GSM Over VSAT: Choosing The Right Backhaul Solution

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Foreword

Reaching the next billion subscribers is the motto of the GSM industry. Fueling that drive is the ever-expanding demand for GSM services in the emerging markets. Satellite GSM backhaul has taken its place as a recognized and efficient means to deliver GSM services in geographically challenged areas, or areas in which conventional terrestrial transmission solutions are either not available or not appropriate.

Space segment costs are typically the most significant operating expense (OPEX) for any GSM service provider considering satellite-based service. Satellite transmission backhaul costs may represent up to 40% of the total OPEX related to a Base Transceiver Station (BTS) deployment and so careful design and of the satellite network solution and choice of the right technology have a direct impact on the viability and profitability of the service.

Satellite transponder costs are determined by occupied bandwidth, as well as power used. For optimal results, a satellite circuit should use similar share of transponder bandwidth and power.

Traditionally, this has involved trade-offs between modulation and coding once the satellite and earth station parameters are fixed. The newer Forward Error Correction (FEC) schemes, such as Turbo Product Codes (TPC) and now the Low-Density Parity-Check Codes (LDPC) can provide increased link reliability while requiring less power, but the trade off for this ability is a marginal increase of the satellite delay. However, higher order modulation schemes can increase data throughput (Megabits Mbps) without increasing the bandwidth (Megahertz MHz), but will decrease the link reliability or else require significant increase in power. Another consideration is antenna size. Larger antennas with increased gain require less power, however, it is not always economically feasible to use large antenna and so increasing the power budget may be necessary. A well-designed satellite network should balance these different elements to optimize the overall Total Cost of Ownership of the solution for a given site deployment.

This study presents a variety of approaches to backhauling GSM traffic and presents throughput (Mbps) and bandwidth (MHz) approximations. These results are a function of modulation and coding but they do not consider other aspects such as power and antenna sizes. Assuming the link parameters (Bit-Error-Rate-BER- and bandwidth) are fixed for a given application, the trade-off between modulation, coding, power and antenna dish are variables that can only be dealt with when considering the satellite abilities in the coverage areas. Comtech EF Data provides a power web tool for balancing and cost optimizing these four variables for given satellite parameters. This tool can be found at http://optimize.comtechefdata.com/.

Finally, by comparing and explaining the different approaches, this study provides the operator with sufficient information to make an informed decision as to which backhaul solution is right for them.

Today, there are two dominant solutions available to the service provider. These solutions – Point-to-Point Single Channel Per Carrier (SCPC) solutions or Point-to-Multipoint solutions (based on either TDM/MF-SCPC or TDM/MF-TDMA Time Division Multiplexing/Multiple Frequency-Time Division Multiple Access technologies) – have created a healthy and lively debate within the industry as to which solution is ultimately the most effective solution for a service provider. By comparing and explaining the different approaches, this study should provide a service provider with sufficient information to make the "right" decision

This study considers the following approaches:

- Point-to-Point SCPC GSM backhaul
- Point-to-Point SCPC GSM backhaul with Abis Optimization
- Point-to-Multipoint GSM backhaul topologies
    - Point-to-Multipoint TDM/MF-SCPC solutions
    - Point-to-Multipoint TDM/MF-TDMA solutions

First, an understanding of the underlying benefits and capabilities of Abis Optimization is in order.

Abis Optimization

Memotec Inc., a subsidiary of Comtech EF Data, pioneered the use of Abis optimization over satellite as the most cost effective means to tap emerging markets. By using Memotec's proven Abis optimization backhaul solution, GSM operators can reduce both the high operating expense (OPEX) associated with transponder usage as well as the time it takes to deploy new remote network services in highly competitive markets. With the dual functions of bandwidth optimization and traffic conversion to packet technology, Memotec's Abis solutions enable service providers to roll out remote GSM over VSAT nodes with lowest possible operating expense. As a result, a whole new business model is now possible and GSM operators today are reaping the rewards.

To start, let's review the optimization process as developed by Memotec. The Memotec Abis optimizers (see Figure 1) performs a deep inspection/optimization of the Abis interface, generating traffic packets that are bandwidth reduced and directly proportional to the amount of active calls being used. Optimization is achieved by removing idle and silence frames while statistically multiplexing the active call traffic and Abis signaling traffic. This optimized traffic can be routed via IP or HDLC routed packets. Essential to Abis optimization (and the conversion from TDM to packet based transport) is the need to provide high service level availability and Quality of Service (QoS). Memotec Abis optimization aligns signaling, voice and data traffics into separate traffic streams and implements a QoS and anti-congestion scheme that ensures that traffic essentials are preserved.

