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EXPANDING 5G INDOOR CONNECTIVITY WITH OPEN RAN

White Paper

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Comba Telecom Limited

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EXECUTIVE SUMMARY

As operators enter the era of 5G and digitalization, the overall mobile network requirement to address the three 5G use case categories (eMBB, URLCC, eMTC) from the deployment and performance perspective will become increasingly demanding, particularly for Radio Access Network (RAN). The RAN needs to be transformed to become more software-driven and intelligent.

RAN components contribute approximately 70% of the total network deployment cost. 5G RAN is expected to cost much more than any of the predecessors because of larger network site density, higher energy consumption, higher capacity and bandwidth etc. Since the era of 4G, mobile data connection has become a daily necessity wherever we are including indoor environment. As a result, significant amount of investment has been spent on indoor infrastructure over the past 10 years. Moving forward, the top ten 5G indoor use cases may potentially open up a new revenue stream for MNO but also drive the capital expenditure (CAPEX) spending over the coming years. The return of investment in building the infrastructure may not be strong enough to make a good business case and mobile network operators (MNOs) may be hesitant to provide seamless indoor 5G coverage. Therefore, Open RAN solution has a strong value proposition which may potentially reduce the RAN CAPEX, and MNOs may eventually increase their profitability while actively building up a new 5G business model. In addition, the lower cost barrier will encourage more enterprise-led or private network deployment so that many enterprises from various industries can fully utilize 5G to improve their business and operation performance.

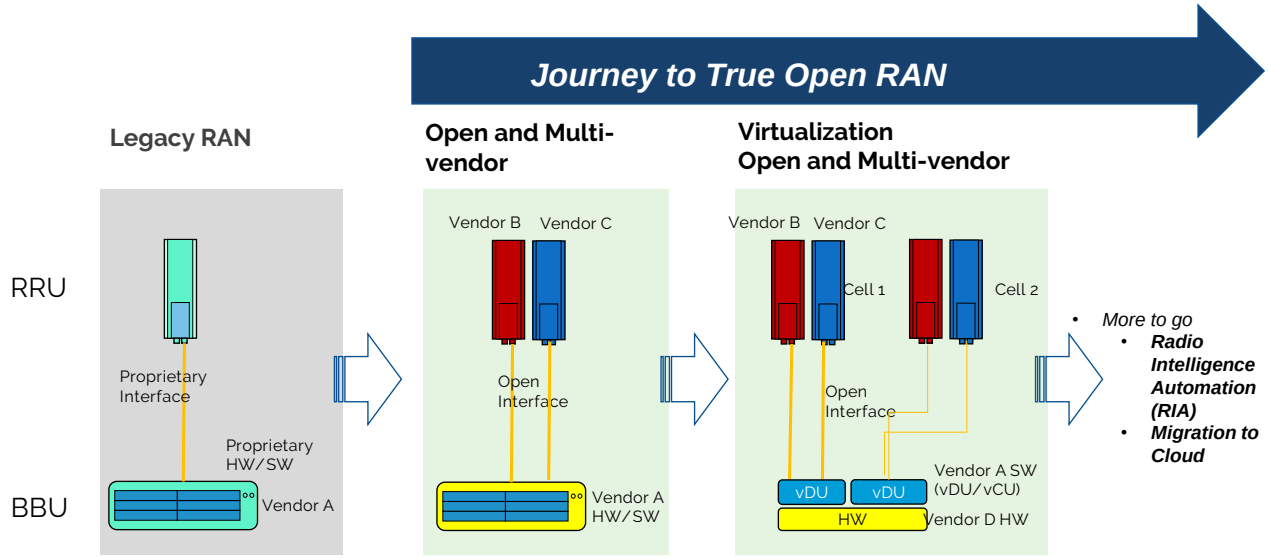
Open RAN has been viewed as the next generation RAN with the commitment of achieving open interface, multi-vendor interoperability, network scalability and built-in intelligence. With the concerted effort and support from software vendors, chip suppliers and MNOs, it is strongly believed that Open RAN technology will bring in innovation to enable network's CAPEX and OPEX saving in the long run. Since the foundation of ORAN Alliance and TIP, great progress has been observed in the development of the open interface specifications, ecosystem, network requirement, deployment use case etc. A great number of MNOs worldwide are showing much interest in Open RAN and they are seeking to evaluate this new RAN technology to modernize their networks and infrastructure. In the past two years, several brownfield MNOs have started trials and commercial pilots of Open RAN solution at a smaller scale. For instance, Vodafone has deployed Open RAN solutions from multiple vendors in UK, Ireland and Turkey. For the past 20 years, the RAN market has been dominated by a couple of incumbent vendors and the top 5 vendors have taken up more than 95% of the worldwide market share. However, this status quo may be disrupted very soon by new Open RAN players. Undoubtedly, Open RAN solutions will gain more traction in both Macro and Indoor deployment in the coming years.

