Open a what-to-do document. Only available when HVT is working in the</td>
</tr>
<tr>
<td></td>
<td></td>
<td>receiver mode.</td>
</tr>
<tr>
<td>e</td>
<td>Auto calibration button</td>
<td>Start an automatic central frequency offset (CFO) calibration.</td>
</tr>
<tr>
<td>f</td>
<td>DC value</td>
<td>Show the Direct Current value of the received signal.</td>
</tr>
<tr>
<td>g</td>
<td>Central Frequency Offset</td>
<td>Show the central frequency offset between the receiver and the sender.</td>
</tr>
<tr>
<td>h</td>
<td>I/Q imbalance</td>
<td>Show the I/Q imbalance of the received signal (amplitude and phase).</td>
</tr>
<tr>
<td></td>
<td></td>
<td>It is only available in the sine test mode.</td>
</tr>
<tr>
<td>i</td>
<td>Signal-to-Noise Ratio (SNR)</td>
<td>Show the SNR of the currently received signal. It is only available in</td>
</tr>
<tr>
<td></td>
<td></td>
<td>the SNR test mode.</td>
</tr>
<tr>
<td>j</td>
<td>Status bar</td>
<td>Show the current status message.</td>
</tr>
<tr>
<td>---</td>
<td>------------</td>
<td>---------------------------------</td>
</tr>
<tr>
<td>k</td>
<td>Log window</td>
<td>Show the full logs during the test.</td>
</tr>
<tr>
<td>l</td>
<td>Save log button</td>
<td>Save the logs into a text file.</td>
</tr>
<tr>
<td>m</td>
<td>Clear button</td>
<td>Clear the logs.</td>
</tr>
<tr>
<td>n</td>
<td>Save parameter button</td>
<td>Save the parameters into a configuration file.</td>
</tr>
<tr>
<td>o</td>
<td>Load button</td>
<td>Load the parameters from a configuration file.</td>
</tr>
<tr>
<td>p</td>
<td>AGC enable/disable</td>
<td>Check/uncheck to enable/disable AGC (Automatic Gain Control).</td>
</tr>
<tr>
<td>q</td>
<td>RxPa selection</td>
<td>Select the value for RxPa. RxPa refers to the Low Noise Amplify (LNA) at the receiving chain of USRP XCRV2450. It has three valid settings: 0 or 0x1000 – 0dB; 0x2000 – 16dB; 0x3000 – 32dB.</td>
</tr>
<tr>
<td>r</td>
<td>Sampling rate</td>
<td>Set the sampling rate of the RAB (40/44MHz).</td>
</tr>
<tr>
<td>s</td>
<td>Central Frequency</td>
<td>Select the Central Frequency (channel) of the radio.</td>
</tr>
<tr>
<td>t</td>
<td>Gain adjustment</td>
<td>Drag to change gain setting. In the sender mode, it changes the Tx gain; While in the receiver mode, it changes the Rx gain of the radio chip.</td>
</tr>
<tr>
<td>u</td>
<td>Mode selection</td>
<td>Choose the sender or receiver mode of HVT.</td>
</tr>
</tbody>
</table>

HVT can perform two tests between two Sora boxes: the sine test (single tone test) and the SNR test (wide-band test). In the sine test, the sender transmits one single 1MHz sine waveform. Using this waveform, the receiver can compute the Central Frequency Offset (CFO) between the sender and receiver radio, and reveal the best receiver gain setting. To perform a sine test, you can follow the steps listed below:

1. Run HVT on two Sora boxes. Select “sine test” at both machines.
2. Configure one as the sender and the other as the receiver.
3. Select the sampling rate at the receiver that matches your RAB sampling rate.
4. Click “start” at the sender. You may notice the sender’s status bar displays the message “Sending 1MHz sine wave”.
5. Click “start” at the receiver. Now you should be able to see the received signal like Figure 3. The left window shows the energy plot of the signal and the right window shows the constellation plot of I/Q samples. Since the transmitted signal is single sine waveform, the constellation plot is a circle.
You can perform the SNR test by selecting the SNR test mode and follow the similar steps as in the sine test. In the SNR test, the sender transmits a wide-band 16-QAM modulated OFDM signal. Figure 4 shows the received signal in both energy plot and constellation plot in the SNR test. The actual SNR value is displayed in the SNR field in the main window.

You can further use HVT to find the best receiver gain parameters, I/Q imbalance and the CFO between the two Sora boxes. For a complete reference of HVT, please refer to Chapter 10.4.

### 2.3.2 Receiving frames from a commercial WiFi card

If you have only a single set of Sora machine, you can use it as the receiver and use a laptop with WiFi interface as the sender. The laptop should support flexible WiFi configurations (e.g.,

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**Figure 3. Received signal from the sine test.**

**Figure 4. Received signal from the SNR test.**
Atheros NIC with MadWiFi driver) because you will need to set it to ad hoc mode with SSID “sdr” at channel 3 (by default, the HwTest driver configures the RF front-end to channel 3). You will also need a tool like iperf to send out broadcast packets.

At the Sora machine (receiver), you can use **dut.exe** to take a snapshot of the channel with the following command sequence (text following “##” are comments and not meant to be included in the command line).

```plaintext
  dut start  # start the HwTest driver
  dut centralfreq --value 2422  # channel 3 in 2.4GHz band
  dut rxpa --value 0x2000
  dut rxgain --value 0x1000
  dut dump  # store a snapshot of channel signal in a dump file
```

The generated dump file is located at **c:\** with the “.dmp” extension. You can easily identify them by examining the file creation time.

You can use the software oscilloscope tools to view the stored signals. These tools are located at **%SORA_ROOT%\bin**. If the source signal is 802.1b (DSSS) signal, you should use **sdscope-11b.exe** to view the recorded signal. Otherwise, you should use **sdscope-11a.exe** to view OFDM modulated signals. After you start the software oscilloscope tool (e.g. **sdscope-11b.exe**), you can press ‘o’ to bring up an open file dialog window, from which you can select the newly stored dump file. **sdscope-11b** decodes and displays the result in screen as shown in Figure 5.

To view dumped OFDM signals (802.11g rates of 6Mbps ~ 54Mbps) with **sdscope-11a**, you should also specify the sampling rate of the RAB with following command lines,

```plaintext
  sdscope-11a.exe -s40  # If your RAB’s sampling rate is 40MSps
  or,
  sdscope-11a.exe -s44  # If your RAB’s sampling rate is 44MSps
```
2.4 Build and Install SoftWiFi Driver

2.4.1 Build environment

You need to install Windows Driver Kit (WDK) before you can compile the sample SoftWiFi miniport Driver. You can download WDK from Microsoft downloads.

The installer of Sora SDK package has created two shortcuts to build command windows in the start-menu (located in Start\Programs\Microsoft Research Asia\Software Radio Academic Kit 1.5). Before you can use them, you should configure the WDK path by adding an environment variable, WINDDK_ROOT. This variable should point to the root path of the WDK. Environment variables are configured using Windows Control Panel. Figure 6 shows a screen snapshot when you add a new environment variable on Windows XP.
Then, you can click the menu item of “SORA Build Environment (Free)” to open a command window. You can type the command “bcz” to build the SoftWiFi driver (the sample SDR miniport driver), Sora User-mode Extension (UMX) samples and other tools. All target files (like .exe, .dll, .lib, .sys, etc.) are generated in the folder %SORA_ROOT%\target\fre(chk)_wxp_x86\i386.

![Environment Variables](image)

**Figure 6. Setting up WINDDK_ROOT environment variable.**

### 2.4.2 Install SoftWiFi Driver

After you successfully build the SoftWiFi source, the driver binary is generated at %SORA_ROOT%\target\fre(chk)_wxp_x86\i386, where you can also find the corresponding inf file (sdr.inf). You can use “Add Hardware Wizard” to install them on Windows. You should choose ‘manually add a new driver’ and specify the driver files location. Since the HwTest and SoftWiFi drivers are contending the hardware resources through the RCB driver, they cannot be enabled simultaneously. You should disable the HwTest driver before enabling the SoftWiFi driver. The SoftWiFi driver can be configured into DSSS mode (802.11b) or OFDM mode.
(802.11a/g). The default mode is OFDM. To change to a different mode, you can modify the `ModMode` registry entry in sdr.inf by specifying value of “802.11a” or “802.11b”.

The SoftWiFi driver exposes an Ethernet interface to the operating system. You can try to use the SoftWiFi driver to communicate with a commercial WiFi card in real-time. You should make sure the SoftWiFi driver is configured in a proper mode, i.e. DSSS (802.11b) or OFDM (802.11a/g) (The default mode is OFDM). If you are using OFDM mode, you should also make sure you have specified the same sampling rate in sdr.inf file as your RAB. Chapter 2.4.3 lists all configurations to the SoftWiFi driver.

### 2.4.3 Configure the SoftWiFi driver

The sample SoftWiFi driver can be configured by editing entries in sdr.inf file.

**Table 3. Configuration with SDR.INF.**

<table>
<thead>
<tr>
<th>Entry Name</th>
<th>Description</th>
<th>Type</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>NetworkAddress</td>
<td>MAC address</td>
<td>String</td>
<td>The default value is &quot;02-50-F2-00-00-01&quot;. This default value will make the driver to randomly select last three bytes as the MAC address. A user can explicitly specifies a MAC address if needed (the last three bytes cannot be “00-00-01”)</td>
</tr>
<tr>
<td>BSSID</td>
<td>Basic service set identification</td>
<td>String</td>
<td>The driver will automatically replace the value from a valid beacon it receives.</td>
</tr>
<tr>
<td>ModMode</td>
<td>Protocol of modulation and demodulation</td>
<td>String</td>
<td>802.11a / 802.11b</td>
</tr>
<tr>
<td>11ADataRate</td>
<td>Data rate in Mbps in 802.11a modulation</td>
<td>String of decimal number</td>
<td>6 / 9 / 12 / 18 / 24 / 36 / 48 / 54</td>
</tr>
<tr>
<td>DataRate</td>
<td>Data rate in 100</td>
<td>String of hex-</td>
<td>0x0A / 0x14 / 0x37 /</td>
</tr>
<tr>
<td>kbps in 802.11b modulation</td>
<td>number</td>
<td>0x6E (in unit of 100Kbps)</td>
<td></td>
</tr>
<tr>
<td>----------------------------</td>
<td>--------</td>
<td>---------------------------</td>
<td></td>
</tr>
<tr>
<td>ModSelect</td>
<td>Modulation option in 802.11b modulation</td>
<td>String of number</td>
<td>0 for CCK, 1 for PBCC</td>
</tr>
<tr>
<td>PreambleType</td>
<td>Preamble type in 802.11b modulation</td>
<td>String of number</td>
<td>0 for long, 1 for short</td>
</tr>
<tr>
<td>SampleRate</td>
<td>sample rate in MHz of the radio PCB</td>
<td>String of number</td>
<td>40 / 44MSps</td>
</tr>
</tbody>
</table>

## 2.5 Directory Structure

The directory structure shown here assumes the Sora SDK is installed at d:\SORASDK1.5

<table>
<thead>
<tr>
<th>D:\SORASDK1.5</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>\AcademicKit-LA.pdf</td>
<td>Agreement to purchase the academic kit</td>
</tr>
<tr>
<td>\MSR-LA.pdf</td>
<td>MSR License agreement</td>
</tr>
<tr>
<td>\Sample Code-LA.pdf</td>
<td>MSR License agreement for the sample source code</td>
</tr>
<tr>
<td>\Readme.htm</td>
<td>The ReadMe file</td>
</tr>
<tr>
<td>---</td>
<td>---</td>
</tr>
<tr>
<td>\bin</td>
<td></td>
</tr>
<tr>
<td>| dut.exe</td>
<td>Hardware diagnosis tool. Run dut without any command line parameter for help.</td>
</tr>
<tr>
<td>| HwVeri.exe</td>
<td>A helpful tool to test and configure Sora hardware components. Refer to Chapter 10.4 for detail.</td>
</tr>
<tr>
<td>| dot11config.exe</td>
<td>SDR miniport driver configuration tool. See Chapter 9.1 for command line reference. Source code provided in %SORA_ROOT%\src\driver\SDRMiniport\dot11config</td>
</tr>
<tr>
<td>| demod11.exe</td>
<td>Command line tool to demodulates 802.11a(b) dump files and displays statistics about data frames. Source code provided in %SORA_ROOT%\src\bb\demod11</td>
</tr>
<tr>
<td>| UMXDot11.exe</td>
<td>User mode 802.11 decoder based on UMX. It has a full featured 802.11a/b/g decoder. It is also able to modulate a frame and send it through UMX. Refer to Chapter 7.4 for detail. Source code provided in %SORA_ROOT%\src\bb\UMXDot11</td>
</tr>
<tr>
<td>| sdscope-11a.exe</td>
<td>User mode utility which demodulates 802.11a frames from dump file and displays intermediate results in GUI. Refer to Chapter 10.2 for detail.</td>
</tr>
<tr>
<td>sdscope-11b.exe</td>
<td>User mode utility which demodulates 802.11b frames from dump file and displays intermediate results in GUI. Refer to Chapter 10.2 for detail.</td>
</tr>
<tr>
<td>SrView.exe</td>
<td>A simple Sora dump file viewer. See Chapter 10.3 for detail.</td>
</tr>
<tr>
<td>IntFiltr.reg</td>
<td>Interrupt-Affinity Filter registry setting</td>
</tr>
<tr>
<td>IntFiltr.sys</td>
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Chapter 3.  
Sora Fundamentals

3.1 Architecture

The overall system architecture of Sora is illustrated in Figure 7. The RCB interconnects RF front-ends to the PC. The RCB talks to the PC using the PCI-E interface, and with read/write digital signal samples from/to PC memory using direct memory access (DMA). It connects to the RF front-end boards with the Sora Fast Radio Link (SoraFRL). SoraFRL defines the necessary protocol for the RCB to control the RF boards. Any Sora compatible RF boards should implement SoraFRL. For more information on SoraFRL, please refer to the “Sora Fast Radio Link Specification”.

![Figure 7. Sora System Architecture.](image)

Figure 8 shows the Sora software architecture. The RCB driver manages the RCB and RF front-end hardware resources and provides APIs to the SDR miniport driver to send/receive digital waveform samples. The SDR miniport driver usually exposes an Ethernet interface to the operating system, so that all network applications can seamlessly use it for communication. In Sora SDK, a sample SDR miniport driver, named SoftWiFi, is provided, which implements the 802.11a/b/g protocol. Alternatively, one can write user-mode SDR application programs that
interact with RCB/RF hardware through *Sora User-Mode Extension API (UMX API)*. Sora SDK version 1.5 provides a set of highly optimized UMX API to facilitate high performance and low latency DSP implementation in user-mode, including exclusive thread library, zero-copy sample transport and integration with network stack. This new UMX framework allows programmers to implement sophisticated user-mode SDR drivers, and greatly reduces the development efforts. In Sora SDK version 1.5, we provide a sample UMX application that implements a full featured 802.11a/b/g receiver entirely in user-mode.

![Figure 8. Sora Software Architecture.](image)

Figure 9 shows the architecture of a typical Sora SDR miniport driver. It usually exposes an Ethernet interface to the operating system based on the Windows NDIS framework. A SDR miniport driver should implement the lower three layers, i.e. the link layer, MAC and the physical layer. The link layer performs the frame conversion and encapsulation. For example, in the sample SoftWiFi driver, the link layer converts the Ethernet frames to 802.11 frames and back before and receiving. The MAC layer is basically a finite state machine (FSM) that handles media access protocols. A set of FSM APIs are provided in Sora SDK to facilitate the MAC programming. The Physical layer (PHY) contains all implementation of the baseband signal...
processing. The basic routines that need to be implemented are modulation, demodulation and channel monitoring (carrier sensing).

For ease of cross-reference, a global context, called SDR_CONTEXT, is used in the sample SoftWiFi driver to pass data across different layers. This SDR_CONTEXT also contains pointers to other useful data structures and is used as the sole parameter for many routines in the SoftWiFi driver.

![Typical Architecture of a Sora application Driver](image)

**Figure 9. Typical Architecture of a Sora application Driver.**
3.2 Abstract Radio and Radio Object

An Abstract Radio (AR) is a software abstract of radio hardware. An abstract radio contains a Tx channel, a Rx channel, and a set of control registers. A SDR application – either a SDR miniport driver or a UMX-based user-mode program – is operating on abstract radio objects (ARO). The RCB driver and hardware map every ARO to a real RF front-end. Figure 10 illustrates the Abstract Radio architecture. If a SDR application sets a Control Register of an ARO, the command is transferred to the RAB through the RCB driver and firmware. The RAB firmware is responsible to translate the abstract command into the real operation sequence to the RF front-end chipset. With this architecture, the same SDR application can ran on various RF front-end without modification. Current RCB supports up to eight ARs. These ARs can map to different RF front-ends, or they can be grouped to form a MIMO system.

