Cellular Backhaul: Extending the Edge of the Network

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Advancing a Connected World

iDIRECT

Introduction

The global demand for voice and data services delivered over cellular networks continues to grow as new markets open and existing ones increase capacity. The networking infrastructure to support subscriber growth and new services has experienced aggressive expansion as the worldwide economy evolves, yet millions of people throughout the world have limited or no access to cellular services. Bringing communications to remote areas of the world presents an opportunity for cellular operators to profitably expand their networks and acquire millions of new customers.

The challenge lies in the cost and time-to-market to deploy service to remote areas where limited terrestrial infrastructure exists. Cellular operators need to insure profitability and maintain low operating expenses, all while overcoming difficult geography, lack of existing infrastructure, and operational costs associated with connectivity to core networks. In order to extend the edge of their networks to incorporate new or underserved markets, cellular operators require an inexpensive and reliable alternative to terrestrial links.

Fortunately, with new innovations in cellular infrastructure and satellite backhaul technology, operators can profitably pursue rural and emerging markets to expand their networks quickly and efficiently. With iDirect's terrestrial-grade satellite links and unique IP-based Deterministic -TDMA solution, carriers are able to share network capacity across multiple locations and allocate bandwidth on demand to maximize efficiency while reducing costs.

This paper is intended to provide a description of the technical requirements for cellular backhaul over satellite and to outline why the iDirect solution, as it applies to this application, is well positioned to cost effectively and efficiently satisfy these requirements.

Challenge

One-third of the world's population is currently lacking cellular service, leaving an underserved marketplace for cellular operators. There are several reasons compelling today's carriers to expand to remote territory:

- Expand the market opportunity into previously unserviceable areas
- Extend coverage footprint for metropolitan subscribers that travel into remote areas
- Create customer loyalty and roaming revenue from competitors
- Satisfy regulatory requirements — many governments require carriers to cover remote and sparsely populated areas as a requirement for licenses in the cities

Given that many of these remote areas are devoid of telecommunications infrastructure, a traditional terrestrial build-out can be cost prohibitive and time consuming. Optical fiber and leased lines are not easily deployable in rural areas, sometimes taking over a year to install after an order has been placed. Microwave links are costly to deploy and maintain and have limited reach capabilities and require line-of-sight to operate.

As the edge of existing networks continues to press outward, satellite becomes the de facto solution to extend to more remote regions. Satellite transmission is an ideal candidate for sites that are sensitive to distance and is immune to the challenges posed by remote locations, harsh environments, and terrestrial obstacles. In this rapidly expanding market, satellite backhaul also allows a carrier to get to market quickly and efficiently.

GSM Network Overview

GSM (Global System for Mobile Communications) is available in practically every major city on the globe, and is rapidly expanding from those major metropolitan areas into less densely populated areas. GSM cellular service currently accounts for approximately 80% of worldwide traffic, distantly followed by CDMA (Code Division Multiple Access) at 14% and TDMA (Time Division Multiple Access) at 6%.

GSM networks employ standards-based technologies to provide mobile services to their customers. A typical GSM implementation is shown in Figure 1.

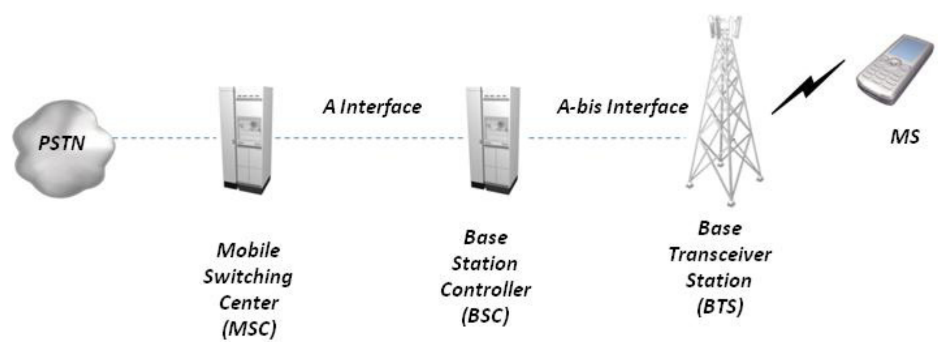

Figure 1 – Typical GSM Implementation

The key GSM components in this example are the Mobile Switching Center (MSC), the Base Station Controller (BSC), the Base Transceiver Station (BTS), and the interfaces between them. The major functions of these components are:

- *MSC* – The Mobile Switching Center is the interface from the Base Station Controller (BSC) to the external networks such as the PSTN (Public Switched Telephone Network) or mobile networks. The MSC is a switch responsible for coordinating and controlling the call set-up.
- *BSC* — The Base Station Controller provides all the control functions and physical links between the MSC and BTS. It is a high-capacity switch that controls functions such as call handover, cell configuration data, and control of radio frequency (RF) power levels in base transceiver stations. Multiple BSCs are served by a single MSC.
- *BTS* — The Base Transceiver Station, which includes transceivers (TRXs) and antennas, handles the radio interface to the mobile stations needed to service each cell in the network. A group of BTSs are controlled by a single BSC.