Such optimization techniques are commonplace in the VoIP space, but only the Memotec Abis optimization solution can bring such bandwidth saving benefits to the GSM network. Since the resultant traffic is no longer TDM based (i.e. T1/E1 is no longer required), it may be forwarded across any type of IP or serial modem. It is precisely this capability that has enabled various IP VSAT modem solutions to now offer GSM backhaul over VSAT.

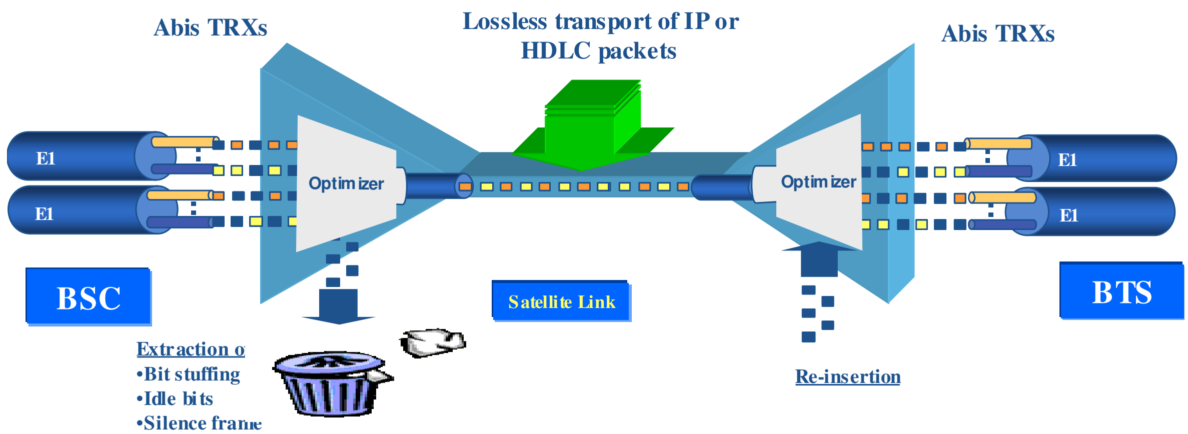

Figure 1: Abis Optimization

Abis optimization technology has now achieved broad acceptance by carriers and service providers. The Abis optimization also enables a new competitive offering to the GSM backhaul by enabling TDM/MF-TDMA based VSAT solutions to compete in a market which has traditionally been the undisputed domain of SCPC based VSAT solutions. Solutions are currently available to service providers coupling Abis optimization with both SCPC and/or TDM/MF-TDMA environments. The availability of new competitive solutions only highlights the need for a study intent on explaining the benefits and deficiencies of the different approaches.

Point-to-Point SCPC GSM Backhaul Solutions

Traditionally GSM backhaul over VSAT has been supported over SCPC modems supporting G703 (T1/E1) interfaces or fractional T1/E1 circuits over VSAT in static bandwidth allocated point-to-point (Base Station Controller –BSC- to BTS) topology (see Figure 2).

