APPLICATION NOTE

MOBILE FRONTHAUL

ENABLING CLOUD-RAN WITH MOBILE FRONTHAUL

Mobile Operators to Migrate Small and Micro Cells to a Cloud-RAN Architecture

As data capacity in mobile networks continues to rise at an exponential rate, mobile operators are looking at new architectures that can help them reduce cost, simplify networks and share resources to match the dynamic nature of mobile networks. Power and space are scarce resources at cell sites, and the total cost of power for these operators is considerable. Therefore, they look for every possibility to reduce these ongoing power costs and space requirements and to enable more dynamic use of network resources and spectrum.

One current trend by mobile operators to address power and space requirements is to move to centralized radio access networks and eventually cloud radio access networks Both are commonly abbreviated C-RAN, but for the purposes of this document, C-RAN refers to cloud radio access networks. Both centralized-RAN and C-RAN involve moving some parts of the radio network control function from being colocated with the antenna at the cell site to locations deeper in the network, and introduce a new transmission network into the overall mobile network infrastructure – mobile fronthaul. This new C-RAN architecture helps control ongoing operational costs, such as reduced power consumption and fewer truck rolls to the cell site, and also greatly increases the flexibility of the network for small cell and macro cell deployments.

This application note provides an overview of the benefits and challenges of C-RAN architectures in the transmission network. With many options available, Infinera addresses a full range of networking requirements.

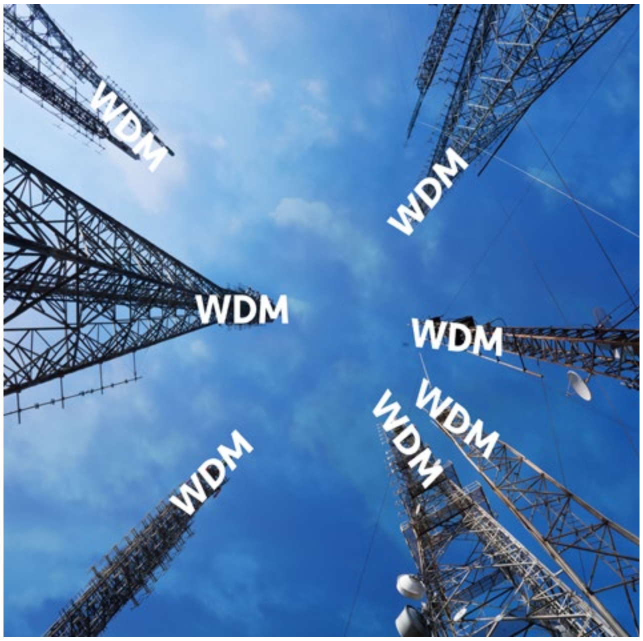
Infinera's strengths in synchronization and transparent data transport bring unique advantages to mobile and wholesale operators rolling out C-RAN and fronthaul networks.

*Source: China Mobile Research Institute, C-RAN, The Road Towards Green RAN, White Paper, 2013

Mobile Operator Challenges and the Migration to C-RAN

As the demand for network traffic grows, network capacity must grow to meet this demand. Newer technologies allow greater capacity per cell site, but this increase comes at a cost beyond the capital cost of the new equipment. Power consumption in cell sites is becoming a greater and greater portion of the overall network cost, and operators are looking for methods to reduce these costs.

Data published by China Mobile* shows that over a seven-year period, operational expenditure (OpEx) accounts for 60 percent of the total



cell site, 40 percent of which is for initial capital expenditure (CapEx). Power costs are approximately a third of OpEx, which is approximately 20 percent of the overall cell site cost over that seven-year period. Also, according to China Mobile, cell site power accounts for more than 70 percent of the overall network power requirement. Cell site power consumption, therefore, is a significant cost factor that must be addressed in order to operate an economically viable mobile network.

Another value that the migration to C-RAN brings is the removal of complex networking equipment from the cell site. Fewer truck rolls and less need for technically-advanced field technicians are some examples that play a significant role in reducing OpEx when this equipment is removed from the cell site.

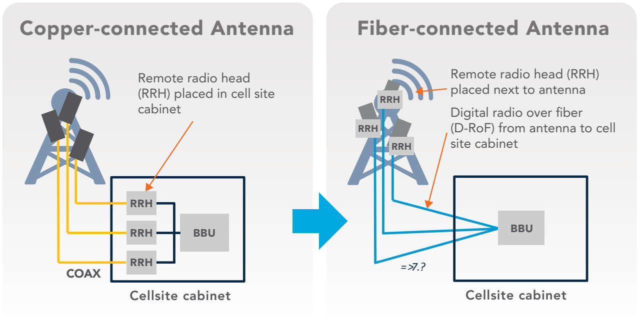


Fig 1: Fiber-connected Antennas Allow the RRH to Be Placed with the Antenna, Bringing Advantages Such as Lower Power Consumption at Cell Sites, Whether They Are Small Cells or Macro Cells

Key Benefits of Migrating to Fiber-interconnected Antennas

One approach that operators have taken to lower power costs is to migrate from coax to fiber-based interconnections between the baseband unit (BBU), which performs signal processing functions and creates the radio signal, and the remote radio head (RRH), which converts the radio signal into a radio frequency (RF) signal.