- *A* interface – Interface between the MSC and BSC carrying uncompressed voice and signaling for call set-up.
- *A.bis Interface* – Interface between the BTS and BSC carrying compressed voice and signaling.
- *MS* – Mobile Station, commonly known as cell phones or mobile handsets

The terrestrial A.bis interface can carry up to eight TRXs each carrying eight channels or voice calls on a single E1. One TRX takes up to two timeslots and a Link Access Protocol – Dm (LAPDm) signaling channel takes up one time slot. An example of this channelization is shown in Figure 2.

Timeslot	Assignment	Timeslot	Assignment
0	Framing	17	Unused
1	TRX 1 8 channels	18	Unused
2		19	Unused
3	TRX 2 8 channels	20	OA&M
4		21	OA&M
5	TRX 3 8 channels	22	TRX 8 signaling
6		23	TRX 7 signaling
7	TRX 4 8 channels	24	TRX 6 signaling
8		25	TRX 5 signaling
9	TRX 5 8 channels	26	Unused
10		27	TRX 4 signaling
11	TRX 6 8 channels	28	TRX 3 signaling
12		29	TRX 2 signaling
13	TRX 7 8 channels	30	TRX 1 signaling
14		31	Unused
15	TRX 8 8 channels		
16			

Figure 2 – A.bis Interface Channelization

As Figure 2 illustrates, the information that is transferred over the A.bis interface is channelized into a terrestrial TDM connection, and consists of signaling between the nodes, voice information and potentially data from customer devices.

Satellite Implementation of A.bis Interface

Due to the innovations in cellular infrastructure and satellite backhaul technology, there are new opportunities that enable operators to profitably pursue customers in remote rural markets. There are lower cost, more powerful cellular infrastructure components on the market, including updated BTS equipment and handsets. Also, when leveraging existing MSCs and BSCs, the cost benefits of supporting remote BTSs via satellite are compounded, further minimizing expenses for cellular operators.

Legacy Single Channel per Carrier (SCPC) satellite connections have historically bridged the gap where traditional terrestrial networks were not viable options. By its nature, SCPC supports only one transmission (BTS) per satellite channel, requiring that each link be engineered to support the peak hour at each base station (BTS) location, resulting in significant unused bandwidth during non-peak hours. SCPC is difficult and costly to manage, forcing operators to over-dimension networks to avoid carrier resizing to accommodate future traffic growth. The net result is that costly satellite bandwidth goes unused, and the cellular operator pays for the inherent inefficiency out of their bottom line.

Today with Deterministic TDMA (D-TDMA) links, an efficient single large "pipe" solution can be cost effectively serviced over a satellite connection for many BTSs and can easily be scaled to add capacity as markets develop and traffic increases.

> Consider this example:
> When comparing the bandwidth efficiency of D-TDMA vs. SCPC, assume a BTS has relatively low traffic usage of two Erlangs thus requiring seven channels. An SCPC network of 50 such BTSs would require 350 channels of bandwidth capacity. In a D-TDMA network, the same 50 BTSs with two Erlangs of traffic each would require 100 Erlangs of capacity, which only requires 117 channels of capacity. That is over a 65% reduction in channel capacity required to support the same levels of traffic.

The graph below shows for a range of traffic densities (in Erlangs) how the efficiency of the D-TDMA solution increases as the number of sites increases.