This whitepaper will mainly discuss the role of Open RAN solution for indoor wireless connectivity and present a case study on the network CAPEX and OPEX saving by introducing Open RAN into the 5G NR roll out.

General Introduction – Why Open RAN?

Traditionally, a standalone base station is configured with both the radio and the baseband located at the same location for instance the bottom of a tower, or the rooftop of a building etc. Distributed Baseband unit (BBU) and Remote Radio Unit (RRU) were introduced around 2005 and are still widely adopted for a lot of 3G and 4G network deployments. Typically, RRU will be installed closer to the antenna or on top of the tower whereas BBU will be installed some distance away or in the equipment room on the ground. The interface between BBU and RRU is typically a proprietary CPRI interface and BBU and RRU are from a single vendor.

Figure: Evolution of RAN Architecture towards Disaggregation and Multi-Vendor



The very first target for Open RAN is to open up the fronthaul interface, ***to Increase RAN competitive landscape and build up bigger ecosystem and supply chain***

The first step of Open RAN is to open up the fronthaul interface and enable multi-vendor interoperability between BBU and RRU. As shown in the figure above, the architecture will be more flexible with the ability to mix and match multiple vendors to create the competition and encourage more innovation.

Since the 4G era, the supply chain for RAN equipment has been dominated by five major vendors, and for MNOs in countries which are restricting procurement from Chinese OEMs, they are left with only three choices. The situation has a negative impact on price competition and the vendors may not have enough pressure to create more innovative products and solutions. On the other hand, a bigger ecosystem with a multi-vendor scenario could encourage the vendors to stay focused in terms of resource and investment allocation. Baseband vendors could spend more efforts on developing RAN features and enhancing software to better position themselves ready for various scenarios, namely Cloud RAN, virtualized RAN or typical distributed RAN. Similarly, Radio manufacturers should further enhance and optimize advanced techniques over air interfaces like massive MIMO.

In the past, the fronthaul interface has always been proprietary and based on the sort of split option 8. To enhance the CAPEX and OPEX saving, RAN architecture can be disaggregated, for instance, deploy baseband in a more centralized location and only Radio unit installed at the site but a reliable transport network is required between BBU and Radio. Various studies and analysis have shown that split option 7-2 will be the better candidate to achieve the balance between

the complexity of RRU hardware and the fronthaul transport requirement. Hence, the move to open and define the fronthaul specifications for 7-2 option is seen as a big step to kick start the open RAN.

5G will be the catalyst *as ultimately MNOs want to maintain their leadership in delivering 5G connectivity profitably, hence* ***improved network performance and Total Cost of Ownership (TCO) benefit must be proven to drive Open RAN development and deployment in the long run***

5G network may look similar to its predecessor but there are quite a number of major differences. Firstly, 5G network is required not only to serve end consumers but also to address many diverse applications such as autonomous car, smart city, telesurgery, connected drone etc. 5G network architecture has to be more flexible and scalable than 3G and 4G network as 5G services based on mMTC, URLLC, FWA will generate unique traffic patterns compared to typical mobile data service. MNOs has to build a network with agility to timely meet the network requirement without much delay. In the past, a simple site expansion may take a couple of months which involve site survey, equipment lead time, commissioning and so on. Virtualization can play a crucial role in the migration of RAN functions from dedicated hardware to software components. Open RAN together with virtualization could shorten the time taken for site expansion or virtually moving the baseband resource here and there wherever it is needed. From a hardware perspective, the COTS server will have a shorter lead time compared to customized BBU whereas Radio hardware could be sourced from many suppliers thanks to the open interface.

On the other hand, a true open RAN should deliver a better network performance. For example, both the UPF (user plane function in packet core) and the user plane of central unit (CU) can be virtualized and be located at site to significantly improve the latency performance and enable URLCC application. Furthermore, user experience will greatly improve as the occurrence of network congestion issue will be reduced thanks to the network function virtualization.

The investment to put up nationwide 5G connectivity similar to the legacy 4G network is expected to be much larger. MNOs have been exploring the alternative like Open RAN to justify the return on investment (ROI). According to Rethink Research whitepaper titled *"Without Automation, 5G Networks will not Achieve Profitability"*, the expected cost reductions achievable with Open RAN architectures include a fall in Total Cost of Ownership (TCO) of about 34.5% compared to a traditional RAN, and reductions up to 40% in CAPEX and 33.5% in OPEX. A larger ecosystem with higher price competition may help to reduce the equipment cost. On top of a cheaper COTS server, a virtualized baseband unit (vBBU) at a centralized location can reduce the hardware footprint and effectively achieve optimal resource pooling for TCO savings. In the long run, open architectures in RAN could bring in large saving for both the CAPEX and OPEX though the cost of integration among various sub-system components is expected to be high at the initial roll out.