With traditional copper interconnection, the BBU and RRH are colocated within a cabinet in the cell site, and a coax cable is used to connect the RRH to the antenna at the top of the cell site. With fiber-based interconnection, the RRH is colocated with the antenna at the top of the cell site and interconnected to the BBU in the cabinet using a digital radio over fiber (D-RoF) protocol such as either the Common Public Radio Interface (CPRI) or the Open Base Station Architecture Initiative (OBSAI) protocols. The use of an optical interface results in much lower power consumption, especially at higher data rates within the cell.

This approach of colocating the RRH with the antenna is equally applicable to small cell as well as macro cell deployments. Small cells would typically have one RRH, whereas macro cells typically have three or more RRHs. The value that a fiber-based interconnection between the RRH and the BBU would bring is still the same in both cases.

Moving the BBU to the Central Office Reduces Power and Space Requirements

One key benefit that migration to fiber-based interconnection between BBU and RRU allows is the possibility of longer-reach optics. This, in turn, allows moving the BBU from the cell site back into the network, centralizing stacked BBUs at the central office location. This enables three advantages for the network operator.

First, OpEx is reduced by lowering the overall power requirements of the network and also by reducing the space requirement within the cell site, which becomes increasingly important as more and more antennas are added to existing cell site locations.

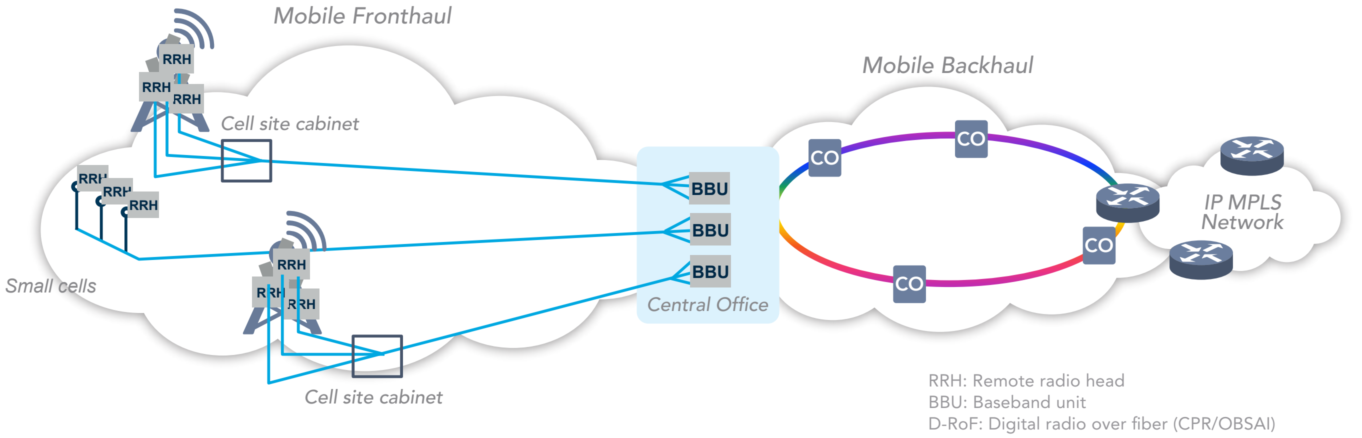


Fig 2: Mobile Fronthaul and Mobile Backhaul within a Mobile Network.

Second, from a networking perspective, the move to colocated BBUs greatly simplifies the X2 interface between BBUs in Long Term Evolution (LTE) networks and also increases security over the BBU to RRH link, removing the need for Internet Protocol Security (IPsec).

Third, moving the BBU to the central office location also brings an operational benefit as it allows fewer truck rolls out to the cell site and technical expertise can be colocated with other central office technicians.

Centralized BBUs Optimize the Use of Networking Resources

The move to centralized BBUs creates a new domain within the mobile network. The network between the BBU and the core network is still referred to as the mobile backhaul network, and the new network between the BBU and the RRH in the cell site is referred to as the mobile fronthaul network.

Operators may also combine stacked BBUs at the central office into a single larger BBU with load balancing to enable C-RAN where capacity/spectrum can be load-balanced across a number of antennas. Resources can then be closely matched to demand at different times of day and at various locations covered by these antennas.

