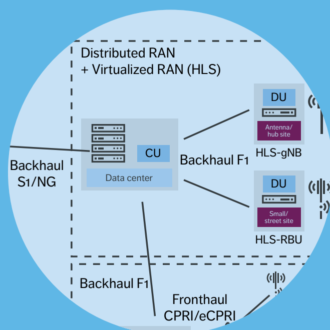
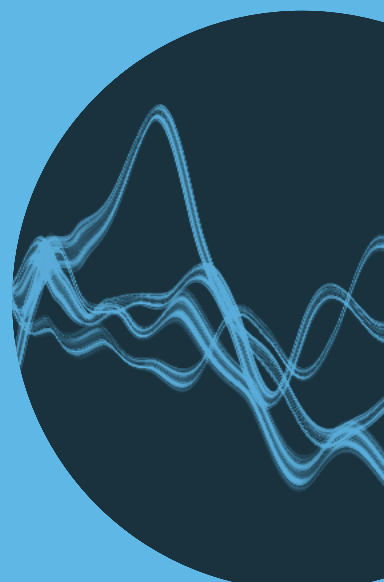
CHARTING THE FUTURE OF INNOVATION | #10 · 2019

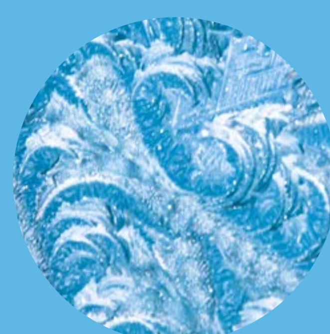
Review

ERICSSON TECHNOLOGY





5G NEW RADIO RAN & TRANSPORT OPTIONS



ERICSSON

5G New Radio RAN & transport

CHOICES THAT MINIMIZE TCO

By deploying self-built transport in the RAN area instead of using leased lines, mobile network operators gain access to the full range of 5G New Radio RAN architecture options and minimize their total cost of ownership (TCO).

ANN-CHRISTINE ERIKSSON,
MATS FORSMAN,
HENRIK RONKAINEN,
PER WILLARS,
CHRISTER ÖSTBERG

The 5G evolution is well underway – leading mobile network operators (MNOs) in several regions of the world have already launched the first commercial 5G NR networks, and large-scale deployments are expected in the years ahead. The use of self-built transport in denser areas with a suitable RAN architecture will play a key role in ensuring cost-efficiency.

A cost-efficient 5G NR deployment requires MNOs to take several factors into consideration. Most obviously, they need to make sure that the 5G NR deployment complements their existing 4G LTE network and makes use of both current 4G LTE and new 5G NR spectrum assets. Beyond that, it is vital to consider the various RAN architecture options available and the ways in which the transport network needs to evolve to support them, along with the large increase in user data rates per site.

While urban areas with high user density will be the first priority for 5G NR deployments, suburban and rural areas will not be far behind. These three area types have different preconditions such as available transport solutions, inter-site distance (ISD), traffic demand and spectrum needs that must be taken into consideration at an early stage in the deployment process.

Predicted 5G traffic

5G is projected to reach 40 percent population coverage and 1.9 billion subscriptions by 2024 [1], corresponding to 20 percent of all mobile subscriptions. Those figures indicate that it will be the fastest global rollout so far. The total mobile data traffic generated by smartphones is currently about 90 percent and is estimated to reach 95 percent by the end of 2024. With the continued growth of smartphone usage, total worldwide mobile data traffic is predicted to reach about 130 exabytes per month – four times higher than the corresponding figure for 2019 – and 35 percent of this traffic will be carried by 5G NR networks.

The growing data demands for mobile broadband can generally be met with limited site densification [2]. There are benefits to deploying 5G NR mid-bands (3-6GHz) at existing 4G sites, resulting in a significant performance boost and maximal reuse of site infrastructure investments. By means of massive MIMO (multiple-input, multiple-output) techniques, such as beamforming and multi-user MIMO, higher downlink capacity can be achieved along with improved downlink data rates – both outdoors and indoors.

