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White Paper

NFV C-RAN for Efficient RAN Resource Allocation

NEC Corporation

Executive Summary

Thanks to the development of software-defined networking (SDN) and network function virtualization (NFV) in recent years, virtualizing carrier network functions is now a realistic proposition. In addition, this virtualization technology can be applied even more extensively to next-generation 5G wireless networks. With the introduction of cloud radio access networks (C-RAN), computer resources are being deployed near user equipment, making it easier to deploy core network functions and applications in the virtualization environment of C-RAN. Mobile network operators can offer advanced services by linking them to mobile-edge computing (MEC) for lower latencies and distributed processing.

In the run-up to 5G networks, more and more devices will be connected to the internet and user data rates will rise. Network providers will have to operate large-scale communication facilities more efficiently to cope with such high-capacity usage. A good response to these issues would be to develop next-generation NFV C-RAN architecture that,

- *i. uses wireless base station digital processors to serve a number of cells,*
- *ii. offers a scalable processing facility that can respond to varying processing volumes using virtualized platforms on general purpose servers,*
- *iii. facilitates high-grade coordinated control of network cells.*

C-RAN architecture and function splitting

Traditional C-RAN splits wireless base station facilities into remote radio units (RU) consisting of antenna and RF circuits and digital units (DU). Multiple digital units are placed in a single location to form a concentrated base station, and fronthaul interface between RU and DU is common public radio interfaces (CPRI). To satisfy the demand for high capacity and low latency, multiple RUs and DUs would need to be connected using optical fiber, representing a considerable increase in total system cost if additional fiber has to be installed.

The cost of broadening fronthaul bandwidths for 5G mobile access, which aims to offer ten times the speed of 4G networks, is clearly an issue. Introducing massive MIMO in particular is expensive because CPRI lines would have to be attached to every antenna element. A new system that resolves all of these issues is required.

To reduce fronthaul costs and mitigate demands for higher capacity and lower tolerable delay, we need a structure that uses cheaper connection options such as Ethernet and wireless link, etc. NEC has been looking at ways to create a suitable C-RAN; investigating ways to drastically reduce fronthaul bandwidth by introducing new interfaces that separate RU-DU functions in the protocol layer above the physical layer. Figure-1 illustrates the proposed C-RAN structure, equipped with new RU-DU interfaces. NEC is considering two possible new CRAN structure: (a) L2 C-RAN where the RU would cover L1 physical layer functions and below, and the DU would cover MAC sublayer functions and above. And (b) L3 C-RAN: The RU would cover RF/L1/MAC/RLC functions and the DU would cover PDCP/RRC/RRM/SON functions.

In case of L2-CRAN, the volume of the fronthaul traffic can be reduced to that of transport block layer, that is equivalent to the necessary bandwidths for the user information. Although the L2 C-RAN would need the low latency fronthaul to transmit data within the radio-link sub-frame interval, it could concentrate control of the MAC scheduler using the DU, and accommodate CoMP/carrier aggregation and other high-grade technologies for coordinating small cells.

The L3 C-RAN would transmit IP packet information via RU-DU, and can reduce fronthaul bandwidth in line with user information transmission rates in the same way as the L2 C-RAN. It would also drastically reduce latency by placing the MAC scheduler on the RU side, with the added benefit of relatively cheap connections by using Ethernet or wireless link.

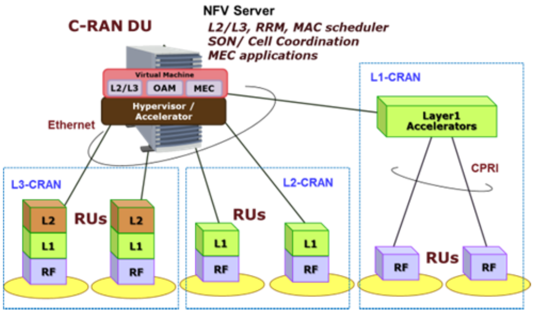

Figure-1: NFV C-RAN Architecture

However, there are limitations with the L3 C-RAN in terms of inter-cell coordination, such as interference control, etc. NEC is looking to resolve interference between densely deployed RUs by using its FERMI resource management system to effectively reduce interference, even in large transmission delayed environments (Figure-2).