A further advantage of combining BBUs in the central office is that mobility management, i.e. management of users moving between cells, can be simplified. In addition, the cost base of the network is lowered because less total BBU capacity is required. Moreover, less backhaul capacity is required.

Making Fronthaul a Network

Both the options, in which the BBU is moved from the cell site to a central office, require a fronthaul network, which can take many forms. The simplest option is a dedicated fiber per RRH running the CPRI or OBSAI protocol.

The CPRI and OBSAI protocols are defined with a range of speeds from 600 megabits per second (Mb/s) to 12 gigabits per second (Gb/s). While three of these rates closely match the 1 Gb/s, 2.5 Gb/s and 10 Gb/s line rates of wavelength-division multiplexing (WDM) optics, recent advances in optics options now enable the full range of protocol rates to be supported over WDM.

Accordingly, WDM technology may be added to the fronthaul net- work, allowing for better use of available fiber and adding networking capabilities, such as management and protection, which become increasingly more important as these networks grow in capacity and reach.

Strict Latency and Synchronization Requirements

The fronthaul network and the CPRI/OBSAI protocols have very stringent requirements that need special consideration. These protocols are extremely latency-sensitive, which is often the overall limiting factor in how far the network can extend. This is particularly the case with the higher-speed CPRI/OBSAI options that are required for today's high-capacity mobile networks.

Fronthaul networks also require that the signal synchronization is transferred transparently if active WDM systems are used. Additionally, consideration is required for the space and power requirements of any networking solution as space in cell sites is extremely limited, and a large driver behind the change to centralized BBU is reduction in power consumption.

Fronthaul networks may appear to be relatively simple, but due to the need to meet strict latency and synchronization requirements and to support the CPRI and OBSAI protocols, these networks are actually quite complex, and consequently the networking options available in the market are limited.

Different Fronthaul Options Are Required

In our opinion, there is no such thing as a generic fronthaul network. There may be different characteristics of fronthaul deployments in terms of the density of small and macro cells, fiber infrastructure, management requirements, and cost focus. For this reason, a mix of fronthaul networking options may be needed to fulfill various requirements across the mobile transport network.

Infinera Mobile Fronthaul Solution

Infinera packet-optical solutions are built on two key technologies; Ethernet and WDM. Infinera XTM Series-based WDM solutions have specific strengths from a heritage in metro and regional networking that are highly applicable in fronthaul networks. These include compact and low-power solutions, passive and active WDM options, ultra-low latency and superior synchronization performance.

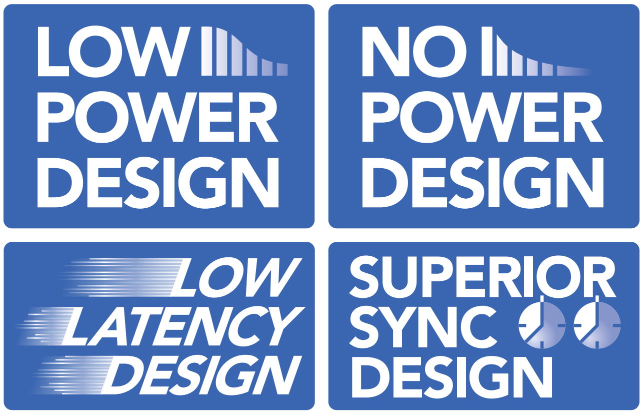


Fig 3: The Infinera Mobile Fronthaul Solution Presents Key Values in Low or Even No Power Consumption, Superior Synchronization Capabilities and Extremely Low Latency.

Another key strength of the Infinera mobile fronthaul solution is its support for all the defined speeds of the CPRI protocol. This includes all rates defined in CPRI V6.1, including the newest rate of 12.16512 Gb/s.

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The capabilities mentioned on the previous page allow Infinera to offer three main options to mobile operators or wholesalers looking to build fronthaul networks:

- Active WDM
- Semi-passive WDM
- Passive WDM

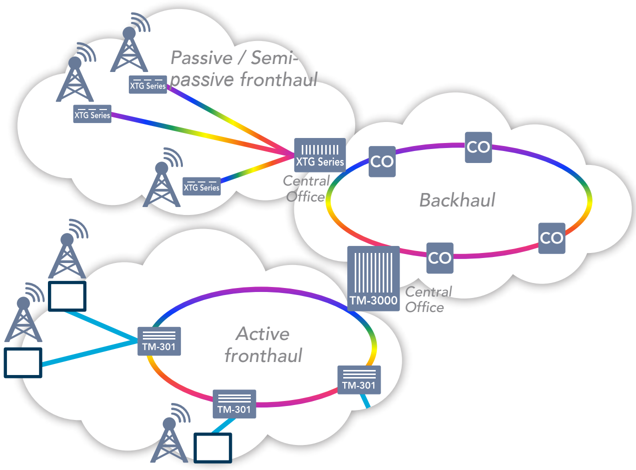


Fig 4: The Infinera Mobile Fronthaul Solution Offers Three Main Options: Passive WDM, Semi-passive WDM and Active WDM Options. All Options Tie Smoothly into the Mobile Backhaul Solution

Within the active and semi-passive options there are sub-options addressing different kinds of manageability requirements, service mix or reach characteristics.

