Airvana

Mobile Broadband. **Everywhere.**

Femtocells: Transforming The Indoor Experience

An Overview

How Can the Mobile Phone Become the Only Phone?

Consumers continue to replace fixed line calling with mobile minutes – and in the case of younger callers, mobile phones are increasingly their only phones. In fact, callers under the age of 24 make up to four-fifths of their long distance calls on wireless networks (see Figure 1). What stands in the way of making the mobile phone the primary phone for the rest of the demographic? Fundamentally, consumers want great voice quality, reliable service, and low prices. But today's mobile phone networks often provide poor indoor coverage and expensive per-minute pricing. In fact, with the continued progress in broadband VoIP offerings such as Vonage and Skype, wireless operators are at a serious disadvantage in the home.

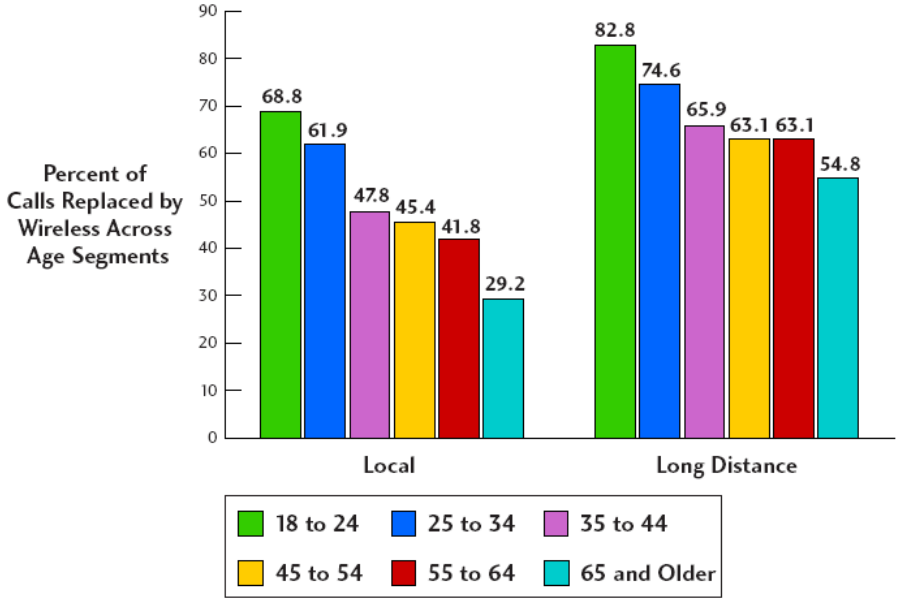

Figure 1: Wireless – wireline substitution, *Source: Yankee Group 2006 TAF Survey*

Femtocells

A new class of small "base stations" has emerged, called *femtocells* (sometimes written as two words, i.e. "femto cells"). These devices are the size of a DSL router or cable modem and provide indoor wireless coverage to mobile phones using existing broadband Internet connections (see Figure 2). They will be:

Low-cost – Femtocells will be offered as a consumer purchase through mobile operators.

User-installed – Like cable modems and DSL routers, femtocells will be installed by consumers and activated through service providers.

Low-power – Femtocells will transmit at 10-100 milliwatts, similar to Wi-Fi access points.

Broadband-connected – Femtocells utilize Internet protocol (IP) and flat base station architectures, and will connect to mobile operator networks via a wired broadband Internet service such as DSL, cable, or fiber optics.

Based on cellular network standards – Femtocell will be purpose-built for existing UMTS and CDMA standards, as well as emerging standards such as WiMAX, UMB, and LTE.

Compatible with existing mobile handsets – In each technology market, femtocells will support existing handsets.

Deployed in operator-owned spectrum – Femtocells operate in licensed spectrum owned by wireless operators, and may share the same spectrum with the macro cell network.

