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OSS RAN Implications of LTE

White Paper

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1 What is LTE?

It seems that every 10 years, the mobile phone industry develops a new, improved radio standard which offers lower costs, higher speeds and improved performance. The first generation analogue systems of the 1980's gave way to 2G GSM (launched in 1991), then 3G UMTS (launched in 2002). CDMA networks also evolved in a similar timescale through IS95 (now called cdmaOne) and EV-DO.

LTE (Long Term Evolution) is a radical new radio interface which was commercial launched in 2010. With the GSM family of standards dominating the global market with over 89% share of subscribers, the previously competing CDMA operators such as Verizon and KDDI Japan have also adopted LTE and joined the same common standard. LTE is now commonly accepted as the primary technology for 4G (4^{th} generation).

Just as the radio interfaces for 1^{st}, 2^{nd} and 3^{rd} generation were based on totally different transmission technologies, so it is with 4^{th} generation. Two different schemes are used for LTE:

- OFDM (Orthogonal Frequency Division Multiplex) for the downlink
- SC-FDMA (Single Carrier Frequency Division Multiple Access) for the uplink

The first version of the LTE standard was formally approved by the 3GPP standards committee in December 2008 (3GPP Release 8). As with all new standards, further clarifications and optimisations will be added in each new update. LTE Advanced, standardised in Release 10 during 2011, offers even higher data rates and theoretical performance in excess of 1 GBit/s under ideal laboratory condition.

In addition to providing more speed and capacity for traditional mobile data services, LTE makes it economically attractive to deliver broadband data services in rural areas and developing countries where wireline (DSL or Cable) isn't available or cost effective.

What are the Benefits of LTE?

The primary objectives of each new radio interface have been to deliver higher performance and better user experience at lower cost. LTE achieves this in different ways:

- **Faster Data Speeds:** Headline data rates of over 100Mbit/s have been demonstrated in laboratory conditions. This not only enables services which require higher speeds, but drastically reduces the time for any data interaction to be sent and received. End-user data rates in the real-world can be expected in the range 10Mbit/s to 30Mbit/s.
- **Fits wide range of spectrum bands:** One reason that some operators had been reluctant to adopt 3G is that each carrier requires a full 5MHz of paired spectrum. LTE has been designed to operate in the limited 1.5MHz carriers commonly deployed in North America, yet also expand to 20MHz carriers which would allow much faster data rates.
- **Efficient use of Spectrum:** By squeezing more bits per second per sector per Hertz through the available spectrum, operators can deliver the same capacity with fewer cellsites, or more capacity from the same cellsites. Estimates are given of between 2x and 5x greater throughput compared to 3G.
- **Self-Optimising and Self-Organising:** In the early days of mobile networks, it was not uncommon to find radio planning departments with hundreds of staff. These carefully designed and tuned the performance of the radio network using complex predictive analysis tools and configuration of many parameters. LTE includes processes which allow each individual cellsite to analyse its own environment and negotiate with nearby cellsites to agree the best settings on an ongoing basis. This will reduce the size of radio planning teams and also increase overall network performance, resulting in fewer dropped calls and better quality.
- **Improved Data Services:** There are several improvements compared to 3G systems, which have been designed from the ground up to improve end-to-end data services. The few seconds delay common with starting up 3G data sessions will reduce to milliseconds. Latency will also drop to milliseconds, which combined with higher processing power in handsets will substantially improve the end-user browsing experience and enable a range of new applications. The transition to an all-IP core network should also increase the range of applications available.

But there are some drawbacks

LTE is associated with SAE (System Architecture Evolution), a new streamlined all-IP core network. It is likely (but not mandatory) for voice calls and other services to use the new IMS core network. This requires service providers to build and rollout new core network elements at the same time as LTE, adding complexity when managing and delivering services across both types of network. Supporting the same services across both 2G/3G and LTE/IMS will add complexity, cost and risk.

In particular, the way that voice calls are handled is intended to change significantly. A SIP (Session Initiation Protocol) based protocol will be used to setup and teardown calls. This will require some duplication and interworking between the existing 2G voice services – the upgrade path will involve some radical change. One benefit of the new system will be a wider range of audio and video services, such as wide-band /high quality voice and more extensive video calling options.