![Figure 10. Abstract Radio Architecture.](image)

An ARO is represented as a SORA_RADIO structure. Figure 11 shows partial definition of the structure. The full definition of SORA_RADIO can be found in the header file _radio_manager.h. __ctrl_reg refers to the abstract control registers, _rx_queue manages the Rx channel, and pTxResMgr manages the TX channel. Each AR is allocated a unique hardware ID as shown in RadioID. To read from the Rx channel, a SDR driver can use a helper object named SORA_RADIO_RX_STREAM. The RX_STREAM object hides the structure of RCB DMA buffer and provides a simple stream of I/Q samples received from the RF front-end. Each ARO is allocated single buffer for transmission, called TX sample buffer. Any modulated waveform samples are placed in this buffer, from where they are downloaded into the RCB and sent to the RF front-
end. The TX sample buffer is initialized at the beginning and is a shared resource. Therefore, when the SDR driver uses multiple threads for modulation, the access to the TX sample buffer from different threads should be properly coordinated by __TxBufLock.

The RCB hardware may also send PnP events to software. These PnP events may be passed to a SDR driver as well. In particular, two PnP events should be monitored for a SDR driver. They are:

1) **Power management notification.** This event is defined as **PnPEvent** in a SORA_RADIO object. The SDR driver is encouraged to monitor the event to handle unexpected disconnection or power outage of the RF radio board.

2) **Force release event.** This event is actually generated by the RCB driver when it detects an abnormal behavior of RCB, or if it is being unloaded. When receiving this event, the SDR driver should release the resource immediately. The event is shown as **ForceReleaseEvent** in the SORA_RADIO definition.

```c
/*
 SORA_RADIO defines the basic abstract to a hardware radio.
 A Sora radio contains mainly three parts:
 1) A Control channel - control registers
 2) A Rx channel - Rx queues, further wrapped as rx_stream
 3) A Tx channel - Tx buffer, further with Tx resources.
 */
typedef struct __SORA_RADIO {
    LIST_ENTRY RadiosList;

    __HW_REGISTER_FILE __ctrl_reg;

    __RX_QUEUE_MANAGER __rx_queue;

    PTX_RM pTxResMgr;

    ULONG __radio_no; //radio index
    ULONG RadioID;    //unique radio id

    __SORA_RADIO_STATUS __status;    // radio status
    ULONG __uRxGain;
    ULONG __uTxGain;

    KSPIN_LOCK __HWOpLock;//DMA upload and TX lock
    LOCK __Lock;

    KEVENT ForceReleaseEvent;
    KEVENT PnPEvent;

    /* Context - usually linked to a PHY bond on the radio */
    PVOID __pContextExt;
}
```
3.2.1 Radio Allocation and Release

The SDR driver should allocate abstract radios before accessing the radio resources, e.g., TX channel, RX channel, or control registers. Abstract radios should also be released to the system when no longer being used. Function `SoraAllocateRadioFromDevice` is used to allocate one or more radios. Prepare a linked list to hold the returned SORA_RADIO objects before calling the function. A name tag is provided by the caller to track the radio usage.

The SDR driver should call `SoraReleaseRadios` to release the allocated radio objects.

3.2.2 Radio Configuration and Start

After allocating a radio, the SDR driver should call `SoraRadioInitialize` to allocate TX and RX resources for the radio object. After initialization, the SDR driver can call `SoraRadioStart` to enable the abstract radio on the RCB. The function call also provides the Tx/Rx gain settings.

3.2.3 Radio example

Figure 12 shows a code piece that illustrates the allocation and initialization of a SORA_RADIO object. You can find the full function in `sdr_phy_main.c` in the SDK.

```
HRESULT SdrPhyInitialize( PPHY pPhy, PSDR_CONTEXT SDRContext, ULONG ulRadioNum )
{
    HRESULT hRes = S_OK;
    LIST_ENTRY* pRadiosHead = &pPhy->RadiosHead;
    ...
    hRes = SoraAllocateRadioFromRCBDevice ( pRadiosHead, ulRadioNum, NIC_DRIVER_NAME);
    If ( FAILED ( hRes ) )
    {
        DbgPrint("[Error]SoraAllocateRadioFromRCBDevice failed\n");
    }
```
3.3 Transfer and Transmission

Before sending out a waveform, a SDR driver should first download the waveform samples onto the onboard memory of the RCB. Then, the SDR driver can issue another command to instruct the RCB to emit the waveform through the RF front-end. The download operation is referred as transfer, and we denote transmission (or simply TX) the behavior the send out waveform. The benefits of this two-phase operation are two-folds. First, the RCB’s on-board memory naturally absorbs the potential burstiness of the CPU processing and the PCIe-Bus communication, thereby ensuring the correctness of the waveform transmission. Second, the RCB memory can also be used to store pre-modulated signals, providing additional flexibility.

3.3.1 PACKET_BASE object

A SDR driver uses a PACKET_BASE object to allocate TX resources of an abstract radio object. The PACKET_BASE object also contains a pointer to the original packet data. Figure 13 shows the definition of the PACKET_BASE object, which can also be found in _packet_base.h.
typedef struct __PACKET_BASE
{
    PMDL      pMdl;   // memory descriptors for original packet data
    PTX_DESC  pTxDesc; // Refers to TX channel of an Abstract Radio
    LONG      fStatus;
    ULONG     PacketSize;
    ULONG     Reserved1; // for customized attachment
    ULONG     Reserved2; // for customized attachment
    ULONG     Reserved3; // for customized attachment
    ULONG     Reserved4; // for customized attachment
    PVOID     pReserved;
} PACKET_BASE;

Figure 13. Definition of PACKET_BASE object.

A PACKET_BASE object has a pointer to a Memory Descriptor List (MDL) that describes the data in the original packet. MDL is a common data structure in the Windows kernel to describe a memory buffer. For more information of the MDL, the reader may refer to WDK references.

The fStatus field tracks the packet’s current status. The SDR application driver should check this status before conducting operations on it. The status can be one of following:

- **PACKET_NOT_MOD**: The modulated waveform of the packet has not been generated.
- **PACKET_TF_FAIL**: The Transfer operation failed.
- **PACKET_CAN_TX**: The Transfer operation succeeded. So the modulated waveform is not in the RCB Waveform Cache and is ready for Transmission.
- **PACKET_TX_PEND**: The modulated waveform is being transmitted.
- **PACKET_TX_DONE**: The Transmission is done.

If a PACKET_BASE object is in the **PACKET_TF_FAIL** state, the SDR driver should not attempt to transmit it.

3.3.2 Modulation

A SDR driver should call **SoraPacketGetTxResource** to bind a PACKET_BASE object to the TX channel for a radio. **SoraPacketGetTxResource** will initialize the status to **PACKET_NOT_MOD**. Then, the SDR driver can call **SoraPacketGetTxSampleBuffer** to obtain a sample buffer to hold the waveform generated. The structure of this modulation sample buffer is shown in Figure 14. It is basically an array of complex I/Q samples. Each I and Q component is 8-bit. The sample with the smallest address is transmitted first by the RF front-end board.
Once the SDR driver gets the modulation sample buffer, it should immediately generate waveform samples from the packet data (modulation). The SDR application driver should call SoraPacketSetSignalLength to specify the size of the buffer that is actually filled with the waveform samples. The size MUST be a multiple of 128 bytes. Therefore, some padding may be needed to ensure this.

3.3.3 Transfer and Transmission

A SDR driver calls SORA_HW_TXTRANSFER to download the waveform samples from the Tx sample buffer to the RCB’s memory. After the transfer operation, the SDR driver can call SORA_HW_BEGIN_TX to instruct the RCB to send out the waveform. After the transmission, the SDR application driver should call SoraPacketFreeTxResource to unbind the PACKET_BASE object from the radio’s TX channel.

3.3.4 Example

Figure 15 shows a code excerpt for an SDR application driver to bind packets to the radio TX channel and call PHY layer functions to modulate the packet data to waveform samples. The full code can be found in sdr_mac_send.c. Figure 16 shows an excerpt where an SDR application driver instructs the RCB to transmit a waveform already stored in the RCB’s memory. The full code can be found in sdr_mac_tx.c.

```c
VOID SdrMacSendThread ( IN PVOID pVoid )
{
    NTSTATUS Status;
    HRESULT hRes;
    LARGE_INTEGER Delay;
    PDLCB pTCB = NULL;
    PSDR_CONTEXT pSdrContext = SORA_THREAD_CONTEXT_PTR(SDR_CONTEXT, pVoid);
    PMAC pMac = (PMAC)pSdrContext->Mac;
    PPHY pPhy = (PPHY)pSdrContext->Phy;
    PSEND_QUEUE_MANAGER pSendQueueManager = GET_SEND_QUEUE_MANAGER(pMac);
    PSORA_RADIO pRadio = NULL;

    // Thread start
    ...
    Delay.QuadPart = -10 * 1000 * 10;
}```
do
{
    ...pRadio = RadioInPHY(pPhy, RADIO_SEND);
do
{
    // Try to dequeue a pending packet and do modulation
    SafeDequeue(pSendQueueManager, SendSrcWaitList, pTCB, DLCB);
    if (!pTCB)
    {
        break;
    }
}
if (!DLCB_CONTAIN_VALID_PACKET(pTCB)) // invalid packet, pass through the pipeline
{
    SafeEnqueue(pSendQueueManager, SendSymWaitList, pTCB);
    InterlockedIncrement(&pSendQueueManager->nSymPacket);
    InterlockedDecrement(&pSendQueueManager->nSrcPacket);
    continue;
}

// Allocate Tx Channel Resource for a packet
if (!IS_PACKET_NO_RES(&pTCB->PacketBase))
{
    hRes = SoraPacketGetTxResource(pRadio, &pTCB->PacketBase);
    if (FAILED(hRes))
    {
        InterlockedIncrement(&pSendQueueManager->nSymPacket);
        InterlockedDecrement(&pSendQueueManager->nSrcPacket);
        SafeEnqueue(pSendQueueManager, SendSymWaitList, pTCB); // let it go
        DbgPrint("[Transfer][Error] insufficient TX resource \n");
        break;
    }
}
else
{
    KeBugCheck(BUGCODE_ID_DRIVER); // src packet should not own TX resource.
}

// Call PHY Modulation Routine
hRes = (*pPhy->FnPHY_Mod)(pPhy, &(pTCB->PacketBase));

// Transfer operation
hRes = SORA_HW_TX_TRANSFER( pRadio, &pTCB->PacketBase);
SoraPacketAssert(&pTCB->PacketBase, pRadio); // for verification.
if (FAILED(hRes))
{
    SoraPacketPrint(&pTCB->PacketBase);
    SoraPacketFreeTxResource(pRadio, &pTCB->PacketBase);
    InterlockedIncrement(&pPhy->HwErrorNum);
}
SafeEnqueue(pSendQueueManager, SendSymWaitList, pTCB);
InterlockedIncrement(&pSendQueueManager->nSymPacket);
InterlockedDecrement(&pSendQueueManager->nSrcPacket);
// both case: let the packet go.
} while (TRUE);

while(!IS_SORA_THREAD_NEED_TERMINATE(pVoid));
// Thread cleanup
...
VOID
SdrMacTx(IN PFSM_BASE StateMachine)
{
HRSENULT hRes = S_OK;
PSDR_CONTEXT pSDRContext = SoraFSMGetContext(StateMachine);
PMP_ADAPTER pAdapter = (PMP_ADAPTER)pSDRContext->Nic;
PMAC pMac = (PMAC)pSDRContext->Mac;
PPHY pPhy = (PPHY)pSDRContext->Phy;
PSEND_QUEUE_MANAGER pSendQueueManager = GET_SEND_QUEUE_MANAGER(pMac);
PSORA_RADIO pRadio = RadioInPHY(pPhy, RADIO_SEND);
PDLCB pTCB = NULL;
do
{
SafeDequeue(pSendQueueManager, SendSymWaitList, pTCB, DLCB);
if (!pTCB)
{
break;
}
if (pTCB->PacketBase.fStatus == PACKET_TF_FAIL) //The packet can't be TX out, so complete it.
{
  DbgPrint("[TX][Error] I can't tx it out because transfer fail, make it TXDone to complete\n");
  // skip the packet
  ...
  break;
}
pMac->fTxNeedACK = (pTCB->PacketType == PACKET_NEED_ACK);
pTCB->RetryCount++;
  // Start transmission
hRes = SORA_HW_BEGIN_TX(pRadio, &pTCB->PacketBase);
if (FAILED(hRes))
{
  DbgPrint("[TX][Error] TX hardware error , ret=%08x\n", hRes);
  SoraHwPrintDbgRegs(pRadio);
  InterlockedIncrement(&pPhy->HwErrorNum);
}
if ( !IS_MAC_EXPECT_ACK(pMac) || pTCB->RetryCount > TX_RETRY_TIMEOUT)
{
Pcb->bSendOK = (pTCB->RetryCount <= TX_RETRY_TIMEOUT);
  // if retry is not so big, assume it is sent out successfully.
  SoraPacketFreeTxResource(pRadio, &pTCB->PacketBase);
  SoraPacketSetTXDone(&pTCB->PacketBase);
  InterlockedIncrement(&pSendQueueManager->nCompletePacket);
  InterlockedDecrement(&pSendQueueManager->nSymPacket);
  SafeEnqueue(pSendQueueManager, SendCompleteList, pTCB);
  //MarkModulatedSlotAsTxDone(pSendQueueManager); //dequeue the packet from send queue
  SDR_MAC_INDICATE_PACKET_SENT_COMPLETE(pMac); //indicate to complete NDIS_PACKET MAC_DISLIKE_ACK(pMac); // we don't need ACK any more.
} else
{
SafeJumpQueue(pSendQueueManager, SendSymWaitList, pTCB);
  //wait for ack to retry or complete
}
3.4 Reception

The RX channel of a radio is enabled by `SORA_HW_ENABLE_RX`. The SDR driver can read the RX channel through an `RX_STREAM` object. The SDR driver can obtain a `RX_STREAM` object by calling `SoraRadioGetRxStream`. The RX channel of a radio is organized as a stream of signal blocks. Each signal block contains an array of 28 complex I/Q samples. The I or Q component are both 16-bit long. Figure 17 shows the structure of a signal block. Function `SoraRadioReadRxStream` loads a signal block into memory. It is a blocking function that will not return until a full signal block is delivered from the RCB (or timeout). The `pbTouched` flag is set when the returned signal block is the last block in the RX channel, i.e., the most recently received signal block. The SDR driver can use `__SoraRadioSetRxStreamPos` to obtain the current position of the RX channel.

![Figure 17. Structure of a signal block.](image-url)
3.4.1 Example

Figure 18 shows sample code to read from an RX_STREAM object. The full code can be found in bbb_spd.c.

```c
HRESULT BB11BSpd(PBB11B_SPD_CONTEXT pSpdContext, PSORA_RADIO_RX_STREAM pRxStream)
{
    // ...
    FLAG touched;
    ULONG PeekBlockCount = 0;
    HRESULT hr = S_OK;
    SignalBlock block;
    do
    {
        // ...
        while (TRUE)
        {
            hr = SoraRadioReadRxStream(pRxStream, &touched, block);
            FAILED_BREAK(hr);
            // Estimate and update DC offset
            // ...
            PeekBlockCount++;
            // Measure energy
            // ...
            if (energyLevel != EL_NOISE)
            {
                if (pSpdContext->b_gainLevel == 0 && energyLevel == EL_HIGH)
                    pSpdContext->b_gainLevelNext = 1;
                else if (pSpdContext->b_gainLevel == 1 && energyLevel == EL_LOW)
                    pSpdContext->b_gainLevelNext = 0;
                pSpdContext->b_evalEnergy = BlockEnergySum[0];
                hr = BB11B_OK_POWER_DETECTED;
                break;
            }
            if (touched && PeekBlockCount > pSpdContext->b_minDescCount)
            {
                hr = BB11B_CHANNEL_CLEAN;
                break;
            }
            if (PeekBlockCount >= pSpdContext->b_maxDescCount)
            {
                hr = BB11B_E_PD_LAG;
                break;
            }
        }
    } while(FALSE);
    // ...
    return hr;
}
```

} Figure 18. Example code to read from RX_STREAM.
Chapter 4.
MAC Programming

Sora provides a utility library to program a Finite State Machine (FSM). An FSM is commonly used in the MAC and other protocol implementations. For example, Figure 19 shows a simplified MAC state-machine of 802.11 that contains three states: carrier sense, transmission (TX) and reception (RX).

Figure 19. A simplified MAC state machine of 802.11.

4.1 State Machine declaration and initialization

The SDR driver declares an FSM through `SORA_BEGIN_DECLARE_FSM_STATES`, `SORA_END_DECLARE_FSM_STATES`, and `SORA_DECLARE_STATE`. After that, the SDR driver should further declare an FSM type using `SORA_DECLARE_FSM_TYPE`. An FSM instance can then be declared for this FSM type. Each state of an FSM is associated with a state handler. At initialization, the SDR driver should assign these handlers to an FSM instance using `SORA_FSM_ADD_HANDLER`.

In Sora, a state machine may usually run in an *exclusive thread* that provides real-time support. The SDR driver uses `SORA_FSM_CONFIG` to assign a parameter to the FSM instance, which will be passed to each state handler. This parameter is usually a pointer to `SDR_CONTEXT`. During
initialization, one should also specify the initial state on which the FSM starts using

SoraFSMSetInitialState.

Figure 20 shows an excerpt from *sdr_mac.h* to declare the simplified 802.11 MAC FSM. Figure 21 shows sample code from *sdr_mac_main.c* to initialize an FSM instance declared as a member of the PMAC object.

