WSTS June 19th 2018 – San Jose, CA.

Emerging Fronthaul Techniques of eCPRI, IEEE P1914.1 Packet-based Fronthaul Transport Networks, IEEE P1914.3 Radio over Ethernet Encapsulations and Mappings

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Mobile Wireless Network Deployment Strategies

- The primary driver for any Deployment Strategy is ARPU, Average Revenue Per User.
- In the beginning deployment was all about COVERAGE.
- Then the deployment was all about COVERAGE/CAPACITY.
- Now the deployment is all about COVERAGE/CAPACITY/THROUHPUT.

Traditional methods for Mobile Wireless Network Equipment Deployment are Expensive and use Fit for Purpose Hardware

- Stand Alone Base Stations are expensive and require unique installation and environmental consideration.
- Remote Radio Heads have traditionally been using a Distributed Antenna System, DAS.
  - This historically required a dedicated fiber buildout from the distribution amplifier co-located with the Base Station to the remote radio antenna array.
  - Digging up streets and implementing large non-architecturally attractive antenna arrays is very expensive, requires building permits and lease agreements.

The New Mobile Wireless Network Implementation Methods

- Virtualization of approx. 20 operational functions into the Network Functions Virtualization, NFV, paradigm.
- Establishment of both C-RAN's, Centralized RAN and Cloud RAN.
- Hybridization of deployment models using virtual nodes and physical small nodes, small cells.
- These changes have demanded a shift in the interconnect between baseband processing and antenna.

What are eCPRI, IEEE P1914.1 & IEEE P1914.3?

- These are a new generation of what is now called Fronthaul transport.
- They evolved from an economic demand for lower cost and higher performance connections from Mobile Baseband processors to the radio head.
- The primary driver for these changes is mobile network densification thru implementation of hybrid LTE-A and 5G-NR technologies.

eCPRI - Standard 8-22-2017

- The Common Public Radio Interface (CPRI) is an industry cooperation aimed at defining publicly available specifications for the key internal interface of radio base stations, such as eCPRI connecting the eCPRI Radio Equipment Control (eREC) and the eCPRI Radio Equipment (eRE) via a so-called fronthaul transport network.
- Compared to the CPRI [1], eCPRI makes it possible to decrease the data rate demands between eREC and eRE via a flexible functional decomposition while limiting the complexity of the eRE.
- The scope of the eCPRI specification is to enable efficient and flexible radio data transmission via a packet based fronthaul transport network like IP or Ethernet. eCPRI defines a protocol layer which provides various - mainly user plane data specific - services to the upper layers of the protocol stack.

eCPRI node

- The radio base station system is composed of two basic eCPRI nodes, the eCPRI Radio Equipment Control and the eCPRI Radio Equipment. The radio base station system shall contain at least two eCPRI nodes, at least one of each type: eREC and eRE.
- eREC / eRE element: A hardware or software component within an eCPRI node which alone does not constitute a full eCPRI node.
- Protocol planes, The following planes are outlined:
  - C&M Plane: Control and Management data flow for the operation, administration and maintenance of the nodes.
  - User Plane: Three data flows covered by the user plane: a) Data flow to be transferred from the radio base station to the User Equipment (UE) and vice versa. b) Real time control data related to a). c) Other eCPRI flows not covered by other protocol planes/flows.
  - Synchronization Plane: Data flow for synchronization and timing information between nodes. Reference clock of a Precision Time Protocol-based Transport network. The GM can be located in the network as well as in the eREC or eRE.

IEEE P1914.1 Packet-based Fronthaul Transport Networks

- Scope –
- 1) Architecture for the transport of mobile fronthaul traffic (e.g., Ethernet-based), including user data traffic, and management and control plane traffic.
- 2) Requirements and definitions for the fronthaul networks, including data rates, timing and synchronization, and quality of service.
- The standard also analyzes functional partitioning schemes between Remote Radio Units (RRUs) and Base- Band Units (BBUs) that improve fronthaul link efficiency and interoperability on the transport level, 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

IEEE P1914.1 Packet-based Fronthaul Transport Networks

- Purpose –
- The Fronthaul Packet Transport standard enables the implementation of critical 5G technologies, such as massive Multiple-Input-Multiple-Output (massive MIMO), Coordinated Multi-Point (CoMP) transmission and reception, and scalable Centralized/Virtual Radio Access Network (C-RAN/V-RAN) functions.
- This standard simplifies network design and operation, increases network flexibility and resource utilization, and lowers cost by leveraging existing, mature Ethernet-based solutions for vital functions, such as quality of service, synchronization, and data security.
- The fronthaul architecture provides unified management and control solution, common networking protocols, and universal network elements, thus facilitating migration to future C-RAN/V-RAN mobile networks.

