White Paper

Cisco 5G Vision Series: Small Cell Evolution

What You Will Learn

With spiraling traffic volumes experienced by mobile networks around the world, small cell radio access network (RAN) has been proposed as the way to accommodate billions of users with a myriad of devices and demanding applications. With the coming of fifth generation (5G) networks, several small cell architectures and technologies have been proposed to reengineer the small cell environment that has yet to proliferate in 3G and 4G networks. This paper in the Cisco® 5G Vision Series examines these proposals.

Scalable Small Cell Indoor Solutions

Licensed spectrum is a scarce resource. Mobile RAN technology has reached its limits in terms of spectral efficiency. Tighter spatial reuse enabled through cell densification through small cells has been positioned for many years as the main solution for addressing exponentially increasing mobile data usage. Yet to date, small cells have not been deployed en masse as predicted. This has left Wi-Fi, with its increasingly attractive 5 GHz unlicensed spectrum and native multioperator support, as the primary offload technology for 3G and 4G macro networks.

What has slowed deployment of small cells? Cisco believes that it is a combination of factors that include total cost of ownership (TCO) issues that inhibit adoption by carriers coupled with issues related to being able to support an increasingly diverse set of bring-your-own-device (BYOD) users with differing carrier affiliations that inhibits adoption by the vertical enterprises. From a carrier perspective, the significant operational expenditures (OpEx) associated with deploying small cells have discouraged mobile network operators (MNOs) from doing so. Specifically, the costs for site acquisition, installation, configuration, backhaul, power, and maintenance are high. Coupled with this, without a neutral host capability in 3G and 4G small cells today, the vertical enterprise needs to incur costs associated with deploying multiple parallel small cell networks to enable all their staff, contractors, and visitors to be supported. It’s an expensive, redundant, inefficient environment.

As we approach 5G standards and the 4G LTE to 5G evolutionary period, Cisco has noted two trends in the industry that could address these small cell challenges for MNOs, enabling 3G and 4G small cell deployments to be accelerated by addressing the needs of the vertical enterprises. The first is the trend toward simplified and virtualized networks through network function virtualization (NFV) and software-defined networking (SDN).
The second is the network function centralization that decomposition facilitates, moving some functions out of the small cell base station to enable a range of new capabilities in the RAN and allow each operator to more cost-effectively participate in small cell deployments.

Benefits from small cell decomposition are shown in Table 1.

Table 1. Small Cell Decomposition Benefits

Benefit	Description
Greater scalability	Through the definition of one single virtual cell that is supporting multiple physical remote cells.
Scalable hierarchical mobility	Based on hiding interremote cell mobility from upper-layer elements.
Multioperator capable	Enables a physical radio unit to be connected to multiple virtual network functions, enabling systems to be shared between operators.
Policy enforcement	Applied at an aggregate level (for example, enabling site-specific admission control type capabilities).
Enhanced security	Enhances security of the RAN by terminating user-plane encryption above the remote physical unit.
Enables statistical multiplexing of resources	This lowers the peak-to-mean ratio of the load experienced by the centralized function. It can then be used to lower footprint and/or energy consumption of the system.
Facilitates deployment of advanced radio technologies	For example, coordinated multipoint (CoMP) transmission, including coordinated scheduling and beam forming; carrier aggregation, including cross-carrier scheduling; and high-order multiple-input, multiple-output (MIMO), to enhance the coverage and/or capacity of the virtualized small cell system.
Support for enhanced self-optimizing network (SON) operation	Provides visibility into operation across a cluster of physical remote small cell units, including allowing dynamic resource allocation and traffic load balancing.
Improved future proofing	Can add functions at a small number of accessible central locations versus upgrading a large number of individual base stations in less accessible public spaces.
Simplifies remote management	Remote management of the physical network functions is possible as capability is relocated to the centralized component.

How Much RAN to Centralize?

