

UNSTRUNG **insider**

TARGETED ANALYSIS OF THE WIRELESS INDUSTRY

3G Home Base Stations: Femto Cells & FMC for the Masses

TABLE OF CONTENTS

- I. Introduction: 3G Home Invasion**
- II. Femto Cell Market Dynamics**
 - Home Base Station Concepts
 - Business Drivers
 - Market Potential
- III. Femto Cell Product Requirements**
 - Air Interfaces
 - Femto Cell Design Challenges
 - "Collapsed RAN" Architecture
 - Form Factors & Price Points
- IV. Core Network Integration**
 - Tunneled Iub to RNC
 - Iu Interface via Concentrator
 - UMA/GAN Architecture
 - SIP-based via PDG (I-WLAN)
- V. Company Profiles**
 - Public Mobile Infrastructure Providers
 - Private Mobile Infrastructure Providers

Report Highlights

Vendors say femto cells could sell for \$100 by the end of 2008 – the price is attainable, but the timeline is not; \$200-\$300 is more likely

Startups 3Way, AirWalk, ip.access, picoChip, RadioFrame, and Ubiquisys are spurring innovation

Alcatel-Lucent, Ericsson, NEC, and Samsung have the most advanced femto development programs of major equipment vendors; Huawei, Motorola, Nokia-Siemens, and ZTE will likely work with OEM partners

Core network integration is a critical issue, with three options on the table: Iub over IP, UMA, and IMS/SIP

"Collapsed stack" femto designs will win out over RAN-based architectures in the medium term; this offers vendors looking to break into new accounts an entry point, but is negative for incumbent RAN vendors

Use of this PDF file is governed by the terms and conditions stated in the Subscriber License Agreement included in this file. Any violation of the terms of this Agreement, including unauthorized distribution of this file to third parties, is considered a breach of copyright. Light Reading Inc. will pursue such breaches to the full extent of the law. Such acts are punishable in court by fines of up to \$100,000 for each infringement.

I. Introduction: 3G Home Invasion

The deployment of third-generation (3G) cellular networks has been one of the dominant themes in wireless over the past several years. Now 3G, combined with the rapid uptake of residential broadband services, could launch a new phase in mobile networking and service provisioning. The idea is to take the capability of low-cost IP access and combine it with the robustness and usability of carrier-grade telephony services by deploying ultra-low-cost, low-power, cellular base stations in subscriber's homes.

Also known as femto cells or 3G access points, these devices typically support around four to six simultaneous users and look similar to a residential wireless local-area network (WLAN) access point. The major difference between femto cells and dual-mode fixed/mobile convergence (FMC) plays analyzed by *Unstrung Insider* in the past is that this technology works with millions of mobile handsets already in use. In essence, it is a tradeoff between loading cost and complexity into end-user devices with WiFi chipsets or adding devices to a subscriber's home network.

There are multiple business drivers propelling interest in the femto cell concept. Most obviously, by deploying capacity indoors, where it is most needed, cellular operators gain greater flexibility to introduce disruptive pricing strategies, allowing them to accelerate the capture of wireline voice minutes and grow revenues.

Over the long term, there's also an opportunity to develop services that take advantage of low-cost, high-speed Internet access to mobile devices, which could include free video calling or mobile TV from home. Service innovation could potentially also extend to applications that use handsets to access and control multimedia home networks.

Other benefits of home base station technology over traditional cellular network technology include the ability to provide capacity that scales in line with subscriber demand, a reduced requirement to deploy additional macro carriers to support indoor users, and an opex requirement that is kept in check by IP backhaul paid for by the customer.

This report seeks to identify key market opportunities for emerging femto cell technology and analyzes the product strategies and roadmaps of more than a dozen leading providers of home base stations. Key findings of the report include:

The use of standard mobile handsets in this kind of FMC play has obvious benefits over dual-mode WiFi phones. These benefits include more choice of cheaper, less-complex devices and simpler user interfaces combined with more subtle benefits, such as a radio interface designed and optimized for battery-powered devices with greater receive sensitivity, and therefore greater range at lower power. Because 3G operates in licensed spectrum, there is also far less risk that interference will affect radio-link performance and usability.

Vendors believe femto cells could sell for \$100 by the end of 2008. However, while this price looks attainable at some point in the future, \$200 (including network-side equipment) looks like a more realistic (yet still aggressive) target for 2008.

Femto cell unit pricing is extremely sensitive to equipment costs and volume manufacturing. This will drive vendors to more system-on-chip components that integrate as much functionality as possible into hardware. The problem is that major silicon vendors aren't convinced that the volume is there to justify the necessary investment in such products.

The relentless focus on cost suits the operator business case. Even at volume, however, it seems likely that the market will eat itself, leaving vendors competing for a low-margin commodity business. This may explain the reticence some larger equipment providers have shown in committing to this market.

The operator business case for home base station deployment is driven in part by the opportunity to replace investment in macro cells with less expensive and more focused investment in femto cells. This is negative for incumbent radio access network (RAN) vendors unless it boosts 3G usage to such an extent that it reinvigorates demand for macro capacity.

Privately held vendors are driving innovation in femto cell product development. Standout startups include 3Way, AirWalk, Airvana, ip.access, picoChip, RadioFrame, and Ubiquisys. Of the major equipment vendors active in this market, Alcatel-Lucent, Ericsson, NEC, and Samsung have the most advanced development programs. Huawei, Motorola, Nokia Siemens, ZTE, and consumer electronics vendors will likely opt to work with OEM partners.

