RDBE Setup and Operations

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Agenda

• System overview
  • Hardware components
  • Firmware components
  • Software components

• Features

• Command set

• Basic operation

• Next Generation

• Demonstration (time permitting)
System Overview

- **RDBE – ROACH Digital Backend System**
  - Originally a joint collaboration between NRAO and Haystack
  - Name is assigned to a specific base system
    - Specific hardware components
    - Was available from Digicom (ROACH reached EOL)
  - Variations are expected
    - Represented by hyphenating the name **RDBE-X**
      - **X** represents the hardware components of the RDBE
    - Presently there are RDBE-H, RDBE-S, RDBE-G
    - This overview covers the new RDBE-G
RDBE Hardware Components

• ROACH Board
  • Reconfigurable Open Architecture Computing Hardware
  • Developed by the CASPER group at Berkeley / NRAO / KAT
• Virtex 5 FPGA
• 440 PPC processor
• 2G RAM
• 2 ZDOK connectors
  • iADC
• RS232 interface
• 1G / 100M Ethernet
• 4 CX4 10G Ethernet ports
• 1 XPORT interface
RDBE Hardware Components

• iADC
  • Analog to Digital Converter (sampler board)
    • Developed by the CASPER group
  • 2GHz bandwidth
  • 1 Giga sample / sec
  • 8 bits / sample
• 2 iADC cards supported per ROACH
RDBE Hardware Components

• Synthesizer / timing board
  • Developed AEER
• Inputs
  • 10 or 5 MHz
    • Jumper configurable
  • 1pps
• Outputs
  • 1pps
    • four SMA’s
  • 1024 MHz
    • four SMA’s
RDBE Hardware Components

• Attenuators
  • Analog level control (ALCs)
  • Off the shelf
    • Mini-circuits
  • 1 IFs in / 1IFs out
    • Two boards per system
  • 0-31.5 dB attenuator
    • 0.5dB steps
  • No 20dB solar attenuation
RDBE Hardware Components

- GPIO Board
  - Mated to high speed differential connector on ROACH Board
- Developed to support interfaces to:
  - LCD front panel
  - Diode control (calibration)
  - Attenuator control communication
  - etc.
RDBE Hardware Components

- Miscellaneous
  - Power supply
    - 90 ~ 132 VAC or 180 ~ 264 VAC auto sensing
  - 1pps LED
    - Indicates 1pps internal to FPGA code (DOT Clock)
  - 5MHz lock LED
  - Power LED
  - 4 SMA connectors front
    - Output
  - 8 SMA connectors back
    - Inputs + Diode control out + pps
RDBE Firmware

• 4 Personality types (FPGA code)
  • Polyphase filter bank-geodesy (PFBG) Ver. 3.0
  • Input is two 512MHz IFs
  • Standard output is sixteen of 32 possible 32-MHz channels (2Gbps)
    • Mode of all thirty-two 32 MHz channels available (4Gbps)
  • Output is a 8224 byte VDIF data format (next slide)
    • Complex Data
    • Standard 32 byte header
  • eVLBI VTP protocol available
• Original Polyphase filter bank-geodesy (PFBG) Ver. 1.4
  • Input is two 512MHz IFs
  • Output is sixteen of 32 possible 32-MHz channels
  • Output is a 5008 byte Mark5B data format

• Polyphase filter bank-astronomy (PFBA) Ver. 1.5
  • Input is four 512 MHz IFs
  • Output uses two of the four 10Gbps CX4 interfaces
    • 2-bit quantized
    • 4Gbps / interface
    • 8224 byte packets using the VDIF format.
• Digital down converter (DDC)
  • Input is two 512MHz IFs
  • Output is four tunable channels
  • Bandwidths 128 / 64 / \ldots / 1 MHz (same for all 4 channels)
    • Data rate proportional to bandwidth
  • Tunable in 15.625 kHz quanta (testing incomplete)
  • Output is in 5008 byte Mark5B format 2 bits / sample
  • 250-kHz common quantum with 10-kHz on legacy systems
VDIF Payload Options

Standard VDIF Payload

VDIF Header (8 words)

1024 64 bit complex words

VTP Compliant Payload

VDIF Header (8 words)

64 bit PSN

1024 64 bit complex words
RDBE Software
RDBE Software

- rdbe\_dev.ko
  - Linux kernel device driver
  - Allows the application to read / write to the FPGA personality

