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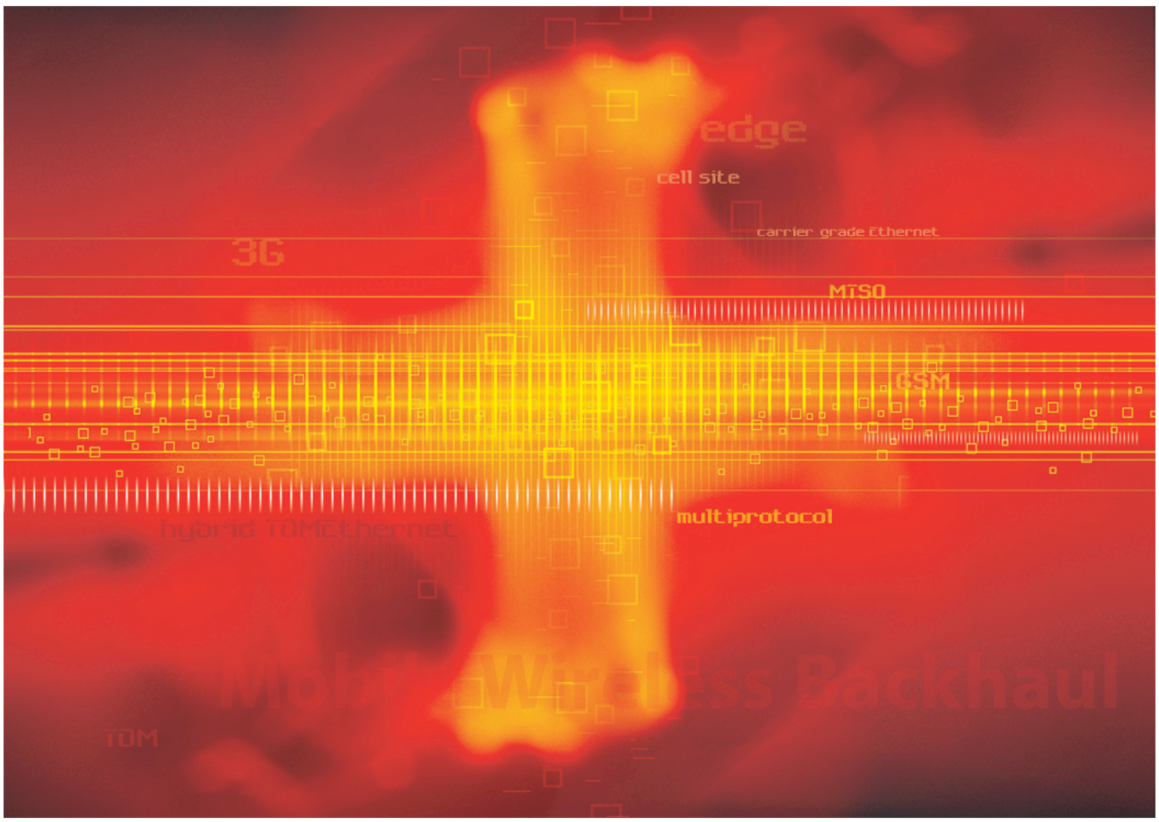
Understanding Mobile Wireless Backhaul



Introduction

Wireless networks are evolving from voice-only traffic to networks supporting both voice and high-speed data services. As this transition occurs, there will be an increasing need for additional bandwidth at cell sites. Wireless service providers have very specific transport requirements and specifications for their services; understanding these requirements is key to choosing the right technology and type of network for the application.

The wireless industry backhaul transport requirements are defined by three primary factors:

1) Wireless 2G/3G standards
2) Cell site capacity requirements
3) Performance metrics (latency, jitter, availability).

A thorough understanding of these factors ensures operators choose the right technology, network and architecture to implement a successful wireless backhaul business strategy.

Typical 2G/2.5G GSM Network Overview

In a typical GSM wireless network, as shown in Figure 1, base station transceivers (BTS) are located at the cell site and provide the control and radio air interface for each cell. Base station controllers (BSC) provide control over multiple cell sites and multiple base station transceivers. The base station controllers can be located in a separate office or co-located at the mobile switching center (MSC).