IEEE P1914.1 Packet-based Fronthaul Transport Networks

- Synchronization
- The NGFI (xhaul) must service the synchronization needs of 4G and 5G applications. These 4G and 5G applications have both phase and frequency requirements that allow their radios to operate efficiently and effectively. In an ideal situation, all the radios in a designated group have the same Time of Day (ToD) and would have the exact same frequency.
- Time Alignment Error (TAE) Requirements Phase requirements are specified in terms of the maximum allowed Time Alignment Error (TAE). The TAE requirements for many generations of mobile applications are described and summarized in Appendix II of ITU G.8271, with pointers to their associated specifications from 3GPP. The TAE requirements are specified at the radio antenna connectors of the RU and specify the maximum absolute deviation in the start-time of the radio-frame between any pair of antenna. Some of these requirements are for applications that pertain only to a localized cluster of cells. Because NGFI (xhaul) timing does not extend all the way to the antenna, additional margin typically needs to be assigned to allow for deviations within the RU

IEEE P1914.3 Radio over Ethernet Encapsulations and Mappings

- Scope
- This standard defines the encapsulation and mapping of radio protocols to be transported over Ethernet. The transport of packetized radio signal over Ethernet is referred to in this standard as fronthaul. Furthermore, both structure-agnostic and structure-aware definitions are provided for the most common and current radio protocol – Common Public Radio Interface (CPRI).
- This standard does not specify whether or how the Ethernet packets are guaranteed the strict quality of service (QoS) required by the encapsulated radio protocols. It does however recommend the support of IEEE Std 802.1TMCM profile or equivalent to help ensure such QoS guarantees. A full implementation of Radio over Ethernet would comprise;
  - a) the above mentioned encapsulations,
  - b) a networking technology that minimizes delay and packet delay variation (PDV),
  - c) a clock distribution mechanism, and d) ingress/egress mapping functions that encapsulate/de-encapsulate while dejittering and retiming the recovered signal.
- This specification is concerned with encapsulation and mapping only

IEEE P1914.3 Radio over Ethernet Encapsulations and Mappings

- Purpose
- The purpose of this standard is to describe the header formats and packet encapsulations required to transport any newly defined fronthaul protocol over Ethernet (i.e., the "native RoE") encapsulation that can be used as-is or used to transport other existing fronthaul protocols as follows:
  - Transport a C-RAN Radio Fronthaul protocol such as CPRI in a bit-transparent manner (structure agnostic) over Ethernet.
  - Transport the C-RAN Radio Fronthaul protocol CPRI over Ethernet where knowledge of the frame format is used (structure aware) to optimize the choice of packet sizes/headers/alignment etc.

IEEE P1914.3 Radio over Ethernet Encapsulations and Mappings

- Timestamp field
- The timestamp field is generated by the mapper; it is 32 bits in size and expresses the absolute time for presentation, relative to a defined reference plane, of the information within the packet at the receiving end-point of the RoE packet. Both the transmitting and receiving end-points share the same understanding of the ToD in order for the information to be presented at the desired time.
- Bit 0 is the Start of frame (.SoF) marker and is an indication of a radioframe boundary. When the SoF bit is set to 1, this indicates the start of the payload contained within the packet is the start of the radio frame. Bits 1 and 2 contain the 2 least significant bits of the p-counter from the seqNum information. Bits 3 through to 26 of the timeStamp field count in units of nanoseconds and the value ranges from ones to 1 16,777,216ns (0x0 to 0xffff ff respectively). Bits 27 through to 31 of the timeStamp field count in fractions of a nanosecond (0.03125ns) where 0x0 represents ones and 0x1f represents 0.96875ns. If sub-nanosecond timestamping is not used, these five bits shall be set to 0 at the sender and shall be ignored at the receiver.
- The timestamp value is capable of expressing a presentation time of almost 17ms in the future. Both nodes account for the rollover condition of the timeStamp field after 16,777,216.96875ns.

What are eCPRI, IEEE P1914.1 & IEEE P1914.3, Now you know.

- These new fronthaul technologies were created for:
  - The increasing demands for radio signal densification.
  - Enabling transport networks to support “sliced” radio endpoint type carriage over single fibers.
  - Dramatically reduce radio signal delivery costs between baseband and antenna systems.
  - Support Massive MIMO and Hybrid LTE-A & 5G – NR simultaneously.
- P1914.1 & P1914.3 IEEE standards are expected to be ratified by the IEEE SA in the fall of 2018.

Thanks to the following people for their assistance in creating this presentation.

- Richard Tse – Chair IEEE P1914.3 task group
- Bomin Li – Chair IEEE P1914.1 task group
- Huang Jinri – Chair IEEE 1914 working group