Overlay strategies for 700 MHz LTE deployment

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Executive Summary

Implementation of Long Term Evolution (LTE) at 700 MHz in North America calls for a cost-effective and rapid rollout. LTE provides wireless carriers with a common next-generation (4G) platform and delivers much higher data rates. Deploying this technology in the 700MHz band allows for more efficient RF propagation and greater structural penetration. However, there are also issues with 700 MHz associated with a multitude of interference scenarios. And while an independent service overlay would be the easiest and cleanest approach, the advantages are far outweighed by the cost and impact on real estate. Co-locating new infrastructure while allowing different services to share physical resources such as transmission lines, feeder cables and antennas, will enable operators to realize significant savings in capex and opex, and improve time to market. As 4G services gain traction, robust and optimized network operation at 700 MHz will ensure a smooth migration of LTE into the Cellular, PCS and AWS bands.

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Overlay strategies for 700 MHz LTE deployment

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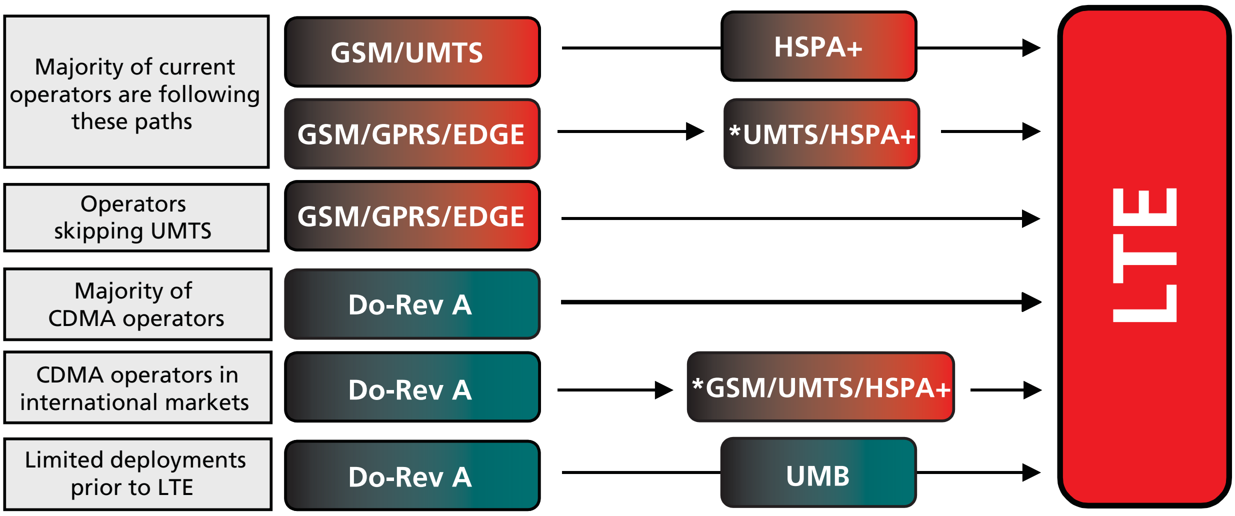
Introduction

Long Term Evolution (LTE) is positioned as the fourth-generation (4G) cellular network technology standard. Defined in 3GPP Release 8, LTE relies on a simplified architecture network based on OFDM (Orthogonal Frequency Division Multiplexing), MIMO (Multiple Input, Multiple Output) and IP (Internet Protocol). It can be deployed in any IMT-2000 band with scalable bandwidth, and lends itself to evolution from every current mainstream cellular technology **[see Table 1]**.

Although Mobile WiMAX is positioned as a 4G alternative, it is not as widely supported by the industry, and only one major wireless carrier in the US has committed to the technology to date. Mobile WiMAX has several limitations in comparison to LTE. It does not provide the same quality of voice communication, while its higher-power transmission requirement drains the mobile device's battery life faster. Furthermore, a limited number of handset manufacturers support the technology, which has made it difficult for service providers to source handsets.

LTE provides a common platform for wireless carriers when compared with the patchwork of cellular technologies deployed previously into the North American market **[see Table 2]**. The technology provides commonality not only between US carriers, whose networks have historically been incompatible or focused on providing voice or data only, but with wireless carriers worldwide migrating to LTE.



