LOTUS^{GSM} White Paper

Cost-Effective Rural GSM, LTE and Backhaul

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INTRODUCTION

Providing cellular wireless coverage in rural areas has always proved difficult. However providing service in remote mountainous regions in areas such as the Middle East and Southeast Asia is far more challenging. The main reason is not the vast size of these regions (although this is a factor), it is the cost of building and deploying Macro Base Station sites, combined with lower Average Revenue per User (ARPU). This increase in deployment costs and reduction in revenue effectively nullifies the business case, meaning that any deployment becomes unviable.

Analysis of the business case identifies the following significant costs associated with deploying Macro Cellular Base Stations in rural areas:

- Base Station Equipment
- Installation & Commissioning
- Indoor Cabinet & Air Conditioning
- Transmission
- Power
- Access

Base Station Equipment

Macro Base Stations delivering cellular voice and data services traditionally consist of many separate elements, including a large indoor equipment rack and outdoor antenna elements. The equipment is often very expensive, and requires additional ancillary equipment to operate.

Installation & Commissioning

The architecture of cellular Macro Base Stations, along with the amount of equipment that needs to be installed, results in a complex and time consuming installation & commissioning process. This requires a highly skilled work force, driving up the operational costs (OPEX) associated with the network rollout.

Additionally, the network configuration to allow handover between cells is manually intensive, requiring extensive radio planning and a highly skilled work force. This has a major impact on the initial roll-out of the network, requiring ongoing optimization as cells are added to the network.

Indoor Cabinet & Air Conditioning

Conventional Macro Base Station equipment consists of a mixture of indoor and outdoor equipment, requiring large indoor cabinets which need to be weather protected and temperature controlled. This combination of shelter and air-conditioning units are a significant cost to the network, both in terms of the initial capital expenditure (CAPEX), and the ongoing operational expenditure (OPEX).

Transmission

The viability of any cellular network is dependent on the ability to connect each BTS with the core network. In rural locations of places as the Middle East and Southeast Asia there is no wired infrastructure available, so operators need to either lay their own Fiber cables, or deploy specialist microwave point-to-point systems. Fiber cables are extremely expensive to deploy, and impractical for rural locations. When Fiber infrastructure is available, it takes an excessive amount of time and additional bureaucracy to obtain a fiber or wired transmission solution. Issues with fiber solutions include right-of-way issues, aerial suspension, trench digging, contracting to lease existing capacity etc. Microwave point-to-point systems normally consist of a split indoor / outdoor architecture, with very large directional antennas. These require elaborate alignment procedures, and towers which can withstand the additional equipment and wind loading requirements. Microwave point-to-point systems require installation & commissioning expertise, and sufficient space to be allocated within an indoor cabinet.

Power

Providing power to remote Base Station sites involves significant costs, particularly since it is not often possible to rely on national electricity infrastructure. As a result many sites are powered using generators, which require a regular supply of fuel, and appropriate on-site storage facilities.

Macro Base Stations tend to have high power consumption, and therefore require high-powered generators, which use lots of fuel. This results in considerable CAPEX and OPEX costs to the network.

Access

Site access is most important to enable delivery of fuel supplies to maintain operation. However, it is also necessary for delivering bulky equipment to the site, such as conventional cellular Macro Base Stations, and other equipment such as indoor cabinets. In some cases the rough terrain means that an access road may need to be built from a nearby public road, significantly increasing the cost of building the site.

Site access is also required for ongoing maintenance of the conventional Macro Base Stations, including software, firmware and hardware changes. Since changes to the Base Station require site access, the number of changes per year directly affects the ongoing OPEX for each site.

CREATING A COST-EFFECTIVE SOLUTION

The only way an operator can develop a viable business case and successfully provide 2G Voice and 4G Data services in remote rural areas is to reduce the costs associated with deploying and operating the network. This is necessary due to the difficulty in increasing the ARPU amongst users with a low average income, as well as the low population density in rural areas.

