The Economic Benefits of Open RAN Technology

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EXECUTIVE SUMMARY

Mobile network operators are engaged in a far-reaching evolution of their infrastructures toward support of 5G. Enabling these deployments involves significant upgrades to the capacities, functionality, and footprints of their networks. This involves a substantial evolution of the radio access networks with the adoption of 5G New Radio technologies and the capabilities to support them. The scale of these new 5G infrastructures and the range of technology innovations 5G networks will usher in are stimulating operators to do significant amounts of planning and design to ensure they achieve their goals. These include not only maintaining but, in some cases, improving the quality of their offered services, at the same time ensuring they increase their overall efficiency and continue to earn a positive return on investment.

An important option that operators have available for enhancing their RANs is to disaggregate the architecture, modularize, and virtualize the deployments (which have largely been deployed as tightly bundled, integrated systems in preceding generations of mobile networks). Open RAN designs are ultimately expected to use lower-cost radio units, based on increased levels of competition for those parts of the deployments and eventual mass deployments and economies of scale. They will also use a more efficient system architecture to support the additional processing 5G infrastructures require. This will provide operators with flexibility to optimize their deployments based on the characteristics of each area they serve. At the same time, it will require operators to develop a clear perspective on which architectural options and which types of modularity will serve them best in each of these different environments.

Dell and Intel have done considerable research into the types of infrastructure offerings that will assist operators to create the most effective deployments for their 5G RANs. At the same, that there are numerous technical dimensions that need to be addressed in considering the deployments, evaluating the economics of alternative deployment approaches is an equally critical goal. Such an evaluation benefits from an independent perspective in developing a robust economic model of the alternatives available in deploying open RANs. To that end, they engaged ACG Research to leverage the firm's strong capabilities in network architecture, design, and economic analysis. In addition to constructing an economic model of alternative RAN deployment scenarios, a goal was to augment the analysis with a set of independent interviews with operators about their 5G RAN deployments and distill the findings from those interviews into meaningful insights. The goal is to help operators determine the most effective alternatives they can pursue in deploying their 5G RANs.

Two Companion Reports

The findings of ACG's research on these topics are captured in two integrally related companion reports. This report describes the economic model of open RAN deployment options service providers have considered. It compares the total cost of ownership (TCO) of the most prominent options and the advantages of open RAN architectures over time that operators have in deploying open RANs for 5G. The second report communicates the findings of the interviews ACG conducted with prominent mobile network operators about the approaches they are taking to deploying open RANs in their 5G networks.

Overview

The Radio Access Network (RAN) is the largest and most important part in both physical and financial terms of a mobile operator's network. Physically, it extends to every individual radio that is running in an operator's network. Financially, it consumes, proportionally, more of the operator's expenses in deploying the network than any other portion.

Historically, RANs comprised tightly integrated physical radio and baseband processing elements, which we reference as physical RANs (Table 1). More recently, baseband architectures have evolved into a modular design framework that deconstructs the Baseband Unit (BBU) into two closely related elements known as the Centralized Unit and the Distributed Unit. The total 5G gNodeB architecture now breaks down into:

- Radio Units (RU),
- Centralized baseband processing units (CU)
- Distributed baseband processing units (DU) and,
- Network transport infrastructures providing connectivity between RU, DU, CU, and the mobile packet core.[1]

Using this modular, disaggregated framework allows for greater flexibility in deployments for mobile operators than the prior tightly integrated designs have allowed. For this reason, comparing the relative efficiency and economics of the various deployment models for 5G operations is a critical planning task.

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[1] See, for example, O-RAN Architecture Overview at *https://docs.o-ran-sc.org/en/latest/architecture/architecture.html* for a description of the components.

To put the impact of the overall RAN costs in perspective, the TCO of the RAN represents approximately 70%–80% of the TCO for an average mobile network. Thus, achieving meaningful cost savings in the RAN represents the best opportunity to reduce overall network costs.

Table 1 describes the three distinct technology alternatives available to operators in creating 5G RANs.

Technology	Definition
Physical RAN (PHY RAN)	PHY RAN is the most common RAN technology currently deployed. All components of the RAN use physically integrated, proprietary network functions based on custom hardware designs. A single vendor delivers the PHY RAN solution; components are not interoperable with those provided by other vendors.
Virtual RAN (vRAN)	The CU and DU functions are virtualized in vRAN and run as software on standard x86 servers. vRAN provides virtualization but not open interfaces. This means that a single vendor is responsible for delivering an end-to-end solution but not open interfaces. A single vendor is responsible for delivering an end-to-end solution.
Open RAN (O-RAN)	O-RANs provide both virtualization and open interfaces to all components, which include open RU, DU, and CU. The RU is an open radio design and provides open interfaces to the DU. The DU and CU are also open and virtual designs running on x86 servers. An O-RAN allows network operators to combine hardware and software from different vendors and from the open-source community.

Table 1. RAN Technology Alternatives

In addition to the three technology alternatives there are two network architecture (or RAN topology) design approaches available in building a RAN:

- **Distributed RAN (D-RAN):** All baseband processing (DU/CU) equipment is located at the cell site base station.
- **Centralized RAN (C-RAN)[2]:** Baseband processing (DU/CU) equipment is located in edge data centers and shared among multiple cell sites.