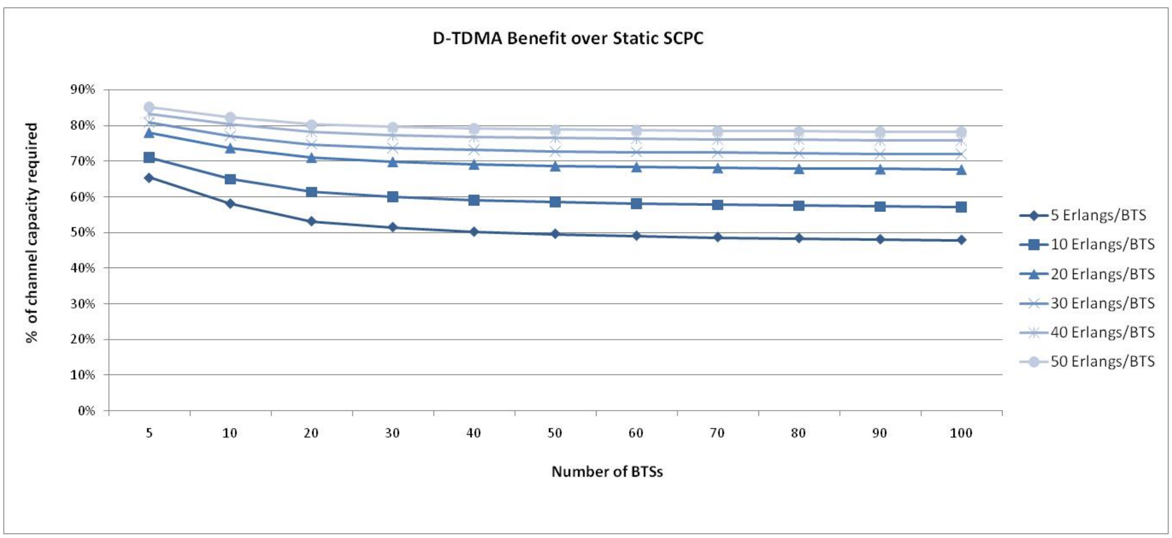

Figure 3 – D-TDMA Efficiency

Unified cellular and satellite IP networks further increase network efficiency and improve performance through the efficiencies enabled by IP. The migration from traditional static TDM to low-cost transport of IP and Ethernet is playing a significant role in reducing transport costs and enabling service for low revenue users.

The iDirect Solution

Bandwidth Efficiency

iDirect's unique IP-based D-TDMA approach significantly reduces the satellite bandwidth required and allows carriers to groom bandwidth across multiple locations spanning a wide geographic region, even the most remote locations and in the harshest environments. More importantly, it offers an economical option without sacrificing the speed or quality that the cellular industry demands. The shared platform allocates bandwidth according to real-time requirements and not the busy-hour maximum as dictated by SCPC networks. Shared TDMA satellite networks are able to efficiently support small, medium, and large network requirements, eliminating the need to over-dimension networks at a significant cost.

The iDirect satellite remotes are equipped to dynamically allocate bandwidth to remote sites based on actual utilization. The remote systems communicate with the hub multiple times every second and relay their demand for payload traffic. The hub then allocates the appropriate number of time slots for data transmission based on the real-time network demand and traffic patterns, dramatically reducing the need for voice channels and satellite bandwidth.

System Interoperability

iDirect's solution is vendor agnostic and is directly interoperable with all cellular technology for backhaul including GSM, EDGE, GPRS, UMTS and CDMA 2000, whether using mediation devices, A.bis over IP solution, or other IP-based solutions.

A network design using the iDirect system with a mediation device is shown below in Figure 4.

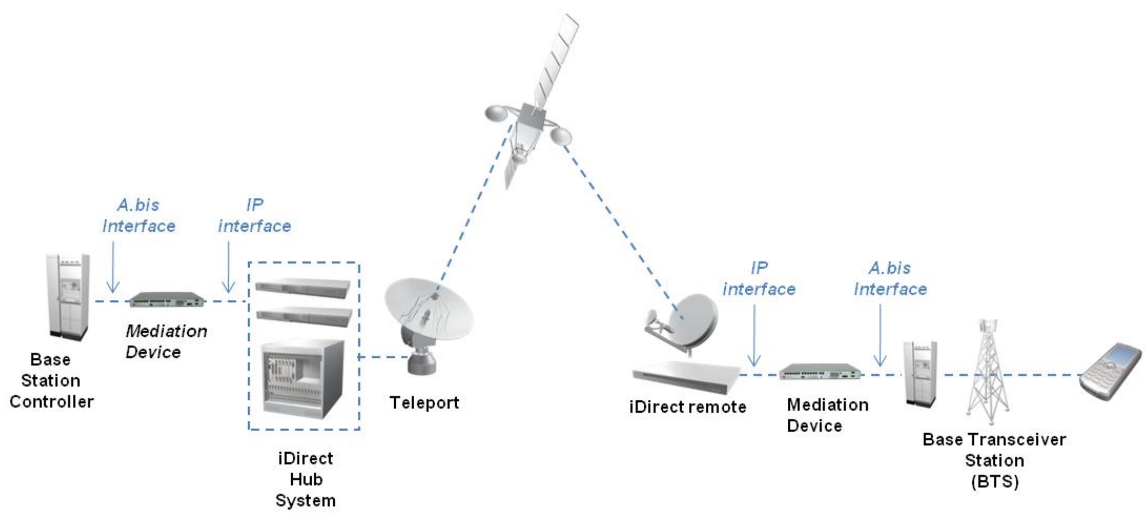

Figure 4 – iDirect/RAN Optimizer Cellular Backhaul Network Diagram

Mediation devices optimize bandwidth by:

- Eliminating data typically sent when there is no voice (idle/silence suppression)
- Restricting transmissions to true signaling frames and removing fill in 'flag' bytes
- Compressing data channels

The implementation of these techniques may vary by vendor, but the result is a significantly reduced payload flow on the A.bis interface. In addition to reducing the data rates, the backhaul converter will change the format from TDM to IP. Since the transferred data is no longer channelized, and is frequently bursty, IP is an ideal transport. Not only is the format well suited for IP transport, but it is also very effective in reducing the overall bandwidth required by the network as a whole, which is termed the “trunking efficiency.”

Newer trends in cellular backhaul technologies point to A.bis over IP and all-IP solutions. These solutions include a new bandwidth paradigm, the packetizing of the A.bis interface into an IP-Ethernet frame, making it ideal for different size base stations such as pico, micro and macro base stations.

iDirect interoperates with all major IP BTS equipment vendors and conducts extensive tests to ensure full compatibility. Ericsson’s A.bis over IP solution is currently available for all their BTSs and the efficiency of their solution over the iDirect platform has been jointly validated by iDirect and Ericsson.

iDirect has also tested with other IP cellular vendors including Huawei and ZTE and will continue to verify the major cellular vendors IP solutions as they become available.

The A.bis over IP and all-IP solutions improve efficiency by eliminating the need for external mediation devices to be added to the network to encapsulate and optimize cellular traffic. The solution improves network performance by making intelligent decisions and taking compensating action such as reducing existing voice calls from full-rate to half rate or slowing GPRS data should congestion arise.

The iDirect/A.bis over IP Cellular Backhaul Network is shown below in Figure 5.

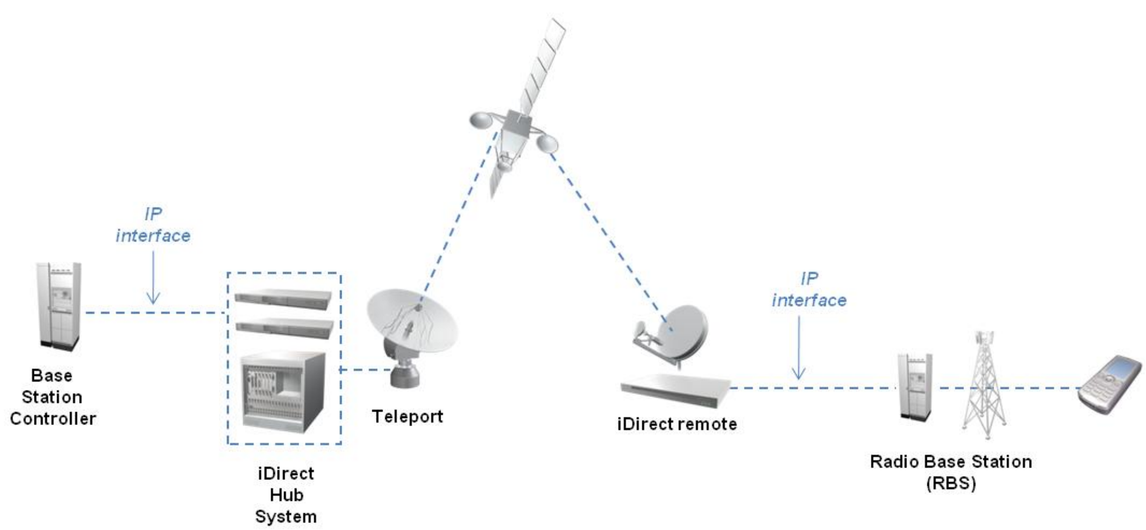

Figure 5 – iDirect/Ericsson Cellular Backhaul Network Diagram

By optimizing the A.bis interface to perform functions such as silence suppression and efficient multiplexing of signaling channels, the operator is able to significantly reduce bandwidth requirements without impacting the user experience. And, because the iDirect platform delivers a fully shared network topology, operators will enjoy greater efficiency and improved bandwidth performance.