The high performance of LTE will provide an excellent platform for a wide range of new services and applications. This will include so-called "Over the top" IP voice services, such as Skype, Fring and Vonage. Mobile network operators may lose or reduce premium prices charged for basic voice calls.

Wider Global Adoption

LTE has been adopted as the next step in the evolution of both GSM and CDMA networks, and endorsed by almost all mobile network operators in America, Europe and the Far East. This has justified substantial R&D investment from many vendors and created a highly competitive market. The expected high volumes of product will quickly reduce unit costs and widen available expertise.

The common standard will also build on the existing roaming arrangements, whereby users can take their handsets and use them abroad.

We are witnessing a more urgent adoption of LTE amongst CDMA operators, keen to achieve the substantial cost and performance benefits. UMTS/HSPA operators are also planning to adopt LTE, but with a more conservative timeframe. Some are continuing to invest in HSPA+, which offers some of the promised benefits of LTE such as higher data rates (already delivering up to 21Mbit/s), lower latency and improved battery life. Other HSPA operators have indicated they plan to skip HSPA+ and move more directly to LTE.

Where and when will LTE be deployed?

Over 250 operators worldwide have declared their intent to rollout an LTE network in the next few years. These are broadly grouped into four categories:

- **CDMA operators**: including Verizon Wireless US and KDDI Japan. With the CDMA Development Group adopting LTE as their evolution path, CDMA operators are keen to catch up with the cost effectiveness and high performance of competing technologies.
- **HSPA operators**: Whilst we can expect most current UMTS/HSPA operators to migrate to LTE in due course, a few have indicated they plan to skip HSPA+ and move more quickly to adopt LTE because of the higher performance and lower cost.
- **Emerging Markets**: A surprising number of cellular operators, often with limited or no 3G capability, have announced plans for LTE. This would provide broadband services in areas which don't currently have wireline alternatives.
- **China Mobile**: Being such a large operator, with over 600 Million subscribers, its decisions impact the industry substantially. Having been required to adopt a Chinese specific variant of the 3G UMTS standard, the operator is reported to be enthusiastic about rejoining the mainstream as soon as practicable.

What's involved in LTE deployment?

Spectrum

The first essential requirement for any mobile network service is availability of licensed spectrum. Potential LTE operators must either acquire new frequencies, or re-farm their existing 2G and 3G spectrum by slowly migrating their subscribers with new handsets over a period of years.

When 3G UMTS was developed, spectrum regulators across the globe generally agreed to set aside frequencies at 2100MHz. Although a few countries including North America and Australia did not follow this path, it helped accelerate adoption through standardised products with the same characteristics.

This approach has not happened for LTE. The standard allows operation at a wide range of different frequencies and band sizes from 1.5MHz to 20MHz. More than 40 different spectrum bands and configurations are specified so that the system can be used in almost any scenario. However this flexibility gives the device and handset industry a difficult problem – vendors must choose which subset of possible spectrum configurations to focus on, with these benefiting from the low costs achieved through high volumes shipped.

The particular spectrum choices with most interest to date include:

- 700MHz frequencies released by switching off analog TV (the so-called Digital TV Dividend), already in use in North America and Germany.
- 1500MHz used in Japan
- 2500-2600MHz in Europe

Spectrum refarming (i.e. repurposing frequencies previously used for 2G or 3G to LTE) has been suggested particular for:

- 1800MHz, which is widely used for 2G GSM today, could be reallocated for LTE. Telstra, the Australian network, has announced plans to use this. Such refarming does require the permission of the national regulator, but this should not present an unsurmountable problem in most countries.

As with any mobile cellular system, lower frequencies tend to provide longer range and better in-building penetration which is beneficial for coverage during the initial rollout and for rural areas. Higher frequencies have lower range, but this can allow better frequency re-use, and therefore higher overall capacity in dense urban environments.

