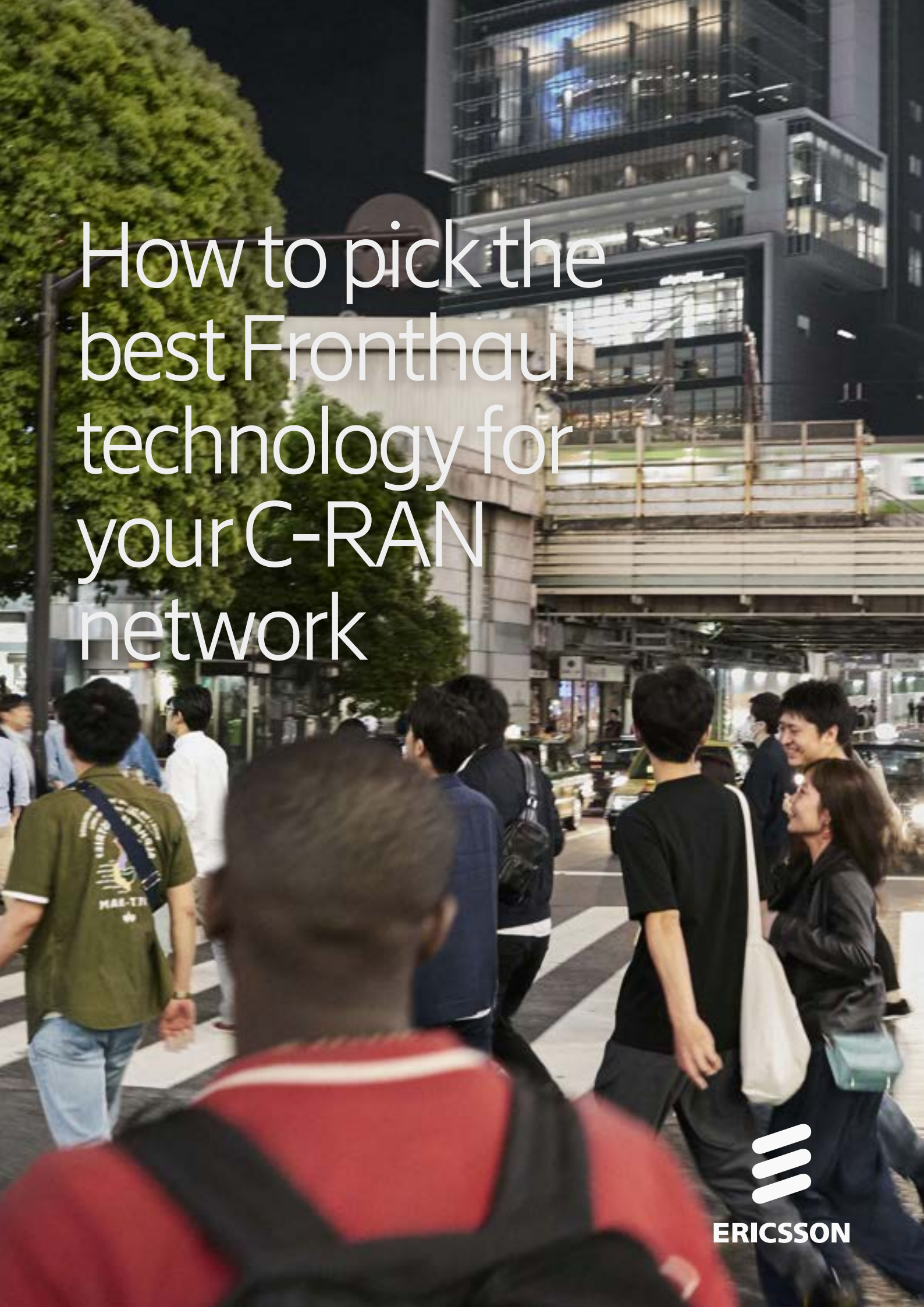

How to pick the best Fronthaul technology for your C-RAN network

ERICSSON

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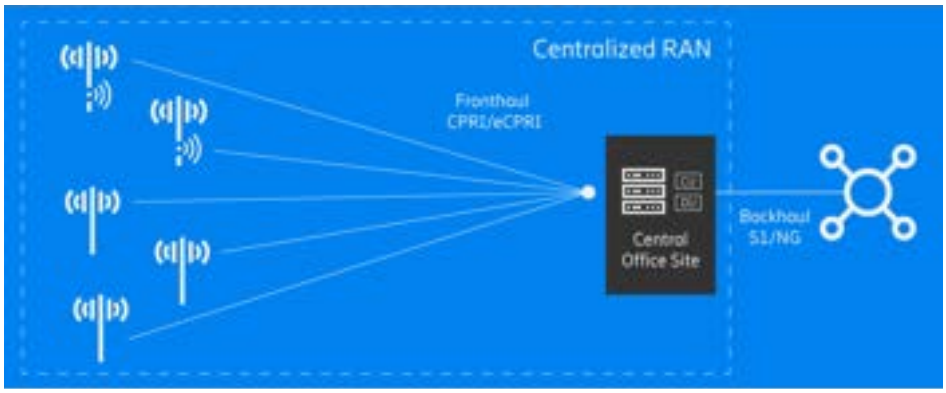
Introduction

Radio Access Networks (RAN) are evolving rapidly with different architecture options varying from Distributed-RAN (D-RAN) to Centralized-RAN (C-RAN). Each has different benefits and specific requirements. In this paper we will be focusing on how to build the fronthaul network for C-RAN architectures.

Centralized-RAN

The C-RAN architecture is characterized by connecting remote antenna sites via a fronthaul network to centralized basebands in a hub location. In dense urban areas, with access to dark fiber, centralizing and pooling the baseband units to an aggregation site can be a good option. It allows for tighter and easier coordination between the basebands resulting in a superior radio performance, key to app coverage and user experience. It also reduces network costs by simplified centralized operations and reduces space, power and cooling requirements at the cell site.
The network "in front" of the baseband towards the remote radio unit is called the fronthaul network. The prevalent fronthaul protocols used are the common public radio interface protocol (CPRI) and the newer enhanced CPRI protocol (eCPRI). CPRI is TDM-based and constant bitrate, independent of actual user traffic. CPRI defines line bit rate options 1 (614.4 Mbps) through option 10 (24.3Gbps) with CPRI-3 (2.5 Gbps), CPRI-7 (9.8 Gbps) and CPRI-8 (10.1 Gbps) being the most deployed in the North American market. The new eCPRI protocol introduced in 2017 is a packet interface and is up to 10x more efficient compared to CPRI from a transport perspective since it scales in proportion to user traffic. The eCPRI radio interfaces used are either 10GE or 25GE.

Figure 1 : Fronthaul network



Fronthaul options

When building your fronthaul network, you need to use the right tool for the job. The options in the fronthaul toolkit include:

- Passive Optical Fronthaul
- Active Optical Fronthaul
- Semi-Active/Semi-Passive Optical Fronthaul
- Packet Fronthaul
- Microwave-based Fronthaul
- Any combination of above solution (where applicable)

The optimal solution depends on a number of factors such as fiber availability, CPRI vs eCPRI radios, site types, distance between radio and the hub etc.

Traditional CPRI is typically transported over fiber using Dense Wave Division Multiplexing (DWDM) in which multiple CPRI services are optically multiplexed into a single fiber strand to reduce fiber costs. An emerging complementing solution is transporting CPRI over packet using either Radio Over Ethernet (ROE) encapsulation or converting CPRI to eCPRI. In the following sections we will explore the Passive, Active and Semi-Passive/Semi-Active Optical Fronthaul options as well as Packet Fronthaul and Microwave based Fronthaul options. In real deployments, you will see a combination of several technologies to fulfill the needs of a specific site.