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[2] Terminology in the industry varies related to the acronym C-RAN. Some use it, as we do, to reference a centralized configuration in which DU and/or CU elements are pooled and installed with each other at a site separated from the radios. Others use it to reference a cloud RAN, generally referring to use of virtualized functions in configuration of RAN control elements at some site. Both of the terms tend to reference the same kind of configuration we are considering in our analysis. We normalize on using centralized for consistency.

These architectures are depicted in Figure 1. The distributed RAN architecture is at the top of the diagram. Both the DU and CU functions are located at the cell site with the RUs. The network transport is backhauled from the base station to the regional data center where the packet core is located. Beneath that, two alternatives for C-RAN architecture are shown:

- Distributed DU (at the cell site) and CU with midhaul transport.
- Central DU with fronthaul and CU with midhaul transport.

The network transport technology is defined as X-haul that consists of either backhaul, midhaul or fronthaul depending on the level of centralization and the location of the DU and CU. Fronthaul requires significantly more bandwidth than either backhaul or midhaul and has stringent requirements for latency and jitter, which means that DUs generally cannot be located more than 10 kilometers from the cell site.

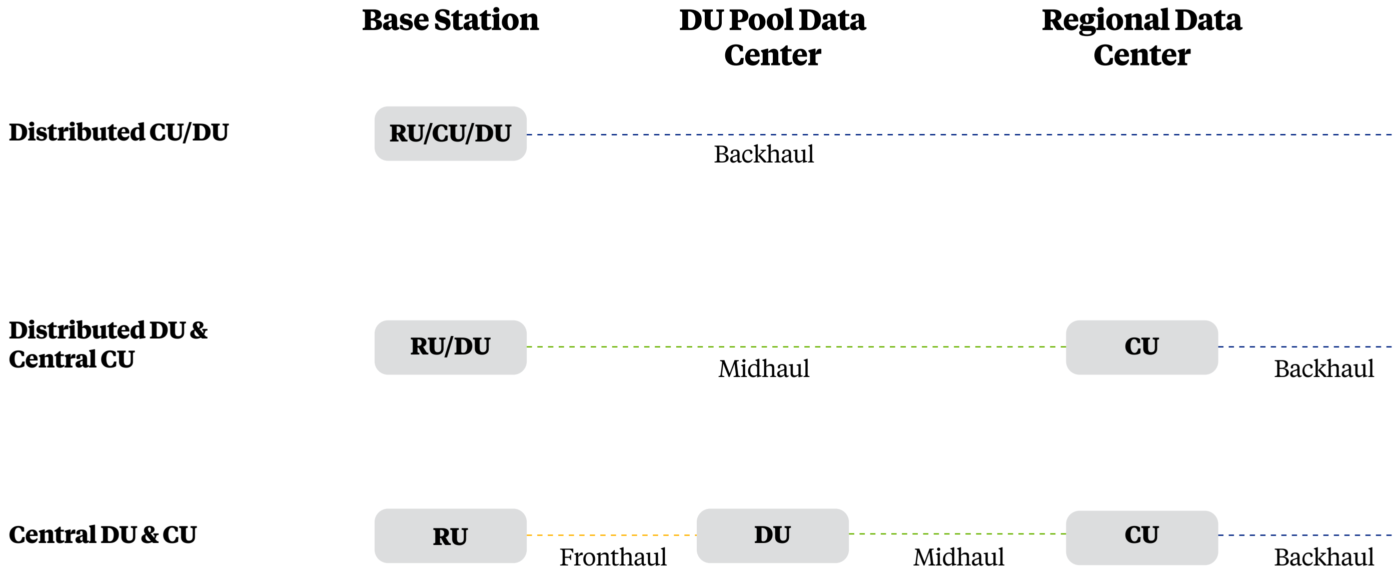

Figure 1. Alternatives for O-RAN Architecture

Aligning RAN design alternatives with considerations that work in different deployment environments is a fairly complex process. We can use either PHY RAN, vRAN or O-RAN as the fundamental technology in a deployment, and for each of these it is possible to use either D-RAN or C-RAN architectures. Generally, D-RAN and C-RAN will be mixed in a mobile network, with C-RAN typically being used more frequently in urban areas and D-RAN being more common in suburban and rural areas. C-RAN with a centralized DU can only be used in areas where there are many cell sites within 10 kilometers of an access central office that can be used as a DU pooling site.

The focus of this analysis is on comparing PHY RAN with O-RAN technology elements in a mixture of D-RAN and C-RAN deployment architectures.

TCO Benefits of Open RAN

The conclusion of our analyses is that O-RAN technology choices will most often be more economically beneficial for operators to use than PHY RAN and vRAN alternatives. The key factors driving the more attractive TCO of O-RANs are:

- Whether the technology choice of the RAN is proprietary or open.
- Whether the architecture of the RAN is distributed or centralized.

