MOBILE FRONTHAUL FOR CLOUD-RAN DEPLOYMENT

EFFICIENT USE OF OPTICAL INFRASTRUCTURE FOR REMOTE RADIO ARCHITECTURES

APPLICATION NOTE

ABSTRACT

In the current environment of continuing traffic growth driven by data services, the mobile backhaul and fronthaul network must keep pace. Operators realize the need to enhance and evolve their network architectures to support new revenue generating services and rapidly deploy and maintain network elements while managing their network resources in a more efficient and proactive manner.

In essence, Cloud-RAN or C-RAN involves a separation of base station functions into the principal radio components located at the cell site, and the processing and control functions, which are located more centrally in the network. The radio function at the cell site is known as the remote radio head (RRH) and the centralized processing function as the baseband unit (BBU).The RRHs are connected to the BBU by the Common Public Radio Interface (CPRI)

The C-RAN architecture shows strong potential for cost control and operational flexibility. This paper examines the attributes of the C-RAN architecture and the options available for fronthaul transport of the CPRI. The Alcatel-Lucent solution for fronthaul transport is described and its features and benefits outlined.

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EXECUTIVE SUMMARY

In a distributed C-RAN architecture, remote radio heads (RRHs) connect to the baseband unit (BBU) using the Common Public Radio Interface (CPRI). This separation can bring advantages in resource usage, for example in the flexible sharing of processing resources and in spectral efficiency. However, CPRI traffic must be transported (fronthauled) efficiently and within tight quality constraints between the RRH and BBU locations.

Simple, cost-effective CPRI fronthaul enables a range of use cases for RRH deployments. While a number of techniques and media options are being explored for CPRI fronthaul, passive Coarse Wave Division Multiplexing (CWDM) has many advantages in cost-effectively transporting the CPRI interface with strong performance (low delay and high capacity).

Alcatel-Lucent CPRI optical fronthaul solutions provide network operators with optimal utilization of fiber facilities, increasing the value and efficiency of their optical infrastructure. Environmentally sealed devices as part of the solution bring many opportunities for capacity increase without adding undue complexity or cost.

The Alcatel-Lucent fronthaul solution is highly differentiated as it operates seamlessly with the Alcatel-Lucent IP/MPLS and Ethernet-based backhaul solution for a scalable, flexible and operationally efficient capability to comprehensively support the evolving heterogeneous radio access network (RAN).

BASE STATION DEPLOYMENT APPROACHES

Conventional and all-in-one approaches

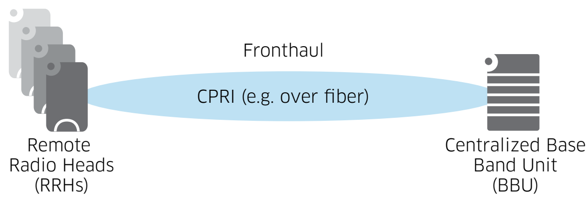
A conventional Long Term Evolution (LTE) base station architecture combines the BBU and the radio, amplifier, filter, and antenna in a single installation location. In the case of a small cell, it could be a single physical unit, that is, an all-in-one architecture. Connection to the network is via the standard S1-u, S1-MME and X2 interfaces. Because a packet interface is exposed to the Evolved Packet Core (wireless core), there is tremendous flexibility in transport technology. The backhaul is required to transport IP and for some traffic streams can tolerate some controlled latency and jitter. Typical backhaul bandwidth requirements are currently in the order of several hundreds of Mb/s, although this is rising.

C-RAN approach

The C-RAN architecture separates the required functionality in order to meet desired performance and efficiency goals. A remote-radio base station includes a radio, amplifier, filter, and an antenna, all combined in an RRH. The BBU functionality in a C-RAN is implemented as a separate entity. This separation, and the associated centralization of processing in the BBU, can enable improved coordination of radio capabilities across a set of RRHs. This becomes increasingly important in LTE and LTE-Advanced where such techniques can bring increased efficiency through interference mitigation, for example. This separation can also bring further operational cost savings with simpler radio installation. It also brings the opportunity to adopt a standard pooled server approach in supporting baseband processing, thus supporting the trend toward Network Functions Virtualization (NFV) architectures.

Remote radio units connect to the BBU using the CPRI interface as shown in Figure 1. The CPRI interface imposes strict limits on latency and bandwidth in the connection between the RRH and its BBU.

Figure 1. RRH, BBU and the CPRI interface



CPRI TRANSPORT

CPRI background

CPRI is a digital interface standard for encapsulating radio samples between a radio and a digital baseband processing unit. The interface is not packet-based; rather signals are multiplexed in a low-latency timeslot-like fashion. Consequently, CPRI defines a maximum latency, a near zero jitter, and a near zero bit error rate. In practice, a value of 0.4 milliseconds for transport leaves an acceptable delay budget for processing requirements and propagation delay. The capacity required is up to 10 Gb/s, with distances of up to 40 kilometers between the RRHs and the BBU.

Transport options

A number of transport options are potential candidates for CPRI transport including the following:

- Dedicated fiber. This can be an attractive option for scenarios where an operator has a large installed base of available fiber. This solution may also be an option for scenarios where it is more cost effective to lease/install fiber than to deploy an optical transport element at the cell site. The issue of fiber availability and the cost associated with deploying new fiber limit the applicability of this option.
- Optical transmission network (OTN). The introduction of OTN brought a standardized format for carrying different types of protocols (voice and data) across an optical network. OTN also introduced forward error correction (FEC) to reduce instances of far-end bit errors and increase the reach of metro optical networks. However, utilizing OTN for CPRI transport does require careful consideration as a number of the highly valuable features of OTN also add latency.
- Passive optical network (PON). PON is a potentially attractive option for CPRI transport as it can provide access to an existing fiber plant located in high-traffic areas, for example, in dense urban neighborhoods, where small cell deployment is most likely to occur. A typical PON with a split ratio of 1:32 using a 28 dB loss budget, results in about a 20 kilometer reach. An additional consideration is the location of the BBU. If it is not collocated with the OLT, additional latency will be incurred, which will further limit the cell radius.
- Microwave. For some situations where CPRI transport between RRH and BBU is required over short distances (1 kilometer or less) and fiber is not available, microwave transport is a potential option. Currently this transport technology could only support a subset of the CPRI line bit rate options.

Wavelength-based systems, particularly CWDM, offer a good combination of characteristics for CPRI transport. CWDM brings low delay and high throughput yet is economical, both in equipment costs and in its use of fiber resources.

CWDM transport

The use of CWDM entails deploying CWDM optics in each RRH and the use of passive optical filters to combine multiple client CPRI signals (different, standardized wavelengths) onto a single optical fiber pair. These individual wavelengths are broken out again by similar CWDM filters at the BBU location.

Maximizing effectiveness in urban environments requires placing the radio elements as close to users as possible, which in many cases is near street level, located on lampposts or buildings. CWDM technology fits well with the unpredictable nature of remote placement. With no active electronics, and relatively simple optics at both ends, a CWDM transport solution can be deployed in all outdoor environments, providing significant CAPEX/OPEX savings. There are no specialized enclosures, no requirement for battery backup and minimum power is consumed. CWDM technology provides a cost-effective transport option necessary to support the projected RRH small cell rollouts.

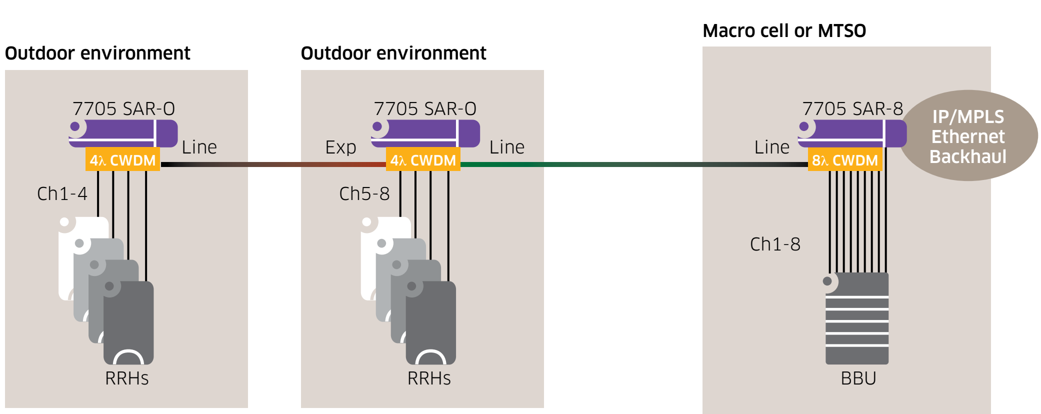
The stringent delay requirements of the CPRI protocol are also well supported by using CWDM. The lack of active electronics along the optical path between the RRH and the BBU means that the only source of transport-incurred latency is due to signal propagation. This allows the operator to maximize the distance between the RRH and BBU.

THE ALCATEL-LUCENT CPRI FRONTHAUL SOLUTION

The Alcatel-Lucent fronthaul solution leverages passive CWDM techniques to extract maximum value from a fiber infrastructure.

The RRHs connect to the BBU using the CPRI interface. Rather than dedicating a single fiber or fiber pair to each RRH-BBU connection, an Alcatel-Lucent 7705 Service Aggregation Router (SAR-O) can be located in an optimal location to efficiently multiplex CPRI connections for transport to the BBU using CWDM.

Figure 2. Alcatel-Lucent CPRI fronthaul: a typical configuration



Referring to Figure 2, the 7705 SAR-O is a weather-proof, environmentally hardened fan-less CWDM optical add-drop multiplexer (OADM), providing high-reliability operation for excellent network availability in outdoor environments. The 7705 SAR-Os add, drop and pass through frequencies as required to multiplex multiple CPRI instances on a single fiber pair instance.

At a macrocell site, a 7705 SAR-8 (as shown in Figure 2) can be used to multiplex the CPRI traffic stream to a BBU for processing. Depending on the scale of the deployment, a 7705 SAR-18 or a 7705 SAR-M can be used in this role.

The solution can be used to transport multiple CPRI links over a single fiber strand or multi-stranded fiber fronthaul. The BBU presents a packetized traffic stream over an Ethernet interface, which can then be routed deeper into the backhaul network by the 7705 SAR-8. Thus, the solution uniquely offers fully integrated optical fronthaul and feature-rich packet backhaul in a single platform and as part of an end-to-end mobile backhaul solution.

Synchronization

Cell sites may rely on the network to deliver a stable reference from which to derive radio frequencies and to ensure reliable subscriber handover between cells. A number of features of LTE and LTE-A require progressively more accurate phase (and time of day) synchronization. Time division duplex mode LTE (TD-LTE), evolved Multimedia Broadcast and Multicast Services (eMBMS) and Coordinated Multipoint (CoMP) all fall into this category.

The Alcatel-Lucent solution supports a full suite of synchronization options, including line timing, adaptive clock recovery (ACR), differential clock recovery, synchronous Ethernet and also timing distribution using IEEE 1588v2. 1588v2 Master Clock, Boundary Clock, Transparent Clock, and Ordinary Clock are all supported for frequency, phase and time of day. Accuracy and high-performance timing for packet solutions, such as ACR and 1588v2, are accomplished by a combination of built-in architectural features, efficiently tuned algorithms, and powerful QoS mechanisms to minimize the delay experienced by synchronization traffic. Management of the synchronization distribution infrastructure is a key differentiating capability. The Alcatel-Lucent 5620 Service Aware Manager (SAM) provides tools for managing synchronization, providing centralized synchronization path visualization, proactive monitoring and alarm correlation to allow rapid discovery and correction of synchronization impairments.

Part of an end-to end mobile backhaul solution

The Alcatel-Lucent IP/MPLS Mobile Backhaul solution comprises a suite of IP, optical and microwave products. The principal IP routing product elements are: the 7705 Service Aggregation Router (SAR), 7210 Service Access Switch (SAS), 7750 Service Router (SR), and 7950 eXtensible Routing System (XRS). The solution is managed end-to-end by the 5620 SAM. Microwave capabilities are a part of the solution with high levels of integration. The 9500 Microwave Packet Radio (MPR) family offers solutions for tail, hub and aggregation sites, across a full range of licensed and unlicensed frequencies for both macro cell and small cell backhaul.

The Alcatel-Lucent IP/MPLS Mobile Backhaul solution delivers a strong set of features and capabilities to support the evolution to 4G/LTE wireless broadband. The solution also efficiently supports 2G and 3G RAN architectures. Newer trends, such as small cell deployment and network infrastructure sharing, are well supported. Fixed-Mobile Convergence and IP transformation are enabled and augmented by the solution. The Alcatel-Lucent fronthaul solution complements and extends the backhaul capability. For a full description of the Alcatel-Lucent backhaul solution, see the application note, "Backhaul Considerations for LTE and LTE–Advanced."

