IEEE1914.3™ Standard for Radio over Ethernet Encapsulations and Mappings

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Editor of IEEE1914.3 Radio over Ethernet (RoE)

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25th October 2017
IEEE 1914 WG

- Website: http://sites.ieee.org/sagroups-1914/
- Extensive awareness with ~160 subscribers
- ~ 20 voting members, ~ 90 members

IEEE1914 NGFI: Next Generation Fronthaul Interface (xhaul)

IEEE1914.1: Standard for Packet-based Fronthaul Transport Networks
IEEE1914.3: Radio over Ethernet (RoE) Encapsulations and Mappings

Participants from:
- operators
- chipset manufacturers
- telecom vendors
- academia

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- operators
- chipset manufacturers
- telecom vendors
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NGFI:
- IEEE 1904.3
- IEEE 1914 - NGFI

RoE:
- 1904.3 development
- 1914.3 development
- 1914.1 development

IEEE 1914 - NGFI
IEEE 1904.3
IEEE 1914.1
IEEE 1914.3
IEEE1914.1 PAR

Title: Standard for Packet-based Fronthaul Transport Networks
Working Group: Requested: Next Generation Fronthaul Interface (COM/SDB/NGFI)

Scope:

- 1) **Architecture for the transport of mobile fronthaul traffic** (e.g., Ethernet-based), user data traffic, and management and control plane traffic.
- 2) **Requirements and definitions for the fronthaul link**, including data rates, timing and synchronization, and quality of service.
- The standard also **defines functional partitioning** schemes between Remote Radio Units (RRUs) and Base-Band Units (BBUs) that improve fronthaul link efficiency and interoperability among various vendors, and that facilitate the realization of cooperative radio functions, such as massive Multiple-Input-Multiple-Output (massive MIMO) operational modes, Coordinated Multi-Point (CoMP) transmission and reception, etc.

Status: D0.4 Available.
IEEE1914.1

- Fronthaul-I (NGFI-I), connecting the RU to a DU;
- Fronthaul-II (NGFI-II), connecting the DU to a CU;
- Backhaul (BH), connecting the CU to the packet core elements.

<table>
<thead>
<tr>
<th>Class Split</th>
<th>$\tau_0$</th>
<th>$\tau_1$</th>
<th>$\tau_2$</th>
<th>$\tau_3$</th>
</tr>
</thead>
<tbody>
<tr>
<td>URLLC</td>
<td>6,7,8</td>
<td>50µs</td>
<td>100µs</td>
<td>1ms</td>
</tr>
<tr>
<td>BH</td>
<td>2,3,4,5</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Figure A.1 - Generic fronthaul and backhaul network model
Title: Standard for Radio Over Ethernet (RoE) Encapsulations and Mappings IEEE1914.3TF
Working Group: IEEE1914 Access Networks

Scope

- **The encapsulation of digitized radio** In-phase Quadrature (IQ) payload, possible vendor specific and control data channels/flows into an encapsulating Ethernet frame payload field.

- **The header format for both structure-aware and structure-agnostic** encapsulation of existing digitized radio transport formats. The structure-aware encapsulation has detailed knowledge of the encapsulated digitized radio transport format content. The structure-agnostic encapsulation is only a container for the encapsulated digitized radio transport frames.

- A structure-aware **mapper for Common Public Radio Interface (CPRI) frames** and payloads to/from Ethernet encapsulated frames. The structure-agnostic encapsulation is not restricted to CPRI.

Status: Currently at Draft 2.0
Start: Oct 2014. Draft 2.1 released this week
Functional Partition Comparison

IEEE1914.3 Frequency domain IQ
IEEE1914.3 Time domain IQ

Bit processing
Modulation
Layer mapping
Precoding
Resource mapping
IFFT/CP
DA
Analog beamforming

Bit oriented
IEEE1914.3 Structure-agnostic & Structure-aware CPRI

IQ oriented
Optional (for mMIMO)
Standardization Status

- eCPRI v1.0 released on August 2017
- IEEE1914 released 1914.3 D2.0 March 2017,
- IEEE1914.1 released D0.4 Sept. 2017
- IEEE1914.3 releasing D2.1 Oct. 2017
- xRAN completed 1st stage agreement
- TIP – still in early stage discussion
- Small Cell Forum Released “Small cell virtualization functional splits and use cases” January 2016
- NGMN released “5G End-to-End Architecture Framework” v0.6.5 May 2017
- 3GPP – TR38.801 v14.0. 0 (2017-03)
IEEE1914.3™ Deep dive
RoE – Radio over Ethernet
IEEE1914.3 RoE Use Cases

- Allow CPRI to be efficiently & agnostically tunneled
- Allow CPRI to be structurally remapped over RoE

- **Native RoE.**
  - Time domain IQ
  - Frequency domain IQ
  - 3GPP splits 8, 7.x
Common Header Format

subType – Packet type
- Control, structure agnostic, structure aware, native time domain, native frequency domain & slow C&M packet types are defined

flowID – Flows allow SA/DA pairs to distinguish connections

length – Payload size

orderingInfo – Sequence number or timestamp

Payload – The IQ data / control information
Ordering Info

Sequence number
- Split into 2 counters (e.g. BFN & symbol number)
- Configurable for traffic type (GSM/LTE/ etc.)