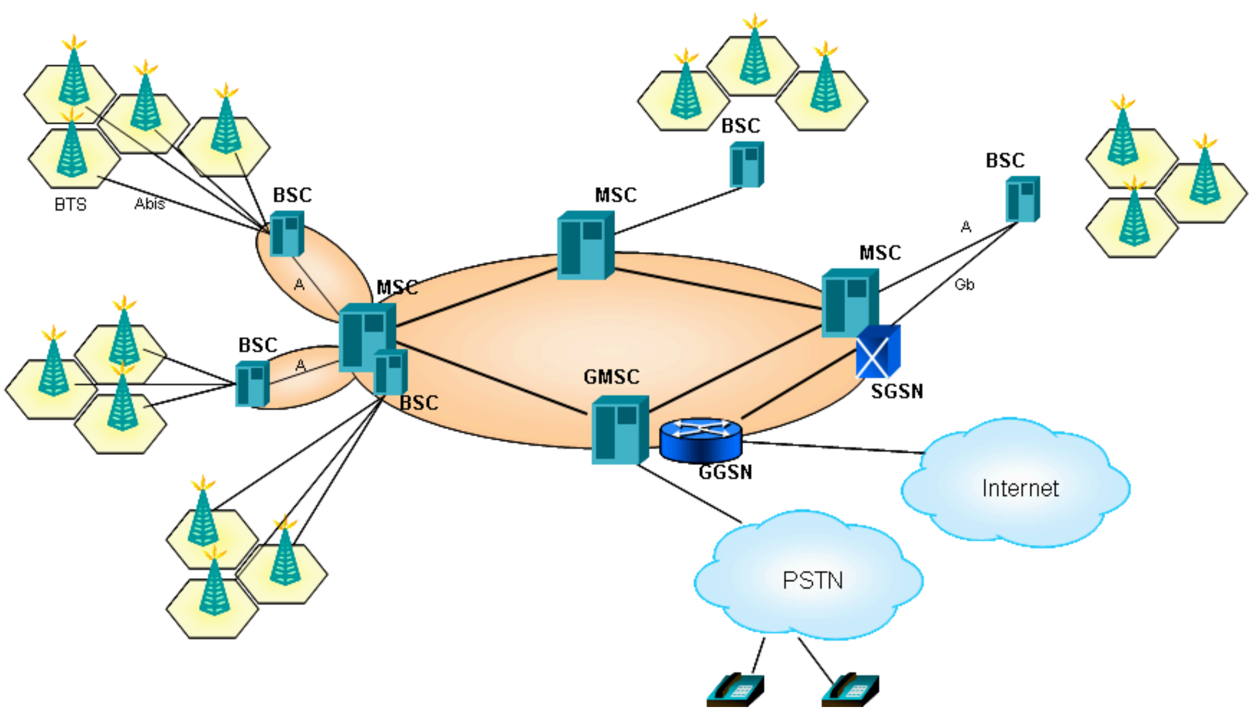


Figure 1: Typical GSM Network

The wireless industry developed standard interfaces for interconnecting these devices, so they could deploy interoperable systems from multiple vendors. The **Abis** interface connects the base station transceivers to base station controllers. The **A** interface in Figure 1 connects the base station controller to the mobile switching center. A basic understanding of these interfaces is important because the industry standards also specify the physical layer 1 interfaces. These physical interfaces define the wireless backhaul transport services and requirements.

As data services were added to GSM cell sites, new elements were introduced into the network. An EDGE (Enhanced Data rate for GSM Evolution) blade is typically installed in the base station transceiver node to support data services up to 400 Kb/s. The EDGE blade communicates over the **Gb** interface, as shown in Figure 1, to the Serving GPRS/EDGE Support Node (SGSN) located in the mobile switch center. Voice services continue over the **A** interface, while data services are handled over the **Gb** interface.

Similarly, 3G networks have their own set of defined interfaces between their base stations, (Node B), radio network controllers (RNC) and voice and data switches, as shown in Figure 2.

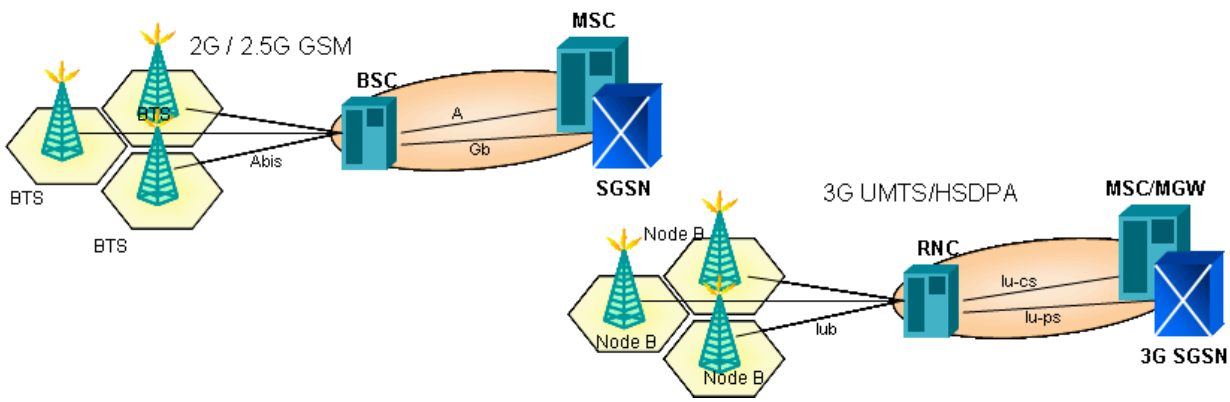


Figure 2: Wireless Interface Requirements

These **Abis**, **A**, **Gb** and **Iu** interfaces have historically defined backhaul transport requirements, since they specify the physical layer 1 implementation. The wireless industry's heavy reliance on T1 transport services is defined by and *required by their industry specifications.* While 3G/UMTS specifications have recently added native Ethernet interface support, 3G/UMTS equipment that supports native Ethernet interfaces is not expected to be available until early 2008.