* Limited area of deployment

Table 1 All roads lead to LTE

	Frequency Bands					
	700 MHz	850 MHz	1900 MHz	1.7/2.1GHz AWS	2.5 GHz	3.5 GHz
2G		GSM CDMA IDEN	GSM CDMA	GSM CDMA		
3G		UMTS CDMA (EV-DO)	UMTS CDMA (EV-DO)	UMTS		
4G	LTE	LTE (Phase 2)	LTE (Phase 2)	LTE	WiMAX	WiMAX

Table 2 Technologies by North American frequency bands

Crucially, LTE delivers the following advantages:

- High-speed digital data transmission over a fully IP-based wireless system capable of greater than 80 Mbps in both the downlink and uplink
- The most spectrally efficient standard currently developed using an Orthogonal Frequency Division Multiple Access (OFDMA) modulation scheme **[see 'New Banding Specifics']**

Demand for high-speed data

Today, 3G cellular networks are supporting data rates of approximately 10 Mbps. LTE enables an order of magnitude above that, supporting a theoretical 326 Mbps in the downlink, and 86.4 Mbps in the uplink - boosting broadband service capabilities significantly. Emerging services such as real-time streaming video and interactive gaming will be a reality with 4G networks using LTE and, in supporting multiple communication media, wireless carriers can realize much higher annual income per user.

Consumers in North America have shown considerable appetite for 3G services, especially following the introduction of Apple's iPhone. The US now leads the world in mobile Web browsing, accounting for 29% of global traffic[1], while demand for mobile video streaming has been demonstrated by the success of services such as Hulu[2] – which initially targeted PC users, but has subsequently been a hit with mobile subscribers. Similarly, there is a big push into mobile with interactive video gaming. Again, having started out as home computer media, interactive video gaming has become popular with mobile users, who like to participate while travelling. These applications employ high-resolution graphics and two-way communication, making them data-intensive, but LTE is well suited to delivery of these types of services.

[1] According to data provided by mobile Web solutions provider, Bango.
[2] Visit: http://www.hulu.com/

While consumer demand is driving the market for high-speed wireless data, LTE will address the corporate space too. For example, it will offer mobile field computer users much better access to the LAN via the VPN, at speeds equivalent to, if not exceeding those available in the fixed-line domain. And it is likely that PC Cards operating at 700 MHz will be one of the first LTE products offered.

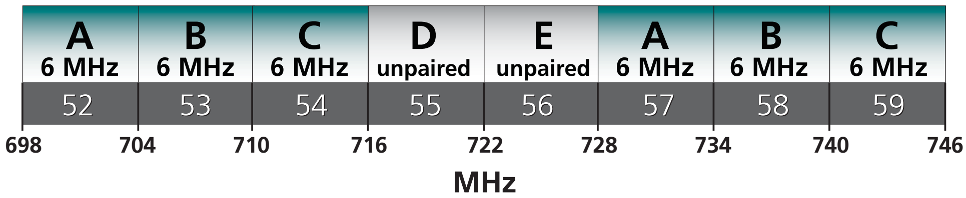


Figure 1 Overview of 700 MHz spectrum blocks

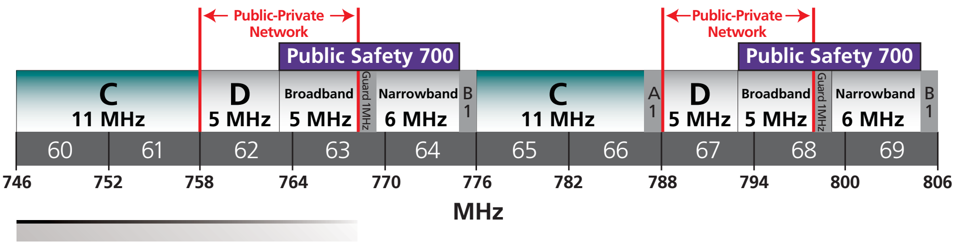


Figure 2 Overview of 700 MHz spectrum allocations

Certainly, voice will be a comparatively basic application within the LTE portfolio. As a fully packet-switched architecture, LTE will deliver voice over IP (VoIP) that, contrary to user perception, will provide better quality than current circuit-switched systems. However, the real potential for LTE lies in the provision of emerging data-intensive multimedia applications that can be accessed by increasingly sophisticated mobile devices.

