

NEC 5G Vertical Business Platform White Paper

Open & Virtualized

-The Future of Radio Access Network-

February, 2020

NEC Corporation



Introduction

The Telecom Industry is facing unprecedented challenging times. Communication Service Providers (CSPs) try to accommodate unstoppable traffic growth, improve their Customer's experience and finding ways to overcome the strong CAPEX and OPEX pressures caused by the typical services revenue shift to Over-The-Top (OTT) providers.

The arrival of the latest generation of mobile technology - 5G, is being looked at as the engine to enable CSPs to reconsider the way they have been managing their networks and services, as the old traditional model is now becoming unsustainable to address the dynamics, capacity and flexibility required. CSPs are now exploring innovations and new operating models to drive fundamental changes in the way new networks are built. The success cost reduction obtained with the virtualization on the core side functions of their networks, is being now extended to the Radio Access part as well.

Radio Access Network (RAN) meeting the cloud, getting virtualized and opening their interfaces. There are clear evidences that networks will no longer be the same. The questions are now: How and When?

1. Times are rapidly changing in the Telecom Market

While 2G was all about connecting people, 3G tried to connect people to the internet and 4G improved that. 5G is the first wireless technology that was created to allow everything to be connected, not just mobile handsets. Enhanced Mobile Broadband (eMBB) is the first step, Ultra Reliable Low Latency Communications (uRLLC) and Massive Machine Type Communications (mMTC) will follow.

The new 5G skills, with 10x faster speeds and 10x quicker response times, supporting up to one million devices within an area of one square kilometer enabled by Massive multiple input/multiple output (MIMO), that provides a much greater contribution to capacity, due to the high spectral efficiency, will set the path for an improved cost per bit. Primary actors driving the ecosystem are motivated by potential cost benefits where 5G is expected to offer CSPs an opportunity to stay ahead of a declining yield curve. But while 5G offers a path to an improved cost per bit, the cost savings benefits will likely take too long to realize to justify the investment just by its own, meaning that a focus on business cases that create revenue lift is paramount.

In B2C segment, a "Flat Rate" world where mobile service offerings are currently locked to eMBB by itself will not be the game changer. Enhanced connectivity alone will not allow 5G to keep on its promise. This will require CSPs to renew their commercial models approach to end users, as pricing based on data allowance or speed need to be clear and illustrated with concrete use case examples. Service offering based on content will also be the way to go, and not just connectivity delivery, as well as bundling services and devices to improve the level of business they do with each customer.

On the other end, for B2B and B2B2C, the full potential of 5G will rely on uRLLC and mMTC, aided by virtualization. Operators can tailor their networks to create the so called network slices that are focused on a specific set of requirements normally associated to a determined use case being capable to provide a network-as-a-service type of solution, which provides exactly the functionality that is needed by the industry (or vertical).

2. The Telecom Market Context and the 5G Transformation

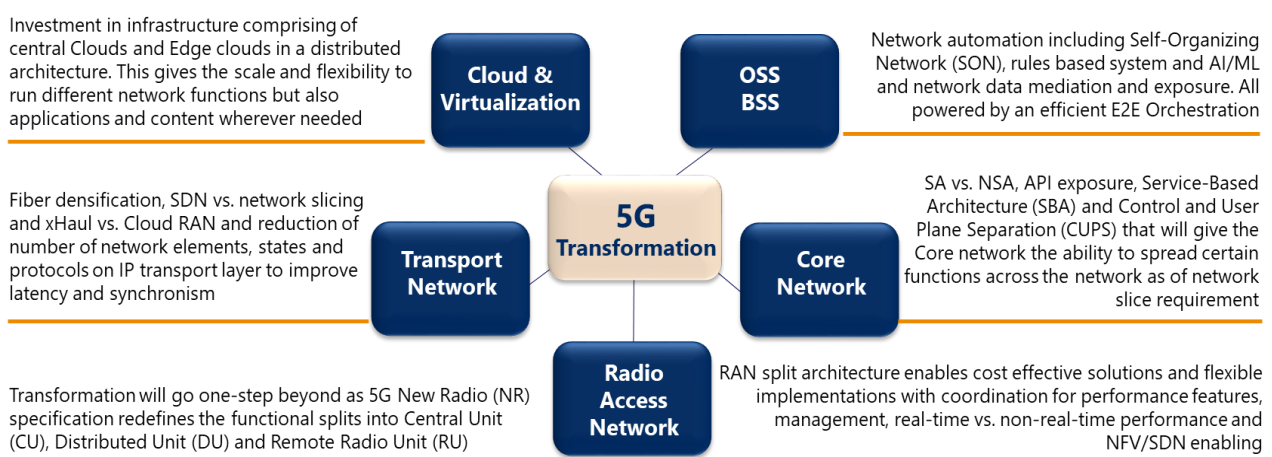
3GPP Release 16 has been just finalized and will bring expected enhancements around uRLLC and mMTC, which means that the 61 commercial 5G Networks in 34 countries reported by the latest Global mobile Suppliers Association – GSA, 5G Market Snapshot, are mostly exploring eMBB based services today. Anyway, and according to the same source, 8% of LTE operators in the world have launched 5G, a good industry sign that the race is on. We need to take into account that these are just the initial steps, as all of the 5G networks deployed are still based on a Non-Standalone Architecture (NSA) relying on 4G Core to deploy 5G Radio service. In order to fully benefit of 5G capabilities, a complete End-to-End (E2E) transformation of the network is required, that will only come with Stand Alone architecture (SA) with a new 5G Core. Latency of 1ms, required for uRLLC mission-critical based use cases, cannot be accomplished by deploying just 5G new radio. Similar rational applies to mMTC and the capability to support 1 million connections per km2.

The capability to dynamically support multiple use cases, all with different performance requirements and network demands, will require much more flexible, adaptable and responsive networks compared to what we have today. To accomplish that, only a deep transformation of network architecture principles will allow to create the foundations to accommodate all the new 5G requirements.