Option 1 – Active WDM

Active WDM components can affect network latency and sync performance, which are critically important in fronthaul networks. To address this, Infinera's Active WDM option provides unique features for delay compensation as well as offers various protection mechanisms. It is also the option of choice when facing limited fiber availability due to the efficient use of wavelengths that active WDM offers. The Infinera XTM Series has particular strengths that make it highly suitable for these active networks.

The active WDM option provides two sub-options:

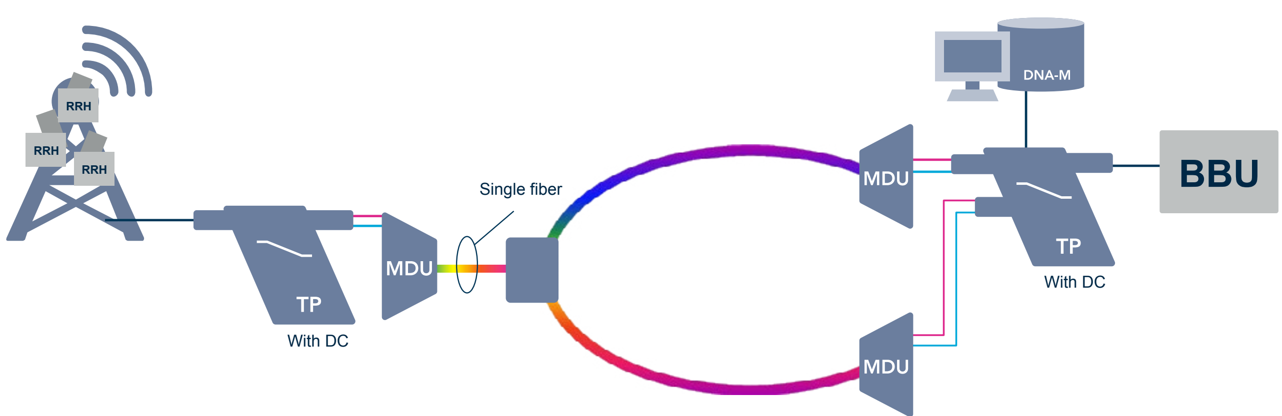
- Flexponder option
- Transparent WDM transponder option

Flexponder Option

The flexponder option uses a mobile fronthaul-specific set of 12-port units, called a flexponder, that can act as either multiple muxponders supporting up to six channels each or up to six individual transponders, depending on the network requirements. Both cases support point-to-point and ring architectures. The flexponder also has a unique architecture that saves on expensive line interfaces.

Usually to provide a protected channel around a ring, two independent optical paths are needed, with a total of four endpoints. By using Infinera's mobile fronthaul architecture, operators can cut this to just three, saving 25 percent of the cost associated with optics, which makes up a substantial part of the overall network cost.

Ring architectures carrying CPRI traffic should have two optical paths with identical latency characteristics to ensure that there is no change in latency in the event of a protection switch.



Active Mobile Fronthaul – Flexponder option in Transponder mode

Fig 5: The Infinera Approach to Ring Architectures with Delay Compensation Saves 25 Percent of Pluggable Optics Costs

The XTM Series can be configured to constantly monitor the latency of both paths to ensure that the shorter path is correctly delayed to match the latency of the longer path. As this is done in real time, the network can cope with changes in latency due to temperature effects, for example, which are especially important in fronthaul where sometimes aboveground fibers are used.

The flexponder supports this approach with industry-leading mobile fronthaul performance, such as 0.6-14 Gb/s support, 4 microsecond (µs) latency in muxponder mode and 2 µs latency in transponder mode (per pair of units), and sub 15 millisecond (ms) switchover time. The non-hardened variant of the flexponder fits into any XTM Series chassis for use in the BBU or suitable equipped RRH sites, and the hardened unit may sit in non-controlled environments such as street and wall cabinets. A second hardened variant which supports this option is the Remote Fronthaul Unit (RFU), which is designed for outdoor deployments, such as direct mounting on an external wall or pole. These hardened units have a broader temperature range support (-40 to +65 °C) and additional features such as external alarm contacts.

