TESTING LIFECYCLE OF A MOBILE BACKHAUL NETWORK

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In wireless network technology, mobile backhaul services are used to transport voice and data traffic from the base transceiver station (BTS) to a base station controller (BSC).

There are over 2 million base stations deployed globally. This is estimated to increase to 3.6 million by 2009. Each base station requires dedicated backhaul transmission, which traditionally consists of multiple circuit-switched T1 or 2M connections.

Today in North America, the lion's share of T1 base-station backhaul is supported by leased-line circuits provided by wireline service providers.

Leased-line infrastructure represents a significant portion of a typical service provider's operational expenditures. Globally, this accounts for $22 billion (source: Yankee Group) in operational expenditures for wireless service providers. According to the Light Reading Cable Industry Insider, dated August 2007, mobile backhaul typically represents 20-40% of a mobile operator's operating expenditures (OPEX). This percentage varies depending on how much backhaul infrastructure is owned by the carrier. From a US perspective, the mobile backhaul market is approximately $2.8 billion for 2008 and growing to $15 billion by 2011!

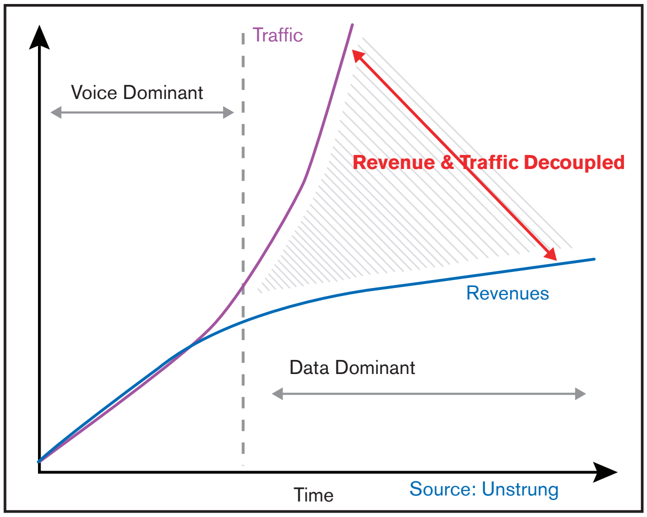

Figure 1. Wireless network traffic timescale

Figure 1 shows that with new wireless technologies (3G and soon 4G), networks now support not only voice, but also data services. However, even as these new services are being deployed, the revenue is not increasing as fast as the traffic being carried (revenue sometimes remains flat). This decoupling of the revenue and traffic is very painful for wireless operators as they do not have the revenue to justify the increase in OPEX. This is where new technologies can play a role; namely, they are being considered to connect the BTS to the BSC.

Each new technology generation (e.g., high-speed downlink packet access (HSPDA)) provides new capabilities, but also requires more bandwidth–both for the air interface and in the radio access network (RAN), sometimes referred to as the backhaul network. So, each new generation of services, especially new data services, also involves additional backhaul expenses. Whereas capital equipment and spectrum licenses are one-time expenses or fixed costs, ongoing backhaul expenses in the RAN are an entirely different matter, as they are constant and keep increasing.

Backhaul Network Architecture

As stated earlier, the mobile backhaul network connects the BTS to the BSC. The backhaul architecture varies depending on the generation of the wireless network (i.e., 2G, 2.5G, 3G or 4G) and the region. In North America, copper is the preferred facility to deliver backhaul services, whereas microwave technology is predominant in Europe. Figure 2 provides a more detailed comparative view of the situations in EMEA and North America.

