

# Deploying Reliable Fiber-to-the-Antenna Networks

## Understanding the Drivers, Challenges, and Solutions

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### Overview

Mobile network bandwidth demands continue to increase with no end in sight. The subscriber hunger for higher bandwidth and higher capacity services is driving fiber deeper and higher into the radio access network (RAN). This paper will explore the technology drivers, the challenges of deploying reliable and robust fiber-to-the-antenna (FTTA) networks, and new radio interface standards like Common Public Radio Interface (CPRI) or Open Base Station Architecture Initiative (OBSAI).

The proliferation of newer, more powerful mobile devices is the driving force behind this bandwidth growth. Leveraging powerful processors and operating systems, mobile applications present considerable network requirements; for example, loading an average mobile web page requires 25 kB while a 10-minute mobile video requires 7000 kB. In recent years, Google's Android™ operating system has further accelerated new product introductions from several device manufacturers, quadrupling processor speeds. Averaging 300,000 activations per day over 26 months on more than 100 phones, Android and other powerful mobile platforms, such as Windows® and iOS, have fostered an environment enabling rapid introduction of new, interactive, video-based applications. For instance, the Apple® iPhone® 4 FaceTime application alone increases the average bandwidth requirement per subscriber to more than 2 Mbps. Android users alone download an average of 400 MB per month.

Unfortunately, for mobile operators, these per-subscriber bandwidth increases are not offset by higher recurring revenues. Presently, 10 percent of the handsets generate 50 percent of all mobile traffic. However, by 2014, more than 5 billion machine-to-machine devices will be using wireless, such as sensor networks, SmartGrid, intelligent applications, and the connected home. As a result, mobile network operators are racing to deploy new technologies such as LTE. This evolution delivers both higher bandwidth and capacity to subscribers, while LTE's IP-based architecture helps operators reduce the costs of delivering mobile services.

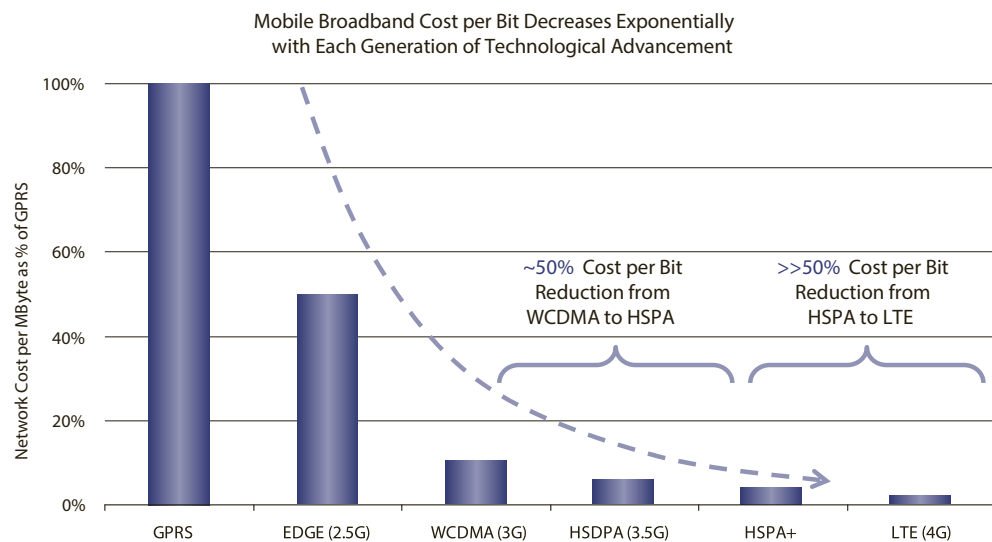
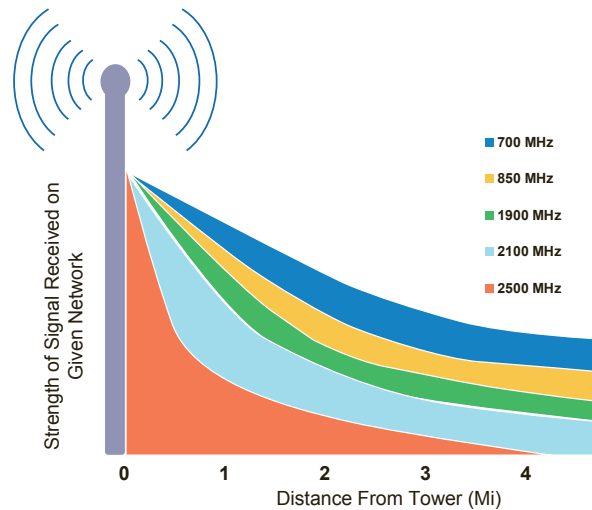