Transparent WDM Transponder Option

The XTM Series also provides simple multi-rate transparent transponders that cover the full range of CPRI/OBSAI protocol speeds and were originally designed as simple low-cost and low-power alternatives to the more complex transponders available in the XTM Series.

These transponders have the great advantage of extremely low latency, as low as 4 ns for a pair of 10 Gb/s transponders, which is industry-leading and is equivalent to adding just one meter of fiber to the route. The transponders support transparent synchronization, making them very useful in mobile fronthaul networks.

This approach naturally adds back a small portion of the power consumption saved by the move to mobile fronthaul and C-RAN, but these solutions are very low power and still represent a significant overall power savings.

The small addition in power and space to deploy active WDM adds a number of advantages to the fronthaul network.

First, active WDM removes the need for I-Temp CWDM CPRI/OBSAI SFP units in the RRH, as the existing optics can be used to connect to the transparent transponder.

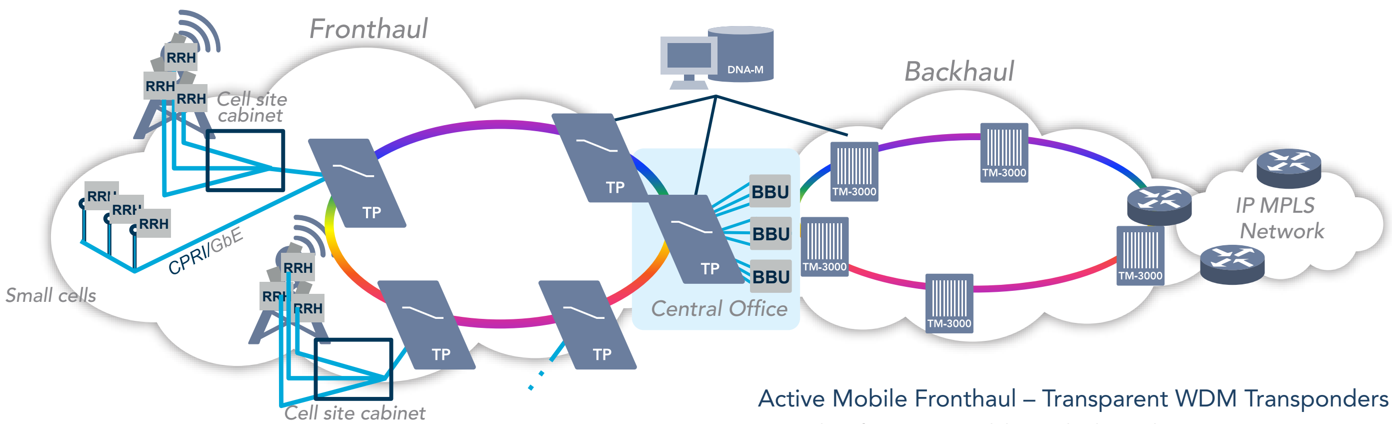
Also, the addition of active WDM facilitates transmission over greater distances. In addition, more complex optical architectures may be employed with higher insertion loss requirements, such as rings with many add/drop nodes or reconfigurable optical add-drop multiplexer (ROADM)-based flexible optical networks. Active WDM also allows the fronthaul network to be managed with functionality such as the simple performance monitoring provided in DNA-M.

Mobile operators can create a cost-effective active WDM point-to-point or ring network for transmission of all CPRI/OBSAI signals with options for traffic protection. Accordingly, active WDM addresses key performance areas such as compactness, low power, ultra-low latency and transparent data/synchronization transmission.

Option 2 – Semi-Passive WDM, Adding Monitoring Capabilities to Passive Option

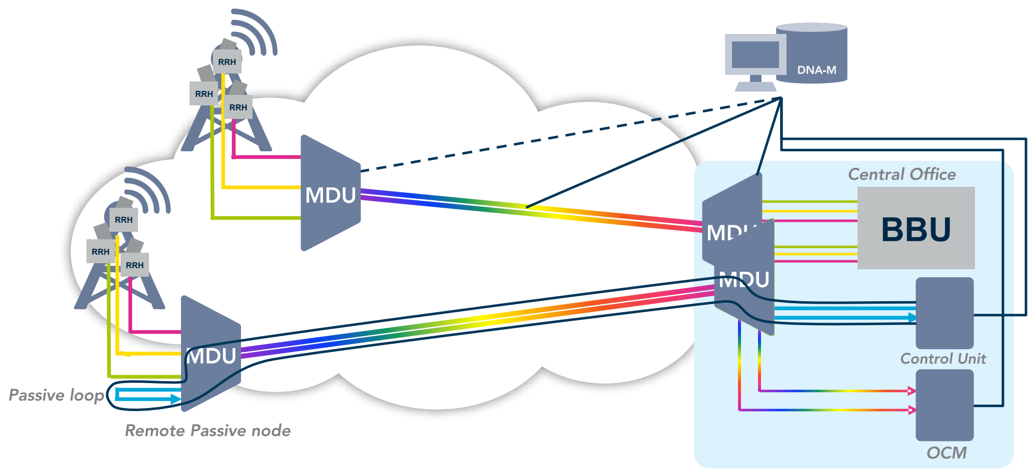
Infinera offers a semi-passive option that provide more advanced operations, administration and maintenance (OAM) capabilities than those available with the passive option. The semi-passive option includes active monitoring capabilities, but is based on passive equipment at the remote cell site.