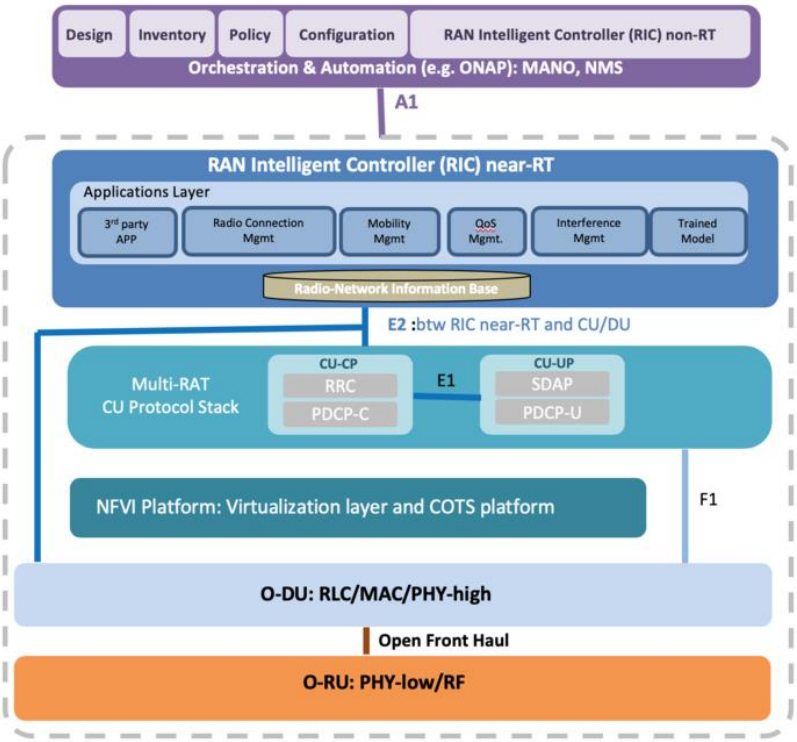
A True Open RAN – ***Open, Intelligent, Virtualized and Fully Interoperable RAN****, to achieve better network performance and higher cost efficiency*

Openness and multi-vendor interoperability are only part of the transformation towards the true Open RAN. There are more efforts to complete the job and virtualization is one of the key components to be integrated into RAN. Both central unit (CU) and distributed unit (DU) can be virtualized on COTS server for scalability and flexibility. Each vCU (virtual CU) or vDU (virtual DU) can have its own size to target different scenarios or use cases. For vCU, dimensioning for control and user plane traffic can be independently carried out to maximize resource usage efficiency, for instance, the control plane or signaling traffic pattern will change significantly if a heavy number of IoT devices are deployed in a particular coverage area. Likewise, vDU components can be scaled in and out whenever necessary.

In addition, intelligent RAN or RAN Intelligent Controller (RIC) with the capability to enable automation will be the last step of transformation but may be the most challenging task and continuous effort is required to make the network stay intelligent. The real gain in the long run will be tremendous and new business cases may emerge.

There are many different reasons why the whole industry is working hard and collaborating closely to push Open RAN deployment, in a nutshell, Open RAN will benefit various market players in expanding the ecosystem, stimulating innovations, improving network performance and reducing the TCO in the long run.

Figure: O-RAN Architecture



Source: ORAN Alliance

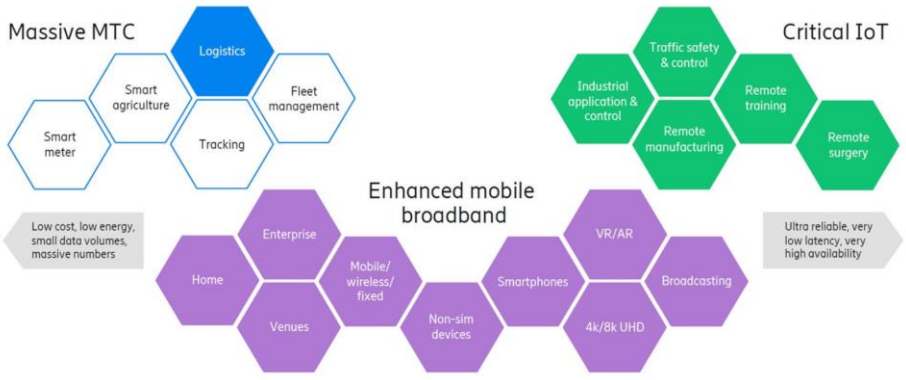
EXPAND INBUILDING COVERAGE WITH OPEN RAN

Investment in 5G Indoor infrastructure is a must *to capture the existing eMBB market and potentially generate* ***new business cases*** *for vertical industry and enterprise markets. An Open and virtualized RAN is required to deliver the promised network performance (Low Latency and High Capacity)*