Evolution of network to 5G and architecture transformation

5G architecture foundations will be highly virtualized, on top of a cloud based infrastructure, managed by an end-to-end service orchestrator that assures seamless interconnection in between all network nodes and functions. Computing power will be pushed towards the edge of the network where the access network will be composed by new RAN technologies, assisted by Software Defined Network (SDN) enhanced transport network.

However, the network evolution to 5G is not linear and involves alignment through multiple areas, increasing the level of complexity behind network transformation journey:



Picture 1 – Network transformation journey with 5G introduction

The new 5G technological capabilities will undoubtedly open the doors to explore a completely new way of doing business and generating new revenue streams for CSPs, while enabling the right tools to address the challenges

they are currently facing:

OPERATION COMPLEXITY

The usage of cost effective and data driven Automation powered the AI/ML, Open API, Analytics and DevOps will transform network operational management

TECHNOLOGY UNCERTAINTIES

The growth of optimized cloud and virtualization of network functions brings much needed flexibility, programmability and elasticity to support network slicing

CUSTOMER CHURN

A new set of digital services will rapidly increase digital engagement and increase customer retention through offering consumers a more personalized and intelligent service, paving the way for CSPs to become a Digital Service Provider (DSP)

The new generation of Mobile Networks, is expected to transform end user experience of the networks significantly further complicating CSPs' landscape. The point is to understand up to what extent and how obvious will that transformation going to be?

The 'game-changing' capabilities of 5G and the critical enablers to unlock its full potential

The implementation challenges on 5G along different areas follows the current trends on network automation, virtualization and orchestration. This white paper focuses on the RAN evolution, where the baseband split in CU-DU enabled the separation between real-time and non-real-time processing functions, greatly benefit from previous concepts: Centralized RAN (C-RAN) and Cloud RAN.

The concept of Centralized RAN (C-RAN) opened the doors to a centralized management of radio resources optimizing spectral efficiency and quality of experience with a pool of baseband units in a co-located facility shared between base stations. The base station main functions are divided into Radio Unit (RU), Distributed Unit (DU) and Centralized Unit (CU) in order to optimize processing between radio functionalities and baseband computation. C-RAN minimizes operator's footprint with lower CAPEX and OPEX in terms of server and software requirements and quantities for baseband. Centralization also allows quicker upgrades or new functionalities introduction.

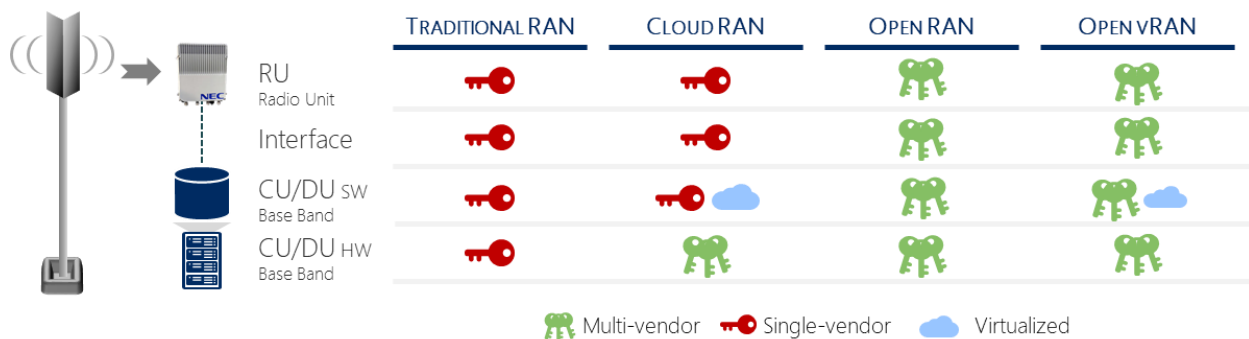
Following a similar path from the IT world, where network functions virtualization (NFV) have started a long time ago, the disaggregation that reached other parts of the network has finally arrived at radio elements. The virtualization trend evolved C-RAN to Cloud RAN, a virtualized radio access network (vRAN) that coordinates base-station functions from a datacenter using NFV and SDN technologies, simplified deployments, allowing to deliver capacity where needed dynamically. CU/DU functions have now been also virtualized enabling OPEX reduction through, e.g., energy savings, IT conversion of RAN and easy network extension with the installation of new RU and connect them to the CU/DU pool. Also CAPEX savings are expected, as less investment is needed due to capacity pooling and RAN resources optimization.

3. Emergence and Disruption by Open vRAN

Together with virtualization and to complement the disaggregation movement inside RAN environment, another disruptive and powerful technology shift emerged: open interfaces, allowing innovation to happen independently in different RAN network elements.