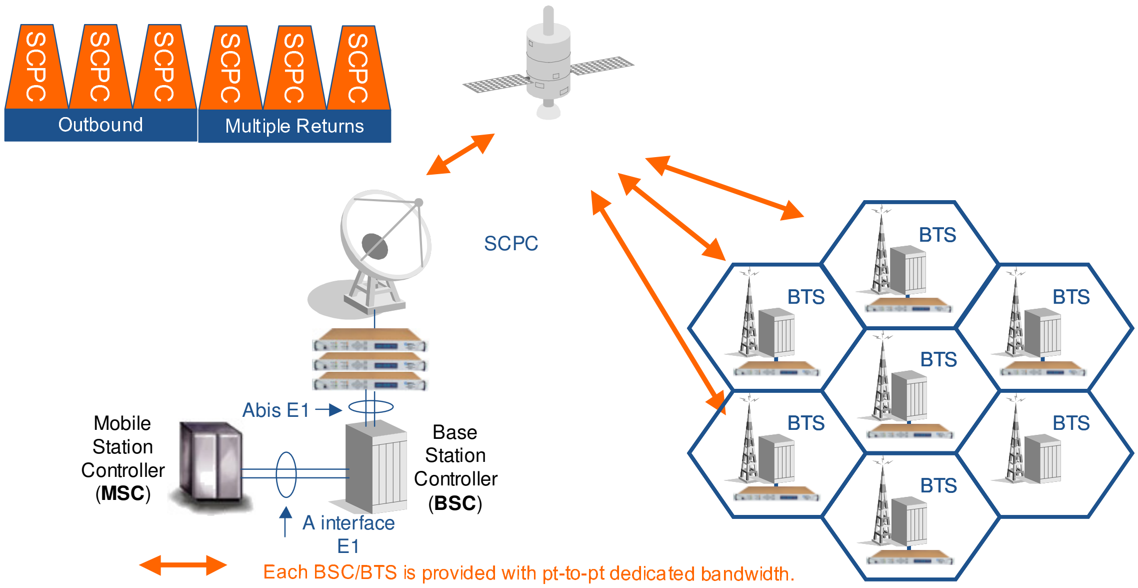

Figure 2: The Point-to-point SCPC topology.

This type of solution offers fast availability and connectivity anywhere within a satellite coverage area. This solution provides complete transparency, since the VSAT modem is simply providing physical layer connectivity between the BSC and BTS. The only avenue for controlling or reducing the Operating Expenses (OPEX) related to backhauling the GSM traffic is in the optimization of the physical layer (i.e. reducing the amount of MHz required to transport the E1 or fractional E1 circuits). Selecting quality SCPC modems capable of higher modulations, Turbo Product Codes (TPC) or LDPC reduces power requirements and provides the means to optimize the physical layer greatly reduce the amount of MHz and thereby reduce also the OPEX for the service provider. Table 1 below demonstrates the amount of satellite transponder space that would be required to support 30 sites with different number of BTS Transceiver/Receiver (TRX), as a function of VSAT modem modulations and TPC (assumption of 1.20 spacing between carriers). Note: In all cases, we are assuming that the satellite transponder bandwidth determination is bandwidth limited and not power limited.

Cell Size (TRX)	Cell Size (Calls in busy hour)	Mhz used by SCPC (30 sites)		
		Worst case QPSK 2/3	8PSK 3/4	16QAM ¾
3	24	21	12	9
4	32	28	16	12
5	40	35	20	15
6	48	42	25	18
9	72	63	37	28
12	96	84	49	37

Table 1: Transponder usage as a function of TRX and modem capabilities.

Additionally, a recent new product offering by Comtech EF Data called DoubleTalk™ Carrier-in-Carrier™ promises to even further reduce the bandwidth required to support those deployments. Carrier-in-Carrier is based on Applied Signal Technology's DoubleTalk, which uses "Adaptive Cancellation," a patent pending technology that allows full duplex satellite links to transmit concurrently in the same segment of transponder bandwidth. The result is a reduction of the occupied bandwidth by up to 50%, depending on the initial link configuration.

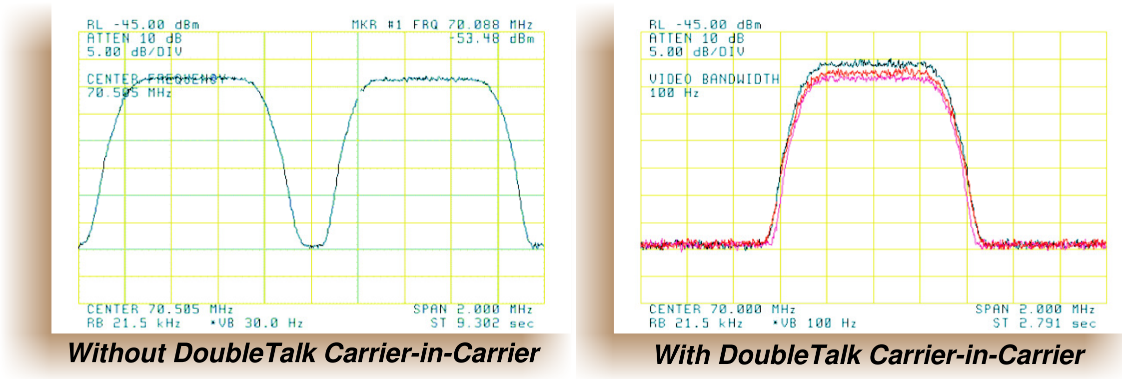

Figure 3: DoubleTalk™ Carrier-in-Carrier™ Transponder Spectrum

This technology is most beneficial when the amount of bandwidth is greater than 1.5 Mbps and so for high capacity sites (i.e. greater than 6TRX), where higher order and more power efficient FEC algorithm such as LDPC can be used. As a result, DoubleTalk™ Carrier-in-Carrier™ can reduce the transponder space required by up to ½ that shown in the table above.