Technology	*Interface*	*Physical Layer Spec*	*Standard*
GSM	**Abis**	**TDM - T1/E1**	**TS 48.054**
	A	**TDM - T1/E1**	**TS 48.004**
	Gb	**TDM - T1/E1**	**TS 48.014**
UMTS	**Iu-b, Iu-cs, Iu-ps**	**ATM / TDM – DS1 to OC -12**	**TS 25.411**

Understanding Wireless Capacity Requirements

Given the wireless industry's historical reliance on T1 circuits, the next issue in understanding wireless backhaul is the actual capacity required at cell sites (# T1s). There has been a great deal of "hype" in the industry about the need for 100 Mb/s broadband services to every cell tower, however the reality is far more limited. Today, most cell towers are serviced by one to four T1s, equivalent to 1.5 Mb/s to 6 Mb/s. The addition of 2.5G and 3G data services will increase the need for more bandwidth to cell sites, but the requirements are still relatively modest.

The amount of bandwidth on a wireless network is ultimately constrained by two factors: the amount of spectrum available and the spectral efficiency of the wireless interface. Wireless frequencies, or spectrum, is allocated and auctioned by the FCC, typically in 10 or 20 MHz blocks. Half of each block is used for transmitting signal and the other half for receiving (FDD). Blocks are further subdivided into "channels" that are shared across cell areas. To avoid interference, adjacent cells use different sets of frequency channels, typically in a 1:4 or 1:7 pattern, as shown in Figure 3.

Spectral efficiency is the amount of data (bits/s) that can be transmitted for every Hz of spectrum. Newer technologies, such as EDGE and UMTS/HSDPA use advanced modulation schemes that allow higher data rates. The modulation schemes dynamically adjust to the channel conditions between the base station and handset (power, noise, interference and so on).

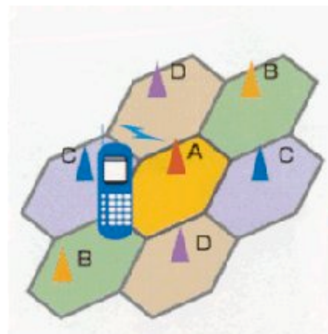


Fig 3 1:4 reuse pattern

The maximum amount of bandwidth required at a cell site is simply the amount of spectrum available multiplied by the spectral efficiency of the wireless interface. For example, the table below illustrates the cell site bandwidth required for three scenarios, each with a different spectrum allocation:

- GSM 2G voice 1.2 MHz
- GSM/EDGE 2.75G 3.5 MHz
- UMTS/HSPDA 3G 5.0 MHz

Wireless Capacity Requirements

	Voice Spectrum (MHz)	Data Spectrum (MHz)	Voice Spectral Efficiency (bit/s/Hz)	Data efficiency (bit/s/Hz)	# sectors	Traffic Eng % Peak	Total bandwidth (Mb/s)	# T1s
GSM 2G	1.2		0.52		3	65%	1.2	1
GSM / Edge 2.75G	1.2	2.3	0.52	1	3	65%	5.7	4
HSDPA 3G		5	0	2	3	65%	19.5	13

The results show that current 2G and 2.75G EDGE networks are easily serviced by one to four T1s worth of bandwidth. Even 3G cell sites, with three sector antennas and base stations, only require 19.5 Mb/s of bandwidth or approximately 12–16 T1s. While bandwidth requirements are increasing, they are far less than 100 Mb/s per cell site.

Another factor that determines the amount of bandwidth required at cell sites are the handsets themselves, a factor not included in the study shown above. Currently, only 15% of US handsets are 3G capable[1]. Even the widely popular Apple iPhone operates over the EDGE network (384 Kb/s) rather than the faster, more advanced 3G (HSDPA) network. Bandwidth requirements will remain modest until there is a wider adoption and deployment of 3G handsets, smart phones and mobile PC cards, which in turn drive the need for higher capacities and throughputs at cell sites.