Over the last decade, thanks to the continuous investment in inbuilding network infrastructure, people could enjoy good mobile connections in many venues such as shopping mall, stadium, metro station, airport, office tower etc. Predominantly, MNO is the single paymaster for the inbuilding infrastructure including RAN equipment, transmission network and passive infrastructure. User traffic is used to be the main justification for the investment, while the regulator's requirement and marketing event trigger could be other supplemental reasons. In reality, the return on investment (ROI) especially for inbuilding infrastructure is getting harder to justify when the consumer market's mobile subscription in many regions is mostly saturated. How to expand indoor coverage to cater for 5G use cases in a profitable way is really a big question to either MNO or neutral host.

eMBB or consumer market will remain the main contributor to MNOs' mobile revenue while going into an early 5G roll out. Based on a widely cited statistic, around 80% of all mobile data traffic is consumed indoors and this figure may continue to increase in the future. Moving forward, 5G use cases generally can be divided into three primary categories, where subsets representing relevant indoors are filled with color in the figure below. 5G indoors will usher in the possibilities of home VR, holographic communication and HD mobile office services in driving potential user demands. Besides, cloud VR live broadcasting of games and concerts delivers an immersive and near-real-life experience for indoor users.

Figure: 5G use cases with relevant indoors



Source: Ericsson

Many 5G indoor use cases like smart manufacturing or industrial IoT, virtual and augmented realitycould potentially generate new business models and revenue opportunities for MNOs, hence indoor 5G infrastructure could be monetized. In order to enable 5G mobile broadband use cases, certain conditions such as wide channel bandwidths (up to 100 MHz) and good indoor coverage must be present. Therefore, it is inevitable to expand network coverage in the building or venue by putting up the infrastructure.

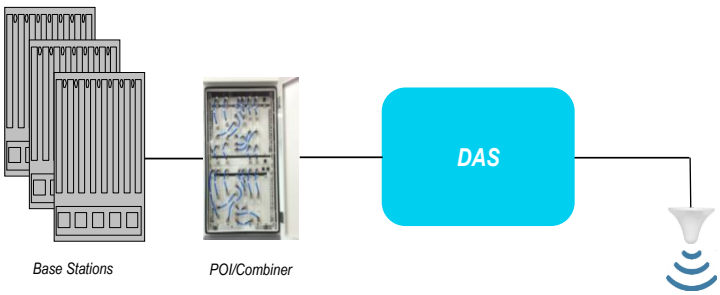
Unlike the legacy 4G system, 5G is gaining transformational power and makes good on its revolutionary promise with a brand-new core network and RAN to carry an ultra-reliable low-latency communications (URLLC) services which current infrastructure cannot support. For industrial automation happened indoors, use cases involve communication transfers

enabling time-critical factory automation that is required in many industries across a wide spectrum. To enable these applications, an end-to-end latency lower than 0.5ms and exceedingly high reliability with BLER of 10-9 is required. The enterprise market specifically the industrial 4.0 use cases will be expected to grow significantly later on to create new revenue streams for mobile operators, vendors as well as system integrators. In some regions or countries like Germany and the UK, the regulator has taken initiative to reserve a certain spectrum for enterprise or private network deployment. The availability of the spectrum is the key to encourage more participation of small player and drive more enterprise deployment, eventually should benefit various vertical industries. Current network architecture including RAN should be transformed to meet the enterprise environment in different industries. Open RAN solution together with virtualization technique will be better positioned to fit into this market segment.

Return On Investment (ROI) for providing seamless indoor 5G coverage must be justifiable *to support higher frequency band deployment****. Indoor Open RAN solution*** *favoring multi-operator sharing will be the best option*

Since the 4G era, macro sites on the mid-band (Band 1, 3 and 7) will find it hard to reach inbuilding users, let alone the higher frequency band (n78 band) as widely adopted for 5G. Besides, the network performance requirement is much higher in order to deliver the 5G use cases as discussed previously. The current indoor solution leader, Distributed Antenna System (DAS), is almost certainly not a viable option for a 5G indoor solution under many circumstances. As shown in the figure below, a DAS is constructed with passive components like splitter, coupler, coaxial cable and antenna. The architecture works well with a legacy system but lacks of flexibility and scalability. The network performance may get degraded due to Passive Intermodulation (PIM) when multi-operator and multi-system (legacy and 5G system) are carried simultaneously in the DAS. From a commercial perspective, the advantage of being cost effective diminishes when a lot more antennas are required to provide 5G indoor coverage on high frequency band.