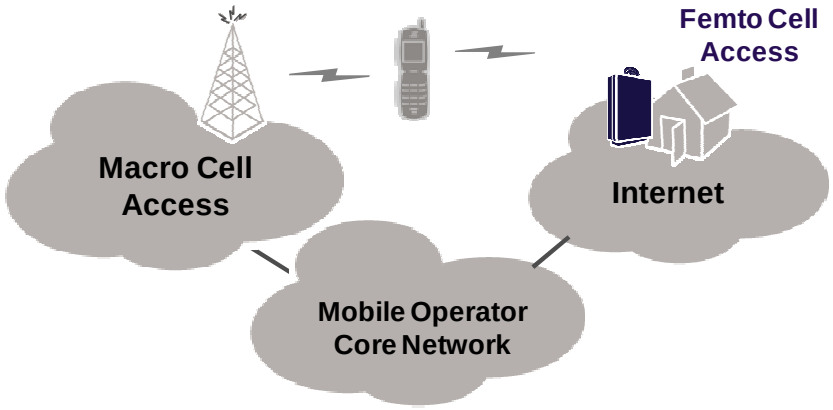

Figure 2: Femtocell access via broadband Internet

What Femtocells Deliver for Users

For end users, femtocells will solve a number of existing problems and enable new applications and services:

Increased indoor coverage – Most femtocells will cover a radius of 50-200 meters. In most homes, this can provide "five bars" of coverage throughout the household.

Higher performance data – Unlike macro cells that support hundreds of users, femtocells will support 4-6 simultaneously active users. As a result, femtocell-based EV-DO and HDSPA connections will have less contention and deliver higher data rates per user than in the macro cellular environment.

Improved multimedia experience – With higher performance data, femtocells will deliver a better multimedia experience with music, photos, and live video to laptops, smartphones, and feature phones.

Better quality voice – In addition to the obvious voice quality gains attributed to better coverage, femtocells will enable support for a new generation of higher rate voice codecs that leverage fewer users per access point and the proximity of the handset to the femtocell.

Enhanced emergency services – Because femtocells will know their location, emergency services will find it easier to locate callers seeking emergency services.

Converged mobile VoIP services – By using VoIP technologies, many femtocells will be able to connect existing fixed line phones as well as mobile phones.

Operators Need Capacity and Coverage

With the increase in mobile usage, operators are forced to plan for increased capacity and coverage. But they continue to wrestle with several fundamental and on-going problems.

Site acquisition is expensive – Increasing existing macro cell densities can solve some of these problems, but site acquisition is problematic and has long been a major expense and stumbling block for operator build-outs. Nearly 50% of the cost of constructing a macro cell network is the cost of site acquisition. In Europe where the density of GSM sites is already high, acquisition of additional sites is highly regulated. In the US, many communities negotiate long and hard to control cell site location and visual impact.

Denser cells mean more backhaul – Smaller cells such as micro cells and pico cells can improve coverage and capacity, but deployment can be a political challenge. Instead of large tower sites, access to utility poles and other common utility structures must be secured and provided with power and network backhaul. Resulting deployments can be uneven, require considerable manpower to install, and need widespread and potentially expensive backhaul facilities.

Indoor coverage is a stumbling block – In the GSM market, operators transitioning to UMTS networks are discovering that indoor coverage is more difficult to achieve with current cell densities. UMTS typically operates at higher frequencies, making it more difficult to penetrate building walls. In addition, UMTS' transition from low-speed SMS to higher-speed multimedia increases the demand for consistent mobile broadband coverage. Among CDMA operators, new applications such as push-to-talk and the burgeoning growth of corporate laptop Internet access require blanket coverage to be effective.

Existing phones must be supported – The widespread deployment of Wi-Fi access points has spurred the development of Wi-Fi fixed mobile convergence (FMC) solutions – technology that allows dual-mode phones with both Wi-Fi and cellular radios to access mobile operator networks. But these early FMC solutions will not support existing cellular handsets in either UMTS or CDMA markets.

