C-RAN Mobile Architecture Migration

Economic Benefits of Fujitsu's Smart xHaul Solution

EXECUTIVE SUMMARY

Mobile service providers are facing increasing bandwidth demands and adapting mobile network architectures in response. One such adaptation is the deployment of centralized radio access networks or C-RAN architectures with performance improvements up to 30% and reduced costs up to 50%[1]. The deployment of C-RAN architectures has given rise to deployment of optical mobile fronthaul solutions to deliver low-latency, high-bandwidth connectivity between the remote radio heads and the base-band units hosting the electronics.

There is a plurality of mobile fronthaul deployment models that service providers may consider when deploying a C-RAN architecture. They range from point-to-point (P2P) dedicated dark fiber with one common public radio interface (CPRI) signal transported per fiber pair to sophisticated dense wave division multiplexing (DWDM) solutions with advanced intelligence and service assurance that support up to 80 CPRI signals per fiber pair.

In this paper, we analyze the total cost of ownership (TCO) and compare the economics of P2P dedicated dark fiber to that of Fujitsu's Smart xHaul solution. We analyze the operational expense (opex) of the Smart xHaul solution to competing mobile fronthaul alternatives. All analyses are performed over five years with deployment of 150 macro cell sites, each supporting three frequency bands and three sectors. We also consider deployment of five small cells per macro cell site for a total of 750 small cell deployments.

The results of our analyses demonstrate that although the capital expense (capex) of deploying a DWDM solution such as Smart xHaul is multiple times greater than the capex of P2P dark fiber, the reduction in fibers due to signal multiplexing and the advanced service assurance capabilities delivers 66% lower opex and 30% TCO savings. When looking at competing DWDM solutions, we also find that the advanced functions of the Smart xHaul solution deliver 60% lower opex associated with detecting, identifying root cause and resolving field issues.

KEY FINDINGS

- Fujitsu's Smart xHaul solution offers advanced performance monitoring and service assurance
- In a five-year analysis, Smart xHaul produced **30% TCO savings** vs. P2P dark fiber
- When leasing fiber, Smart xHaul produces **66% lower opex** than P2P dark fiber
- Smart xHaul **TCO cross-over occurs in Year 2** of the five-year analysis vs. P2P dark fiber
- Smart xHaul advanced RCA and Issue Resolution delivers **60% lower category opex** than competitive DWDM solutions

INTRODUCTION

Many mobile service providers have begun migrating to C-RAN architectures in response to the 45% compound annual growth rate in global mobile traffic from 2016–2022[2]. In 4G LTE/LTE-Advanced networks a traditional macro site radio base station is referred to as an eNodeB and contains both the radio frequency (RF) functions to transmit digital signals over the air at specific frequencies and frequency bands as well as the advanced electronics necessary to create and decode the bit streams that are transmitted and received. One of the biggest challenges with this deployment model is that every place the mobile operator needs RF coverage requires deployment of an eNodeB with both the RF and electronics.

