LTE Femtocell Roadmap from Concept to Reality

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The LTE femtocell stands to serve as a key weapon in the mobile operator arsenal.

The market is buzzing about the critical role of "small cells" in Long Term Evolution (LTE) deployments – femtocells, picocells and microcells. LTE is the next generation 3rd Generation Partnership Project (3GPP) standard for mobile networks born out of the GSM family of cellular technology. LTE enjoys unprecedented support from the global operator community with the Global mobile Suppliers Association (GSA) reporting 39 operator commitments to LTE network deployment throughout 19 countries. LTE networks promise a true mobile broadband experience with peak data rates of over 100 Mbps, high-speed mobility and reduced latency supporting a variety of real-time applications.

The concept of LTE small cells is undeniably sound. Orthogonal frequency-division multiple access (OFDMA), the basis of LTE mobile networks, is a shared channel radio technology and, by definition, the fewer users in a cell the more bandwidth each user is allocated. Furthermore, the user device (i.e., mobile phone, dongle, data card, etc.) has a smaller cell radius and is closer to the radio which limits signal degradation and increases throughput. However, once one gets past these foundational benefits the details become murky. The fact remains that early LTE trials and deployments, including any form of LTE femtocell, are not yet underway. This article identifies the key business and technology actions and evaluates progress required to take the LTE femtocell from concept to doorstep.

Integrated Silicon

Silicon provides the heartbeat of the LTE base station and for femtocell devices is both a critical challenge as well as an opportunity for differentiation. Similar to the 3G femtocell market, LTE femtocell silicon will need to evolve from a collection of distinct parts to an integrated and optimized system on a chip (SoC). This high degree of integration is needed to achieve competitive price points as well as meet power constraints in both residential and metropolitan deployment scenarios.

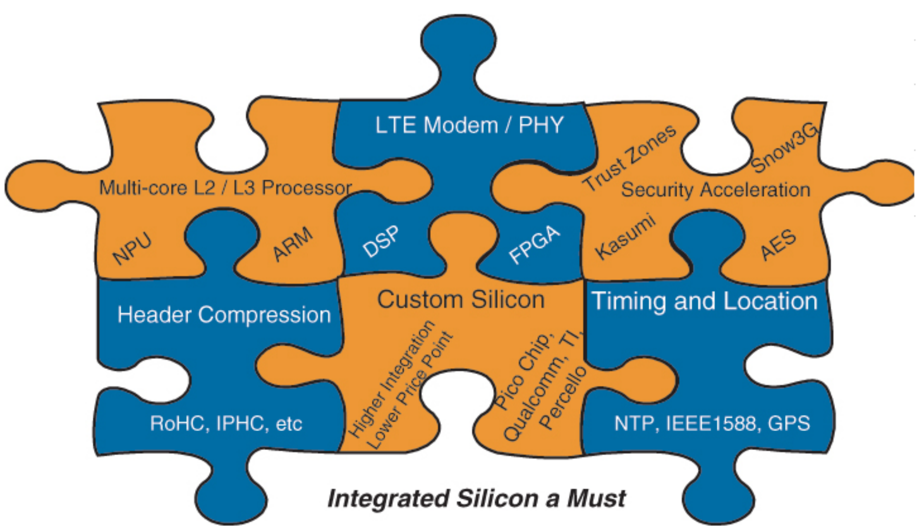

Figure 1: Different processor functions of an LTE base station that must be collapsed into an integrated, purpose-built LTE SoC

Today's solutions consist of a separate radio; FPGA for radio to modem interface; dedicated FPGA, DSP, or ASIC for modem processing; and a distinct co-processor for crunching Layer 2 and above protocol and application functions. This multi-chip approach is absolutely necessary to support the scalability requirements of a multi-sector macro cell LTE base station but it is not a feasible long-term solution for LTE femtocells. In addition to collapsing these disparate devices, there are LTE femtocell-specific functions that must be pulled into the integrated device including header compression / decompression (e.g., Robust Header Compression (RoHC)), encryption / decryption (e.g., Snow3G) as well as timing and location (e.g., IEEE1588, GPS).