Passive Optical Fronthaul

Passive optical fronthaul is ideally suited for deployments optimized for space and power (e.g. small cells), as it is small and very cost effective. Flexible compact design allows it to be mounted out of sight in a pole, handhole or small cell enclosure. Passive fronthaul does not require any additional power, colored optics are simply plugged directly into the radio and baseband and connected to an optical add/drop filter.

The filters are protocol and bit-rate agnostic and can transport any mix of CPRI, eCPRI, and/or Ethernet service. Pluggable modules based on SFP+ and SFP28 technology provides connectivity at 10G and 25G through fixed, narrowband tunable and full tunable variants. For optical fault and performance monitoring you must rely on the radio and baseband to monitor the passive optical infrastructure and coordinate between RAN and transport organizations. Passive fronthaul also requires good planning, administration and installation to ensure that the ports and colors align correctly. Passive Fronthaul portfolio includes 8 pizzabox/enclosures variants: figure 2 shows the compact Fronthaul 6585 with integrated DWDM filter.

Figure 2 : Passive Fronthaul 6585 outdoor IP68 box with OAD-9-S Optical Add/Drop filter

Table 1 : Passive Fronthaul benefits and challenges

Passive Fronthaul Benefits	Passive Fronthaul Challenges
• Compact in size • No additional power required • Lower cost • Faster permitting • Rail, cable ladder and antenna mount • Flexible support of many fiber architectures • Protocol and bit rate agnostic	• No demarcation points between transport and radio • Limited management capabilities • Requires disciplined installation and operations practices • Requires validated optics that are able to fulfill power and temperature requirements for radios

Active Optical Fronthaul

Active fronthaul is commonly used for macro sites with many radios, or where fiber monitoring and management is critical. Typically, the transponder in the outdoor cabinet converts up to 24 grey radio services to specific DWDM colors and multiplexes them onto a single fiber strand or 48 services onto a fiber pair. This makes it easy to convert previous installed radios to DWDM without requiring a tower climb to change the optics in the radios. Outdoor rail-mounted transponders can also be used for zero footprint installations or when there are not enough fibers available between the antenna platform and the bottom of the cell tower. The main benefit of active fronthaul are the integrated optical performance, the fault management capabilities and the clear demarcation between the DWDM transport domain and the grey optics radio domain.
Active Fronthaul portfolio includes 5 pizzabox/ enclosure variants. Figure 3 shows new indoor Fronthaul 6650 XPonder that offers up to 20 grey to color conversions@10G or @25G. Its modular cassette is open to support high rates like 50G or 100G.

Figure 3 : Fronthaul 6650 with integrated 25G cassette

Table 2 : Active Fronthaul benefits and challenges

Active Fronthaul Benefits	Active Fronthaul Challenges
• Clear demarcation between transport and radio • Superior OA&M capabilities • Alarm, Fault location, Performance, Inventory • Reduces costly tower climbs • Grey to Color conversion done in transponder • Protocol, Rate & RAN vendor agnostic • Convert any signal into DWDM	• Active solution requiring space and power • Less efficient for packet-based client interfaces (e.g. eCPRI)

Semi-Passive/Semi-Active Optical Fronthaul

The Semi-Passive/Semi-Active Optical Fronthaul solutions balance the benefits and challenges for different sites. It is a hybrid deployment solution that places the active transponder at either the central site (semi-passive) or at the remote site (semi-active).

In Semi-Passive solutions, the pluggable DWDM SFP+ are inserted directly in the radios and the Transponder is placed at the C-RAN hub. When self tunable pluggable optics are inserted in the RRU, the full management of the link is possible via Remote Digital Diagnostic Monitoring interface (R-DDMI). A Semi-Passive configuration allows for simplified OA&M for the transport network providing single point of access for DWDM operations, and compatibility with any baseband and router interface, while keeping the cell site small.

In Semi-Active Fronthaul, the pluggable DWDM SFP+ are inserted in the baseband at the main C-RAN hub and the transponder is placed in the cabinet at or close to the antenna site. A Semi-Active configuration allows for cost and footprint saving at the C-RAN hub site which may be important for colocation cages or when Central Office space is limited. It retains many of the advantages of a fully active solution simplifying ordering, installation and commissioning at remote sites compared to passive solutions.