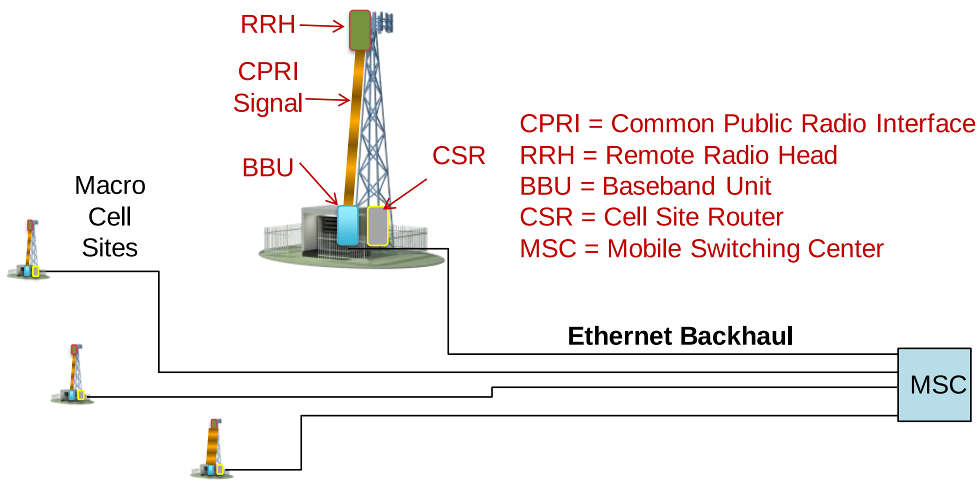

Figure 1. eNodeB Distributed Macro Cell Site Deployment Model

Service providers know that mobile subscribers migrate throughout the day, resulting in different hot spots in the network at different times. As an example, urban centers and the central business district (CBD) achieve maximum mobile network utilization during weekdays and traditional working hours as the CBD is where a high percentage of the metropolitan population work. It is also typical for the suburbs to see peak utilization during the evening hours when many commuters return home. By viewing the flow of mobile traffic throughout the day, one sees that deploying both RF and electronics with every eNodeB results in excess electronics capacity in the suburbs during weekdays and excess capacity in the CBD at nights and weekends.

One way for service providers to reduce mobile networking costs is to better align the total electronics capacity of the network to the total network utilization at any given time. By separating the electronics into a centralized pool where multiple radios or remote radio heads (RRH) can have access to it, we can drive down capital costs and eliminate the excess electronics capacity. With centralized electronics, the network can also make easier handoff and dynamic RF decisions based upon the input from a combined set of radios at a centralized location.

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[1] China Mobile Research Institute, “C-RAN the Road Towards Green RAN,” 2013.

[2] Ericsson Mobility Report, Nov. 2016.

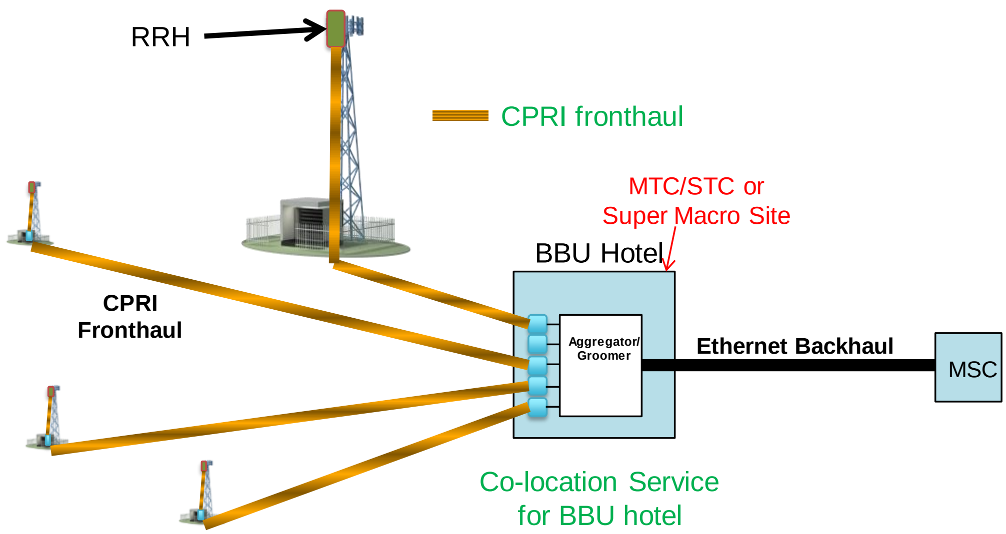

Figure 2. C-RAN Architecture

CHALLENGES FOR SERVICE PROVIDERS

With high-density urban centers, countries in the Asia-Pacific region, specifically Korea and Japan, were early adopters of C-RAN architectures. SK Telecom has more than 150,000 RRHs deployed today; NTT Docomo has more than 100,000 RRHs. Numerous Tier-1 service providers are migrating toward C-RAN deployments. In North America, AT&T, Verizon and Telus have recently begun deployment of C-RAN architectures with mobile fronthaul connectivity.