These capabilities address three main areas of functionality: resource monitoring, optical channel monitoring and link status monitoring. All



Active Mobile Fronthaul – Transparent WDM Transponders

Fig 6: The Infinera Active Mobile Fronthaul Uses the Active XTM Series Transparent Transponders, Bringing Key Values such as Low Latency and Superior Sync.



Semi-passive Mobile Fronthaul – Passive Wavelength Monitoring

Fig 7: The Infinera Semi-passive Mobile Fronthaul Provides Passive Wavelength Monitoring Capabilities to Allow More Advanced OAM. Only Macro Cell Deployments Are Shown in this Example, but the Semi-passive Option Is Equally Beneficial in Small Cell Deployments.

these performance statistics can be monitored in the Infinera Digital Network Administrator for XTM Series (DNA-M).

Resource monitoring is based on inventory capabilities and channel use information to allow the operator to quickly and easily understand network usage and add new services.

The semi-passive WDM option provides two sub-options:

- Passive wavelength monitoring
- Active wavelength monitoring

Passive Wavelength Monitoring

Optical channel monitoring uses the XTM Series optical channel monitor (OCM) to monitor the optical power levels of individual wavelengths. Offset and degradation alarms can then be set to alert the operator to problems in the optical BBU-to-RRH connection that is running over the semi-passive network.

Link status monitoring uses a spare wavelength to loop a wavelength from the BBU site to the remote cell site and back to monitor the status of the link. This wavelength can either be one of the unused C/DWDM wavelengths or 1310/1625 nanometer (nm) ports that are available on the XTG Series filters.

The wavelength is then connected to an XTM Series control unit and the wavelength status is monitored by the management system. This enables the operator to be alerted in the case of a fiber cut or some other network issue if the link status wavelength is lost.

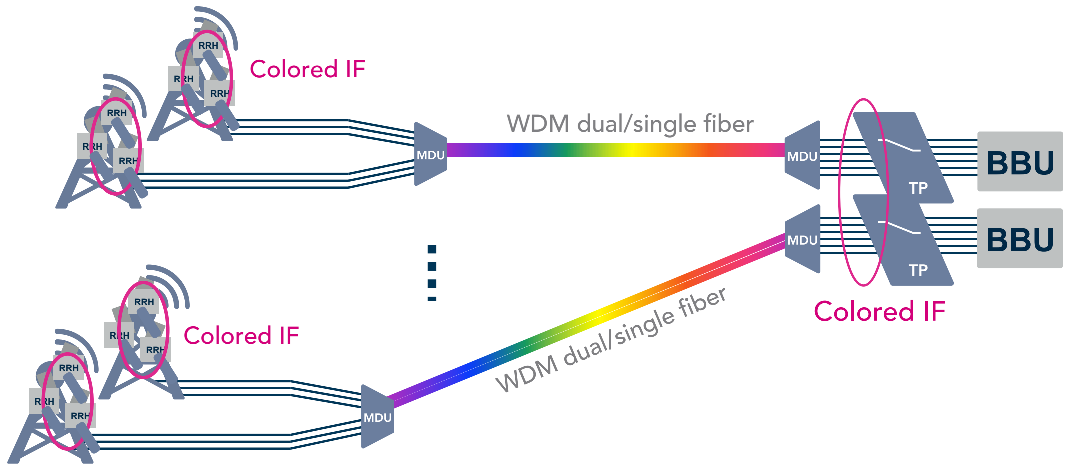
One important advantage of this approach is that as the remote equipment is all passive, it is possible to detect other external fault conditions such as cell site power failure. In this scenario, the remote cell site equipment could all fail, causing alarms in those systems and in the Infinera OCM, leading operators to assume that perhaps the fiber had been cut. But here the link status monitor wavelength would remain up, showing the operator that the fiber isn't cut and another issue has caused the loss of all systems, such as cell site power failure or an environmental issue such as flooding.

Active Wavelength Monitoring

Active wavelength monitoring takes passive wavelength monitoring one step further and adds active elements to the network, but purely for management reasons, not for any transport reasons.