Deep indoor coverage is maintained through interworking with LTE and/or NR on low bands using dual connectivity or carrier aggregation. Further speed and capacity increases can be attained by deploying 5G NR at high bands (26-40GHz), also known as mmWave. If additional spectrum does not satisfy the traffic demand (due to, for example, the introduction of fixed wireless access) densification with solutions such as street sites may be required.

Increasing user data rates per antenna site

The introduction of new spectrum for 5G NR will increase the carrier bandwidths from the 5MHz, 10MHz and 20MHz used for LTE to 50MHz and 100MHz for the mid bands (3-6GHz) and 400/800MHz for the high bands (24-40GHz), allowing for gigabit-per-second data rates per user equipment (UE). In urban areas, the total amount of spectrum will grow from a few tens or hundreds of megahertz to several hundred or thousand megahertz per antenna site.

Simultaneously, traffic demands per subscriber will increase exponentially. All in all, this implies that the bitrate demands in the backhaul and fronthaul transport network will increase significantly (per antenna site, for example). The bitrate demand will be multiple gigabits per second, compared with the few hundred megabits per second in current mobile networks.

The spectrum increase per antenna site will be less in suburban areas, while in rural areas refarming of current spectrum or spectrum sharing between LTE and NR will be more common. RAN transport networks will need to evolve to address the increase in accumulated user data rates, particularly in urban areas, and in many suburban ones as well.

Transport network options

Evolving the transport network in the local RAN area is an important first step when deploying 5G on top of LTE.

In most cases, the mobile backhaul transport for Distributed RAN (DRAN) – the architecture traditionally used to build mobile networks – has been a rented packet-forwarding service, Ethernet or IP based, typically called a leased line and provided by traditional fixed network operators. Another option is white fiber, an optical wavelength service offered by many traditional fixed network operators.

Instead of leasing a transport service, some mobile operators deploy self-built transport solutions using microwave links, which usually enables short installation lead time. Integrated Access and Backhaul (IAB) is another option for self-built transport in 5G. With IAB, the mobile spectrum is also used for backhaul, which is especially relevant for high-frequency bands where the bandwidth may be hundreds of megahertz.

Alternatively, it is possible for a mobile operator to deploy a self-built transport solution on top of physical fiber (known as dark fiber) that is available for rent from fixed network operators, or more recently from pure fiber network operators and municipal networks. The mobile operator then builds and owns the transport equipment in a RAN area, defined as the local urban area in a city and the suburban areas close to cities.

Urban areas tend to have multiple fiber network operators that deploy fiber to every street, which means that dark fiber is readily available for rent. While dark fiber is less common in suburban areas,

> “TRAFFIC DEMANDS PER SUBSCRIBER WILL INCREASE EXPONENTIALLY”