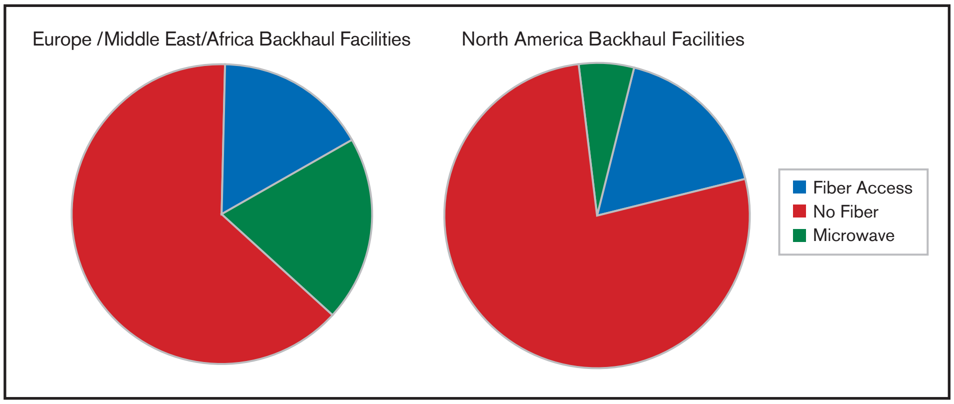

Figure 2. Mobile backhaul facilities

Understanding the various delivery architectures is crucial. According to Heavy Reading, here is the big picture:

There are approximately 2.2 million wireless base-station sites worldwide.

- Asia 50% (1.1 million)
- North America 11% (250 000)
- Central/Latin America 6% (125 000)
- Europe 26% (575 000)
- Middle East/Africa 7% (150 000)

Virtually all copper backhaul facilities use T1/2M PDH connections; this is the case in North America.

In Asia, fiber is the preferred medium. China Mobile and China Unicom have about 500 000 base stations, the majority of which are served by fiber.

The predominance of microwave in Europe/Middle East/Africa—where 60% of connections are microwave, 25% are fiber, and only 15% are copper—can be explained by the costly $2 million pricing of copper. This high price has forced an evolution to microwave early on.

Figure 3 below provides a breakdown of the backhaul connections from an installed based and new connection perspective for 2007. Although Ethernet is starting to appear more and more in new connections, it is still far behind plesiochronous digital hierarchy (PDH). This is due in part to BTS not providing native Ethernet connectivity and to wireless service providers that do not “trust” Ethernet to meet service-level agreements (SLAs) with mobile users and do not consider it a reliable solution from a QoS perspective.

With the deployment of such an infrastructure to support legacy and new wireless technologies, it is again safe to say that the test and measurement market in the wireless backhaul market is alive and well.

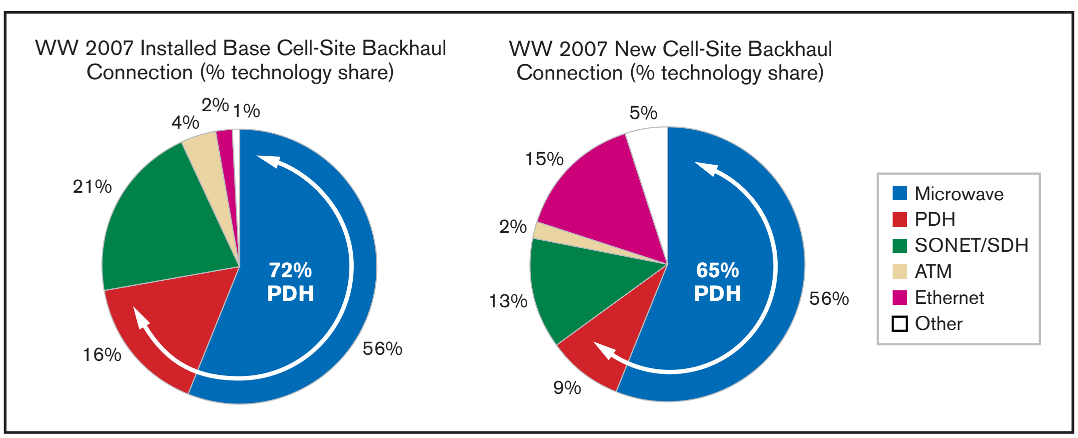

Figure 3. Breakdown of existing and new mobile backhaul connections by technology share (source: Infonetics 2007)

Overview of Time-Division Multiplexing (TDM) at the Base Station

From a US PDH bandwidth perspective, many wireless providers have up to four T1s (approximately 6 Mbit/s) per base station now and plan to increase this to up to twelve T1s (approximately 18 Mbit/s) in the near future. Figure 4 below illustrates the current and future bandwidth expectations per cellular site. It shows that the majority of links are forecast to require nearly 10 T1s, and some will require even greater bandwidth in higher-use areas. Rural areas that are expensive to cover due to their low penetration and long distances will also see the need for increased bandwidth.

With over 250 000 cellular base stations in the US today, there is a large opportunity for cable operators to offer cellular backhaul services. This potential upside illustrates the tremendous growth opportunity that exists before them.

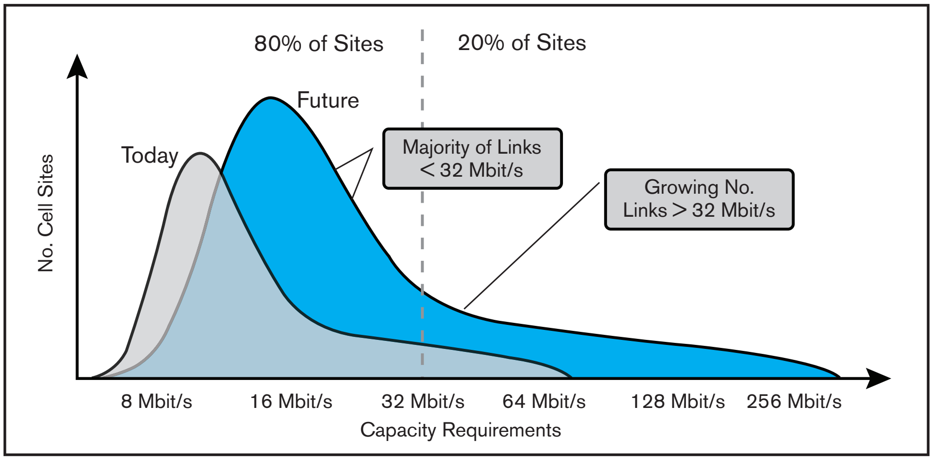

Figure 4. Estimated future bandwidth needs per cell site (source: Light Reading)

Traditionally, mobile backhaul networks have used TDM-based private lines or microwave links to connect to the base station. With carrier-grade Ethernet now being available as a service for mobile backhaul, new network architectures have been created to deliver current and future backhaul networks. Figures 5 and 6 provide a view of each network architecture.

Figure 5 demonstrates two types of mobile backhaul architectures that can be used to leverage carrier Ethernet in a hybrid configuration.

The legacy split-access network scenario uses two parallel networks: a legacy network and a metro Ethernet network (MEN) that transport different types of wireless traffic. The very-high-priority traffic (voice) is kept on the TDM network, whereas the low-priority high-bandwidth traffic is offloaded from the legacy network to the MEN, to scale network demand. This provides an economical growth path to relieve the transport bottleneck found on the mobile backhaul side of the network.

From the radio access network base transceiver station (RAN BTS) the high-priority TDM traffic is transported to the RAN network controller (NC) by the legacy TDM network. The low-priority traffic (usually data traffic) is connected to a generic interworking function (GIWF) device that will convert the TDM RAN interface (I/F) traffic to Ethernet. This device is then connected to the user network interface (UNI) of the MEN and generally encapsulates TDM traffic in pseudo-wire.

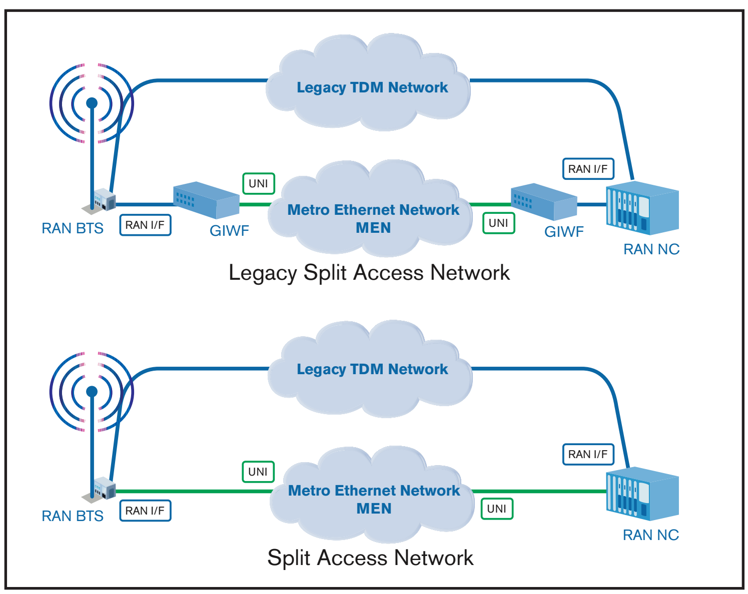

Figure 5. Split-access mobile backhaul network architecture (reproduced with permission of the Metro Ethernet Forum)

The second network architecture illustrated in Figure 5 is the split-access network. It is very similar to the legacy split-access network scenario. The only difference is that the RAN BTS has PDH and native Ethernet interfaces that can connect directly to the UNI of the MEN. The major advantage in this scenario is that the legacy TDM network provides not only the infrastructure to deliver voice services, but also supplies the much needed synchronization required by the base station.

The next mobile backhaul scenarios are depicted in Figure 6. In the legacy backhaul network, both high-priority voice and low-priority data traffic are being encapsulated into the metro Ethernet network. The generic interworking function (GIWF) will handle the encapsulation function and also recover clocking information for the base station.

Finally, the last scenario is the full Ethernet network. In this scenario, all RAN nodes are equipped with native Ethernet interfaces, and all traffic is transported via Ethernet services over the metro Ethernet network. As demonstrated earlier in this document, we are still far from this implementation.

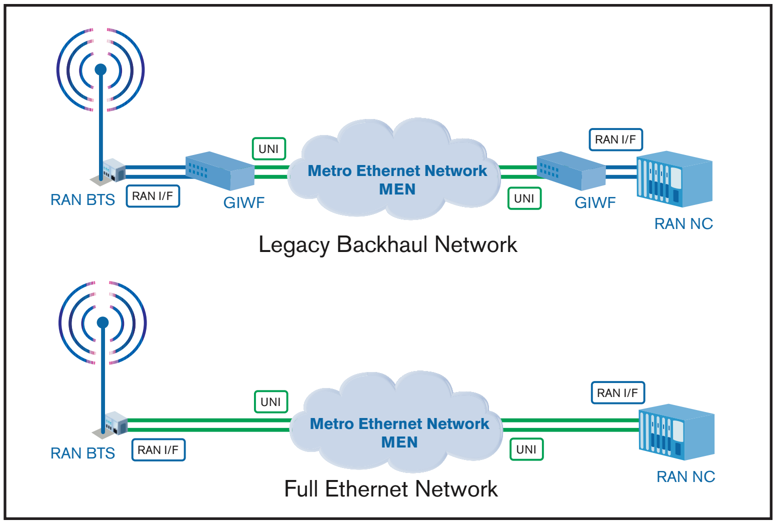

Figure 6. Ethernet mobile backhaul network architecture (reproduced with permission of the Metro Ethernet Forum)

Installation, Commissioning and Turn-Up of Mobile Backhaul Services

When mobile backhaul service providers turn up new backhaul services, it is the only time they have full access to the services they are delivering to customers. As the competition in mobile backhaul services is becoming fiercer, the need to deliver quality services has never been more important. Testing at installation, commissioning and turn-up ensures the quality of the services being delivered, thus increasing customer satisfaction.

Portable test equipment can create reports with test results and demonstrate that the service delivered meets the SLA, as specified in the customer contract. These tests can also serve as a baseline that can be saved for future reference (i.e., the "birth certificate").

As part of the SLA, there are performance criteria that need to be met: network availability and mean time to repair (MTTR) can easily be verified, but performance criteria are more difficult to prove. Demonstrating important parameters (e.g., performance availability; transmission delay and delay variation; link burstability and service integrity) cannot be done with a single ping test! An example of different SLAs can be found in Table 1 below.

The only current methodologies that are widely accepted are by using test instruments to measure the performance criteria as defined in RFC 2544 and 3393.