This approach uses the same passive infrastructure at the cell site but adds an active transponder at the BBU site to allow additional management capabilities. In the RRH and on the corresponding colored interface in the transponder, colored CPRI pluggable optics are used that support digital diagnostics monitoring (DDM).

DDM adds a management channel to the embedded data channel and allows the RRH site to report management data that is then extracted in the BBU site in the transponder. The management data is reported in real time and includes parameters such as optical input/output power, temperature, laser bias current and transceiver supply voltage.



Semi-passive Mobile Fronthaul – Active Wavelength Monitoring

Fig 8: The Infinera Semi-passive Option with Active Wavelength Monitoring Adds Transponders to Enable DDM Data to Be Extracted in the BBU Site.

Option 3 – Passive WDM – Simple Networking with Zero Power Consumption

Passive WDM is the simplest way to add WDM networking to a fronthaul network. The Infinera XTG Series is a widely deployed passive WDM platform with characteristics that make it a leading solution in this area of networking.

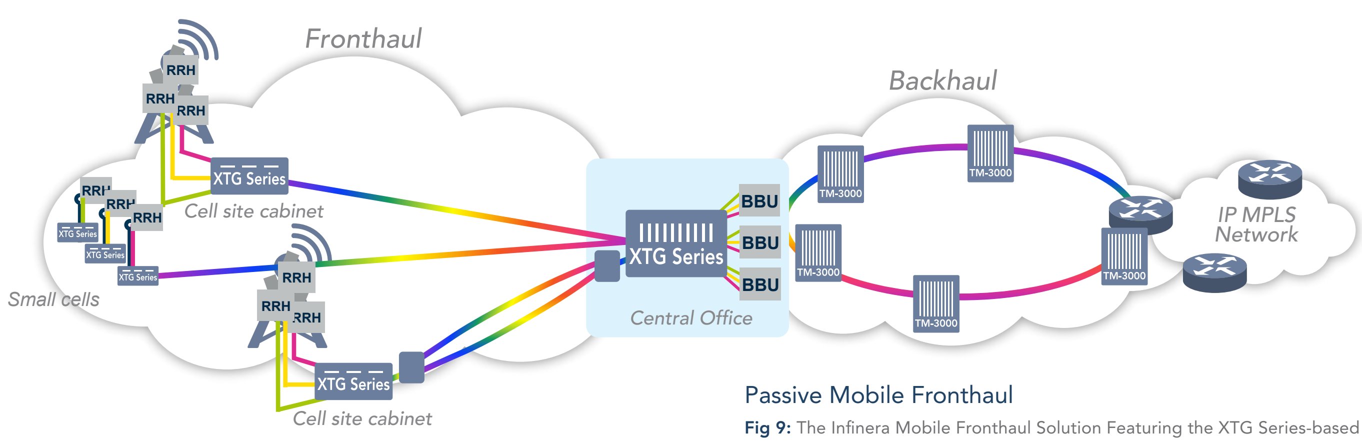
The XTG Series has an extremely broad range of networking options including coarse wavelength-division multiplexing (CWDM) or dense wavelength-division multiplexing (DWDM), single fiber or fiber pair, point-to-point or ring architectures using terminal or add/drop filters and scalable capacity up to 80 wavelengths.

The platform also offers strong optical performance with excellent optical specifications (insertion loss, etc.), upgrade ports allowing simple hitless capacity expansion without loss of spectrum/channels and monitor ports to assist fault finding.

The XTG Series supports an extended temperature range and a range of mounting options for racks, street cabinets or splice chambers, allowing deployment outside traditional telco environments.

