mobilitie LLC **white paper**

Femtocells

Enabling 4G

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Significant Demand for Wireless High Speed Data Services

Despite the fact that the global telecommunications industry is generally in good health, and likely positioned for growth even in these uncertain economic conditions, these are challenging times for mobile operators. Not only is there a downward trend in consumer spending, many cellular markets are at, or approaching, saturation, and price competition is intensifying with new competitors entering the market. In addition, the demand for higher data rates, and the new technology to support them, will require massive near term investment in new infrastructure and devices.

The good news for cellular carriers and operators is that some 16% of all US households have abandoned their wired phones and are now solely dependent on their wireless phones, at least for voice communication. In the US, subscribers under the age of 35 use their mobile phones for more than 60% of their local and long distance calls and across all age groups, it is still greater than 40%. Wireless Broadband Analysts estimate that a third of all personal mobile phone minutes in the US are used in the home. This could easily be higher, but for some of the population, spotty service, poor voice and data connections, and dropped calls are preventing this from happening.

With the demand to migrate from fixed to mobile communications devices, strongly supported by the WiFi boom, many consumers would like to abandon wired devices altogether but current mobile data services are still a poor cousin to their fixed data relatives served by DSL, cable and fiber. Mobile SMS, MMS, email and limited internet browsing do not compare to the high speed wired connections available to most of us today. What is more, with the advent of Voice over IP (VoIP), services such as Vonage and Skype, wireless operators are seeing serious competition in the home.

Current Cellular Architectures Won't Support High Speed Data

Most current cellular network architectures are based on macrocells with a centralized Radio Network Controller (RNC), Base Stations (Node Bs), and circuit switched Time Division Multiplexed (TDM) or Asynchronous Transfer Mode (ATM) backhaul that was originally designed to give wide area coverage to a comparatively small number of subscribers. A macrocell can support a few hundred simultaneous calls, so scaling on the radio side can be achieved by adding more macrocells or filling in the gaps with microcells and even picocells to support a higher density of subscribers — and/or to provide higher data rates. Increasing site densities can solve some of the problems, but site acquisition can be a major problem, and has always been a huge expense and challenge for operators. In the US, many communities fight long and hard to control cell site locations and their visual impact. In Europe, where the density of cell sites is higher than in the US, the acquisition of new cell sites is highly regulated and more predictable.

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Prior to joining Mobilitie, Bud served as Vice President of National Site Development for Sprint Nextel Communications. In this role, Bud was responsible for defining and implementing enterprise site deployment and operational strategies across a multibillion-dollar portfolio of assets. Earlier in his career at Nextel, he served as Vice President of Site Development for the Northeast Region, Director of Radio Services for New England and held various field engineering and network operations roles. Throughout his tenure, he oversaw numerous large-scale buildout initiatives and gained deep experience in all facets of the deployment cycle and network operations. He holds a Bachelor of Science in Engineering from East Carolina University and a Business Leadership Certificate from Georgetown University's McDonough School of Business.

Adding microcells or picocells is also a significant source of cost, and can be a political and legislative challenge. Instead of large tower sites used for macrocells, micro and picocells require access to utility poles, building roof tops or other utility structures and still have the same requirements for commercial power and network backhaul. Resulting deployments can still be uneven, require considerable manpower to organize, manage and install, and need widespread and expensive backhaul connections.

But even adding more base stations isn't enough. Operators upgrading to high speed networks are discovering that indoor coverage is difficult to achieve with current cell site architectures. There are two major problems. First, the frequency bands for these networks tend to be in the higher ranges making it more difficult to penetrate building walls. Second, data rates tend to decrease the further the user is from the transmitter. This occurs because interference and propagation delays cause errors in the data bit stream; the faster the transmission rate, the greater the number of errors. To correct for these errors, exotic error correction techniques are used or data is retransmitted until the received information is error free. Both approaches result in lower effective transmission rates.

New Technologies are Driving Data Rates Higher

There are multiple technology protocols in use today including GSM EDGE, UMTS and LTE (Long Term Evolution). GSM EDGE based technology can generally achieve data rates of up to 200kbps. The more recent 3G UMTS networks can expect a transfer rate of 384kbps or, if equipped with HSPA, several Mbps. (Telstra in Australia is seeing 21Mbps with HDPA+, though this is not yet in deployment, and hopes to achieve speeds above 40Mbps in the not too distant future). The 3G CDMA2000 technology path can achieve a few Mbps using EV/DO Rev B, but its evolution to 4G has been curtailed in favor of 3GPP's LTE.

