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ThinkSmallCell

The Compelling Business Case for Multi-Mode Small Cells

Burgeoning Demand Can Really Only Be Addressed By Small Cells

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Overview

The evidence of the rapidly growing uptake of mobile data is easily visible. Walking down the street today, you often need to dodge smartphone users checking their screens. From cafés to shopping malls, at business and at home, the wide range of data services has taken firm hold. Smartphones comprise 70% of device sales in the US today,[1] and across the world network planners are preparing to satisfy forecast mobile data traffic growth of between 20 and 50 fold over the next 5 years.[2]

A focused 3GPP workshop identified that the vast majority of network capacity to meet this demand will come from small cells. Of the 1,000 fold capacity increase needed in the highest traffic case, this broke down to 3x through additional spectrum, 6x through increased spectral efficiency, but a substantial 56x by deployment of small cells.

Vendors and network operators alike are waking up to this truth, borne from the laws of physics, and marshalling their resources to address the problem effectively.

This paper considers the reasons driving the choice of multi-mode small cells, then discusses a staged approach for implementation, and finally reviews some of the challenges likely to arise.

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The Difficult Choice Between 3G and LTE Investment

One question taking much time from strategic network planners is what proportion of their on-going investment should continue to grow their 3G capacity, and how much should be dedicated to 4G/LTE.

Most of the installed base of smartphones worldwide are based on 3G and will continue to be so for some time. Informa Telecoms and Media predict growth of 3G connections from 1.3 Billion today to 4 Billion by 2017, while LTE devices starting from a low base will reach 1 Billion in the same timeframe.[3] As the technology continues to mature, the price of 3G devices will be driven further down the technology maturity cost curve and be bought by late adopters. The continuing evolution of 3G HSPA+ delivers ever higher speeds, with 21Mbit/s widespread and 42Mbit/s already commercially deployed.

By comparison, there is strong brand kudos to be had by launching LTE. Its high speed, low latency and fast setup time dramatically improve the end user experience. LTE attracts high spending early adopters who champion the brand and reinforce value for 3G customers. Especially, for CDMA networks, without the option of HSPA+, it is extremely attractive. Premium smartphones and many tablets already have or shortly will have LTE capability. This drives more prolific use, evidenced by the Verizon Wireless CTO predicting that data volume on their LTE network is expected to surpass that using 3G before the end of 2012.[4]

Regional and national factors impact the decision strongly. Globally, the fragmentation of LTE spectrum has caused major disruption. There are three separate physical models of the iPhone 5 and yet these still don't support LTE worldwide. In the US, strong competition from CDMA network operators has driven more rapid uptake. In Japan and Korea, competition for technology leadership has accelerated rollout. Europe seems content to focus more on 3G, perhaps partly also due to uncertainty in the regional economies.

Long term, there seems little doubt that LTE will dominate but some analysts forecast that 3G investment could remain higher than LTE until 2017.

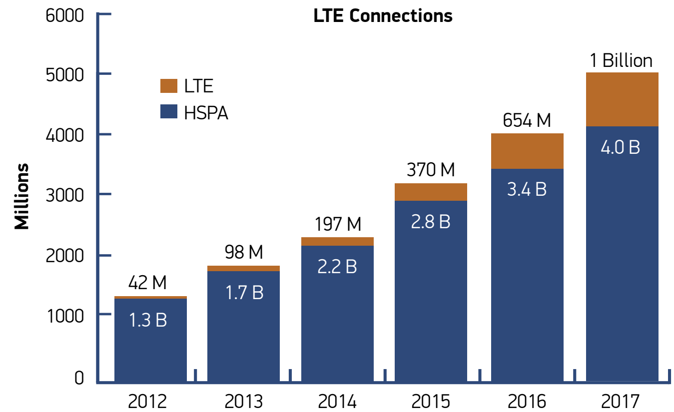

Figure 1. *Source: Informa Telecoms & Media, WCIS+, June 2012 (www.4gamericas.org)*

What is a Multi-Mode Small Cell?