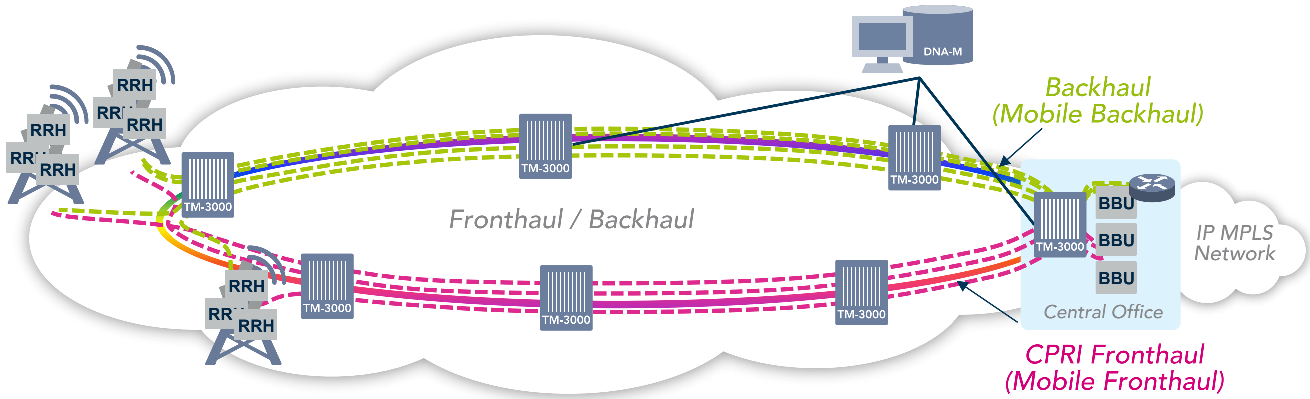
For mobile fronthaul, 16-channel CWDM or higher- capacity DWDM can be used depending on the specific requirements of the network. In this case C/DWDM small form-factor pluggables (SFP) supporting the CPRI/OBSAI protocol are used directly in the RRH to provide the necessary WDM wavelength signal. The SFPs may also support a broad industrial temperature (I-Temp) range, which may be experienced at antenna locations. In order to use these SFPs, the RRH equipment should have an SFP option or allow the use of third-party SFP units.

Once the RRH is equipped with WDM optics, the XTG Series components can be used to provide the best networking options. Furthermore, it optimizes the available fiber with multiple RRH to BBU connections sharing the same fiber(s) in either ring or point-to-point architectures to save on the amount of fibers needed in the network.



Passive Mobile Fronthaul

Fig 9: The Infinera Mobile Fronthaul Solution Featuring the XTG Series-based Passive WDM Option Enabling Low – or Even No – Power Consumption.



Same Network Used for Both Mobile Fronthaul and Mobile Backhaul Services

Fig 10: Mobile Fronthaul and Mobile Backhaul Networks Overlapping. Infinera Has Solutions in Both Areas, Both Based on the Same XTM Series, Providing Synergy Benefits.

All these options are extremely compact and are totally passive, requiring no power, and thus helping the network operator with their cost-reduction goals. Passive WDM networks can support optical paths of up to approximately 80 kilometers (km) and are therefore ideally suited for mobile fronthaul networks.

As the RRH to BBU connection can extend over long outside plant fiber distances, protection against fiber cuts and other faults should be provided. Some purely passive WDM systems just consist of optical filters and are not able to provide adequate protection. The XTG Series, however, provides protection with a fiber protection unit.

This unit splits the signal into two identical signals, which can then be routed in diverse routes around the network to the far end, where a second unit recombines the signals and switches between them in case of a network failure such as a fiber cut. This can be used on both point-to-point and ring architectures.

Practical Deployment: Mixing Up Fronthaul and Backhaul

The Infinera passive XTG Series and active XTM Series have many features that make them particularly suitable for mobile fronthaul networks. But deployment of fronthaul is often not as simple as looking at the fronthaul in total isolation from the wider network.

When looking at a specific geographic area that requires mobile fronthaul, there will be traffic over the same region that is traditional mobile backhaul traffic.

Some cell sites may maintain the traditional RRH/BBU colocation, while others may have migrated to a fronthaul architecture. Some may be macro cells while others are small cells or aggregation points for small cell traffic. Even if the entire network migrates to a fronthaul architecture, the cell sites furthest away from the core nodes will have a fronthaul network to a central office. This fronthaul network is then "backhauled" over the same network as the fronthaul traffic for those nodes that are closer to the core.

Of course it is possible to totally separate fronthaul and backhaul networks with completely separate infrastructure. But this is unnecessary and more costly.

For more information on mobile fronthaul solutions from Infinera please visit http://www.infinera.com/applications/mobile-transport/mobile-fronthaul. Both the mobile fronthaul and the mobile backhaul solutions are managed with the same management system: DNA-M.

The Infinera mobile fronthaul solution can carry legacy mobile backhaul traffic as alien wavelengths.

Conclusion

Centralized-RAN, C-RAN and mobile fronthaul are emerging technology trends that have great potential in helping address the ongoing rapid growth in mobile traffic by reducing power, space, truck rolls while improving agility and scale. Optical networking will play an important role in meeting the goals of these network architecture initiatives. However, while it may appear simple on the surface, the technical challenges in meeting the strict latency and synchronization requirements of mobile fronthaul networks are challenging.

Infinera brings a wealth of experience in WDM access technologies and offers active, semi-passive and passive mobile fronthaul options, each with unique advantages to the network operator. The XTM Series, with its strength in signal and synchronization transparency, its wide support of the CPRI/OBSAI rates and broad active product range, coupled with the XTG Series broad passive product range, provides network operators with a robust toolkit to address the challenges presented by mobile network.