```c
// Declare MAC FSM states for 802.11
SORA_BEGIN_DECLARE_FSM_STATES(Dot11)
SORA_DECLARE_STATE(Dot11_MAC_CS)
SORA_DECLARE_STATE(Dot11_MAC_TX)
SORA_DECLARE_STATE(Dot11_MAC_RX)
SORA_END_DECLARE_FSM_STATES(Dot11)

// Declare a FSM structure type for 802.11
SORA_DECLARE_FSM_TYPE(DOT11FSM, Dot11)
```

**Figure 20. Example to declare an 802.11 MAC state machine.**

```c
VOID SdrMacInitStateMachine(IN PMAC pMac, IN PSDR_CONTEXT SDRContext)
{
    // Associate the real state handlers to the FSM
    SORA_FSM_ADD_HANDLER(pMac->StateMachine, Dot11_MAC_CS, SdrMacCs);
    SORA_FSM_ADD_HANDLER(pMac->StateMachine, Dot11_MAC_TX, SdrMacTx);
    SORA_FSM_ADD_HANDLER(pMac->StateMachine, Dot11_MAC_RX, SdrMacRx);

    SORA_FSM_CONFIG (pMac->StateMachine, SDRContext, 0);

    // Set the initial start state
    SoraFSMSetInitialState ((PFSM_BASE)&pMac->StateMachine, Dot11_MAC_CS);
}
```

**Figure 21. Initializing an FSM.**

### 4.2 FSM Start, Stop, and State Transition

To start an FSM, the SDR driver should call **SoraFSMStart**, which starts the state machine in an exclusive thread.

A call of **SoraFSMStop** from any state handler terminates the FSM. **SoraFSMGotoState** is called before exiting the current state handler to transit to other states. The state handler of the new state will be invoked by the FSM thread.

#### 4.2.1 Example
Figure 22 shows an example state handler from `sdr_mac_cs.c` for carrier sense. It enters different states based on the result of the PHY sensing function.

```c
VOID SdrMacCs(IN PFSM_BASE StateMachine)
{
    HRESULT hRes = S_OK;
    //Get SDR context initialized by SORA_FSM_CONFIG;
    PSDL_CONTEXT pSDRContext = (PSDL_CONTEXT)SoraFSMGetContext(StateMachine);
    //Get all references from SDR context
    PMP_ADAPTER pAdapter = (PMP_ADAPTER)pSDRContext->Nic; //initialized by SdrContextBind;
    PMAC pMac = (PMAC)pSDRContext->Mac; //initialized by SdrContextBind;
    PPHY pPhy = (PPHY)pSDRContext->Phy; //initialized by SdrContextBind;
    PSORA_RADIO pRadio = NULL;
    ...
    pRadio = RadioInPHY(pPhy, RADIO_RECEIVE);
    if(!SoraRadioCheckRxState(pRadio))
    {
        DbgPrint("[MAC_CS] enable Rx for the first time\n");
        SORA_HW_ENABLE_RX(pRadio);
    }
    if(pPhy->HwErrorNum > HW_ERROR_THRESHHOLD)
    {
        DbgPrint("[Error] Reset MAC send \n");
        InterlockedExchange(&pPhy->HwErrorNum, 0);
        //SdrMacResetSend(pMac);
    }
    if(pMac->fDumpMode)
    {
        _Dump(pMac, pRadio);
    }
    hRes = PhyDot11BCs(pPhy, RADIO_SEND);
    if (hRes == E_FETCH_SIGNAL_HW_TIMEOUT)
    {
        DbgPrint("[MAC_CS][Error] E_FETCH_SIGNAL_HW_TIMEOUT \n");
    }
    switch (hRes)
    {
    case BB11B_CHANNEL_CLEAN:
        if (IS_MAC_EXPECT_ACK(pMac))
        {
            hRes = __ExpectAck(pPhy);
            if (hRes != BB11B_OK_POWER_DETECTED)
            {
                DbgPrint("[MAC_CS][Error] Ack detect fail, we don't need ACK anymore \n");
                MAC_DISLIKE_ACK(pMac);
            }
            else
            {
                SoraFSMGotoState(StateMachine, Dot11_MAC_RX);
                return;
            }
        }
    ```
DbgPrint("[MAC_CS] channel clean, goto tx \n");
SoraFSM_gotoState(StateMachine, Dot11_MAC_TX);
return;

case BB11B_OK_POWER_DETECTED:
    SoraFSM_gotoState(StateMachine, Dot11_MAC_RX);
    return;

case E_FETCH_SIGNAL_HW_TIMEOUT: //Hardware error
    SoraFSM_gotoState(StateMachine, Dot11_MAC_TX);
    DbgPrint("[Error] E_FETCH_SIGNAL_HW_TIMEOUT \n");
    //InterlockedIncrement(&pMac->pPhy->HwErrorNum);
    break;

default:
    DbgPrint("[MAC_CS] CS return %x\n", hRes);
    break;
}
Chapter 5.
Real-Time Support

5.1 Using Sora thread

Sora supports real-time behavior via exclusive threading. An exclusive thread (or ethread) is a non-interruptible thread running on a multi-core system. In previous versions, an exclusive thread is bound to a dedicated CPU core and the programmer should manually assign CPU cores. In Sora SDK version 1.5, the core assignment is performed by the library that dynamically allocates CPU cores to ethreads.

The SDR driver should allocate an ethread object by calling SoraThreadAlloc. Then, the SDR driver can call SoraThreadStart to start the ethread. SoraThreadStart takes three parameters: a valid ethread handle, a user-defined thread routine, and a user-defined parameter passed to the thread routine. If the return value of the thread routine is FALSE, the ethread will be terminated; otherwise, the routine will be called from the Sora core library after it re-computes the best core allocation and reassigns each ethread to a proper core. Since the ethreads are scheduled in a cooperative way, the ethread routine must return periodically (usually when critical tasks are done). Note that the dynamic scheduling of ethread imposes minimal overhead.

To terminate an ethread, one should call SoraThreadStop. It should be note it is prohibitive to call any Sora Thread API from the ethread routine; otherwise, a deadlock will occur. To exit from the thread, a user-defined routine should return with a FALSE value.

Comments: For user mode applications, the corresponding thread APIs are SoraUThreadAlloc, SoraUThreadStart, SoraUThreadStop and SoraUThreadFree.

Figure 23 shows code excerpts from sdr_phy_main.c to initialize and start a Sora thread that performs Viterbi decoding.

```c
HRESULT SdrPhyInitialize(
    IN PPHY pPhy,
```
IN PSDR_CONTEXT SDRContext,
IN ULONG ulRadioNum)
{
    ...
    if (pPhy->PHYMode == DOT_11_A) {
        hRes = NDIS_STATUS_FAILURE;
        pPhy->Thread = SoraThreadAlloc();
        if (pPhy->Thread)
            if (SoraThreadStart(pPhy->Thread, viterbi_proc, &pPhy->BBContextFor11A.RxContext))
                hRes = NDIS_STATUS_SUCCESS;
        ...
    }
    ...
}
BOOLEAN viterbi_proc(PVOID pVoid) {
    BB11ARxViterbiWorker(pVoid);
    return *(PBB11A_RX_CONTEXT)pContext->ri_pbWorkIndicator;
}

Figure 23. Using Sora thread.

Figure 24 shows the sample code of a Viterbi work routine from arx_bg1.c. The function calls different Viterbi decoding modules based on the data rate. It starts by checking if there is work to do. If not, the routine will immediately return. Otherwise, it will accept the work by clearing the flag and perform the decoding task. After decoding, the routine returns to the state waiting for a new task.

void BB11ARxViterbiWorker(PVOID pContext)
{
    PBB11A_RX_CONTEXT pRxContextA = (PBB11A_RX_CONTEXT)pContext;
    if (BB11A_VITERBIRUN_WAIT_EVENT(pRxContextA))
    {
        BB11A_VITERBIRUN_CLEAR_EVENT(pRxContextA);
        pRxContextA->bCRCCorrect = FALSE;
        switch (pRxContextA->bRate & 0x7)
        {
            case 0x3:
                VitDesCRC6(pRxContextA);
                break;
            case 0x7:
                VitDesCRC9(pRxContextA);
                break;
            case 0x2:
                VitDesCRC12(pRxContextA);
                break;
            case 0x6:
VitDesCRC18(pRxContextA); break;
case 0x1: VitDesCRC24(pRxContextA); break;
case 0x5: VitDesCRC36(pRxContextA); break;
case 0x0: VitDesCRC48(pRxContextA); break;
case 0x4: VitDesCRC54(pRxContextA); break;
}
_mm_mfence();
BB11A_VITERBIDONE_SET_EVENT(pRxContextA);
}

Figure 24. Example ethread routine.

5.2 Interrupt affinity

With ethread, the SDR application driver can prevent the task from being preempted by other threads. But the task may still be interrupted by hardware. Although most hardware interrupt handlers are very light-weight, some may still require a significant amount of time to finish (e.g., disk access) and thus cause a real-time task to miss deadlines. To address this issue, one could set the interrupt affinity for all hardware devices to avoid sending interrupts to the reserved core. On Windows 7, the interrupt affinity can be configured via the registry. But there is no native system support on Windows XP. The Sora SDK includes a tool, called interrupt filter, which can configure the interrupt affinity of hardware devices. The tool can be found in %SDR_ROOT%\bin folder.

5.2.1 Installing and Configuring Interrupt Filter

To install the interrupt filter driver, first copy intfiltr.sys to Windows system driver folder (e.g., c:\windows\system32\drivers). Then, add the registry entries specified in intfiltr.reg, and, finally, reboot the machine to enable the interrupt filter driver.
Add interrupt affinity set filter driver
-\texttt{r} : Remove interrupt affinity set filter driver
-\texttt{m} affinity mask :
Specify the affinity mask

Figure 25. Help page of intfilitrcmd.exe.

You can configure the interrupt affinity using \texttt{intFiltrCmd.exe}. Type \texttt{intfilitrcmd}, and you can see the help page shown in Figure 25. The default interrupt affinity is 0xFFFFFFFF, meaning all cores can be interrupted. You can turn off the bits corresponding to the reserved cores and specify the new affinity using command

\begin{verbatim}
Intfilitrcmd -a -m <core affinity that allows to be interrupted>
\end{verbatim}

To remove the affinity (or reset to default), run

\begin{verbatim}
Intfilitrcmd -r
\end{verbatim}
Chapter 6.
Signal Cache

One key design choice for the Sora system is to provide a large on-board memory on the RCB. This on-board memory can serve as a cache for pre-generated signals. The SDR driver can call SoraInitSignalCache to initialize a SIGNAL_CACHE structure. After initialization, a portion of the RCB memory is allocated to the signal cache and the SDR driver can store signals in it. The cache is organized into a number of equal size slots.

SoraInsertSignal adds a signal to a cache entry that is indicated by an 8-byte hash key. The signal can be later retrieved using this hash key by calling SoraGetSignal. If the signal exists in the cache, SoraGetSignal returns a TX_DESC of the signal, which can be passed to SORA_HW_FAST_TX to send out the stored signal.

The SDR driver must clean up the cache before it is unloaded or the cache is no longer used. SoraCleanSignalCache will release all resources allocated.

6.1 Example

In the Sora 802.11 sample driver, a signal cache is used to store ACK frames to corresponding senders. It defines an ACK_CACHE_MAN structure that is inherited from the SIGNAL_CACHE.

Figure 26 shows the initialization function of the ACK cache from sdr_phy_ack_cache.c. The function tries to allocate a SIGNAL_CACHE from the RCB onboard memory.

```c
HRESULT SdrPhyInitAckCache(
    OUT PACK_CACHE_MAN pAckCacheMan,
    IN PDEVICE_OBJECT pDeviceObj,
    IN PPHY pOwnerPhy,
    IN PSORA_RADIO pRadio,
    IN ULONG MaxAckSize,
    IN ULONG MaxAckNum
)
{
    HRESULT hr;

    PHYSICAL_ADDRESS    PhysicalAddress    = {0, 0};
    PHYSICAL_ADDRESS    PhysicalAddressLow = {0, 0};
    PHYSICAL_ADDRESS    PhysicalAddressHigh = {0x80000000, 0};
```
When MAC detects that a required ACK frame is not in the cache, it will queue a request, wake up a worker thread that does the modulation, and insert the generated waveform in the ACK Cache. The key to identify the frame is the MAC address of the destination. Figure 27 shows the sample code from `sdr_phy_ack_cache.c`.

```c
VOID AckCacheMakeThread(
    IN PDEVICE_OBJECT DeviceObject,
    IN PVOID Context )
{
    PACK_CACHE_MAN pAckCacheMan = (PACK_CACHE_MAN)Context;
    ...
}
```

Figure 26. ACK_CACHE_MAN initialization.
MAC_ADDRESS MacAddr;
PHY_FRAME_KEY Key;
ULONG Length = 0;
HRESULT hr;

UNREFERENCED_PARAMETER(DeviceObject);

MP_INC_REF(pAckCacheMan);
do {
    int i;
    __Dequeue(pAckCacheMan, &MacAddr);
    Key.QuadKey.u.HighPart = 0;
    Key.QuadKey.u.LowPart = 0;
    for (i = 0; i < MAC_ADDRESS_LENGTH; i++)
    {
        Key.KeyBytes[i] = MacAddr.Address[i];
    }
    Length = SdrPhyModulateACK(
        MacAddr,
        pAckCacheMan->pAckModulateBuffer);
    hr = SoraInsertSignal(
        &pAckCacheMan->PhyAckCache,
        pAckCacheMan->pAckModulateBuffer,
        &pAckCacheMan->AckModulateBufferPA,
        Length,
        Key);
    if (hr == E_TX_TRANSFER_FAIL)
    {
        DbgPrint("[TEMP1] Ack insert cache failed, return 0x%08x\n", hr);
        InterlockedIncrement(&pAckCacheMan->pOwnerPhy->HwErrorNum);
    }
    else
    {
        DbgPrint("[TEMP1] Ack insert cache succ, return 0x%08x\n", hr);
    }
} while(InterlockedDecrement(&pAckCacheMan->PendingReqNum) != 0);

MP_DEC_REF(pAckCacheMan);
return;
}

Figure 27. Modulate an ACK and insert the waveform in the signal cache.
Chapter 7.
User-Mode Extension

Since version 1.1, Sora provides a new programming model, called User-Mode eXtension (UMX), which allows user-mode applications to access the radio resources. With UMX APIs, developers can write baseband processing in user-mode, and therefore the programming and debugging efforts are greatly reduced. Sora SDK version 1.5 further enhances UMX APIs.

7.1 UMX Initialization and Configuration

UMX is based on the HWTest driver (see also Chapter 10.), as shown in Figure 28.

![Figure 28. Architecture of Sora UMX.](image)

The UMX application initializes UMX library with `SoraUInitUserExtension`. The function needs the device name of the HWTest driver, which is “\HWTest”. HWTest will allocate an abstract radio from the RCB, and the UMX application can configure the radio parameters using the corresponding APIs. After the radio is properly configured, the UMX application can start the radio by calling `SoraURadioStart`. Before exiting, the SDR application should call `SoraUCleanUserExtension` to clean up the resource that has been allocated.
Figure 29 shows the sample code from **umx_sample.cpp** to initialize and configure UMX.

```c
void RadioConfig()
{
    SoraURadioStart(TARGET_RADIO);
    SoraURadioSetTxPA (TARGET_RADIO, SORA_RADIO_DEFAULT_RX_PA);
    SoraURadioSetRxGain (TARGET_RADIO, SORA_RADIO_DEFAULT_RX_GAIN);
    SoraURadioSetTxGain (TARGET_RADIO, SORA_RADIO_DEFAULT_TX_GAIN);
    SoraURadioSetCentralFreq (TARGET_RADIO, 2422 * 1000); //central frequency: 2422MHz
    SoraURadioSetFreqOffset (TARGET_RADIO, -5 * 1000 * 1000); //frequency offset: -5MHz
    SoraURadioSetSampleRate (TARGET_RADIO, 40); //sample rate: 40MHz
}

int __cdecl main(int argc, char *argv[])
{
    BOOLEAN isTx = FALSE;

    // Initialize Sora user mode extension
    BOOLEAN succ = SoraUInitUserExtension("\\\HWTest");
    if (!succ)
    {
        printf("Error: fail to find a Sora UMX capable device!n");
        return -1;
    }

    RadioConfig();

    ...

    SoraUCleanUserExtension();
    return 0;
}
```

**Figure 29. Sample code to initialize and configure UMX.**

## 7.2 Reception

To access the RX channel of a radio object, the UMX application should first call **SoraURadioMapRxSampleBuf** to obtain a pointer to the receiving buffer as well as the buffer size. Then, the UMX application can get a RX_STREAM from the receiving buffer using **SoraURadioAllocRxStream**, from which it can read I/Q samples. To read a signal block, the UMX application needs to call **SoraRadioReadRxStream**. Before exiting, the UMX application should call **SoraURadioReleaseRxStream** to release a RX_STREAM and **SoraURadioUnmapRxSampleBuf** to release the memory mapped to the RX buffer of a radio.