Femtocell Benefits for Operators

Many of the challenges facing mobile operators can be addressed by femtocells. As the technology rolls out, carriers stand to reap significant benefits from femtocell deployment (see Table 1).

Increased network capacity – With customers installing femtocells, operators will relieve stress on macro cell networks and increase the overall capacity of mobile operator networks. Each femto represents up to 4-6 calls offloaded from the macro cell radio network for roughly a third of each day.

Lower capital costs – Even as the number of subscribers in a mobile operator's network increases, the introduction of femtocells will reduce the capital spent per user on new macro cell equipment.

Expanded revenue opportunities – With excellent coverage and superior broadband wireless performance, mobile multimedia services will increase in popularity, raising average revenue per user (ARPU).

Lower backhaul costs – The cost of backhauling traffic to the operator's core network will be handled by the user via DSL, cable, or fiber access lines without any cost to the operator.

Increased customer stickiness and conversion – With excellent in-home coverage and home zone calling plans, operators will reduce customer churn and attract more users to their family plans.

User Benefits	Increased indoor coverage	Higher performance data	Improved multimedia experience	Higher quality voice	Lower cost home zone calling
Operator Benefits	Increased network capacity	Lower capital costs	Expanded revenue opportunities	Lower backhaul costs	Increased customer stickiness

Table 1: User and operator benefits from femtocells

Hybrid Mobile Networks Emerge

The combination of femtocells and wired IP broadband will yield a new generation of wireless network – the hybrid mobile network. Previously, macro cell networks were owned and operated end-to-end by mobile operators. As private networks, they were inherently secured by the operating practices, equipment, and leased line services.

Hybrid mobile operator networks, on the other hand, will utilize a combination of network transport services, some owned and controlled by the operator, and some not. As femtocells are deployed, operators will re-use large scale elements of their current core networks such as billing, authentication, authorization, accounting (AAA), policy, and mobility services. But the use of the Internet as a backhaul network will cause a fundamental architectural change for mobile operators.

Because femtocells will use any residential IP broadband connection, customers will be plugging femtocells into the Internet via cable modems and DSL routers. This will put increased emphasis on another category of products – security and mobility gateways – to protect the integrity of operators' core networks from the public environment of the Internet, to protect the integrity of users' traffic, and to support seamless transitions between the macro and femtocell networks.

To meet that need, a new generation of high-performance security and mobility gateways has emerged. Designed to handle very large numbers of encrypted tunnels and to manage handoffs between macro cell and Wi-Fi networks, such gateways will become critical anchor points for the security of femtocells and a fundamental element in future mobile networks (see Figure 3).