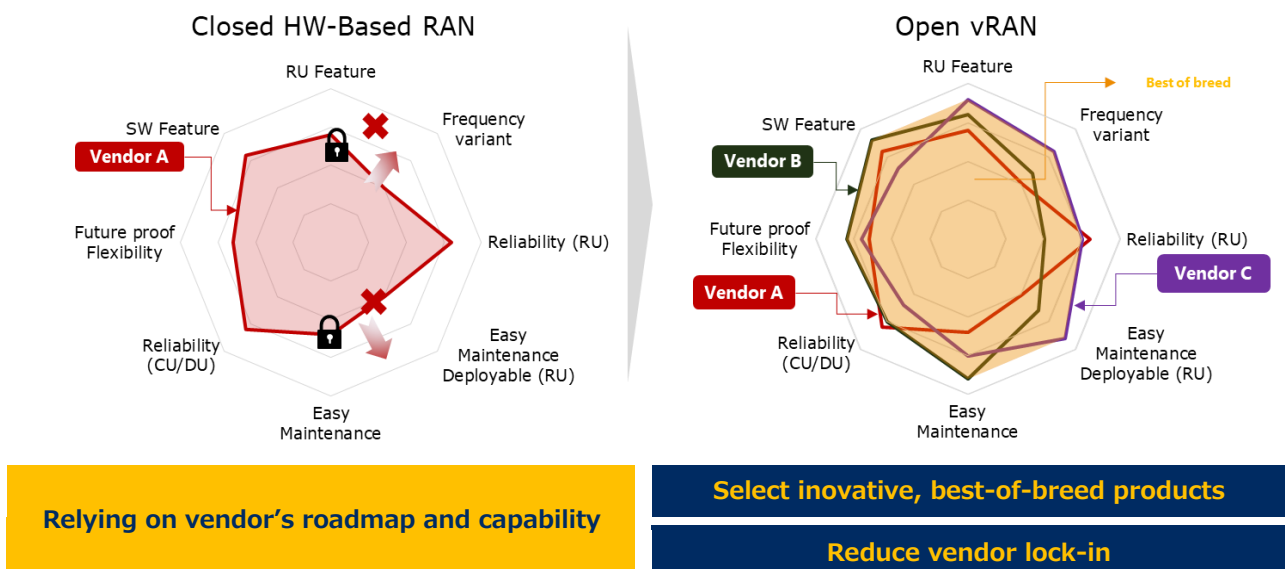
Cloud RAN potentiates the Software-defined infrastructure with the use of Commercial Off-The-Shelf (COTS) servers or white-boxes to deploy network functionalities. In the Open RAN approach, the architecture leverages the use of “white-box” hardware servers that can work flexibly with software-defined radio network functions like DU or CU and open interfaces to avoid vendor lock-in. The Open RAN Alliance (ORAN Alliance) was created to define the open and interoperable interfaces between RAN elements, allowing operators the flexibility to work with different vendors. Also other groups like Telecom Infra Project (TIP) are moving into similar strategies.

Compared to a distributed traditional RAN, Open vRAN offers a software-centric approach based on commoditized hardware, providing the means to build interoperable multi-vendor RAN ecosystems.



Picture 2 – RAN proposals comparison

The following diagram illustrates the comparison between legacy Closed HW-based RAN and Open vRAN. By introducing Open vRAN, it allows to select innovative, best-of-breed products more flexibly without the need to fully rely on the vendors who provide RAN by only HW-based own RAN product.



Picture 3 – Closed HW-based RAN vs Open vRAN

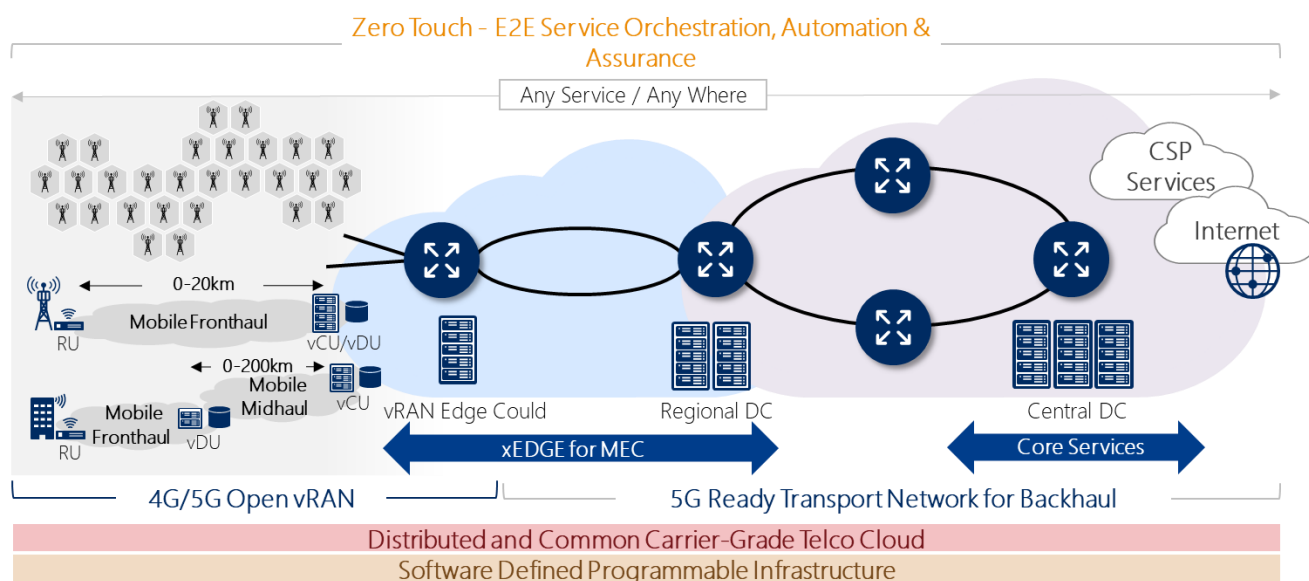
Like previously experienced in the IT world, an open ecosystem, besides increasing competitiveness of the CSP, will also foster innovation. Specifically addressing the 5G rollout challenges mentioned before in this report, Open vRAN will improve:

- **TCO** – by allowing a better control and balance between Capital Expenditures (CAPEX) and Operating Expenses (OPEX) investments, as virtualized functions will be deployed dynamically according to needs, aligning capacity with demand. For example, vCU/DU can be provisioned closer to the RU if a network slice requires extreme low-latency, without the need of expensive and time consuming truck roll. Additionally ease of maintenance due to a lower footprint versus traditional RAN architecture will significantly contribute for cost reduction;
- **Time-to-Market** – NFV decreases the cost of deploying a new SW version or feature, allowing CSPs to test and innovate at a lower risk. DevOps and continuous integration and development become an option;
- **Operational efficiency** – by automating the provisioning and full lifecycle management (scaling, healing, upgrades etc.) of RAN elements and services, spectrum will be used more efficiently and capacity managed on demand to bring the agility and cost savings needed for new services. Examples around new radio features developments to allow an improved interference mitigation like coordinated multipoint (CoMP) transmission/reception will require extreme coordination between cells to optimize coverage. Virtualization allows to manage RAN elements remotely and dynamically, which will enhance the usage of AI/automation and self-configuration capability translated into workload and time reduction of Open vRAN provisioning. Open interfaces will allow to deploy the best-of-breed network elements that better address your network requirements in a specific location, avoiding a typical “one-size fits all” that brings additional operational complexity to setup, configure and fine-tune;
- **Play diversity** – Removing proprietary solutions and single-vendor constraints, will allow new market entrants companies which are best in class in a specific part of a solution to provide and to improve it. Vendor collaboration becomes mandatory and a strong ecosystem around Open vRAN will be key for success;

The ecosystem for Open access is wide and growing with different providers for chipsets, optical and RF equipment, SW stack and integration/support services. Open architecture intends to disrupt the legacy network models and O-RAN alliance is working closely with several operators to define open architecture specifications. Open ecosystem breaks vendor lock-in where the operators are able to select the best-fit software and hardware for their use-cases.

Merging virtualization benefits with Open RAN new capabilities, makes Open vRAN a massive disruptive way mobile networks are built. Impact is massive on the Radio side but part of a major transformation journey already started and impacting networks E2E.

The industry interest around these initiatives is exciting, for example in Japan, Rakuten Mobile, claimed to be building the world's first end-to-end cloud native architecture and Open Virtualized RAN concepts, with ultimately end-to-end automation for both network and services. Built to serve millions of subscribers and adopting 5G systems architecture from launch.



Picture 4 – Illustrative E2E Architecture with vRAN

The CSP's perspective – Key buying factors

Broadly, CSPs are following Rakuten Mobile case-study with strong and active interest. Rakuten model emerged as Greenfield scenario and CSPs are interested to see how successful it will be due to challenges such as scalability, reliability and capacity to handle all traffic loads. Market is showing that first steps are already taking place with trials and strategical live implementations happening around the world exploring the benefits of a fully virtualized Open RAN. The current maturity level of this disruptive technology and considering the recent modernization investments already done in some "traditional" networks, most of the operators are considering to adopt Open vRAN somehow in the mid-term, addressing either network densification or specific challenging coverage requirements.

A recent analyst study conducted on behalf of NEC, engaged with several industry leading players and with various operators around the world to understand their perspectives and expectations about Open vRAN adoption, allowed to identify main common motivation factors to move into this solution and understand possible challenges:

MOTIVATIONS

- **Avoids Vendor lock-in:** Reduces dependency on a single vendor, enabling independent network operations control and the choice of the best hardware/software that fits the use-case;
- **Flexible deployment:** Virtualized DU/CU will allow a more dynamic network, bringing baseband capacity where and when is needed much faster and automated way, whenever more resources will be centralized or pushed to the edge of the network;
- **Simplified operations:** Significantly less requirements for network maintenance and optimization enabled by the use of predictive analytics and automation;
- **Cost-Reduction potential:** This topic normally comes on the top of the list. Innovation and more efficient technology bring about positive impacts on allowing industry to rollout connectivity in places where is not economically viable to do today, no matter the type of environment, being rural or urban;
- **Innovation enabler:** Flexibility to experiment the technology without the restrictions that has stifled innovation. Deploying new features just by SW upgrade will be less risky and R&D cycles will be shortened. Disaggregation of RAN components will also allow to choose the best solution matching customer's networks requirements for each component, allowing to deploy the most innovative solution each vendor has to offer.

CHALLENGES

- **Depth of virtualization:** To deploy an open and fully virtualized RAN solution there will be the need to ensure a suitable telco cloud based infrastructure first;
- **Maturity on Open vRAN vendors:** Open vRAN rollouts are far from massive numbers, and not yet handling similar amounts of traffic as traditional solutions;
- **Performance:** Traditional 5G vendors are able to rely on their experience and expertise to deliver superior performance compared to Open vRAN, essentially on latency performance requirements and scalability to handle high traffic loads. Although initial Open vRAN deployments presented good KPI results, still to confirm similar performance under more demanding traffic conditions;
- **Skills and capabilities:** Mobile operators will need to rapidly upskill existing talent on IT/Cloud and recruit new talent to build new competencies to handle network maintenance and fault management. Also at procurement level, dealing with a wider vendor environment based on SW with new business models, will be new;
- **Transport network requirements:** Mobile operators will need to implement fiber roll out for fronthaul to cover the need of more capacity to connect centralized network elements to cell sites. Latency requirements will also be an important challenge to address;
- **Interoperability:** Open vRAN ecosystem still needs to provide a clear view on responsibilities and accountabilities when Telcos are interoperating. While relying in a collaborative model as clearly a lot of potential and adopting open interfaces will simplify interactions, live networks will demand a clear evidence that a simple call drop problem will be rapidly identified, investigated and fixed.

A clear common understanding among all CSP's feedback is the key role that **system integrator** will play in the future network architecture, regardless if you have in-house skills or relying on a trusted partner, reducing risk of deployment and securing long-term support aligned with networks lifecycle model that operators are used to.

Actually, the System Integrator capabilities, are just a part of a broader transformation that needs to happen at several CSP's organizational levels:

⇒ Operational:

- Upskill existing talent - CSPs will need to ensure they have the capabilities and talent in-house to do the role of a SI. Historically, services such as network maintenance have been outsourced
- Operational model - There will need to be a radical change in who takes responsibility of playing the role of SI and CSPs will need to refine their operating model to ensure they have the appropriate capabilities in-house to support SI activities. Also a transition from NetOps to DevOps will be needed;

- Accountability for network issues - CSPs have the experience to manage multiple vendors, however the biggest challenge will be to determine who is responsible for network issues investigation and support.