Point-to-Point SCPC GSM Backhaul with Memotec Bandwidth Optimization

As mentioned above, the VSAT modem optimizes the physical layer (i.e. reduces the bandwidth to the minimum possible MHz for reduced transponder costs). Memotec, on the other hand, brings Abis level bandwidth benefits by removing idle and silence frames while statistically multiplexing the active call traffic and Abis signaling traffic. This reduces the Abis overall throughput (Mbps) thereby reducing the transponder bandwidth (MHz) requirements and ultimately the transponder cost.

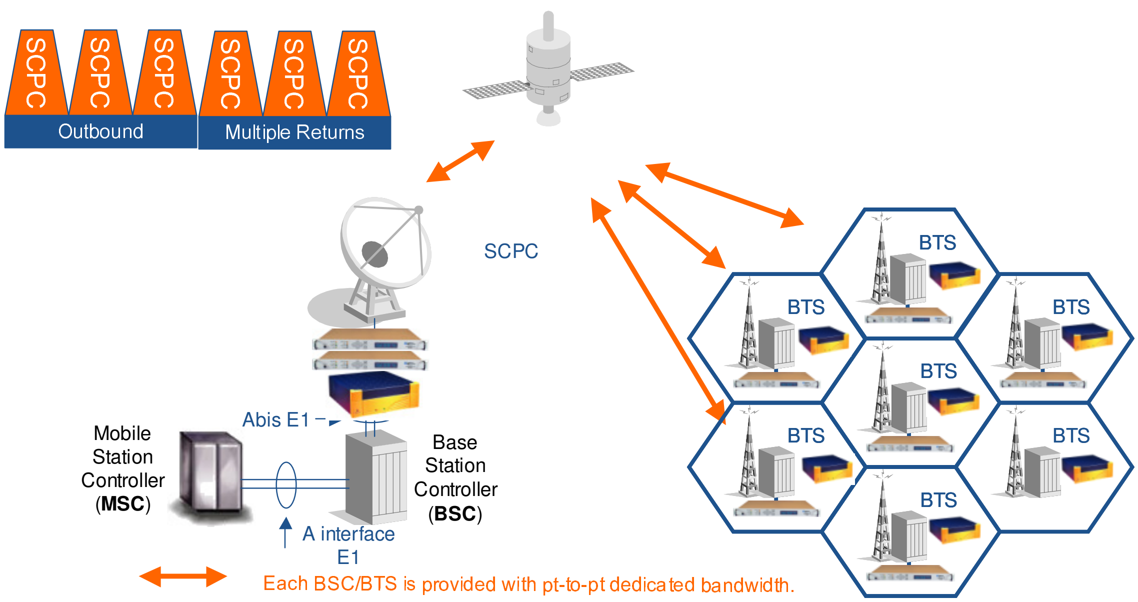

Figure 4: The Point-to-point topology with the Memotec bandwidth optimization.

The mobile environment is typically noisier than landline environments and so typical silence ratios seldom go over 30 to 35%. As such, typical savings realized through the Abis optimization process are usually on the order of 33 to 60%, depending on the GSM vendor implementation of Discontinuous Transmission (DTX) silence suppression, signaling, and site capacity. Table 2 below demonstrates the amount of satellite transponder space that would be required to support 30 sites with different number of BTS TRX, as a function of VSAT modem modulations and TPC (assumption of 1.20 spacing between carriers) with Memotec optimization gear.

Cell Size (TRX)	Cell Size (Calls in busy hour)	Mhz used by SCPC (30 sites)		
		Worst case QPSK 2/3	8PSK 3/4	16QAM 3/4
3	24	14	8	6
4	32	19	11	8
5	40	23	13	10
6	48	28	17	12
9	72	42	25	19
12	96	56	33	25

Table 2: Transponder usage with Memotec bandwidth optimization.

Point-to-Multipoint Topologies

The previous deployment example demonstrated the bandwidth savings aspect of Abis optimization but did not factor in the additional benefits that may be gained by taking advantage of the statistical multiplexing ability provided by Memotec's Abis optimization technology.