The primary CAPEX and OPEX costs identified previously are analyzed below to explain how a cost-effective solution can be created.

Base Station Equipment

The most effective Base Station cost reduction is achieved through technology and innovation. For example, the use of Software Defined Radios creates a far more flexible platform, which can evolve through software changes and deliver multi-standard (e.g. GSM + LTE) services rather than expensive hardware changes or additions.

Integration of different functions (such as Access & Backhaul) into a single Base Station also reduces cost, reducing the overall footprint of a Base Station site, and lowering ongoing installation and operational costs. This strategy also dramatically reduces the inventory holdings, simplifying the initial roll-out and subsequent storage of spares.

Installation & Commissioning

The installation and commissioning costs are dominated by the requirement for a high skilled work force. The best way to reduce these costs is by utilizing "plug and play" equipment, which does not require complex commissioning procedures, but can simply be installed at a given location.

Additional costs can be avoided if the amount of equipment installed on site is reduced. For example, the use of external, all-in-one pole mounted equipment eliminates the need for an indoor cabinet, and the associated installation team. This not only saves on the size of the installation team, but also reduces the time taken to install each site, translating into further cost savings.

Operationally, one of the most significant costs is the assignment of neighbors to facilitate handover between cells. The only way to reduce these costs is through

self-optimization technology, where the system can automatically detect nearby cells, and add them to the neighbor lists.

Indoor Cabinet & Air Conditioning

The costs associated with an indoor enclosure, and air conditioning system can be completely eliminated if all of the Base Station and ancillary equipment is capable of being installed outdoors, exposed to the weather. Any requirement to protect Base Station equipment from the weather results in costly indoor cabinets and air conditioning systems.

The elimination of indoor cabinets and air conditioning systems reduces the footprint of the site, and significantly reduces the power consumption, since air conditioning is notoriously power-hungry.

Transmission

The most cost-effective solution for providing a backhaul connection from the Base Station site to the core network is using wireless technology, as opposed to wired technology (e.g. Fiber or DSL). This is due to the lack of existing wired infrastructure in rural areas in the Middle East or Southeast Asia, and the costs associated with deploying new wired infrastructure.

The choice of which spectrum to use for Wireless backhaul connections is very important. Traditional microwave point-to-point systems operate at high frequencies over 6GHz, and typically require annual "rental" of the spectrum from the local regulator, as well as strict licensing to minimize interference. The costs associated with this spectrum are justifiable in dense areas, or when traffic is aggregated together. However, in more remote regions when wireless backhaul is only used to connect a handful of sectors, a different approach is preferred. Use of the sub 6GHz licensed bands provides a cost-effective, flexible solution for wireless backhaul, since nationwide spectrum can often be obtained by the operator in conjunction with their existing spectrum assets.

Backhaul of cellular Base Stations has traditionally relied on circuit switch links, which are based on E1 or T1 circuits. A more flexible approach, is to use IP-based technology, which allows far higher capacity backhaul links, and even point-to-multipoint backhaul to be used. This flexibility allows the overall network architecture to be simplified, reducing the operational costs associated with the core network.

Power

The costs associated with deploying a generator to provide uninterrupted power in remote rural locations can be reduced by using renewable energy resources, such as solar power. In order to achieve this, the overall power consumption of the Base Station site must be reduced as much as possible to support standard solar power systems.

Access

Site access is important for any site, so the costs associated with providing access cannot be eliminated completely. However, if bulky equipment such as fuel, high-power generators and indoor cabinets are no longer required, then site access is only required for installation personnel, and vehicles carrying the base station equipment. The size of the Base Station then becomes the most important criteria affecting site access. If the Base Station is small enough, then there is no need for an access road to be built, therefore significantly reducing the build cost of each site.

LOTUS^{GSM}

LOTUS^{GSM} is a revolutionary new product from Lotus Solutions and Services, designed to allow carriers to serve rural and underserved markets economically, addressing the challenges identified in this white paper. The product is the result of collaboration with Airspan, a leading 4G wireless solutions provider, and ip.access, a pioneering femtocell and picocell manufacturer.

