SMALL CELL BACKHAUL SERVICES
WITH A DISTRIBUTED ACCESS ARCHITECTURE
AND PACKET BASED CABLE METRO NETWORKS

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Abstract

The growth in mobile voice and data usage is placing tremendous pressure on operators to build scalable backhaul networks to support emerging LTE and LTE-A architectures. At the same time, wireless spectrum is at a premium and must be used in an efficient manner, and the competitive market for cellular customers requires a consistent user experience. For these reasons, operators are exploring architectures to enable a small cell radio to be placed in or near residential or business environments. A modernized cable last mile and metro network could be one path forward. This paper will explore a possible architecture for large scale, small cell backhaul over a Distributed Access Architecture (DAA) and a contemporary all-packet metropolitan transport network.

SMALL CELL OVERVIEW

In mobile telephony and data, the goal is to get data off the air and onto a wire as quickly as possible. A "small cell" is a cellular radio that services a limited area and number of devices. For many years, the notion of a small cell was seen as a device to fill geographic service gaps, such as in rural areas, or as a method to offload traffic from larger macro cell facilities.

In LTE and LTE-Advanced (LTE-A) networks, the small cell is an integral part of the network architecture. The demand for mobile data services simply cannot scale with the existing macro cell architecture, and the constraint of spectrum availability means what capacity exists over the air must be managed with utmost efficiency. These constraints force the operators to deploy small cell architectures to deliver the expected service to end-users. In the LTE and LTE-A architecture, all cells will be self-organizing and are based on the architectural principles specified in Home eNodeB.

In order to make the small cell useful, traffic to and from the small cell must be backhauled to the mobile operator's core network. This can be quite challenging as the small cell will be located in much harder to reach locations than macro cells, and there will be many more of them. The connectivity to the small cell must be of a service provider grade, and the cost to deliver such connectivity must not impede the ultimate goal of blanketed service. Indeed the problem of backhaul of small cell services is cited by most operators as one of the biggest challenges to small cell rollout.

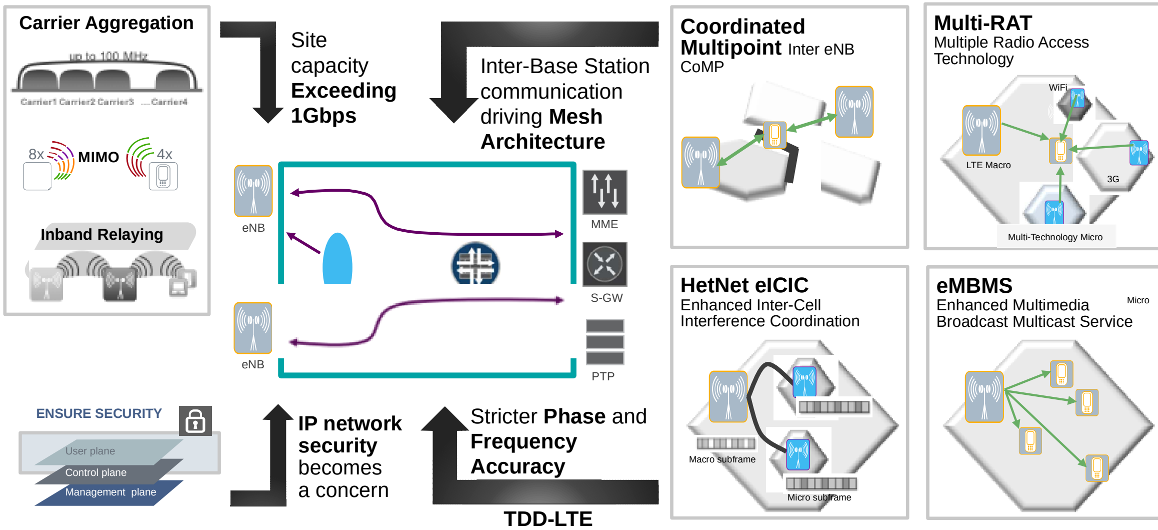

Figure 1: LTE Drivers for Modern Backhaul

DISTRIBUTED ACCESS ARCHITECTURE OVERVIEW

An emerging architectural shift in the cable industry could be tapped to provide effective small cell backhaul services to mobile operators, and solve the challenge of geography, capacity, reliability and cost. This new architecture is known as a Distributed Access Architecture (DAA).

The cable industry is undergoing a dramatic change in the type of product consumers are demanding, and the network must adjust to these new demands. The rise of unidirectional over-the-top video services, such as Netflix, Amazon and others, has changed the economics and expected value of Internet services to the home. As the demand for increased bandwidth capacity grows, the incumbent network architecture centered around a chassis-based CMTS or CCAP, analog optical transport and analog last mile systems will not economically scale. As a result the cable operators are actively exploring inverting the architecture, such that the centralized CMTS device is distributed into many hundreds of elements, deeper (closer to the home) in the network, and connected back to the cable facility with digital Ethernet. In such an architecture the coaxial last mile is preserved. It is envisioned that such an architecture can defer the large capital investment of alternative last mile modernizations, such as PON, for a very long time if not eliminate such investment all together.

A benefit of DAA is the RF characteristics of the analog signal carried by the coaxial last mile dramatically improve. In a typical scenario, this enhancement would be leveraged to provide very high capacity, on the order of many hundreds or even thousand of megabits per second broadband Internet, to the home. In this paper, we explore leveraging part of that bandwidth for small cell backhaul. A second benefit is the transition from analog optical transport to Ethernet enables a large capacity increase and a huge increase in system reliability and dependability. All are key requirements if we are going to leverage DAA for cellular services.

There are, as of this paper being written, two “flavors” of DAA being proposed to the cable industry. One is called “Remote PHY” where the DOCSIS MAC and PHY are “split”, with the MAC remaining in the cable facility on a CMTS device and the distributed device (the “node”) containing only the PHY circuitry. The other architecture is a Remote MAC-PHY approach, where the centralized CMTS device is eliminated and/or replaced with a permutation of carrier grade Ethernet switching and a service provider edge router, or merged into an existing service provider IP/MPLS infrastructure. In the Remote MAC-PHY case, all cable specific functionality is distributed to the node, freeing the rest of the network from the burden of implementing and managing cable specific technology. In both the Remote PHY case and the Remote MAC-PHY case, the analog transport is replaced with Ethernet.

Because of the applicability of carrier and service provider grade IP/MPLS infrastructure to the Remote MAC-PHY case, this paper will focus exclusively on that architecture. There are several shortcomings of Remote PHY that would make implementation of small cell services quite challenging in that architecture. A specific critique of Remote PHY is beyond the scope of this paper.

CORE AND METRO CABLE NETWORK

The third major element of this architecture is the cable IP/MPLS core or regional network itself. Ultimately all traffic to and from any device in a cable network must transit the regional or core network, and in this case small cell backhaul services are no different.

In a typical regional network there exists a rich deployment of IP/MPLS transport, augmented with MPLS Traffic Engineering such that cellular backhaul services, typically for macro cell, are transported along with other types of VPN traffic and standard Internet access traffic. This document does not explore the specifics of this part of the network, except to indicate that a tight integration between the MPLS VPN infrastructure, the DOCSIS service flows provisioned for small cell backhaul, and timing & synchronization services all must work in harmony for this system to be deployable.

PROPOSED ARCHITECTURE

Cable modem and eNodeB

With the collection of previous elements, we can now begin to explore how to assemble an architecture capable of small cell backhaul over DOCSIS.

The first step is the actual provisioning of the last mile DOCSIS service flows to a DOCSIS 3.1 cable modem or Home NodeB with an integrated DOCSIS 3.1 cable modem. In either case, the Ethernet side of the cable modem will hand data and synchronization services to the small cell device itself. These sync services will be established via a combination of 1588v2 and SyncE from the cable modem. The cable modem will receive it’s synchronization from the CMTS via the DOCSIS 3.1 specified DOCSIS Timing Protocol (DTP). This will ensure precise synchronization between the eNodeB, the cable modem, and the upstream CMTS.

A typical small cell will require on the order of 150-200 Mb/s of symmetric bandwidth. To achieve this level of bandwidth on a sustained basis with DOCSIS 3.1, an upstream/downstream split of 200 MHz must be deployed, which typically can produce a usable upstream bandwidth capacity on the order of 1.2 Gb/s.

The distributed nature of the Remote MAC-PHY architecture plays a critical role in upstream bandwidth considerations. First, the notion of deploying a 200 MHz split broadly in a traditional cable network is a daunting task, requiring a large degree of re-engineering and physical plant modifications to accommodate. Because the Remote MAC-PHY node can be placed in a targeted fashion, deployment of the 200 MHz upstream split can be made strategically and tactically. Second, the deployment of the Remote MAC-PHY node lends itself well to the creation of much smaller DOCSIS Service Groups. A Service Group is a collection of homes or end users that share a common pool of bandwidth. In the small cell backhaul architecture, bandwidth in the upstream will be reserved using UGS (Unsolicited Grant Service) DOCSIS flows or RTPS (Real Time Polling Service) type of provisioning based on the specific cable environment.

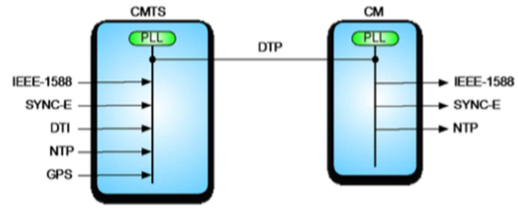

Figure 2: DOCSIS Timing Protocol

TIMING AND SYNCRONIZATION

LTE and LTE-A have very strict timing requirements that must be provided by the backhaul network. All elements in the network must participate as 1588v2 clocks (boundary or transparent) and have SyncE enabled.

LTE-A CoMP

The LTE-A architecture makes use of a scheme called Coordinated MultiPoint Radio. In this scheme, the handset will associate itself with multiple, different base stations to diversify the cellular service delivered to the end user. The benefits are much better utilization of the network and enhanced reception performance of the cellular device.

This means your cell phone will attach to your small cell, and simultaneously your neighbor's small cell and your neighbor's neighbor small cell. In order to make this work, the round trip time (latency) between the small cell eNodeB and the LTE Security Gateway must be very strict, on the order of 3-5 ms.

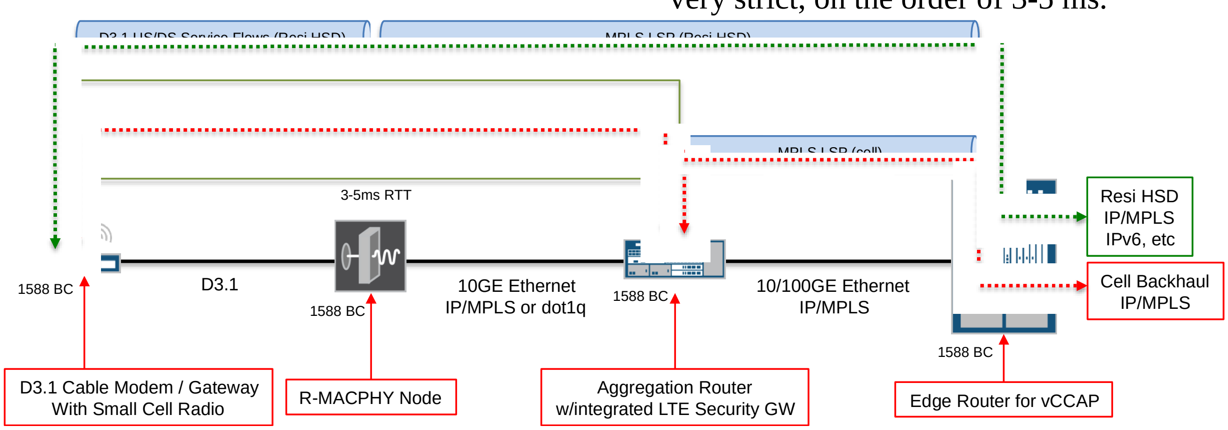

Figure 3: Overall system architecture

In this architecture, we propose locating the Security Gateway close enough to the Remote MAC-PHY node such that the latency to the small cells can be accounted for. In this way, the traffic for small cell backhaul with CoMP can be treated differently and with more accuracy than standard high speed data Internet services. The Security Gateway will then label switch cell backhaul traffic to the Edge Router.

vCCAP EDGE ROUTER

The Edge Router in this architecture is the central administrative and policy enforcement point for all services transiting the vCCAP architecture.

In this architecture, the Edge Router will handle small cell backhaul and traditional residential internet access (HSD) independently. That is, small cell can be treated with a degree of service that is different than regular HSD. Leveraging the featureset inherent in MPLS, the edge router can hand cell backhaul traffic directly to the cell operator via any standardized mechanism – optical wavelength, dedicated interface, or an MPLS LSP. At the same time, residential internet can be simply IP routed or can also be encapsulated into an MPLS LSP, depending on the cable operator’s existing infrastructure.

In this way the addition of small cell backhaul services is a net additive operation on top of the existing edge router, and not a wholesale architectural change for this portion of the network.

SUMMARY AND CONCLUSION

This paper has explored, at a high level, how an ensemble of emerging technology could be applied to the challenge of small cell backhaul services. We have attempted to build off of shipping, standards based technology and to create a unique integration of the cable access environment with the specific demands of cellular services.

Admittedly there exist gaps in this architecture. No vendor currently is building a combination small cell eNodeB with DOCSIS 3.1 cable modem. The R-MACPHY architecture has yet to be deployed in mass at any operator (to be fair, no DAA has been deployed as of this writing). And there are some operational considerations with MSO’s when extending MPLS VPN technology to the cable last mile that must be accounted for.

But overall, there exists a tremendous opportunity for the cable industry to leverage a very lucrative asset in the coaxial last mile, and apply it to services other than traditional high speed Internet. DOCSIS and coax cable can be used to carry just about any sort of data service, and with efforts like that explored in this paper we predict a very strong case for continued investment in cable infrastructure for the foreseeable future.

Ian Goetz of Juniper Networks contributed to this paper.