4G/LTE Radio Access Network Testing Across the CPRI or OBSAI Link

by

Absolute Analysis
Agenda

• 1 - The 4G/LTE Radio Access Network (RAN) Evolution

• CPRI/OBSAI testing in the Laboratory: Investigator

• CPRI/OBSAI testing in the Field: Integris

• 3 RAN Testing Case Studies
Presenter/Corporate Info

About Absolute Analysis

• Mission: Validate serial communications
• “We never miss a bit”
• Help customers test high speed systems in:
  – Telecom
  – Military
  – Data centers
• Fully employee owned

About Speaker
Summary: RAN Testing Solutions

• Investigator
  – For the lab
  – Full CPRI/OBSAI debugging
  – Multiple ports

• Integris
  – For the field
  – RRH Installation checks
  – CPRI/OBSAI compliance
  – RF Interference analysis
2G to 4G/LTE Evolution: Multi-Technology

2G Antenna

2G Technology

RF

RRH

BBU

CPRI/OBSAI

3G Evolution

2G

3G

RRH

BBU

CPRI/OBSAI

4G/LTE

LTE

W-CDMA

Legacy

This presentation contains Proprietary Information. Not intended for public distribution.
4G/LTE Evolution: Baseband Pooling

- 2G/3G: Up to 10km
- 4G/LTE: Up to 60km

C-RAN: The Next Generation

Passive Optical Network

Baseband Pool

BBU
Challenges Arising from New Technology

- Limited RF signal availability
  - Only digital RF at the bottom of the tower
- RRH separation makes it difficult to debug commands
- Distance requires more performance testing of PON
- Multi-technology introduces complex timing issues
Visibility into the link is the key to testing the RAN. For CPRI...
RP3 Specification v.4.1
- Point-to-point serial interface up to 6.144 Gbps for Uplink/Downlink telecom Data, Control & Sync.
- Support all air-interface standards (GSM/EDGE, WCDMA/LTE, 802.16d-e, CDMA2000)
- The stack is based on a packet concept using a layered protocol with fixed length messages
- IQ Sample envelope size is fixed and defined from the air-interface used.

RP3-01 has fixed Msg & sample envelope size
**LTE Radio Access Networks**

**Major Testing Stages**

- **Development:** Development and integration of RRH and BBU in **Laboratory**
- **Deployment:** Installation of RRH and BBU in the **field**
- **Operations:** Monitoring anomalies and RF interference

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**Diagram:**

- RRH
- CPRI or OBSAI link
- DWDM PON
- BBU
Section 2

DEVELOPMENT: DEBUGGING CPRI/OBSAI IN THE LABORATORY

INVESTIGATOR INTRODUCTION
INVESTIGATOR™
A Comprehensive High-Speed Serial Protocol Test System

- Monitor and Capture Data
- Inject errors and delay
- Decode IQ Data
- Decode Control Data
- Generate OBSAI traffic
- BER Testing
Detailed Type of Testing

- **Testing for Protocol Compliance**
  - Proper HFN, BFN incrementing
  - Control word formatting
  - Boot up sequence debugging

- **RRH/BBU Control and Management**
  - When RRH receives command, what is it’s response? And vice versa?
  - What is the latency of any one device?

- **RF Analysis**
  - Are my DPD algorithms working?
  - Is the problem in my baseband IQ or my RRH modulation?

- **Stress Testing**
  - Inject errors via traffic generation
  - Introduce delay into link
Solution: Visibility

- Find Where the Problems Are Quickly
- Stop the finger pointing
- Visibility into:
  - L1 Inband
  - C&M Layer
  - IQ Data
  - Vendor specific data
- No other tool in the world can do this.

**Investigator Visibility**
- Protocol specific data
- Control & Management Data
- Vendor specific data
- IQ data of RF signal
Development Stage’s #1 Problem

WHERE is my problem?

RRH Team
Software Team
RF Engineers

BBU Team
Hardware Team
DSP Engineers
Network Connection: Interpose Mode
Network Connection: Tap Mode
CPRI Compliance Testing

SYNC and L1 Inband Monitoring and Capture

- User Plane
- Control & Management Plane
- SYNC

Layer 2
- IQ Data
- Vendor Specific
- Ethernet
- HDLC
- L1 Inband Protocol

Layer 1
- Time Division Multiplexing
- Electrical Transmission
- Optical Transmission
OBSAI Compliance Testing
### OBSAI Type Field

#### 4.4.7 Message Format – TYPE Field

Application layer is responsible for defining the type of the message. The TYPE field identifies the content of payload data. The following table presents the possible payload types.

**Table 12: Content of type field.**

<table>
<thead>
<tr>
<th>Payload data type</th>
<th>Content of Type field</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control</td>
<td>00000</td>
</tr>
<tr>
<td>Measurement</td>
<td>00001</td>
</tr>
<tr>
<td>WCDMA/FDD</td>
<td>00010</td>
</tr>
<tr>
<td>WCDMA/TDD</td>
<td>00011</td>
</tr>
<tr>
<td>GSM/EDGE</td>
<td>00100</td>
</tr>
<tr>
<td>TETRA</td>
<td>00101</td>
</tr>
<tr>
<td>CDMA2000</td>
<td>00110</td>
</tr>
<tr>
<td>WLAN</td>
<td>00111</td>
</tr>
<tr>
<td>LOOPBACK</td>
<td>01000</td>
</tr>
<tr>
<td>Frame clock burst</td>
<td>01001</td>
</tr>
<tr>
<td>Ethernet</td>
<td>01010</td>
</tr>
<tr>
<td>RTT message</td>
<td>01011</td>
</tr>
<tr>
<td>802.16</td>
<td>01100</td>
</tr>
<tr>
<td>Virtual HW reset</td>
<td>01101</td>
</tr>
<tr>
<td>LTE</td>
<td>01110</td>
</tr>
<tr>
<td>Generic Packet</td>
<td>01111</td>
</tr>
<tr>
<td>Multi-hop RTT message</td>
<td>10000</td>
</tr>
<tr>
<td>Currently not in use</td>
<td>10001-11111</td>
</tr>
</tbody>
</table>
Capture Link Data for Debug