This statistical multiplexing effect allows for a new phenomenon in Abis backhaul, which is the ability to deploy transponder capacity based on site Erlang requirements rather than deployed Abis capacity.. In providing the means to statistical multiplex optimized Abis and Erlang traffic, Memotec technology enables the use of non-SCPC based VSAT solutions (such as TDM/MF-TDMA solutions) since the amount of bandwidth required at any time is variable and may be dynamic deployed across a network.

First, let us review the manner in which Erlang capacity and Abis capacity are connected. BTSs TRX capacity is deployed in the field to meet a number of service provider and network design criteria. BTSs deployed in urban areas experience very high usage and are scaled to support specific Erlang requirements. In rural areas, usage is typically lower and service providers/network designers design to different criteria than those of urban networks. In addition to Erlang, other design criteria's such as of range, cell topology, population density, use of repeaters, etc. are also essential deciding factors in the radio configuration of the BTS and therefore the number of TRXs deployed at the BTS site.

Let us consider a new factor that we will call ***Abis utilization*** as the level of voice capacity required to support the Erlang to be delivered vs. the capacity deployed. Typically a BTS radio (TRX with 7 possible voice channels) is deployed to provide 4.8 Erlang of capacity. Multiple radios may deploy to meet the ERLANG requirement of a subscriber region. As an example, we can consider an subscriber region with 1400 subscribers at 10mErlang (with a total 14Erlang). Typically the operator would deploy 3 TRX (4.8Erlang each) for a total of 14.4Erlang. If we consider 10 such sites, we would suppose a total network Erlang requirement of 140 Erlang at the BTS to accommodate 100% network utilization. Providing 140 Erlang at the BSC assumes 154 possible voice ports out of a deployed 210 voice ports and so the Abis utilization is 73%. Since the Memotec essentially only requires bandwidth when voice sessions are in progress, we need only provision bandwidth to meet the Erlang being delivered (which in this example represents 73% of the actual bandwidth being deployed). This means that in addition to the bandwidth savings realized by the Abis optimization we can factor in the additional savings being realized with the Abis utilization factor.

It often occurs that not all the subscribers within a region are within the coverage range of a TRX and so; operators often increase TRX capacity of the BTS to extend the radio range. In the example above, imagine that the operator needs to double the TRXs to provide greater range. The overriding Erlang has not changed, but the backhaul capacity has doubled from 3 TRX to 6 TRX (or 21 voice channels to 42 voice channels) per

BTS. With Memotec, we need only provision the bandwidth to support the desired Erlang and so the addition of TRX can be virtually disregarded in terms of backhaul. In this example, the Abis utilization would actually be 36%, since we are still deploying only enough bandwidth to support the 140 Erlang (ie. 150 voice ports) but the sum of the deployed voice capacity is 420 voice ports.

As such, the point-to-multipoint topology, combined with Memotec Abis Optimization, at 36% ***Abis utilization***, will save up to 68% of the total outbound carrier bandwidth required on the satellite transponder, compared to a conventional equivalent point to point SCPC solution without optimization. The solution allows us to size a single statistically multiplexed outbound carriers (BSC toward BTS) to meet the desired utilization of the network while the return carriers (BTS to BSC) can be either fixed return SCPC or shared bandwidth TDMA.

Point-to-Multipoint TDM/MF-SCPC Solution
In point-to-multipoint TDM/MF-SCPC solutions (the Memotec/Comtech AbisXtender solution shown in Figure 5), a TDM outbound carrier is fixed to a size that would meet the service providers network utilization expectation. The SCPC return links from each site are then sized to provide 100%Erlang capacity guarantees (after optimization) for that site.