Small cells are miniaturized mobile phone basestations, transmitting at low power and with a range of 50 to more than 200 metres. They are compatible with all 3G and LTE devices and transparently offer the same full set of mobile services. The close proximity to the cell ensures high data speeds, excellent voice quality and long battery life. Reuse of the same spectrum across large numbers of small cells dramatically increases the total available network capacity and throughput.

Different types of small cells include:

- *Residential* (typically single use in the home handling 4 to 8 concurrent active users),
- *Enterprise* (for business/office use with slightly higher power, longer range and 8 to 16 users)
- *Metrocells* (for public access areas, typically in dense urban downtown areas, both indoors and outside)
- *Rural* (for remote villages which may not even have mains power or wireline service). These cells may have higher RF power to increase the range to as much as a few kilometers.

A wide variety of different small cell products today support either 3G or LTE for each of the above categories. A multi-mode small cell would incorporate both technologies, and optionally also Wi-Fi. Metrocells are the main class of small cell being considered for multi-mode today, but this may expand into the enterprise and/or rural applications in the longer term.

Deployment of Small Cells

Cost Breakdown

Network operators are under a great deal of pressure to reduce OPEX.

The majority of the cost of a small cell network is in its deployment and operation rather than capital cost of the small cells. The breakdown (Table 1) at right[5] provides a typical OPEX breakdown although this will vary widely by region and locale.

Personnel costs include both field staff that need to visit and maintain each small cell site, together with centrally located operations teams who plan, monitor and configure the systems. The more self-configuring and self-optimising the small cell system and software is, the fewer staff required.

Transmission costs vary depending on whether the link is owned by the operator directly. This might be a wireless link for the last few hundred metres, and then piggyback on an existing backhaul connection. Wireless backhaul would have higher initial CAPEX costs (a microwave link could cost $6K today, although there are cheaper options available) but virtually no on-going OPEX. Alternatively, a leased line (DSL, Fibre etc.) might have very low setup cost but carries hefty on-going rental charges.

Site acquisition can be a difficult problem for operators, especially in premium urban environments and continues to form the most significant element of OPEX. Deployment of separate and independent 3G and LTE small cells has the potential to double site acquisition costs, requiring a duplicate set of backhaul transmission equipment to the local hub, twice the number of site visits and associated overheads.

Maintenance and repair will vary not only with the product quality and capability, but also with the environment the small cells is operating in. While small cells are designed to be self-configuring and self-optimising, SON features cannot overcome practical issues such as equipment failure in the field, damage (e.g. weather related, vandalism, accidental, etc), or environmental changes (e.g. temperature range, foliage growth through a wireless line of sight backhaul link, etc). High equipment reliability and extensive on-board self-management software with good remote diagnostics can help reduce or avoid site visits.

Aspect	OPEX range
Personnel	10% to 15%
Transmission	5% to 24%
Site leases	35%-45%
Maintenance and Repair	5%-15%
Services	10%-20%
Other Costs	5%-15%

Table 1.

Services are mostly related to mains power supply for the small cell and backhaul transmission equipment. Where mains power is available, the low power consumption of metrocells is not significantly affected when increased to handle multi-mode. Of greater concern is the security of supply, where off-grid solar powered units with battery backup are not feasible in metropolitan areas but may be of great use in rural areas.

The significant factors of site rental, backhaul, physical installation and power all result in a minimal increase whether 3G, LTE or multi-mode technology is deployed. However, with a mixed subscriber base the operator could be looking at deploying multiple single mode products over time which would substantially increase the net OPEX costs of the small cell layer. Alternatively, deploying sites with either existing multi-mode capability or the ability to inexpensively transition to multi-mode (e.g. via a software upgrade) provides a future proofed approach to the mobile operator.

Determining firm CAPEX costs for metrocells today is difficult to do with certainty. Future predictions of cost depend on many factors, not least volume of product shipped. For example, Deutch Telekom presented a total cost breakdown in October 2012 which indicated that CAPEX is slightly more than the 7 year OPEX cost. They forecast that both could be reduced by 47% over time through us of multi-mode small cells.