As service providers deploy C-RAN architectures, they are faced with many challenges and decisions, including selection of their mobile fronthaul solution. The CPRI protocol is extremely latency sensitive, which results in a latency link budget that limits the distance between RRH and base-band units (BBU) to less than 20 km. The mobile fronthaul transmission equipment must minimize its latency contribution or this distance will become even shorter. Common public radio interface (CPRI) signaling is also highly inefficient, resulting in as much as 16x transmission bandwidth versus the actual data rate seen by the mobile applications. As an example, a 150 Mb/s wireless data communication rate for mobile devices may require as much as 2.64 Gb/s in mobile fronthaul transmission capacity depending upon the configuration of the RRH and BBU. That is why CPRI-7, which supports 9.83 Gb/s CPRI transmission rate and 600 Mb/s wireless data rate (for example, by a multi-MIMO, 20 MHz LTE configuration), is commonly deployed today. With 45% annual mobile traffic growth, CPRI latency sensitivity, up to 16:1 CPRI transmission inefficiency, and a need for service providers to have some headroom for growth, the BBU to RRH transmission medium is optical with a 10 Gb/s data rate.

If 10 Gb/s optical connectivity is the predominate choice for BBU to RRH connectivity, how many CPRI signals are generally needed per macro cell site? The answer partially depends upon the number of sectors and the number of frequency bands supported by each RRH. Three-sector RF transmission is a common deployment model used to minimize RF interference. Use of three frequency bands to provide adequate spectrum and throughput is also quite common. Such a configuration then requires a total of nine CPRI signals per RRH. It is also common for the RRH deployment location to include an additional signal for Ethernet backhaul of 2G/3G traffic. Thus, a total of 10 signals may be necessary to service a single macro cell site. It is also common to extend the macro cell site radio coverage area and service capacity with additional small cell RRH deployments. Small cells RRHs may also be sectorized and support multiple frequency bands. In our analysis, we include five small cell RRHs supporting two frequency bands per macro, resulting in a need for 10 incremental CPRI signals to feed through the macro cell site location. The composite fronthaul transmission picture then begins to take shape: with 20 CPRI signals per macro RRH deployment location.

MOBILE FRONTHAUL SOLUTIONS

As outlined previously, current C-RAN architectures require many signals (CPRI and/or Ethernet) between an RRH and BBU. Mobile service providers must choose from a range of mobile fronthaul solutions with the two extremes being a dedicated dark-fiber passive solution that utilizes a fiber pair per transmitted signal (P2P dark fiber) or an active, dedicated transmission solution that multiplexes up to 80 signals per single fiber pair (DWDM). P2P dark fiber is generally known to have significantly lower capital expenses (capex), but the solution also utilizes many fibers. Service providers must then consider operational expenses (opex) and total cost of ownership (TCO) when selecting the right mobile fronthaul solution.

Mobile Fronthaul Challenges	Comments
1. Latency sensitivity	20km or less, results in fiber optic transmission
2. CPRI inefficiency	As much as 16:1, leads to 10G, CPRI 7 or higher
3. Signal count per RRH location	>20 possible (sectors, bands, small cell, 2G/3G)
4. RCA, resolution and service assurance	Smart xHaul extensive, P2P dark fiber limited
5. Capital expenses	P2P dark fiber low, DWDM more expensive
6. Operational expenses	Fiber lease, power, maintenance all play a role

Table 1. Challenges Facing C-RAN and Mobile Fronthaul Deployments

P2P Dedicated Dark Fiber

The P2P dedicated dark fiber solution uses grey light pluggable optics to connect the BBU to each macro or small cell RRH. Each CPRI signal or 2G/3G backhaul signal is transmitted over a unique fiber pair. Thus, the macro RRH site with three sectors and three RF bands requires nine fiber pairs. The 2G/3G backhaul traffic also requires a separate dedicated fiber pair resulting in a total of 10 fiber pairs to deliver xHaul connectivity to a single macro site. The small cell RRHs also then require two fiber pairs to support a single sector, dual RF band configuration.

The dedicated dark fiber solution is straightforward, but it is fiber intensive and simplistic in terms of performance monitoring. Other than loss of signal or bit error rate alarms, there is generally very little diagnostics or performance monitoring built into the solution. As an example, if the network topology changes because of network splicing or macro RRH insertion, path latency could increase and exceed CPRI latency budget. With P2P dedicated dark fiber, there may not be any indication as to the root cause of the problem other than the possible errors at the RRH or increased customer care incidents as reported by mobile subscribers.