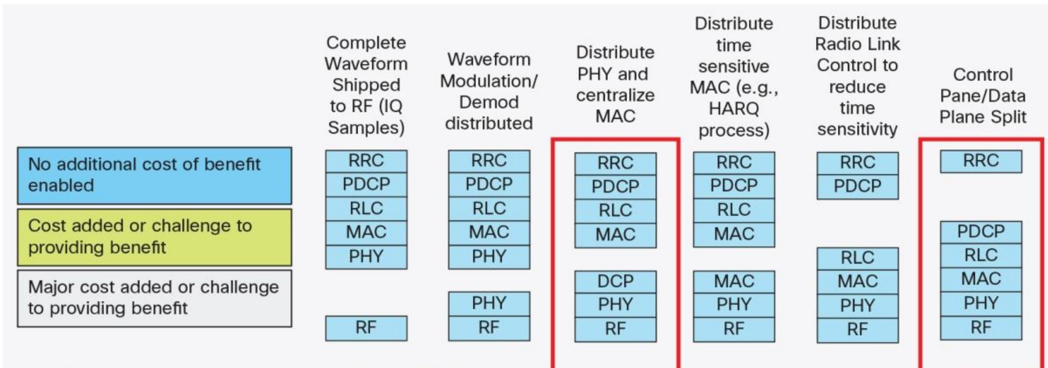
Such an architecture evolution raises this question: How much of the RAN does it make sense to centralize? Placement of RAN functions in either a centralized or distributed location depends on the deployment scenario, available operator assets, and each operator’s TCO models. In some parts of the world where dark fiber is abundant, centralization of the entire RAN stack using Common Public Radio Interface (CPRI) might be preferred. However, there is increasing recognition that CPRI as a decomposition to support RAN centralization—along with virtualization and cloudification—has some fundamental issues.

There are practical limitations to the deployment of CPRI because the interface required has a significantly higher data rate and latency requirements compared to conventional backhaul. The dark fiber or wavelength-division multiplexing (WDM) connections needed might not be widely available, and the severe latency limitations restrict placement of the centralized workloads. Virtualizing the physical layer (PHY) digital signal processing and putting these processing resources in the cloud might present significant risks to overall RAN performance, especially because it is unlikely that the commercial, off-the-shelf hardware solutions available will have sufficient performance or energy-efficient features.

Cloud RAN Architectures

These challenges and limitations have led to an industry trend known as cloud RAN (C-RAN) architectures, which do not require excessively high bandwidth for front haul and are more tolerant to front haul latency. Many studies have been performed in the industry looking at the tradeoffs of different RAN decompositions. Figure 1 summarizes the primary points from these studies. It is increasingly accepted that there are at least two alternative RAN decompositions, or “split points,” that are emerging compared to the centralized PHY of conventional CPRI. When full PHY remains decentralized, there is a significant reduction in the front haul bandwidth requirements. This makes the media access control (MAC) and PHY split point very attractive because it represents the architecture that centralizes as much of the RAN as possible without requiring high front haul costs.

Figure 1. Costs and Benefits of Various RAN Decompositions



	CPRI	Split PHY	MAC-PHY	Split MAC	PDCP-RLC	RRC-PDCP Split
Fronthaul delay requirements	100 us transport latency	<6 ms latency for interleaved HARQ	<6 ms latency for interleaved HARQ	RLC ACK Windowing latency only	Same as legacy backhaul	Same as legacy backhaul
Fronthaul bandwidth requirements	30 x BW expansion	UL BW expansion due to soft bits	Same as legacy backhaul	Same as legacy backhaul	Same as legacy backhaul	Same as legacy backhaul
Multi-vendor alignment	Limited multi-vendor ORI Support	Proprietary	Small Cell Ecosystem defining	Proprietary	Challenging	Challenging
Virtualization Support	Specialized HW required	Some functions virtualized	Some functions virtualized	Virtualized central functions	Maximal virtualization	Maximal virtualization
Performance Improvements	Inter-cell gains possible	Inter-cell gains possible	Some inter-cell gains possible	Limited inter-cells gains	Limited inter-cells gains	Some handover optimization