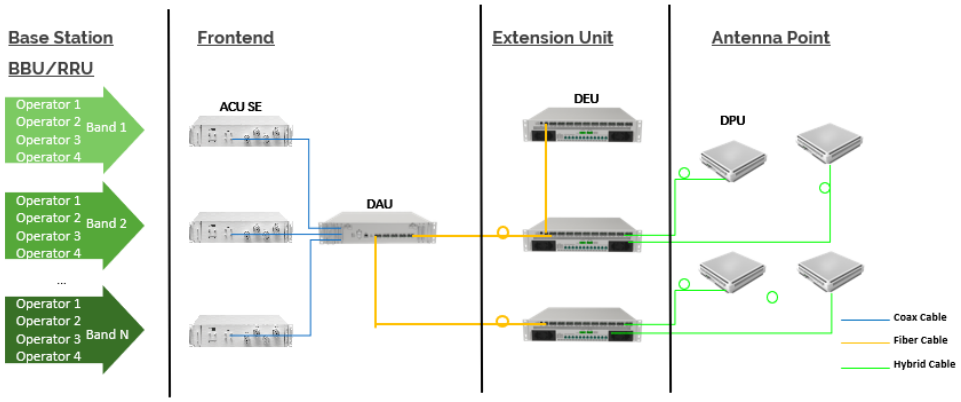
Figure: Simplified Passive DAS Architecture



As a result, an active solution consists of active headend unit, fiber transmission, active antenna will have the opportunity to stand out as the leading option for 5G indoor coverage roll out. The active solution has the advantage of providing consistent coverage performance, end-to-end monitoring capability and configuration flexibility and scalability. The major reason why it doesn't really compete with DAS for the roll out in the past is that the upfront cost in terms of active equipment or hardware is higher. However, the gap in the cost difference between DAS and active solution will close eventually when a large scale of 5G indoor deployment adopts an active solution.

The existing active solution will still require an RF input signal from the base station or RRU. However, by opening up the fronthaul interface, it is possible to bypass the RRU and connect the indoor infrastructure directly to the BBU, hence overall CAPEX and OPEX could be reduced significantly. Furthermore, with the capability of supporting multi-operator and multi-system, Open RAN provides a viable option for MNOs to expand indoor coverage in a more cost-effective manner.

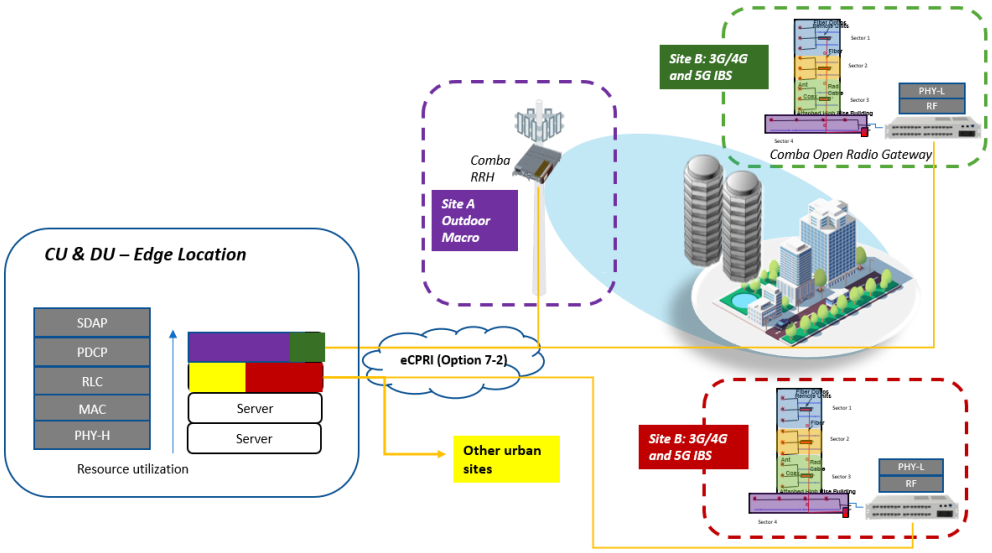
Figure: Typical Indoor Active Solution Architecture



Indoor RAN network and infrastructure requires optimization to increase cost efficiency. Existing challenges such as ***cell resource underutilization, high indoor site acquisition cost and high energy consumption*** *could be addressed by applying Open RAN*

For urban scenarios, it is common to have many macro and inbuilding sites to provide seamless connectivity. Most of the cell site traffic loading is changing all the time across the day, while some hours it spikes up and remains low for other hours. The trend for the inbuilding cell and macro cell may be very different, for instance, indoor traffic can be relatively high during lunch hour. Thanks to the large availability of fiber networks, centralized RAN deployment will be possible to meet the required fronthaul bandwidth and latency. For instance, having the CU/DU located at the edge location connecting multiple macro and indoor cells as shown in the figure below, resource utilization can be maximized to enable CAPEX saving.