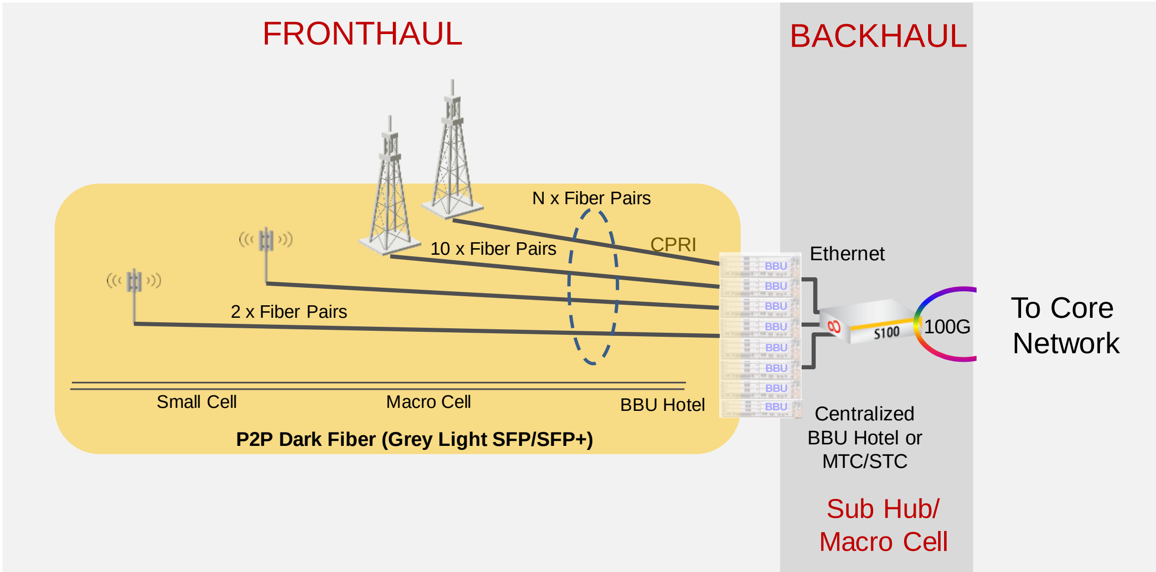

Figure 3. Point-to-Point Dedicated Dark Fiber Solution

Smart xHaul with DWDM

In contrast with a dedicated dark fiber solution, the Smart xHaul solution is flexible and supports multiple network architectures: P2P, hub-n-spoke, optical rings and hybrids of these topologies with or without redundant paths. To prevent in-service call drops between RRH and BBU during link failover, integrated differential delay compensation automatically measures and adjusts for latency differences in active and standby paths. The solution minimizes fiber utilization by enabling up to 80 signals to be multiplexed onto a single fiber pair. The solution also supports additional advanced performance monitoring and service assurance capabilities, enabling rapid detection, analysis and resolution of issues before impacting the mobile subscriber. By rapidly detecting and pinpointing issues, the Smart xHaul solution ensures the right technician with the correct skills is assigned and no-trouble-found incidences are avoided.