In order to achieve ROI on LTE, wireless carriers will adopt business models similar to those applied to 3G. Services will be provided independently of standard voice packages, based on flat-rate data packages with unlimited data load, but at a substantially higher tariff. It is already proven that consumers are willing to pay more (up to three times the typical monthly tariff for voice) to receive higher-speed data, and this is a factor that wireless carriers are well positioned to exploit with the introduction of 4G.

New banding specifics

Key to unlocking the LTE opportunity in North America has been the re-allocation of the 700 MHz spectrum. The conversion of several analog broadcast TV stations to digital transmission standards has freed-up UHF broadcast channels 52-69, with each channel initially occupying 6 MHz – enabling new systems to use the 108 MHz block of spectrum available. A few major wireless carriers and several smaller players have obtained licensed spectrum in this band.

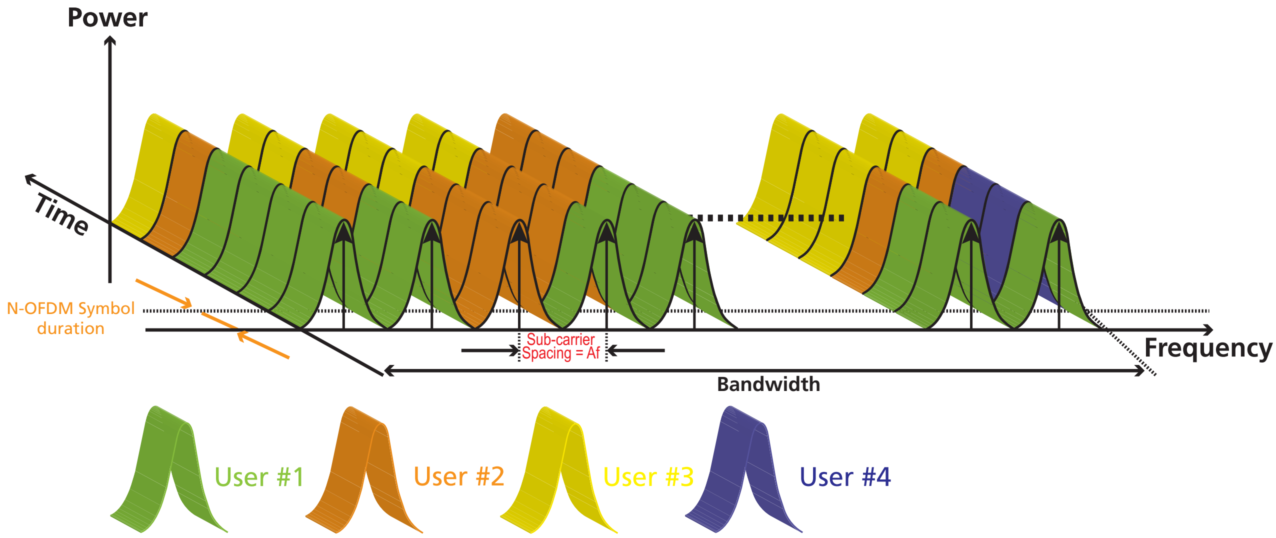


Figure 3 OFDMA – efficient frequency re-use

The 700 MHz spectrum has been sub-divided into three usable bands split between LTE, mobile TV and public safety applications. There will also be further, miscellaneous services operating in these bands, once the spectrum has been auctioned fully. LTE will use the lower A, B, and C blocks, with each block being 2 x 6 MHz. Lower D and E blocks will be used for Broadcast media **[see Figure 1]**. LTE will also use upper C block (2 x 11 MHz), while upper D block will be used by public safety, but has yet to be auctioned **[see Figure 2]**.

A major wireless carrier in the US has obtained a significant portion of LTE spectrum at 700 MHz, and is therefore well positioned to provision for high traffic volumes, whereas some of the smaller blocks of spectrum (such as lower C block) are shared between another major wireless carrier and several smaller players. For these carriers, the provisioning of 4G services will not be as seamless. That said, one of the major advantages to LTE is its spectral efficiency, which will ensure all players achieve a phenomenal amount of capacity – and certainly enough to meet market demand for at least 3-4 years. LTE employs OFDMA modulation, which delivers efficient re-use of frequency. Any dead space in a call for example, is used to squeeze in information from another call **[see Figure 3]**.