Figure 1. Technology evolution reduces the cost of mobile services

Lower cell site densities are required in order to mitigate radio-spectrum efficiencies. Increasing the number of antennas and sectors decreases the number of subscribers per sector. Spectrum is an important factor when designing a mobile network. Lower-frequency blocks of spectrum propagate farther so that handsets are able to receive stronger signals when further from a tower as shown in figure 2. Use of lower-frequency spectrum requires fewer towers and less equipment, establishes coverage faster, and allows for better re-use of existing macrocellular towers.



Source: Morgan Stanley

Figure 2. Spectrum and signal strength go hand-in-hand and impact cell site strategies

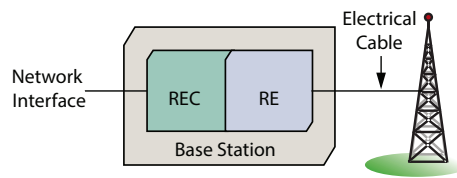
## Understanding Base Station Deployments

Because the existing mobile network footprint was based on low-data-rate, intermittent voice services, the focus was first on coverage over capacity. That is, mobile operator strategies involved erecting large macrocellular towers in order to obtain the broadest radio frequency (RF) footprint possible to cover the largest possible number of subscribers. A typical network in the United States averages 1000 subscribers per cell site, or 333 subscribers per sector. An LTE network using 10 MHz radio channels with a 1.5 bps/Hz spectral efficiency will deliver 15 Mbps of sector throughput. The 3GPP specification defines 5 km (3 miles) as the LTE optimal sector size with 200 subscribers or fewer. With today's technologies, fewer than 20 iPhone FaceTime users will saturate today's cell sites.

Considering these statistics, significantly more antennas are needed to meet today's mobile network coverage and performance needs. While LTE or 4G introduction begins with macrocells, the initial focus will be on coverage and re-using the 2G and 3G tower infrastructure. However, the traditional macrocell deployment model is neither economical nor practical for all coverage needs and, therefore, will require a variety of mobile network architectures.

### Understanding Base Station Architecture

A mobile base station consists of two functional elements, the radio equipment controller or base band unit (BBU) and the radio equipment or the radio remote unit (RRU). In traditional base stations, the RRU and BBU were co-located at the base of a macrocellular tower and heavy, lossy coaxial cables connected the ground equipment to the antenna at the top of a mast, shown in Figure 3. This type of deployment resulted in large equipment footprint, high power consumption, and high deployment costs.