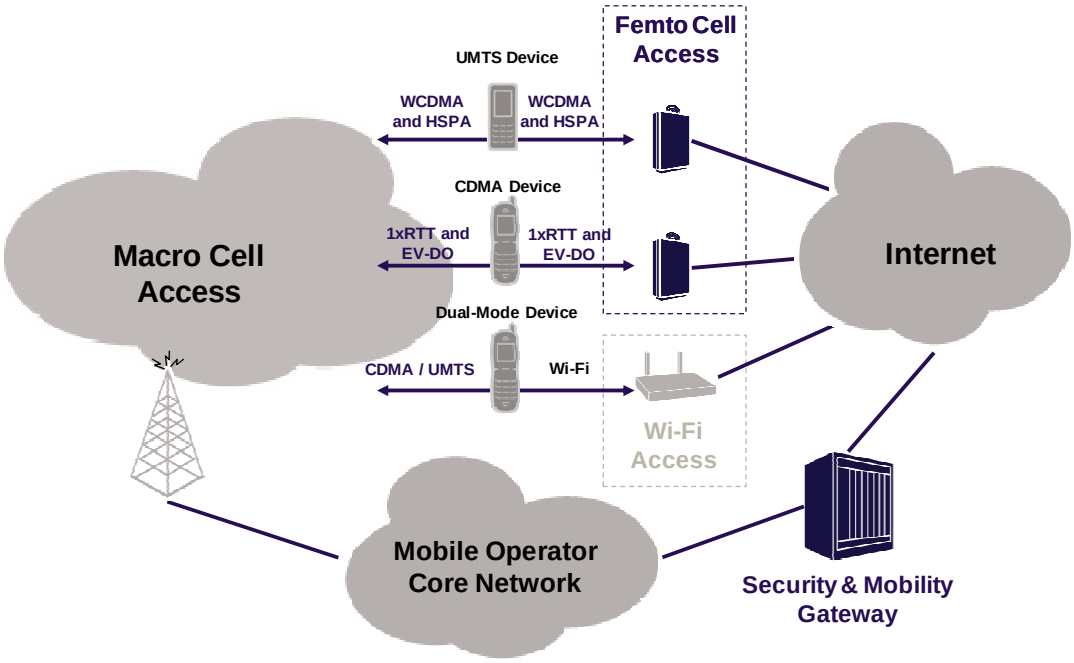

Figure 3: Security & mobility gateways for femtocells

Femtocell Enablers

Why have femtocells suddenly become a viable element in the evolution of mobile networks? Three market and technology advances have led to this shift.

Widespread wired broadband – Widespread availability of DSL, cable, and fiber optic broadband have opened the door for femtocell deployment scenarios. Because customers are already utilizing broadband Internet, femtocells can be deployed anywhere there is a residential broadband IP service.

Low-cost processors – The recent availability of low-cost, powerful field programmable gate arrays (FPGAs) and digital signal processors (DSPs) has allowed complex base station software to be run on very small platforms. FPGAs have traditionally been the basis of high-end network equipment with parts costing upwards of a $1,000 each, but prices have been on a steep decline. According to the FPGA Journal, FPGA costs per 1000 gates fell by 97% between 1998 and 2005. In addition, FGPAs now offer the option of conversion to even lower-cost application-specific integrated circuits (ASICs).

Flat architectures – Because powerful processing can be applied to low-cost femtocells, network software stacks can be substantially collapsed. In addition, the standard Internet protocol (IP) has rapidly replaced hierarchic telecom-specific transmission protocols. The combination of collapsed software stacks and IP transport enable femtocells to utilize flat networks – such as the Internet – as a backhaul transport to operator core networks (see Figure 4).