Some wireless carriers are to commence LTE trials in Q4 2009, with various portions of their networks being serviceable in 2010 – primarily in urban areas where current 3G networks are heavily loaded. As more users are migrated to the 700 MHz band, wireless carriers will then be able to unload their systems in the 850 and 1900 MHz PCS bands and, eventually, in the 1700-2100 MHz AWS band, for wider implementation of LTE.

Deployment timescales have shortened considerably given LTE's rapid evolution and wide-scale industry support. The commercial need has become all the more pressing, with demand for high-speed data applications in North America far exceeding carrier expectations. Also key to wider implementation is the efficient RF propagation inherent within LTE, which allows each cellular site to have a larger footprint. This is particularly beneficial for extending coverage in less densely populated and residential areas, and means that it may only be necessary to upgrade 75-80% of sites with a 700 MHz LTE system. This potentially leaves tens of thousands of sites unaffected. However, operation in the 700 MHz band does have associated challenges and issues. The major concern is the multitude of interference scenarios.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Mixed channel allocation within the 700 MHz band means that the highly sensitive LTE base station-receive architecture will be co-existing in the immediate vicinity (in respect of frequency) with high-power DTV broadcast (CH 51) and mobile broadcast TV (e.g. MediaFLO). Additionally, there could be interference between upper and lower 700 MHz blocks, since there are high-powered broadcasting services operating in between them.

LTE hardware requirements

Dozens of interference possibilities have been identified with LTE operation at 700 MHz – and this is before potential harmonic interference from other PCS and AWS networks (i.e. 2G/3G) is considered. The result is that a significant RF filtering capability is required for the network to function optimally. Wireless carriers have already submitted LTE RFPs (Requests for Proposals) that include extensive filtering requirements. Both standalone filters, and those that are integrated with other site infrastructure, such as cross-band couplers, TMAs (Tower Mounted Amplifiers) and BTS (Base Transceiver Station) are needed.

By keeping signals clean and system noise to a minimum, TMAs on the uplink, for example, can be helpful in increasing data rates. TMAs will not be deployed at every site, but are necessary in densely populated urban areas, where noise (RF interference) is generated by multiple sources – e.g. buildings (multi-path reflection), vehicles and factories (electrical). TMAs not only increase the received signal down the transmission line, but also reduce the noise in a complete BTS (Base Transceiver Station) system, ensuring better data reception at the receiver.

Similarly, cross-band couplers allow feeder systems operating on different bands to share the same transmission line. Cross-band couplers allow reduction in transmission line without impairing RF performance, for a minimum investment **[see Figure 4]**.

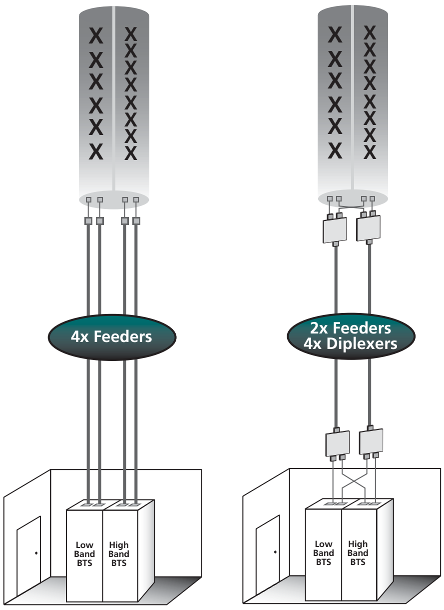


Figure 4 Cross-band coupler advantages

To efficiently utilize the available spectrum, other new implementations of LTE hardware will also be deployed. One of these is the MIMO antenna, which transmits and receives the same signal simultaneously on multiple antenna elements **[see Figure 5]**. MIMO antennas will be essential in reducing the amount of real estate required at the top of the cell tower. By having multiple redundant transmit/receive paths in the air, cell sites will be more immune to atmospheric noise and multi-path reflection interference, while achieving higher data throughput, since twice as much data can be transmitted/received by each MIMO antenna. Furthermore, 'smart' BTS's at the bottom of the tower can also utilize this capability to increase data rates.

Lastly, surge arrestors with wide band capability are needed, to protect wireless BTS, switching equipment and transmission lines from the damaging effects of extreme high voltage surges caused by lightning strikes.