New Multi-Standard Basestations

Over 80% of a cellular network's capital equipment and operating costs are associated with the RAN – the Radio Access Network. Basestation product costs (typically measured by the cost of a voice traffic channel) have been declining year-on-year since the first cellsites were sold. The large market has attracted powerful competitors, such as the newer Chinese vendors, and physical manufacturing operations for most vendors have been moved to the Far East.

A problem that existed with the migration to 3G was that completely new basestations were required. Existing 2G sites were doubled in size with duplicated antenna, basestation equipment and any associated cooling and power requirements. Often a separate outdoor cabinet was provided – effectively doubling the equipment and running costs.

For LTE, leading vendors have provided basestation architectures which can support all of 2G/3G and 4G in the same cabinet, substantially reducing the impact of upgrade. New antenna may well be required, particularly where different frequencies are used. A range of compact, multi-frequency antenna are becoming available which reduce the physical impact – otherwise simply adding further antenna may exceed the physical weight limits of the tower or exceed local town planning limits.

RAN Refresh and Basestation Swapouts

Arguably, RAN vendors have been clever to promote these multi-standard basestations because it reduces the opportunity for open competitive tender from other suppliers and consolidates their position within their existing accounts.

In some cases, network operators have made a larger investment by replacing their entire basestation equipment nationwide. Where equipment may be 10 or more years old, the ongoing maintenance and operational costs (repairing equipment failures, power consumption, limited upgrade capability) makes the business case for a large investment worthwhile. In most cases, the remaining installed equipment (physical towers, antenna, microwave transmission, power, air-conditioning etc.) is unaffected.

The close interworking between the 2G/3G/4G radio network means that opportunities to build and manage a 4G only radio network are reduced, since it makes more commercial sense to manage these as a single operation. Either all 2G/3G/4G would be outsourced or none.

Adding many small cells for capacity and performance

Although the initial launch of LTE will be based mostly on existing 2G/3G cellsites, the full capacity and speed benefits will require a radical change in network topology. Performance at such high data rates is highly dependent on proximity of the user to the cellsite, creating a need for many more smaller, low power and short range basestations. These so-called small cells, which are in effect miniaturised cell towers, will work in conjunction with medium and large scale cell towers to create a comprehensive, high capacity and high speed network.

This Heterogeneous Network (or HetNet for short) will comprise a mix of different cellsites from different vendors, with forecasts of up to 10 times the total number of cellsites being required to achieve anticipated traffic demand and speed.

Initial performance results from NTT DoCoMo, one of the pioneers of commercial LTE service, presented at technical conferences indicate that high data rates cannot easily be achieved indoors in urban areas. This reinforces the demand for a large number of small cells deployed liberally in dense urban areas.

Vendors have responded with a range of cost effective small cells with greater automation and self-management to meet this need.

Backhaul Transmission

The high data rates and capacity available through each basestation has a consequential effect on the transmission capacity between cellsites and the central switching centres. The rapid traffic growth of 3G has caused a cellsite backhaul capacity increase of up to 10 times, and LTE is likely to grow this by a further order of magnitude. With peak traffic loads concentrated on perhaps 10% of cellsites, backhaul transmission capabilities are rising from 4Mbit/s in early 2G systems to something around 400Mbit/s in the largest 4G cellsites today and forecast to require more than 1Gbit/s in due course.

Even small cells with a peak capacity of 100Mbit/s will require dramatically increased transmission speeds to make full use of the technology.

This enormous growth in capacity is causing operators to switch transmission technologies and re-architect their entire transmission network. The balance between in-house and 3rd party leased transmission is being carefully scrutinised. Many operators are actively deploying Ethernet transmission, both over fiber and point-to-point wireless links to meet this demand. This includes short range NLOS (Non-Line of Sight) wireless backhaul for small cells, connected through distributed hubs to higher speed fiber.

Capacity planning for the backhaul transmission network is now even more important, where the design choices for each of tens of thousands of individual wired and wireless links must be made to meet overall cost and strategic objectives.

Many operators are reviewing the OSS management tools they have in place to determine if they can satisfy management of this rapidly changing environment.