Timestamp
- A presentation time for when the IQ data should be transmitted
- 32 bits with integer ns bits fractional ns bits
- Based on Time of Day
Object Hierarchy

Ethernet Links

Flow mappers and de-mappers (and their objects)

CPRI Ports
Mappers

De-mapper is opposite operation

Structure agnostic
- Simple tunneling / remove line coding
- Simply encapsulates the serial stream
- Optionally removes 8b10b / 64b66b

Structure aware (CPRI)
- Can create multiple flows (per antenna carrier AxC for example)
- Has a concept of containers (for AxC)
- Can skip empty/used areas in the frame
- Can skip (modulo) containers and with an index
- Can treat control data differently VSS etc.

Native
- Time or frequency domain IQ
- PRACH
### Packet Types

<table>
<thead>
<tr>
<th>subType</th>
<th>Packet Type</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>RoE Control Packet</td>
</tr>
<tr>
<td>2</td>
<td>RoE Structure-agnostic</td>
</tr>
<tr>
<td>3</td>
<td>RoE Structure-aware CPRI</td>
</tr>
<tr>
<td>4</td>
<td>RoE Slow C&amp;M CPRI</td>
</tr>
<tr>
<td>16</td>
<td>RoE Native time domain data</td>
</tr>
<tr>
<td>17</td>
<td>RoE Native frequency domain data</td>
</tr>
<tr>
<td>18</td>
<td>RoE Native PRACH data</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>opCodes</th>
<th>(Control Packet)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>RoE OAM TLV</td>
</tr>
<tr>
<td>1</td>
<td>Ctrl_AxC data</td>
</tr>
<tr>
<td>2</td>
<td>Vendor specific control packet.</td>
</tr>
<tr>
<td>3</td>
<td>Timing Control Packet</td>
</tr>
</tbody>
</table>
## RoE Object Type Enumeration

<table>
<thead>
<tr>
<th>enTLV</th>
<th>Object Type</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>Ethernet link</td>
<td>Ethernet link object type.</td>
</tr>
<tr>
<td>1</td>
<td>CPRI port</td>
<td>CPRI port object type.</td>
</tr>
<tr>
<td>2</td>
<td>Mapper</td>
<td>RoE mapper object type.</td>
</tr>
<tr>
<td>3</td>
<td>De-mapper</td>
<td>RoE de-mapper object type.</td>
</tr>
<tr>
<td>4</td>
<td>Mapper container</td>
<td>RoE mapper container object type, belonging to an RoE mapper.</td>
</tr>
<tr>
<td>5</td>
<td>De-mapper container</td>
<td>RoE de-mapper container object type, belonging to an RoE de-mapper.</td>
</tr>
<tr>
<td>6</td>
<td>Mapper FFT</td>
<td>RoE mapper FFT object type, belonging to an RoE mapper.</td>
</tr>
<tr>
<td>7</td>
<td>De-mapper FFT</td>
<td>RoE de-mapper FFT object type, belonging to an RoE de-mapper.</td>
</tr>
<tr>
<td>8</td>
<td>Mapper PRACH</td>
<td>RoE mapper PRACH object type, belonging to an RoE mapper FFT.</td>
</tr>
<tr>
<td>9-63</td>
<td>Reserved</td>
<td>Reserved</td>
</tr>
<tr>
<td>64</td>
<td>RoE 1914.1 TLV</td>
<td>Service OAM. This object type allows TLVs described in IEEE Std 1914.3™ to be uniquely enumerated for parameter exchange.</td>
</tr>
<tr>
<td>65-127</td>
<td>Reserved</td>
<td>Reserved</td>
</tr>
</tbody>
</table>
### RoE Parameter Enumeration (mapper)