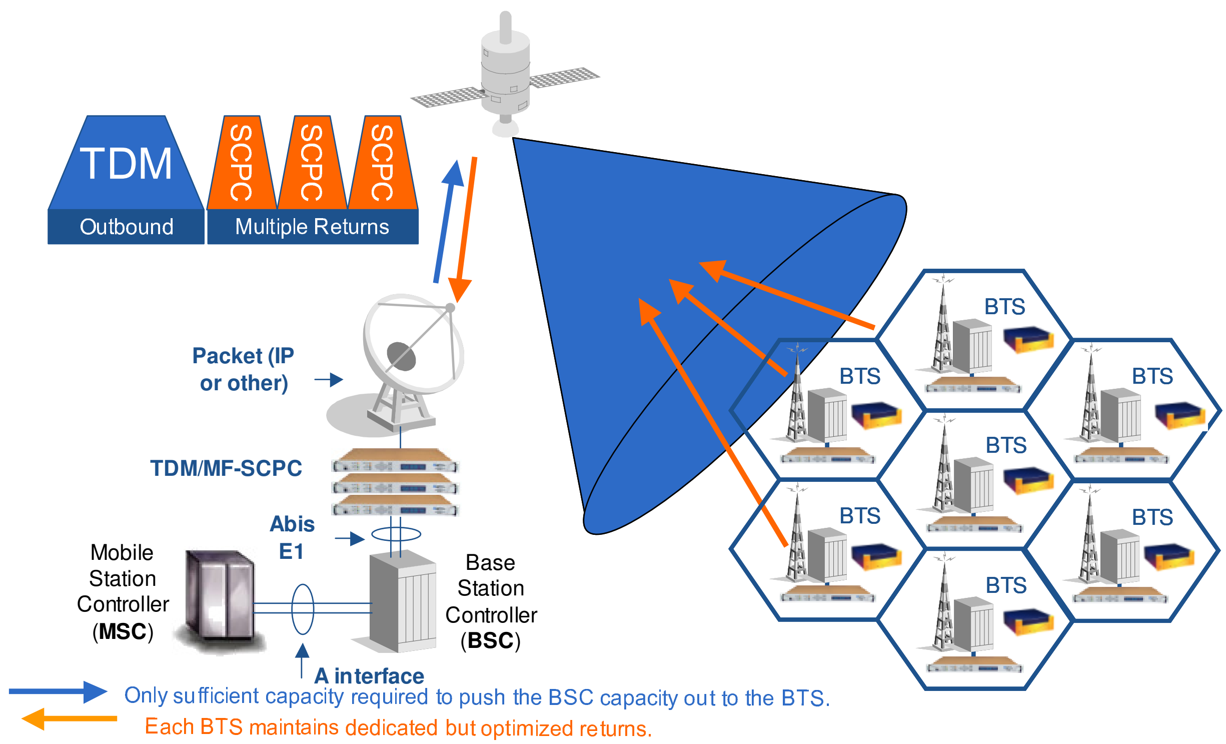

Figure 5: Point-to-multipoint TDM/MF-SCPC solution (AbisXtender)

Point-to-Multipoint TDM/MF-TDMA Solutions
Point-to-multipoint TDM/MF-TDMA solutions (Figure 6), whether they are based on DVB-RCS, or some TDM/MF-TDMA shared bandwidth on demand approach, also provide a single outbound carrier that is fixed to meet the service provider network utilization expectation. The benefit from the shared bandwidth on demand approach is that the return links from the remotes can be allocated dynamically based on the demands from each site individually. This implies that the network is sized to the service provider network utilization expectations in both the forward and return directions. Since the Abis optimization statistical multiplexing reduces bandwidth, it is easy to see that the TDM/MF-TDMA yields lower overall bandwidth (Mbps) than the SCPC approach.