⇒ Business:

- Procurement will face complex vendor management - The ecosystem is completely changing as more vendors enter the market; CSPs will not be able to manage vendors in the same ways. Accountability will be different and CSPs need to develop fit-for-purpose vendor management frameworks
- Service management - it will be difficult to outsource service management. In the current environment, there is distinction between vendors on the network and the management can be outsourced to the appropriate vendors

Taking these steps into account, CSPs generally believe that will take 1-2 years to understand the Open vRAN commercially and then further time to adopt into the market. Nevertheless, there are some use cases that might accelerate the adoption of Open vRAN though, such as:

DRIVERS FOR OPEN vRAN ADOPTION

NETWORK DENSIFICATION	NEW RAN DEPLOYMENT MODELS	NEW NEXT GENERATION TECH
Getting more network capacity exactly where is needed in a faster and more efficient way	RAN sharing and decoupling infrastructure from SW, allows alternative service deployment models, by a TowerCo for example	Cutting-edge technology use-cases are likely to accelerate Open vRAN adoption e.g. autonomous cars, where dynamic networks will be required to provide the processing power
MULTI-ACCESS EDGE COMPUTING	LOWER OPEX / CAPEX	
MEC is a very important use case, bringing processing power closer to the user, reducing network latency and helping to keep content local in case of data privacy restrictions and offloading the network	Lower costs will enable better coverage and deployment in rural areas or facilitate NW densification	

Some of these drivers are behind the extensive Open vRAN trial activities across the industry with large operators and no longer limited to remote countries in areas where financial models make it very difficult to deploy a traditional distributed RAN solution that is the public case of Vodafone or Telefónica in the UK for example. Tier-1 operators are more suitable for adoption considering the ability to realize cost savings through economies of scale/volumes. However, some operators believe that this time is a significant period for the technology to mature, but bet on mass deployment in 2-5 years.

Meanwhile, a common agreement amongst operators note the need to move, as a first step, to a fully virtualized environment, what can be financially challenging. Decisions on the RAN side, in what regards the virtualization of CU and DU, will depend on the traffic loads, network density or computing power required. Virtualizing the central unit is likely to be a first step as full virtualization might be most likely in major cities while in rural areas there are not use-cases that justifies the investment. Overall opinion is that full virtualization will take time for adoption, nevertheless edge computing requirements and user plane functions (UPF) distribution to the edge of the network, will also be key drivers to take into account.

Implications of adopting Open vRAN on Total Cost of Ownership (TCO)

Initial expectations about possible Open vRAN impact on TCO, indicate a CAPEX reduction by 40% to 50% in and 35% to 40% in OPEX costs, while comparing distributed traditional RAN and vRAN. Considering that, a significant share of the CSPs' Capital Expenditures are spent on Radio Access Network to address the continuous traffic growth, and another similar share in Operating Expenses to operate and maintain that part of the network, the vRAN solution becomes an attractive alternative solution for 5G Rollout. CSP's are at the beginning of the RAN virtualization process, as such it is difficult to provide a consolidated view on Open vRAN vs traditional RAN cost to NMOs. Several factors are responsible for this:

- Traditional vendors bundle Services with SW/HW prices, turning it difficult to decouple both prices allowing a fair comparison exercise with Open vRAN suppliers;
- Scale of the current Open vRAN deployments do not allow to have concrete figures comparable with the maturity of traditional distributed networks;
- And volumes are not yet comparable to allow similar commercial models.

However, the initial view is that Open vRAN introduction in a brownfield operator that has not yet given the fundamental steps towards RAN virtualization and fiber rollout, will initially require some CAPEX investment in cloud infrastructure to enable RAN virtualization and also aligning specific Radio Features needs to enable co-existence of both network solutions. Nevertheless, COTS based HW investments will allow mid-long term significant savings enhanced by the fact that HW will be more efficiently used and managed by the new RAN SW architecture. The same investment will also enable MEC and UPF deployments across the edge network, closer to the users and enabling new services to be deployed. Depending on CSP strategy and preference, MEC deployment can optionally be aligned with vDU/CU rollout, sharing the same infrastructure. Nevertheless, these are independent functionalities and not mandatory to be jointly deployed.

On top of these valid points, there is also the fact that deploying an Open vRAN based solution might serve different strategies and deployment models, depending on each CSPs existing footprint (ex: greenfield vs brownfield, urban vs rural, etc...).

There is a wide recognition of Open vRAN's potential to disrupt the existing marketplace and in particular to break vendor lock-in, deliver TCO savings and accelerate innovation:

- Redefining Market Norms

BREAKS VENDOR LOCK-IN	Greater freedom to partner with multiple vendors and paving the way to a 'plug and play' network where 'best in breed' solutions can be implemented across the CSP value chain to provide a differential proposition to CSPs
INCREASING COMPETITIVE INTENSITY	New Open vRAN vendors are increasingly entering the market as barriers to entry soften and increasing competitive intensity. Downward pricing pressure on hardware, software and services is widely anticipated with a greater focus on providing differential and innovative solutions / services