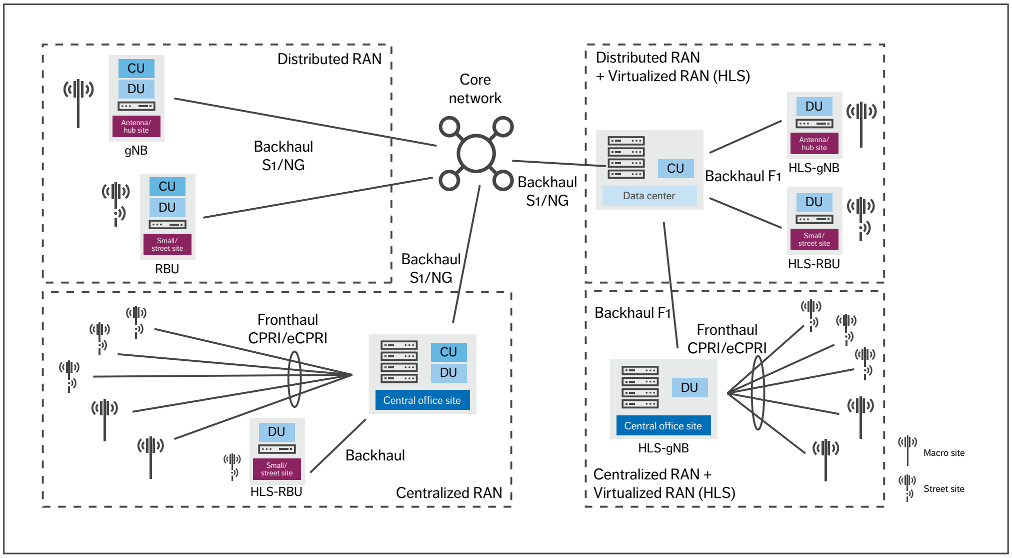


Figure 1 RAN architecture deployment options

its availability is steadily increasing. In rural areas, there is often only one fiber operator, and fiber is only deployed to specific sites such as businesses and schools. In these cases, dark fiber is usually not provided as a service.

On top of dark fiber, mobile operators can deploy an optical (passive or active) or a packet-forwarding solution. The passive optical solution uses colored small form-factor pluggable transceivers (SFPs) in the endpoints and optical filters in between for add/drop to subtended sites/equipment along the fiber path. An active optical system uses gray SFPs in the endpoints and active optical switching equipment to generate wavelengths and perform optical switching on the sites/equipment on the fiber. The packet-forwarding solution can be an Ethernet or IP solution with packet-forwarding capabilities on all sites/equipment along the fiber path.

RAN architecture options

Figure 1 illustrates DRAN along with the other RAN architecture options available for use in 5G NR. The option that is most appropriate for a particular deployment will largely depend on the type of deployment area (urban, suburban or rural) and the availability of dark fiber.

In all options, outdoor site deployments can be either macro sites (typically mounted on rooftops or antenna masts covering a larger area) or street sites (typically mounted on poles, walls or strands covering smaller areas or spots).

The flexibility of locating RAN functionality in different locations in 5G NR RAN architecture and the ability to support more radio sites increases the need for network automation, making it necessary to simplify the installation, deployment and operation of both the RAN and transport pieces. For example, the automation capabilities used to simplify installation in the RAN must also be introduced into transport to improve the interaction between the two.

Distributed RAN

DRAN with unitary eNodeB base stations has been the dominant architecture for 4G LTE. DRAN will also be a commonly used architecture in 5G NR deployments, with the benefit of reusing the legacy

> THE USE OF DARK FIBER IS A GOOD FIT WITH THE NEW WIDE NR FREQUENCY BANDS...

infrastructure investments. The backhaul – that is, the transport between the RAN and the core network (CN) – uses an S1/NG interface [3].

DRAN is well suited for use in all areas (urban, suburban and rural) and can use a large variety of transport solutions. DRAN reuses legacy infrastructure investments, such as existing sites and operations and maintenance structure, and is of particular value in areas where the population density is low and the users are scattered. The utilization of statistical variations in traffic for the dimensioning of self-built packet transport in the RAN area transport network is another benefit of DRAN.

Where densification is needed for coverage or capacity, DRAN street sites fit well together with the existing DRAN macro sites. Specific DRAN units tailored for street sites, denoted as RBU in Figure 1, have benefits such as integrated baseband functions, simple installation and reduced street site space.

Centralized RAN

Centralized RAN (CRAN) is characterized by centralized baseband for multiple pieces of radio equipment. With a CRAN deployment, the baseband units located in a central site and the radio equipment located at the antenna sites are interconnected with a transport network denominated fronthaul, either Common Public Radio Interface (CPRI) or evolved CPRI (eCPRI) [4].

In areas with small ISDs and access to dark fiber (urban and in some cases dense suburban areas), centralizing and pooling the baseband units to an aggregation site can be a good option. The use of CRAN can lead to reduced costs for site space and energy consumption at the antenna sites, as well as easier installation, operation and maintenance.