The scenarios in our TCO analysis show an Open RAN has the following financial benefits over a physical RAN:

- **Open radios** will be 30% less expensive than currently available proprietary radios over time. This is because there will be more manufacturers building to a standardized radio specification. We expect profit margins to be lower for open, white-box radios than currently available proprietary radios.
- **Open RAN software** will be 30% less expensive than currently available proprietary software over time. This is a result of a combination of open-source and multiple software vendors in an open ecosystem.
- **x86 servers** will eventually become less expensive than proprietary BBUs. This is a result of Moore's Law and the continued improvements in Intel processors that are designed for O-RAN requirements.

A centralized RAN has important benefits over a distributed RAN; however, additional costs are also incurred when centralizing a RAN, meaning the decision about centralizing the RAN needs to be made when the benefits outweigh the additional costs. The benefits of centralizing the RAN are:

- CU/DU pooling allows greater efficiency and less BBU hardware and software than a distributed solution.
- CU/DU pooling can also provide spectral efficiency through pooling gains and improved efficiency for the three main 4/5G central coordination features: Carrier Aggregation, Inter-Cell Interference Coordination (ICIC) and Coordinated Multi-Point (CoMP).
- CU/DU pooling reduces labor expenses because it decreases truck rolls and maintenance at cell sites. It also allows for more efficiency of field engineering resources focused on highly skilled maintenance at the cell site versus the data center.
- CU/DU pooling reduces power consumption and allows for CapEx savings with overall reduction in cell site equipment (such as GNSS receivers) that can now be shared at the centralized data center.

Spectral efficiency benefits are complex and are primarily due to the use of technologies enhanced by C-RAN and O-RAN (Table 2).

Technology	Definition
Carrier Aggregation	Multiple carriers can be aggregated into a transmission channel with higher bandwidth to provide higher data rates to end users.
Inter-Cell Interference Coordination	By controlling radio resource management, interference between cell sites can be mitigated, thus increasing spectral efficiency.
Coordinated Multipoint Transmission and Reception	When a UE is in the cell-edge region, it may be able to receive signals from multiple cell sites. Given that, if the signaling transmitted from the multiple cell sites is coordinated, the DL performance can be increased significantly. This coordination can be simple as in the techniques that focus on interference avoidance or more complex as in the case where the same data is transmitted from multiple cell sites.

Table 2. Technologies Enhanced by C-RAN and O-RAN

However, the benefits of a C-RAN come at a cost. C-RAN architectures require fronthaul networks, which have much higher bandwidth requirements than traditional backhaul networks. Backhaul for current 4G networks is carried over 1 GbE. For 5G, backhaul link speeds will need to increase to 10 GbE. Fronthaul with multiple RF carriers/radios at a cell site will drive higher bandwidth requirements as carriers and carrier bandwidth is increased, resulting in the move from 10 GbE to 100 GbE fronthaul connections, which adds a significant expense but is typically off-set by the benefits.

TCO Model and Assumptions

ACG Research developed a TCO model that evaluates O-RAN TCO compared with alternatives in multiple scenarios. The model has been built using the ACG Business Analytics Engine (BAE)[3], a next-generation economic simulation platform for networks, data centers, cloud, and NFV. The model in this network is representative of a large metro area RAN[4]. An overview of the O-RAN TCO model is presented in Figure 2.

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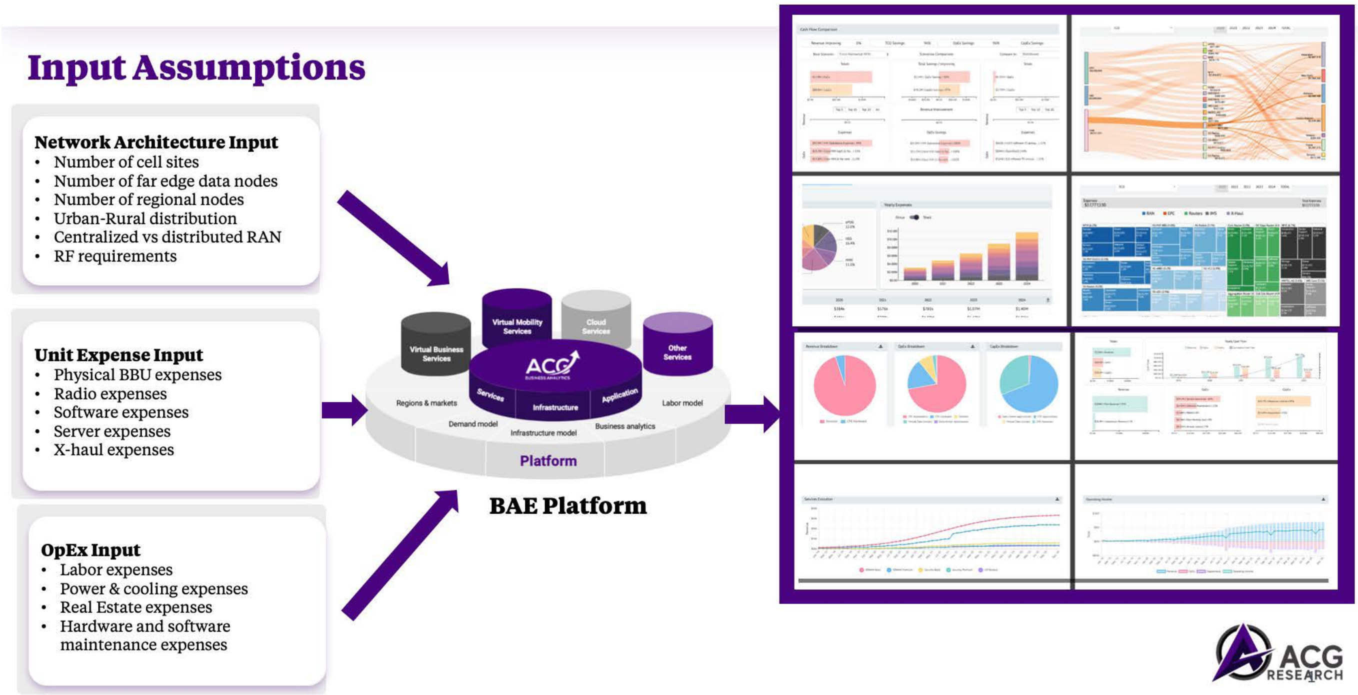
[3] https://www.acgcc.com/p/bae-software/