- Driving Internal Efficiencies

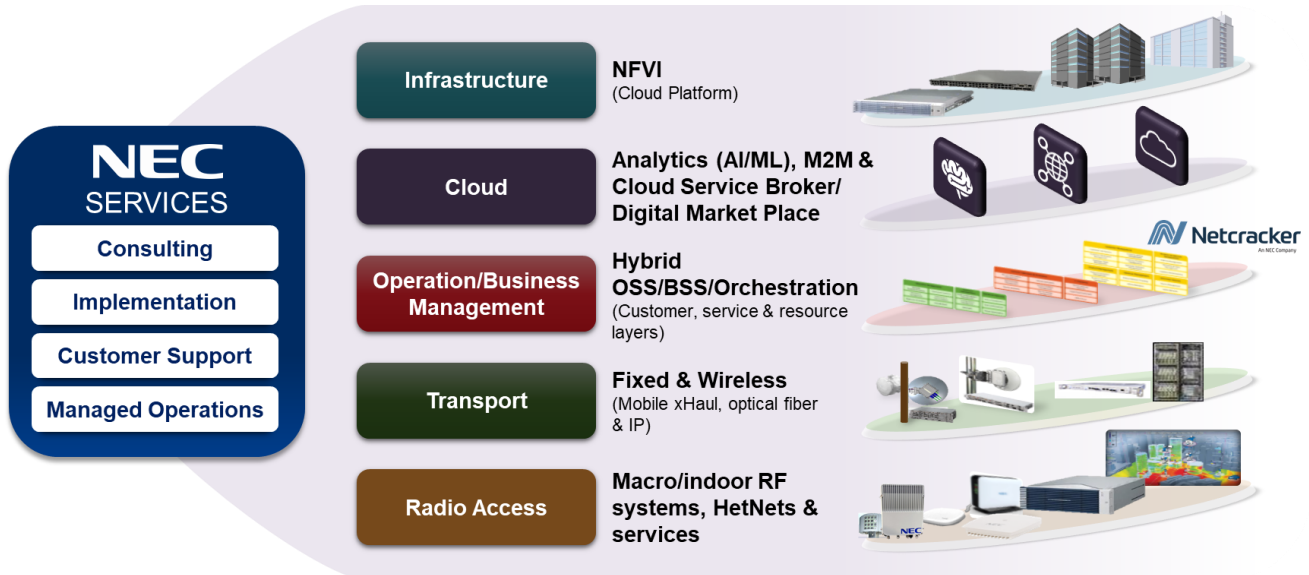
FOSTERS INNOVATION	Open vRAN will encourage shorter, more agile R&D cycles which will accelerate the emergence of a new ecosystem of truly innovative products that can be deployed into market more rapidly and at a reduced cost point
EMERGENCE OF A NEW COST BASE	The shift to open virtualized networks will redefine network economics – widespread cost savings are anticipated through a) lower CapEx as the need to install proprietary hardware diminishes and b) lower OpEx as CSPs scale back site footprint and streamline their operations
SIMPLIFIED OPERATIONS	As networks continue to increase in operational complexity driven by densification and the emergence of 5G – CSPs need to look beyond existing norms to optimise and manage their operations. Open vRAN provides new ways to harness the proliferation of advanced technology and Machine Learning, Automation can be embedded into the network

4. NEC Drives Open vRAN adoption

NEC is one of the top five global telecommunications suppliers with an extensive portfolio of products and solutions that benefit CSPs, businesses and people around the world. Our end-to-end solutions include not only the technology, but also consulting, implementation and managed services resulting in a vast experience of large-scale transformation projects.

NEC, along with its fully owned subsidiary Netcracker, is a leader in the integration of IT and network technologies providing highly reliable communications networks to CSPs. NEC and Netcracker supply network appliances, whether hardware-based or virtual, along with network control platform systems, orchestration, Business Support System (BSS)/Operation Support System (OSS) as well as leading edge AI/ML and analytics.

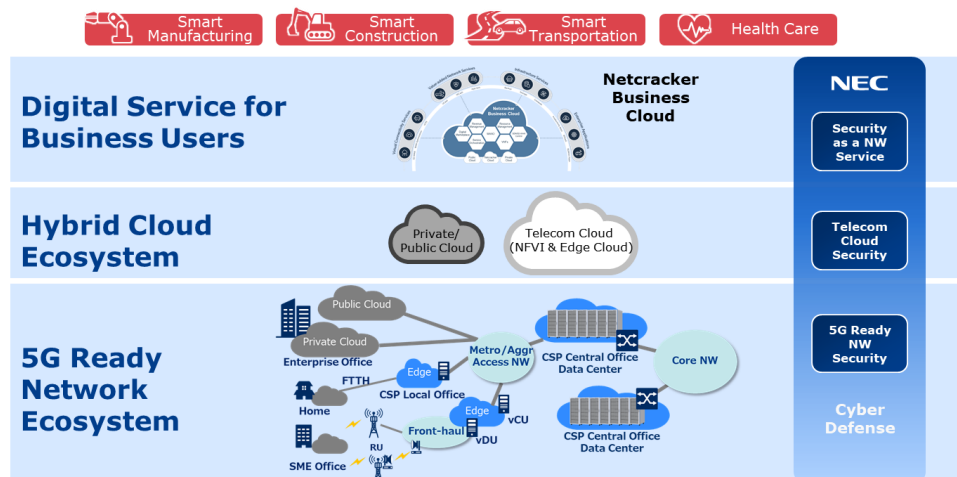
The diagram below illustrates NEC's differentiated proposition portfolio, related to the telecom business:



Picture 5 - NEC Services for its End-to-End solution

Based on extensive portfolio and expertise, NEC is in a leading position to understand and respond to the challenges CSPs are facing with the arrival of virtualization and RAN disaggregation.

NEC is bringing together the best vRAN software, RU's and xHaul equipment with various types of cloud and management elements from broad industry partners by expanding **NEC Vertical Business Platform** best-of-breed ecosystem benefits to Open vRAN. Part of this framework relies on a very important role, the E2E orchestration and coordination. NEC/Netcracker's E2E orchestration capabilities benefit from maximizing its real commercial NFV experience since 2015.



Picture 6 - NEC Vertical Business Platform

NEC Vertical Business Platform translates NEC's 5G Ready E2E Solution Architecture, with a consolidated open ecosystem of industry world-leading players as partners that is so critical in such an open collaborative environment that telecom industry is turning to.



Picture 7 - NEC 5G Open Ecosystem Partners

Pioneer in Open vRAN

NEC was one of the early adopters of Open vRAN and is a firm proponent of open ecosystems to foster innovation and new technology development whilst driving costs down.