Figure: Open RAN enables resource sharing among macro and inbuilding cell sites

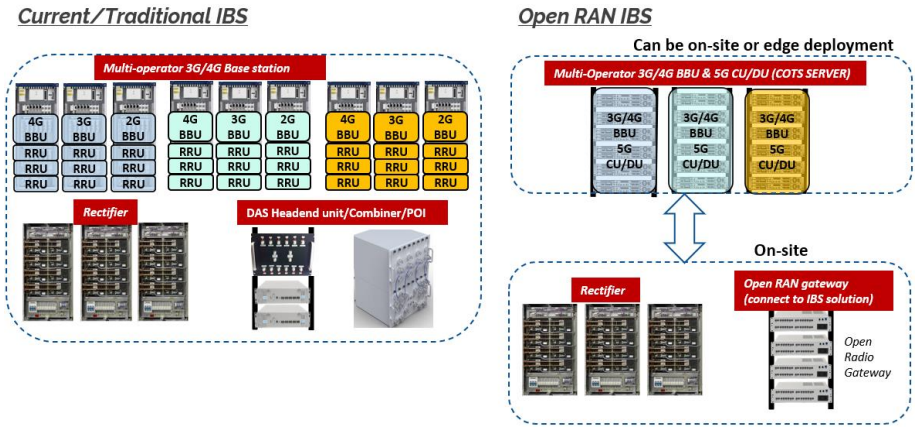


Opening up the fronthaul interface between BBU and RRU can reduce the overhead of RRU equipment. A fronthaul gateway supporting 7-2 split option can connect the inbuilding infrastructure directly to BBU or DU. The onsite equipment footprint can be greatly reduced as compared to the traditional inbuilding equipment room where many 19-inch racks or cabinets are installed to house multiple system BBU and multiple band RRU. On the other hand, power

consumption will be much lower after getting rid of multiple high power RRU. A case study is created in the next Chapter to further analyze the savings.

It is foreseeable that Open RAN inbuilding solution will be the first deployed in venues located in urban or city areas whereby cost saving and performance improvement can be maximized while reusing the existing fiber network without too much major investment.

Figure: Open RAN enables smaller equipment footprint

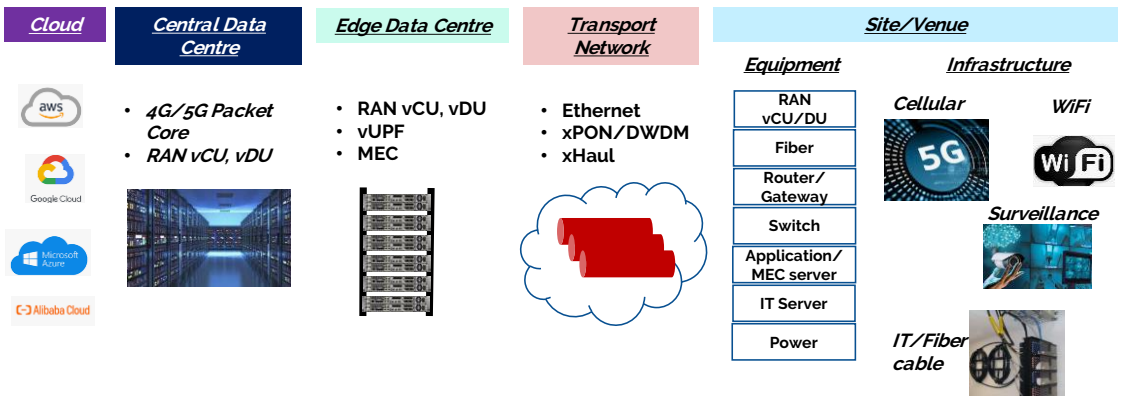


*Open RAN with disaggregation and virtualization could encourage **new inbuilding coverage deployment model** and stimulate innovation and competition*

The existing inbuilding deployment model is predominantly led by MNOs. MNOs basically will be the owner of the infrastructure and system integrators will be employed to carry out installation, testing and commissioning. In some of the regions, a neutral host model is common as well. The neutral host company will own, build and maintain the inbuilding infrastructure. MNO could rent the infrastructure to provide mobile services at a particular venue.

In the future, multi-vendor Open RAN architecture may drive more changes and transformations from an implementation perspective. More players will come into the play on building RAN access and infrastructure whereas MNOs will shift their focus to services and application development. For example, the host company may take up more responsibilities such as hosting the RAN sharing model by deploying CU on the cloud and DU/RRU on the site, and even build and manage transport network and data centers.