Table 3 : Semi-Passive/Semi-Active Fronthaul benefits and challenges

Semi-Passive Fronthaul	Semi-Active Fronthaul
Benefits • Better OA&M compared to passive • Radio site is kept compact in size • No additional power at radio site • R-DDMI for full management (like in Active) Challenges • Power and temperature limitations of radios • Requires good inventory administration, planning and installation practices. • More active components	Benefits • Better OA&M compared to passive • Reduced footprint in Hub • Reduced tower climbs Challenges • Requires additional space and power at remote site • Requires highly disciplined installation and operations practices • Requires out of band management of transponder at remote site

Packet Fronthaul

Packet fronthaul is based on an Ethernet circuit between the radio and the baseband. It is managed just like any other ethernet service, providing the stringent latency and synchronization requirements are met. For larger macro sites and street sites, it typically uses a single redundancy grey 100Gbps connection between the radio and hub location. Packet fronthaul circuits can connect any radio to any baseband using flow through provisioning with the additional benefit that the provisioning system becomes the "database of record" tracking tens of thousands of connections, between all radios and all baseband ports.

Radios with native eCPRI interfaces can be transported directly over Ethernet using packet fronthaul gateways. Traditional CPRI radio protocols can be either encapsulated and mapped over Ethernet frames using Radio over Ethernet (RoE) or converted into eCPRI by using a conversion function on the radio signal carried in CPRI. RoE is more RAN vendor agnostic and uses a book-ended encapsulation/decapsulation function to map the constant bitrate CPRI into ethernet packets at the radio and baseband locations. The function is similar to circuit emulation of TDM services. RoE can provide up to 20% bandwidth saving with line code removal for low speed CPRI interfaces.

CPRI to eCPRI conversion at the antenna site can provide a substantial 60%-80% bandwidth reduction compared with RoE. At the C-RAN hub, the eCPRI traffic is connected directly to the baseband without requiring an additional conversion step. The conversion mode is specific to the radio type and RAN vendor. Most sites will have a combination of CPRI and newer eCPRI radios. Packet fronthaul supports native eCPRI, RoE and/or eCPRI conversion to adapt to different antenna sites situations. In addition, some operators may choose to leave older basebands (e.g. 3G) at the remote site, in which case transport of the backhaul interface can also be supported.

Critical to packet fronthaul is the quality and distribution of both frequency and time/phase synchronization across the transport network. The time errors incurred across each hop will determine which radio capabilities can be supported.

Figure 4 : Router 6673 Fronthaul Gateway supporting RoE and CPRI conversion

Table 4 : Packet Fronthaul Benefits and Challenges

Packet Fronthaul Benefits	Packet Fronthaul Challenges
• Radio and enterprise services over same Ethernet facilities • End to end flow through provisioning • Better circuit inventory management • Flexible radio to baseband cross-connections for future baseband pooling scenarios • Reduces costly tower climbs • Clear demarcation between transport and radio	• Active solution requiring space and power at antenna site • Stringent synchronization, QoS and timing requirements • Adds more latency compared to WDM Fronthaul solutions

Microwave-based Fronthaul

High capacity 10Gbps microwave using E-band (70/80GHz) can be used for sites without fiber access, or as a temporary solutions until fiber is available.

Packet fronthaul using eCPRI is very bandwidth efficient and well suited for microwave.

With Dual polarization and XPIC – Cross Polarization Interference Cancellation – you can create 20Gbps links using a single antenna.

Typical uses cases are small cells in cities where trenching a fiber under the sidewalk is cost prohibitive and time consuming

Figure 5: MINI-LINK 6352 E-band microwave

Table 5 : Microwave Fronthaul Benefits and Challenges

Microwave Fronthaul Benefits	Microwave Fronthaul Challenges
• Quick time to market • Short ROI compared to fiber • All outdoor node	• Antenna line of sight • Maximum capacity 20 Gbps/antenna • Maximum up to 3 Km distance

Ericsson – comprehensive transport portfolio

The Ericsson transport portfolio offers a comprehensive selection of products for any of the described fronthaul deployment options while managed by the same Ericsson Network Manager (ENM) as the radio network.

