CERAGON WHITE PAPER

Mobile Backhaul: Fiber vs. Microwave

Case Study Analyzing Various Backhaul Technology Strategies

Tzvika Naveh, Solutions Marketing Manager

October 2009

Introduction

The advent of 3G and 4G mobile services brings with it a surge in data traffic, which in turn puts a strain on existing cellular networks. Nowhere is the demand for more available capacity felt more than in the Backhaul.

Looking into their backhaul options, operators can choose one of three physical mediums; copper, fiber or microwave. A recent report by Heavy Reading Research[1] estimates that microwave represents nearly 50% of global backhaul deployments. As shown in Figure 1, the report also finds that the use of microwave is not distributed evenly across nations. In fact, microwave is frequently deployed in developing markets and in emerging markets in which fiber is not available. Microwave is also frequently used in developed markets as an alternative to costly line-leasing services offered by Telecom incumbents.

Copper networks, that according to Heavy Reading make up for nearly 20% of all backhaul deployments, are likely to decrease due to their limited capacity support and their inability to scale in a cost efficient manner. Looking forward, fiber is expected to take the place of copper based wire-line connections, and increase its overall share (albeit not at the expense of Microwave).

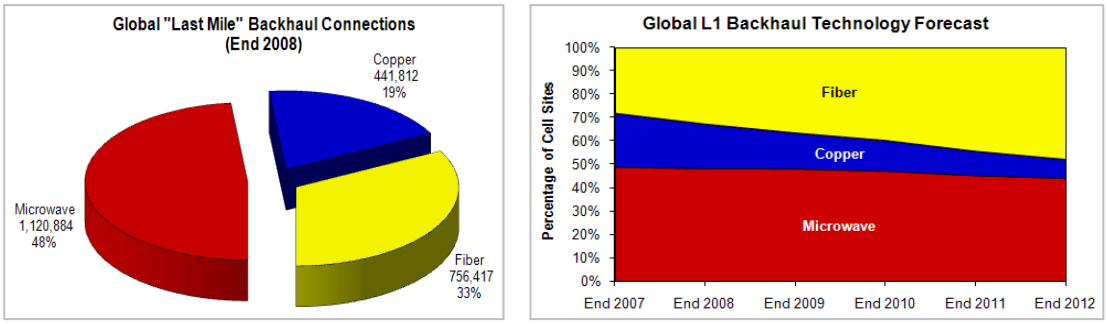

Figure-1: Estimate for the global share of cell-site connectivity of microwave fiber and copper at the end of 2008 and Global layer 1 backhaul technology forecast (Source : Heavy Reading)

This paper compares two self-owned backhaul alternatives: fiber and point-to-point microwave. In the following chapters we will attempt to shed some light on the considerations that impact the decision making process of operators when choosing the right backhaul option for their network. We will also cover regional aspects and present a case study based on real life parameters.

[1] *Ethernet Backhaul Quarterly Market Tracker, Heavy Reading Research, July 2009*

Comparing Microwave with Alternate Technologies

This discussion focuses on fiber vs. microwave assuming a cost and capacity evolution as described in Figure 2 below.