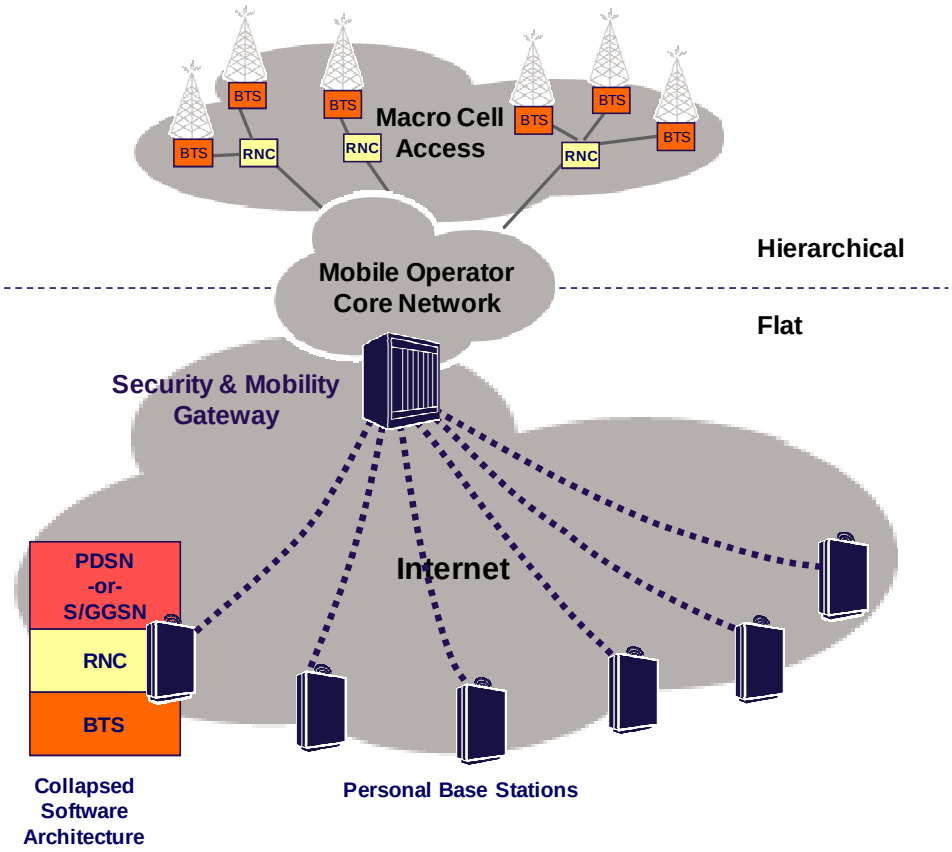

Figure 4: Flat mobile networks of femtocells

Technical Hurdles for Femtocells

Though the technology has advanced quickly, a number of challenges still need to be addressed to make femtocells successful as high-volume products. Because each represents an area of innovation, many will become significant aspects of competition and differentiation among femto access point suppliers.

Radio interference mitigation – Unlike macro cellular installations where the RF coverage can be manually tuned and optimized by technicians over a long period of time, femtocells will need to sense the radio environment around them from the moment they are plugged in by the consumer. Femtocells will then need to mitigate potential interference by dynamically adjusting for two typical scenarios.

- Macro-femto interference. Though they are statically configured, macro cell RF densities and through-wall penetration will be unpredictable and will vary depending on where a femtocell is installed. Though operators will understand the general RF footprint of their macro cell deployments, they will have no control over where their end customers will deploy femtocells. The femtocells must adjust themselves to avoid interference in macro cell networks.
- Femto-femto interference. As many consumers install their own femtocells, the RF environment will become more complex. Femtocells will begin to impact other femtocells, particularly in urban multi-tenant environments but also in some densely packed suburban situations. When a neighbor installs a new femtocell, other femtocells must adjust their transmissions to control interference.

In both scenarios, mobile operators will need the ability to see what femtocells see – or hear what femtocells hear – in the RF domain. This will be true both for installation and on-going maintenance of femtocells.

Automatic system selection – When an authorized user of a femtocell moves in or out of the coverage of the femtocell – and is not on an active call – the handset must correctly select the system to operate on. In particular, when a user moves from the macro cell into femtocell coverage, the handset must automatically select the femtocell, and visa versa. Since some operators will be offering special home-zone pricing when a subscriber is connecting through a femtocell, an indication is also needed on the handset to inform the subscriber of the network it is operating on.

Active macro-femto handoffs – When an authorized user of a femtocell moves in or out of coverage of the femtocell – and is on an active call – the handset must correctly hand off between the macro cell and femtocell networks. Such handoffs are especially critical when a user loses the coverage of a network that is currently serving it, as in the case of a user leaving the house where a femtocell is located.

Security – Because femtocells will connect back to an operator's network via the public Internet, each femtocell establishes an encrypted tunnel into the network using industry standard IPsec technology. A femtocell must identify and authenticate itself to the operator's network as being valid – so a hacker cannot spoof the network into thinking his femtocell is someone else's and fraudulently use another customer's services.

Scalability – Security and scalability are interdependent problems. Because each femtocell must be secured using IPsec, each could represent at least one or more IPsec tunnels. With millions of femtocells deployed in a network, operators will require large scale security gateways at the edge of their core networks to handle millions of femtocell-originated IPsec tunnels. In addition to aggregating large numbers of tunnels, femto security gateways will be required to protect the operator's network from Internet generated attacks such as man-in-the-middle and denial of service attacks.