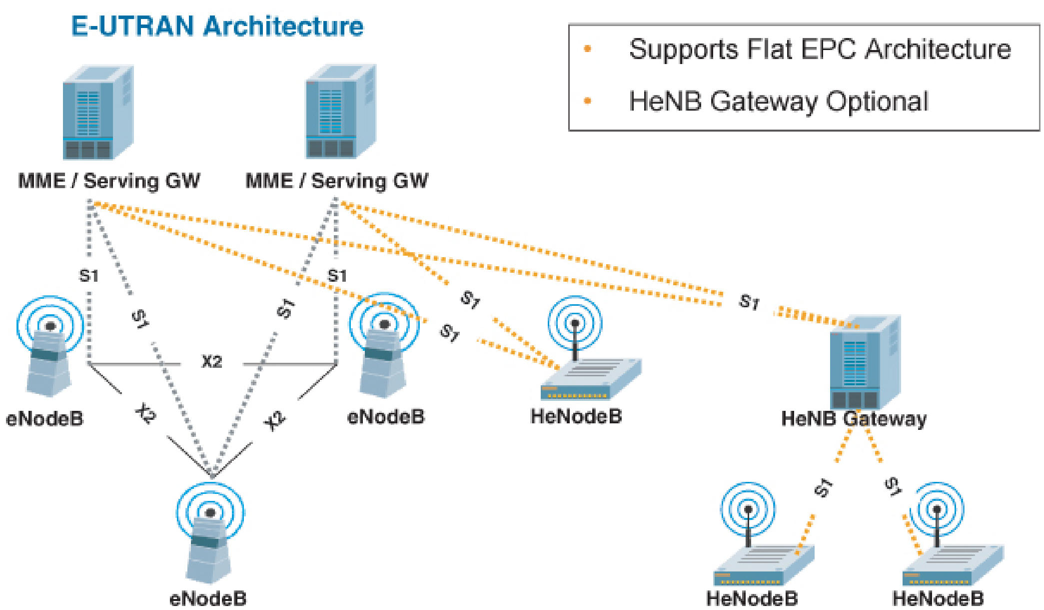

Figure 2: DPI HeNB network architecture

The task seems daunting and expensive, but silicon vendors have the benefit of being able to leverage designs and sub-components from the latest generation of 3G femtocell devices. Integrated 3G femtocell silicon has met a lot of these challenges, albeit with less drastic data throughput requirements, and today includes functions such as integrated timing, location and security accelerators. Additionally, embedded multi-core devices continue to evolve and can be designed into the integrated silicon to support the increased L2 and above processing requirements.

Standards

Any discussion of next generation telecommunications technology cannot be complete without referencing the progress of standards. Operators are acutely aware of the economic and technical challenges presented by proprietary technologies and will require standards to be in place prior to mass LTE femtocell deployments. To ensure support and as a sign of the criticality of femtocells in LTE, early on the 3GPP identified a work item in the LTE standards to support LTE femtocells, known as Home eNodeB (HeNB).

Unfortunately, the HeNB definition in the LTE Release 8 baseline remains significantly under-specified. The primary focus has been on requirements and architectural definition leaving question marks in the scenario, protocol, security and management tiers. Figure 2 illustrates the current architectural definition for HeNB.