Figure 30 shows an example to receive I/Q samples using UMX, from **umx_sample.cpp**.
void RxRoutine ()
{
    PVoid pRxBuf = NULL;
    ULONG nRxBufSize = 0;
    HRESULT hr;
    ...
    SORA_RADIO_RX_STREAM SampleStream;

    // Map Rx Buffer
    hr = SoraURadioMapRxSampleBuf (TARGET_RADIO, // radio id
                                    & pRxBuf,     // mapped buffer pointer
                                    & nRxBufSize  // size of mapped buffer
                        );
    if ( FAILED (hr) ) {
        printf ( "Error: Fail to map Rx buffer!
                    
                
            ");
        return;
    }
    printf ( "Mapped Rx buffer at %08x size %d
                    
                
            ");
    // Generate a sample stream from mapped Rx buffer
    SoraURadioAllocRxStream( &SampleStream,
                             TARGET_RADIO,
                             (PUCHAR)pRxBuf,
                             nRxBufSize );
    // start reading the sample stream and compute the energy
    FLAG fReachEnd;
    int index = 0;
    SignalBlock block;
    ...
    for (;;)
    {
        hr = SoraRadioReadRxStream(
                                    & SampleStream,      // current scan point
                                    & fReachEnd,   // indicate if end of stream reached (you must wait for hardware)
                                    block);
        if (FAILED(hr))
        {
            printf("stream ended, hr=%08x\n", hr);
            break;
        }
        QueryPerformanceCounter(&End);
        if (End.QuadPart - Start.QuadPart > Freq.QuadPart / 2)
        {
            Start = End;
            // almost 1s
            // compute the energy
            vcs* pSamples = &block[0];
            // single block contains 28 samples or 7 vector cs
            vi sum;
            set_zero (sum);
            // this is an approximated way to calc energy
            for (int i=0; i<7; i++)
            {
7.3 Transmission

To transmit waveform using UMX, the UMX application should obtain the Tx sample buffer of the radio to store the modulated samples. To do so, it calls `SoraURadioMapTxSampleBuf` and fill the buffer with I/Q samples. Then, the UMX application should call `SoraURadioTransfer` to bind TX resources for the modulated signal and transfer the waveform to the RCB. A call to `SoraURadioTx` can transmit the stored signal, possibly multiple times, and `SoraURadioTxFree` can unbind all TX resources if the signal is no longer needed.

Figure 31 shows the sample routine for transmitting using UMX, from `umx_sample.cpp`. After mapping the modulation buffer, it calls a user-defined function `PrepareSamples` to fill the buffer with I/Q samples, which in this implementation is simply load from a sample file.
&SampleBuffer,
&SampleBufferSize);
printf("Tx Sample buffer ret: %08x\n", hr);
FAILED_BREAK(hr);

printf("Tx Sample buffer: %08x\n", SampleBuffer);
printf("Tx Sample buffer size: %08x\n", SampleBufferSize);

ULONG TxID;
ULONG SigLength = PrepareSamples(fname, (char*)SampleBuffer, SampleBufferSize);
if (SigLength == 0)
{
    printf("file access violation\n");
    break;
}
//
// First Allocate Tx Resource
// The size should be a multiple of 128
//
ALIGN_WITH_RCB_BUFFER_PADDING_ZERO(SampleBuffer, SigLength);
hr = SoraURadioTransfer (TARGET_RADIO, SigLength, &TxID);

printf("parallel tx resource allocated, hr=%08x, id=%d, length=%d\n", hr, TxID, SigLength);
if (SUCCEEDED(hr))
{
    //
    // Tx to the radio
    //
    hr = SoraURadioTx(TARGET_RADIO, TxID);
    printf("tx return %08x\n", hr);
    hr = SoraURadioTxFree (TARGET_RADIO, TxID);
    printf("tx resource release return %08x\n", hr);
}
FAILED_BREAK(hr);
} while (FALSE);
if (SampleBuffer)
{
    hr = SoraURadioUnmapTxSampleBuf (TARGET_RADIO, (PVOID)SampleBuffer);
    printf("unmap Tx sample buffer ret: %08x\n", hr);
}
}

Figure 31. A sample routine to send with UMX.

7.4 Sample: UMXDot11

In Sora SDK ver 1.5, we include a sample 802.11 decoder based on UMX, called umxdot11.
Umxdot11 has a full featured 802.11a/b/g decoder. It is also able to modulate a frame and send it through UMX. You can find the source code at $SORA_ROOT$\src\bb\UMXDot11. UMXDot11 relies on the SoftWiFi modulation/demodulation library. UMXDot11 is configured through a file
named **umxdot11.ini**. Both “.exe” and “.ini” files should be under the same folder. Figure 32 shows a sample ini file. The file defines the modulation method (802.11a OFDM or 802.11b DSSS), the data rate, and a frame length. It also specifies the sampling rate of your RAB.

Command “umxdot11 rx” will launch umxdot11 in the receiving mode. Based on the configuration, the umxdot11 searches OFDM or DSSS signals. However, it tries to demodulate and decode frame with any valid rate.

Command “umxdot11 tx” will put umxdot11 in sending mode. It will continuously send a random generated frame with the modulation method and the size specified in the configuration file.

**Note that you should use command “dut start” to enable the HwTest driver as well as the UMX library.**

```
;; Protocol:        802.11a / 802.11b
;;
;; Configuration for 802.11b / 802.11b.brick
;; Data Rate:  1000/2000/5500/11000
;;
;; Configuration for 802.11a
;; Data Rate:  6000/9000/12000/18000/24000/36000/48000/54000
;;
;; Sample Rate: 40 | 44
;;
[Modulation]
Protocol = 802.11a
DataRate = 6000
PayloadLength = 1000

[Hardware]
SampleRate = 44
```

**Figure 32. A sample umxdot11.ini.**
Chapter 8.
Vector1 Library

Vector1 is a new template library for SIMD programming since Sora SDK 1.1. Vector1 library provides new vector data types and vector operations to accelerate PHY signal processing.
Vector1 provides a general vector abstraction that is rather independent from the real processor architecture. Therefore, it improves the portability of algorithms implemented using SIMD instructions. When porting to a new SIMD processor, only a new implementation of Vector1 library is needed, while the algorithm implementations can remain unchanged (or with only minor modification). Currently, Vector1 is implemented based on C++ SSE3 intrinsic functions, which are supported in most modern C++ compiler. The implementation of Vector1 can be found in the header file `vector128.h`.

8.1 Data type

Vector1 defines vector data type which contains an array of elements. An element can be of various types, from integer, float, to complex values. The element type is typedef-ed as elem_type in the vector type, for example vb::elem_type is defined as “Signed Byte”. Table 4 summarizes the vector types supported in the Vector1 library. It also summarizes the size of each element and the number of elements in one vector type. For example, a vb variable contains a vector of sixteen 8-bit long integers (a byte) and a vub presents a vector contains sixteen unsigned bytes. Note that a vector type should be 16-byte aligned.

<table>
<thead>
<tr>
<th>Vector Type</th>
<th>Element Type</th>
<th>Element Size</th>
<th>No. of Elements</th>
</tr>
</thead>
<tbody>
<tr>
<td>vb/vub</td>
<td>Signed /Unsigned Byte</td>
<td>8b</td>
<td>16</td>
</tr>
<tr>
<td>vs/vus</td>
<td>Signed /Unsigned Short</td>
<td>16b</td>
<td>8</td>
</tr>
<tr>
<td>vi/vui</td>
<td>Signed /Unsigned Integer</td>
<td>32b</td>
<td>4</td>
</tr>
<tr>
<td>vq/vuq</td>
<td>Signed/Unsigned Quad Word</td>
<td>64b</td>
<td>2</td>
</tr>
<tr>
<td>vf</td>
<td>Float</td>
<td>32b</td>
<td>4</td>
</tr>
<tr>
<td>vcb/vcub</td>
<td>Complex Signed / Unsigned Byte</td>
<td>16b</td>
<td>8</td>
</tr>
<tr>
<td>vcs/vcus</td>
<td>Complex Signed / Unsigned Short</td>
<td>32b</td>
<td>4</td>
</tr>
<tr>
<td>vci/vcui</td>
<td>Complex Signed / Unsigned Integer</td>
<td>64b</td>
<td>2</td>
</tr>
<tr>
<td>vcq/vcuq</td>
<td>Complex Signed / Unsigned Quad Word</td>
<td>128b</td>
<td>1</td>
</tr>
</tbody>
</table>
8.2 Basic Operations

The Vector1 library defines many operations on the vector types. The most common operations are arithmetic operations on vector types, including \texttt{abs, abs0, add, conj, conj0, conj_mul, conj_mul_shift, conjre, mul_high, mul_j, mul_low, mul_shift, pairwise_muladd, reduce4_add, reduce4_saturated_add, reduce_add, reduce_saturated_add, saturated_add, saturated_pack, saturated_sub}, and \texttt{sign}. For example, you can perform an “add” operation on two variables of the same vector type. Each element in the resulting vector is the sum of the corresponding elements from two vectors. Figure 33 shows sample code to remove the DC component from incoming samples using Vector1.

```c
Void RemoveDC (SignalBlock & block, vcs &dc) {
    For (int i=0; i<7; i++) {
        block[i] = sub(block[i], dc);
    }
}
```

Figure 33 Removing the DC component with Vector1.

There are also logic operations, including \texttt{and, andnot, or}, comparison operations, including \texttt{hmax, hmin, is_greater, is_less}, and \texttt{smax}, shift operations, like \texttt{shift_left, shift_right}, and element data manipulation, including \texttt{comprise, extract, flip, interleave_high, interleave_low, pack, permutate, permutate_high, permutate_low}.

One can also use \texttt{set_all, set_all_bits, set_zero} or assignment operator to initialize a vector.

8.3 Vector1 References

The following sections explain each operation defined in current Vector1 Library. For the sake of simplicity, we use the following format:

- In the \texttt{Vector type} line, we define the list of vector types. We use \texttt{T} to refer any vector type in the list.
In the **prototype** line, we define the prototype of the operation. The symbol T may refer to any vector type defined in the **Vector type** line.

For example, we define **abs** operations as follows:

**Vector type:** $T = vb/s/i/q$

**Prototype:** $T \text{ abs}(\text{const } T & a)$;

This means **abs** operation can be applied to a vb, vs, vi, or vq type. The prototype will take a constant reference to a variable of any of above vector type, and return a same vector type as the parameter.

### 8.3.1 abs

**Vector type:** $T = vb/s/i/q$

**Prototype:** $T \text{ abs}(\text{const } T & a)$;

**Description:** approximately compute the element-wise absolute value of a vector, based on “xor” operation.

### 8.3.2 abs0

**Vector type:** $T = vb/s/i/q$

**Prototype:** $T \text{ abs0}(\text{const } T & a)$;

**Description:** compute the actual element-wise absolute value of a vector.

### 8.3.3 add

**Vector type:** $T = vb/s/i/q/f/ub/us/ui/uq/cb/cs/ci/cq/cf/cub/cus/cui/cuq$

**Prototype:** $T \text{ add}(\text{const } T & a, \text{ const } T & b)$;

**Description:** compute the sum of two vectors

### 8.3.4 and

**Vector type:** $T = vb/s/i/f/ub/us/ui/cb/cs/ci/cf/cub/cus/cui$

**Prototype:** $T \text{ and}(\text{const } T & a, \text{ const } T & b)$;
Description: compute the logic bit-wise and of two vectors

8.3.5 andnot


Prototype: T andnot(const T & a, const T & b);

Description: compute the logic bit-wise and of the logic not of vector a and vector b.

(a,b) = (not(a) and b).

8.3.6 average

Vector type: T = vub/us/cub/cus

Prototype: T average(const T & a, const T &b);

Description: Element-wise average of two operand vectors.

8.3.7 comprise

Prototype: void comprise(vci & r1, vci& r2, const vi& re, const vi& im);

Description: Make two complex vectors from two real number vectors. One real number vector defines the real part and the other defines the imaginary part. The resulted complex vector r1 contains the first two complex numbers, and r2 gets the second two complex numbers.

8.3.8 conj

Prototype: vcs conj(const vcs & a);

Description: compute an approximate conjugate of each complex number in a vector, using the “xor” operator for sign reversion. It is not accurate but has better performance.

8.3.9 conj0

Prototype: vcs conj0(const vcs & a);

Description: Compute the accurate conjugate of each complex number in a vector.

8.3.10 conj_mul

Prototype: void conj_mul(vi& re, vi& im, const vcs& a, const vcs& b);
**Description:** Multiply the first source vector by the conjugate of the second source vector. re gets all real parts of the product, and im gets all imaginary parts.

### 8.3.11 conj_mul_shift

**Prototype:** `vcs conj_mul_shift(const vcs& a, const vcs& b, int nbits_right);`

**Description:** Multiply the first operand by the conjugate of the second source, right shift the results by `nbits_right` bits, and keep the low 16-bit of the results.

### 8.3.12 conjre

**Prototype:** `vcs conjre(const vcs& a);`

**Description:** Invert the sign of the real part of each complex numbers.

### 8.3.13 extract

**Vector type:** `T = vb/s/i/q/ub/us/ui/uq`

**Prototype:** `typename T::elem_type extract(const T& a);`

**Description:** Extract element from a vector type, similar to the index operator. The index is 0-based and starts from the lowest address.

### 8.3.14 Flip

**Vector type:** `T = vcs/vcus`

**Prototype:** `T flip(const T& a);`

**Description:** Swap the real and imaginary parts of each complex number

### 8.3.15 hmax

**Vector type:** `T = vb/s/ub/us`

**Prototype:** `T hmax(const T& a);`

**Description:** Copy the largest element in the source vector to all elements of a vector128 type

### 8.3.16 hmin

**Vector type:** `T = vb/s/ub/us`
Prototype: T hmin(const T & a);

Description: Copy the smallest element in the source vector to all elements of a vector128 type

8.3.17 `interleave_high`
Vector type: T = vb/s/i/q/ub/us/ui/q/cb/cs/ci/cub/cus/cui

Prototype: T `interleave_high`(const T & a, const T & b);

Description: Interleave the elements in the higher half of the 2 source vectors to a resulting vector. The first source operand will be interleaved to the even indices, and the second source to the odd indices.

8.3.18 `interleave_low`
Vector type: T = vb/s/i/q/ub/us/ui/q/cb/cs/ci/cub/cus/cui

Prototype: T `interleave_low`(const T & a, const T & b);

Description: Interleave the elements in the lower half of the 2 source vectors to a resulting vector. The first source operand will be interleaved to the even indices, and the second source to the odd indices.

8.3.19 `is_great`
Vector type: T = vb/s/i/f

Prototype: T `is_great`(const T & a, const T & b);

Description: Element-wise greater than (>) test for two vectors. The result is a vector of the same type, with all-1 element for true test and all-0 for false test.

8.3.20 `is_less`
Vector type: T = vb/s/i/f

Prototype: T `is_less`(const T & a, const T & b);

Description: Element-wise less than (<) test for two vectors. The result is a vector of the same type, with all-1 element for true test and all-0 for false test.
8.3.21  mul_high
Prototype: vs mul_high(const vs& a, const vs& b);

Description: Element-wise multiplication, keeping only the higher half of the product.

8.3.22  mul_j
Prototype: vcs mul_j(const vcs& a);

Description: Multiply by the imaginary unit

8.3.23  mul_low
Prototype: vs mul_low(const vs& a, const vs& b);

Description: Element-wise multiplication, keeping only the lower half of the product

8.3.24  mul_shift
Prototype: vcs mul_shift(const vcs& a, const vcs& b, int nbits_right);

Description: Multiply and keep the low part product after right-shifting, i.e., return a * b >> nbits_right

8.3.25  or
Vector type: T = vb/s/i/q/ub/us/uq/cb/cs/cq/cub/cus/cui/cuq

Prototype: T or(const T& a, const T& b);

Description: Bitwise OR

8.3.26  pack
Prototype: vs pack(const vi& a, const vi& b);

Description: Pack elements in the two operand vectors into returned vector, keeping only the low 16-bit for each element.

8.3.27  pairwise_muladd
Prototype: vi pairwise_muladd(const vs& a, const vs& b);

Description: Add the element-wise multiplication product pair-wise. i.e.,
result[0] := (a[0] * b[0]) + (a[1] * b[1])


8.3.28 permutate

Vector type: \( T = \text{vcs}/\text{ui} \)

Prototype: template<int a0, int a1, int a2, int a3> T permutate(const T& a);

template<int n> T permutate(const T& a);

Description: Permute four elements in a vector.

Template parameter n: each 2-bit field (from LSB) selects the content of one element location (from low address) in the destination operand. i.e.,

\[ r[0] := a[n(1:0)] \]

\[ r[1] := a[n(3:2)] \]

\[ r[2] := a[n(5:4)] \]

\[ r[3] := a[n(7:6)] \]

Template parameter a0 ~ a3: selects the contents of one element location in the destination operand. i.e.

\[ r[0] := a[a0] \]

\[ r[1] := a[a1] \]


\[ r[3] := a[a3] \]

8.3.29 permutate_high
Vector type: \( T = \text{vs/cs/us/ucs} \)

Prototype: template\(<\text{int } a_0, \text{int } a_1, \text{int } a_2, \text{int } a_3> T \text{ permutate\_high}(\text{const } T & a)\);

template\(<\text{int } n> T \text{ permutate\_high}(\text{const } T & a)\);

Description: Permute 4 elements in the higher half vector.

The definitions of the template parameters are similar to \text{permutate\_low}.

8.3.30 \text{permutate\_low}

Vector type: \( T = \text{vs/cs/us/ucs} \)

Prototype: template\(<\text{int } a_0, \text{int } a_1, \text{int } a_2, \text{int } a_3> T \text{ permutate\_low}(\text{const } T & a)\);

template\(<\text{int } n> T \text{ permutate\_low}(\text{const } T & a)\);

Description: Permute 4 elements in the lower half vector.

The definitions of template parameters are similar to \text{permutate\_low}.

8.3.31 \text{reduce\_4\_add}

Vector type: \( T = \text{vcs/i} \)

Prototype: \( T \text{ reduce\_4\_add}(\text{const } T & a_0, \text{const } T & a_1, \text{const } T & a_2, \text{const } T & a_3) \);

Description: Take for vector operands and perform horizontal addition to each vector. The return vector contains the result for each operand vector.

Input: \{A_{00}, A_{01}, A_{02}, A_{03}\}, \{A_{10}, A_{11}, A_{12}, A_{13}\}, \{A_{20}, A_{21}, A_{22}, A_{23}\}, \{A_{30}, A_{31}, A_{32}, A_{33}\}

Output: \{R_0, R_1, R_2, R_3\},

\begin{align*}
R_0 &= A_{00}+A_{01}+A_{02}+A_{03} \\
R_1 &= A_{10}+A_{11}+A_{12}+A_{13} \\
R_2 &= A_{20}+A_{21}+A_{22}+A_{23} \\
R_3 &= A_{30}+A_{31}+A_{32}+A_{33}
\end{align*}

8.3.32 \text{reduce\_4\_saturated\_add}
Prototype: `vcs reduce4_saturated_add(const vcs& a0, const vcs& a1, const vcs& a2, const vcs& a3);

Description: Take for vector operands and perform saturated horizontal addition to each vector. The return vector contains the result for each operand vector.

Input: `{A0_0, A0_1, A0_2, A0_3}, {A1_0, A1_1, A1_2, A1_3}, {A2_0, A2_1, A2_2, A2_3}, {A3_0, A3_1, A3_2, A3_3}`

Output: `{R_0, R_1, R_2, R_3}`

\[ R_0 = \text{saturated_add}(A0_0, A0_1, A0_2, A0_3) \]
\[ R_1 = \text{saturated_add}(A1_0, A1_1, A1_2, A1_3) \]
\[ R_2 = \text{saturated_add}(A2_0, A2_1, A2_2, A2_3) \]
\[ R_3 = \text{saturated_add}(A3_0, A3_1, A3_2, A3_3) \]

8.3.33 reduce_add

Vector type: \( T = \text{vcs}/\text{i/ui} \)

Prototype: `T reduce_add(const T& a);`

Description: Add all elements of the operand vector (horizontal addition). Every element of the return vector contains the same result.

8.3.34 reduce_saturated_add

Prototype: `T reduce_saturated_add(const vcs& a);`

Description: Saturated add all elements of the operand vector (horizontal addition). Every element of the return vector contains the same result.

8.3.35 saturated_add

Vector type: \( T = \text{vb/s/ub/us/cb/cs/cub/cus} \)

Prototype: `T saturated_add(const T& a, const T& b);`

Description: Element-wise saturated add

8.3.36 saturated_pack

Prototype: `vb saturated_pack(const vs& a, const vs& b);`
Description: Saturated packs the 2 source vectors into one. The elements in the resulting vector have half the length of the source elements.

8.3.37 saturated_sub
Vector type: $T = vb/ub/us/cb/cs/cub/cus$

Prototype: $T$ saturated_sub(const $T$& $a$, const $T$& $b$);

Description: Element-wise saturated subtract

8.3.38 set_all
Vector type: $T = vb/s/i/cs/q/f$

Prototype: void set_all($T$& $x$, typename $T$::elem_type $a$);

Description: Assign the same value to all elements in a vector

8.3.39 set_all_bits

Prototype: void set_all_bits($T$& $a$);

Description: Set all bits in a vector

8.3.40 set_zero

Prototype: void set_zero($T$& $a$);

Description: Clear all bits in a vector

8.3.41 shift_left
Vector type: $T = vs/i/q/ci/cq/us/ui/ucb/cs/cq/cf/cub/cus/cui/cuq$

Prototype: $T$ shift_left(const $T$& $a$, int $n$bits);

Description: Element-wise arithmetic left shift

8.3.42 shift_right
Vector type: \(T = \text{vs/i/cs/ui/cus/cui/ub}\)

Prototype: \(T\ shift\_right(\text{const } T&\ a, \text{int } nbits)\);

Description: Element-wise arithmetic right shift

8.3.43 sign
Vector type: \(T = \text{vb/s/i/q/cs}\)

Prototype: \(T\ sign(\text{const } T&\ a, \text{const } T&\ b)\);

Description: Element-wise polarization on the first operand based on the second operand, ie.
\[r[n] := (b[n] < 0) ? -a[n] : ((b[n] == 0) ? 0 : a[n])\]

8.3.44 smin
Vector type: \(T = \text{vs/cs/ub/cub/b/cb/us/cus}\)

Prototype: \(T\ smin(\text{const } T&\ a, \text{const } T&\ b)\);

Description: Compute element-wise minimum

8.3.45 smin
Vector type: \(T = \text{vs/cs/ub/cub/b/cb/us/cus}\)

Prototype: \(T\ smin(\text{const } T&\ a, \text{const } T&\ b)\);

Description: Compute element-wise minimum

8.3.46 store
Vector type: \(T = \text{vb/s/i/q/ub/us/ui/uq/cb/cs/ci/cq/cub/cus/cui/cuq}\)

Prototype: \(\text{void }\ store(\text{void }\ast p, \text{const } T&\ a)\);

Description: Store 128-bit vector to the address \(p\), which is not necessarily 16-byte aligned

8.3.47 store_nt
Vector type: \(T = \text{vb/s/i/q/ub/us/ui/uq/cb/cs/ci/cq/cub/cus/cui/cuq}\)

Prototype: \(\text{void }\ store\_nt(T \ast p, \text{const } T&\ a)\);
Description: Store 128-bit vector to the address p without polluting the caches

8.3.48 sub

Prototype: $T\ sub(const\ T & a, const\ T & b);$  
Description: Element-wise Subtract

8.3.49 unpack
Vector type: $T = vb/s/i/ub/us/ui$

Vector type: $T = vs/i/q/us/ui/uq$

Prototype: void unpack(\text{T} & r1, \text{T} & r2, const \text{T} & a);$  
Description: Unpack elements in source vector to 2 destination vectors. Each element will be unpacked to a double-length field; r1 gets the unpacked elements in the lower half of the source vector, r2 get elements in the higher half.

8.3.50 xor

Prototype: $T\ xor(const\ T & a, const\ T & b);$  
Description: Bitwise XOR
Chapter 9.
The Sample SoftWiFi Driver

Since version 1.1, Sora SDK package includes the SoftWiFi sample SDR driver. SoftWiFi implements the IEEE 802.11a/b/g standards. The driver follows the Windows NDIS 5 framework and exposes a virtual Ethernet interface to the operating system. All applications can run on SoftWiFi without modification.

The SoftWiFi driver can be found in folder `%SORA_ROOT%\src\driver`. The files in sub-folder SDRMinport implements the NDIS driver framework as well as the device I/O control to the driver. Sub-folder ll contains the link layer implementation, whose main function is frame format converting, i.e. from Ethernet to 802.11, and vice versa. Folder mac contains the implementation of the MAC state machine; while folder phy contains the implementation of the physical layer. It calls the baseband signal processing routines defined in folder `%SORA_ROOT%\src\bb`.

The architecture of the SoftWiFi driver is shown in Figure 34. The Link Layer receives frames from NDIS and converts them to 802.11 frames (see `sdr_ll_send.c`). The converted frames are stored in a frame queue. A sending thread monitors the queue and calls PHY functions to modulate the frame into waveform (see `sdr_mac_send.c`), which is then transferred to the RCB. The MAC state machine implemented in this sample driver is shown in Chapter 4, Figure 19. The state machine is initialized to the carrier sense state. It continuously calls the PHY function `FnPHY_Cs` to read incoming samples and computes the energy. If it senses a frame, the state machine goes to the RX state. Otherwise, it will continuously sense the channel. Carrier sense is implemented in `sdr_mac_cs.c` and `sdr_phy_cs.c`. In the RX state, MAC calls the PHY function `FnPHY_Rx` to demodulate the received signal. The RX functions are implemented in `sdr_mac_rx.c` and `sdr_phy_rx.c`. For 802.11a/g, an additional thread is created for Viterbi decoding, whose implementation is in `arx_bg1.c`. The demodulated/decoded frame is put into a receiving queue. Another thread monitors this receiving queue, and indicates the correctly received frames to NDIS.
The initialization routines of the link layer, MAC and PHY are in `sdr_ll_main.c`, `sdr_mac_main.c`, and `sdr_phy_main.c`.

**Figure 34. Software Architecture of SoftWiFi.**

A novice is encouraged to learn the NDIS programming model before working on the SoftWiFi sample driver and you can find much information about NDIS at MSDN web site (http://msdn.microsoft.com).

### 9.1 Configuring the SoftWiFi driver

You can use the `dot11config.exe` tool to configure the SoftWiFi driver. The table below shows a summary of command line parameters for `dot11config.exe`.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td><code>-r</code></td>
<td><code>--datarate [Kbps]</code></td>
</tr>
<tr>
<td><code>-c</code></td>
<td><code>--channel [channel NO.]</code></td>
</tr>
<tr>
<td>Command</td>
<td>Option</td>
</tr>
<tr>
<td>---------</td>
<td>--------</td>
</tr>
<tr>
<td>-f</td>
<td>--freqoffset [Hz]</td>
</tr>
<tr>
<td>-a</td>
<td>--setmacaddr</td>
</tr>
<tr>
<td>-p</td>
<td>--preamble [0/1]</td>
</tr>
<tr>
<td>-s</td>
<td>--spdmax [blocks]</td>
</tr>
<tr>
<td>-t</td>
<td>--spdthd [energy]</td>
</tr>
<tr>
<td>--spdthd_lh [energy]</td>
<td>Set energy threshold for 802.11b power detection</td>
</tr>
<tr>
<td>--spdthd_hl [energy]</td>
<td>Set energy threshold for 802.11b power detection</td>
</tr>
<tr>
<td>--rxgain_preset0 [gain value]</td>
<td>Set radio RX gain preset0 to gain value in 1/256 db, i.e., 0x1000</td>
</tr>
<tr>
<td>--rxgain_preset1 [gain value]</td>
<td>Set radio RX gain preset1 to gain value in 1/256 db, i.e., 0x2400</td>
</tr>
<tr>
<td>-R</td>
<td>--rxgain [gain value]</td>
</tr>
<tr>
<td>--rxpa [power level]</td>
<td>Set radio RX PA. This value is RF front-end dependent. For USRP XCVR2450 receives only values of 0, 0x1000, 0x2000, 0x3000, 0x1000 – 0dB; 0x2000 – 16dB; 0x3000 – 32dB. * Note that it is preferred to use high RxPa instead of high RxGain.</td>
</tr>
<tr>
<td>-T</td>
<td>--txgain [gain value]</td>
</tr>
<tr>
<td>-S</td>
<td>--shift [bits]</td>
</tr>
<tr>
<td>-d</td>
<td>--dump</td>
</tr>
<tr>
<td>-i</td>
<td>--info</td>
</tr>
<tr>
<td>-g</td>
<td>--regs</td>
</tr>
</tbody>
</table>

### 9.2 Offline Wrapper

Sora SDK ver 1.5 also provides an offline wrapper for SoftWiFi baseband library. The source code of the wrapper application, named demode11, is located at %SORA_ROOT%\src\bb\exe. It is very handy to use demode11 to read from a dump file to debug or test your modifications to baseband algorithms. The usage of the demod11 tool is summarized below.
<table>
<thead>
<tr>
<th>Option</th>
<th>Command Line</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>-a</td>
<td>--802.11a</td>
<td>specify 802.11a mode</td>
</tr>
<tr>
<td>-b</td>
<td>--802.11b</td>
<td>specify 802.11b mode</td>
</tr>
<tr>
<td>-m</td>
<td>--mod</td>
<td>To modulate</td>
</tr>
<tr>
<td>-c</td>
<td>--conv</td>
<td>specify converting mode</td>
</tr>
<tr>
<td>-d</td>
<td>--demod</td>
<td>specify demodulation</td>
</tr>
<tr>
<td>-k</td>
<td>--ack</td>
<td>specify ack test mode</td>
</tr>
<tr>
<td>-f</td>
<td>--file [file name]</td>
<td>specify signal file</td>
</tr>
<tr>
<td>-o</td>
<td>--out [file name]</td>
<td>specify output file (mod/conv only)</td>
</tr>
<tr>
<td>-t</td>
<td>--spdthd [energy]</td>
<td>set energy threshold for 802.11b power detection (802.11b demod only)</td>
</tr>
<tr>
<td>--spdthd_lh [energy]</td>
<td>set energy threshold for 802.11b power detection (802.11b demod only)</td>
<td></td>
</tr>
<tr>
<td>--spdthd_hl [energy]</td>
<td>set energy threshold for 802.11b power detection (802.11b demod only)</td>
<td></td>
</tr>
<tr>
<td>-S</td>
<td>--shiftright [bits]</td>
<td>set shift bits after downsampling (802.11b demod only)</td>
</tr>
<tr>
<td>-s</td>
<td></td>
<td>start processing from startDescCount (802.11b demod only)</td>
</tr>
<tr>
<td>-r</td>
<td>--bitrate [bit rate]</td>
<td>bit rate in unit of Kbps for modulation</td>
</tr>
<tr>
<td>-p</td>
<td>--samplerate [sampling rate]</td>
<td>Specify the sampling rate at RAB (40/44MHz)</td>
</tr>
</tbody>
</table>

Example command lines:

1. Modulate an input file and store the generated waveform
   ```
   demod11.exe -a -m -f d:\frame.bin -o d:\frame.tx
   ```

2. Convert a Tx signal file to a Rx signal file
   ```
   demod11.exe -a -c -f d:\frame.tx -o d:\frame.dmp
   ```

3. Read a Rx signal file (dump file) and decode the frames
   ```
   demod11.exe -a -d -f d:\frame.dmp
   ```
Chapter 10.
Tools and Utilities

10.1  dut tool

10.1.1 Using dut to configure the HwTest driver

dut is the configuration tool for the HwTest driver. The command **dut start** will enable the driver as well as the UMX library. You can use dut to configure radio parameters. For example, run

```
dut txgain --value 0x1000
```

to set the transmission gain. Or, you can set the receiving gain with

```
dut rxgain --value 0x1000.
```

Or you can set the central frequency of the radio with

```
dut centrafreq --value 2414.
```

You can also use “**dut dump**” to take a snapshot of the channel and store the dump file at root of disk C. You can use the software oscilloscope to load the dump file and check the signal.

10.1.2 Using dut to transmit a signal

To transmit a signal, you can first prepare the waveform in a Tx signal file. The Tx signal file is simply an array of I/Q samples (each I or Q component is of 8-bit). The total file size should be less than 2MB. The following command line transfers the signal to the RCB memory,

```
dut transfer --file d:\frame.tx.
```

You can use “**dut info**” to check the id of all signals stored on RCB and run “**dut tx --sid 0x01**” to transfer the cached waveform (assuming the id of the frame.tx returned is 0x01). You may optionally specify a repeat number for the tx command. For example,

```
dut tx --sid 0x01 --value 100
```

tells the hwtest driver to transmit the signal 0x01 for 100 times. You can use “**dut stoptx**” to cancel a repeating transmission. When transmission is complete, you can remove the signal from the RCB memory using
dut txdone --sid 0x01.

10.1.3 Dut usage summary

<table>
<thead>
<tr>
<th>Command</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>start</td>
<td>Enable the radio hardware.</td>
</tr>
<tr>
<td>stop</td>
<td>Disable the radio hardware.</td>
</tr>
<tr>
<td>tx</td>
<td>Transmit a signal</td>
</tr>
<tr>
<td>txdone</td>
<td>Remove a stored signal from the RCB memory</td>
</tr>
<tr>
<td>dump</td>
<td>Dump the radio Rx channel</td>
</tr>
<tr>
<td>txgain</td>
<td>Set Tx Gain</td>
</tr>
<tr>
<td>rxgain</td>
<td>Set Rx Gain</td>
</tr>
<tr>
<td>rxpa</td>
<td>Set RX PA. With USRP XCVR2450 can only be 0, 0x1000, 0x2000, 0x3000</td>
</tr>
<tr>
<td>info</td>
<td>Get driver and RCB information</td>
</tr>
<tr>
<td>transfer</td>
<td>Transfer a signal to the RCB memory</td>
</tr>
<tr>
<td>centralfreq</td>
<td>Set the radio central frequency (in MHz)</td>
</tr>
<tr>
<td>freqoffset</td>
<td>Set the radio frequency compensation (in Hz), i.e., -5Hz</td>
</tr>
<tr>
<td>stopTx</td>
<td>Stop Tx</td>
</tr>
<tr>
<td>samplerrate</td>
<td>Change sample rate. No effective to USRP XCVR2450 or WARP RF daughter board</td>
</tr>
<tr>
<td>--value</td>
<td>Specify a number value to the command</td>
</tr>
<tr>
<td>--sid</td>
<td>Specify a signal ID</td>
</tr>
<tr>
<td>--file</td>
<td>Specify a file name</td>
</tr>
</tbody>
</table>

10.2 Oscilloscope

Sora SDK ver 1.5 releases software oscilloscope applications for both 802.11b DSSS and 802.11a/g OFDM signals. You can find them, `sdscope-11b` and `sdscope-11a` at `%SORA-ROOT%in`. Figure 35 and Figure 36 show the graphic interface and the annotation of each view on the windows. The following table summarizes the basic operations for the scope applications. You can press “o” to open a dump file and start/stop the processing with the space key. You can also set a “processing point” by clicking on the overview panel.
**Sdscope-11a** also allows you to specify the sampling rate of the dump file with command line, `sdscope-11a –s[40|44]`.

<table>
<thead>
<tr>
<th>Key</th>
<th>Function</th>
</tr>
</thead>
<tbody>
<tr>
<td>o/O</td>
<td>Open a dump file</td>
</tr>
<tr>
<td>Space</td>
<td>Start or Pause the processing</td>
</tr>
<tr>
<td>s/S</td>
<td>Rotate the sampling rate (sdscope-11a only)</td>
</tr>
<tr>
<td>Left Arrow/Right Arrow</td>
<td>Speedup or Slow down</td>
</tr>
<tr>
<td>Up Arrow/Down Arrow</td>
<td>Scale up/down of amplitude</td>
</tr>
</tbody>
</table>

### 10.3 SrView

SrView is a simple but handy GUI tool to view a Sora dump file. It can cut a portion of dumped signal and store it to a separate file for further analysis. You can use Menu item File/open to load a dump file. The window displays the energy of each recorded samples. You can use “up-arrow” and “down-arrow” to zoom-out and zoom-in, or use the scroll-bar at the bottom of window to view the different portion of the signal. You may select a portion of the signal – you click on the window to set a start marker and shift-click to set an end marker. You can save the selection into a separate file for later processing. Figure 35 shows a snapshot of Srview.

![SrView](image)

**Figure 35.** The main window of SrView.
Figure 36. The main window of sdscope-11b.
Figure 37. The main window of sdscope-11a.
10.4 Hardware Verification Tool

The Hardware Verification Tool (HVT) is a helpful tool to test and configure Sora hardware components. HVT supports two types of tests: the sine test (single tone test) and the SNR test (wide-band test). To use HVT, you need two Sora boxes: one works as sender and the other is a receiver.

In the sine test, the sender transmits a 1MHz sine signal; the receiver captures and analyzes the received signal. Based on this simple test, HVT can compute many useful radio related parameters, such as frequency offset between the two machines, I/Q imbalance, the direct current (DC) value and the best receiver gain setting.

In the SNR test, the sender transmits a wide-band 16QAM-modulated OFDM signal. The receiver can demodulate the signal and compute the wide-band signal-to-noise ratio (SNR). The SNR value is one key parameter to assess channel quality.

Figure 2 (at page 17) shows the main window of HVT. A summary of all elements on the window can also be found in Table 2 (at page 12). HVT is based on UMX APIs. Please make sure the RCB driver and the HwTest driver are properly installed.

10.4.1 The Sine Wave Test

a) Start the test.
   - Set up two Sora boxes. Place the two antennas about one meter apart.
   - Select sine test on both boxes.
   - Choose one box as the sender (select send) and the other as the receiver (select receive).
   - Click start button (b) at the sender. You will see the sender’s status bar (j) showing “Sending 1MHz sine wave”. If a failure occurs, the error message will be shown in the log window (k).
   - Select a proper Tx gain (t) setting at the sender (for example 15dB).
   - Choose the same sampling rate (r) as your RAB at the receiver.
Click **start button (b)** at the receiver to capture the signal. You will see the waveform displayed on two popup windows, as shown in the first row of Table 5. If failures occur, the error messages will be shown in the **log window (k)**.

By default, the receiver gain is automatically adjusted (The **AGC box (p)** is checked). But the user can disable the AGC and adjust the receiver gain manually by unchecking the box.

The user can also start a central frequency offset (CFO) calibration by clicking the **auto calibration button (e)**. The tool will automatically compute the frequency offset between the sender and receiver and adjust the receiver’s frequency setting to match the sender’s. The calibration result will be shown in the **log window (k)**.

The calibration results (parameters) can be stored in a file and the user can later configure the RF front-end based on these values. Figure 38 shows a sample configuration file.

```
[Parameter]
freqOffset=8064
txgain=0xb80
rxgain=0x1800
rxpa=0x1000
centralFreq=2422
sampleRate=40

[Calibration]
freqOffsetLineSlope=-0.894473
freqOffsetLineIntercept=121178
```

**Figure 38. A sample configuration file after calibration.**

b) Diagnosis

The user can use the sine test to pin-point several hardware related issues. Table 5 summarizes some typical graphs and their explanations. This table can be displayed anytime when the user clicks the **suggestion button (d)** at the receiver.

<table>
<thead>
<tr>
<th>Overview</th>
<th>Constellation</th>
<th>Description</th>
</tr>
</thead>
</table>

**Table 5. Typical graphs shown in the sine test and their descriptions.**
Normal signal.

The overview window displays the energy level of the received signal. Since the sine wave is sent in burst, the overview window will show this on-off pattern. The constellation view of the sine wave is a circle.

No signal received.

The receiver receives no signal. Please try the following actions to solve this problem:
1. Check if the hardware are connected properly;
2. Check if the drivers are installed properly;
3. Move the antennas closer;
4. Increase txgain at the sender side;
5. Increase rxgain and rxpa, or enable AGC at the receiver side;
6. Try to reset the hardware and disable/enable drivers.

Saturated signal.

The received signal has been saturated. Please try the following actions:
1. Decrease the rxpa and rxgain or enable AGC at the receiver;
2. Decrease the txgain at the sender side;
3. Move the antennas further away.

### 10.4.2 The SNR Test

a) Start a test

- Set up two Sora boxes. Place the two antennas about one meter apart.
- Select **snr test** on both boxes.
- Choose one box as the sender (select `send`) and the other as the receiver (select `receive`).
Click **start button (b)** at the sender. You will see the sender’s **status bar (j)** showing “Sending 16QAM wave”. If a failure occurs, the error message will be shown in the **log window (k)**.

- Select a proper **Tx gain (t)** setting at the sender (for example 15dB).
- Choose the same **sampling rate (r)** as your RAB at the receiver.
- Click **start button (b)** at the receiver to capture the signal. You will see the waveform displayed on two popup windows, as shown in the first row of Table 6. If failures occur, the error messages will be shown in the **log window (k)**.
- The SNR value, DC, as well as the frequency offset are computed and displayed on the corresponding fields in the window.

b) Diagnosis

The user can use the SNR test to pin-point several hardware related issues. Table 6 summarizes some typical graphs and their explanations. This table can be displayed anytime when the user clicks the **suggestion button (d)** at the receiver.

<table>
<thead>
<tr>
<th>Overview</th>
<th>Constellation</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td><img src="image1.png" alt="Overview" /></td>
<td><img src="image2.png" alt="Constellation" /></td>
<td>Channel quality is high. The 16QAM constellation graph is clearly displayed.</td>
</tr>
<tr>
<td>Issue</td>
<td>Solution</td>
<td></td>
</tr>
<tr>
<td>----------------------------------------------------------------------</td>
<td>--------------------------------------------------------------------------</td>
<td></td>
</tr>
<tr>
<td>No signal. The receiver receives no signal.</td>
<td>Please try the following actions to solve this problem:</td>
<td></td>
</tr>
<tr>
<td></td>
<td>1. Check if the hardware are connected properly;</td>
<td></td>
</tr>
<tr>
<td></td>
<td>2. Check if the drivers are installed properly;</td>
<td></td>
</tr>
<tr>
<td></td>
<td>3. Move the antennas closer;</td>
<td></td>
</tr>
<tr>
<td></td>
<td>4. Increase txgain at the sender side;</td>
<td></td>
</tr>
<tr>
<td></td>
<td>5. Increase rxgain and rxpa or enable AGC at the receiver side;</td>
<td></td>
</tr>
<tr>
<td></td>
<td>6. Try to reset the hardware and disable/enable drivers.</td>
<td></td>
</tr>
<tr>
<td>Channel quality is poor. The 16QAM constellation graph can hardly</td>
<td>Please try the following actions to solve this problem:</td>
<td></td>
</tr>
<tr>
<td>be observed.</td>
<td>1. Adjust the radio parameters, e.g. adjusting frequency offset, gain.</td>
<td></td>
</tr>
<tr>
<td></td>
<td>You can find proper values using the sine test;</td>
<td></td>
</tr>
<tr>
<td></td>
<td>2. Reset hardware and disable/enable the drivers;</td>
<td></td>
</tr>
<tr>
<td></td>
<td>3. Use better antennas or use a cable connection.</td>
<td></td>
</tr>
<tr>
<td>No frame detected. The receiver receives signals but no valid frame</td>
<td>Please try the following actions to solve this problem:</td>
<td></td>
</tr>
<tr>
<td>is detected.</td>
<td>1. Make sure no other interfering sources exist;</td>
<td></td>
</tr>
<tr>
<td></td>
<td>2. Increase txgain at the sender side;</td>
<td></td>
</tr>
<tr>
<td></td>
<td>3. Increase rxpa and rxgain or enable AGC at the receiver side;</td>
<td></td>
</tr>
<tr>
<td></td>
<td>4. Move the antennas closer;</td>
<td></td>
</tr>
<tr>
<td></td>
<td>5. Adjust frequency offset. You</td>
<td></td>
</tr>
</tbody>
</table>
can find proper values using the sine test;  
6. Reset hardware and disable/enable the drivers.

10.4.3 Misc functions

a) Save/Load calibrated parameters

Click save button (n) in the parameters group to save calibrated parameters in a file. A saved file can be loaded by clicking the load button (o) in the parameters group. In log window (k), the loaded parameters are displayed.

b) Save/Clear logs

Click save button (l) to save the messages in the log window to a file. Click clear button (m) to clear the messages in the log window.

c) Dump

HVT can also save a snapshot of received signal in a dump file for further analysis. To make a dump, HVT must run in the receiving mode. Clicking dump button (c) will save the signal to a file.
Chapter 11.
Reference

11.1 Kernel Mode API

1) SoraAllocateRadioFromRCBDevice

```c
HRESULT SoraAllocateRadioFromRCBDevice(
    IN OUT PLIST_ENTRY pRadiosHead,
    IN ULONG nRadio,
    IN PCWSTR UserName
);
```

Parameters

- `pRadiosHead`
  - Pointer to a list head the returned radio objects are linked to.

- `nRadio`
  - Number of the radios to allocate.

- `UserName`
  - Pointer to a Unicode string specifying a tag for the allocated radios. Each allocation code path should use an identical tag to help system to identify the code path.

Return Value

- **SoraAllocateRadioFromRCBDevice** returns `E_DEVICE_NOT_FOUND` if the RCB device cannot be found; it returns `E_NOT_ENOUGH_FREE_RADIOS` if there are not enough available radios to allocate. Otherwise, it returns `S_OK` and the allocated radios are linked to `pRadiosHead`.

Comments

- **SoraAllocateRadioFromRCBDevice** allocates one or more radios from the RCB device.

  The allocated radios are linked to the list specified by `pRadiosHead`. Otherwise, `pRadiosHead` will point to an empty list.
The allocated radios should be released using `SoraReleaseRadios`.

Requirements

IRQL: PASSIVE_LEVEL

Headers: Include sora.h

See Also


2) `SoraReleaseRadios`

```c
VOID
SoraReleaseRadios(
    IN LIST_ENTRY *pRadiosHead
);  
```

Parameters

- `pRadiosHead`
  - Pointer to the radio list.

Return Value

None

Comments


Requirements

IRQL: PASSIVE_LEVEL

Headers: Include sora.h

See Also


3) `SoraRadioInitialize`

```c
HRESULT
SoraRadioInitialize(
    IN OUT PSORA_RADIO pRadio,
    IN PVOID pReserved,
    IN ULONG nTxSampleBufSize,
    IN ULONG nRxSampleBufSize
);  
```

Parameters

- `pRadio`
Pointer to a radio object.

`pReserved`

Reserved.

`nTxSampleBufSize`

The size of the buffer that holds the transmission digital samples. Each radio object is assigned to a unique Tx sample buffer.

`nRxSampleBufSize`

The size of the buffer that holds the received digital samples. The RCB will fill the Rx sample buffer with latest received samples. The size must be a multiple of 4K.

Return Value

`SoraRadioInitialize` returns `E_NOT_ENOUGH_CONTINUOUS_PHY_MEM` if not enough memory is available. It returns `S_OK` if succeeds.

Comments

`SoraRadioInitialize` initializes a radio object and allocates the Tx and Rx sample buffers. Any allocated radio object should be first initialized before use.

Requirements

IRQL: PASSIVE_LEVEL

Headers: Include Sora.h

See also

`SoraRadioStart`

4) `SoraRadioStart`

```c
HRESULT SoraRadioStart ( IN OUT PSORA_RADIO pRadio, ULONG RxGain, ULONG TxGain, PSORA_RADIO_CONFIG pConfig );
```

Parameters
pRadio

Pointer to the radio object to be enabled.

RxGain

Reception gain in units of 1/256 dB, e.g. a value of 0x200 means 2dB.

TxGain

Transmission gain in units of 1/256 dB, e.g. a value of 0x200 means 2dB.

pConfig

Pointer to a reserved configuration structure.

Return Value

SoraRadioStart returns S_OK if the radio hardware is enabled successfully. It returns E_RADIO_NOT_CONFIGURED if the radio object is not properly initialized and E_REG_WRITE_FAIL if hardware fails.

Comments

SoraRadioStart enables the RF front-end and sets the gain control parameters.

The SDR driver may change the gain setting later using SoraHwSetTXVGA1 and SoraHwSetRXVGA1. The SDR driver can get the current gain setting using SORA_RADIO_GET_RX_GAIN and SORA_RADIO_GET_TX_GAIN.

Requirements

IRQL: PASSIVE_LEVEL

Headers: Include Sora.h

See also

SoraHwSetTXVGA1, SoraHwSetRXVGA1, SoraHwSetCentralFreq.

5) SoraRadioGetRxStream

```c
__inline
PSORA_RADIO_RX_STREAM SoraRadioGetRxStream ( PSORA_RADIO pRadio );
```
Parameters
   pRadio
       Pointer to a radio object.

Return Value
   SoraRadioGetRxStream returns the pointer of RX_STREAM associated with the radio object.

Comments
   When a radio object is initialized, an RX_STREAM object is also created and associated to
   the radio object. A SDR driver should use the RX_STREAM object to read the radio’s Rx
   sample buffer.

Requirements
   IRQL: <= DISPATCH_LEVEL
   Headers: Include Sora.h

See Also
   SoraRadioReadRxStream

6) SoraRadioReadRxStream

```
HRESULT SoraRadioReadRxStream (
   PSORA_RADIO_RX_STREAM pRxStream,
   FLAG * pbTouched,
   SignalBlock& block
);
```

Parameters
   pRxStream
       Pointer of the RX_STREAM object.

   pbTouched
       Pointer to a flag that receives the indication of the emptiness of the RX channel.

   block
       Signal block just read.

Return Value
The return value is S_OK if a signal block is succeeded read. Otherwise, the return value is E_FETCH_SIGNAL_HW_TIMEOUT if no new signal blocks are available in a timeout period. This may indicate an error in hardware.

Comments

This function gets a new signal block from the RX_STREAM object. pbTouched points to a flag variable that receives the indication whether or not the returned signal block is the last one in the RX channel. If the flag is set, the RX channel of the radio is empty.

This function can also be called in user-mode.

Requirements

Headers: Include soradsp.h

See Also

SoraRadioGetRxStream

7) SoraRadioGetRxStreamPos

```c
PRX_BLOCK SoraRadioGetRxStreamPos (PSORA_RADIO_RX_STREAM pRxStream);
```

Parameters

pRxStream

Pointer of RX_STREAM object.

Return Value

The current position of the RX_STREAM object.

Comments

This function returns the current position of the RX_STREAM.

This function can also be called in user-mode.

Requirements

Headers: Include _rx_stream.h

See Also
SoraRadioReadRxStream

8) SoraInitSignalCache

```
HRESULT SoraInitSignalCache(
    OUT PSIGNAL_CACHE pCache,
    IN PSORA_RADIO pRadio,
    IN ULONG uSize,
    IN ULONG uMaxEntryNum
);
```

Parameters

- **pCache**
  - Pointer to a signal cache object to be initialized.

- **pRadio**
  - Pointer to the radio object that allocates the signal cache.

- **uSize**
  - The size, in bytes, of each entry in the signal cache. The size must be a multiple of 128 byte.

- **uMaxEntryNum**
  - The maximum number of entries in the signal cache.

Return Value

- **SoraInitSignalCache** returns S_OK if succeeded. It returns E_NO_FREE_TX_SLOT if there is not enough onboard memory associated to the radio object. It returns E_INVALID_SIGNAL_SIZE if the specified size is not a multiple of 128.