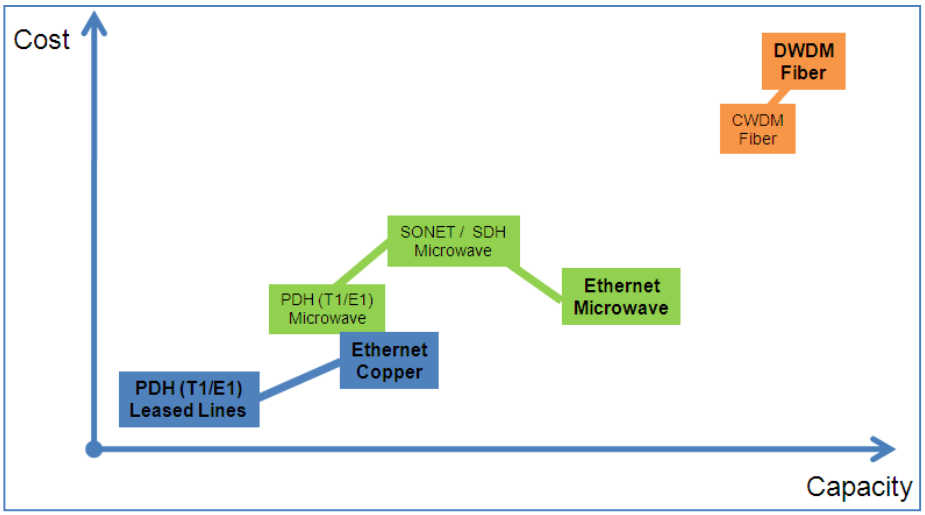

Figure-2: Mobile backhaul technology evolution. Ethernet microwave appears as a reasonable solution as capacity increase and backhaul cost decrease.

For the sake of discussion let us consider the relevance of two additional alternatives infrastructure; Copper and Cable. Copper based services are designed for E1 or DS1 services. Supporting 1.5-2Mpbs, Copper lines do not scale easily to provide adequate bandwidth at a distance above few hundred meters to support broadband usage of 3G and emerging LTE/4G technologies. For longer distances, bonding configurations are required in which monthly costs increase linearly with bandwidth requirements. xDSL technology was thought to be a good method for offloading data traffic, but this too was abandoned in favour of fiber.

Another promising contender is backhaul based on Multiple System Operator (MSO) infrastructure leveraging DOCSIS 3.0 high capacity to backhaul wireless base stations. Two reasons make it less relevant for this discussion; First, it is a shared media technology, making it difficult to deploy with the right traffic engineering. Secondly, MSO and Hybrid-Fiber-Coax (HFC) foot print is limited to only a few countries such as the US, UK and Germany. In rest of the world, Cable footprint is considered insignificant. On the other hand, in places where MSOs play and own substantial fiber assets, they can leverage those assets to offer high capacity, fiber based Ethernet services for cell sites situated near their POPs.

Operators have traditionally used the following basic strategic guidelines to decide which technology to use in their backhaul:

1. **Incumbent operators**: Self deploy and rely as much as possible on existing facilities, while laying new fiber when and where an up-selling is possible. This assumes large capital resources and long-term ROI models
2. **Challenger/competitive operators**: Challengers typically have more limited resources and a limited installed base, leading to two major backhaul strategies; One is to self-deploy backhaul relying almost entirely on microwave (examples include Orange Spain and Orange UK both with over 95% microwave in their network). On the other hand, some operators opt for leasing copper or fiber from incumbents or other challengers (such as T-Mobile US that has only 5% self built microwave and relies almost entirely on leased line services).

   The reasons for choosing one way or the other are related to ownership structure, available cash during inception and long term strategic plans.
3. **Rural Broadband operators**: Mainly self deployed microwave. Leased fiber may be used for some of the core when the price is right.

Table 1 summarizes briefly the main difference between microwave and fiber

	Microwave	Fiber lines
Capacity	• Up to several Gbps	• Unlimited
Regulation	• Requires spectrum • Visual impact considerations	• Requires right of ways and infrastructures; renovation construction works after trenching
Distance influence on Costs and Deployment Time	• Cost per link with some incremental cost with the distance • Fast deployment time	• Costs increase per feet/meter • Deployment time increases linearly with distance
Terrain	• Suitable for any terrain • Requires line-of-sight between two link end-points	• Becomes costly when trenching in difficult terrain (Mountains, Desert, swamps, rocky plains or Jungles) • Accessibility - requires access for vehicles along the trenching path
Reuse options	• Equipment can be disassembled and relocated somewhere else	• Fiber, in most cases, cannot be relocated • Copper ducts may be reused for fiber lines
Climate	• Influenced by climate • Adaptive modulation and a proper link planning reduces climate effects	• Normally, not influenced , except for floods

Table-1: Microwave and Fiber consideration

Regional Differences in Microwave Backhaul Adoption

Globally, an increasing percentage of new backhaul investment is in microwave. But to estimate demand, one needs to understand how acceptance differs on a regional basis as well as by each individual carrier. Several such examples are depicted in table 2 below:

Country	Carrier	Legacy Installed Base	Strategic Direction
Italy	Vodafone	Mainly microwave, following a 1995 decision to avoid reliance on Telecom Italia's leased lines	Subject to periodic review
U.K.	Vodafone	High reliance on leased lines	Aggressive shift to microwave
U.K.	"3"	Relies mainly on leased lines. Decision made in order to avoid initial CapEx hit from self-building microwave on top of an $8B 3G license fee and aggressive network rollout expenditure	Subject to periodic review, probable shift to microwave in the future
U.K.	Orange	High proportion of microwave, but early generation of point-to-point microwave now nearing end of life	Considering upgrade options including new microwave and fiber
U.S.	Sprint	High reliance on microwave, using multiple platforms	Shift in balance toward microwave
France	SFR	High reliance on leased lines	Aggressive shift to microwave
Malaysia	Maxis	High proportion of point-to-point microwave	Trialing Point-to-multipoint

Table-2: Regional Differences in Microwave Backhaul Adoption. Based on Heavy Reading Research, Backhaul Strategies for Mobile Carriers,

Regional differences depend on a number of factors including the availability of equipment, spectrum and licence costs, the extent of existing copper and fiber resources and geographical span. Microwave spectrum is more expensive, for example, in Europe than in Africa, where the regulatory conditions are relaxed and bandwidth is plentiful. The mobile affiliates of fixed operators are more likely to use the leased lines and fiber of their affiliate, while "challenger" operators will more frequently rely on microwave. While fiber essentially provides unlimited bandwidth with the aid of wave division multiplexing (WDM), it is expensive and challenging to deploy. The business case for microwave rests on its ease of deployment and greater range, performance and flexibility. CAPEX is offset by low OPEX, making microwave more cost effective.

Case Study

This case study describes two self-owned mobile backhaul scenarios, as shown in Figure 3. It assumes new cell sites (not co-located) that need to be backhauled to the RNC/MME site. We will assume the bandwidth required in the range of 25Mbps – 500Mbps and that the changing variable is the distance from the cell-site to the aggregation site.

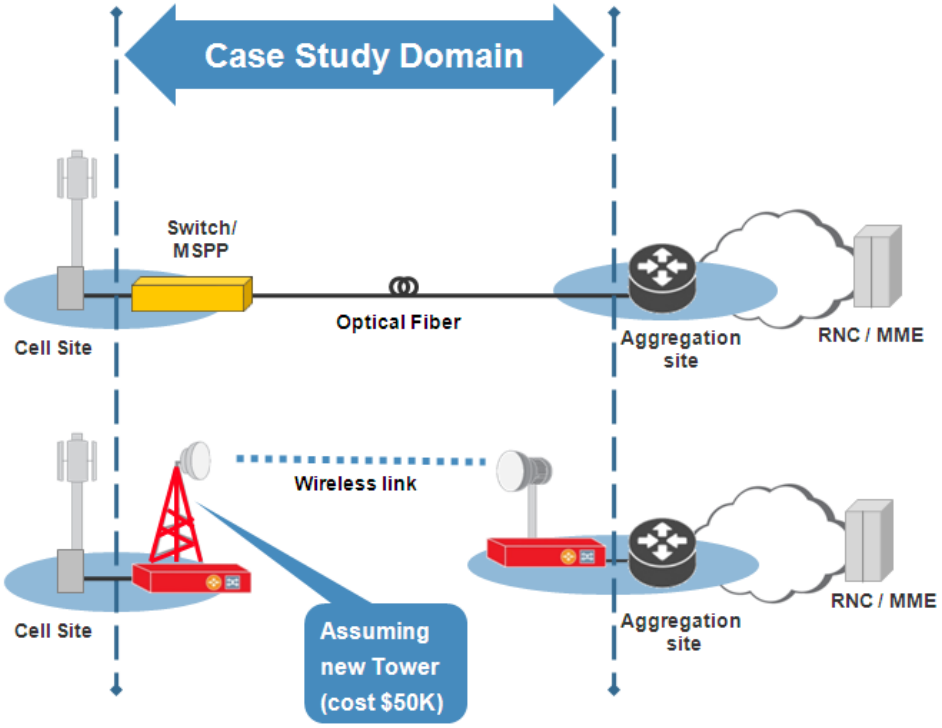

Figure-3: Mobile Backhaul Case study domain

In our example we assume that Switch/ADM equipment for aggregation is installed at Hub site. At the cell site we either have switch / MSPP connected to fiber all the way to the aggregation equipment or a licensed wireless microwave link that holds integrated Carrier Ethernet switching capabilities (e.g. Ceragon FibeAir IP-10). On the far end of the link, in the aggregation site, we assume we already have a mast in place over the rooftop for backhaul antenna.