LOTUS^{GSM} is a compact, all-in-one Base Station, delivering 2G Voice and 4G LTE Data services plus integrated wireless backhaul using Airspan's Software Defined Radio (SDR) technology. It consists of a single outdoor enclosure, optimized to operate in harsh environments without need for any indoor cabinets or shelters. LOTUS^{GSM} has reduced power consumption, allowing it to easily utilize renewable energy sources such as solar and wind.

LOTUS^{GSM} adopts an all-IP architecture, with the connection between the BTS and BSC, and eNB to EPC GW, carried over an IP network using a proprietary IP-based technique. LOTUS^{GSM} supports multiple backhaul options, allowing a choice of wired or wireless technologies. However, the key advantage offered with LOTUS^{GSM} is the ability to add advanced software defined radio (SDR) backhaul technology to provide integrated low latency, high capacity wireless backhaul.

Use of LOTUS^{GSM}'s integrated backhaul allows the system to self-connect with the core network, and eliminates the need for separate, high cost microwave links between sites. The backhaul also supports self-healing technology, ensuring a highly robust architecture which is able to automatically restore backhaul connections in the event of a failure in the network. Relay functionality is a key characteristic, allowing nodes to act as relay agents to provide backhaul connectivity to other LOTUS^{GSM} systems in the network.

LOTUS^{GSM} is a full plug and play solution, ensuring rapid deployment using a low skilled workforce. This ensures that complex configuration and planning parameters can be automatically provisioned when a connection is established to the network.

The key advantage of using a SDR solution is that LOTUS^{GSM} incorporates virtually every existing mobile carrier radio interface through different software loads, including the following:

➢ 2G and 2.5G GSM Edge
➢ LTE Release 8.0 and 9.0, both TDD and FDD
➢ SDR Broadband Wireless Backhaul

Product Highlights

Sustainable; LOTUS^{GSM} power consumption of around 200W per sector (assuming use of two GSM TRX, LTE and backhaul) is around 1/4 the power of a conventional Macro base station.

Simple to Deploy; LOTUS^{GSM} requires very low maintenance, and no specialist radio experience to deploy. The small form factor also means that LOTUS^{GSM} can be installed by a single installation engineer, and the smart backhaul means that a connection with the network will be automatically established.

LOTUS^{GSM} adopts Network Listen functionality, allowing the detection of neighboring cells, and the automatic configuration of neighbors for handover. This simplifies the planning and deployment of the network, and also aids with the detection of interference sources.

Strong Security; LOTUS^{GSM} provides a secure environment, utilizing advanced encryption techniques to prevent interception of traffic on the access and backhaul interfaces. Authentication is also used to validate end user devices and LOTUS^{GSM} nodes when registering with the network in order to provide a robust environment for rural service providers.

Integrated Backhaul; LOTUS^{GSM} provides integrated backhaul using Airspan's iBridge backhaul technology. This delivers a high capacity backhaul with Quality of Service (QOS) all the way to the end user devices. iBridge provides a highly efficient, self-optimizing backhaul which delivers up to 14bit/s/Hz spectral efficiency. iBridge protects against redundancy through self-healing, allowing backhaul connections to automatically reconnect in the event of any failure.

Multi-Standard Multi-Radio; LOTUS^{GSM} supports multiple standards of access radio technology (i.e. 2G and 4G), in particular supporting GSM, GPRS and LTE 4G

standards running hybrid MIMO modes. Use of SDR technology allows a 2G network to be <u>remotely</u> upgraded to support LTE.

Wide Area Coverage; LOTUS^{GSM} features "macro" class high transmit power enabling coverage of a wide area. This is essential to minimize the number of Base Stations required to provide coverage of large rural areas in places such as the Middle East and Southeast Asia.

Fully Featured; LOTUS^{GSM} is a fully featured GSM + 4G LTE Base Station, supporting advanced features such as dynamic timeslot allocation, handover to 3G Base Stations, Automatic Neighbor Relation (ANR), RAN Sharing and Inter-Cell Interference Coordination. LOTUS^{GSM} supports voice and data services, as well as SMS.