SLA Parameter	Service			Comments
	Ethernet Services	Mobile Backhaul services	Legacy TDM services	
Frame Delay	Typical 5 ms - best effort up to 30 ms	5 ms (max 8 ms)	50-60 ms	MEF 3 < 25 ms
Frame Delay Variation	2 ms			MEF 3 < 10 ms Service dependant
Frame Error Rate	Better than $1x10^{-6}$ (0.0001%)		-	Service dependant
Bit Error Rate	-	From $1x10^{-9}$ to $1x10^{-11}$	From $1x10^{-11}$	-
Service Disruption	50 ms			From Layer 1 perspective
Network Availability (Protected Core)	From 99.995 to 99.999%			26.28 to 5.26 min. per year
Mean-time to repair	Target 2 hour (max 4h)		Target 4 hour	-

Table 1. Service-level agreement for mobile backhaul and other services

As demonstrated in the previous section, multiple technologies can be used to deliver mobile backhaul services. Fortunately, from a test and measurement perspective, the accesses to these services are either TDM-based (T1/2M) or Ethernet-based interfaces (see Figure 7).

For TDM-based backhaul services (T1/2M), the tests generally used for installation, commissioning and turn-up are bit error rate (BER), round-trip delay and service-disruption measurements.

For Ethernet-based backhaul services, the tests generally used are throughput and latency/frame delay (according to RFC 2544), as well as frame delay variation (according to RFC 3393). Additional tests are required to validate backhaul services. The capability to measure frame loss over time will provide an idea of the long-term integrity of the service. Finally, by testing the link redundancy with a service-disruption measurement, service backhaul providers will ensure that the long-term goal of network availability can be met.

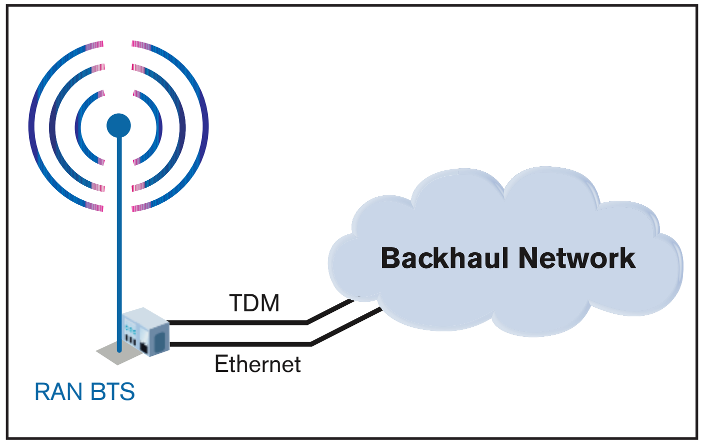

Figure 7. Interface access to mobile backhaul network

Maintaining Mobile Backhaul Networks

Wireless service providers are not only facing OPEX challenges as their backhaul networks grow exponentially, they also face new quality of service (QoS) and quality of experience (QoE) challenges beyond just voice quality and service coverage. As wireless operators add new, interactive multimedia services, they increase network complexity, bandwidth demands, and performance sensitivity, while significantly raising the bar on user expectations. To acquire and retain customers, mobile operators must focus on their subscribers' QoE and use it as a competitive advantage. This is why service quality matters to mobile operators.

For a wireless operator, most outages originate from the mobile backhaul network. By dividing the mobile network into sub-categories, it can be stated that the cause of these outages is attributable to the following components:

- Mobile backhaul services (TDM or Ethernet): up to 80%
- Base transceiver station: 15%
- RF section: 5%
- Facility: 5%
- Other 5%
- Mobile switching center (MSC) software: 3%
- Digital crossconnect system (DCS/DACS): 2%

Having the capability to monitor the mobile backhaul network will ensure that the main cause of service outage is supervised on a constant basis. It will enable mobile backhaul service providers to be pro-active in the detection of service-deteriorating problems and fix these issues before they affect service.