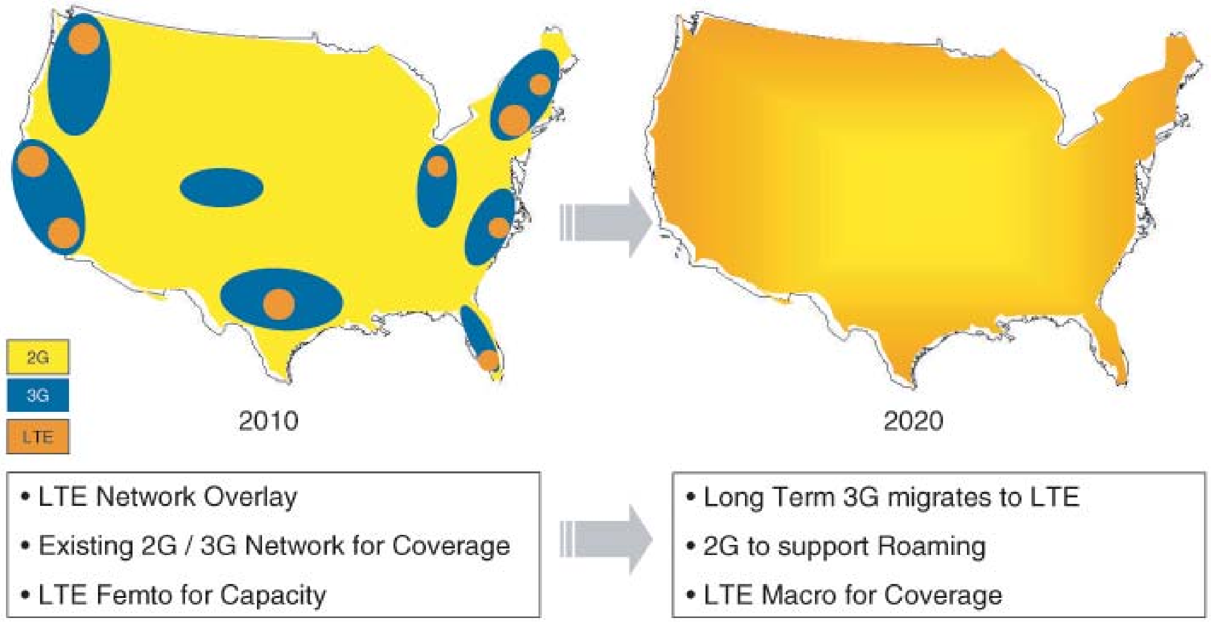

Figure 3: LTE femtocell deployment

(Potentially) Poisonous Combination

As is shown in the diagram there are two options for LTE femtocell deployment still under discussion. One option has the HeNB directly interfacing with the Mobility Management Entity (MME) and Serving Gateway (SGW) in the LTE Evolved Packet Core (EPC). The second option has the HeNB interfacing through an HeNB Gateway mimicking the WCDMA / HSPA femtocell architecture standard. From a standards perspective, multiple open items remain:

- Is there a requirement for a new protocol to manage the femtocell network specifics? In the 3G femtocell standards a new protocol, HNBAP (Home NodeB Application Part), was defined to support the specifics of the femtocell network (e.g., femtocell registration).
- Is there a need for a femtocell-to-femtocell interface? In the standard LTE radio access network (RAN), the X2 interface provides for radio and handover coordination among cells, but a similar concept has yet to be defined in the HeNB standards.
- How will LTE femtocells be managed? What are the security requirements? As seen with 3G femtocells, the specifications need to stretch beyond signaling, data plane scenarios and protocols to include the management and security aspects.

The LTE femtocell standards activity stands to benefit greatly from the large amount of work already put into the 3G femtocell standards. Both 3GPP and 3GPP2 (which manages the CDMA2000 / EV-DO specifications) have ratified 3G femtocell standards including both networking as well as security and management aspects. A great deal of the management and security work can be re-used in the LTE specifications as well as femtocell-specific networking protocols and procedures. The primary challenge will be maintaining focus on this area within the standards organizations. There are a significant amount of work items outlined for Release 9 and 10 of the LTE standards, and with early operators focusing deployments on the macro network, the attention on the issues relating to HeNB may be ignored.

Self Organization and Optimization

The efficient and economical deployment of thousands or even millions of small cells necessitates a drastic change in management and radio planning methodologies. Traditional macro networks are deployed with a semi-static configuration whereby cell planning is done via simulation and spectral analysis. This approach is not feasible when the cell size is reduced and the number of cells increases drastically. The development of Self Organizing Network (SON) techniques, algorithms and eventually standards is a critical step in LTE femtocell deployments.

The basic requirement for SON is self-configuration. LTE operators deploying small cells need the base station to configure itself based on location, surrounding cells and the core network or edge equipment that will be its primary entry point into the LTE core. Here, operators will be able to leverage developments from the 3G residential femtocell market into LTE. Residential femtocells have borrowed and extended (via definition of a new data dictionary) the TR-069 protocol from the Broadband Forum to identify the device and support zero-touch installation. Similar concepts, data dictionaries and procedures may be adapted to support self-configuration of LTE femtocells as well. However, beyond self-configuration, at initialization LTE small cells will require the ability to modify their configuration based on surrounding cells, cell loading and other environmental considerations that affect the radio network on an ad hoc basis. In other words LTE small cells become self-optimizing.