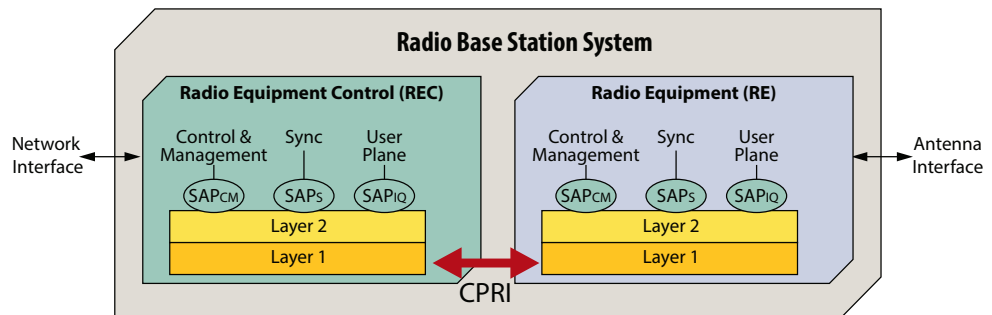


Source: www.cpri.info  
Figure 3. Traditional base station

A distributed base station architecture was required to reduce system, deployment, and operational costs. RRU and BBU functions could be physically separated so that RF transceivers could be relocated next to their respective antennas, in RRU enclosures. BBU equipment could then be optimized for size and power and more conveniently located.

### Understanding New Interface Standards—CPRI and OBSAI

CPRI protocol is used for RF communications between the RRU and BBU and was created to enable physical partitioning of the base station, as Figure 4 shows. The standard began in 2003 and was defined by leading mobile equipment manufacturers such as Ericsson, Huawei, Siemens, and Nortel. The standard defines the digitized base station interface between the radio equipment controller and the radio equipment itself.



Source: www.cpri.info  
Figure 4. Physical base station partitioning with CPRI protocol

While CPRI is the predominant standard, a similar proposal led by other equipment suppliers also exists. OBSAI is an alternative competing standard that was started in 2002. CPRI is more efficient with lower overhead because it covers only Layers 1 and 2 of the OSI protocol stack. CPRI specifies a bit-error-rate specification for data plane is 10 to 12, which is less strict than the OBSAI requirement of 10 to 15. CPRI also provides a migration path to higher data rates in the future. Table 1 compares the two standards, and Figure 5 shows the turn-up qualification.

Base Rate Multiplier	CPRI (Gbps)	OBSAI (Gbps)
1x	0.614	0.768
2x	1.229	1.536
4x	2.457	3.072
5x	3.072	—
8x	4.9152*	6.144*
10x	6.144*	—
12x	7.3728*	—

\*Higher data rates are under development and are not yet specified in any standard.

The lowest data rate specified for OBSAI/CPRI transmission was 0.6144 Gbps. As systems have been re-engineered for higher bandwidths, higher data rates have been integral multiples of this legacy rate.