<table>
<thead>
<tr>
<th>enParam - Parameter</th>
<th>Bits</th>
<th>Name</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>0 - Identifier</td>
<td>8</td>
<td>.mapperID</td>
<td>Each flow RoE mapper in a given node has a unique identifier.</td>
</tr>
<tr>
<td>1 - Flow</td>
<td>8</td>
<td>.flowID</td>
<td>For an RoE mapper, the flowID = .mapperID.</td>
</tr>
<tr>
<td>2 - Source link</td>
<td>16</td>
<td>.srcID</td>
<td>Identifies the source Ethernet link/CPRI port.</td>
</tr>
<tr>
<td>3 - Destination Ethernet link</td>
<td>16</td>
<td>.destID</td>
<td>Identifies the destination Ethernet link.</td>
</tr>
</tbody>
</table>
| 4 - orderInfo type  | 1    | .orderInfoType | 0 indicates seqNum is used.  
1 indicates timeStamp is used. |
| 5 – RoE mapper Type | 4    | .mapperType | 0 indicates structure-agnostic simple tunneling mode.  
1 indicates structure-agnostic mode & remove line encoding.  
2 indicates structure-aware mode.  
3 indicates native time domain mode.  
4 indicates native frequency domain mode.  
5-15 reserved. |
| 10 – Sample Width   | 8    | .sampleWidth | Indicates the number of bits in each I portion and in each Q portion of an I/Q sample. By default, 16-bit I and 16-bit Q width is assumed. |
C&M Parameter Exchange

Uses TLV’s. Control packet type subType=0, opCode=0
- Type = enTLV, enumerated object type
- Length = TLV information string length
- Value
  - enParam, enumerated parameter
  - ID, ID of the object
  - Value

mapper[5].lenPack=500
demapper[6].destID=1
### IQ Examples

**CPRI**

#### Structure agnostic

<table>
<thead>
<tr>
<th>Byte</th>
<th>bit 0</th>
<th>16</th>
<th>32</th>
<th>0</th>
<th>64</th>
</tr>
</thead>
<tbody>
<tr>
<td>MSB</td>
<td>LSB</td>
<td>MSB</td>
<td>LSB</td>
<td>MSB</td>
<td>LSB</td>
</tr>
<tr>
<td>subtype</td>
<td>flowID</td>
<td>length</td>
<td>orderingInfo</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

#### Structure aware (1 flowID)

<table>
<thead>
<tr>
<th>Byte</th>
<th>bit 0</th>
<th>16</th>
<th>32</th>
<th>48</th>
<th>64</th>
</tr>
</thead>
<tbody>
<tr>
<td>MSB</td>
<td>LSB</td>
<td>MSB</td>
<td>LSB</td>
<td>MSB</td>
<td>LSB</td>
</tr>
<tr>
<td>subtype</td>
<td>flowID</td>
<td>length</td>
<td>orderingInfo</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Native RoE**
IEEE1914.3 Native RoE Packets
Time and Frequency domain

Time Domain
- Split 8
- Like CPRI

Frequency Domain
- Split 7.1
- Symbols
- Split 7.2 & 7.3 by flowIDs
IEEE1914.3TF Summary

Allows for a smooth transition from CPRI to IQ over Ethernet.

Does define
- Header formats and encapsulations
- Structural hierarchy, Parameter list and C&M encapsulations
- Methods for structurally re-containerizing CPRI into RoE
- 3GPP Splits 8, 7.1 & 7.2
- Parameter exchange

Does not define
- Profile of the underlying network – IEEE802.1CM
- Functional splits beyond 8 & 7.x – IEEE1914
- Any compression/encryption schemes (can select)
- System bring up state machines (yet?)
- How end to end timing synchronization is achieved
Contact information

• Website http://sites.ieee.org/sagroups-1914/
• Bi-weekly teleconferences

• Email reflectors:
  – stds-p1914-1@ieee.org
  – stds-p1914-3@ieee.org
  – stds-1914-wg@ieee.org

Contributions are welcome
Back-up
IEEE 1914 WG

**P1914.1**
- Standard for Packet-based Fronthaul Transport Networks
  - Use cases and scenarios
  - Architecture
  - Requirements

**P1914.3 (ex1904.3)**
- Standard for Radio Over Ethernet Encapsulations and Mappings (RoE)
  - Structure-agnostic
  - Structure-aware
  - IQ (CPRI/native RoE) encapsulations and mapping
  - IQ in time and frequency domain

NGFM Forum, Seattle 24th October 2017
Title: Time-Sensitive Networking for Fronthaul

Scope:
- This standard defines profiles that select features, options, configurations, defaults, protocols and procedures of bridges, stations and LANs that are necessary to build networks that are capable of transporting fronthaul streams, which are time sensitive.

Status: Currently at draft (D1.0).
End to end timing

Not sensitive to Ethernet network delay
- Packet must arrive in time
- Buffer must be large enough
- Ingress vs. Egress
Logical connections

Packet types
- Timing
- Control
- Data

Node types
- Pass-thru
- Termination

Topologies
- Point to point
- Multi-point to point
- Chain
- Ring
- Star
- Tree

Logical connection for timing packets
Logical connection for control packets
Logical connection for data packets

RoE Node
RoE Node
RoE Node

Link
Pass-through
Termination

LCₜ
LCₖ
LCₐ
LC₉

IEEE STANDARDS ASSOCIATION
Structure aware mapper example

Mapper is told
- how many containers there are
- Length of the packet (in containers
- Container sizes
- FlowIDs
- etc.