CAPEX Benefits

CAPEX levels are reduced in the following areas when using LOTUS^{GSM}

Site Acquisition

Expensive site acquisition costs are avoided with LOTUS^{GSM} through its small size and integrated functionality. Its all-outdoor form factor means that it does not require expensive indoor enclosures thus making site selection simpler, faster, and more straightforward. The only installation requirement is for a source of power.

Network Planning & Implementation

LOTUS^{GSM} provides the planners with more flexibility in planning and implementing a wireless network deployment. Its integrated backhaul allows connectivity to be automatically established between the access node and nearby Points of Interconnect, enabling greater flexibility in the sites that can be utilized for LOTUS^{GSM} access nodes. Use of the GSM Network Listen functionality and LTE Automatic Neighbor Relation (ANR) enables the detection of neighboring cells, and the automatic configuration of neighbors for handover.

Equipment Costs

LOTUS^{GSM} minimizes CAPEX expenditure on radio access network equipment. It provides a low cost cellular Base Station and integrated backhaul. This simultaneously provides high capacity voice and data services on the access radio interface, and a "middle mile" backhaul solution to a local Point of Interconnect. LOTUS^{GSM} also supports relay capabilities, allowing coverage to be extended to un-served or underserved remote locations.

Site Construction

LOTUS^{GSM} provides real and tangible benefits in terms of site construction, due to the ease with which it can be installed on towers and rooftops. It is physically small and light, allowing installation by a single person. This dramatically speeds up deployment.

LOTUS^{GSM} is an all outdoor solution, not requiring costly indoor cabinets or bulky cabling. In most locations network connectivity is provided wirelessly using the integrated iBridge backhaul.

OPEX Benefits

OPEX levels are reduced in the following areas when using LOTUS^{GSM}

Power

Sustainability of most operators' business case is significantly impacted by the cost of power. LOTUS^{GSM} requires around 1/4 the power of a conventional Macro base station solution, which makes a considerable difference to the sustainability of any operation, especially in environments with a limited number of users (e.g. Rural Broadband), or restricted availability to power.

LOTUS^{GSM} delivers high performance 2G and 4G services whilst also being highly efficient from a power perspective. It requires 200W per sector (assuming use of two GSM TRX, LTE and backhaul) due to the super-efficient Power Amplifier and baseband technology. LOTUS^{GSM} can therefore be powered using renewable power sources such as solar and wind. This choice of power supplies allows LOTUS^{GSM} to be deployed in remote locations where conventional energy solutions are unavailable or uneconomical.

Transmission

LOTUS^{GSM} provides integrated backhaul using Airspan's iBridge technology, enabling installation in locations without existing transmission infrastructure, or locations not suitable for additional bulky equipment. LOTUS^{GSM} enables the traffic from multiple sectors to be aggregated over a single iBridge backhaul connection. In addition, LOTUS^{GSM} supports iBridge relay functionality allowing coverage to be extended far beyond the Point of Interconnect to the network.

LOTUS^{GSM}'s unique architecture significantly reduces the transmission investment, and the amount of equipment that needs to be managed.

Operations & Maintenance

LOTUS^{GSM} comes in an all-in-one outdoor package which fully integrates the access and backhaul functions. This simple product architecture, with units interchangeable with one another, dramatically reduces spares holding and inventories. LOTUS^{GSM} makes it easy to replace a defective unit, as it assumes the identity and features of the old one.

LOTUS^{GSM} supports self-optimization and self-healing, ensuring the maximum throughput is delivered to the end user, and the network automatically recovers in the event of failure. This, combined with LOTUS^{GSM}'s low Mean Time To Repair (MTTR) characteristics, increases overall service availability.

AFGHANISTAN CASE STUDY

Afghanistan represents a challenging environment to provide cost-effective voice and data services to rural areas. It is a mountainous region with a rapidly growing population, from around 20 million people in 2000, and 29 million people in 2010. As a result it makes an excellent place to examine whether a viable business case can be established in underserved rural locations in Southeast Asia.