Source: www.cpri.info

Table 1. CPRI and OBSAI comparison

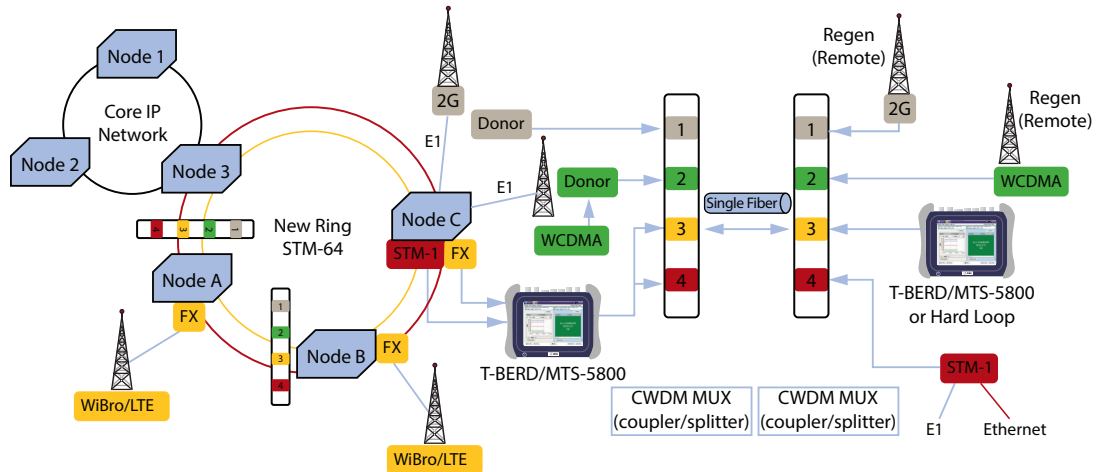


Figure 5. CPRI/OBSAI field turn-up qualification

### Radio Access Network Evolution

With digital interfaces rather than analog, fiber is preferred over coaxial cables for interconnecting RRU and BBU equipment. CPRI requires high bandwidth, reliable, and low-latency transport, which is ideal for fiber. CPRI supports a 10 dB optical link budget and upper distance limit of 10 km (limited by protocol latency). Eliminating the need for coaxial cables and extending fiber simplifies installations because it eliminates the need to pull heavier and costlier coaxial cables, typically 1.5 to 2.25 inches thick, to the top of towers. Furthermore, each sector requires two of these installations, and an average deployment typically requires six. When multiple operators share the same infrastructure, towers quickly become entangled with cables and cause power, wind, and weight load concerns.

When fiber is deployed up the tower, a remote fiber feeder (RFF) runs from the BBU located at ground level to a breakout box at the top of the tower, shown in Figure 6, which is then patched into the RRU. In addition to lowering deployment and component costs, this approach also significantly cuts power consumption sometimes in half.

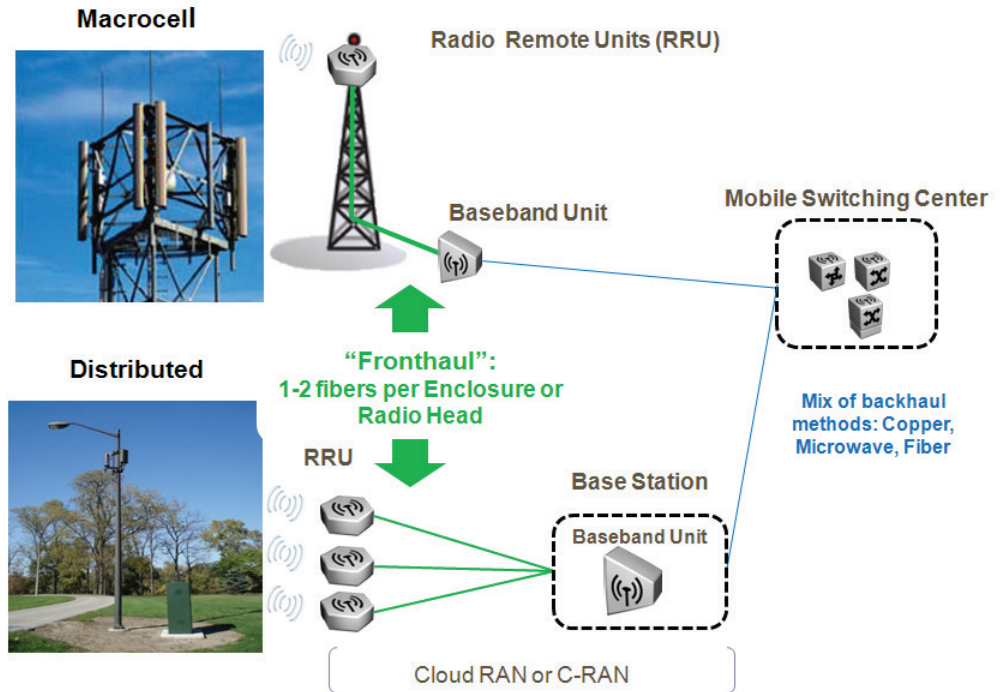


Figure 6. Radio access network strategies

Fiber now permits the physical separation of BBU and RRU letting mobile operators re-think their wireless deployment strategies. An advanced example is cloud RAN, also known as C-RAN, where the RRU is deployed closer to subscribers and more complex BBU are housed in a central facility similar to a cloud-computing model. This distributed base station model, shown in Figure 7, consists of a network of spatially separated antenna nodes connected to a common source via a transport medium to provide wireless service within a geographic area. Typically, a node comprises an antenna and a small radio head (small cell) mounted on existing distributed structures, such as utility poles. These components may be physically separated by up to 40 km. This RF-over-fiber backhaul segment is sometimes referred to as the “fronthaul,” differentiating it from traditional mobile backhaul.