Cell site co-location strategies

In an ideal world, the most effective deployment of LTE would be a Greenfield rollout – i.e. starting from scratch with entirely new cell sites and infrastructure. Naturally, this is not commercially viable for established wireless carriers who, in most cases, already operate 2G and 3G networks simultaneously. Thus a 4G LTE system represents a third service overlay at existing cell sites, for which there are two basic co-location strategies: #1 install all equipment required for the new service as a completely independent overlay; or #2 employ techniques allowing different services to share physical resources.

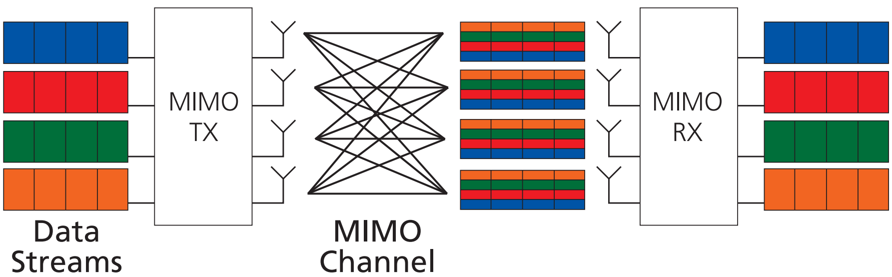


Figure 5 MIMO antenna technology

Strategy #1: independent service overlay

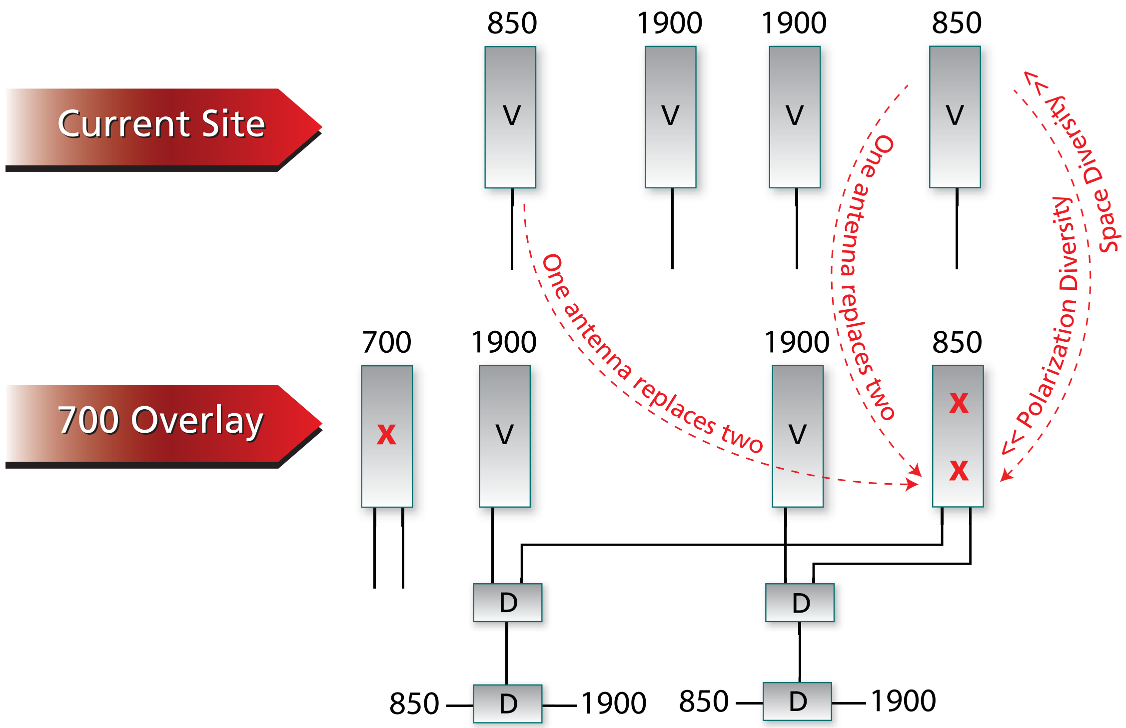
The advantages of an independent overlay of new equipment are clear. It provides the highest level of electrical and RF isolation between the new service and existing services, helping to limit short-range signal interference between new and current systems. Such an approach also limits the impact on existing services, since there is no need to disconnect (i.e. de-cable) and/or reconfigure the present hardware, or even shut sites down – apart from the short periods where engineering crews are working on cell towers.