Mobile phone usage has increased dramatically in Afghanistan, with over 20 times more cellular phones than fixed lines. However there is little penetration outside of urban areas, which with an area covering nearly 250,000 square miles, may not seem surprising. However, the principle reason that GSM coverage is so poor is the cost of building and deploying Macro Base Station sites and backhauling traffic to the core network.

Working in partnership with local operators in Afghanistan, Lotus Solutions and Services deployed a LOTUS^{GSM} solution to provide 2G services, with integrated wireless backhaul to the core network. The purpose of the deployment was to demonstrate the significant cost savings of the LOTUS^{GSM} product when compared with traditional Macro Base Stations.

The project focused on the costs associated with building and maintaining each site, and the ongoing operational costs. In addition the ability to cover a large area, and add capacity to the network was studied.

The following diagrams illustrate the dramatic changes possible when moving from a traditional GSM Macro Base Station, to the compact LOTUS^{GSM} product.
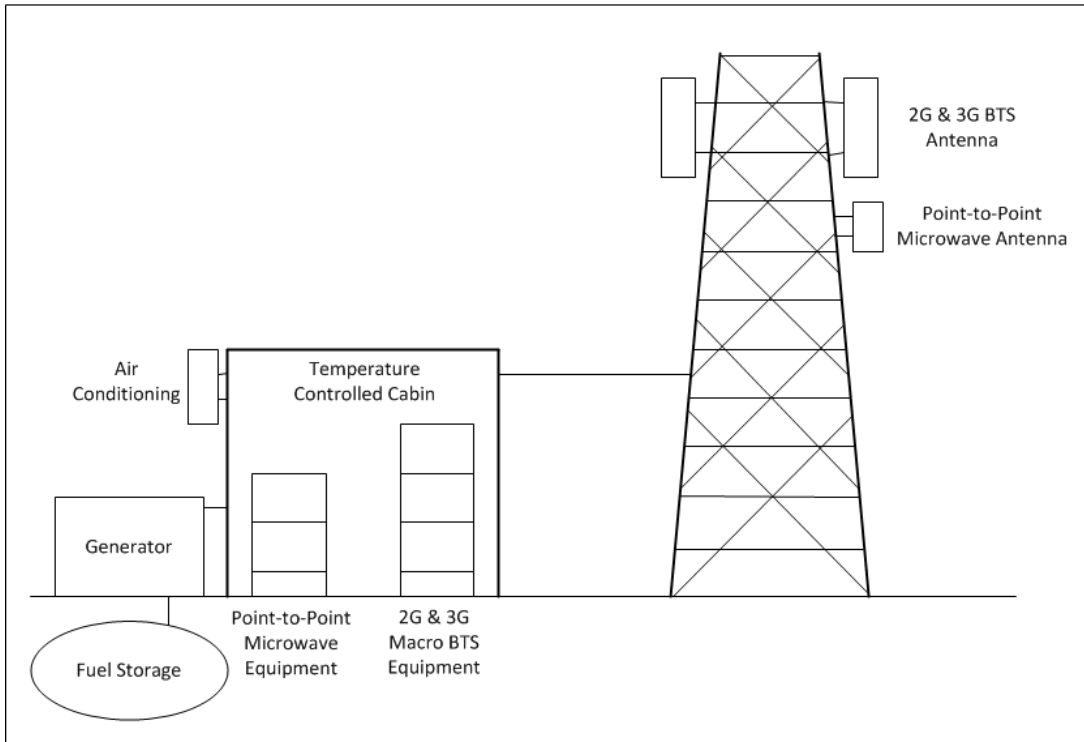
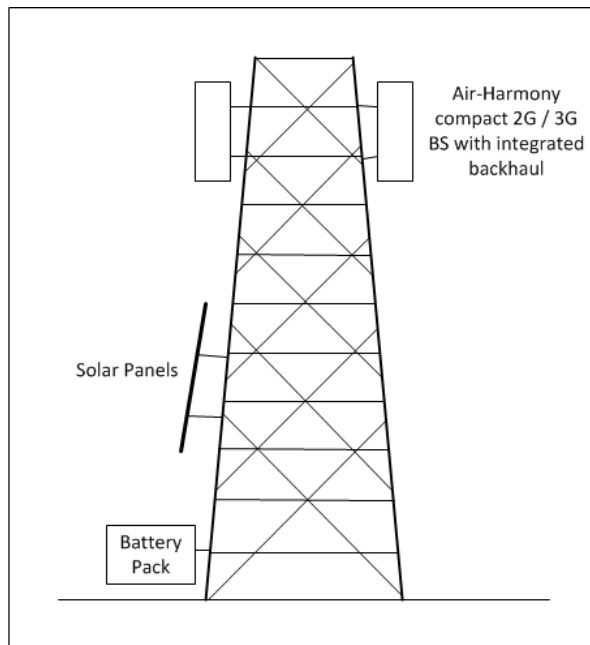**Figure 1 - Macro Base Station Example Site Configuration**