Optical Fronthaul

The Fronthaul 6000 portfolio supports a wide variety of DWDM and CWDM filter options which can be installed in different indoor/outdoor enclosures. They can be combined with any of the indoor or outdoor transponders. Fronthaul 6000 supports a diverse assortment of fiber architectures, such as point-to-point, rings, linear chains, and hub and spoke.

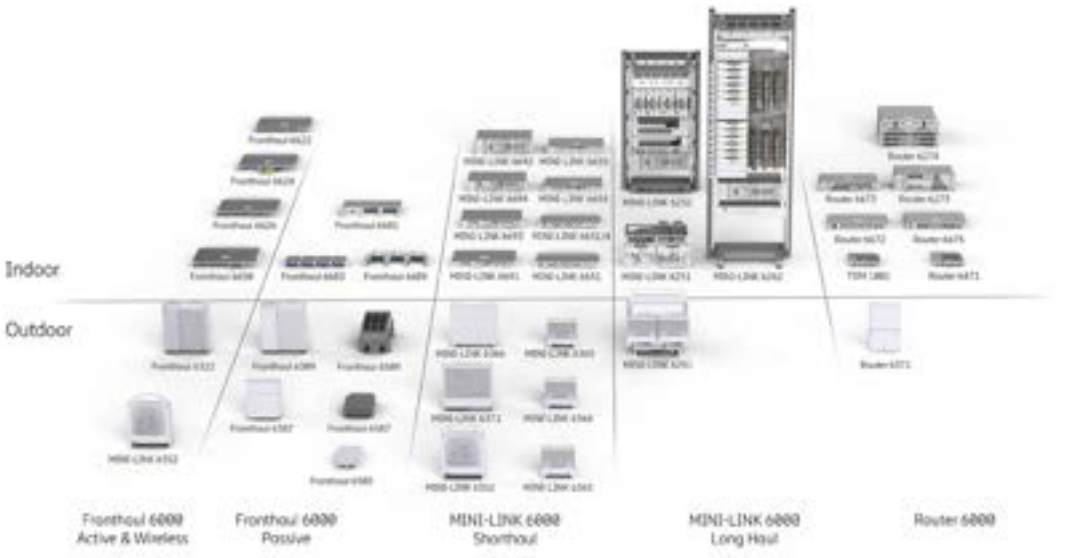
Packet Fronthaul

The Router 6000 portfolio offers both CPRI to eCPRI conversion and CPRI to RoE encapsulation combined with best-in-class synchronization quality and features. It has advanced QoS capabilities to support different radio and enterprise traffic types at the same time.

Microwave Fronthaul

The MINI-LINK 6352 use the E-band frequency and is a complete all-outdoor node, providing fast time to market. It supports up to 2x10 Gbps eCPRI packet fronthaul using a single antenna.

Figure 6 : Ericsson comprehensive transport portfolio



Conclusion – use the best tool

Centralized RAN architectures provide superior radio performance while reducing network cost in dense urban areas. Different transport solutions can be used to build the fronthaul networkby combining optical ,packet and microwave options depending on the specific needs. Each technology option has its own benefits and challenges. Ericsson's comprehensive transport portfolio allows you to pick the best tools for your network needs.

Table 6 : Fronthaul typical applications

Fronthaul option	Typical application
Passive Optical Fronthaul	Small cell deployments which need to have a small footprint.
Active Optical Fronthaul	Macro sites where operations and maintenance are critical.
Semi-Active Optical Fronthaul	Better OAM for small cells while keeping the remote site small.
Semi-Passive Optical Fronthaul	Better OAM for macros while keeping the C-RAN hub footprint small.
Packet Fronthaul	Flexible solution for macro sites and street sites and allowing future compute resource pooling
Microwave-based Fronthaul	For small cell sites where there is no fiber available in a timely matter or fiber costs are too high.

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