LTE based networks are being designed to deliver speeds of up to 100 Mbps on the downlink and 50Mbps on the uplink. Achieving these speeds in practice will not be possible using current cellular architectures. If mobile wireless data rates are going to be able to compete with fixed data rates, including WiMAX, a new approach is required. This is where femtocells come in.

Properties & Benefits of Femtocells
They are physically small, aesthetically pleasing, unobtrusive, and easy to connect and set up.
They are low cost with Bills Of Materials (BOM) of less than $100. Carriers will supply them or they will be purchased at many retail outlets.
They have a low transmission power between 10 and 100 milli-watts. This compares with up to 1 Watt for WiFi routers and carriers can off-set this operating expenditure to the consumer.
They can provide simultaneous connections for up to 6 users. Data rates of up to 100 Mbps will be possible.
They are activated and controlled by the carrier and operated in the carrier's licensed spectrum. In-home pricing will be attractive and provide different levels of service — voice only, voice + low speed data, voice + high speed data etc.
They use internet protocol (IP) for the backhaul, such as cable, DSL or optical fiber. There will be no connections through the legacy cellular network other than at the carriers Core Network. Carriers will benefit by off-loading some of its valuable TDM bandwidth (and opex) on to the Internet.
Because femtocells will know their exact location, Emergency Services will find it easier to locate the caller.

Telecom Facts & Figures

In 2008, the number of global mobile subscribers exceeded 4 billion and is expected to rise to 6 billion in 2012.

Over 30% of all cellular traffic is generated inside the home or office. 16% of all US households are entirely wireless.

There were over 3 million wired backhaul connections to cell sites in 2007, growing to around 5 million in 2009.

Two out of three cell towers already have two or more mobile carriers/operators on them.

Current backhaul networks are very expensive to run. In the US, costs are expected to more than treble over the next three years.

Existing backhaul networks are incompatible with, and cannot support the demand for, high speed data services.

Carrier ARPUs are remaining relatively flat, even though some 20% is being generated through data services.

Femtocell Architecture

Femtocell architecture owes its origins to the WiFi camp in which small, inexpensive base stations covering an area just a few tens of yards wide, are located in the office or house and are connected to the user's broadband internet service (like a cable or DSL modem). Although the femtocell is completely independent of the tower cell site/TDM/ATM architecture, subscriber devices have the ability to roam or connect seamlessly to either; this is termed Fixed Mobile Convergence or FMC.

Femtocell base stations can be carrier owned or consumer owned, will support half a dozen simultaneous users and will only have sufficient coverage for the home or office. Just like wired and WiFi routers, they will be quick and simple to install, requiring just power and IP connections.

As the technology for high speed data services rolls out, carriers and operators stand to reap significant benefits from the femtocell architecture. The stress on existing networks will be significantly relieved and the overall capacity of a carrier's network will be increased. Each femtocell can handle up to 6 simultaneous calls. These calls will be off-loaded from both the RAN and backhaul side of the carrier's macrocell network. This means that subscribers using the legacy network will also see an overall improvement in service.

Capital costs will be reduced, even as the number of new subscribers increases. The introduction of femtocells will reduce the capital spent per user on new macrocell equipment. This will enable the carriers to free up valuable capital for the deployment of other network enhancements. Also, with excellent, error free coverage, the use of mobile multimedia services will increase, thereby raising ARPU. Furthermore, the cost of backhauling the traffic to the carrier's core network will be borne by the end user via cable, DSL or optical fiber instead of the carrier. Another key benefit will be that excellent in-home and office coverage, and service will reduce customer churn and increase customer loyalty.

Concerns and Challenges

There are, however, concerns and challenges surrounding large scale femtocell deployment. Macro (and micro/pico) installations are carefully planned, installed and maintained by carriers or transport service companies. The networks are carefully tuned to give maximum coverage with minimum interference. This will not necessarily be true for femtocell installations.

There will be interference between the macrocell network and femtocells. Indeed it is possible that the signal from the macrocell will be stronger than the signal from the femtocell. Femtocells must have the ability to adjust themselves so that they reject the signal from the macrocell.

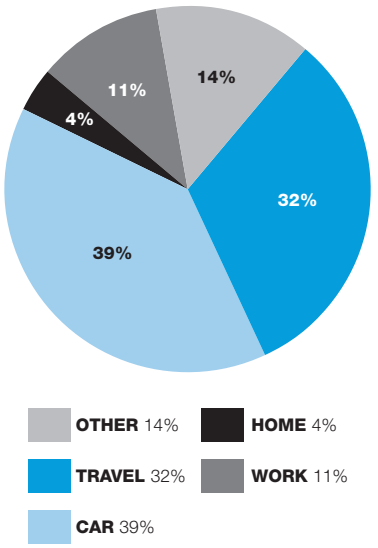
As femtocell installations become more widespread, and this is likely to happen quickly, the network will become much more dense, and the radio environment will become more complex. Femtocells will begin to interfere with neighboring femtocells, especially in urban situations. Femtocells must be continually aware of the radio environment and have the ability to adjust to any given situation.