- rdbe\_server
  - Version 3.0 will be required for operation with FS
  - Accepts VSIS commands
  - Verifies and takes actions on valid commands
  - Specified in the RDBE command set version 3.0
  - Not backward compatible with 1.4/1.5/DDC
<table>
<thead>
<tr>
<th>Command</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td><code>dbe_1pps_mon</code></td>
<td>Set the 1pps monitoring broadcast state</td>
</tr>
<tr>
<td><code>dbe_atten</code></td>
<td>Set / get the attenuator setting for INPUT 0/1</td>
</tr>
<tr>
<td><code>dbe_bstate?</code></td>
<td>Quantizer state counts in percent for all channels</td>
</tr>
<tr>
<td><code>dbe_chsel</code></td>
<td>Set / get the input to output channel assignments</td>
</tr>
<tr>
<td><code>dbe_chsel_en</code></td>
<td>Set / get the data rate (2/4Gbps), chsel enabled/disabled, psn enabled / disabled</td>
</tr>
<tr>
<td><code>dbe_arp</code></td>
<td>Set / get the IP to MAC address resolution</td>
</tr>
<tr>
<td><code>dbe_data_connect</code></td>
<td>Set / get the destination IP the data is being sent</td>
</tr>
<tr>
<td><code>dbe_data_send</code></td>
<td>Transmit a data stream out of the DBE 10G interface</td>
</tr>
<tr>
<td><code>dbe_diode</code></td>
<td>Set / get diode control frequency and blank time in micro-seconds</td>
</tr>
<tr>
<td><code>dbe_dot</code></td>
<td>Set / get the Data Observable Time (DOT) clock information</td>
</tr>
<tr>
<td><code>dbe_dot_inc</code></td>
<td>Increment the DOT clock, default is 1 second</td>
</tr>
<tr>
<td><code>dbe_gps_offset?</code></td>
<td>Get the GPS offset in micro-seconds to 1pps DOT clock</td>
</tr>
<tr>
<td><code>dbe_hw_version?</code></td>
<td>Get the hardware version information from the DBE</td>
</tr>
<tr>
<td><code>dbe_ifconfig</code></td>
<td>Set / get DBE 10G network interface configuration</td>
</tr>
<tr>
<td><code>dbe_init</code></td>
<td>Resets FPGA sampler, clocks and enables PPS interrupt</td>
</tr>
<tr>
<td><code>dbe_mac</code></td>
<td>Set / get the 10 CX4 port MAC address</td>
</tr>
<tr>
<td><code>dbe_ntpdate</code></td>
<td>Set / get the NTP server's IP address to synchronize to</td>
</tr>
<tr>
<td><code>dbe_option</code></td>
<td>Set / get formatting options (spaces, long time format - fractional seconds)</td>
</tr>
<tr>
<td><code>dbe_pcal</code></td>
<td>Set / get phase cal frequency in hertz (default is 0 Hz)</td>
</tr>
<tr>
<td><code>dbe_personality</code></td>
<td>Set / get the RDBE FPGA bit code personality</td>
</tr>
<tr>
<td><code>dbe_pps_mon</code></td>
<td>Set / get the once per second multicast data IP address and port.</td>
</tr>
<tr>
<td><code>dbe_pps_offset?</code></td>
<td>Get the pps offset to the incoming MASER pps signal</td>
</tr>
<tr>
<td><code>dbe_quantize</code></td>
<td>Set / get present channel quantization data</td>
</tr>
<tr>
<td><code>dbe_raw?</code></td>
<td>Get 100 raw samples for an interface from the DBE</td>
</tr>
<tr>
<td><code>dbe_reboot</code></td>
<td>Set the number of seconds before the DBE reboots</td>
</tr>
<tr>
<td><code>dbe_status?</code></td>
<td>Get system status (query only)</td>
</tr>
<tr>
<td><code>dbe_sw_version?</code></td>
<td>Get the software version information from the DBE</td>
</tr>
<tr>
<td><code>dbe_tsys?</code></td>
<td>Get 16 Tsys on values followed by 16 off values normalized to 1000000</td>
</tr>
</tbody>
</table>
Basic Operations

• Topics addressed on the following slides
  • Boot Up
  • rdbe_server daemon communication
    • dbe_data_send operational modes
    • Monitoring capabilities
      • 1pps
      • tsys
      • pcal
      • raw capture mode
      • PPS / GPS offsets
  • Software utilities
Boot Up

• U-Boot options
  • Environment variables defining what the boot loader will execute
    • location of the kernel in flash (address)
    • location of the root file system
      • USB
      • NFS
      • SDRAM
      • bootp
  • Network configuration
    • Static
    • Dynamic
• Details are beyond the scope of this talk
  • Detail documentation available if needed
Loading the FPGA personality
- Located where the root file system is mounted
- /home/roach/personalities

Initialization
- Setting the FPGA registers
- Setting the DOT time
  - system time
  - manually
- Quantization
  - Formats the filter bank channels at 2 bits / sample
- Monitoring capabilities
- Set for normal operations
  - Transmitting data out CX4 interface
  - Status / etc.
IO Channel Selection

• Capability to set the input output channel assignment for the VLBI Payload
  • Feature for PFBG personality only
    • Input is two 512MHz IFs
    • Output is 8 out of 16 per IF possible 32-MHz channels
    • Version 1.4/1.5 has any possible combination
      • Version 3.0 does not
  • The command
    • dbe_chsel = <input>:<channel(s)>;
      • input
        • 0 or 1 for IF0 or IF1
      • channel(s)
        • individual channels
Configuration