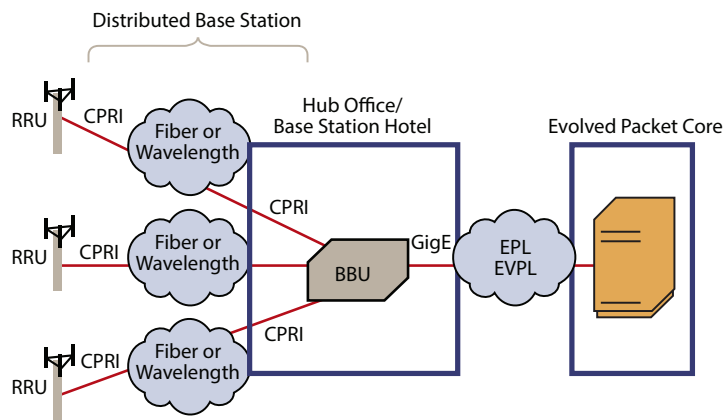


Figure 7: Distributed base station architectures

Vendor product examples include LightRadio from Alcatel-Lucent and LiquidRadio from Nokia Siemens Networks. In both cases, a centralized BBU services multiple remote RRU to create distributed base station architectures.

## Fiber to the Antenna Deployment Challenges

Fiber “front-haul” or FTTA enables a new connectivity infrastructure to transport digital RF over fiber signals. Fiber offers many benefits, notably high capacity, easy installation, extended reach resulting from low loss, and immunity from noise; however, it also presents new challenges. RF installers who are familiar with pulling thick, heavy cables up towers to the RRU must now learn to work with and handle more sensitive fiber cables to confidently install reliable, robust services. Fiber is more susceptible to damage from crimping, bending (even microbending), or straining caused while pulling or hauling the cable trunks or feeders.

The fiber-optic industry is well aware that scratches, defects, and dirt on fiber-optic connector end faces negatively impact optical signal performance. Troubleshooting statistics show connector contamination as the number one cause of poor network performance, and mating contaminated fibers is the primary cause of permanent optical component (connector) damage. Dirty connectors can create disproportionate numbers of failures such as increased attenuation, back reflection, and bit errors that can prevent network delivery and impact quality of service (QoS). This failure mode extends troubleshooting times because often the contamination sources are difficult to isolate. Without systematically addressing dirty and damaged end faces, the defects can degrade RF network performance or eventually take down the entire link.

Figure 8 shows the fiber-optic connector architecture where the glass fiber strand consists of an outer area or “cladding” and an inner area or “core”, each with its own different refractive index. The glass cladding traps the light within the core, but does not conduct light itself. The fiber is mounted within a round ceramic “ferrule,” which is then captured by a plastic body. The connectors are male; therefore, a female-to-female adapter joins them together.