[4] The BAE model is adaptable to specific service providers' networks and is available to Dell's customers on request.



Input Assumptions

Network Architecture Input
- Number of cell sites
- Number of far edge data nodes
- Number of regional nodes
- Urban-Rural distribution
- Centralized vs distributed RAN
- RF requirements

Unit Expense Input
- Physical BBU expenses
- Radio expenses
- Software expenses
- Server expenses
- X-haul expenses

OpEx Input
- Labor expenses
- Power & cooling expenses
- Real Estate expenses
- Hardware and software maintenance expenses

Figure 2. O-RAN TCO Model

Architectures Included in the TCO Comparison Analysis

The following are the RAN architectures we used in the TCO comparison analysis:

1. Distributed Physical RAN (PHY D-RAN Figure 3).
2. Centralized Physical RAN (PHY C-RAN Figure 4).
3. Distributed Open RAN (Open D-RAN Figure 5).
4. Centralized Open RAN (Open C-RAN Figure 6).

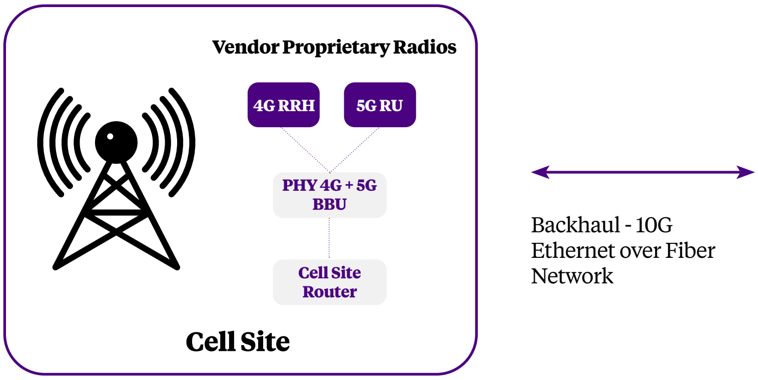


Figure 3. PHY D-RAN

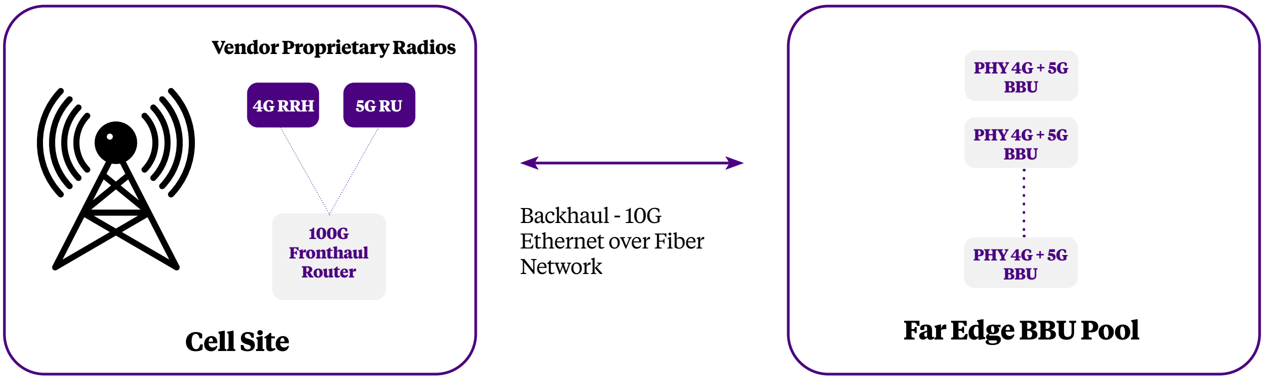


Figure 4 . PHY C-RAN

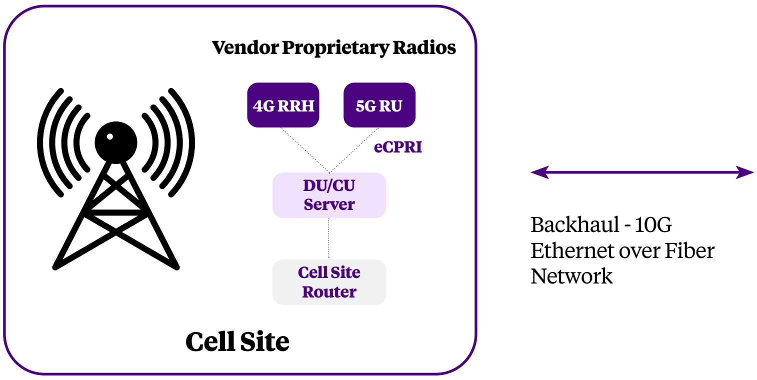


Figure 5. Open D-RAN

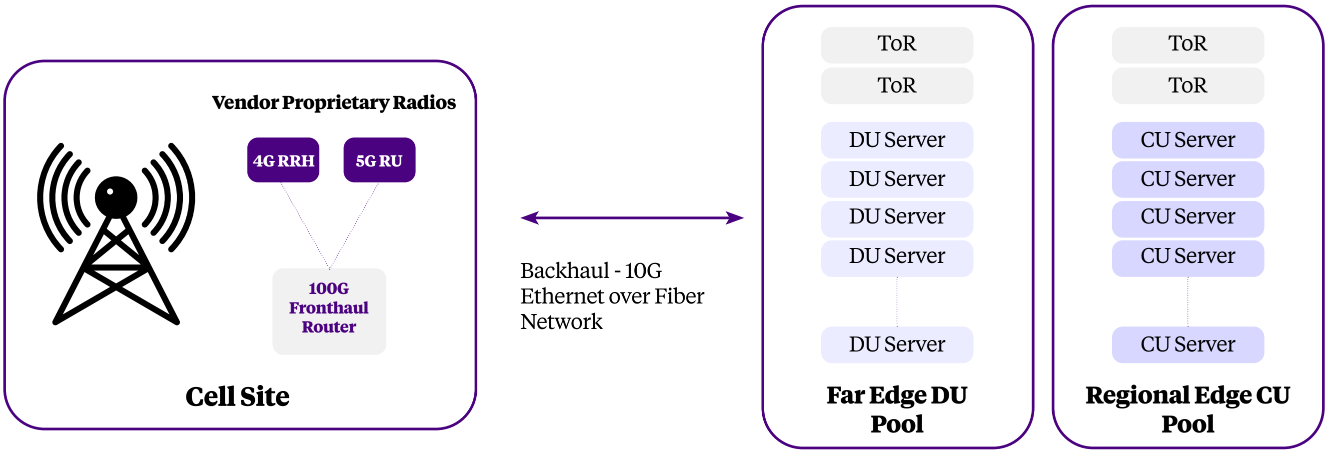


Figure 6. Open C-RAN

Key TCO Assumptions

For each of the architectures there are many assumptions factored into the scenario:
Size of the network,

- Distribution of cell sites in urban and rural areas,
- Radio carriers used,
- Power and space required, and
- Many software, hardware, and maintenance expenses.

In each of the scenarios we model a greenfield network, including 30,000 base stations. We assume 70% of the cell sites are urban, and 30% of the sites are rural. We assume there are 900 DU pool edge data centers with approximately 33 cell sites per DU pool. The number of base stations and the number of edge data centers grows over five years, following an S-Curve pattern.