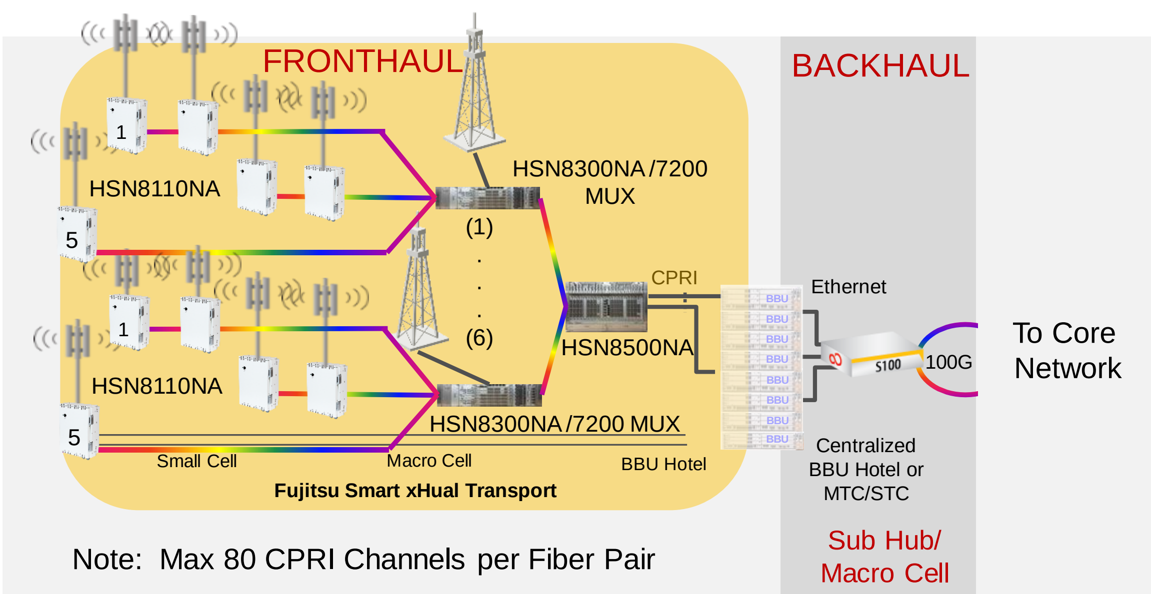

Figure 4. Smart xHaul Solution with DWDM Support

Functions	Fujitsu Smart xHaul	P2P Dark Fiber
Bit error rate testing	Yes	No
Forward error correction	Yes	No
Delay compensation	Yes	No
Distance measurement	Yes	No
Loopback	Yes	No
OAM	Yes: AIS, RDI	No
CPRI monitoring	Yes	No
Fiber monitoring	Yes: LOS	Yes: LOS
Performance monitoring	Yes: DDM, CV (or BIP), ES, SES, UAS	No

Table 2. Advanced Performance Monitoring and Service Assurance

MOBILE FRONTHAUL ECONOMIC ANALYSIS

ACG Research developed a mobile fronthaul economic modeling tool with more than 40 distinct input variables. The variable input parameters include the number of RRH and small cells, RRH configurations, equipment power utilization, equipment rack space utilization, labor hours for various tasks, labor rates and equipment pricing. Following discussions with multiple service providers, we created a baseline configuration consisting of one BBU location serving six macro RRH sites, each with a total of five small cell RRHs extending radio coverage per macro RRH site location. This six macro RRH, 30 small cell RRH cluster is the atomic unit for the deployment model. We then selected a total of 25 atomic units or clusters for deployment over the five-year analysis window. The main input parameters for the economic analysis are in Table 3.

Modeling Input Parameter	Value
Macro cell site per BBU hotel	5
Sectors per macro cell site	3
Frequency bands per macro cell site	2
Small cells per macro cell site	5
Sectors per small cell	1
Frequency bands per small cell	2
Fiber pair leasing cost per month	$300
CPRI rate	CPRI-7

Table 3. Partial Input Values for Economic Analysis

Total Cost of Ownership

Total cost of ownership is the result of looking at both capital and operational costs. The Smart xHaul solution delivers 30% TCO savings over five years versus the P2P dark fiber alternative. Although the capex is significantly higher for Smart xHaul, the opex is considerably lower. As seen in subsequent graphs, the sheer volume of fibers needed to service the P2P dedicated dark fiber solution dominates the economic analysis.