Overall, the contrast of costs between small cells and macrocell equipment is stark, with site equipment costs measured in thousands of dollars per site rather for small cells compared with tens of thousands for macro cells. As the volume of shipments grows, it will drive down unit costs significantly in the bringing the CAPEX ever lower. The falling CAPEX in combination with a multi-mode strategy to manage OPEX provides a clear path to low cost capacity and coverage enhancement for both 3G and LTE mobile networks.

Co-Located Traffic Demand for 3G & LTE (Unlike 2G and 3G)

As outlined above the OPEX considerations are a key cost driver and if not managed properly create a barrier for large scale small cell deployments. A key component of efficient small cell deployment is choosing the appropriate location. The deliberately limited range of as little as 100 to 200 metres requires the small cell to be positioned as closely to the traffic source (i.e. the user) as possible. Close proximity also improves the radio channel between the handset and the small cell, enabling higher modulation and thus faster data speeds—delivering on the promise of improved Quality of Experience (QoE) from small cells. This translates to both greater utilisation with the small cell capturing more traffic, higher capacity due to higher order modulation, and better end-user experience via shorter response times.

When network operators first selected sites for 3G small cells, it was often convenient to co-locate these with existing 2G sites. However there were two problems with this approach. Firstly, the usage patterns for voice and data differ, which meant the peak traffic locations for voice did not overlap with the 3G service needs. Secondly, the lower frequencies used for 2G provided a different footprint from those of 3G, providing a much better coverage area including in-building penetration. In short, co-location and ultimately a multi-mode solution for 2G and 3G made little sense. In some cases, this can be true for Wi-Fi mainly in the outdoor case driven by the significantly different cell size and propagation of licensed spectrum versus unlicensed Wi-Fi.

This is much less likely to be an issue between 3G and LTE, because data traffic hotspots are likely to coincide. Additionally, the radio interfaces for 3G and LTE can be tweaked to create a common cell size to ensure congruent coverage enhancement for multi-mode deployments. Since these small cells are providing capacity, the different frequency used is less significant—the small cells aren't range limited by frequency. Capacity planners would need to take account of the lack of LTE in areas where there is 3G overload, and determine how much would be offloaded by a 3G or LTE small cell based on current device capabilities (i.e. which types of device could take advantage of LTE if available).

Backhaul

Backhaul is significant element of the operational cost of a network, as shown earlier in the paper contributing up to 30% or more of the network OPEX, particularly those heavily reliant on 3rd party leased lines. Operators with their own fixed network assets may appear to have an advantage, but this is less significant once transparent internal accounting procedures are often used to ensure good business decision making. Wireless links of various technologies are frequently deployed, particularly close to the edge of the network, trading off an initial CAPEX charge against low on-going costs.

For public access metrocells, network planners are typically designing clusters of small cells with short range wireless backhaul to a central point—often an existing macrocell site—which may already have fiber or other high speed backhaul in place.

One of today's dilemmas for the planner is whether to design the backhaul with adequate capacity to handle a full multi-mode small cell network from the outset, with the attendant higher initial CAPEX outlay, or defer this for a planned upgrade in the future when equipment costs may have fallen further. A second factor is whether to provision peak capacity across the backhaul or design for mean throughput. Although the headline speeds for LTE and LTE Advanced might not be achieved, these are typically only feasible when the network is very lightly loaded (i.e. one or two users per cell), and in this case the mean speed would still deliver a good end-user experience.

A further consideration relates to timing and synchronisation. The much tighter demands for LTE Advanced, which requires both frequency and phase accuracy, determines the choice of timing methods that can be used by the small cells. A combination of GPS, IEEE 1588 v2, Synchronous Ethernet is likely to be used—replacing the traditional E1/T1 PDH methods used for 2G. Choosing a backhaul solution that meets the less demanding requirements of 3G may require an expensive rip-and-replace when adding LTE and/or LTE Advanced in the future.

Designing the backhaul solution to cater for multi-mode from the outset drives long term commercial success. This involves choosing wireless backhaul technologies which can support multi-mode small cells from the outset, either with adequate throughput when first installed or remotely upgradeable. The combined costs of replacement backhaul equipment and the large number of site visits to implement the upgrade are undesirable. Fortunately, there are many new small cell backhaul products coming on to the market today which provide this capability. Finally, many of today's high traffic hotspots are likely to continue to place heavy demands in the future, so it is a false economy to constrain capacity growth for the future.