The model calculates the number of DU and CU pool servers based on a radio carrier demand model. We assume DUs use Intel IceLake processors in servers. For the centralized physical RAN we assume a set of physical BBUs is used in the pooling sites. For the distributed O-RAN we use CU/DU servers at urban and rural cell sites that meet the radio requirements. For the physical RAN, custom BBUs are used for baseband signal processing.

The types of radio carriers we include in urban and rural cell sites are presented in Tables 3 and 4. These are used to drive the configuration of CU and DU servers in the O-RAN scenarios and the physical BBUs in the PHY-RAN scenarios. For the centralized O-RAN scenario we assume that there is a 20% improvement in spectral efficiency based on the benefits outlined in Table 2.

Urban Cell Sites

Cell Site Radio Technology	Sectors per Site	Carriers per Sector	Sector Carriers
LTE 10MHz 2X2	3	2	6
LTE 30MHz 4X4	3	1	3
LTE 20MHz 4x4	3	1	3
5G 20MHz 4X4	3	1	3
5G 10MHz 2X2	3	1	3
5G 90MHz 32X32	3	1	3

Table 3. Radio Carrier Requirements for Urban Cell Sites

Rural Cell Sites

Cell Site Radio Technology	Sectors per Site	Carriers per Sector	Sector Carriers
LTE 10MHz 2X2	3	2	6
LTE 30MHz 4X4	3	1	3
5G 20MHz 4X4	3	1	3
5G 10MHz 2X2	3	1	3

Table 4. Radio Carrier Requirements for Rural Cell Sites

Results of TCO Comparisons

The TCO of the Open RAN technology-based scenarios compared with the physical RAN technology-based scenarios in the different combinations we evaluated are presented in Table 5. The results show cumulative savings in a greenfield network in each comparison over five years.