CRAN provides efficient coordination (via interband carrier aggregation and CoMP – coordinated multipoint – for example) between physically separated antenna sites. It also enables dimensioning of a baseband pool to handle more and larger antenna sites due to statistical variations of traffic per site, which also makes baseband resource expansion easier when traffic grows in the CRAN area. Resilience and energy efficiency are other benefits, as the baseband pool serves many antenna sites. The statistical variation of traffic per site may also be utilized in RAN area transport network dimensioning.

In environments where CRAN is deployed, a dark fiber transport solution is required for the fronthaul. The connected radio sites also need to be within the latency limit required by the baseband units. The use of dark fiber is a good fit with the new wide NR frequency bands and the expansion of the fronthaul due to the use of advanced antenna systems [5].

When deploying CRAN, it is most beneficial to connect sites in the same area to the same baseband pool. In cases where it is difficult to deploy a dark fiber transport solution, either a DRAN or a high-layer split virtualized RAN (HLS-VRAN) architecture may be deployed for those sites, coexisting with other CRAN-connected nodes.

To achieve the benefits of statistical multiplexing of traffic to/from the radio equipment in the transport network and in the baseband pool, it is necessary to use an Ethernet-based fronthaul such as eCPRI [4]. The radio equipment at the antenna sites may either have support for eCPRI or include a converter from CPRI to eCPRI. It is also possible to mix eCPRI and CPRI radio equipment, using an optical fronthaul transport solution, but without transport multiplexing gains.

CRAN requires suitable sites (such as central office sites) to colocate the baseband units. The size and density of these central office sites depends on each situation, but a typical case could be central office sites with an ISD of less than 1km up to a few kilometers in an area.

Higher-layer split applied as a virtualized RAN deployment

For both DRAN and CRAN, it is possible to add a VRAN by implementing an HLS where the gNB

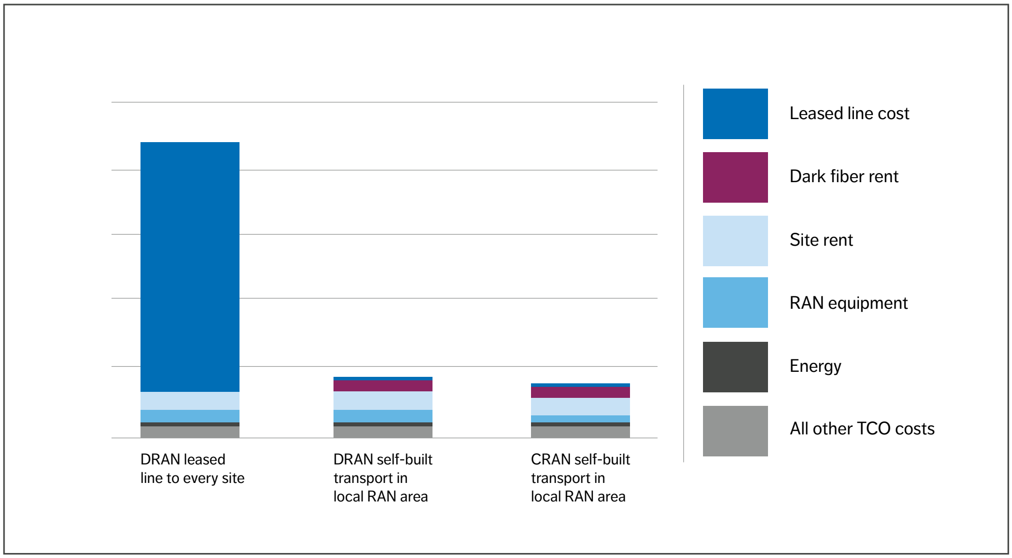


Figure 2 Relative operator TCO for 5G NR introduction in an urban local RAN area

is divided into a central unit (CU) and distributed units (DUs). This is known as HLS-VRAN. The DUs and the CU are separated by the F1 interface, carried on a backhaul transport network. These are denoted HLS-gNB for macro and HLS-RBU for street sites in Figure 1.