Handsets

With the primary benefit of LTE associated with high speed data services, USB data dongles are the first devices offering this capability. With LTE not yet providing nationwide coverage, most such data dongles will need to be multi-mode – capable of 2G/3G/4G operation.

Qualcomm has been leading the field with its Gobi module that is capable of not just 2G and 3G, but also CDMA and GSM/UMTS – effectively operating across all countries and markets globally. These are being integrated into laptops to make them compatible with 3G everywhere. Extending this to include LTE is on their roadmap and will make for a highly desirable product, with high volumes bringing economies of scale.

A growing range of LTE capable smartphones, which also benefit from high performance/low latency data, will come onstream in the next few years. These will require not just the new radio interface, but additional software to work with the new IMS core network whilst maintaining feature transparency. Although CDMA networks are amongst the first to roll out LTE, mobile handset vendors do not appear to want to invest heavily in a wide range of dual-mode CDMA/LTE devices. Those which have appeared have independent internal 3G and 4G components, effectively using 3G for voice service and LTE for data where available. Premium devices, such as the iPhone, are expected to evolve to support CDMA/UMTS/LTE in the same unit in the medium term.

At the low cost end of the handset market, 2G and 3G technologies are already well down the cost curve. A 2G chipset sells for less than $2 today. Licence fees due to early patents are starting to expire, reducing costs further. It will be many years before LTE can compete on cost alone, and high volumes in emerging markets today are built on straightforward voice and text capabilities.

Informa forecast that LTE is capture 8% global market share of the 8 billion mobile connections by 2016, growing from zero to over 600 million users in the space of 6 years.

New Features

The improved data capabilities and associated all-IP network will stimulate creation of a wide range of new services and even new types of devices for applications so far unthought-of.

The explosion in the number of applications available for the iPhone and Google Android, together with the accessibility of downloading from an Application Store (App Store) highlights the potential.

2 How will OSS differ for LTE?

LTE accentuates the issues already seen in growing 3G networks:

- Many more cellsites to manage, and therefore many more associated transmission links
- Greater transmission capacity required at specific high capacity cellsites
- Wider range of end-user services to provision and manage

Much the same as 2G and 3G for existing cellsites?

When 3G was launched, it was deployed as a separate, parallel network. Many operators tendered competitively for suppliers, who were frequently different from encumbent 2G vendors. This led to complexity in managing geographical areas with overlapping 2G and 3G basestation types. The savings gained through competitive tender between suppliers justified extra complexity for the operations teams.

Radio Access Network (RAN) vendors have had more foresight with their product plans for LTE, with many current basestation designs catering for 2G, 3G and 4G radio modules sharing a common platform. Rather than installing additional and often duplicating equipment from alternative suppliers, an extra 4G module can simply be installed into the existing cellsites to provide the 4G capability.

But many more small cells

The highest speed and capacity will be achieved by deploying a large number of much smaller basestations – small cells – which are quickly and cost effectively deployed close to the point of usage. Several vendors already have commercial versions of these products, with many more in the pipeline.

These self-contained, low power units only require a power source and physical mounting point. NLOS (Non-Line of Sight) microwave radio links provide shared backhaul to the nearest hub, typically a larger existing cellsite or nearby small cell with its own high capacity fiber connection.

Installation of these unobtrusive small cells can be as short as 60 minutes, fitting them to existing “street furniture” such as street lamps or the sides of buildings. This avoids concerns from local residents about more visible changes to existing towers, such as installation of additional antenna.

More Accurate Planning Tools

Initially, the radio planning tools and processes will be an extension of 2G and 3G – current predictive planning tools will support all three technologies and be used to evaluate the location of each new cellsite and capacity upgrades. The built in features of LTE, such as Self-Organisation and Self-Optimisation, should reduce the additional workload imposed by yet another new radio technology.

As these networks grow, and particularly as more small cells are deployed, we can expect to see greater use of direct network measurements. Several software performance analysis tools exist which collate and process the high volume of radio measurement reports sent from mobile devices on active calls and data sessions. These can aggregate the data and calculate the location of each device to within around 50 meters.