Historical Reliance on TDM

Based on industry specifications and capacity requirements, it is very easy to understand why wireless service providers have historically relied on T1 circuits for cell site transport. Given the heavy reliance on TDM services in the wireless industry, it is worth investigating the options for fiber optic transport of these circuits. There are several methods of transporting TDM services in their native format (SONET, CWDM, DWDM) or by converting the TDM service to Ethernet (Circuit Emulation Service, known as CES). Due to a number of performance factors, many wireless service providers continue to rely on and require TDM services carried over a native TDM transport infrastructure. It is important to understand these performance issues when selecting the appropriate transport technology for their wireless backhaul networks.

Latency, Jitter and Availability: *They Still Matter*

T1s have historically been utilized for providing connections to cell sites. T1s are specified in the wireless industry standards, they are a widely available service and T1 prices have declined from $1500 to $300 per month over the last ten years. The reduction in T1 prices has reduced or eliminated the disparity with Ethernet services.

With the advent of Ethernet and IP data networks that support T1 circuit emulation (CES), the question becomes whether these packet-based networks can offer the same performance levels as their TDM counterparts and whether these networks meet the expectations of wireless service providers. Wireless providers have strict performance metrics for latency, jitter and availability, as shown in Figure 4.

The Metro Ethernet Forum specifications for these parameters are a bit "loose" and fail to meet wireless backhaul targets. However, it should be noted that many vendors have carrier-grade Ethernet transport platforms that vastly exceed MEF specifications.

Parameter	Mobile Target	MEF Spec	TDM / SONET
Delay	<5 ms	<25 ms	<100 us
Jitter	1 ms	<10 ms	<3.2 us
Availability	99.999% < 5.3 min/yr	99.95% < 263 min/yr	99.999% < 5.3 min/yr

Figure 4: Performance Metrics[2,3]

Circuit Emulation – Delay vs Efficiency

T1 circuit emulation (CES) provides a method for carrying T1 TDM services over an Ethernet network. For many service providers, T1 CES allows them to transition to all-packet networks, while still supporting legacy services. However, T1 CES has its own set of performance issues, which may not be acceptable to wireless service providers.

Circuit emulation involves a trade-off between latency (delay) and bandwidth efficiency. Delay through the network can be reduced, but at the cost of reduced efficiency. Likewise, efficiency can be improved, but with consequent longer delays. Figure 5 illustrates this concept. In the first diagram, a single T1 frame is transported inside of a single Ethernet frame. The delay is very low, since only a single T1 frame (125 us) is transported. However, the efficiency is not very good due to the CES overhead bytes (not shown), Ethernet overhead bytes, preamble bytes and interframe gap. The alternative is to stuff many T1 frames into an Ethernet frame, as shown on the right side of Figure 5. This minimizes the impact of the overhead bytes, however the latency is much longer due to the fact that four, eight, or 16 T1 frames worth of information must be buffered prior to transmission.

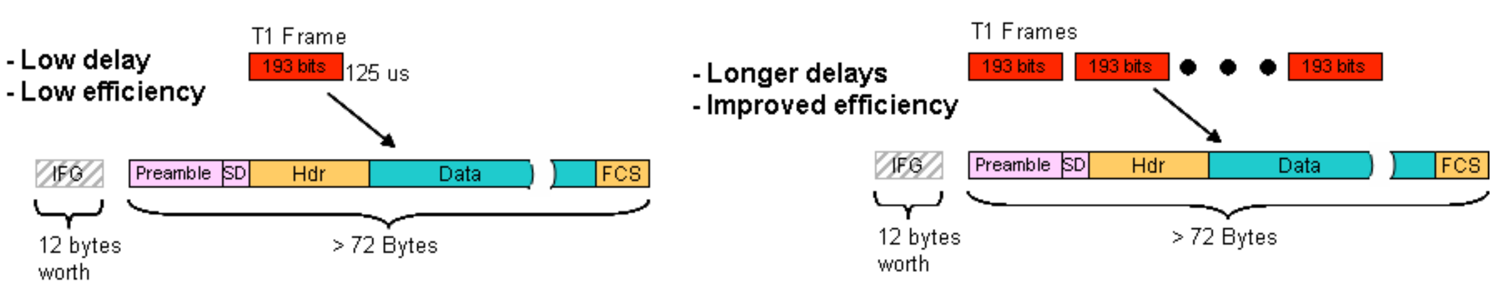


Figure 5: CES Latency vs. Efficiency

T1 circuit emulation services are typically 50% efficient because of the amount of overhead information transmitted with each Ethernet frame (CES header, Ethernet header, preamble, interframe gap). The table below shows typical T1 CES efficiency for the given number of T1 frames mapped into every packet. Using four T1 frames per Ethernet frame, approximately 2.94 Mb/s is required to transport the T1 circuit (1.544 Mb/s native), or 52% efficiency.