Figure: End-to-end Cloud Native Network Architecture

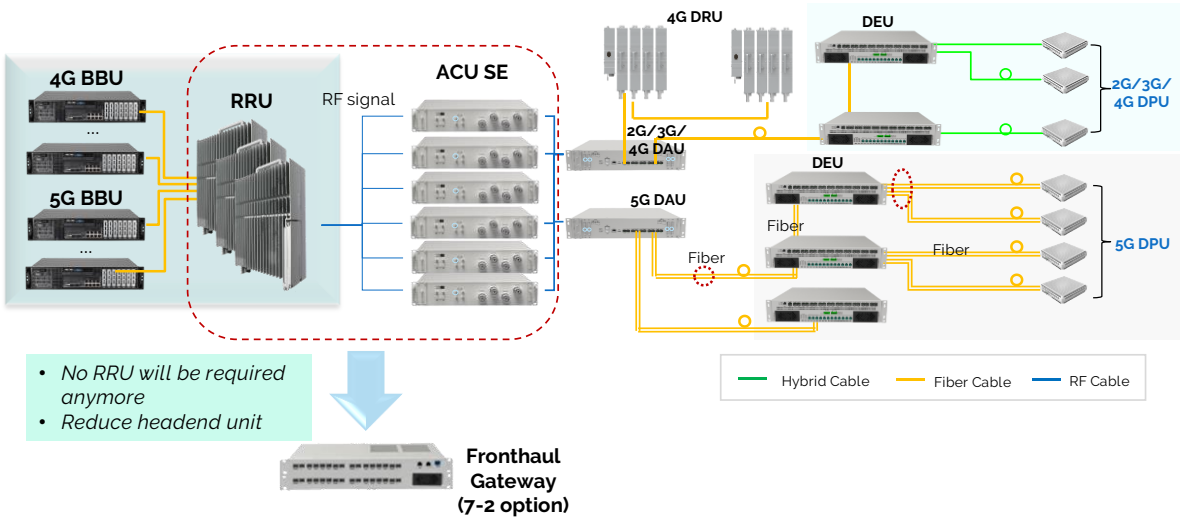


THE BENEFIT – CAPEX AND OPEX SAVING

Having discussed the drivers and the benefits for bringing Open RAN into the inbuilding coverage roll out in the last chapter, a case study with a couple of different scenarios is created and analyzed to drill down into the real benefit in terms of the CAPEX and OPEX saving in this Chapter.

With the introduction of Open RAN, the fronthaul interface will be opened up, and it is possible to remove the need of the RRU and reduce the headend unit as shown in the figure below.

Figure: Open RAN Inbuilding Network Architecture



From a typical cell site's CAPEX perspective, RAN equipment and inbuilding infrastructure cost will be relatively larger components out of the total deployment cost. Three typical scenarios to address different sizes of the venues are considered in this study.

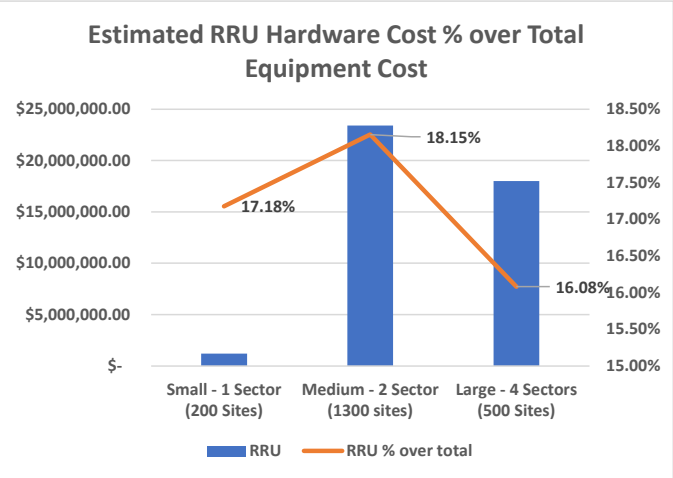
	Site Count	2G/3G/4G Site Configuration	Capacity
Small	200	Dual-Band	1 Sector
Medium	1300	Tri-band	2 Sectors
Large	500	Tri-band	4 Sectors

Note: The inbuilding infrastructure is assumed to be shared by three MNOs

Large venues such as airport, stadium and metro station will typically require multi-band and multi-sectors configuration to accommodate huge crowds. Medium venues referring to shopping mall, office tower, etc., and small venues including shop houses, residential, and the likes. To provide an overview on the network level, 2,000 inbuilding cell sites with the distribution of 200 small sites, ,1300 medium sites and 500 large sites are taken into the study.

Based on the total 2,000 cell sites, the overall saving would be close to ~USD $42 million. The cost of the RRU alone will be around 16%~18% of the total RAN equipment and infrastructure hardware cost. In other words, this component could be removed from the CAPEX by introducing an Open RAN inbuilding solution.

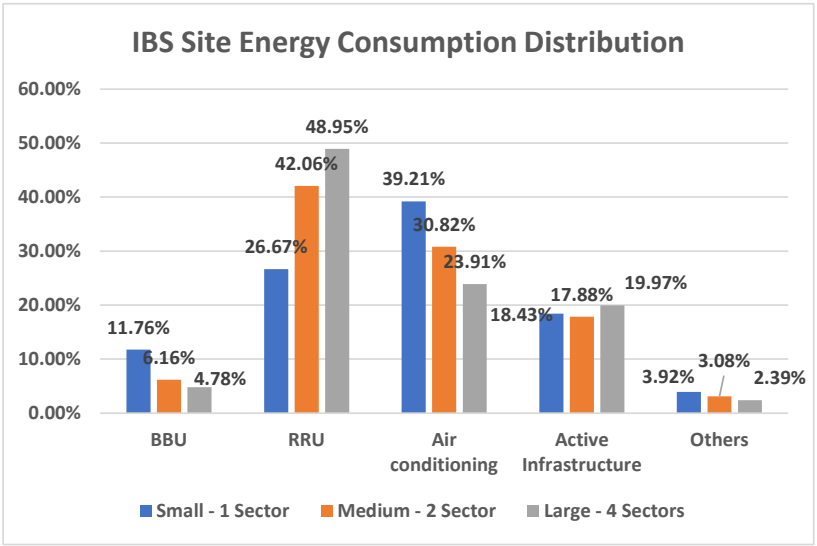
Figure: The CAPEX saving from removing the RRU



MNOs have been spending big on energy, the total energy bill is expected to grow significantly in the 5G era. RRU alone will consume around 25% ~ 50% of the total site power consumption.