When a cloud infrastructure already exists in the network, the HLS-VRAN deployment may be beneficial from an operational and management point of view. For a DRAN deployment, adding HLS-VRAN could result in dual connectivity gains if it is expected that it will be common for UEs to be connected to different baseband sites.

In areas where a street site deployment is needed as a coverage or capacity complement to the macro site deployment, a street HLS-VRAN deployment fits well with macro HLS-VRAN. Specific HLS-VRAN units tailored for street sites, denoted as HLS-RBU in Figure 1, have the same benefits as the RBU.

5G New Radio total cost of ownership

A mobile operator's TCO for 5G NR introduction in a RAN area includes both capital expenses (one-time costs) and operating expenses (recurring costs). Typical capital expenses include radio/RAN and transport equipment, site construction, installation costs and site acquisition. Typical operating expenses include costs for a leased line, dark fiber rental, spectrum for wireless transport, site rental, energy consumption, operation and maintenance costs and vendor support. Since the RAN area type and deployment solution alternatives affect the TCO, it is useful to compare the TCO of the deployment solution alternatives in different RAN areas.

Based on Ericsson customer price information and internal analysis, *Figure 2* presents the relative operator TCO covering all capital expenses and operating expenses for an urban local RAN area in a high-cost market. Different regions and customers have variations in cost structure. Local deviations can be significant, leading to reduced differences but with the same relation in the relative cost structures. The largest cost components are transport rent cost, site rental, energy consumption and radio/RAN equipment. The graph indicates that using self-built transport in the local RAN area is a much more cost-efficient approach than using a leased line to every site, both in DRAN and CRAN architectures. The cost difference is especially large in high-cost markets.

The reason for this is that the introduction of 5G NR significantly increases the radio bandwidth compared with previous generations, which results in increased transport bitrate demands. While typical transport bandwidth to a radio site ranged from 10s to 100s of Mbps in 2G-4G, it is typically up to multiple gigabits per second in 5G. In the lower range of the bandwidth scale, the traditional leased line cost has been manageable. But at sites where the required transport bitrate reaches gigabits-per-second rates, the relative cost for the leased line increases dramatically, accounting for as much as 70-80 percent of the RAN area TCO.

The second largest cost in the "DRAN with leased line to every site" example (and the largest in the other two examples) is site rental. Some scenarios will require densification with new sites, which could be a mix of both macro sites and smaller site types (street sites). However, network densification is likely to face challenges due to the high cost of site rental and limited site availability.

> “USING SELF-BUILT TRANSPORT IN THE LOCAL RAN AREA IS A MUCH MORE COST-EFFICIENT APPROACH”

There are, however, ongoing discussions in several regions about regulating the high site rental fee for antenna sites, which would significantly increase the opportunity to densify with new sites. The clear trend of tower companies taking over the operation of physical sites and offering site sharing may also decrease site rent cost.

RAN equipment and energy rank as the third and fourth largest costs in all three examples. These cost components are dependent on the deployed RAN architecture. Due to different prices in different markets and areas, DRAN is more cost-efficient in some cases, while CRAN is in others. This explains why the choice may differ between MNOs.

Leased line versus dark fiber

Leased line is a high value type of service and the fee increases with the required bitrate, making it a big challenge for 5G RAN, as the needed transport bitrates are much higher than in previous generations. White fiber has basically the same cost challenges as leased lines, because it is a service with a Service Level Agreement.