Comments

- A signal cache allocates a portion of RCB onboard memory to store pre-computed signals.

- These cached signals can be transmitted for multiple times later using **SORA_HW_FAST_TX**.

Requirements

- IRQL: If the cache object is non-paged, **SoraInitSignalCache** can be called at IRQL <= DISPATCH_LEVEL; Otherwise it must be called at PASSIVE_LEVEL.

- Headers: Include sora.h
See Also
SoraCleanSignalCache, SoraGetSignal, SoraInsertSignal.

9) SoraInsertSignal

HR SoraInsertSignal(
   IN PSIGNAL_CACHE pCache,
   IN PCOMPLEX8 pSampleBuffer,
   IN PHYSICAL_ADDRESS *pSampleBufferPa,
   IN ULONG uSampleSize,
   IN CACHE_KEY Key
);

Parameters
pCache
   Pointer to the signal cache object.

pSampleBuffer
   Pointer to a buffer containing the signal samples to be inserted.

pSampleBufferPa
   Pointer to the physical address structure of the sample buffer.

uSampleSize
   The size, in bytes, of the signal to be inserted. It must be a multiple of 128 bytes.

Key
   An 8-byte key associated to the signal.

Return Value
SoraInsertSignal returns E_SIGNAL_EXISTS if a same key is already in the cache. [Kun: what happens next? The signal is overwrote or not?] It returns E_NOT_ENOUGH_RESOURCE if there is no free entries in the cache.

SoraInsertSignal returns E_INVALID_SIGNAL_SIZE if uSampleSize is not a multiple of 128.

Comments
The size of the signal should be less than the buffer size of a cache entry; Otherwise it will cause a fatal error.
Requirements

IRQL : <= DPC_LEVEL

Headers: sora.h

See Also

SoraGetSignal, SORA_HW_FAST_TX.

10) SoraGetSignal

```c
PTX_DESC
SORAAPI
SoraGetSignal (  
    IN PSIGNAL_CACHE pCache,  
    IN CACHE_KEY   Key  
);  
```

Parameters

pCache

Pointer to the signal cache object from which to retrieve a signal.

Key

The 8-byte key associated to a cache entry.

Return Value

**SoraGetSignal** returns a TX descriptor of the stored signal; otherwise, it returns NULL if the key cannot be found in the cache.

Requirements

IRQL: <= DISPATCH_LEVEL

Headers: Include sora.h

See Also

SoraInsertSignal

11) SoraCleanSignalCache

```c
void
SoraCleanSignalCache (  
    IN PSIGNAL_CACHE pCache  
);  
```

Parameters

pCache

Pointer to the signal cache to be cleaned.
Return Value

None.

Comments

The SDR application should call `SoraCleanSignalCache` to free the RCB onboard memory.

12) **SoraHwSetSampleClock**

```c
VOID SoraHwSetSampleClock ( 
    PSORA_RADIO pRadio, 
    ULONG Hz 
); 
```

Parameters

- **pRadio**
  
  Pointer to the radio object to be configured.

- **Hz**
  
  The desired sampling rate, in unit of Hz.

Return Value

None.

Comments

The sampling clock depends on the implementation of the RF front-end board. This function only provides a hint to the hardware and can be silently ignored by the hardware component.

13) **SoraHwSetCentralFreq**

```c
VOID SoraHwSetCentralFreq ( 
    PSORA_RADIO pRadio, 
    ULONG kHzCoarse, 
    LONG HzFine 
); 
```

Parameters

- **pRadio**
  
  Pointer to the radio object to be configured.

- **kHzCoarse**
  
  The coarse part (KHz) of the desired central frequency.
HzFine

The fine part (Hz) of the desired central frequency.

Return Value
None.

Comments

*SoraHwSetCentralFreq* sets the central frequency of the RF front-end. The desired central frequency is split into the coarse part (kHz) and the fine part (Hz), and

Central freq = kHzCoarse * 1000 + HzFine.

14) *SoraHwSetFreqCompensation*

```c
VOID SoraHwSetFreqCompensation ( 
  PSORA_RADIO pRadio, 
  LONG lFreq
);
```

Parameters

- pRadio
  Pointer to the radio object to be configured.

- lFreq
  The frequency, in Hz, to be compensated.

Return Value
None

Comments

*SoraHwSetFreqCompensation* sets the central frequency compensation. The true frequency that the RF front-end works on is the sum of the frequency sets by *SoraHwSetCentralFreq* and the compensation value specified by *SoraHwSetFreqCompensation*. *SoraHwSetFreqCompensation* provides a convenient way to synchronize the central frequency between the sender and the receiver.

15) *SoraHwSetTXVGA1*
SoraHwSetTXVGA1 (PSORA_RADIO pRadio, ULONG uGain);

Parameters
  pRadio
      Pointer to the radio object to be configured.
  uGain
      The value, in unit of 1/256 dB, to be set to transmission Variable Gain Amplifier (VGA) of the RF front-end.

Return Value
  None

Comments
  SoraHwSetTXVGA1 sets the transmission variable gain amplifier of the RF front-end. The gain control is specified in unit of 1/256 dB. However, the true precision of VGA depends on the implementation of the RF front-end.

16) SoraHwSetRXPA

VOID SoraHwSetRXPA (PSORA_RADIO pRadio, ULONG uGain);

Parameters
  pRadio
      Pointer to the radio object to be configured.
  uGain
      The gain value sent to the RF front-end to configure the receiving Low Noise Amplifier (LNA).

Return Value
  None

Comments
**SoraHwSetRXPA** writes a value to the virtual control register of the RF front-end to provide a hint to configure LNA on the reception path. The value depends on the implementation of the RF front-end board. For USRP XCVR2450 board, there can be three effective configurations: 0 (or 0x1000) means 0dB, 0x2000 means 16dB, and 0x3000 means 32dB.

**SoraHwSetRXVGA1**

```c
VOID SoraHwSetRXVGA1(PSORA_RADIO pRadio, ULONG uGain);
```

**Parameters**

- **pRadio**
  Pointer to the radio object to be configured.

- **uGain**
  The value, in unit of 1/256 dB, to be set to the reception Variable Gain Amplifier (VGA) of the RF front-end.

**Return Value**

None

**Comments**

**SoraHwSetRXVGA1** sets the reception variable gain amplifier of the RF front-end. The gain control is specified in unit of 1/256 dB. However, the true precision of VGA depends on the implementation of the RF front-end.

17) **SORA_HW_TX_TRANSFER**

```c
HRESULT SORA_HW_TX_TRANSFER (IN PSORA_RADIO pRadio, IN PPACKET_BASE pPacket);
```

**Parameters**

- **pRadio**
  Pointer to the radio object that the modulated signal of a frame is transferred to.

- **pPacket**
  Pointer to the packet base object.
Return Value

**SORA_HW_TX_TRANSFER** returns S_OK on success.

Comments

**SORA_HW_TX_TRANSFER** downloads the modulated signals of a frame from the shared TX sample buffer to the memory location on RCB as indicated in the packet base object.

18) SORA_HW_TX

```c
HRESULT SORA_HW_TX ( 
    PSORA_RADIO pRadio, 
    PPACKET_BASE pPacket 
);
```

Parameters

pRadio

Pointer to the radio object to send the signal.

pPacket

Pointer to the packet base object.

Return Value

**SORA_HW_TX** returns S_OK on success.

Comments

**SORA_HW_TX** indicates the hardware to send out the signal at the memory location on the RCB as indicated in the packet base object. The function will be blocked until the signal has been transmitted out. The signal should be previously transferred onto the RCB memory using **SORA_HW_TX_TRANSFER**.

19) SORA_HW_FAST_TX

```c
HRESULT SORA_HW_FAST_TX ( 
    PSORA_RADIO pRadio, 
    PTX_DESC pTxDesc 
);
```

Parameters

pRadio

Pointer to the radio object to send the signal.
pTxDesc

    Pointer to the TX descriptor.

Return Value

    SORA_HW_FAST_TX returns S_OK on success.

Comments

    SORA_HW_FAST_TX indicates the hardware to send out the signal at the memory location on the RCB as indicated in the Tx Descriptor. A Tx Descriptor is normally obtained after querying an entry of a signal cache.

20) SORA_HW_ENABLE_RX

VOID
SORA_HW_ENABLE_RX (  
    PSORA_RADIO pRadio  
    );

Parameters

    pRadio

        Pointer to the radio object whose RX channel is to be enabled.

Return Value

    None.

Comments

    SORA_HW_ENABLE_RX enables the RX channel of a radio object. Once the RX channel is enabled, the hardware starts to fill the RX sample buffer via DMA operations.

21) SORA_HW_STOP_RX

VOID
SORA_HW_STOP_RX (  
    PSORA_RADIO pRadio  
    );

Parameters

    pRadio

        Pointer to the radio object whose RX channel is to be disabled.

Return Value

    None.
Comments

**SORA_HW_STOP_RX** disables the RX channel of a radio object. Once the RX channel is disabled, the DMA operations are stopped.

22) **SoraPacketGetTxSampleBuffer**

```c
VOID SORAAPI SoraPacketGetTxSampleBuffer(
    IN PPACKET_BASE pPacket,
    OUT PTXSAMPLE *ppBuf,
    OUT PULONG pBufSize
);
```

Parameters

- **pPacket**
  Pointer to the packet base object.

- **ppBuf**
  Pointer to a sample buffer pointer.

- **pBufSize**
  Pointer to an unsigned variable that receives the sample buffer size.

Return Value

None.

Comments

**SoraPacketGetTxSampleBuffer** obtains and locks the shared TX sample buffer from the radio that is associated to the packet object. After calling this function, the SDR driver can fill the TX sample buffer with the modulated signal samples.

23) **SoraPacketSetSignalLength**

```c
VOID SORAAPI SoraPacketSetSignalLength ( 
    IN OUT PPACKET_BASE pPacket,
    IN ULONG uLen
);
```

Parameters

- **pPacket**
  Pointer to the packet base object.

- **uLen**
  The length, in bytes, of the modulated signal.
Return Value

None.

Comments

*SoraPacketSetSignalLength* specifies the actual bytes that have been occupied by the modulated signal of a data frame. The SDR driver should call this function right after it stores the modulated waveform in the TX sample buffer.

24) SoraPacketSetTXDone

```c
__inline
void
SoraPacketSetTXDone (
    IN OUT PPACKET_BASE pPacket
);  
```

Parameters

pPacket

    Pointer to the packet base object.

Return Value

None.

Comments

*SoraPacketSetTXDone* sets the status of a packet base object to PACKET_TX_DONE. The function also frees the RCB memory that the signal has previously been transferred.

25) SoraThreadAlloc

```c
HANDLE
SoraThreadAlloc ();  
```

Parameters

None.

Return Value

*SoraThreadAlloc* returns NULL if an error occurred; otherwise it returns the handle of a Sora thread.

Comments
**SoraThreadAlloc** allocates a Sora exclusive thread object. A Sora exclusive thread cannot be preempted by any other thread and should be only used for real-time tasks on a multi-core system. After allocation, the SDR application should call **SoraThreadStart** to start an exclusive thread.

Requirements

IRQL: <= DISPATCH_LEVEL
Headers: Include thread_if.h

See Also

SoraThreadFree

### 26) SoraThreadFree

```c
VOID
SoraThreadFree (  
   IN HANDLE hThread  
);
```

Parameters

hThread

Handle to the Sora thread object.

Return Value

None.

Comments

**SoraThreadFree** release the Sora thread object that is previously allocated by **SoraThreadAlloc**.

Requirements

IRQL: PASSIVE_LEVEL
Headers: Include thread_if.h

See Also

SoraThreadAlloc

### 27) SoraThreadStart

```c
BOOLEAN
SoraThreadStart (  
```
IN HANDLE hThread,  
IN PSORA_UTHREAD_PROC pUserRoutine,  
IN PVOID pParameter  
)

Parameters

hThread

Handle to the Sora thread object.

pUserRoutine

Address of a routine that the Sora thread calls periodically.

pParameter

Parameter provided to the user routine.

Return Value

SoraThreadStart returns TRUE if success; otherwise it returns FALSE.

Comments

SoraThreadStart starts a Sora exclusive thread that will call the user specified routine periodically. The user routine should have the follow prototype

BOOLEAN (*PSORA_UTHREAD_PROC) ( PVOID pParameter ) ;

The user routine should not contain long processing loops. Large processing tasks should be divided into several small pieces and the user routine should return when one piece of work has finished. If the user routine returns a value of TRUE, it will be immediately called again to continue the rest processing work. A return value of FALSE indicates the thread should be stopped. Alternatively, other thread can call SoraThreadStop to terminate this Sora thread.

Caution: Never call SoraThreadStop to terminate a Sora thread from its user routine. It will cause a dead-lock.

Requirements

IRQL: PASSIVE_LEVEL
Headers: Include thread_if.h

See Also
SoraThreadStop

28) SoraThreadStop

```c
VOID SoraThreadStop(
   IN HANDLE hThread
);
```

Parameters

hThread

Handle of the Sora thread object.

Return Value

None.

Comments

SoraThreadStop stops the running Sora thread.

Caution: Never call SoraThreadStop to terminate a Sora thread from its user routine. It will cause a dead-lock.

Requirements

IRQL: PASSIVE_LEVEL
Headers: Include thread_if.h

See Also
SoraThreadStart

11.2 UMX API

29) SoraUInitUserExtension
BOOLEAN
SoraUInitUserExtension (
    const char * szDevName
);:

Parameters

    szDevName
        Pointer to the name of device supporting UMX API.

Return Value

    SoraUInitUserExtension returns true if the initialization succeeds; otherwise, it returns false.

Comments

    SoraUInitUserExtension initializes the user-mode extension. The device name should be "\\HWTest".

30) SoraUCleanUserExtension

VOID
SoraUCleanUserExtension () ;:

Parameters

    None.

Return Value

    None.

Comments

    SoraUCleanUserExtension cleans the resources allocated when initialing the user-mode extension.

31) SoraURadioStart

HRESULT
SoraRadioStart (
    IN ULONG uRadioID
);:

Parameters

    uRadioID
        The ID referring to the radio object.
Return Value

**SoraURadioStart** returns S_OK if the radio hardware is enabled successfully.

Comments

**SoraURadioStart** enables the RF front-end and initializes the gain control parameters.

### 32) SoraURadioSetSampleRate

```c
HRESULT SoraURadioSetSampleRate(
    IN ULONG uRadioID,
    IN ULONG MHz)
);
```

Parameters

- **uRadioID**
  
  The ID referring to the radio object.

- **MHz**
  
  The desired sampling rate, in unit of MHz.

Return Value

**SoraURadioSetSampleRate** returns S_OK if the sample rate is successfully set.

Comments

The sampling clock depends on the implementation of the RF front-end board. This function only provides a hint to the hardware and can be silently ignored by the hardware component.

### 33) SoraURadioSetCentralFREQ

```c
HRESULT SoraURadioSetCentralFreq ( 
    ULONG uRadioID,
    ULONG KHz
);
```

Parameters

- **uRadioID**
  
  The ID referring to the radio object.

- **KHz**
  
  The KHz of the desired central frequency.

Return Value
SoraURadioSetCentralFreq returns S_OK if the central frequency is successfully set.

Comments

SoraURadioSetCentralFreq sets the central frequency of the RF front-end.

34) SoraURadioSetFreqOffset

HRESULT SoraURadioSetFreqOffset(
    ULONG uRadioID,
    LONG lFreq
);

Parameters

uRadioID
    The ID referring to the radio object.

lFreq
    The frequency offset, in Hz, to be set.

Return Value

SoraURadioSetFreqOffset returns S_OK if the frequency offset is successfully set.

Comments

SoraURadioSetFreqOffset sets the frequency offset. The true frequency that the RF front-end works on is the sum of the frequency sets by SoraURadioSetCentralFreq and the offset value specified by SoraURadioSetFreqOffset.

SoraURadioSetFreqOffset provides a convenient way to synchronize the central frequency between the sender and the receiver.

35) SoraURadioSetTxGain

HRESULT SoraURadioSetTxGain ( 
    ULONG uRadioID,
    ULONG uGain
);

Parameters

uRadioID
    The ID referring to the radio object.
uGain

The value, in unit of 1/256 dB, to be set to transmission Variable Gain Amplifier (VGA) of the RF front-end.

Return Value

SoraURadioSetTxGain returns S_OK if the Tx Gain is successfully set.

Comments

SoraURadioSetTxGain sets the transmission variable gain amplifier of the RF front-end. The gain control is specified in unit of 1/256 dB. However, the true precision of VGA depends on the implementation of the RF front-end.

36) SoraURadioSetRxPA

HRESULT SoraURadioSetRxPA (ULONG uRadioID, ULONG RxPa);

Parameters

uRadioID

The ID referring to the radio object.

RxPa

The gain value sent to the RF front-end to configure the receiving Low Noise Amplifier (LNA).

Return Value

SoraURadioSetRxPA returns S_OK if the Rx PA is successfully set.

Comments

SoraURadioSetRxPA writes a value to the virtual control register of the RF front-end to provide a hint to configure LNA on the reception path. The value depends on the implementation of the RF front-end board. For USRP XCVR2450 board, there can be three
effective configurations: 0 (or 0x1000) means 0dB, 0x2000 means 16dB, and 0x3000 means 32dB.