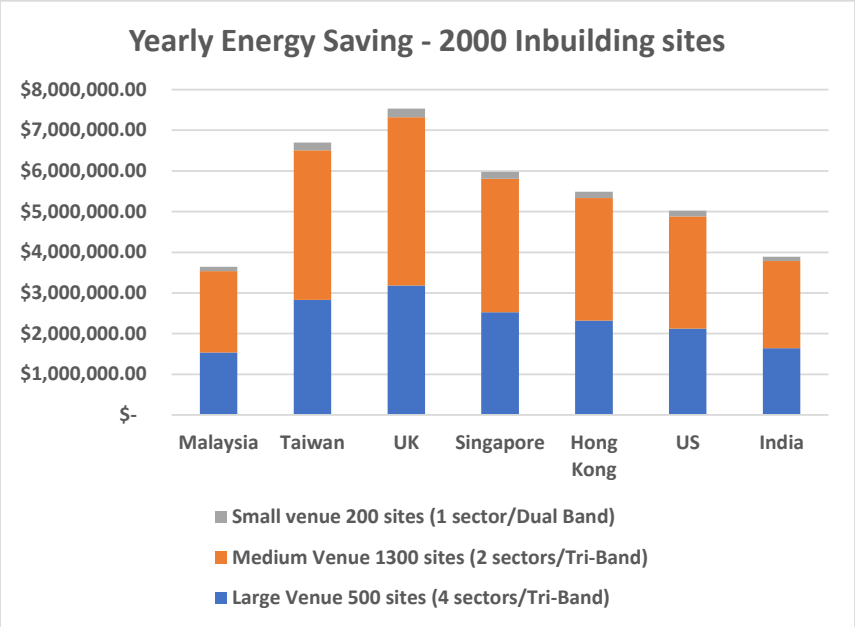
Since the inception of the 4G network, the overall energy consumption due to network densification together with capacity expansion has accelerated. Particularly the radio access network (RAN) has been the bigger contributor with more macro and inbuilding sites being integrated into the network. From an inbuilding site perspective, as shown in the figure below, the energy consumption by RRU will take up from 26% to 49% depending on the site configuration. The figure could go higher if considering more bands or a system configured and higher output power RRU for 5G.

Figure: Inbuilding Site Energy Consumption Distribution



Considering a network with 2,000 inbuilding cell sites in this study, the total achievable annual energy saving by removing RRU will be approximately USD$ 3 million to USD$ 7 million which varies with the tariff plan of each region.

Figure: Total Yearly Energy Saving per Region



In summary, opening up the fronthaul interface alone will reduce TCO significantly for 5G indoor roll out. Looking forward, it can be envisaged that Open RAN solution can be enhanced to bring in virtualization and eventually migrated to the cloud. In the long run, a lot of savings will be realized and it is not a dream to have 5G coverage everywhere even on the high frequency band such as mmWave.

Conclusion

Inbuilding wireless connectivity is getting more critical in the sense that more applications and use cases which require really high throughput and low latency performance will come available in the market place for either public consumers or enterprise users. MNOs have to invest in the infrastructure; however, the greatest concern is still the declining ARPU or total mobile revenue and the initial 5G roll out may not help to boost the ARPU for the consumer market. Even so, vertical industry or enterprise who may benefit from 5G connectivity will very soon contribute substantially to the MNO's revenue. To meet the enterprises' expectations, new network architecture and innovative solutions will be required. A true Open RAN with 5G capability will be able to construct a high performance, flexible and scalable wireless connectivity for the enterprises.

It is certainly no doubt that Open RAN will happen to be part of the 5G mobile network architecture. It is conceivable that Open RAN solutions for inbuilding coverage roll out particularly for 5G will start later but move faster than macro deployment. In reality, the level of collective support from various market players as well as government or authority is an important factor to determine the scale and speed of the deployment.

About Comba Telecom

Comba Telecom is a leading supplier of infrastructure and wireless enhancement solutions to mobile operators and enterprises to enhance and extend their wireless communications networks. With over 50,000 system deployments around the world including turnkey in-building systems, urban/rural wireless systems, and transport wireless networks, Comba Telecom's end-to-end network solutions include consultation, network design, optimization and commissioning.

Comba Telecom's product portfolio includes DAS, small cells, tower mounted systems, antennas, subsystems, passive accessories, Wi-Fi systems and digital microwave links.

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