Terms and abbreviations

CN – Core Network | **CO** – Central Office | **CPRI** – Common Public Radio Interface | **CRAN** – Centralized RAN | **CU** – Central Unit | **DRAN** – Distributed RAN | **DU** – Distributed Unit | **eCPRI** – Evolved CPRI | **F1** – Interface CU – DU | **gNB** – GNodeB | **HLS** – Higher-Layer Split | **IAB** – Integrated Access and Backhaul | **ISD** – Inter-Site Distance | **LoS** – Line-of-Sight | **MNO** - Mobile Network Operator | **NG** – Interface gNB - CN | **NR** – New Radio | **RBU** – Radio Base Unit | **S1** – Interface eNB - CN | **SFP** – Small Form-factor Pluggable Transceiver | **TCO** – Total Cost of Ownership | **UE** – User Equipment | **VRAN** – Virtualized RAN

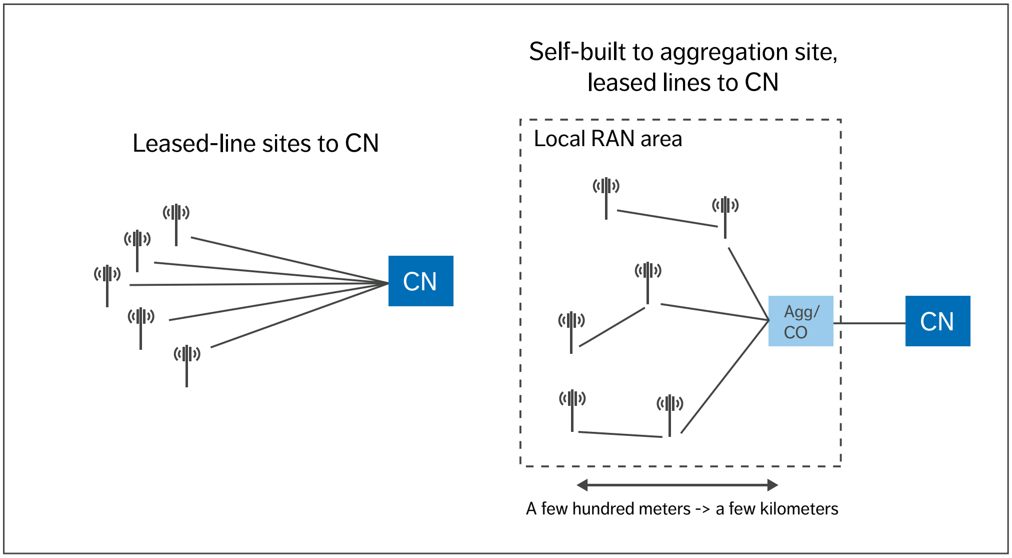


Figure 3 Traditional leased-line approach versus self-built transport in local RAN area

Dark fiber rental also has a rather high cost structure, but the transport fee is independent of bitrates and instead based on the fiber distance. Dark fiber solutions therefore fit well in RAN areas with short distances and are preferably deployed, so that the same fiber can be shared, to some extent, by multiple sites. *Figure 3* illustrates the difference between a traditional leased-line approach and self-built transport based on dark fiber. *Figure 4* shows which of these two transport solutions is most cost-efficient depending on data rate to site and site distance.

A self-built transport network based on dark fiber may be deployed with different fiber and radio site structures such as star, subtend or ring topology. The most cost-efficient topology is subtending, where multiple sites share fiber. If network resiliency is required, a ring topology is suitable at the expense of greater fiber length. A pure star topology gives maximum resilience but has the greatest fiber length and is therefore the most expensive choice.

Figure 4 illustrates the typical fiber length per site, where the shortest lengths appear in urban areas using the subtending topology, and the longest distances in suburban areas using the star topology. Figure 4 also shows the typical user data rates for 5G. Dark fiber is more cost-efficient than leased lines in denser areas where the fiber length per site is low, and the data rates are high. If the fiber length becomes longer, or the data rates are smaller, leased lines are more cost-efficient.

For the different technology options on top of dark fiber, the passive optical solution is the most cost-efficient self-built optical solution. This assumes that the number of sites and equipment subtended on the fiber is within the scaling of wavelengths in the system.