Being part of the first commercial rollout of Open vRAN in Japan, NEC became one of the first global reference, leveraging its vast experience in RAN technologies and IT & network system integration. Leading the 5G open architecture, NEC offers open and standardized RF hardware and E2E system integration services with selective software stacks and transport systems at all layers.

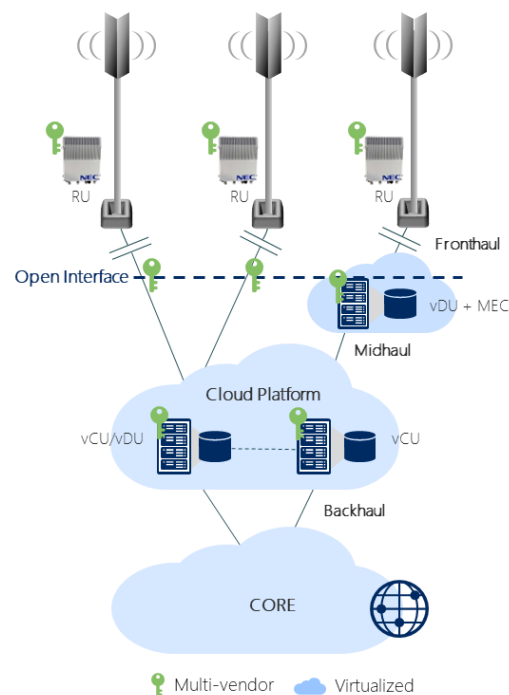
NEC is an active member of O-RAN alliance, aligning its product roadmap with an open architecture direction and compliancy with O-RAN fronthaul. In parallel with 5G trials in Japan, NEC developed a virtualized platform and a 5G massive MIMO antenna radio unit (RU) with digital beamforming supporting open interface.

Simplified evolution to 5G with Open vRAN compliance

Today, NEC provides the RU (Radio Unit) for 5G base stations that comply with O-RAN fronthaul specifications, established by the O-RAN Alliance. Since 5G is expected to require a large number of small-coverage base station devices, NEC's RU are ideal as they are compact, lightweight and consume a low level of power, reducing installation and operational costs. NEC's RUs connects with vCU/vDU by an open interface enabled by Open vRAN standards, allowing CSPs to select distinct vendors for RU and vDU/vCU both hardware and software.

Based on NEC experience, a 3GPP model for 5G architecture relying on Open interfaces together with RAN virtualization, allows an optimized deployment of DU/CU, bringing more flexible solutions to address different business demands that would be extremely difficult to meet with traditional RAN deployment architectures:

- RU, vCU and vDU are collocated – a typical “Network-in-a-box” deployment, addressing specific enterprise needs (office, stadiums, etc);
- RU separated and vCU/DU collocated - Open Fronthaul(ORAN Option 7.2x);
- RU and vDU collocated, vCU separated – for latency sensitive radio control. CU centralized allows a more flexible scaling of resources (3GPP option 2 F1);
- RU separated and distributed vDU, vCU separated – typically vDU can be deployed jointly with edge computing resources depending on operator preferences;



Picture 8 - Open vRAN deployment models

These different Open vRAN deployment models, bring clear flexibility and adaptability to networks, so that different use case requirements can be addressed dynamically and provide a more efficient and rapid response to business requirements. NEC’s RU supporting Open RAN and transport portfolios, provide CSP’s a vast list of optional deployment options.

Advanced orchestration enabling a multivendor ecosystem

One of the major advantages of Open vRAN is the ability to choose multiple vendors for different parts of the solution, and the ease to swap vendors as needed. Whilst open interfaces are critical, this goal can only be achieved through orchestration. With the base band unit further disaggregated and the majority of the solution virtualized compared with previous architectures, it is simply no longer possible to rely on legacy operations to manage the dynamic nature of resources and services. The entire process must be automated.

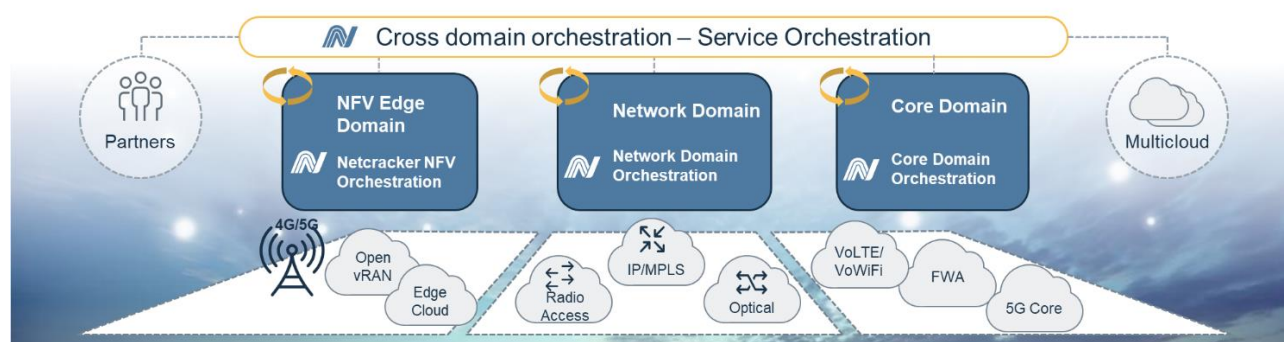
NEC’s subsidiary Netcracker is a leader in orchestration and next generation OSS systems: for physical networks (Network Domain Orchestration), virtual networks (NFV Orchestration) and hybrid networks and services across all domains of the CSP network (Service Orchestration). With our orchestration and Digital OSS solutions (including inventory, configuration management, service activation and fault/performance management all across hybrid networks) we can bring full operations automation within mobile, edge, core and transport domains as well as end to end automation across all domains. Together with our partner ecosystem and customer proof of concepts, we have already demonstrated the significant cost efficiency and agility benefits orchestration brings to Open vRAN through:

- **Multivendor ecosystem:** Support for multiple RAN vendors on common virtualized infrastructure maximizing resource efficiency and the ability switch RAN vendors quickly to remain competitive and avoid any vendor lock in
- **New operational model:** Fast release intervals and service upgrades using agile and DevOps tools and processes

- **Automated lifecycle management:** Immediate scaling of resources where needed to optimize coverage without sending people to a site and instant resolution of issues, even before customers are impacted, without manual intervention
- **Multiservice edge cloud:** Optimize virtual resources further by running open vRAN software as well as other applications on the same distributed edge cloud
- Automate services that cross both physical and virtual networks

As the RAN becomes virtualized, mobile services will cross complex hybrid environments including virtual (e.g DU/CU) and physical (e.g RUs and transport network) resources in distributed platforms using different technologies. The open vRAN solution must also integrate with a CSP's BSS systems such as Netcracker's Digital BSS. With Netcracker's cross domain Service Orchestration solution, services that cross diverse domains can be fully automated from provisioning, to scaling and assurance in closed loop. Using intent based orchestration with standard models, open APIs and a single open interface to BSS, service operations are significantly simplified enabling cost efficiencies and extreme agility.

Netcracker's cross domain Service Orchestration also facilitates the transition from traditional RAN architectures to Open vRAN as shown in picture 9. It provides CSPs with a unified service layer to bring together the various virtual and physical domains of the network progressively. For example as virtualized DU/CU functions are added, Netcracker's NFV Orchestration can be deployed to automate the distributed virtual domain with an open interface to the service orchestration layer. For the physical network (example RUs and transport network), Netcracker's Domain Orchestration brings together orchestration and OSS functions to automate trunk/radio provisioning and assurance, also with an open interface to the service orchestration layer. CSPs can transform gradually to a fully automated end to end Open vRAN solution.



Picture 9 - Netcracker end-to-end orchestration

Netcracker's orchestration solutions also make it easy to evolve when ready to 5G and MEC. Based already on a cloud native architecture, we have enhanced our orchestration systems to enable dynamic network slicing and full lifecycle management for 5G, and orchestrate distributed cloud platforms and applications for MEC.

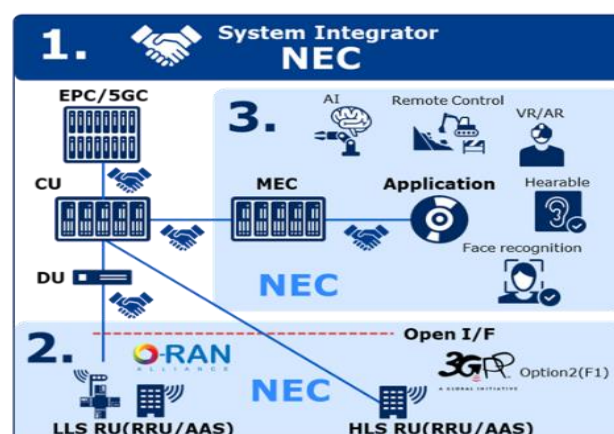
Extensive system integration expertise to speed up Open vRAN adoption

Since the goal of Open vRAN is to broaden the ecosystem of products and components from different vendors, the system integration role is critical to ensure all elements successfully interwork and perform as required. Mission critical services used by several industries demand solution pre-integration and high quality design and testing. NEC is a leading system integrator covering all aspects including requirements management, design alignment, interoperability testing, quality assurance and post deployment optimization.

As Open vRAN matures and gains wider adoption, it will be critical for Telco operators to either take on more responsibility for their own solution integration or rely on a systems integrator to providing these services. System integrators will play a key role for the success of Open vRAN adoption.

With many years of building RAN products for the domestic and global markets, NEC has extensive experience and has successfully integrated complex systems to create innovative solutions for CSPs. Often these products and systems comprise of components supplied from third party partners as well as components developed by NEC.

NEC's rich expertise in both IT and Network sectors, is a fundamental advantage to position NEC at the forefront of System Integration players in the industry.



Picture 10 - NEC interconnections solutions

Conclusions

Unquestionably Open vRAN architecture brings a new disruptive approach to the way Mobile Networks are built. The list of enhancements is extensive, such as avoiding vendor lock-in, flexible deployment, simplified operations and cost reduction potential. Since Rakuten announced their network strategy and vision for the future adopting Open vRAN, CSPs around the world are looking at full network virtualization and Open RAN more seriously. We have confirmed this on the chapters above. Today, industry is clearly demonstrating that in the next years, Open vRAN will clearly become a reality in commercial networks, transforming the way CSPs will deploy and monetize 5G. It is no longer a Greenfield only strategy, but a very serious solution for brownfield operators provide an effective answer to densification or coverage extension in areas that were not financially justifying the investment in a traditional distributed RAN solution.

NEC is well known worldwide for Quality, Reliability, and Technical innovation. NEC has long been recognized for manufacturing the highest quality and most reliable radio network solutions in the industry. Quality and Reliability is, and has always been, NEC's Number One priority. Amidst all its radio network solutions, this is absolutely paramount for the RU solution because of the mission-critical communications. When the infrastructure is built with products and services of the highest Quality and best Reliability, it reduces not only capital costs, but also operating costs. Exact same principle applies to Open vRAN solutions. In addition, maintenance over the life of the network will significantly reduce operating costs.



Picture 11 - NEC Open vRAN value chain

NEC's rich experience and continuous commitment in delivering radio access network solution in different evolving technologies from 2G/3G to 4G, allowed to take the lead on 5G open architecture, leveraging strong RF expertise & Telco system integration capabilities, turning into a key partner supporting CSPs to rethink cellular networks and exploring new ways of deploying innovative services and develop new business models, influencing the future development of the telecoms industry, \Orchestrating a brighter world.