However, the disadvantages to the independent service overlay are significant, and can be split into two major sub-categories based on equipment requirements – namely antennas and transmission lines. The addition of this equipment to existing cell towers introduces several undesirable consequences relating to tower loading, zoning and leasing costs.

In many cases, adding antennas will require zoning board reviews and approvals, which, at minimum, will have associated time delays prior to installation, but which can also carry an associated cost (capex). Carriers must comply with zoning rules as to how much space a site will require and, if an existing site is being expanded, at least three new antennas and associated transmission lines will be needed. Obtaining approvals from the relevant zoning board for such expansion is notoriously difficult - especially in urban areas where the 'NIMBY' (Not In My Back Yard) attitude can be prevalent among residents.

For a typical 3-sector site based on a 100-foot tower, the additional cable, mounting hardware and connectors could add close to 1000 lbs in weight. The cost of structurally analyzing and possibly having to re-enforce cell towers to accommodate this extra weight could be price prohibitive. Furthermore, tower owners and leaseholders typically base leasing costs on both the number, and weight of components installed. Thus deployment of new equipment results in additional opex, as well as capex.

Similar issues apply with transmission line equipment. Between materials and site labor, adding transmission line to all sectors requiring upgrades with LTE could be prohibitively expensive, especially given the associated increase in leasing costs due to the extra weight. The cost of an independent service overlay approach could run in the order of $500-700 million. What's more, the worst-case scenario would be where



Please Note: All frequencies defined in MHz.

Figure 6 Possible co-located sector configuration

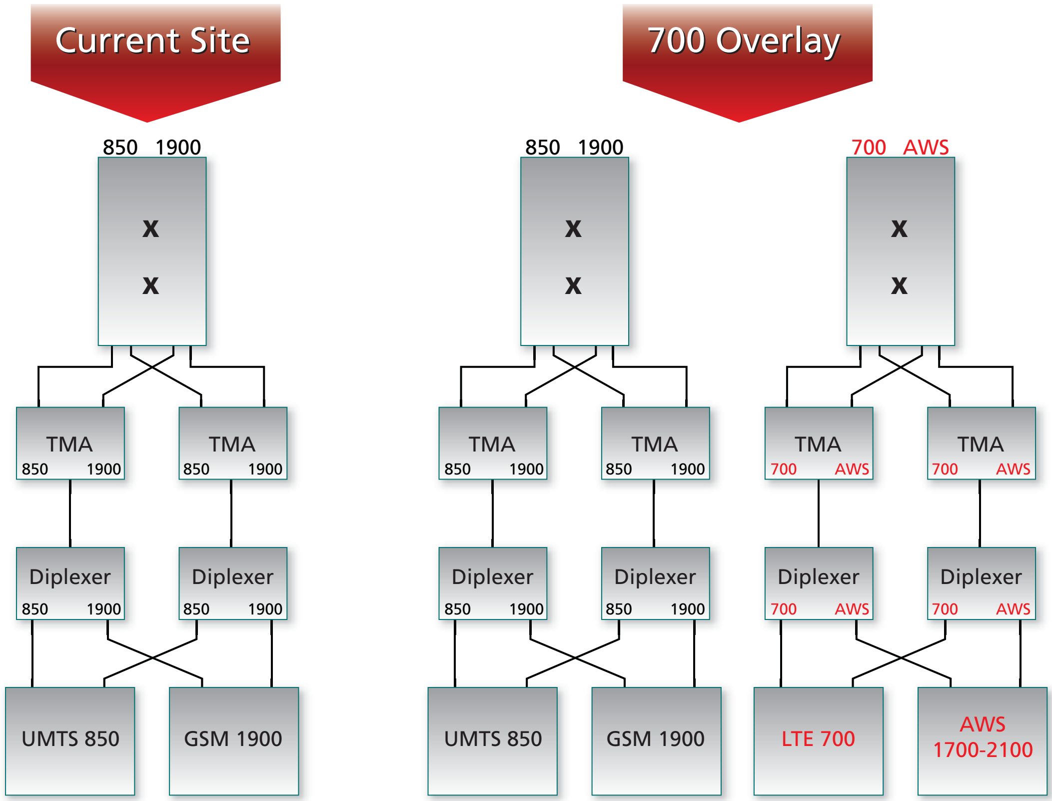
there is not enough tower space on existing structures, meaning many new towers have to be erected at a cost of several $100,000s per tower, across thousands of sites. Thus the total cost of an independent LTE overlay at cell sites could run to hundreds of millions of dollars.