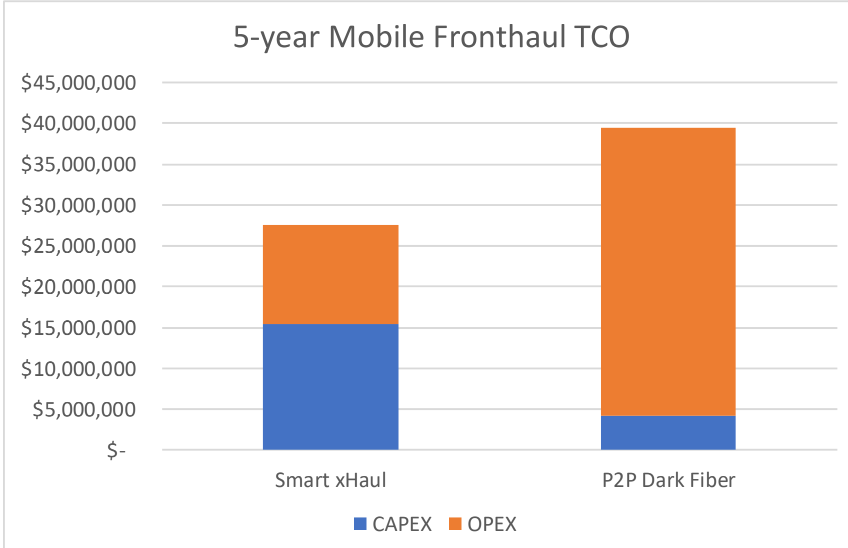

Figure 5. TCO Analysis (Capex + Opex)

Operational Expense

The Smart xHaul solution delivers 66% lower opex over five years versus dedicated P2P dark fiber. The overwhelming operational expense contributor for P2P dark fiber is the monthly recurring cost for leasing the fiber. Each of the six macro RRH atomic clusters requires 120 fiber pairs for P2P dark fiber but requires only 24 fiber pairs for the Smart xHaul solution. Although fiber leasing costs vary widely based upon geography, 20 km fiber leasing costs are generally hundreds of dollars per month per fiber pair. For purposes of this analysis, we utilized $300 per month per pair. Service providers may also pay a one-time non-recurring-engineering (NRE) fee of thousands of dollars when signing a multi-year fiber lease agreement. Because NRE fees are so variable and can significantly impact the economic model, we set them to zero. Even mobile service providers that are encouraged to utilize their company's own fiber network (for example, in-region) should consider the cost of utilizing so much fiber for mobile fronthaul. Companies generally have internal transfer pricing between divisions to enable accurate cost accounting when assets are utilized across different business units. It is common for a fixed-line business unit to assess an internal monthly transfer fee to the mobile business unit for mobile fronthaul or backhaul fiber utilization.

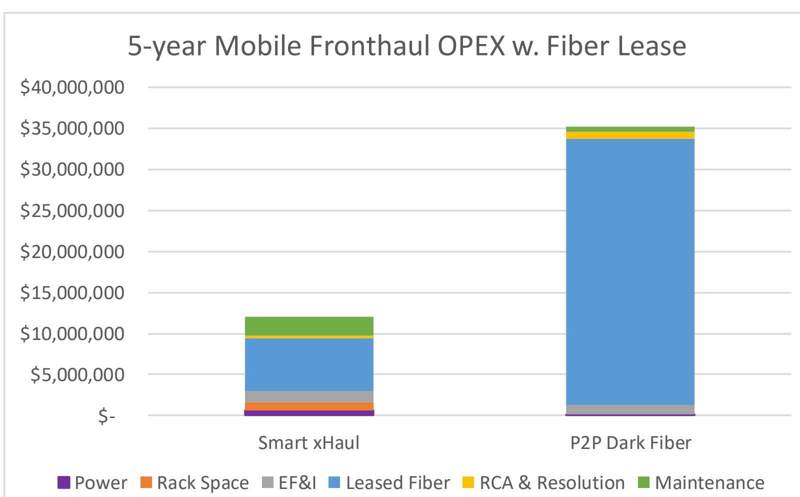

Figure 6. Opex Analysis

Capital Expense

When compared to utilizing pluggable grey optics in a P2P dark fiber solution, Smart xHaul is more than three times the capital cost. The ability of Smart xHaul to multiplex up to 80 signals per fiber pair along with the advanced intelligence and service assurance capabilities to maintain signal integrity and resolve issues rapidly requires additional design and component integration that translates into higher capital expense. However, we must consider opex costs to get a complete total cost of ownership perspective.