Terrestrial-Like Link Quality

iDirect's superior D-TDMA platform provides terrestrial-grade link quality and an award- winning Quality of Service (QoS) application through iVantage™, iDirect's Network Management System (NMS). iDirect's highly differentiated Real Time Traffic Management (RTTM) feature set is an inherent part of the iDirect Intelligent Platform™ and has been specifically designed to support applications such as voice that are not tolerant of delay or jitter. Only iDirect's system delivers "toll quality" digital telephony over a highly cost effective shared bandwidth medium employing the following relevant RTTM features:

- Application QoS and Prioritization
- Segmentation and Reassembly (SAR)
- Committed Information Rate (CIR) settings
- Dynamic CIR and Application Triggered Dynamic CIR
- Network QoS at the network level
- Feathering of timeslot allocation

One of the major technical hurdles when implementing VoIP is jitter. When a network system allocates bandwidth to a remote in order to support a voice call, if the allocated timeslots are not contiguous the voice packets will arrive at the hub in batches, creating an environment conducive to jitter. iDirect's feathering feature significantly reduces jitter between voice packets by evenly spacing timeslots across a frame producing voice quality on par with terrestrial links.

iVantage™, iDirect's Network Management System, allows customers to easily view traffic across the entire network and customize advanced QoS parameters. The iDirect remote and hub are configured via the NMS with a QoS profile that can prioritize real time traffic over non-real time traffic across the shared satellite bandwidth medium and allocate bandwidth appropriately in an "on-demand" mode to each remote.

iDirect's QoS segmentation and re-assembly algorithms enable the system to interrupt large data frames to prioritize voice traffic, eliminating unused time slots and enabling more efficient multiplexing of signaling channels.

In a GSM backhaul solution, there are typically four levels of data priority. They are (in order of highest priority):

1. Signaling between the BTS and the BSC
2. Voice information
3. Data
4. Signaling between the A.bis concentration devices

It is critical that the satellite connections manage these priorities properly. For example, if a connection failed to transport signaling messages, such as during periods of excessive data or voice traffic, the

BTS or BSC could have cause to believe that connectivity has been lost with the other side, and all calls would be cleared. iDirect's solution ensures connectivity and significantly reduces bandwidth by enabling more reliable transmissions through greater data integrity and prioritization.

iDirect's QoS bandwidth allocation algorithms allow for countless possibilities of quality of service levels, bandwidth management and traffic prioritization to avoid contention and service degradation. As traffic is groomed by the backhaul conversion device, priorities are assigned to the various traffic types. Satellite operators can segregate bandwidth by groups of remotes and by applications, giving priority to specific BTSs or to real-time applications such as voice. Cellular operators with diverse profiles can be grouped into the same bandwidth pool, providing further savings.

Conclusion

The cellular marketplace continues to grow and with many of the world's major metropolitan areas already covered, the next horizon for cellular pushes into more remote areas. In the past, it has been difficult to cost effectively address many of these less densely populated or very remote areas, but now with iDirect D-TDMA platform, that model has changed.

Everybody wins with iDirect's cellular backhaul solution: isolated rural customers receive much-needed connectivity, cellular operators can profitably pursue business from these customers, and satellite operators can expand their business with cellular operators.

By modernizing legacy backhaul networks, cellular providers can add new data services, like fixed voice, WiFi, and WiMAX, further increasing revenue per site. Cellular operators can launch service to new markets and gain life-long customers: the first provider in rural markets is most often proven to remain the primary provider by establishing a competitive barrier not easily overcome. By providing service to remote areas, operators can reduce churn from their current customer base that need rural roaming and can also recoup roaming fees from competitors.

Satellite operators also benefit, expanding their business with cellular operators by leveraging existing investments in iDirect's platform to pursue this emerging market opportunity. Satellite operators can make a strong business case to cellular operators to expand their networks and upgrade their legacy backhaul networks by offering affordable terrestrial-grade backhaul links.

Extending the edge of existing cellular networks to incorporate the millions of people in regions with limited or no cellular coverage presents a huge opportunity for both cellular and satellite providers. The ability to build out these networks in a cost efficient manner, and provide ongoing service profitably will be the key to opening these markets and building customer base. As the leader in satellite-based IP communications technology, iDirect recognizes these challenges, and has developed a solution that leverages the most efficient transport in a shared environment to deliver the industry's most cost effective solution. By utilizing an iDirect powered satellite network to carry cellular traffic, cellular providers will enjoy all the benefits of next generation IP networking without concern for geographic constraints, usage patterns, or call quality.