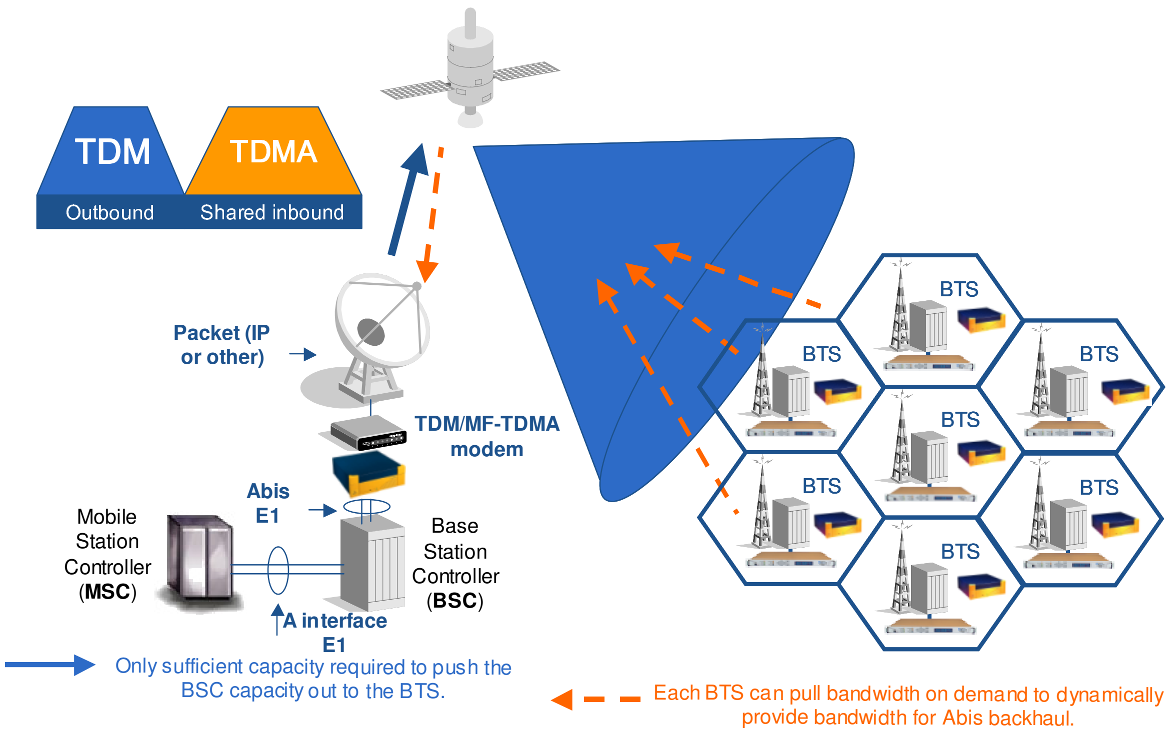

Figure 6: Point-to-multipoint TDM/MF-TDMA solution

Point-to-Multipoint Technology Comparison: Which Solution to Choose?

Though TDM/MF-TDMA requires less throughput capacity (Mbps) than a TDM/MF-SCPC at the same network utilization, TDM/MF-TDMA systems typically use lower modulation technologies and require some level of overhead to cover the needs of the TDM/MF-TDMA bandwidth allocation management. These aspects to TDM/MF-TDMA combine to negate many of the gains of the lower throughput requirements. By comparison, the TDM/MF-SCPC approach is free to use any combination of modulation, TPC and FEC as supported by the satellite to optimize both the outbound and the return links.

Table 3 demonstrates the amount of MHz required to support a 30-site network of 3 TRX when supported across point-to-multipoint TDM/MF-SCPC (assuming Comtech CDM570IP with IP header compression) or point-to-multipoint TDM/MF-TDMA solutions.

		SCPC Approach (Mhz)			*DAMA (Mhz)*	
Cell Size (TRX)	*Erlang*	*Out: QPSK 7/8 Ret: 8PSK 3/4*	*Out:8PSK 7/8 Ret: 8PSK 3/4*	*Out: QPSK 7/8 Ret: 16QAM 3/4*	*Out:QPSK 7/8 Ret: QPSK 3/4*	Out: 8PSK 7/8 Ret:QPSK 3/4
3	14	6.7	5.4	6.0	9.3	7.7
3	13	6.5	5.2	5.7	8.9	7.4
3	12	6.3	5.1	5.5	8.5	7.1
3	11	6.1	5.0	5.3	8.1	6.8
3	10	5.9	4.9	5.1	7.7	6.5
3	9	5.7	4.8	4.9	7.3	6.2
3	8	5.5	4.6	4.7	6.8	5.8
3	7	5.3	4.5	4.5	6.4	5.4
3	6	5.1	4.4	4.4	6.1	5.3
3	5	4.9	4.3	4.2	5.6	4.8
3	4	4.7	4.1	4.0	5.2	4.4
3	3	4.5	4.0	3.8	4.8	4
3	2	4.4	3.9	3.6	4.5	3.8
3	1	4.2	3.8	3.4	4	3.4

Table 3: MHz as a function of ERLANG

The Table demonstrates that Point-to-multipoint TDM/MF-TDMA systems require more MHz than Point-to-multipoint SCPC approach for all but the lowest network utilization percentages. Additionally, there are concerns about point-to-multipoint TDM/MF-TDMA voice and data quality of service and possible instabilities that may come up should bandwidth not be prudently allocated to the site as the demand grows. This is not a real problem in point-to-multipoint TDM/MF-SCPC because the solution always provides return bandwidth for 100% guaranteed capacity from BTS to BSC.

Figure 7 highlights how ***Erlang*** is the important factor in determining which technological approach to embrace. There are a number of interesting conclusions that can be made from the figure below.