FERMI

A centralized resource and interference management system for small cells in large transmission delayed environment

FERMI seeks to protect network capacity from pervasive interference between densely deployed cells. It does this by assigning common wireless resources in the cell center that don't suffer inter-cell interference, and cell-specific wireless resources in the cell edge that severely suffer from the inter-cell interference.

Figure-2 illustrates this procedure. Interference among deployed cells and traffic levels are closely monitored in the DU, facilitating appropriate distribution of overall wireless resources, and cell-specific wireless resources. FERMI would be a useful tool for C-RAN, which monitors overall communication from cell clusters.

In addition to the L2 C-RAN and L3 C-RAN, NEC's C-RAN frameworks for 5G would also cover traditional CPRI for LTE and LTE-A.

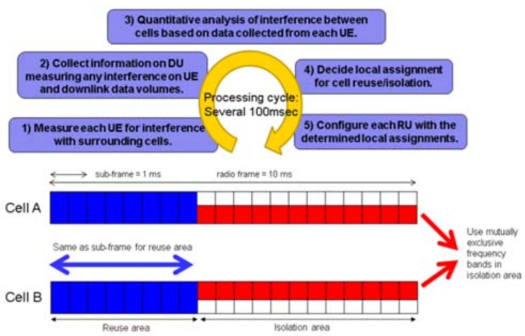

Figure-2: FERMI

Integrated control with C-RAN

In addition to the development of new interface technologies, NEC is also pursuing scalable control, operating DU on virtualized platforms with general-purpose servers, and maximizing statistical multiplexing through resource pooling and the integrated control of L1/L2/L3 C-RAN. NEC is also boosting compatibility with mobile edge computing by developing application functions for general purpose servers.

Migrating to C-RAN

Many operators are expanding capacity in anticipation of 5G, but it would be wise to introduce C-RAN in stages. Figure-3 illustrates a possible step-by-step migration from existing wireless base stations. Figure-3a shows a hotspot service within a macrocell cover area that doesn't have enough capacity. Interference from the macrocell to small cells with identical frequency band is avoided by employing enhanced and further enhanced inter-cell interference coordination (eICIC, FeICIC) technologies. Figure-3b illustrates the case where additional hotspots are incorporated. In this case, the small-cell interference coordination is necessary. NEC uses its FERMI small-cell resource management system to resolve this problem (Figure-2). Figure-3c shows the case migrated to an L3 C-RAN that uses existing eNB for the RU, and FERMI controllers for the DU. With this L3 CRAN, inter-cell interference can be avoided and handover quality is improved.

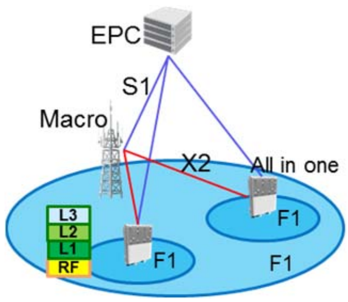

Figure-3a: hotspot service

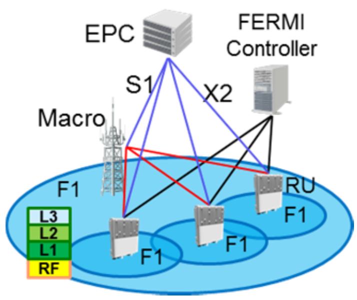

Figure-3b: additional hotspot

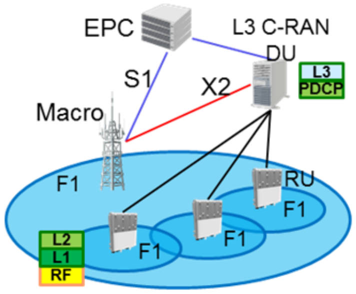

Figure-3c: migrated to L3 C-RAN

On Figure-3d, the assumed increase in frequency bands allocated to operators will facilitate dual connectivity by macro and small cells, and high-performance uplink coordinated multipoint across more widespread L2 C-RAN. On Figure-3e, assuming widespread use of fiber in the fronthaul, massive MIMO will help boost capacity, and high-performance coordination of small cells will make "virtualization of cells" easier (Figure-4).