Base Scenario	Compare Scenario	TCO Savings	CapEx Savings	OpEx Savings
PHY D-RAN	**Open D-RAN**	**28%**	**32%**	**15%**
PHY D-RAN	**Open C-RAN**	**31%**	**33%**	**27%**
PHY C-RAN	**Open D-RAN**	**31%**	**37%**	**11%**
PHY C-RAN	**Open C-RAN**	**35%**	**38%**	**23%**

Table 5. Cumulative Savings in a Greenfield Network over Five Years

The details of the five-year cumulative CapEx and OpEx comparing PHY D-RAN and Open C-RAN are presented in Figures 7 and 8. Similar details comparing CapEx and OpEx of the PHY D-RAN and Open D-RAN scenarios are provided in Figures 9 and 10. Note in the tables that the top 10 expense items in each scenario (for example, 10 CapEx items in the PHY D-RAN case and 10 CapEx items in the Open C-RAN case) are listed top to bottom in the table from largest to smallest within that scenario. Some of the line items (for example, RU acquisition) exist in each scenario and thus appear in the amount related to them in each of the scenario charts. Conversely, other line items (such as DU Pool Server Acquisition) exist only in one scenario (Open C-RAN, for example) are only shown in the chart for that scenario. For each line item the total amount it represents in the scenario is on the left, and the percentage of the total of that scenario is on the right edge of each bar.

In all cases, a major component of savings achieved using Open RAN technologies as compared to using proprietary physical RAN technologies in the deployment is reduced radio expenses. This is based on our projection that open radios will be 30% less expensive than proprietary radios during the time frame of the analysis. BBU software savings are also significant for Open D-RAN and C-RAN scenarios. When we compare Physical D-RAN to Open C-RAN architectures there are spectral efficiencies achieved via CU/DU pooling in the Open C-RAN case, which result in both CapEx and OpEx savings. Some of these savings are off-set by the initial high cost of fronthaul fiber deployment (Figure 7).