37) SoraURadioSetRxGain

```
HRESULT SoraURadioSetRxGain(
    ULONG uRadioID,
    ULONG uGain
);
```

Parameters

- **uRadioID**
  The ID referring to the radio object.

- **uGain**
  The value, in unit of 1/256 dB, to be set to the reception Variable Gain Amplifier (VGA) of the RF front-end.

Return Value

*SoraURadioSetRxGain* returns S_OK if the Rx Gain is successfully set.

Comments

*SoraURadioSetRxGain* sets the reception variable gain amplifier of the RF front-end. The gain control is specified in unit of 1/256 dB. However, the true precision of VGA depends on the implementation of the RF front-end.

38) SoraURadioMapTxSampleBuf

```
HRESULT SoraURadioMapTxSampleBuf(
    IN ULONG uRadioID,
    OUT PVOID *ppBuf,
    OUT PULONG puSize
);
```

Parameters

- **uRadioID**
  The ID referring to the radio object.

- **ppBuf**
  Address of a pointer variable that receives the pointer to the mapped TX sample buffer of the radio.
puSize

Address of an unsigned long variable that receives the size of the mapped TX sample buffer.

Return Value

**SoraURadioMapTxSampleBuf** returns S_OK if success.

Comments

**SoraURadioMapTxSampleBuf** maps the TX sample buffer of the radio object into the user-mode space. The radio object is specified by RadioID. The function needs to be called only once during the initialization phase of a SDR application. The SDR application then can directly output digital samples to the TX sample buffer via this mapped address.

39) **SoraURadioTransfer**

```c
HRESULT
SoraURadioTransfer (  
    IN ULONG uRadioID,  
    IN ULONG uSignalLen,  
    OUT PULONG pTxID  
);  
```

Parameters

- uRadioID
  The ID referring to the radio object.
- uSignalLen
  The signal length stored in Tx sample buffer.
- pTxID
  Address of a ULONG variable that receives the TxID of transferred signal.

Return Value

**SoraURadioTransfer** returns S_OK if success.

Comments

**SoraURadioTransfer** allocates a block of RCB memory and transfers the modulated signal in the TX sample buffer to that memory block. The returned TxID can be later used in **SoraURadioTx** to transfer the signal or used in **SoraURadioTxFree** to remove the signal from RCB memory.
40) SoraURadioTx

HRESULT SoraURadioTx (
    IN ULONG uRadioID,
    IN ULONG TxID
);

Parameters

uRadioID
   The ID referring to the radio object.

TxID
   TX ID of a signal to be transmitted.

Return Value

SoraURadioTx returns S_OK if success.

Comments

SoraURadioTx instructs the hardware to send out the signal indicated by the TX ID. The
signal should have been transferred to the RCB memory using SoraURadioTransfer.

41) SoraURadioTxFree

HRESULT SoraURadioTxFree ( 
    IN ULONG uRadioID,
    IN ULONG TxID
);

Parameters

uRadioID
   The ID referring to the radio object.

TxID
   TX ID of a signal to be freed.

Return Value

SoraURadioTxFree returns S_OK if success.

Comments

SoraURadioTxFree frees the memory block on RCB that holds the signal indicated by the
TxID. After SoraURadioTxFree, the TX ID is no longer valid.
42) SoraURadioUnmapTxSampleBuf

```c
HRESULT SoraURadioUnmapTxSampleBuf ( 
    IN ULONG uRadioID, 
    IN PVOID pMappedBuf 
);
```

Parameters
- `uRadioID` 
  The ID referring to the radio object.
- `pMappedBuf` 
  Pointer to the mapped TX sample buffer.

Return Value

**SoraURadioUnmapTxSampleBuf** returns S_OK if success.

Comments

*SoraURadioUnmapTxSampleBuf* releases the mapped TX sample buffer. The user-mode address, as pointed by `pMappedBuf`, is no longer valid. `pMappedBuf` should contain a valid address that is returned by *SoraURadioMapTxSampleBuf*.

43) SoraURadioMapRxSampleBuf

```c
HRESULT SoraURadioMapRxSampleBuf ( 
    ULONG uRadioID, 
    OUT PVOID *ppBuf, 
    OUT PULONG puSize 
);
```

Parameters
- `uRadioID` 
  The ID referring to the radio object.
- `ppBuf` 
  Address of a pointer variable that receives the pointer to the mapped RX sample buffer of the radio.
- `puSize` 
  Address of an unsigned long variable that receives the size of the mapped RX sample buffer.
Return Value

**SoraURadioMapRxSampleBuf** returns S_OK if success.

Comments

**SoraURadioMapRxSampleBuf** maps the RX sample buffer of the radio object into the user-mode space. The radio object is specified by *uRadioID*. **SoraURadioMapRxSampleBuf** needs to be called only once during the initialization phase of a SDR application. The SDR application then can directly read digital samples from the RX sample buffer via this mapped address.

44) **SoraURadioUnmapRxSampleBuf**

```c
HRESULT SoraURadioUnmapRxSampleBuf(
    ULONG uRadioID,
    OUT PVOID pMappedBuf,
):
```

Parameters

- **uRadioID**
  - The ID referring to the radio object.
- **pMappedBuf**
  - Pointer to the mapped RX sample buffer.

Return Value

**SoraURadioUnmapRxSampleBuf** returns S_OK if success.

Comments

**SoraURadioUnmapRxSampleBuf** releases the mapped RX sample buffer. The user-mode address, as pointed by pMappedBuf, is no longer valid. pMappedBuf should contain a valid address that is returned by **SoraURadioMapRxSampleBuf**.

45) **SoraURadioAllocRxStream**

```c
HRESULT SORA_API SoraURadioAllocRxStream(
    OUT PSORA_RADIO_RX_STREAM pRxStream,
    IN ULONG uRadioID,
    IN UCHAR pMappedRxBuf,
    IN ULONG uSize
):
```

Parameters
pRxStream
    Pointer to a RX_STREAM object.

uRadioID
    The ID referring to the radio object.

pMappedRxBuf
    Pointer to the mapped RX sample buffer.

uSize
    Size, in bytes, of the mapped RX sample buffer.

Return Value

**SoraURadioAllocRxStream** returns S_OK if success. It returns E_RADIO_NOT_CONFIGURED if the radio object is not properly initialized. It returns E_FAIL if the radio object cannot allocate a new RX_STREAM object.

Comments

**SoraURadioAllocRxStream** retrieves a RX_STREAM object from the mapped RX sample buffer of the radio object. A SDR application should use SoraRadioReadRxStream with the RX_STREAM object to read received digital samples, instead of directly accessing the RX sample buffer of a radio. pMappedRxBuf should contain a valid address that is returned by **SoraURadioMapRxSampleBuf**.

46) SoraRadioReadRxStream

```c
HRESULT
SoraRadioReadRxStream (  
    PSORA_RADIO_RX_STREAM pRxStream,  
    FLAG * pbTouched,  
    SignalBlock& block  
);
```

Parameters

pRxStream
    Pointer of the RX_STREAM object.

pbTouched
    Pointer to a flag that receives the indication of the emptiness of the RX channel.

block
    Signal block just read.
Return Value

The return value is S_OK if a signal block is succeeded read. Otherwise, the return value is E_FETCH_SIGNAL_HW_TIMEOUT if no new signal blocks are available in a timeout period. This may indicate an error in hardware.

Comments

This function gets a new signal block from the RX_STREAM object. pbTouched points to a flag variable that receives the indication whether or not the returned signal block is the last one in the RX channel. If the flag is set, the RX channel of the radio is empty.

This function can also be called in kernal-mode.

Requirements

Headers: Include soradsp.h

47) SoraRadioGetRxStreamPos

```c
PRX_BLOCK SoraRadioGetRxStreamPos (
    PSORA_RADIO_RX_STREAM pRxStream
);
```

Parameters

pRxStream

Pointer of RX_STREAM object.

Return Value

The current position of the RX_STREAM object.

Comments

This function returns the current position of the RX_STREAM.

This function can also be called in user-mode.

Requirements

Headers: Include _rx_stream.h

See Also

SoraRadioReadRxStream
48) SoraURadioReleaseRxStream

VOID
SORAAPI
SoraURadioReleaseRxStream (  
   IN PSORA_RADIO_RX_STREAM pRxStream,  
   IN ULONG uRadioID,  
);  

Parameters
  pRxStream
   Pointer to a RX_STREAM object.
  uRadioID
   The ID referring to the radio object.

Return Value
   None.

Comments
   SoraURadioReleaseRxStream releases the RX_STREAM object that allocated from SoraURadioAllocRxStream. Once SoraURadioReleaseRxStream is called, the RX_STREAM is not valid anymore.

49) SoraUAcquireTxBufLock

HRESULT
SoraUAcquireTxBufLock (  
   ULONG uRadioID  
);  

Parameters
  uRadioID
   ID of the radio object whose TX buffer is to be locked.

Return Value
   SoraUAcquireTxBufLock returns S_OK is success.

Comments
   SoraUAcquireTxBufLock acquires the shared TX buffer lock of the radio object. After acquiring the lock, the application has exclusive access to the TX sample buffer of the radio. A SDR application should release the lock after it has transferred the modulated signal to the RCB memory, so that other SDR applications can use the TX buffer to output and transfer their signals.
50) SoraUReleaseTxBufLock.

```c
VOID SoraUReleaseTxBufLock ( 
    ULONG uRadioID 
);
```

Parameters

- **uRadioID**
  - ID of the radio object whose TX buffer lock is to be released.

Return Value

- None.

Comments

- `SoraUReleaseTxBufLock` releases the shared TX buffer lock of the radio object. The SDR application should previously obtain the TX buffer lock by `SoraUAcquireTxBufLock`.

51) SoraUWriteRadioRegister

```c
HRESULT SoraUWriteRadioRegister ( 
    IN ULONG uRadioID, 
    IN ULONG uAddr, 
    IN ULONG uValue 
);
```

Parameters

- **uRadioID**
  - ID of the radio object to be configured.
- **uAddr**
  - Address of the register on the RF front-end board.
- **uValue**
  - Value to be written to the radio register.

Return Value

- `SoraUWriteRadioRegister` returns S_OK if success.

Comments

- `SoraUWriteRadioRegister` writes to a value to a virtual register on the RF front-end board. The definition of the register and the value depends on the RF front-end implementation. This function allows the SDR application to access the extended registers of a RF front-end board.
52) SoraUReadRadioRegister

```c
HRESULT SoraUReadRadioRegister ( 
    IN ULONG uRadioID, 
    IN ULONG uAddr, 
    IN ULONG * puVal 
);
```

**Parameters**

- `uRadioID`
  - ID of the radio object to be configured.
- `uAddr`
  - Address of the register on the RF front-end board.
- `uValue`
  - Address of an unsigned long variable that receives the register value.

**Return Value**

- `SoraUReadRadioRegister` returns `S_OK` if success.

**Comments**

`SoraUReadRadioRegister` reads the value in a virtual register on the RF front-end board. The definition of the register and the value depends on the RF front-end implementation. This function allows the SDR application to access the extended registers of a RF front-end board.

53) SoraUIndicateRxPacket

```c
HRESULT SoraUIndicateRxPacket ( 
    IN UCHAR* pPktBuf, 
    IN ULONG uPktLength 
);
```

**Parameters**

- `pPktBuf`
  - Pointer to the buffer containing a data packet.
- `uPktLength`
  - Size of the data packet, in bytes.

**Return Value**
**SoraUIndicateRxPacket** returns S_OK if success.

Comments

**SoraUIndicateRxPacket** indicates a demodulated packet to the HwTest driver, which then indicates the packet to the upper layers, i.e. TCP/IP, for further processing. **SoraUIndicateRxPacket** enables the seamless integration of the SDR application with Windows network stack.

54) **SoraUThreadAlloc**

<table>
<thead>
<tr>
<th>HANDLE</th>
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</thead>
<tbody>
<tr>
<td>SoraUThreadAlloc ();</td>
</tr>
</tbody>
</table>

Parameters

None

Return Value

**SoraUThreadAlloc** returns NULL if an error occurred; otherwise it returns the handle of a Sora thread.

Comments

**SoraUThreadAlloc** allocates a Sora exclusive thread object. A Sora exclusive thread cannot be preempted by any other thread and should be only used for real-time tasks on a multi-core system. After allocation, the SDR application should call **SoraUThreadStart** to start an exclusive thread.

55) **SoraUThreadFree**

<table>
<thead>
<tr>
<th>VOID</th>
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<tbody>
<tr>
<td>SoraUThreadFree (</td>
</tr>
<tr>
<td>IN HANDLE hThread</td>
</tr>
<tr>
<td>);</td>
</tr>
</tbody>
</table>

Parameters

hThread

Handle to the Sora thread object.

Return Value
None.

Comments

**SoraUThreadFree** release the Sora thread object that is previously allocated by **SoraUThreadAlloc**.

56) **SoraUThreadStart**

```c
BOOLEAN
SoraUThreadStart (  
    IN HANDLE hThread,  
    IN PSORA_UTHREAD_PROC pUserRoutine,  
    IN PVOID pParameter
);
```

Parameters

- **hThread**
  Handle to the Sora thread object.

- **pUserRoutine**
  Address of a routine that the Sora thread calls periodically.

- **pParameter**
  Parameter provided to the user routine.

Return Value

**SoraUThreadStart** returns TRUE if success; otherwise it returns FALSE.

Comments

**SoraUThreadStart** starts a Sora exclusive thread that will call the user specified routine periodically. The user routine should have the follow prototype

```c
BOOLEAN (*PSORA_UTHREAD_PROC)( PVOID pParameter);
```

The user routine should not contain long processing loops. Large processing tasks should be divided into several small pieces and the user routine should return when one piece of work has finished. If the user routine returns a value of TRUE, it will be immediately called again to continue the rest processing work. A return value of FALSE indicates the thread should be stopped. Alternatively, other thread can call **SoraUThreadStop** to terminate this Sora thread.

**Caution:** Never call **SoraUThreadStop** to terminate a Sora thread from its user routine. It will cause a dead-lock.
57) SoraUThreadStop

VOID SoraUThreadStop(
    IN HANDLE hThread
);

Parameters

hThread
   Handle of the Sora thread object.

Return Value

None.

Comments

SoraUThreadStop stops the running Sora thread.

Caution: Never call SoraUThreadStop to terminate a Sora thread from its user routine. It will cause a dead-lock.

58) SoraUGetTxPacket

HRESULT SoraUGetTxPacket(
    OUT HANDLE * phPacket,
    OUT VOID ** ppAddr,
    OUT UINT * puLength,
    IN DWORD dwTimeout
);

Parameters

phPacket
   Address of a pointer variable that receives the TX data packet handle.

ppAddr
   Address of a pointer variable that receives the start address of a TX data packet.

puLength
   Address of an unsigned integer that receives the length, in bytes, of the TX data packet.

dwTimeout
   The timeout interval, in milliseconds, or INFINITE.

Return Value

SoraUGetTxPacket returns S_OK if a TX data packet is successfully obtained.
It returns ERROR_CANCELLED if SoraUEnableGetTxPacket is not called or
**SoraUDisableGetTxPacket** is called to disable the SDR application to obtain a data packet from hwtst driver. **SoraUGetTxPacket** returns ERROR_INVALID_HANDLE if the UMX is not initialized.

**SoraUGetTxPacket** returns ERROR_TIMEOUT if the timeout interval has elapsed without getting a data packet.

Comments
**SoraUGetTxPacket** allows the SDR application to retrieve an Ethernet packet from the HWTest driver, which has received these data packets from upper layers, e.g. TCP/IP, in the Windows network stack. The SDR application can convert the packet format, modulate signal, and finally transmit the signal through RCB and RF front-end boards.

59) **SoraUCompleteTxPacket**

```c
HRESULT SoraUCompleteTxPacket ( 
    IN HANDLE hPacket, 
    IN HRESULT hResult 
);
```

Parameters
- **hPacket**
  Handle to a data packet obtained using **SoraUGetTxPacket**.
- **hResult**
  The resulting status of the packet.

Return Value
**SoraUCompleteTxPacket** returns S_OK if success.

Comments
**SoraUCompleteTxPacket** indicates the hwtst driver (then all upper layers in the network stack) the completion of the data packet transmission. hResult is set to S_OK if the packet has been successfully handled. Otherwise, a S_FAIL should be set. The SDR application should eventually call **SoraUCompleteTxPacket** to release the resource associated to the data packet along the network stack.

60) **SoraUEnableGetTxPacket**

```c
HRESULT SoraUEnableGetTxPacket ();
```
Parameters
None

Return Value
- **SoraUEnableGetTxPacket** returns S_OK if success.

Comments
- **SoraUEnableGetTxPacket** should be called before calling **SoraUGetTxPacket**.

61) **SoraUDisableGetTxPacket**

```c
HRESULT SoraUDisableGetTxPacket ();
```

Parameters
None

Return Value
- **SoraUDisableGetTxPacket** returns S_OK if the function succeeds.

Comments
- **SoraUDisableGetTxPacket** releases all blocking calls to **SoraUGetTxPacket** and disables its function. Subsequent calls to **SoraUGetTxPacket** will return ERROR_CANCELLED.