The alternative self-built packet-based solution has the advantages of statistical multiplexing

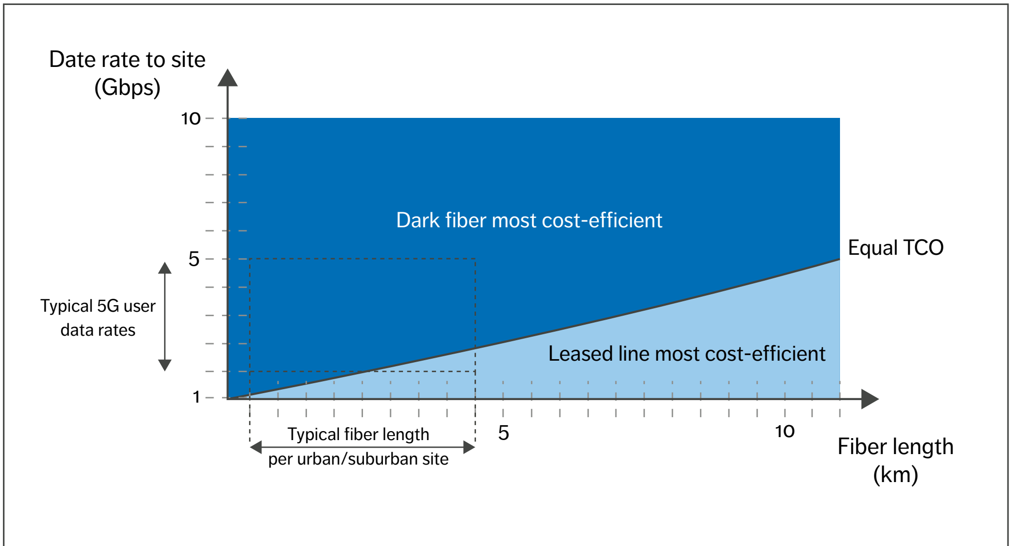


Figure 4 Relative costs for leased lines and dark fiber

throughout the network and can be an L2 Ethernet switched and/or L3 IP routed solution. It assumes that all radio equipment supports a packet-forwarding interface.

Alternatively, when dark fiber is not available or too costly, wireless transport such as IAB or microwave links may be used. These require line-of-sight (LoS) or near-LoS.

Conclusion

Our analysis indicates that due to the large increase in required bit rate per site for 5G NR, the use of traditional leased lines as transport to every radio/antenna site in the RAN will be associated with a high cost in denser areas. Self-built transport in the RAN area is a significantly more cost-efficient alternative for mobile operators. Dark fiber is one self-built transport alternative; microwave links is another.

Since dark fiber cost scales with distance rather than bandwidth, and the trend with 5G is toward shorter site-to-site distances and higher bit rates, dark fiber will be significantly more cost-efficient than leased lines in many scenarios. Further, the large number of fiber providers has boosted availability and competition, resulting in a decrease in fiber rental cost in most urban areas, as well as in some suburban ones. Beyond the RAN area where the local traffic is aggregated and self-built transport is terminated, traditional leased line services to the mobile core continue to be a reasonable solution.

Distributed RAN (DRAN), which works well over both fiber and wireless transport solutions, will continue to be the dominant deployment architecture in most situations. Centralized RAN (CRAN) is an interesting deployment architecture for regions or high-traffic areas where dark fiber transport is available. CRAN offers operational benefits by pooling all baseband to a central site, which results in potential cost savings in site rental and energy, and maximizes the opportunity for inter-site coordination features. In cases where a network has an existing cloud infrastructure, the operator may benefit from adding a high-layer split virtualized RAN deployment to a DRAN or CRAN architecture.

Because the flexibility of the 5G NR architecture enables much greater distribution of equipment and sites than ever before, it is necessary to simplify the installation, deployment and operation of both the RAN and its transport. A high degree of automation and tight integration between the two will be critical to achieving cost-efficient deployments.