Circuit Emulation Efficiency (typ)		
Frames	Efficiency	Bandwidth
1	24%	6.40 Mb/s
4	52%	2. 94 Mb/s
8	65%	2.37 Mb/s

Figure 6: Typical T1 Circuit Emulation Efficiency

Many wireless service providers are uncomfortable with the latency, jitter and efficiency issues related to T1 circuit emulation (CES). For these wireless service providers, their insistence on carrying TDM services in native TDM format is very understandable based on these performance metrics.

Circuit Emulation (CES) allows TDM services to be carried over an Ethernet network, but at the cost of higher inefficiencies and larger network delays. These issues can be minimized by implementing CES when the network traffic is primarily in native Ethernet/IP format, with only a small percentage of traffic in TDM format. The CES inefficiencies and increased delays would then only affect the small number of TDM circuits, and since these would be limited to a small percentage of the total traffic, the overall network impact would thus be negligible. For example, if 90–95% of the network is native Ethernet traffic, performing CES on the remaining 5–10% of services is not a major problem. By contrast, currently deployed 2G/3G wireless networks are based entirely on TDM (T1) backhaul services with little to no native Ethernet.

Multi-Protocol Reality

The reality is that we live in a multi-protocol world and networks must be able to carry a wide array of Ethernet, TDM and SONET services, in other words a “fusion” of different end user services. The debate shouldn’t be about Packet vs. TDM or Ethernet vs. SONET. None of these technologies are inherently “good” or “bad.” The issue is how best to support the embedded base of legacy services, which are traditionally TDM-based, as networks evolve to be much more Ethernet/IP centric. The 2G/2.5G GSM and 3G UMTS networks that are currently deployed will remain an integral part of the wireless infrastructure for the next 12–20 years, so their T1 physical interfaces and transport requirements will be present for a long time to come.

Hybrid TDM/Ethernet Solution

For wireless service providers who require TDM services to be transported in their native format, a hybrid TDM/Ethernet platform provides the optimal wireless backhaul solution because of the latency, jitter, availability and efficiency issues mentioned previously. Figure 7 shows an example of a hybrid TDM/Ethernet platform capable of supporting both TDM and Ethernet services in their native formats. These hybrid platforms allow flexible mixes of TDM and Ethernet services to support existing 2G GSM networks, 2.75 GSM/EDGE networks, 3G UMTS/HSDPA networks, as well as future 4G base stations. In addition, these platforms allow a seamless evolution and transition from all TDM services, or mixed TDM/Ethernet services, to all-Ethernet services.

Many wireless service providers are highly averse to allowing transport of their services over an Ethernet/IP infrastructure, especially a third party network and third-party service provider. The advantage of TDM/Ethernet hybrid architecture is that it can support customers who require native TDM transport along with Ethernet services, as well as those wireless customers already comfortable with an all-Ethernet implementation using T1 CES for legacy T1 circuits. For transport providers this is critical, since most cell sites host two or three individual wireless carriers on the same tower. Hybrid network architecture allows operators to pursue backhaul business and revenue from *all* carriers at the cell site, without getting locked out by the type of network or technology deployed.

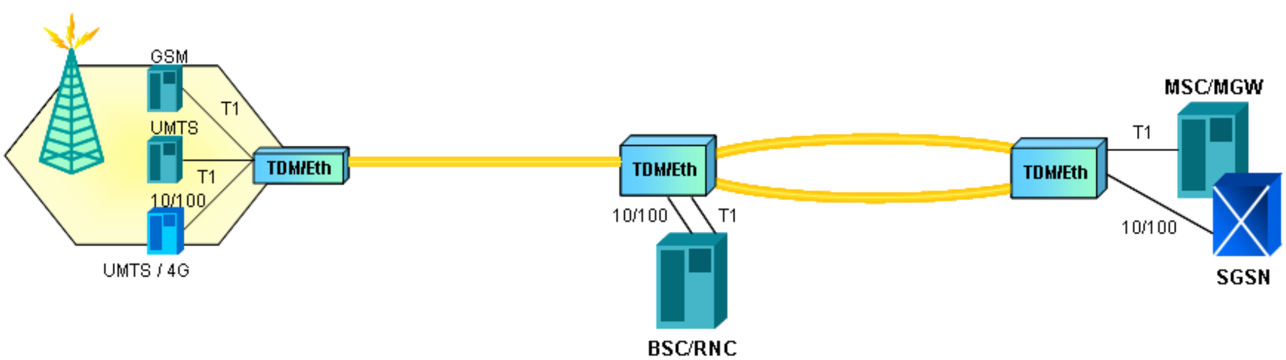


Figure 7: Hybrid TDM/Ethernet Transport Network

Carrier-Grade Ethernet Solution

For wireless customers comfortable with an Ethernet-only infrastructure, the carrier grade Ethernet transport network depicted in Figure 8 provides a great solution. As mentioned previously, the MEF specifications for network latency, jitter and availability are a bit "loose." However, many vendors provide carrier-grade Ethernet transport platforms that vastly exceed the MEF specifications and are suitable for this application.