The Emerging Land Grab and Future Network Sharing

The same traffic hotspots for different network operators are likely to overlap, leading to strong competition for prime sites especially in dense urban areas. Negotiating deals with landlords for large cell sites has often been difficult, with some holding operators to ransom and withholding the chance of good coverage from specific areas. Additionally, in small cell deployments where not only the building owner is to be engaged, but the municipality itself there is even more complexity to acquiring the right sites. The unobtrusive nature of small cells expands the choice of potential locations, but the larger numbers involved should encourage blanket agreements for large areas, such as street furniture and on public highways. How is the municipality to decide to give favour for one operator over the other possibly gaining financial gain for the government, but cutting off a whole constituent of users from the benefits of small cells?

These forces are combining for a period of land grab, as operators scramble to reserve large numbers of potential small cell sites and potentially block competitors. One approach may be to deploy Wi-Fi initially, upgrading to cellular in a second phase especially when the traffic profile has been established.

Alternatively, we may see a growing level of co-operation between operators. Some (e.g. Orange, Spain) have already gone on record stating that they are unable to afford their own dedicated LTE network and are actively seeking a partnership arrangement. Additionally, the municipalities who are dealing the rights for sites in downtown urban areas may end up enforcing a form of RAN sharing to ensure parity for their citizens. In other countries, cell site sharing and RAN sharing are becoming more widespread and the macro cell layer so the technology and business model is being proven out. While the jury is out on whether small cell network sharing is commercially attractive because of apparent cost savings or a disastrous forfeiture of competitive advantage, it is likely we will see both scenarios played out in different regions.

A third way is the emergence of independent hosting known as "Small Cells as a Service." A single company negotiates with the metropolitan district for the rights to install and deploy small cells throughout the area. They do this for several or all mobile operators, installing equipment and wireless backhaul on their behalf and to their specification. This simplifies the negotiations with the landlord, and outsources the main problems for large scale small cell deployment—namely site acquisition, power and field staff. The small cells are owned by each operator and are remotely configured and optimized by their own network planning and operations departments.

Where multiple operators do share the same small cells, this could lead to even higher total capacity due to the larger portion of spectrum assigned.

The Four Stages of Multi-Mode Small Cell Evolution

Today's separate 3G and LTE small cell products are already starting the journey towards a fully integrated single board solution. While it may take some time to reach that destination, several stages of that path are becoming clear. Component and software vendors are already working on later stages, with prototypes at various levels of maturity.

Stage 1: Modular Small Cell Designs

Equipment manufacturers, such as NEC and Alcatel-Lucent, have already brought to market small cell products in a modular format. Independent, sealed plug-in cartridges slide into a compact housing which distributes power, backhaul and external antenna connections. The range of independent modules will evolve to cater for later versions of 3G HSPA+, LTE and LTE-Advanced. The simple mechanical format provides an ability to upgrade the unit onsite quickly without specialist knowledge by simply replacing or adding modules.

This approach caters for an unknown future and allows an operator to defer the choice of 3G or LTE upgrade until a later date. The antenna may also be an easily changeable component. Backhaul may be provided by an external box, powered via Ethernet and so only requiring a single cable connection. This offers maximum choice and straightforward compatibility with the wide variety of wireless and wired backhaul options.

The modular approach works well to hedge risk on making a commitment today to a specific technology, but is not suitable for a large scale deployment of multi-mode small cells. It fails to take advantage of the CAPEX benefit of co-located functionality requiring separate semiconductor, memory and peripheral costs which are a big component of the per unit cost. It also does not effectively enable service differentiation possible from a truly converged multi-mode solution including load balancing, aggregation and multi-mode Radio Resource Management (RRM).

Stage 2: Multi-Mode on Same Board

The latest small cell SoCs (System-on-a-Chip) are already designed to support 3G and LTE concurrently on the same board. Working prototypes have been demonstrated. Typically the capacity and spectrum allocation between 3G and LTE would have to be made during manufacture, and is less easily updated in the field without swapping out the entire board, but the benefits of tighter integration lead to lower cost and power consumption.