This is where the SON movement truly needs to make great strides in capabilities and standards. Current 3G femtocell techniques rely on algorithms that are self-contained within each base station, lacking coordination among cells and focusing primarily on power control. The next evolution of SON is focused on extending these algorithms to include the coordination among cells as well as to take into account power control and parameters like cell loading and proximity of devices to the radio. Significant investments – in network equipment provider (NEP) research and development budgets, as well as venture capital funds – is already being plowed into SON. It is seen as a key area for differentiation by NEPs and an opportunity for innovative startups like Airhop Communications (www.airhopcomm-web.com/) and Eden Rock (www.edenrockcomm.com/) to create value for their customers.

The final and perhaps largest challenge for SON will be standardization. The race is on and the finish line is that golden patent to which all must bow for successful LTE deployments of SON. While potentially good for the investors and companies placing those bets, this approach does not bode well for the standardization or adoption process in the near-term. For small cells to be successful, interchangeability and diversity of supply is a must. The market cannot sustain significant proprietary lock-in as it will squash the economies of scale needed to achieve commercially-viable price points. In addition to the patent sprint, the 3GPP has already identified SON as a critical area for standardization and work is already underway. It would be folly to expect advanced SON in anything sooner than Release 10 specifications, but the work items are established and players large and small are participating.

Backhaul

Backhaul, often the anti-femtocell guild's silver bullet, is a challenge, but not an insurmountable one. Last time we checked, all wireless radio devices need the services of backhaul – including WiFi and macrocell LTE base stations. As a result, backhaul poses a serious challenge for all wireless broadband technologies. Today's 3G networks are already facing sobering backhaul challenges and operators are pushing vigorously for new techniques and technologies that will optimize their backhaul so as to not require significant investment in running fiber to existing cell sites.

The backhaul problem is divided into two areas: the residential or in-building backhaul scenario and the metro or small-cell outdoor backhaul scenario. For in-building LTE femtocells to succeed the proliferation of Fiber to the Home (FTTH) and Fiber to the Curb (FTTC) is required, and in much of the world fiber rollouts are happening very quickly. This does not immediately solve the problem, but it does bode well for the future of the "inside out" LTE femtocell strategy.

The metro backhaul scenario enjoys more than one solution to this challenging problem. In addition to tapping into the local fiber networks that will be rolled out for residential services, LTE outdoor small cells have the ability to leverage fixed WiMAX technology for backhaul service. It may not be immediately apparent, but one of the key applications of WiMAX is for efficient, high bandwidth wireless backhaul. WiMAX is being used in this way to upgrade existing 3G cell site backhaul as well as for green-field 3G deployments.

Deployments

For better or worse, it is clear that initial LTE rollouts will be made up primarily of macrocell infrastructure. A macrocell rollout provides broader coverage and higher speed mobility, plus macro base stations are available today. Additionally, Verizon Wireless, the LTE trailblazer in the United States, is deploying in the 700 MHz frequency band, which will provide much better signal propagation and in-building penetration than the higher frequencies used for 3G networks. Early adopters simply do not want to wait for LTE femtocells to be ready in order to get their LTE network deployments up and running quickly.

This is a good thing for the small cell approach to LTE. A metro-type deployment of small cells can act as an overlay to the broader areas covered through the macro cells. Additionally, it gives time for the diversity and quality of the device ecosystem to evolve. As the devices that support LTE become more advanced (e.g., one can imagine the impact an LTE-enabled iPhone could create), operators can utilize the performance and quality of experience benefits provided by a broad small cell deployment to significantly boost network capacity and throughput.

Although wide area macro LTE deployments are critical, they are not the only way to get to LTE femtocells. The LTE femtocell may prove to be a true game-changer for mobile operators. The advantages of a targeted, inside-out deployment have been expounded by many in the industry. This includes a staged investment in LTE in contrast to the “build it and they will come” approach used in 3G. The ability to target specific hotspot areas with the performance boost of LTE, while leveraging 3G for wide area coverage, is a more economical way to deliver LTE services. Additionally, the locations that are generally most dense and have the biggest consumers of wireless data are generally in the same location where fiber networks are being rolled out in order to solve the backhaul issue. Figure 3 illustrates a possible LTE femtocell deployment scenario.