Access control – Consumers and operators will require a range of access control mechanisms. Since femtocells use the broadband Internet connection owned by the user for backhaul, consumers should be given the option to control the use of their femtocells. In particular, a femtocell owner should be allowed to easily add and delete authorized users and to exclude unauthorized users near the femtocell, such as a stranger walking by or a neighbor in a multi-tenant building.

Activation & management – This area may determine the success or failure of many products and services. Since most femtocell products will be purchased in a way similar to mobile phones, ease of customer installation and activation is paramount. The end-customer must be able to open the box, power up and plug the femtocell into the network, call a number for activation, and have a one-touch means of registering handsets. In addition, operators must have management systems that give first-level support technicians full visibility into the operation of the femtocell and its surrounding RF environment.

Future Considerations & Impact

The emergence of femtocells and hybrid mobile networks will likely lead to structural changes in 3G networks and to potential disruption in the operator market.

Missing the Train

Some mobile operators may only watch as their competitors deploy millions of femtocells. As a result, they will be left with an expensive radio infrastructure, high priced telecom backhaul, and the shared-bandwidth multimedia experience of macro cellular environments. These operators will be at a fundamental disadvantage in terms of network cost, breadth of services, and end-user experience – disadvantages that will rapidly erode their competitiveness and profitability.

Content Focal Point

Although femtocells will start with the humble task of providing voice and data services to the handset, they could deliver other services and become the focal point of user content. Femtocells could become the means by which consumers access all the music, video, and photos that reside in their home – via the mobile network. Because femtocells can provide an improved broadband experience, mobile devices may become the preferred devices for multimedia. With a faster and more responsive femtocell network, mobile devices may expand their functionality, and become the vehicle for creating, managing, storing, and publishing mobile multimedia content.

A Vehicle for 4G Deployment

Femtocells may be an ideal way to introduce the next generation of mobile networks – 4G technologies such as WiMAX, UMB, and LTE. Instead of incurring the enormous expense of upgrading the entire macro cell infrastructure to 4G, mobile operators may choose to introduce islands of 4G in an ocean of 3G. In fact, femtocells may prolong the life of the 3G macro cellular. In addition, femtocells may also be a lower risk technology platform for the introduction of 4G, since the cells are smaller, the numbers of users per cell is significantly less than a macro cell environment, and the higher speed backhaul required for wireless operating at greater than 100 Mbps will be readily available.

Conclusion

Femtocells will change the mobile industry. Operators will use femtocells to build a new generation of lower cost, flat architecture networks that can utilize the Internet as backhaul and deliver expanded capacity for customers. This hybrid mobile network will yield an improved platform for new mobile multimedia services, higher revenue, and new technology introduction.

Femtocells will also change the mobile broadband experience for customers. Excellent wireless coverage in the home will become the norm and not the exception. Femtocells will raise the bar for high performance broadband wireless and customers will expand the utility of mobile broadband devices.

Glossary

For a glossary of technical and marketing terms used in this paper, go to: http://www.airvana.com/technology/technology_glossary.htm.

About Airvana

Airvana is a leading provider of network infrastructure products used by wireless carriers to provide mobile broadband services. Airvana's products enable wireless networks to deliver broadband-quality multimedia services to mobile phones, laptop computers and other mobile devices. These services include Internet access, e-mail, music downloads, video, IP-TV, gaming, push-to-talk and voice-over-IP. Airvana's solutions enable new services and deliver carrier-grade mobility, scalability and reliability with relatively low operating and capital costs.

Worldwide, Airvana's mobile broadband systems are deployed on six continents in 16 major networks by industry-leading service providers who demand high standards of carrier-class performance.

Airvana is headquartered in Chelmsford, MA, USA. For more information, please visit the company's Web site at http://www.airvana.com.