The net result are a set of accurate geographic maps which highlight the areas of poor coverage and data bottlenecks, allowing very precise targeting of the position for new cell deployment. It is tools of this type which will be essential for cost-effective deployment of large numbers of small cells.

Higher Capacity of cellsites impacts backhaul transmission

Telecom Redux forecasts that the cost of backhaul in the US could increase from $2Bn to $16Bn per annum to meet forecast data traffic demands. Transmission capacity for the largest sites has grown from some 4 Mbit/s for 2G up to 40 Mbit/s for 3.5G and is predicted to require up to 400 Mbit/s for 4G – around 100 times the capacity for 2G.

With backhaul capacity already increasing dramatically from the additional load of burgeoning mobile broadband data, most 3G operators have already taken action to upgrade transmission. Generally this involves changing to Ethernet transmission, where both wireless and wireline/fiber connections replace the slower legacy TDM links. In many cases, the older circuit switched traffic can be carried over shared high-speed Ethernet using a technique called pseudo-wire.

Compression and other optimisation can also make much more efficient use of the existing transmission capacity. Factors which can be taken into account are silent periods of conversations (both voice and data) and the highly asymmetric nature of broadband access. As traffic volumes grow, there is more opportunity for multiplexing across larger numbers of users without significantly impacting performance.

Impact of 3G/LTE drives backhaul transmission technology change

To fully benefit from the very high capacity of LTE, backhaul transmission will almost certainly need to change the technology used. Ethernet, through fiber and wireless, is seen as the ultimate choice, but is not available or suitable in all circumstances. Early concerns about timing and clock synchronisation have been addressed through the IEEE 1588 standard (known as Synchronous Ethernet) and/or GPS. Ethernet can also be used to connect to older 2G and 3G cellsites, emulating the legacy circuit switched transmission using a technical called pseudowire and thus avoiding the need to upgrade or replace existing equipment.

With almost 4 million cellsites globally, and an estimated 10 million transmission circuits serving them, operations teams have to manage many moves, changes and upgrades on a daily basis. The problem was already complex for 2G and 3G, and will continue to grow in magnitude.

Without effective automated tools, operators will struggle to evolve quickly to transform their transmission networks in the most cost effective ways, whilst retaining accuracy and high quality.

The major RAN vendors all offer end-to-end solutions with a variety of technology solutions from fiber through wireless, and typically using Ethernet. Operators need systems in place which sit above these various vendors and knit together the fabric of the underlying network.

Managing network capacity is no longer restricted to cellsite radio capacity alone

In the days of 2G, the high cost of a cellsite and radio capacity compared to the backhaul transmission determined a simple rule. Each cellsite was provisioned with backhaul to match 100% of the peak transmission capacity. With voice calls and SMS being the bulk of traffic carried, this equated to one or two E1 or T1 lines per site.

Several factors have changed this strategy in recent years:

- Data traffic has grown to dominate the traffic mix
- The cost of basestations has been driven down
- BSC/RNC equipment have developed transmission resource sharing features
- Dedicated data backhaul standards have evolved, such as IP

This issue is exacerbated in 4G networks, where backhaul capacities of several hundred Mbit/s are reached.

This has led to a new skill of transmission capacity planning, which is handled in conjunction with radio network planning. The substantial growth in transmission costs, if not managed carefully, will affect the ongoing operation costs.

Operators need to ensure they have three layers of OSS tools in place to properly address the issue:

- Accurate technical inventory, which holds the physical and logical information about the transmission network including every card, port and logical end-to-end circuit. This data should be refreshed from the live network on a regular, automated basis.
- Automated technical design processes, which handle the most common activities in transmission design. These processes will select, reserve and execute the planned changes for every new, upgraded and migrated equipment. Automation allows standard business rules to be applied, with engineers able to override or modify the standard selection where required – whilst still ensuring that a technically sound and complete solution is provided.
- Capacity planning, where both short term bottlenecks and longer term trends are identified, tracked and resolved. This leads to investment budgets being applied where they are most needed, looking forward rather than reacting to shortages or other constraints.