The ecosystem for this integrated unit is still not fully mature. Some of the components have not yet reached the level of integration required to deliver the flexibility and cost benefits which could be achieved through this approach. However, this is only a matter of time, and with growing clarity of the requirements of each network operator, we can expect products to become available in this format to meet demand.

Stage 3: Pure Multi-Mode on Single Device (Soc)

This is surely the long term nirvana of the operator, achieving the full benefits of high integration and mass production to drive down cost. Not only will these units have fewer components and become lower cost per unit, but will draw less power and require less maintenance—helping drive down OPEX costs further. We might expect to see early products in this format as soon as the 2014 timeframe.

The close integration of the processing power will allow flexibility to allocate processing power between 3G and LTE on demand to meet the current traffic load. Power management will also be efficient, by putting underutilised CPU cores to sleep during periods of quieter traffic demand.

Some small cells will also have Wi-Fi built into the unit. However, even at this stage, it is unlikely that the Wi-Fi would be integrated onto the same chipset. The already very low cost of today's mature mass market Wi-Fi chips means there would be little if any additional cost saving.

Stage 4: Intelligent Load Balancing

Today's network traffic is split across mostly 3G and Wi-Fi offload; although in some countries LTE is quickly taking up significant load. Verizon Wireless reported in October 2012 that their 4G network already handles 35% of network traffic and is likely to reach over 50% around the end of 2012. Carrier Wi-Fi is becoming more widespread, and the advent of Hotspot 2.0/Next Generation Hotspot will facilitate a more seamless end-user access to this resource.

Operators will then have to further develop how they manage their end-user traffic demand between these different radio technologies. Factors will include traffic load, service type (voice, video, web, email etc.), tariff plan and the capabilities of devices attached to the small cell. This is likely to involve coordination across end user device, small cell and core network elements to ensure the system operates in harmony and achieves its full potential. The capability for the operator, through existing policy management infrastructure, to define an aggregated approach that treats each air interface (i.e. 3G, 4G/LTE and WiFi) as an available resource for managing different types of traffic, under differing load conditions and based on tariff plans is the ultimate power of a multi-mode single SoC and/or platform small cell deployment.

There are already some access manager clients which perform this function today, such as those which aggregate 3G, LTE and/or Wi-Fi. Standards for Hotspot 2.0 and their equivalent 3GPP already define standardised access manager capabilities, and these are likely to evolve further as the solutions mature and are augmented by network side coordination and intelligence either in the small cell or small cell gateway equipment.

Alternative Multi-Mode Deployment Scenarios

Network operators planning their long term small cell strategy have many combinations to choose from.

The industry still has different views on whether to deploy 3G or LTE small cells first, when and where to add Wi-Fi, and how quickly to opt for 3G+LTE.

First Mover Advantage: Site acquisition undoubtedly will be key success criteria, and as stated earlier, forms more than a third of the total OPEX cost. Early deployment secures those sites and grows the operator's expertise in how to deal with small cell site operations. Several operators have launched public Wi-Fi services, which allow them to secure premium sites. These can then be upgraded to 3G and/or LTE in due course.

Maximum Speed and Performance: A few countries are leading the way with LTE adoption, such as Korea, Japan and the USA. Rapid rollout of LTE small cells will enable a very high level of capacity and throughput to meet the needs of their most demanding customers. The rapid adoption rates of the latest technology means that LTE device penetration will relatively quickly catch up and be able to use the service. A combination of LTE + Wi-Fi has been used to retain backward compatibility for data from 3G smartphones. Voice calls are handled by the macro network generally through Circuit Switched Fallback (CSFB), where voice capacity is not under stress.

Maximum Compatibility: Many European countries seem to be keen to serve their existing installed 3G handset base, and while also deploying LTE macro cells, are investing in 3G small cells to cater to the majority of customer needs. These could then be extended to include LTE in the longer term.