- Trigger on any control word byte
- Execute Trigger Instructions
  - Capture
  - Start statistics
  - Send Sync signal out
- Captures:
  - All frame data
  - Control data
  - Sync data
  - Up to 13 continuous LTE radio frames (4Gb buffer)
Monitor Link Health in Real Time

- Performance Statistics
  - Frames transmitted
  - BER
  - Latency
  - Message group count
  - Radio frame count
Automated CPRI Slave (RE) Compliance Testing

- Test Center
- 450 Automated CPRI Compliance tests
- Tests RRH
- Customizable test parameters
- Pass/Fail indicators
- Test Reports
RRH/BBU Command Layer Debug

• Monitor and Capture Command Layer
  – CPRI: Fast C&M
  – OBSAI: Ethernet frame types

• Debug
  – Boot up sequence
  – Link maintenance messages
  – BBU to RRH commands and vice versa

Time: 10 40.040405
NPWR=300
MINOHPWR=230
MAXNUMCARR=8
MAXNUMPORTCARR=8
RF Analysis – IQ Data Extraction

- Capture RF data (IQ data)
- Output to CSV or Matlab format
- Debug
  - DFD Algorithms
  - EVM
  - Noise/Interference
Extract IQ Data

- From IQ Data, plot RF using RF Analysis software tools

Time Domain Graphs

Constellation/EVM Measurements

Spectrum Graphs
Complete Extraction Picture

Spectrum Analyzer

Digital RF Data (IQ) in CSV, text, or MATLAB

RF Software

CPRI/OBSAI link

RRH

BBU

Ethernet TCP Commands

Fast C&M Data (.PCAP or CSV)

Time: 10 40.040405
NPWR=300
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MAXNUMCARR=8
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Stress Testing

- Bit Error Rate degradation
  - Purposely maintain a selected BER
- Delay Injection
  - By Distance
  - By Time
Stress Testing: Delay Simulation

[Diagram showing two RRHs connected by a 10km delay]
Customize Protocol Decodes

• Some companies have protocol customizations
• Insert your own CPRI or OBSAI decodes for display in viewer
Investigator for Laboratory Applications

- Lab Testing Environment
  - Portable or Rackmount
  - Monitor Up to 16 links
  - Record up to 13 LTE radio frames
  - Network control via Ethernet port
Summary: Detailed Type of Testing

- **Testing for Protocol Compliance**
  - Proper HFN, BFN incrementing
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Section 2

FIELD TESTING
INTEGRIS INTRODUCTION
LTE Radio Access Networks
Major Testing Stages

• Development: Development and integration of RRH and BBU in Laboratory

• Deployment: Installation of RRH and BBU in the field

• Operations: Debugging RF anomalies and interference
Integris FIELD PORTABLE TESTER

- Connects Directly into the CPRI or OBSAI link
- Cable testing and basic protocol operation
  - Bit Error rate
  - Performance testing
  - CPRI/OBSAI protocol compliance
- Reads IQ data and streams it real-time to display
Deployment Problem

- RRH installation team different from BBU installation team
- RRH normally installed first
- **Problem:** If RRH is dead after installation, you lose time and money because you need the BBU to determine this
- **Solution:** Test the RRH right after installation to determine proper working condition
The Solution: Integris RRH Tester

- CPRI or OBSAI
- Test Radio Head Installation with the push of a button
  - Bit error rate to test connectors/connections
  - Latency measurements to check cabling and/or PON performance
  - CPRI/OBSAI compliance to check basic RRH operation
- Tester Simulates the Base Station to test
- Available at ground level

We never miss a bit...
Operations: Interference Problem

• In 2G networks, the RRH and BBU were co-located in the hut
• Troubleshooting was accomplished at ground level.
The Interference Problem + The 4G RAN Evolution

• In 2G networks, the RRH and BBU were co-located in the hut.
• Troubleshooting RF Interference was easy.
The Interference Problem + The 4G RAN Evolution

- Beginning with 3G and now 4G networks, the RRH and BBU are separate
- The connection link down the tower is now digital (CPRI or OBSAI link)
- Troubleshooting now requires a “tower climb”

Digital RF Signal (CPRI or OBSAI)
The Solution: The Digital Link

- CPRI or OBSAI
- Digital Link carries:
  - Control plane data for BBU/RRH commands
  - User Plane data: RF Data in the form of IQ
- Available at the bottom of the tower
Collaboration on Analysis

- Recording of RF Data allows offline analysis
- Files can be sent to RF experts
- Export of MATLAB V5 format
- Use Signal Analysis software tools like MATLAB (Mathworks) or SignalVu (Tektronix)

Matlab Screen Shots
Section 2

3 RAN CASE STUDIES
1 – Investigator: Solving Interoperability Example

HFN/BN incrementing properly?

All CPRI/OBSAI parameters operating according to specification?
2 – Investigator: RRH-BBU
Communication Problems

Extract Fast C&M (Ethernet Channel) Data

Captured Trace Data

CPRI/OBSAI Data Extractor

To Wireshark: Ethernet Command Data (PCAP)
3 – Integris: Measuring PON Performance

- Latency Measurements
- Failover (Redundancy) Measurement
- Traffic Test Pattern Selection

Individual Port Measurements
Summary: RAN Testing Solutions

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