These OSS tools must accurately manage configuration parameters to be aligned across thousands of cellsites, transmission hubs and central office switches. Examples include allocation of unique non-conflicting IP addresses, Ethernet VLAN IDs and end-to-end Class of Service bandwidth.

Greater opportunity for commercial agreements

With much larger costs involved, operators are investigating co-operation and outsourcing arrangements more enthusiastically. These range from simple site-sharing agreements, outsourcing of the entire RAN and joint ventures.

We are also seeing the use of 3rd party transmission changing. In some cases, operators are bringing more in-house; in others, there is more leasing of external services.

Several attempts to implement these schemes have failed, not at the commercial level, but on the technical side. Without the inventory and process tools in place, the cost and implications of separating service delivery from in-house to 3rd party or shared arrangement is not feasible. In extreme cases, there has been a disconnect between what the CEO level believed was commercially feasible and what the CTO/operations department could implement with the tools and systems they had in place.

The impact of LTE is likely to drive the need for commercial co-operation further, and will stress the importance of having effective inventory, design automation and capacity management tools.

LTE should make RF planning simpler – but it isn't standalone

An enormous amount of thought and design has gone into making LTE easy to rollout and manage from a radio planning perspective. LTE includes both self-organising and self-optimising features, with each cellsite monitoring its own environment and adapting accordingly. This should reduce (but not eradicate) the need for RF planning engineers to tune the system to the same extent as for 2G and 3G.

However, LTE will co-exist with 2G/3G systems for many years to come – at least a decade if not longer. Most of the LTE operators will also have those systems in place, and will want to maximise the return on the cost of equipment already in place. They'll also want to capture roaming revenues from visitors from other countries which have not adopted LTE so quickly. It will also take some time for LTE handsets to become the vast majority of equipment through natural upgrade/replacement, and for LTE to reach the same coverage levels as 2G/3G.

When 2G networks evolved to 3G, particularly those using a radically different technology such as UMTS, they often chose different vendors through competitive procurement processes. This led to overlapping areas of 2G and 3G coverage handled by different vendors RAN equipment. Although the same RF planning tool would be used to determine the RF parameters for both 2G and 3G cellsites, there were often minor discrepancies arising. These included one-way handover between cells, mismatched 2G/3G neighbour cell lists and/or candidate handover cells many miles apart.

RF designers also determine the policy rules which drive the traffic onto 3G where available, such as using asymmetric handover, and direct traffic between bands (e.g 850/900/1800/1900 MHz) to optimise network capacity with end user performance. There are many clever proprietary handover algorithms at their disposal from the RAN vendors.

With LTE, operators will need to match radio parameters including neighbour lists between three different systems. There will be a need for additional cross checking, and design rules including handover policy across the different network technologies and frequency bands.

Again, the careful management of these rules and resulting radio parameters will be required to achieve optimal performance and end-user experience. This involves staging the parameters generated by RF planning tools and downloading them to the various vendors systems in a controlled manner.

3 Summary

An LTE Radio Access Network (RAN) will have a somewhat different architecture from 2G or 3G:

- Initially, most LTE cellsites will be co-located and even integrated with existing 2G/3G sites
- Subsequently, a large number of standalone small cells will be deployed to complement the wide area coverage, providing capacity and higher speeds closer to the point of use.

Transmission between the cellsites and the central switching centres will quickly evolve to Ethernet, both wireless and wireline. This will be routed through a series of aggregation points at nearby cellsites and other centralised locations.

Planning tools will change so that performance management will take a greater role in identifying precise locations for additional cellsites, deriving this from measured data reported through the network. The much greater number of individual cellsites, with wider choice of backhaul connections, will require network designers to deliver designs for many new small cells in a much more rapid timeframe.

LTE will further accelerate the explosive growth in backhaul transmission capacity required for 3G. This adds a new problem of transmission capacity management which is essential to control operating costs. In addition to radio planning of the location and RF capacity/configuration of each cellsite, operations departments will need to carefully plan the capacity management and design of their transmission networks.

Operators who have the OSS toolkits capable of managing the demands of a combined 2G/3G/4G transmission network will be able to run their business at lower cost, able to respond to changing capacity demand and be much more competitive.

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