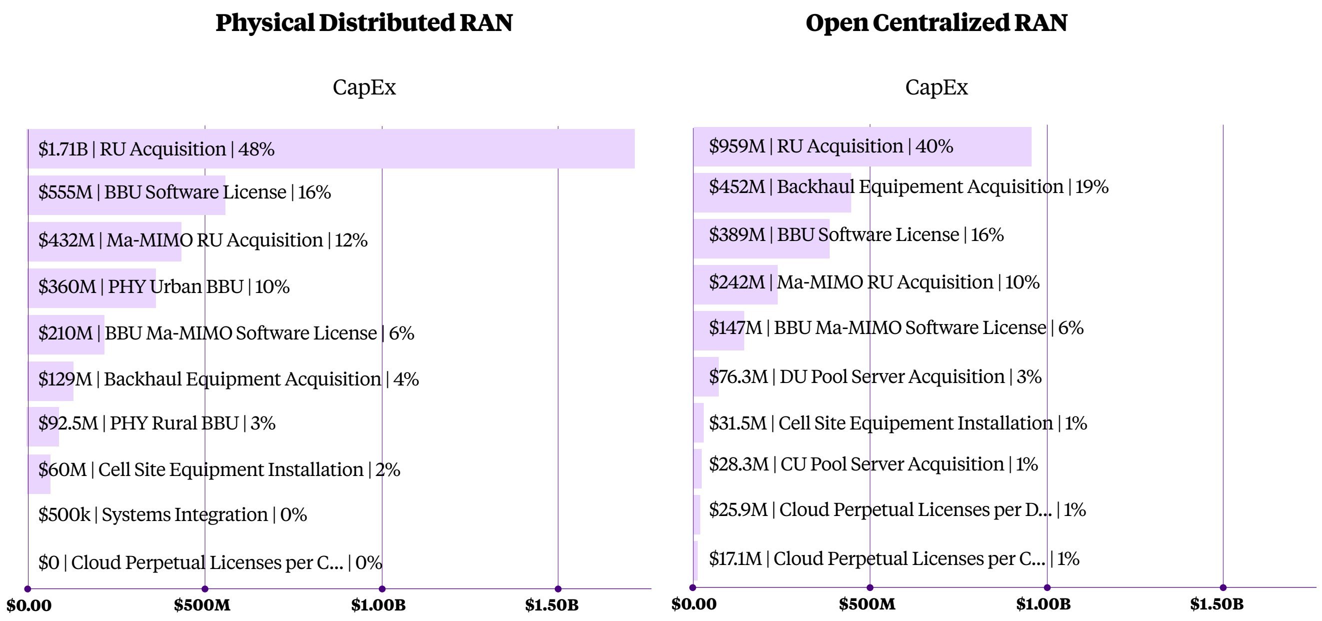


Figure 7. Five-Year Cumulative CapEx Comparison of PHY D-RAN and Open C-RAN

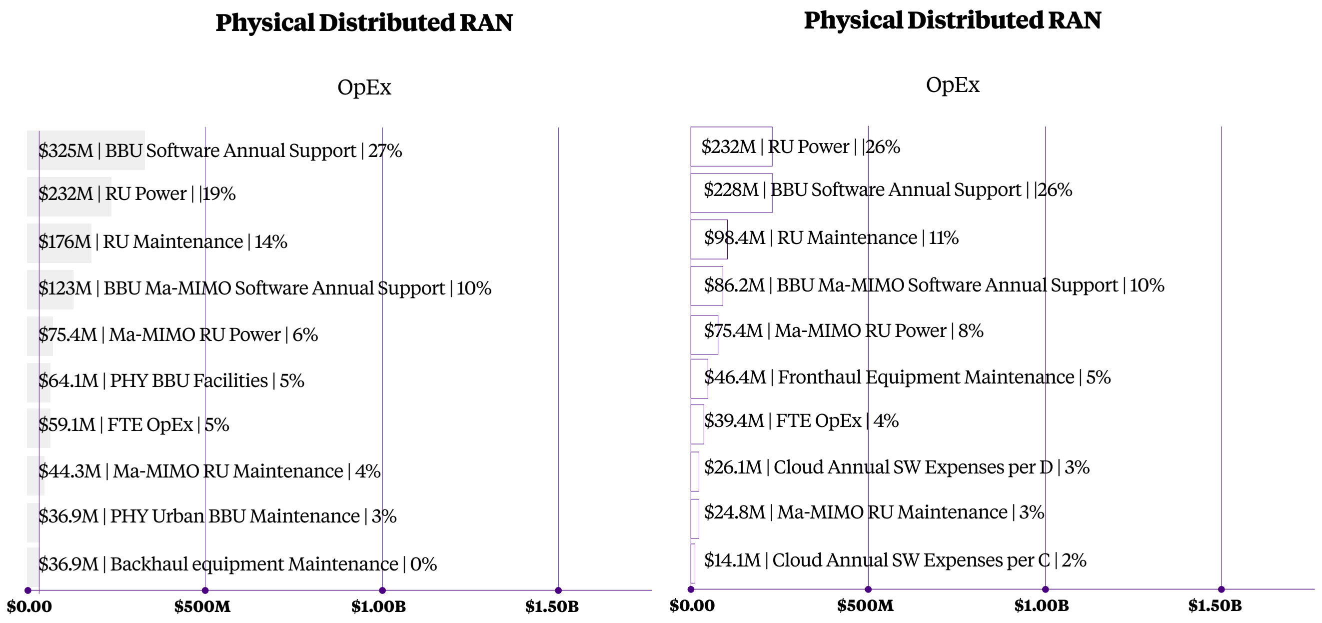


Figure 8. Five-Year Cumulative OpEx Comparison of PHY D-RAN and Open C-RAN

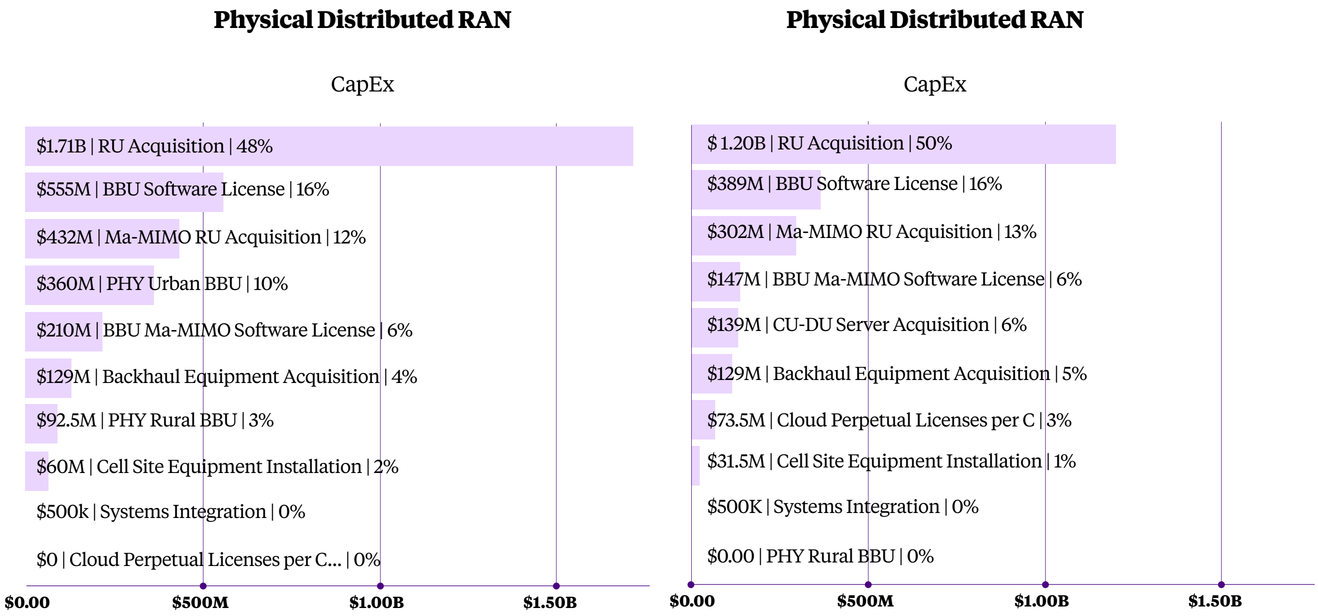


Figure 9. CapEx Breakdowns of PHY D-RAN and Open D-RAN Scenarios

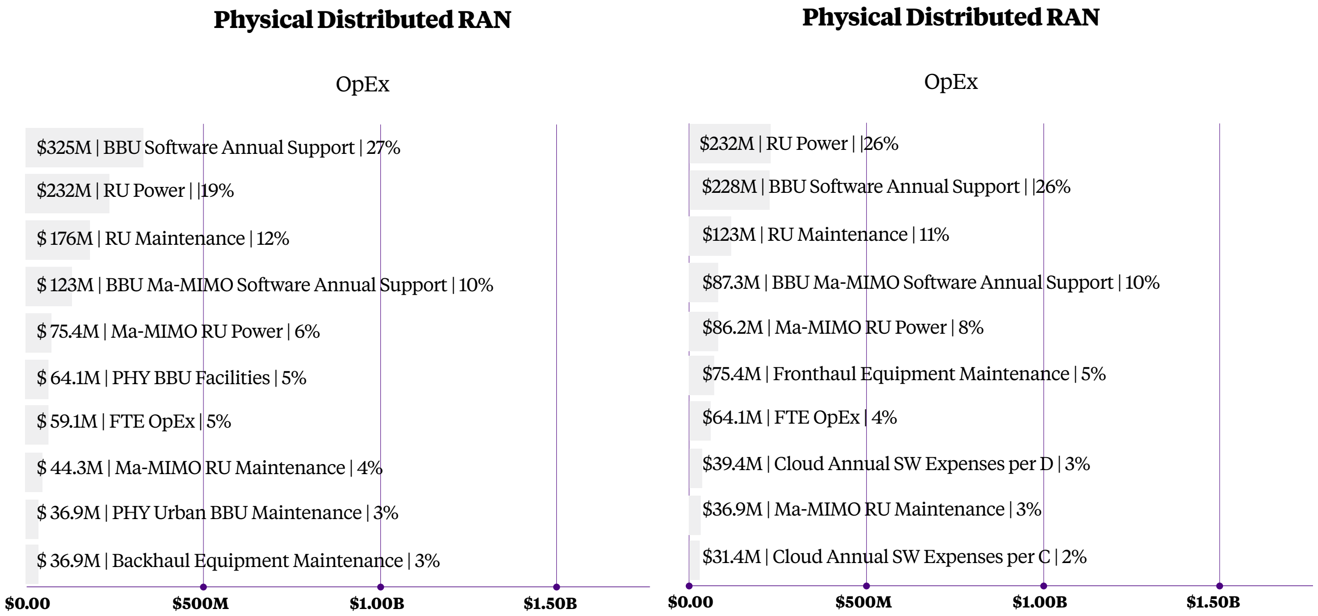


Figure 10. OpEx Breakdowns of PHY D-RAN and Open D-RAN Scenarios

Conclusion

Network operators are currently evaluating Open RAN technology through proof of concept lab work and planning early trials and deployments. There are many benefits they can factor into their plans using RAN virtualization, standard Intel x86 servers, and open RAN network architectures. The key benefits they can anticipate in those initiatives are summarized in Table 6.

Physical RAN	Open RAN
Proprietary systems are closed, and operators are dependent on a single vendor for a complete RAN solution.	Open RAN allows operators to mix and match products and software in an open ecosystem, providing more flexibility and more competition among vendors.
Proprietary radios are comparatively expensive because operators are dependent on procuring radios from a single vendor that makes a high margin selling radios.	Open radios can be manufactured by white-box vendors, which typically have lower margins. These vendors do not incur radio research and development expenses because radio designs are open and available to white-box vendors.
Proprietary BBU software is expensive because of the very nature of proprietary system designs and because operators are dependent on a single vendor of those designs for its software.	Open software will be less expensive because multiple vendors will be competing for the software opportunity and will be developing for openly specified hardware designs; consequently, an open source community will emerge over time.