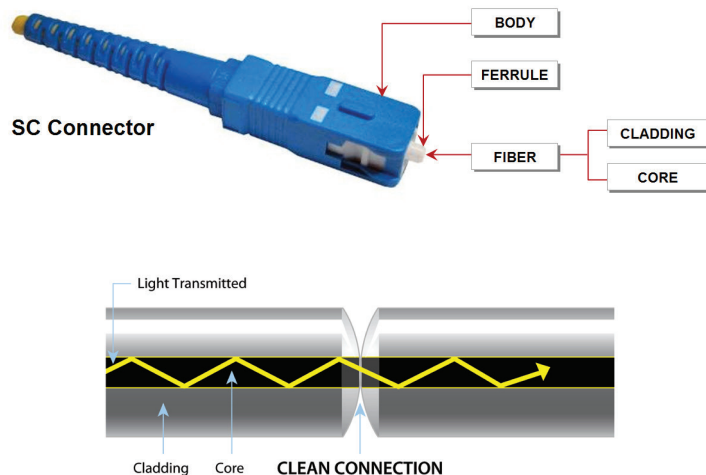


Figure 8. Anatomy of a fiber-optic connector

Trapped microscopic dirt particles between two mated connectors prevents light from moving naturally down the fiber and blocks, absorbs, scatters, or reflects a portion back toward the source, as shown in Figure 9a. Further, some of the trapped dirt can become permanently buried or embedded into the glass that then requires replacing or re-polishing the connector, as shown in Figure 9b. The cost of troubleshooting, asset damage, and network downtime costs are exponentially higher when embedded dirt gets in the fiber inside expensive network equipment; where replacing or re-polishing the fiber is not an option.

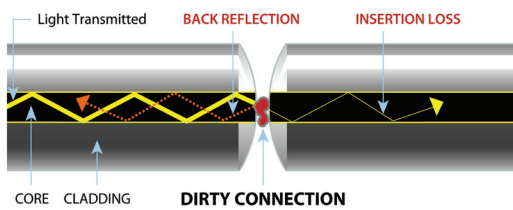


Figure 9a. Contamination degrades signals

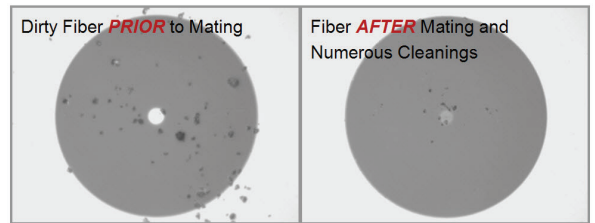


Figure 9b. Embedded dirt on a fiber face as seen through a fiber scope

The OTDR trace illustration in Figure 10 clearly shows the increase in loss resulting from contamination.

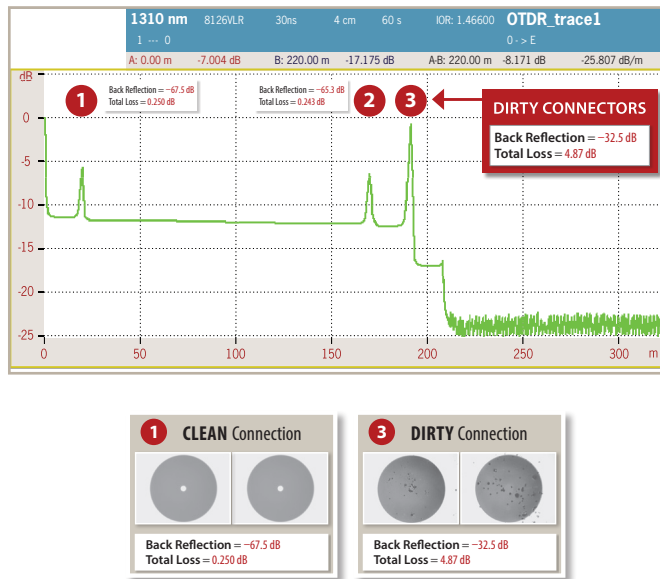


Figure 10. Optical signal performance affected by connector contamination



## Fiber-Optic Connector Standards

To guarantee a common connector performance level, the International Electrotechnical Committee (IEC) created standard IEC-61300-3-35 specifying pass/fail requirements for end-face quality inspection before they are connected. Designed as a common reference for product quality and performance, the IEC standard supports quality control throughout the entire fiber component life cycle, but only after testing compliance at every handling stage. This objective assessment eliminates varied results, allows installers to certify and record product quality, empowers installers of any skill level, and ultimately improves installation quality, and reduces the potential for future performance issues.