The first wave of Tier 1 operators deploying LTE (e.g., Verizon, NTT DoCoMo, TeliaSonera, etc.) have publically stated their focus on the macrocell approach. However, it will be interesting to see if the next wave of operators leverage these early deployments, as there is already significant investment underway for LTE small cells. The small cell approach enables operators to deploy LTE differently and more efficiently than any previous generation mobile networks.

LTE Femtocell Report Card

The prior sections outlined the key business and technology elements that need to progress to push the LTE femtocell along the road from concept to reality; this section outlines how far along the path we have come to date. The report card outlines progress in each area and provides a grade against each parameter; the grading scale is as follows:

*** A = ready today * B = ready within one year * C = ready in one to three years * D = at least three years away * F = no solution in sight**

Silicon: C+

The positives for silicon progression include aggressive roadmaps from innovators like picoChip who recently announced their LTE femtocell development kit1. Additionally, the fact that Tier 1 silicon providers like Texas Instruments and Qualcomm are investing in 3G femtocell is a great portent for their inclination to progress their 3G femtocell solution to support LTE. However, truly optimized and integrated LTE femtocell silicon is at least 12 to 18 months away.

This does not block progress in the LTE femtocell market, though. Lab trials and early field trials can occur on multi-chip solutions which allow operators to test the technology while the market for optimized silicon develops.

Standards: C+

With the number of items on the plate of the 3GPP it is not hard to imagine that rock solid HeNB standards are definitely more than 12 months out. The architecture and basic aspects of the HeNB architecture and procedures are defined today, which is further along than where we were for the first 3G femtocell deployments. The first femtocell deployments happened well before any semblance of a standard existed, and there is no reason the same trend cannot be expected in the case of LTE femtocells. However, do not expect mass deployment before a solid standard is available.

SON: D and B

Right out of the gate we need to break the rules of grading with SON. The reason is that while a consistent standard approach to advanced SON is at least three years away (hence the D), the advancement of proprietary techniques is closer than most expect. There is significant investment going into SON research and development both in startups and Tier 1 NEPs; patent activity is furious and some key breakthroughs are closer than most would predict. Unfortunately, to avoid significant fragmentation and vendor lock-in, operators will be most interested in standards versus proprietary SON. Proprietary approaches will enable trials and targeted deployments, but a standards-based approach is needed for deployment en mass.

Backhaul: B

The backhaul challenge is not from a lack of technical innovation but more about uncertain investment strategies. The solutions exist – whether they are fiber, fixed line, or fixed WiMAX – and it is up to operators to establish the appropriate partnerships and/or make the investment needed. As discussed previously, a lot of investment is going into backhaul optimization techniques for 3G networks, which will benefit LTE deployments. For these reasons the backhaul problem can be expected to be solved within 12 months.

Deployments: B+

The best metric for the LTE femtocell roadmap is deployments. As mentioned multiple times, the LTE standard is enjoying unprecedented global support and the adoption data is simply staggering. According to the GSA, there are 39 operators committed to LTE spread across 19 countries to date. This includes big names such as Verizon, NTT DoCoMo, China Mobile, FT/Orange and KDDI. Not only are operators announcing commitments, but deployments are progressing rapidly, and 14 LTE networks are anticipated to be in service by the end of 2010 with a jump to 31 by the end of 20122.

Regardless of the type of initial deployment strategy (i.e., small cell first as an overlay, or not at all) the user base will be there to enjoy the performance boost provided by LTE femtocells and thus justify the investment.

Conclusions

The report card demonstrates that the LTE femtocell concept is on track to support trials in approximately 12 to 18 months and large scale deployments in 24 to 36 months. While this may still seem a long ways away, if one considers the time required to design, develop and test LTE femtocell equipment, it becomes apparent that the time to invest is now. The advantage of being able to get early trial systems into operator labs over the next six to 12 months is undeniable. Those who can capture the imagination and interest today will be leading the deployments over the next few years.

The LTE femtocell stands to serve as a key weapon in the mobile operator arsenal. It provides a truly disruptive jump in mobile broadband performance and quality of experience. Beyond the market for the LTE femtocell devices themselves, the movement to small cells creates tremendous opportunity for silicon vendors, SON specialists, backhaul optimization and software providers. It will be interesting to re-visit this topic in six months and see if the LTE femtocell has gone from being an average student to one earning straight A's.

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