Strategy #2: shared hardware

Given the substantial capex and opex incurred with an independent service overlay, the accepted method for co-location of LTE infrastructure is the use of a large number of cell site network components that can be shared by more than one system. In each sector, there will be some hardware exchanged for more multifunctional equivalents, while additional hardware will also be necessary.

Current site configurations include layouts for 850 and 1900 MHz GSM and UMTS, and 850 and 1900 MHz CDMA, with V-polarized, X-polarized and mixed-antenna systems employed.

One last consideration in any new configuration is the method used to address receive diversity. Receive diversity is used to reduce multi-path fading, and is also effective in increasing the average signal in the uplink. The two methods generally used are spatial diversity, which employs two antennas physically separated in space, and polarization diversity, which uses two antenna elements operating on different polarization axis (90° offset from each other).



Please Note: All frequencies defined in MHz. AWS defined as 1700-2100 MHz.

Figure 7 Possible co-located sector configuration

For the addition of LTE at 700 MHz, existing antennas will need to be swapped out for dual-polarized, wide-band antennas capable of operation at 700 MHz and 850 MHz (i.e. 698 to 896 MHz), and multi-band antennas featuring single antenna modules (i.e. multiple elements) and capable of serving both the low-band (698-894 MHz) and the high-band (1720-2200 MHz). By moving two bands (either lower or higher) onto a single antenna, an additional antenna can be added to the cell tower without increasing the antenna count.

The same can be achieved with transmission line using cross-band couplers. For example, a low-weight 700/850 MHz cross-band coupler can be deployed at the top and bottom of the cell tower – to split and mix the signals respectively – to enable feeder sharing between bands/systems. The cross-band coupler can also incorporate a highly selective filter to provide a high level of isolation between ports, while keeping insertion loss in both paths to a minimum. Cross-band couplers and TMAs are available in dual-band formats covering multiple combinations of 700 MHz, 850 MHz, PCS and AWS bands.

As shown in **Figure 6**, one possible site configuration is where two 850 MHz, vertically-polarized antennas are replaced by a single, dual-polarized antenna, to accommodate the new 700 MHz antenna. This implementation enables the final configuration to maintain both the antenna and transmission line count while still adding a complete 700 MHz transmission channel. Under this model, the 1900 MHz system maintains spatial diversity for receive, while the 850 MHz system will now employ polarization diversity. New cross-band couplers are also introduced to allow transmission-line sharing for the 850 and 1900 MHz systems.

An alternative site configuration is where the overlay is used to introduce both additional AWS spectrum, as well as the 700 MHz LTE system **[see Figure 7]**. This scenario is, technically, an independent overlay, but also represents a hybrid approach. While the amount of equipment on the tower is doubled, the hybrid approach achieves a quadrupling in capacity. In addition, with the AWS overlay added, all the required infrastructure hardware is in place for future expansion of LTE into any band (i.e. future proofing), while the same wideband cross couplers are used in both the existing and overlay configuration.

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Conclusion

The addition of a 700 LTE system calls for considerable changes to the physical layer of an existing cell site – moving from narrow to wide-band and/or multi-band antennas, and the introduction of MIMO antennas, as well as cross-band couplers and TMAs that incorporate heavy-duty filter assemblies.

However, in the North American market, more than 20 possible site configuration options have been identified, an issue compounded by the regional inconsistencies in wireless carrier deployment strategies. Site design and construction has, historically, been dictated by local operations, and therefore varies from region to region – even within the same wireless carrier. Thus the approaches discussed in this paper are certainly viable, but by no means set in stone.

The key factor is that an LTE overlay onto existing infrastructure is commercially and technically viable, and is based on equipment available today from a broad set of major infrastructure and device manufacturers. Coupled with demand for high-speed data services, the market looks set for a rapid and robust rollout of 4G LTE, with the majority of wireless carrier networks enabled by 2011.

Company profile

RFS serves OEM, distributors, system integrators, operators and installers in the broadcast, wireless communications, land-mobile and microwave market sectors.

As an ISO 9001 & 14001 compliant organization with manufacturing and customer service facilities that span the globe, RFS offers cutting-edge engineering capabilities, superior field support and innovative product design.

RFS is committed to globally fulfilling the most demanding worldwide environmental protection directives and integrating green-initiatives in all aspects of its business.