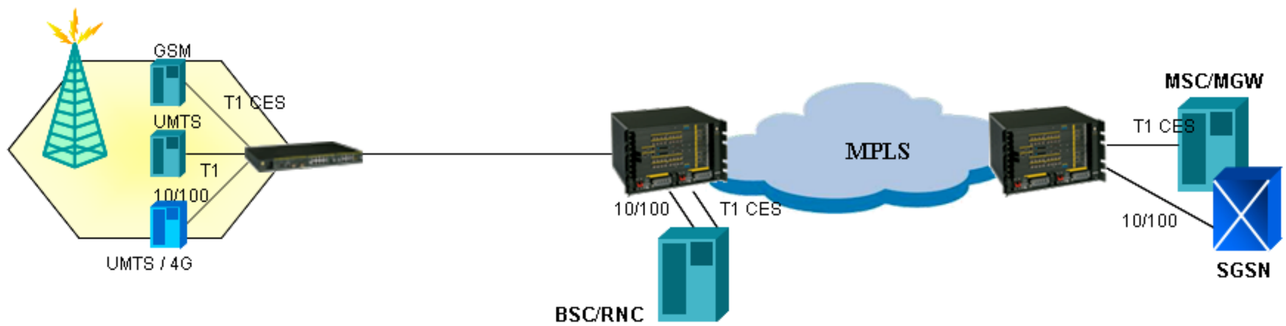


Figure 8: Carrier Grade Ethernet Transport Network

Shifting the Focus

Industry attention has focused on the backhaul of mobile wireless services at the edge of the network, from the cell site (BTS) to the BSC and/or MSC. Providing broadband services to cell sites is a very viable business opportunity. Although current capacity requirements are modest, bandwidths will continue to increase with future generations of wireless networks.

Up to this point, the industry has focused on the interfaces and capacities required at the edge of the network, as shown in Figure 9. However, a larger opportunity has gone unnoticed by the telecommunications industry, in the core of wireless metro networks.

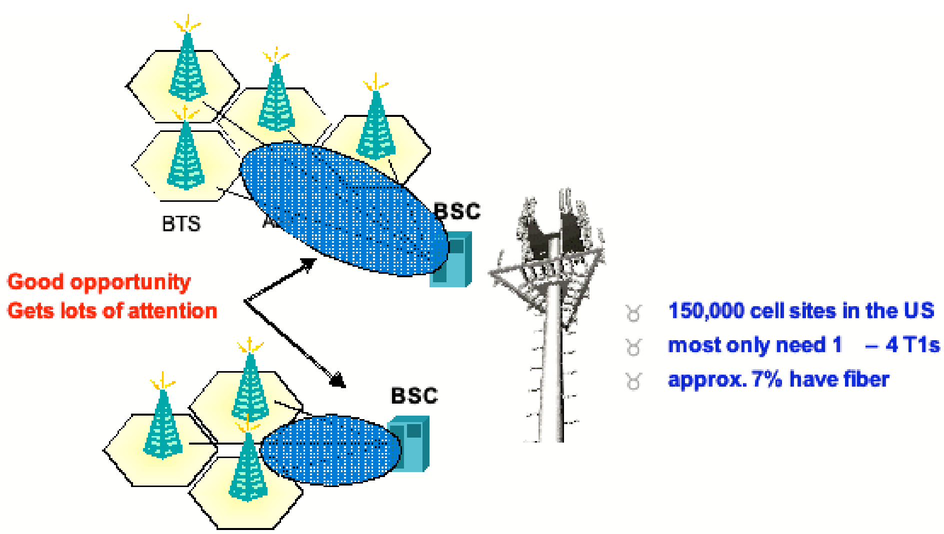


Figure 9: Cell Site Backhaul

Within a large metro area, a wireless service provider typically deploys 4–10 MTSO locations. These MTSOs are connected together for switching and transport of voice and data calls, similar to an IOF network within a wireline telco network. One or two of the MTSOs will be designated as "gateway" locations, providing interconnection to the PSTN and Internet. The MTSO-to-MTSO transport facilities are usually OC-48 and OC-192 leased lines provided by the local telco (ILEC). The MTSO core network bandwidths are very large and represent significant revenue opportunities. This core application and opportunity is immediate, it is happening now and there is no dependency on or delay from future wireless technologies (4G), as there is with cell site backhaul. In addition, most MTSOs are located within the metro areas and close to major fiber network deployments. Wireless service providers are continually seeking to reduce their operational costs, including the selection of alternative transport providers for this application.

Increasing bandwidths to cell sites receives all of the industry attention, providing a more cost-effective core network is the near-term opportunity and winning the real deployments.