“… AUTOMATION AND TIGHT INTEGRATION WILL BE CRITICAL TO ACHIEVING COST-EFFICIENT DEPLOYMENTS”

References

1. **Ericsson Mobility Report, June 2019, available at:** *https://www.ericsson.com/en/mobility-report/reports/june-2019*
2. **Ericsson Technology Review, The advantages of combining 5G NR with LTE, November 5, 2018, Kronestedt, F, et al., available at:** *https://www.ericsson.com/en/ericsson-technology-review/archive/2018/the-advantages-of-combining-5g-nr-with-lte*
3. **3GPP, TS Group RAN; NR; Overall Description; Stage 2, available at:** *https://portal.3gpp.org/desktopmodules/Specifications/SpecificationDetails.aspx?specificationId=3191*
4. **CPRI Common Public Radio Interface, available at:** *http://cpri.info/index.html*
5. **Ericsson white paper, Advanced antenna systems for 5G networks, available at:** *https://www.ericsson.com/en/white-papers/advanced-antenna-systems-for-5g-networks*

Further reading

» **Learn more about building 5G networks at:** *https://www.ericsson.com/en/5g/5g-networks*

THE AUTHORS

Ann-Christine Eriksson

◆ is a senior specialist in RAN and service layer interaction at Business Area Networks. She joined Ericsson in 1988 and has worked with research and development within RAN of the 2G, 3G, 4G and 5G mobile network generations. Her focus areas include QoS, radio resource handling and

RAN architecture. In her current role, she focuses on evaluating different 5G RAN architecture deployment options with the goal of optimizing RAN efficiency, performance and cost. Eriksson holds an M.Sc. in physical engineering from KTH Royal Institute of Technology in Stockholm, Sweden.

Mats Forsman

◆ joined Ericsson in 1999 to work with intelligent networks. Since then he has worked within the areas of IP, broadband and optical networks. Today, his focus is on new concepts for transport within mobile networks at Business Area Networks; one such concept area is 5G RAN transport and automation. Forsman holds an M.Sc. in mathematics and natural science from Umeå University, Sweden.

Henrik Ronkainen

◆ joined Ericsson in 1989 to work with software development in telecom control systems but soon followed the journey of mobile systems evolution as a software and system architect for the 2G and 3G RAN systems. With the introduction of HSDPA, he worked as a system architect for 3G and 4G UE modems but rejoined Business Area Networks in late 2014, focusing on analysis and solutions for the architecture, deployment and functionality targeted for the 5G RAN. Ronkainen holds a B.Sc. in electrical engineering from the Faculty of Engineering at Lund University, Sweden.

Per Willars

◆ is an expert in network architecture and radio network functionality at Business Area Networks. He joined Ericsson in 1991 and has worked intensively with RAN issues ever since. This includes leading the definition of 3G RAN, before and within the 3GPP, and more lately indoor solutions. He has also worked with service layer research and explored new business models. In his current role, he analyzes the requirements for 5G RAN (architecture and functionality) with the aim of simplifying 5G. Willars holds an M.Sc. in electrical engineering from KTH Royal Institute of Technology.

Christer Östberg

◆ is an expert in the physical layer of radio access at Business Area Networks. He joined Ericsson in 1997 with a 10-year background in developing 2G prototypes and playing an instrumental role during the preassessment of 3G. At Ericsson, Östberg began with algorithm development and continued as a system architect, responsible for modem parts of 3G and 4G UE platforms. He joined Business Area Networks in 2014, focusing on analysis and solutions for the architecture, deployment and functionality targeted for the 5G RAN. Östberg holds an M.Sc. in electrical engineering from the Faculty of Engineering at Lund University.

ISSN 0014-0171
284 23-3334 | Uen

Ericsson
SE-164 83 Stockholm, Sweden
Phone: +46 10 719 0000