Most physical RANs are distributed, and centralized physical RANs are more expensive to implement due to the proprietary nature of the hardware and software.	Centralized Open RAN has multiple CapEx and OpEx benefits that result from greater flexibility in DU/CU pooling and the spectral efficiencies they can achieve.

Table 6. Key Benefits of Open RAN

About the Author:

Peter Fetterolf has a multidisciplinary background in the networking industry with over thirty years of experience as a management consultant, entrepreneur, executive manager, and academic. He is experienced in economic modeling, business case analysis, engineering management, product definition, market validation, network design, and enterprise and service provider network strategy. Prior to joining ACG, Dr. Fetterolf worked at Cisco Systems building business case models for service providers. He has also had many other roles and positions in the networking industry. He was a managing partner at Network Strategy Partners, He was a Director of software engineering at Lucent, he was Co-founder and Vice President of Engineering at Ignitus Communications, he was a Director of Software Engineering at Cascade Communications, and was a management consultant at Arthur D. Little.

ACG Research provides in-depth research on ICT innovations and the transformations they create. The firm researches architecture and product developments in a range of ICT market segments. It highlights innovators, early adopters and their solutions in podcasts, webinars and a range of report and briefing formats. It does primary research on forces shaping the segments in which it is working and performs in-depth economic and business case analyses in the same. Its market forecast, outlook and market share reports are referenced widely by stakeholders in its target segments.