Another factor which is being taken into account when making this decision is the operator's voice strategy. While the long term industry direction is the adoption of VoLTE (Voice over LTE) this requires an IP Multimedia Subsystem (IMS) core which many operators do not have today. In those cases operators are often choosing to remain with voice on 3G using CSFB. This may drive a continuing need for 3G service, both to provide voice and to remain compatible with non LTE capable handsets and in that case the 3G portion of the multi-mode small cell provides a needed coverage enhancement for already limited in-building 3G networks.

Spectrum Refarming

Many operators are working aggressively with their local regulators to be allowed to end of life a portion of their legacy 2G or 3G networks to re-use that spectrum for LTE commonly called spectrum refarming. Long used 2G frequencies are being used for more efficient 3G, providing not only higher capacity and faster data rates. Deploying 3G UMTS at 900MHz improves in-building penetration and longer range, so additionally provides much better coverage and end-user service. AT&T Wireless has announced it plans to switch off 2G GSM by 2017, upgrading to at least 3G in that timeframe.

However, refarming has the potential to affect public access small cells especially as deployments occur in parallel to final approval by the regulatory bodies. Some reallocation may be done remotely through reconfiguration, but major band changes are likely to require site visits, so would be infrequent and part of the longer term regular maintenance program. The ability to swap out antenna as well as the RF module should make this relatively quick and seamless.

LTE has been designed for use in many different frequency bands. While new spectrum has been released specifically for its use, some operators have chosen to re-assign existing 2G or 3G spectrum for its use. For example, in the UK and Australia, operators are deploying it in the 1800MHz band originally used for GSM.

The spectrum used by small cells dictates the choice of physical components, such as antenna and some components within the RF circuitry. It also dictates placement of the small cells with lower frequencies having better penetration and propagation properties over higher frequencies. From a physical perspective re-farming could require that a site visit to replace or expand the circuit boards and/or antenna used In the worst case a major switch could obsolete certain site placements if it's a move from high to low frequency. Some of today's metro cell products already support this requirement with a clever design of swappable modules and antenna parts, so that a site visit could be completed in a few minutes. In the longer term, the tighter integration of multi-mode small cells is likely to see greater capabilities to remotely reconfigure and repurpose the existing range of spectrum supported within a small cell across the different radio access technologies.

Summary

The forecast growth of 20 to 50 fold in wireless data traffic over the next 5 years is driving a clear business case for network operators to plan ahead for substantial investment in multi-mode small cell network capacity. Capacity will be achieved through a combination of additional spectrum, higher spectral efficiency of HSPA+/LTE and from deployment of large numbers of small cells. While it is the small cells which will deliver by far the greatest capacity, enabling them to use both 3G and LTE simultaneously provides the most effective and highest capacity solution.

Each individual network operator's roadmap towards a multi-mode solution will depend on their regional and national situation, with some areas adopting LTE more rapidly than others. In any case, it's essential to have the long term vision and target reference solution in order to avoid wasteful building of independent or disparate 3G and LTE systems.

A four step evolution enables an orderly progression towards a fully integrated multi-mode small cell product, and the industry is already making good progress along this path:

- *Modular Small Cell Designs,* where plug-in sealed cartridges contain fully functional radios for 3G or LTE. The simple mechanical format provides an ability to upgrade the unit onsite quickly without specialist knowledge by simply replacing or adding modules.
- *Multi-Mode on The Same Board,* where the benefits of tighter integration lead to lower cost and power consumption.
- *Pure Multi-Mode on Single Device (System-on-a-Chip).* The nirvana of the multi-mode small cell design, reducing cost and form factor to minimum levels.
- *Intelligent Load Balancing,* which manages end-user traffic demand between these different radio technologies. Factors will include traffic load, service type (voice, video, web, email etc.), tariff plan and the capabilities of devices attached to the small cell. This will improve the end user experience and maximise the network performance and profitability.

Complex issues such as backhaul network design, spectrum allocation, timing and synchronisation need to be thoroughly assessed and resolved in advance. However, the clear benefits of a multi-mode small cell outweigh the spectre of these challenges and the industry continues to innovate both procedurally and technically to overcome them.

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