## Additional Fiber Link Loss Attenuation Mechanisms

Fiber microbends or macrobends are another common cause for problems when installing fiber cable systems because they can induce signal or power loss. In distributed base station (C-RAN) deployments, aerially strewn or microtrenched fiber becomes more susceptible to bends from causes such as cable sag in high temperatures and physical impedance or pressures.



Figure 11. Macrobends typically found in RRU enclosures, junction boxes, and fiber trays

Microbending occurs when the fiber core deviates from the axis and can be caused by manufacturing defects, mechanical constraints during the fiber laying process, and environmental variations (temperature, humidity, or pressure) during the fiber's lifetime, such as freezing water that causes external pressure or sharp objects that impede the fiber. As shown in figure 11, fiber macrobending occurs when physical bends exceed fiber bend radius limitations caused by poor installation or when loading fiber into BBU/RRU enclosures, fiber trays, or junction boxes, and also from tampering. Optical signal-level attenuation due to macrobending increases with wavelength. For example, a signal traveling at 1550 nm will attenuate more than a signal traveling at 1310 nm in the presence of a bend.

As FTTA pushes fiber into new and unfamiliar locations, connector contamination, bending, and poor practices become increasingly probable because of both environmental factors and mishandling. Proper fiber handling and a pre-service fiber acceptance testing process become essential and include, but are not limited to, visible fault location/continuity checks, connector inspection certification, and cleaning. It also includes measuring the optical power level, end-to-end link loss, return-loss, or testing optical time-domain reflectometry (OTDR) to qualify fiber continuity and link element parameters.

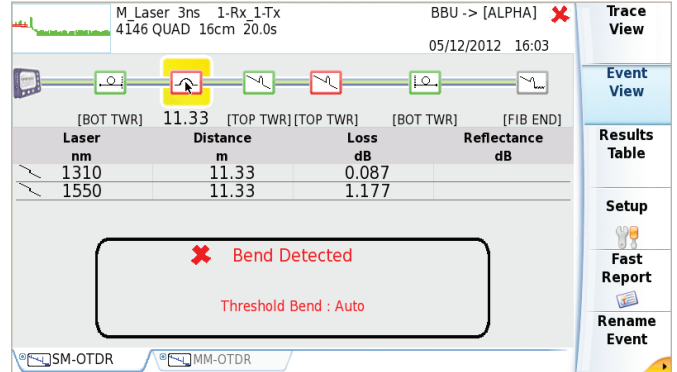


Figure 12. Mishandling can create cable kinks (left). A typical bend fault found on a macrocell using an OTDR SmartLink Mapper (right) during construction (loopback mode).

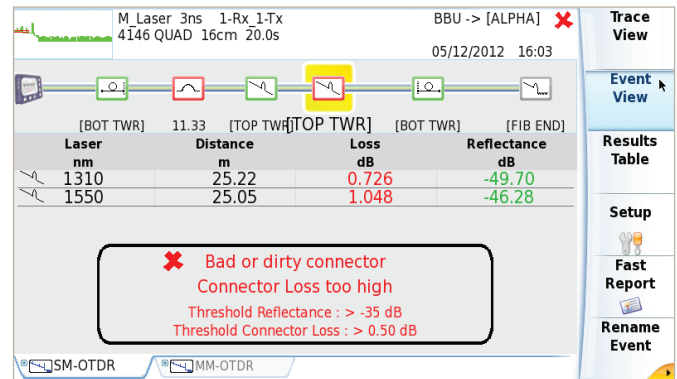
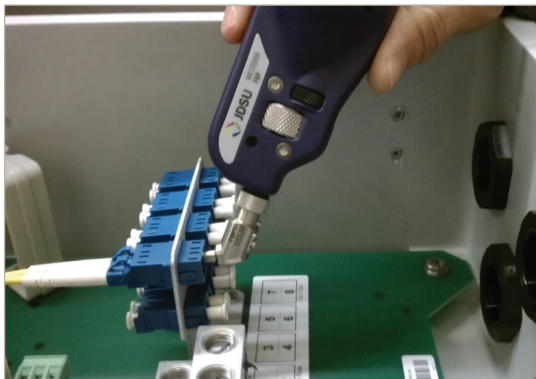