Centralization down to the MAC layer is particularly desirable for the evolution to 5G small cells. It enables the distributed unit to consist only of RF and PHY functions, which can lead to simplification of the physical network function (PNF) and hence to a lower TCO for a single operator RAN system. However, this also enables 5G small cell vendors to focus on providing innovative wideband RF solutions (covering multiple operator bands) that provide enough PHY processing to support multiple MNOs. That dramatically reduces the TCO by enabling a single multitenant 5G access point module to provide access and coverage across many different operators' devices and users. As a consequence, it is predicted that 5G RAN virtualization will trigger a blurring between conventional DAS and small cell systems, delivering the foundational capabilities for 5G to address new vertical markets.

Although the MAC-PHY split point has many benefits, it still has somewhat challenging latency requirements of the order of a few milliseconds. Although this might be fine for some use cases, for example, indoor/campus enterprise scenarios where the centralized function could be located somewhere in a local data center, there are other use cases such as outdoor and remote deployments that require longer distance front haul links and thus demand a decomposed architecture with looser latency requirements. In this case, the Radio Resource Control-Packet Data Convergence Protocol (RRC-PDCP) split point is an interesting option because it represents the architecture that splits control plane and data plane operations. It aligns with many of the recent developments in SDN, while simultaneously avoiding significantly tightening latency requirements (that is, allowing for 10s of ms latency in the front haul).

Addressing Centralization of RAN Architectures

Cisco small cell solutions are already embracing centralization of small cell functionality. The Cisco Universal Small Cell (USC) 8088 is based on a control plane and data plane split and enables the 4G small cell solution to deliver many of the centralization benefits highlighted earlier.

While current systems can be seen as vendor proprietary split architectures, Cisco has been at the forefront of an industry initiative to drive the standardization of multivendor decomposition of the RAN. Specifically, we have been actively contributing to the Small Cell Forum (SCF) to accelerate the definition of such new decompositions specifically to enable RAN virtualization. Although this work has been motivated by the requirements of those operators that are accelerating deployments of small cells today, the fundamental proposition of decomposing a conventional base station into distributed and centralized locations (typically associated with the location of physical and virtual network functions) applies equally to deployment of the RAN in conventional macro, micro, and distributed antenna system (DAS) environments.

The SCF studies have concluded that the optimum solution includes o defining a multivendor small cell based on a MAC/PHY decomposition, delivering all of the centralization benefits and most of the RF coordination capabilities of existing CPRI-based C-RAN. At the same time, the MAC/PHY decomposed RAN can be transported over the packet-switched backhaul networks. From an important ecosystem perspective, this can be seen as a logical evolution from the current SCF-defined functional application platform interface (FAPI) that has been widely used to support conventional multivendor small cells, with the likely definition by the SCF of the enhanced “networked” FAPI (nFAPI) interface complete in mid-CY16.

Conclusion

As demands on networks increase, exciting new approaches to small cell deployments have the potential to make small cells more affordable and attractive to both MNOs and vertical enterprises. With NFV and SDN, simplified and virtualized networks provide the solution building blocks for enhanced capabilities through function centralization. Moving functions out of the small cell base station leads to a range of new capabilities and business models based on a reimaged, multioperator RAN that can now be consumed as a service. Look for these developments to be incorporated in 5G standards.

Americas Headquarters
Cisco Systems, Inc.
San Jose, CA

Asia Pacific Headquarters
Cisco Systems (USA) Pte. Ltd.
Singapore

Europe Headquarters
Cisco Systems International BV Amsterdam,
The Netherlands

Cisco has more than 200 offices worldwide. Addresses, phone numbers, and fax numbers are listed on the Cisco Website at **www.cisco.com/go/offices.**

Printed in USA C11-736762-00 02/16