Figure 2 - LOTUS^{GSM} Example Site Configuration

This unique concept significantly reduced the footprint of the Base Station site, both in terms of real-estate and power requirements. In addition, the complexity

of Installation & Commissioning activities was diminished, enabling a lower skilled workforce to rollout the network.

The key outcomes of the study were as follows:

- LOTUS^{GSM} enables deployment on a tower in a couple of hours
- LOTUS^{GSM} supports GSM calls at up to 35 km, using 900MHz spectrum (35km is the limit due to GSM standard timing advance)
- LOTUS^{GSM} supports both Line of Site (LOS) and Non Line of Site (NLOS) coverage

SUMMARY

Today's GSM Macro Base Stations are extremely costly to deploy in remote rural areas in the Middle East and Southeast Asia, making it impossible for operators to create a viable business case, especially given the low ARPU.

LOTUS^{GSM} dramatically reduces deployment costs, providing a cost-effective solution for operators deploying GSM and LTE in rural environments. This has been demonstrated in remote Afghanistan, where GSM services have been rapidly deployed using compact outdoor Base Stations.

LOTUS^{GSM} offers the following tangible benefits to operators looking to provide cellular services in rural areas:

- Plug and Play Solution
- Reduced CAPEX / OPEX
- GSM and LTE services (voice and data)
- Integrated Wireless Backhaul

About Lotus Solutions and Services

Lotus Solutions and Services, a division of Asia Consulting Group (ACG), delivers a carrier-grade Base Transceiver System (BTS) that enables carriers to profitably extend and expand their networks into hard-to-reach areas without changing existing infrastructures. The Lotus system offers lower costs, easy deployment and easy integration with current networks. Lotus was designed based upon ACG's extensive experience deploying cellular networks in Asia.

About Airspan

With over 500 customers in over 100 countries and as a top vendor for carrier-class broadband wireless solutions, Airspan is recognized as a leader and pioneer in 4G and broadband wireless technologies.

Providing an expansive product portfolio, Airspan offers customers the widest selection of 4G products in the industry with an unsurpassed level of technology to benefit their business case. Airspan has solutions spanning the 700 MHz to 6 GHz frequency bands.

About ip.access

Based in Cambridge, UK, ip.access ltd (www.ipaccess.com) is a leading manufacturer of cost-effective picocell and femtocell infrastructure solutions for GSM, GPRS, EDGE and 3G. These solutions bring IP and cellular technologies together to drive down costs and increase coverage and capacity of mobile networks.

ABI Research ranks ip.access as the world's number 1 picocell vendor; its nanoGSM® and nano3G™ picocell solutions provide 2G and 3G coverage and capacity for offices, shops and (using satellite backhaul) passenger aircraft, ships and remote rural areas. nanoGSM is the world's most deployed picocell, with live installations in more than 50 networks around the world and growing.