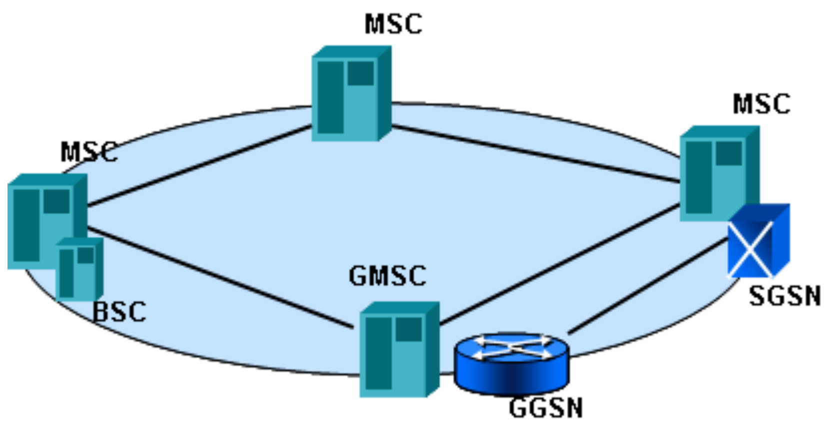


Figure 10: Wireless Core Network

Core Network Example

As a real world example, Figure 11 shows the core network for a wireless service provider in a major US metropolitan area. This city is a "top twenty" US metropolitan area and represents a typical network and application for similarly sized metro areas.

The core mobile network consists of 15 optical rings, 12 operating at OC-48 rates and three operating at OC-12 rates. The rings provide connection from BSC to MSC offices, between MSC and MSC offices and between MSC and telco/ISP gateway offices. The wireless service providers are leasing transport services over these dedicated rings from the ILEC, at an estimated cost of $5–6 million per year.

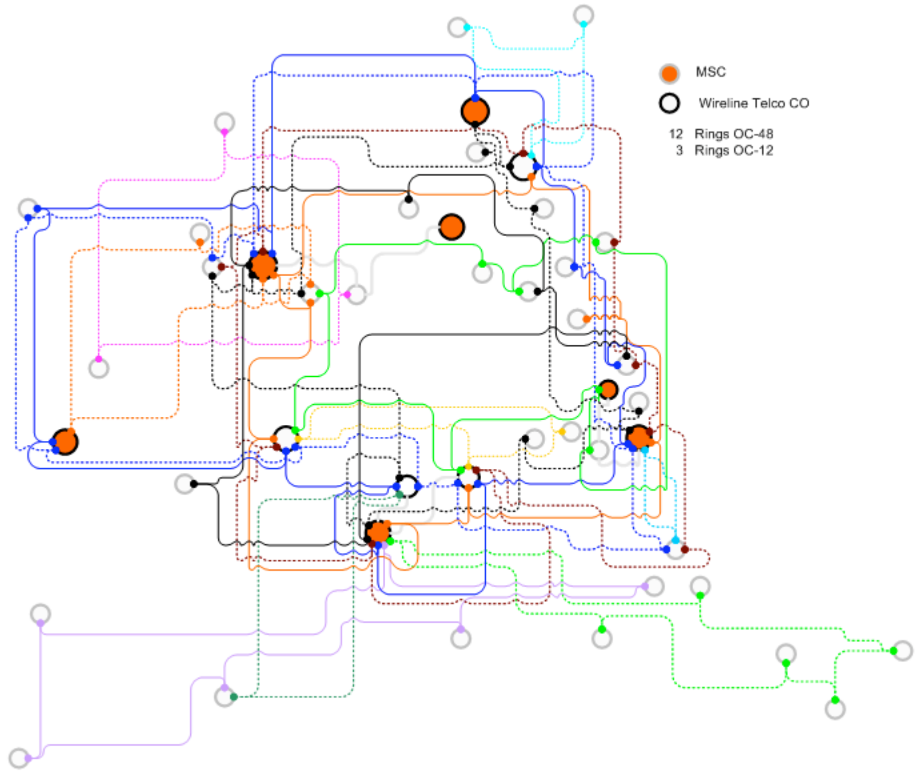


Figure 11: Core Wireless Network

This type of application provides an opportunity to build high capacity core networks for wireless service providers, with multi-million dollar yearly revenue potential. In this particular example, the wireless provider's objective was to reduce ongoing operational costs for core transport services. This provider had three options:

1) Continue leasing services from the ILEC, but optimize their traffic patterns
2) Purchase transport services from an alternate provider
3) Build the network based on direct equipment purchases and dark fiber leases

The wireless service provider opted to explore Option 3, building the network. There simply wasn't an alternative carrier in this metro area with a commercial services business capable of supporting this type of application. Option 2 was therefore not viable and Option 1 only offered limited savings. Figure 12 shows the network that was developed for this project. A single core network connects the MSC offices and core gateway offices, allowing approximately 65% of the previously leased traffic to be transported over this new private network. Even with the cost of equipment and dark fiber leases, the wireless service provider had a projected cost savings of $3.2 million per year.