Figure 13. Inspect before you connect (left). A typical contaminated connector issue found on a macrocell link using an OTDR SmartLink Mapper (right) during construction (loopback mode).

## C-RAN and the Fiber Fronthaul

C-RAN deployments present even more challenges because fiber must be connected from BBU equipment to RRU, which can be on the top of utility poles or attached to the sides of buildings. Acquiring fiber rights-of-way are often challenging; so operators employ a variety of strategies for installing fiber networks, such as aerial or micro-trenching them mere inches below street level. Environmental stresses, susceptibility to accidental construction or civil works damage, and increased risk of tampering, creates even more issues. In C-RAN architectures, where the RRU is installed closer to street level, issues arising from fiber bending are common. Furthermore, multiplexing several signal wavelengths into a single fiber within the coarse wavelength-division multiplexing (CWDM) or dense wavelength-division multiplexing (DWDM) range is common when connecting the BBU to RRUs. Both CWDM and DWDM are common cost-effective strategies for expanding backhaul capacity without laying more fiber. CWDM or DWDM technologies require conducting fundamental fiber tests not covered in this paper, but for more information please visit [www.jdsu.com/en-us/Test-and-Measurement/Products/field-network-test/fiber/optical-spectrum-analysis/Pages/default.aspx](http://www.jdsu.com/en-us/Test-and-Measurement/Products/field-network-test/fiber/optical-spectrum-analysis/Pages/default.aspx).

The C-RAN also creates opportunities for various new types of backhaul service between the RRU and the BBU. The common physical media used is fiber which can be unlit (known as dark fiber) or part of a managed WDM service. This fronthaul network media plays a critical role in overall mobile network performance requiring new types of service-assurance solutions to support FTTA architectures.

A continuous fiber-monitoring solution, serving as a fronthaul optical-service demarcation unit, is ideal for FTTA service assurance. This solution enables wireline operators to implement and manage a fronthaul network for mobile operators, because it delineates the fronthaul services. Of course, the solution must be installable in a variety of harsh environments including directly on utility poles or co-located with remote radio heads. From a centralized location, ideally adjacent to BBU equipment in locations such as base station hotels, central offices, and data centers, fronthaul providers must delineate services, isolating problems between the mobile provider and wireline provider. The continuous fiber monitoring solution can also proactively and predictively monitor fronthaul fiber. Considering that fiber is often aerially strewn or microtrenched inches below street level, it is increasingly susceptible to environmental effects, accelerated aging, and other failures. Continuous fiber monitoring lets fronthaul operators proactively identify potential service issues.

## Summary

Relentless mobile traffic growth will continue to drive innovation in the RAN. FTTA will play a critical role as operators look to reduce costs and improve performance. Even though deployment blueprints and protocols may change with the introduction of the RRU, centralized BBU, and RF-over-fiber protocols like CPRI, the expectations for service quality and backhaul service assurance will not. FTTA can potentially enable a new mobile fronthaul; however, fiber connectivity brings advantages and considerations. Effectively testing the physical layer during installation and deployment is essential for lowering maintenance costs and improving network reliability and long-term robustness. Fiber assurance minimizes customer issues, rapidly locates and isolates faults, and demarcates issues ownership between fronthaul fiber providers and mobile operators, and it helps enable revenue-generating high value services. Also, an end-to-end solution is required that addresses the entire deployment life cycle through installation, test, turn-up, and through continual service assurance.

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