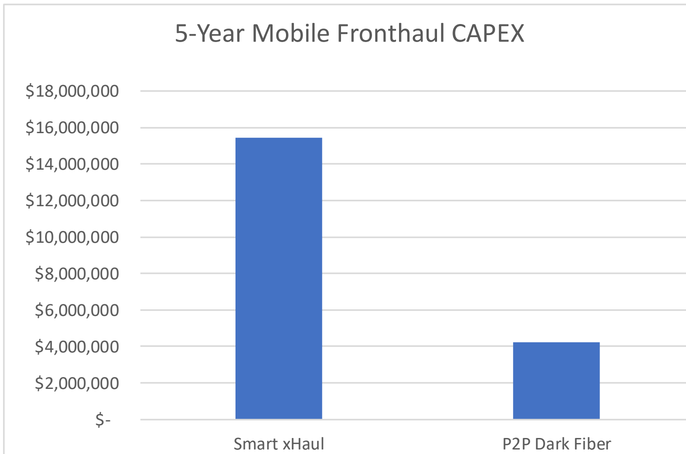

Figure 7. Capex Analysis

ADVANCED PERFORMANCE MONITORING AND SERVICE ASSURANCE

One of the industry-leading features in the Smart xHaul solution is the ability to distinguish between optical transport and radio service impairments, which are identified by inspecting the actual CPRI packet frames. When combined with the other performance monitoring and service assurance capabilities, CPRI frame inspection results in rapid issue identification, assignment and resolution. Without CPRI frame inspection, a service provider may send a radio/RRH technician to tackle what is a mobile fronthaul transmission issue, delaying resolution and resulting in the need to send a second technician with the proper skills. The net economic impact is increased operational costs. Based upon ACG Research's economic modeling, the Smart xHaul solution delivers 60% lower operating costs in the RCA and Issue Resolution category (which is a component of total opex) than competitive alternatives. The ability to detect, isolate and resolve issues is an important one that not only maintains a high quality of service but also saves money and resources for the service provider.

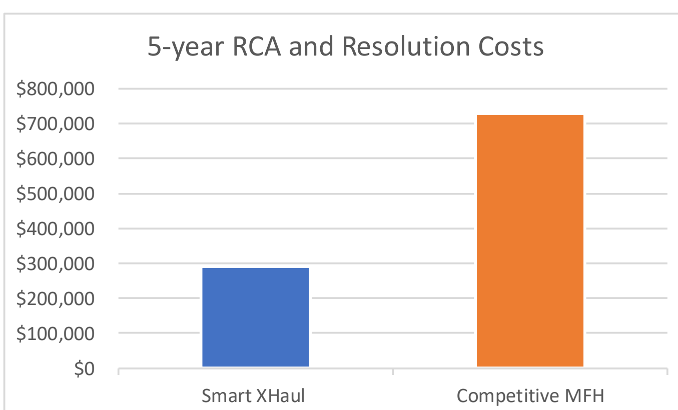

Figure 8. RCA & Resolution Costs for Smart xHaul vs. Competitive Alternatives

ADDITIONAL CONSIDERATIONS

The following are additional considerations to assist service providers in making their mobile fronthaul transmission decisions.

- We did not quantify the financial impact of changes to subscriber churn or quality of experience in our economic modeling. Although the advanced performance monitoring and service assurance capabilities of the Smart xHaul solution should contribute to increased quality of experience and subscribers' satisfaction, we could not isolate and correlate the positive impact of Smart xHaul to these critical mobile service provider metrics.

- We did not consider the migration to non CPRI fronthaul. Although the industry is working in 3GPP and IEEE with mid-split architectures that will eliminate the CPRI protocol in future RRH/BBH connections, the standards are not finalized and neither are the product implementations.

- 5G will drive a fiber-deep architecture and exacerbate the need for reliable high-bandwidth transmission capacity. Although the significantly higher performance of 5G networks will evolve mobile fronthaul into time-sensitive Ethernet, the need for reliable, low-latency, high-bandwidth transmission using advanced performance monitoring and service assurance capabilities will remain.

CONCLUSION

ACG Research's economic model compared capex, opex and TCO between two fronthaul solutions: P2P dedicated dark fiber and the DWDM-based Smart xHaul solution. Although the Smart xHaul solution requires significantly greater capex than P2P dark fiber, the reduction in fibers with signal multiplexing and the advanced service assurance capabilities of the Smart xHaul solution deliver 66% lower opex and 30% overall TCO savings when assuming leased fiber connectivity. When looking at competing DWDM solutions, we also found that the advanced functionality of the Smart xHaul solution delivers 60% lower cost in the field-issue RCA and Issue Resolution opex category. Service providers seeking to minimize opex and fiber utilization should consider the Smart xHaul solution for mobile fronthaul applications.

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