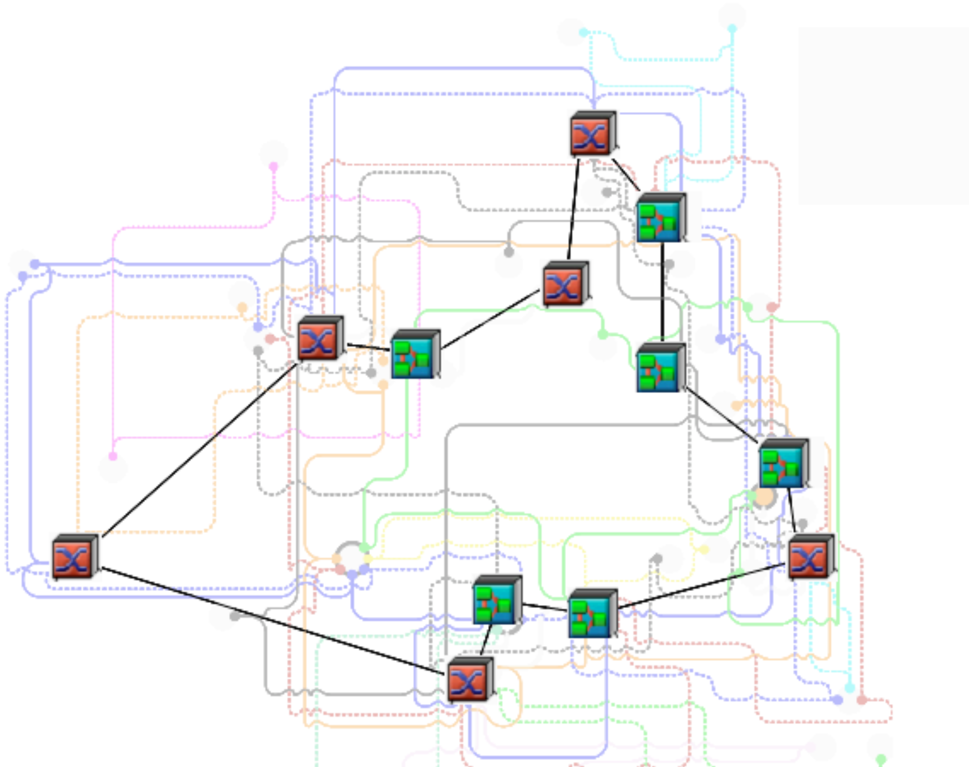


Figure 12: Wireless Core Network Model

Conclusion

Provision of mobile wireless backhaul services represents a significant opportunity for operators. An understanding of wireless equipment, interface specifications and historical deployment practices greatly aids the proper choice and design of networks for this application. The wireless industry has primarily relied on T1 TDM services for equipment connectivity due to industry specifications, wide availability of T1 services, capacity requirements and superior performance metrics. Many wireless service providers remain averse to allowing their services to be transported over Ethernet/IP networks due to latency, jitter, availability and efficiency issues, including the inherent inefficiency in T1 CES. A hybrid network that supports a fusion of TDM, SONET and Ethernet services will allow a completely flexible infrastructure that can seamlessly evolve with the network changes and enable operators to solicit business from all wireless customer types. Finally, while the industry has focused on the backhaul of mobile services from cell sites, a far more interesting, lucrative and-near term opportunity exists for transport providers in the core metro networks.

References

1) Business Week, "Telecom: Back from the Dead," June 25, 2007
2) MEF 3, "Circuit Emulation Service Definitions, Framework and Requirements in Metro Ethernet Networks," sections 9.1, 9.2 and 9.4, April 13, 2004
3) GR-496-Core, "SONET ADM Generic Criteria," section 3.3.5.5, Issue 1, Dec. 1998

Acronyms

3GPP	Third Generation Partnership project
BSC	Base Station Controller
BTS	Base Transceiver Station
CDMA	Code Division Multiple Access
CES	Circuit Emulation Service
EDGE	Enhanced Data rate for GSM Evolution
FCC	Federal Communications Commission
FDD	Frequency Division Duplex
GGSN	Gateway GPRS Support Node
GPRS	General Packet Radio Service
GSM	Global System for Mobile Communications
HFC	Hybrid Fiber Coax
HSPDA	High Speed Packet Downlink Access
ILEC	Incumbent Local Exchange Carrier
MEF	Metro Ethernet Forum
MSC	Mobile Switching Center
MTSO	Mobile Telephone Switch Office (ie MSC)
PSTN	Public Switched Telephone Network
QOS	Quality of Service
RNC	Radio Network Controller
SGSN	Serving GPRS Support Node
SONET	Synchronous Optical Network
TDM	Time Division Multiplex
UMTS	Universal Mobile Telecommunications System