Both of the above scenarios become more complex when you consider the different transmission and reception frequencies used by different carriers, and those used in different technologies such as CDMA, GSM, UMTS, LTE, WiFi, WiMAX, UMA, Bluetooth and so on.

There are also issues of system selection, handoff and access control. The exact radio boundary between a macrocell and a femtocell cannot be predicted or controlled. If the radio signal from the macrocell is stronger in the home or office than the signal from the femtocell, to which one does the consumer device connect? And what happens when the consumer enters the home and needs to change connection from a low data rate macrocell to a high data rate femtocell, or vice versa. The system selection and handoff need to be fast and seamless, both at the radio layer and the switch over from TDM/ATM to Internet-based backhaul. Furthermore, both carriers and consumers will need a range of access control mechanisms. Femtocells will use the consumer's internet connection, so consumers will need the ability to control who uses their femtocells, in particular, to prevent unauthorized access by people within the radio boundary, be they passers-by, or neighbors in a multi-tenant office or residential building.

Security is a major issue for femtocell networks. Security for macrocell based networks is robust and rigorously enforced. Powerful encryption techniques are used to protect customers' voice calls and data transmissions, only revealed under extreme legal and political conditions. This is not true

US Mobile Phone Usage



Macro, Micro, Pico?

The exact definition of the coverage of these cellular structures is somewhat muddy, but macrocells have a radius of between 2 and 10 miles, micro cells between ½ and 2 miles and picocells between a few 10's and up to a few hundred yards.

for internet traffic where hacking, identity theft and fraud are everyday occurrences. Femtocells must establish IPsec encryption connections through the internet to ensure consumers' network privacy is not compromised.

Concerns & Challenges
There will be potential problems of macrocell to femtocell, and femtocell to femtocell interference.
Since the spectrum used by femtocells is the same as the carriers use for their macrocells, issues concerning system selection, hand-over and roaming need to be resolved.
Current macrocell handover planning techniques are inappropriate for femtocells. For example, the sheer number of femtocells versus neighbor lists will make cell planning orders of magnitude more complex than it is today.
Given that the Internet is open access, the risks to security are much more significant than with traditional cellular networks.
Femtocells will need to support all Global network standards such as 3GPP (UMTS), 3GPP2 (CDMA) as well as emerging standards like WiMAX, LTE.
Carriers will need to act quickly and decisively if they are going to meet the challenges of VoIP and UMA.

Femtocells will Change the Mobile Industry

Femtocells will bring a new generation of low cost, flat architecture networks that will use the Internet to deliver to consumer's high quality voice and high speed data. In many developed and third world countries, femtocells will be the sole coverage vehicle to enable wireless mobility in the home and office. Although basic voice and high speed internet services will start the revolution, femtocells will eventually usher in other multi-media services such as music and video download and IPTV. Additionally, as embedded broadband chips (WiMax, LTE) in consumer devices such as cameras, consumer appliances, etc., become commonplace, femtocells will be the foundation for realizing the "true" wireless home.

Femtocells will provide carriers and operators worldwide the ability to generate higher revenues and ARPUs with lower capital, maintenance and operating costs. They are an ideal way to introduce and operate the next generation of mobile networks based on technologies such as WiMAX and LTE.

Femtocells will not, however, replace current macrocellular systems. Hybrid networks will emerge with islands of 4G in the current ocean of 3G technologies. Macrocells will continue to provide inexpensive voice and data services to millions of consumers. In fact, with the introduction of femtocells, the services, and the access to those services, provided by macrocells will dramatically improve as millions of consumers are off-loaded to femtocell networks.

Femtocells will enable the next big leap in performance and quality of service in the mobile industry, and it's closer than you think. Already, femtocell base stations are becoming available and networks are being installed. By the end of 2009, this evolution will be well under way.

Operator Benefits	Subscriber Benefits
Better indoor coverage in-home or office	Improved data performance
Reduced capital cost and opex	Better indoor coverage
Lower or zero backhaul costs	Higher voice quality
Higher revenue and ARPU	Greater multimedia experience
Lower churn, better customer loyalty	Lower cost of service