• Initialization of static information
  • e.g. 10G IP, MAC, ARP entry, etc.
  • Handled with command
    • run_conffile=/path/filename
    • /home/roach/personalities/conf/filename
      • See next page for example / explanation
  • New version of rdbe_server automates this process

• The channel ordering
  • The present geodetic personality
    • The default dbe_chsel? {0,1} returns
      • dbe_chsel ? 0: 0 : 1 : 3 : 5 : 7 : 9 : 11 : 13: 15 ;
# Static Configuration File

<table>
<thead>
<tr>
<th>Command Executed</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>mac=00.00.11.22.33.42</td>
<td>MAC Address of the 10G, made up unique for each RDBE</td>
</tr>
<tr>
<td>chsel_en=2 : chsel_enable : psn_enable</td>
<td># 2 Gbps data rate, with Channel select and PSN enabled</td>
</tr>
<tr>
<td>arp= 192.168.1.3 : 00.60.dd.44.9f.81</td>
<td>ARP entry for destination Mark6 IP address and MAC Address</td>
</tr>
<tr>
<td>data_connect=192.168.1.3 : 9002 : 0xBdC : 1</td>
<td># Set the configuration for IP / UDP / VDIF header. Destination IP address : UDP port : Station / RDBE Identifier : Thread ID</td>
</tr>
<tr>
<td>pps_mon=disable</td>
<td>Disable previous initialized multicast transmission</td>
</tr>
<tr>
<td>pps_mon=enable : 239.0.5.50 : 20055</td>
<td>Multicast enabled : Unique Multicast IP, unique Port. Set these to RDBE IP address</td>
</tr>
<tr>
<td>pcal=1.4e6</td>
<td>Set pcal for UDC factional portion</td>
</tr>
<tr>
<td>data_send=on</td>
<td>Start transmitting data over 10G interface</td>
</tr>
<tr>
<td>option=time_long</td>
<td>Use fractional time long format when replying to requests</td>
</tr>
</tbody>
</table>
Data Transmission

• In the past data were always available and the gating function was performed on the recording device
  • Record = on / off commands
  • Supported with dbe_data_send=on

• One can also gate at the source and destination for transmission over WANs:
  • To gate at the RDBE
    • Since the start and end time are known a priori
      • use the dbe_data_send to gate the output on the 10G
Design Philosophy

• start time <= present DOT time < end time
  • Personality will transmit valid packets
  • Times are specified as integer seconds

• Start and end times are programmed into the FPGA using the command:
  • dbe_data_send
  • command format
    • dbe_data_send = < state > : [< ts >] : [<te>] : [<delta>];
      • state - either “on” or “off”
      • start and end times (ts, te) are of the format YYYYDDDHHMMSS
      • delta - specified in integer seconds.
**dbe_data_send options**

- Specify start / end time
  - YYYYDDDDHHMMSS

- Or specify start and delta time
  - t2 is generated as t1 + delta
  - delta is integer seconds

- Ability to abort an active transmission
  - send the off state with
    - a specified time
    - no time - meaning next integer second
Monitoring Capabilities

• **1pps monitoring**
  • Multicast monitoring data broadcast 1 per second (1pps)
  • $\text{dbe}_\text{1pps}_\text{mon} = <\text{enable}> : <\text{multicast IP address}> : <\text{port}>$
  • Use rdbe_mon.py on a system attached to same network to receive multicast data

• **Tsys monitoring**
  • System temperature measurement
  • On power / off power of the receive chain
  • tsys data is summed every second

• **Raw Capture Mode**
  • Provides ability to see the incoming signal from the iADC before it is processed by the FPGA personality
  • 32000 samples are captured
Input signal

FFT of input signal

Histogram

Pulse cal extraction

FFT of pulse cal phase of pulse cal tones

Power of IFX channels (on / off)
Software Utilities

• \texttt{rbde\_client -h <machine>}
  • Command line interface to RDBE
  • \texttt{-h <machine>} is the target RDBE systems IP address (defaults to localhost).
  • \texttt{rdbe\_server} must be running on \texttt{<machine>}

• \texttt{rdbe30\_mon.py -h <multicast addr> -p <port> -H <RDBE addr> -P <rdbe\_server port>}
  • Graphical command and monitoring application
  • Sends commands / displays multicast output graphically
  • Very CPU intensive, to be used only for snap shot of RDBE
RDBE Next Generation Development

• R2DBE-G:
  • ROACH 2 board
    • Vertex 6
    • 4 SFP+ Connectors
      • Fiber or Copper
    • Leveraged ADC FPGA code from Event Horizon Telescope
      • Code must be ported, extended for Geodetic filter bank features
    • Existing server code must be ported to new platform
  • 2 ADC
    • 2G Samples
  • New GPIO interface board
RDBE Next Generation Development (cont)

• Same form factor as RDBE-G
• Order from Digi-com
• Undergoing zero base-line testing
• Expected by Sept. 2017
Demonstration

time permitting