Figure 8 provides a view of a mobile network deployment. A monitoring system provides a complete end-to-end view of the network. With proper deployment of network monitoring probes and access to monitoring data from the different network elements, wireless and mobile service providers can benefit from the following advantages:

- Meet QoS and QoE expectations through end-to-end service visibility
- Optimize network resources to improve performance and quality
- Reduce customer churn and build loyalty
- Generate new revenue with successful service rollouts
- Cut network operating costs

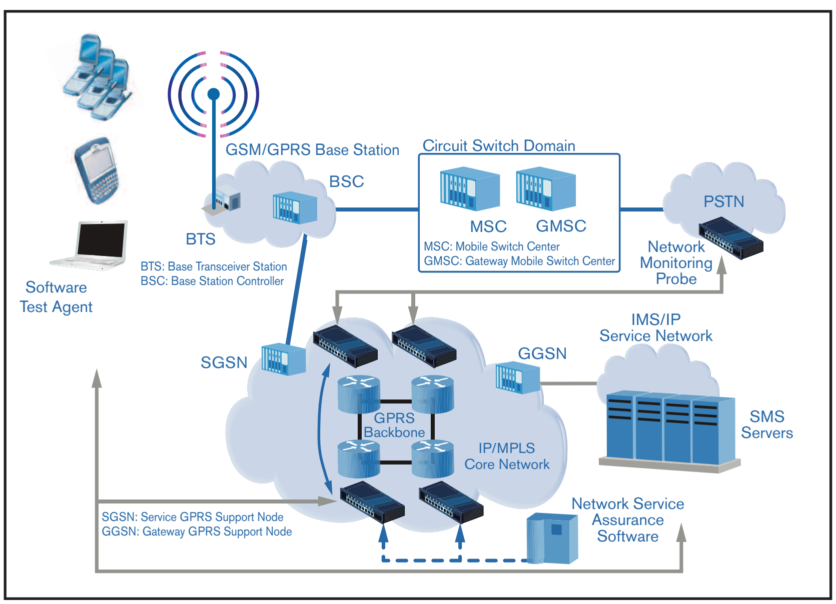

Figure 8. Mobile network deployment

Troubleshooting—Bringing Out the Artillery

Once a mobile backhaul network is deployed, a monitoring system will enable a service provider to have a 24/7 real-time view of the network. If issues occur on the network, they can react quickly and start troubleshooting without even having to send a technical resource in the field.

Unfortunately, the monitoring tool cannot always pinpoint the exact cause of a network fault. Intermittent problems or hard-to-diagnose performance issues might need additional test instruments to be resolved. The tools used during the installation and commissioning portion of the lifecycle can be used to find those hard-to-diagnose problems. The advanced features of these test instruments will help during these times by providing the "birth certificate" of the circuit that was created during the turn-up phase can be used has a performance baseline for the defective circuit.

The capability to perform in-service monitoring provides a view of the network without having to bring the service down. By monitoring the network's PDH or Ethernet OAM overhead, service providers can troubleshoot without affecting service. When delivering services over Ethernet, features like frame analysis will also provide a view of the different errors found on the network. With in-service testing, service providers have a clear view of where the problem is and can prepare their test scenario before conducting intrusive testing, thus reducing downtime.

Conclusion

It is very important to understand the mobile backhaul network architecture, especially before trying to test and monitor it. During the installation, commissioning and turn-up of mobile backhaul services, it is important to validate the different parameters of the service-level agreement to certify the quality of the mobile backhaul services being deployed. This certification will enable mobile service providers to create "birth certificates" for the services being installed and can then use them as a report for their end-customers.

By using a monitoring system, mobile backhaul providers have a means to monitor services 24/7, making sure that their installed services meet SLAs. If the monitoring systems have testing capabilities, they can provide a first level of troubleshooting without any truck rolls. When the monitoring system is not enough to pinpoint the source of the network issue, portable test equipment, such as the ones used in the installation of the network, will provide the advanced testing capabilities to locate and correct any network defect issues.

Test equipment and monitoring systems will provide visibility of the different stages of the mobile backhaul network life cycle. By making sure that the deployed network meets the stringent SLAs defined by wireless service providers, they become the stepping stone to better QoS and QoE, while providing greater OPEX savings due to reduced test times and truck rolls and minimizing customer churn and building loyalty.

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Printed in Canada 09/02

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