Let us now consider the set up costs for each of the two backhaul alternatives using cost estimates that were recently published by a number of market research firms. As shown in Table 4 fiber trenching costs are highly influenced by population density (i.e. rural, metropolitan and urban), terrain and regulation. In the table below trenching costs already include the needed infrastructure renovation construction works and right-of-way.

Fiber Optic Lines		
Ethernet Switch or TDM multiplexer		$2,500
Trenching Costs [$ per meter] Including infrastructures renovation construction works and right-of-way	**Rural**	$30
	Metropolitan	$90
	Urban	$130
Fiber Costs [$ per meter] Including fiber, connectors, fusions and tests		

Table-4: Trenching fiber optic costs. Source –Wireline operator

The costs of setting up a microwave backhaul link, according to industry average, are shown in Table 5.

Wireless Microwave Link (two terminals)		
Costs - Including equipment cost, installation cost, antenna, and annual maintenance costs including license-fees	1+0 Microwave link	$16,000
	1+1 Microwave link	$30,000
	Trunk (Long haul) Microwave link	$40,000
Erect new tower at the cellular base station for wireless backhaul		$50,000
Total 1+0 Microwave link (including new tower setup)		**$66,000**
Total 1+1 Microwave link (including new tower setup)		**$80,000**
Total Trunk (Long haul) Microwave link (including new tower setup)		**$90,000**

Table-5: Wireless point-to-point microwave link costs

In order to compare fiber and microwave not only according to cost and capacity parameters, but also in terms of reliability and distance, our case study shows a 1+1 protected wireless link configuration as well as a wireless long- haul Trunk solution alongside the typical 1+0 unprotected wireless link.

Comparing the various mobile backhaul scenarios versus the increasing distance from the cell-site to the aggregation site, will result the following diagram:

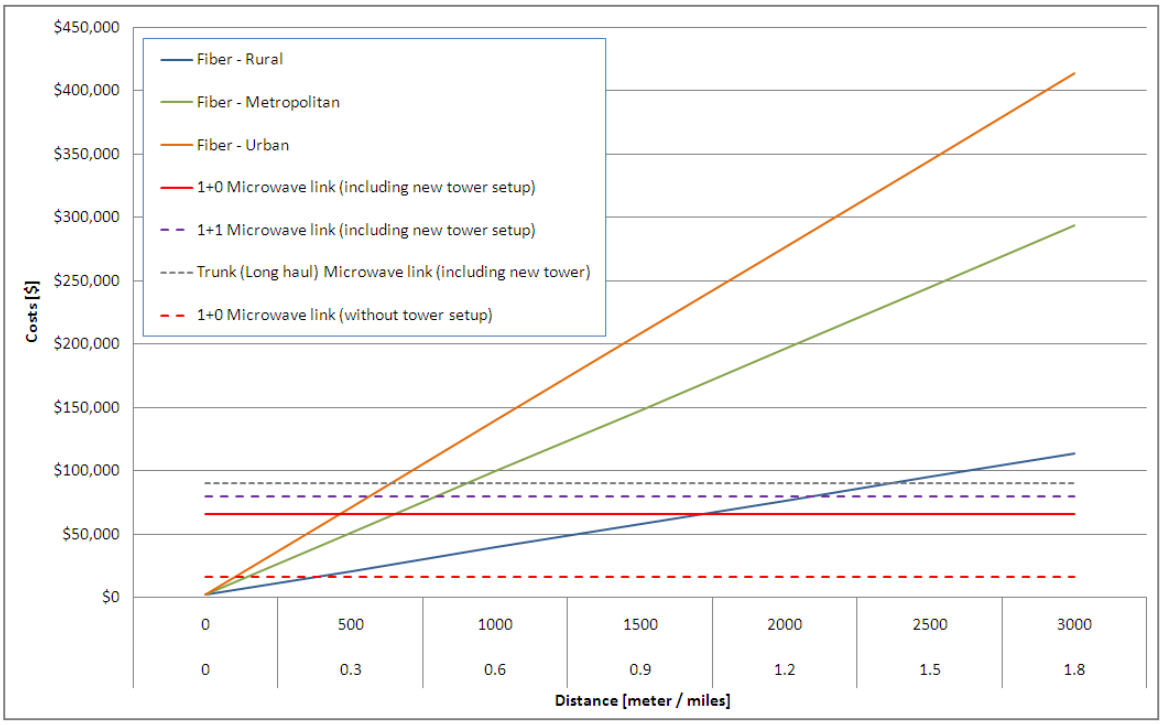

Figure-4: Microwave and Fiber backhaul solutions vs. Distance

Figure 4 clearly shows that in Greenfield base-station deployment scenarios - in which new towers need to be erected for point-to-point microwave - fiber optics are more cost effective over short distances (up to 500m/0.3 miles). Yet, in urban environments, tower set-up is not always required (antennas can be mounted on rooftops for example). In this case the microwave option becomes much more attractive even at a very short distance.

In rural environments microwave becomes more cost effective at around 1.6 Km (~1mile) when tower set-up costs are involved – though even here, new towers are not always required (in which case microwave is more attractive almost from the get-go). At distances above 2.5Km (~1.7 miles) self-owned fiber becomes so expensive, that even a protected Trunk solution becomes more cost effective.

Table 3 below sums up a number of assumptions used form the case study discussed in this section. It is important to mention these assumptions as they might tip the scale in favour of one technology or another.

Assumption	Explanation	Impact on Microwave
No up-selling opportunities	Operators might leverage existing facilities to generate more revenues	*Negative*
Need to erect a new tower for wireless backhaul	Tower cost is roughly $50,000 to construct, and in this case all cost is associated with the backhaul budget and not part of the RAN budget. Obviously a more realistic approach would share these costs as towers or roof top poles are required for the base station and therefore should not impact the microwave case.	*Positive*
Repeaters	At long distances, Microwave links would require expensive repeaters while fiber repeaters are less costly and anyhow are required only after very long distances. This is not part of the discussion as these state level investments have more complex business models	*Negative*
Time to deliver	Time to deliver is not monetized as Microwave is an almost instant media while fiber projects may take years to approve and deploy	*Positive*
Accounting rules	makes for some operators long term investments in fiber, deprecated over 20 years a smart investment while radios are deprecated in shorter cycles (5-8 years) making it a better investment for others	*Negative* / *Positive*

Table-3: Microwave and Fiber simplicity assumptions

Summary

Though fiber-based networks can easily support the rapid growth in bandwidth demands, they carry high initial deployment costs and take longer to deploy than microwave. In most cases the Return-On-Investment (ROI) in fiber installations can only be expected in the long term, making it hard for operators to achieve lower costs per bit and earn profits in the foreseeable future.

Wireless microwave backhaul solutions on the other hand are capable of delivering high bandwidth, carrier-grade Ethernet and TDM services. Microwave is suitable for all capacities up to several Gbps over a single link and may be scaled up to multiple Gbps using aggregated links techniques. Unlike fiber, wireless solutions can be set up quickly and are much more cost efficient on a per-bit basis from day one.

From the market data shown in this article and the case study it presented, it is clear that leased copper lines are becoming too costly - and too inefficient - for the increasing capacities

required for 4G/LTE backhaul. It was also shown that fiber optic sweet spot relies both in short backhaul distances and at aggregation sites where ultra high bandwidths are required. Wireless microwave solutions on the other hand, offer a versatile backhaul option for both short and long-haul deployments. At distances over several hundred meters, Microwave offers a much better cost-per-bit ratio than fiber, without compromising on availability or reliability.

The main reason for mobile operators to use microwave for backhaul is total cost of ownership. With few exceptions, microwave emerged as the de-facto solution for access and aggregation backhaul of mobile traffic, both for voice and data services.

Glossary

ADM	Add/Drop Multiplexer
DOCSIS	Data Over Cable Service Interface Specification
DWDM	Dense wavelength division multiplexing
HFC	Hybrid Fiber Coax
LTE	Long term Evolution
MME	Mobility Management Entity
MSO	Multiple System Operator
MSPP	Multi-Service Provisioning Platform
RNC	Radio Network Controller