Principal fronthaul solution components

7705 SAR-O

The 7705 SAR-O is an environmentally hardened, fan-less optical add-drop multiplexor (OADM). Available variants include the following:

- 2-Fiber CWDM 4 color 1471-1531. A passive optical CWDM OADM of 4 wavelengths (1471/1491/1511/1531 nm) with an expansion port (including 1310 nm passthrough) over a dual fiber cable
- 2-Fiber CWDM 4 color 1551-1611. A passive optical CWDM OADM of 4 wavelengths (1551/1571/1591/1611 nm) with an expansion port (including 1310 nm passthrough) over a dual fiber cable
- 1-Fiber CWDM 8 color Mux (Up). A passive optical CWDM MUX/DEMUX of 8 wavelengths over 4 ports over a single fiber in the upstream configuration (Tx on 1491/1531/1571/1611 nm)
- 1-Fiber CWDM 8 color Mux (Down). A passive optical CWDM MUX/DEMUX of 8 wavelengths over 4 ports over a single fiber in the downstream configuration (Tx on 1471/1511/1551/1591 nm)

With simple installation and maintenance, deployment is rapid and total cost of ownership (TCO) is lowered. No power connection is required for the 7705 SAR-O, freeing the installation point from being close to energy sources, again lowering operating costs. Ongoing servicing requirements are minimal with no requirement for air filters, fuses, and so on.

7705 SAR-8

The 7705 SAR-8 is a modular IP/MPLS router with eight adapter card slots; two slots are allocated for control and switch modules (CSMs), with the remaining six slots being available for user traffic adapter cards. Adapter cards include a wide range of Ethernet, PDH and SDH/SONET interfaces and also a range of CWDM passive optical adapter cards.

This flexible mix of adapter cards enables the 7705 SAR-8 to fulfill the role of both a CPRI terminating device in fronthaul and a full IP/MPLS backhaul router simultaneously. Depending on the scale of the deployment, a 7705 SAR-18 or a 7705 SAR-M can be used in this role.

CONCLUSIONS

The Alcatel-Lucent fronthaul solution complements and extends the backhaul capability. Together they bring a flexible, cost-effective infrastructure solution, supporting the ideal placement of RAN capability for coverage and capacity. The weather-proof enclosure provides high reliability operation for the 7705 SAR-O, bringing excellent network availability in outdoor environments and simplifying network planning. Simple installation and maintenance bring faster deployment and lower TCO. The 7705 SAR deployed in the MTSO or macro cell location can be the 7705 SAR-8, SAR-18 or SAR-M, depending on the scale of the deployment. These devices combine CWDM and IP/MPLS over Ethernet capability for cost-efficient and seamless coexistence of CPRI fronthaul and full-featured IP/MPLS over Ethernet backhaul.

Alcatel-Lucent mobile backhaul and fronthaul solutions have addressed the backhaul requirements of more than 250 network operators globally, including the four largest mobile network operators in North America, and have led the way for seamless transitions to LTE service delivery. Leading rankings from analyst organizations including ABI, Infonetics and Ovum underscore our success. The solution was awarded: “Best LTE Backhauling Solution” at the Telecoms.com LTE World awards in Amsterdam in June, 2013.

ACRONYMS

ACR	adaptive clock recovery
BBU	baseband unit
C-RAN	cloud RAN
COMP	Coordinated Multipoint
CPRI	Common Public Radio Interface
CSM	control and switch module
CWDM	Coarse Wavelength Division Multiplexing
eMBMS	evolved Multimedia Broadcast and Multicast Services
FEC	forward error correction
LTE	Long Term Evolution
MPR	Microwave Packet Radio
MTSO	Mobile Telephone Switching Office
NFV	Network Functions Virtualization
OADM	optical add-drop multiplexer
OTN	optical transmission network
PDH	Plesiochronous Digital Hierarchy
PON	passive optical network
RAN	radio access network
RRH	remote radio head
SAR	Service Aggregation Router
SAS	Service Access Switch
SDH	Synchronous Digital Hierarchy
SONET	Synchronous Optical Network
SR	Service Router
TCO	total cost of ownership
TD-LTE	time division duplex mode LTE
XRS	Extensible Routing System