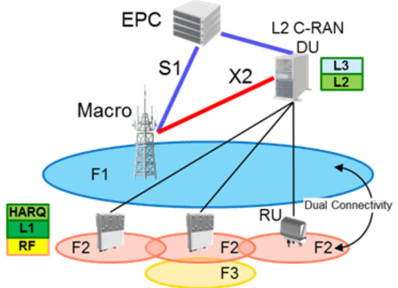

Figure-3d: migrated to L2 C-RAN

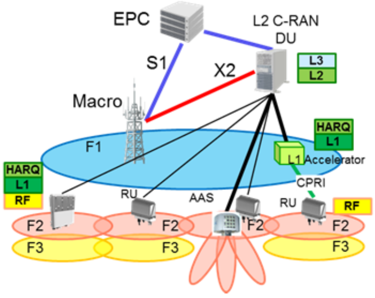

Figure-3e: Massive MIMO introduction

Virtualization of cells

Legacy cells (areas in which services are provided) are determined by antenna location and signal range, and each cell has its own unique cell ID. When a device moves from one cell to another, it has to conduct a handover process, which can create extra traffic. Inter-cell interference can result in deterioration in quality on cell boundaries. Different local traffic can generate wide discrepancies in wireless resource usage per cell. These trends become more obvious, as cells get smaller and more densely deployed.

NEC's "virtualization of cells" concept should help resolve these issues (Figure-4). As shown in this figure, this concept consists of the small cells serviced by low-power RU(the red cells) and the widespan cells that use high-power RU to transmit over wide areas similar to traditional macrocells (the light blue cell). The small cells don't have individual IDs. Instead, dedicated virtual cells are created to service individual users and groups of users wanting to connect devices to the internet from a particular location at a particular time. Services can be directed to a limited number of users by creating a virtual area that delivers signals to designated people. Information generated when a device is moved, or signals that anyone should be able to receive will not be restricted to a narrow transmission area, but transmitted more widely via the broad cell. The DU conducts these controls all together, forming a Cloud RAN.

Virtualizing cells blurs the actual boundaries between small cells. This has several merits:

- Handover is no longer required when a device moves from one small cell to another.
- Interference between small cells can be reduced
- Wireless resources can be allocated efficiently to users within the area.

These enhanced radio resource management can also help reduce the power consumption. Furthermore, by applying massive-element antennas to low-power RU, operators can control the service area of each RU by using beamforming and this makes "virtualization of cells" even more effective.

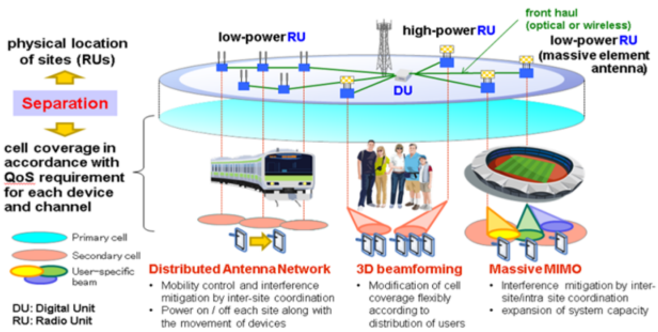

Figure-4: Virtualization of Cells

Abbreviations

SDN	Software-Defined Networking
NFV	Network Functions Virtualization
C-RAN	Cloud-RAN
RAN	Radio Access Network
MEC	Mobile-edge Computing
RU	Radio Unit
DU	Digital Unit
CPRI	Common Public Radio Interface
MIMO	Multiple Input and Multiple Output
L1	Layer-1
L2	Layer-2
L3	Layer-3
RF	Radio function
MAC	Medium Access Control
RLC	Radio Link Control
PDCP	Packet Data Convergence Protocol
RRC	Radio Resource Control
RRM	Radio Resource Management
SON	Self-Optimizing Network
CoMP	Coordinated Multi-point
FERMI	Further Effective Resource Management for Interference Mitigation
eICIC	Enhanced Inter-Cell Interference Coordination
FeICIC	Further Enhanced Inter-Cell Interference Coordination

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