Overall, the point-to-multipoint TDM/MF-SCPC approach is the best performer for this sample network with regards to Point-to-multipoint approaches. Point-to-multipoint TDM/MF-TDMA based solutions are valid solutions if network utilization is relatively low. Aside from extreme low Erlang situations, TDM/MF-TDMA solutions will always result in higher OPEX than SCPC based point-to-multipoint approaches.

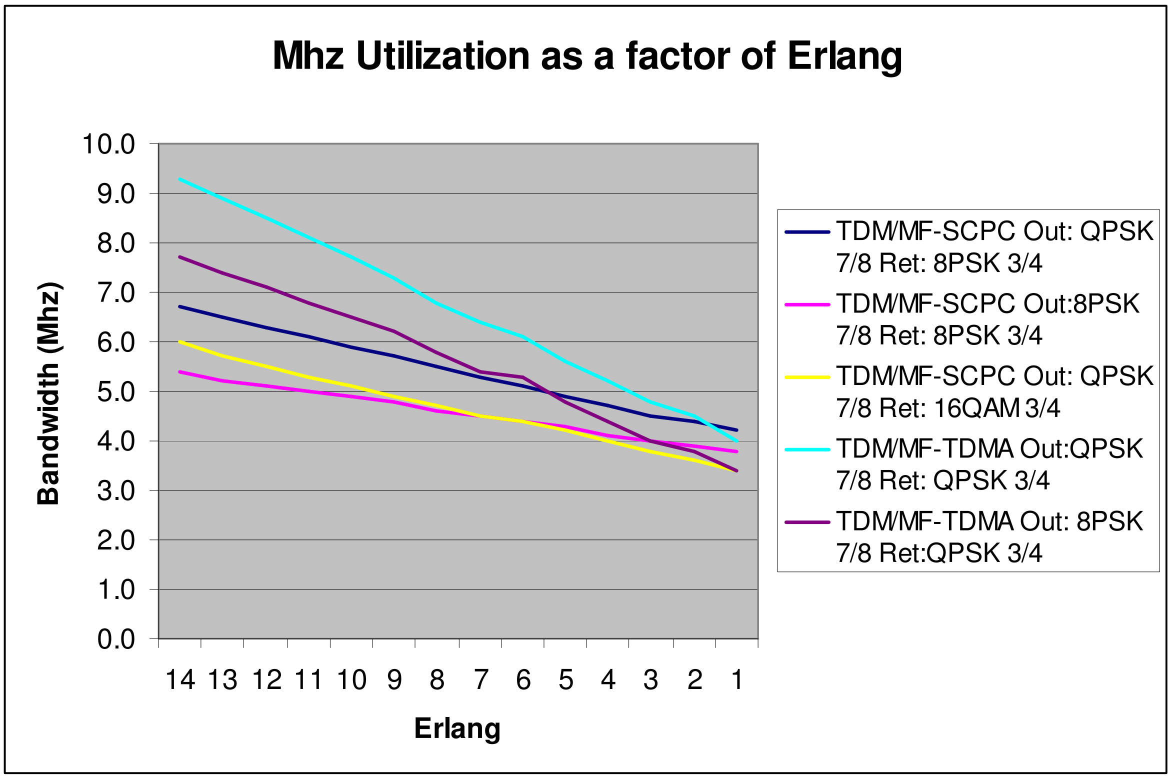

Figure 7: MHz usage as a factor of Erlang.

Conclusions

This study provided visibility to the three dominant approaches to GSM backhaul. The findings of this study reflect that each of the three approaches provide valuable and credible solution to service providers. However, service providers must be wary of the limitations and capabilities of each of these technologies and how they can affect OPEX.

For instance, we can conclude from this study that the point-to-multipoint TDM/MF-TDMA approach is a valid solution when the voice traffic Erlang is low compared to the installed capacity at the BTS sites. In the example presented, Point-to-multipoint TDM/MF-TDMA is a valid solution if the service provider expects the network wide Erlang for all the sites to average in the very low Erlang levels.

Point-to-multipoint TDM/MF-SCPC solution is also a valid solution for all ranges of ERLANG. This solution allows you to benefit from statistical multiplexing bandwidth benefit up to 100% network utilization.

Point-to-point solution, especially in conjunction with advanced technology such as Comtech EF Date Carrier in Carrier (CinC), are excellent solutions when it is necessary to support the full T1/E1 capacity at very high ERLANG and/or on the Ater interface.

Summarizing these conclusions allow us to define the following deployment constraints based on network utilization: