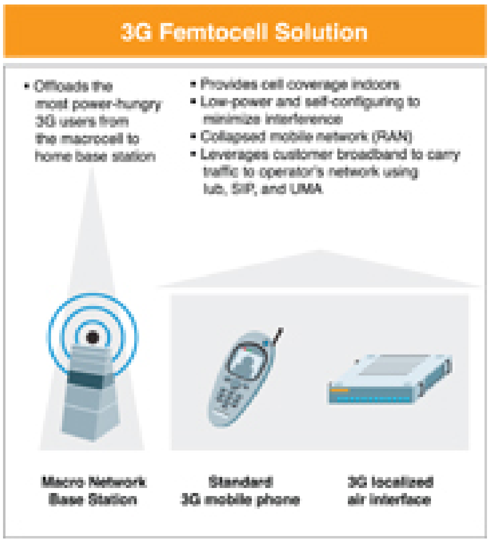
Femtocells: Spectrum Efficiency Improved



Since wireless spectrum is at a premium, it is advantageous for wireless carriers to use the spectrum efficiently in both outdoor and indoor environments.

By Manish Singh, Continuous Computing

One of the most limited resources in telecom is wireless spectrum; therefore, it is not surprising that carriers are paying premium licensing fees for spectrum acquisition. For example, the recent 700 MHz spectrum auction in the U.S. had an aggregate bid value of $19.6 billion. Since acquisition of wireless spectrum is limited, it is advantageous for wireless carriers to use the spectrum efficiently in both outdoor and indoor environments.

From a radio frequency (RF) propagation perspective, buildings and walls have never been friends to a radio signal. Physical structures cause RF signal attenuation because of reflection, diffraction, scattering, and multi-path signal fading, all resulting in poor radio signal reception in an indoor environment. In some cases, virtual dead spots can occur inside buildings, even though there is great coverage outside. Walls can attenuate signals by 10 to 20 dB depending on the type of construction. At the same time, studies have shown that an average consumer spends 50 to 60% of his or her time in an indoor environment, and that 70% of wireless calls originate and terminate indoors. All things considered, this poses the question: Are wireless carriers using their spectrum efficiently in indoor environments?

Market Drivers for Femtocells

From an engineering standpoint, wireless system spectral efficiency is measured in bps/Hz/cell. From a carrier standpoint, this translates into the number of simultaneous subscribers that can be supported in one cell site (i.e., network capacity). From a consumer standpoint, this all translates into quality of voice and video, dropped calls, and high-speed packet access (HSPA) data rates. Poor indoor RF signal penetration has adverse effects on the link spectral efficiency, which has a direct impact on system spectral efficiency. Simply put, carriers lose revenue as mobile minutes are lost to landline minutes when consumers experience dropped calls, poor quality of voice, and lower data rates when indoors. When considered in aggregate, one can easily see the underlying market drivers for femtocells.

What is Femtocell?

A femtocell is essentially a small wireless base station that resides in the consumer’s home or office. Femtocells transmit at very low power, yet create almost ideal indoor radio conditions. For backhaul, femtocells use an IP broadband connection (e.g., fiber/DSL/cable). The very walls which are a radio signal’s adversary actually become their friend as they attenuate RF signal propagation out of the home from the femtocell, thereby minimizing radio interference with an existing macro-cellular network or another nearby femtocell. In fact, femtocells not only provide excellent indoor coverage, but also, by virtue of creating a small indoor cell-site, they free up capacity in the macro-cellular network. In other words, indoor subscribers’ cell phone traffic is parked on a femtocell as opposed to on a macrocell. Femtocells eliminate the need for dual-mode handsets as virtually any existing wireless handset should seamlessly work with a femtocell. And last but not least, one femtocell can support four to six simultaneous voice calls, which means that each member of a family of four can talk simultaneously as if they had four virtual landlines for the price of one.

Why Has it Taken so Long?

So, if femtocells enhance coverage, increase network capacity, and improve spectral efficiency, then why have they not been widely deployed before now? In fact, the femtocell is not a new idea. It has been around for a long time, yet the catalyst for driving a commercially viable rollout for femtocells has only fallen into place very recently. In the earlier days, backhaul costs were a barrier for mass deployment, but today the wide proliferation of IP broadband connections (fiber, DSL, or cable) means that the backhaul infrastructure already exists. In the U.S. alone, more than 52% of homes now have broadband connections, and the figure is growing. Femtocells leverage a consumer’s IP broadband connection to backhaul voice, video, SMS, and data traffic from millions of homes into an existing wireless core network.

Furthermore, thanks to Moore’s Law &#151 which states that silicon performance doubles every 18 months &#151 we are now at the point where integrated custom silicon parts for femtocells are widely available. One silicon part, integrating the required compute, digital signal processing, encryption and various other key features for a small wireless base station, is key to drive the bill of materials (BOM) cost down for a commercially viable femtocell deployment. Lastly, with more than 2.5 billion wireless subscribers worldwide, the economy of scale to justify femtocell deployment is finally in place.

Femtocell in Enterprise

The business case for femtocell rollout is straightforward and can be summarized in three key parts. First, consumers today are paying for landline connections. These landline minutes and Average Revenue Per User (ARPU) are up for grabs due to competition, but only if wireless carriers can provide reliable indoor coverage. In the U.S., the number of cell phone-only homes exceeded the number of landline-only homes in 2007, and household cell phone spending has exceeded landline spending. With femtocells, carriers can provide a robust wireless alternative to landlines and accelerate this social phenomenon of consumers replacing their landlines.

Second, the demand for mobile broadband is on the rise, as fueled by the YouTubes and Facebooks of the world. In the first half of 2007, data revenue in the U.S. alone was 15.5% of all wireless revenue. For AT&T, data ARPU now constitutes 18.4% of their total ARPU, and Vodafone’s data revenue grew 49% over the past year. Femtocells add network capacity and make it possible to deliver 7.2 Mb/s and 14.4 Mb/s HSDPA data rates to consumers in indoor environments &#151 thereby fulfilling market demand for wireless broadband access.

Thirdly, femtocells deliver capital and operational expenditure savings. Adding a new macro base station costs roughly $600,000, depending on site geography, technology, supplier cost model, etc. Add to this approximately $15,000 per month for operation costs, such as leased lines, electricity, and cooling, etc. For the cost of one macrocell site, a network operator could potentially cover 6,000 homes, assuming a cost of $150 femtocell price per unit and operator subsidies of $100 per unit. For $600,000, assuming 7.2 Mb/s HSDPA rate, one macrocell site would add an aggregated 7.2 Mb/s bandwidth capacity, as opposed to 43 Gb/s with 6,000 femtocells. This is a huge difference &#151 especially if revenue is accumulated on a usage basis.

Carrier Benefits

The carriers that roll out femtocells first will benefit from reduced churn as subscribers will not struggle with dropped calls. The quality of the consumer’s experience will improve significantly as clear voice and HSPA data rates are delivered. Most importantly, the carriers that initiate the charge will benefit from "reverse-churn" as femtocells enable home-zone "family tariff plans" which will entice all family members to switch to one carrier in order to take advantage of packaged bulk service benefits.

Challenges of Femtocell Rollout

While the economics for femtocells are compelling, there are many technical challenges that need to be addressed. Utilizing femtocell means that a wireless base station essentially moves into the consumer’s home, and along with that comes the challenge of integrating millions of femtocells with an existing 3G wireless core infrastructure. Many different architecture options, like Tunneled Iub, Tunneled Iu, and SIP/IMS are under consideration, and much more work is needed in order to reduce these choices to only one or two.

Femtocells also bring up the challenge of managing RF interference. RF interference between femto-femto and femto-macro can create virtual dead spots as well as the potential of degrading the performance of an existing carrier's macro network. Traditional RF planning tools used to plan macro cellular networks will not work for femtocell deployments. Instead, femtocells will need the ability to scan the dynamically changing RF environment and configure themselves with frequency bands, scrambling codes and transmit power levels.

Femtocells take security challenges to another level. Since the traffic from femtocells can be carried over a public IP network, the traffic needs to be encrypted to avoid eavesdropping. Potential solutions include establishing IPSec tunnels, SRTP, or TLS for securing the traffic. Carriers also need to secure their existing core network infrastructure from any Denial of Service (DoS) attacks &#151 hence the need for a Security Gateway between femtocells and the core network.

Quality of Service (QoS) is another challenge that needs to be addressed. The best effort of an IP network is just not good enough to carry real-time voice which might be vying for bandwidth on a shared IP link with peer-to-peer (P2P) and other data traffic. In certain deployment scenarios, the DSL uplink bandwidth can be as low as 200 Kb/s and pack four simultaneous voice calls. In this environment, not losing a consumer's VPN connection on his or her PC will be difficult. As a result, classifying, marking, and prioritizing IP packets based on class of service becomes a key requirement. Potential QoS solutions include static Diffserv-based solutions as well as Signaled QoS solutions based on RSVP or SIP.

TR-069 Standard

Management of millions of femtocells requires unique solutions. Traditional Element Management Systems (EMS) that are used to manage NodeBs and Radio Network Controllers (RNCs) in today's 3G networks simply do not scale for femtocells. The DSL Forum already has developed the TR-069 standard for remote customer premise equipment (CPE) device management. This standard needs to be further extended to support femtocells' data models and deployment models. With TR-069, carriers can re-use their existing CPE device management infrastructure by just extending it to include femtocells. Likewise, to support E911 regulations, carriers will need the exact location information of femtocells to effectively route emergency calls to the nearest public safety answering point (PSAP). Femtocell location information could potentially be obtained using global positioning system (GPS) technology; however, GPS itself does not function very well in indoor environments. Another alternative could be mapping a static IP address to a femtocell's physical location. All of these challenges will need to be addressed before widespread femtocell deployment becomes a reality.

What Lies Ahead?

Looking further into the future, femtocells will be more than just access points. In 2008, the market will see more converged CPE devices with femtocell functionality embedded into a residential gateway &#151 an IPTV set top box or a cable/DSL modem. For example, Netgear has already announced the availability of a Residential Gateway incorporating femtocell technology. These converged CPE devices will enable carriers to deploy true quad-play services &#151 voice, video, data, and mobility &#151 all out of one box. And let’s not forget that 3G Long Term Evolution (LTE), or "4G," standardization work is already being influenced architecturally as eNodeBs are also expected to be deployed as home base stations, i.e., Home eNodeBs (HeNB). Carriers that have already secured CPE real estate in consumers’ homes will continue to have an advantage long into the next decade.

Conclusion

Carriers and consumers will both benefit by femtocell rollouts. Carriers will accelerate return on investment (ROI) on spectrum acquisition by efficiently using this scarce and costly resource in indoor environments, while at the same time monetizing mobile minutes substituting for landline minutes; thereby, creating pull for new customer acquisitions through family tariff plans and aggressively growing the data ARPU. Consumers will benefit as they jettison their landlines and become accustomed to their existing cell phones working seamlessly with femtocells while enjoying better coverage, HSPA data rates, zero dropped calls and multiple virtual connections. And this is all just the beginning. In the future, femtocells are poised to play a key role in delivering converged services via IP Multimedia Subsystem (IMS) &#151 a topic for another day and another article.

About the Author

Manish Singh is vice president, product line management at Continuous Computing. Previously he served as vice president of field engineering and vice president of engineering. Mr. Singh is an experienced engineering leader who brings 14 years of experience in telecommunications product design and development. Prior to Continuous Computing, Mr. Singh held various engineering management and architect positions at Intel Corporation, Trillium Digital Systems, and C-DOT (Center for Development of Telematics). Mr. Singh holds the patent as a sole inventor of "Configurable Cache" memory system. Apart from broad telecom domain knowledge, Mr. Singh brings specialized expertise in the wireless and VoIP telecom technology areas.