Although intended as a standalone document, for fuller information this report can also be read in association with previous *Unstrung Insider* reports, such as:

- **Mobile Network Security: The Threat of Convergence & IMS** (Vol. 5, No. 5, May 2006)
- **In-building Cellular: Selling the Great Indoors** (Vol. 5, No. 4, April 2006)
- **Cells in the City: Extending Wireless Coverage** (Vol. 3, No. 2, February 2004)

Companies analyzed in this report include: 3Way Networks Ltd.; Airvana Inc.; AirWalk Communications Inc.; Alcatel-Lucent (NYSE and Euronext Paris: ALU); Andrew Corp. (Nasdaq: ANDW); Ericsson AB (Nasdaq: ERIC); ip.access Ltd.; Motorola Inc. (NYSE: MOT); NEC Corp. (Nasdaq: NIPNY; Tokyo: 6701); Nokia Siemens Networks, a joint venture of Nokia Corp. (NYSE: NOK) and Siemens AG (NYSE: SI; Frankfurt: SIE); picoChip Designs Ltd.; RadioFrame Networks Inc.; Samsung Electronics Co. Ltd. (Korea: SEC); and Ubiquisys Ltd.

II. Femto Cell Market Dynamics

A. Home Base Station Concepts

Cellular networks, based on traditional macro cell topologies, have come to dominate telephony around the world. In second-generation (2G) GSM networks, this often means cells with radiuses of several, or even tens of kilometers. 3G networks, while typically designed with smaller cell sizes, are similarly designed to provide coverage and capacity over a wide area.

As any cellphone user knows, however, there are places where radio signals don't reach. To counter this phenomenon, there is a fairly significant market for in-building wireless systems that typically use distributed antenna systems or repeater technologies. There has even been a modest market for small-footprint indoor 2G base stations.

Now, a new type of product – the 3G femto cell – could open up new service possibilities for consumers and enterprises and help mobile network operators evolve their business models in the era of FMC.

A 3G femto cell is essentially the cellular equivalent of a WLAN access point, except that it uses a radio interface that is purpose-built for mobile handsets and will be more expensive, at least initially. Like a WLAN access point, the femto cell would connect via Ethernet to a home router/modem or corporate network, and traffic would be backhauled over IP to the mobile operator's core network.

The extra cost of the device is primarily due to lower product volumes and higher component costs. Several suppliers interviewed for this report, however, are targeting ultra low-cost 3G devices with pricing similar to low-end 3G handsets. It is also envisaged that 3G radios will be embedded in home gateways, set-top boxes, and other consumer electronics equipment in the same way that WLAN is today.

The idea is that operators would provide 3G home base stations to customers either on a standalone basis, as part of a mobile subscription, or as part of a bundle with home broadband and telephony services. There are several potential benefits, which include scaling 3G capacity in line with paying customers and having customers pay for the backhaul.

3G Capacity Scales In Line with Paying Customers

One of the problems with a 3G macro network is that the mobile network operator must deploy sufficient infrastructure to ensure adequate coverage before it is able to sign up any customers. This "build it and they will come" strategy requires huge up-front investments, and is inherently fraught with risk.

Using home base stations helps in two ways. First, even if a free femto cell is bundled with a subscription, the operator has a guaranteed customer and has an idea of the likely payback period. Second, a femto cell provides capacity and coverage where it's needed most – indoors, likely at home or in the office. This is far less expensive than providing equivalent indoor service by way of the macro network, which would require a much higher density of cell sites operating at high power to provide the required in-building penetration.

Similarly, dedicated indoor coverage should offload traffic from the macro network, which in turn delays the requirement for adding additional capacity at the macro cell site. Yet another benefit from a radio perspective is that the end user will experience better channel conditions – and therefore lower latency – and will suffer less contention with other users, thus receiving higher data rates. This should translate to improved application performance and even open up the market to new applications that are uneconomic on the macro network.

Customer Pays Backhaul Costs

Another benefit of 3G home base stations is that the customer not only pays for and hosts the equipment, but also pays for the backhaul across a home Internet connection. The profitability of 3G data services is especially sensitive to backhaul costs as compared to voice. In a macro network, backhaul is typically provided by time division multiplexing (TDM)-based leased lines or microwave links. These circuits are generally affordable for voice traffic, and most sites have sufficient capacity to absorb increases in voice minutes without incurring large additional costs.

Where data is concerned, however, the picture is entirely different. With up to 10 Mbit/s of capacity likely to be required at a High-Speed Downlink Packet Access (HSDPA)-enabled cell site, operators must invest significant sums in backhaul. This requires either capex, which must precede the actual use of the network by customers, or opex in the form of leased capacity. Opex, in particular, is the enemy of a carrier's profit and loss balance.

B. Business Drivers

Cost and efficiency benefits aside, what is really required by 3G operators are new service opportunities or a way to make 3G more attractive and to help operators differentiate with bundled broadband, television, telephony, and mobile services. Having the 3G access network extend directly into the home will surely help drive new services. But it is fixed-line substitution, and home-zone tariffs in particular, that are really expected to provide the business case.

In markets where home-zone services already exist, they have proved a big hit. Germany is probably the best example, with O2's Genion service having attracted 3.7 million subscribers – which accounts for more than 50 percent of its total customer base – by the end of June 2006. More recently introduced services, such as Vodafone's ZuHause and T-Mobile's @Home, had 900,000 and 700,000 subscribers respectively by mid-2006.

The problem with these services is that the size of a home zone is defined by using cell ID technology, which typically creates zones of a kilometer or more. Because users benefit from home-zone pricing within this entire area, this means operators suffer a lot of revenue leakage. Using femto cells would enable operators to create much smaller home zones and therefore provide much greater flexibility into how these services are priced.

In the short to medium term, femto cells are about increasing loyalty, reducing churn, and capturing minutes from fixed and voice over IP (VOIP) networks. Looking further out, a femto cell can integrate the 3G terminal with in-home networks. As such, the phone becomes an endpoint for accessing content on the user's PC, video server, and so on.

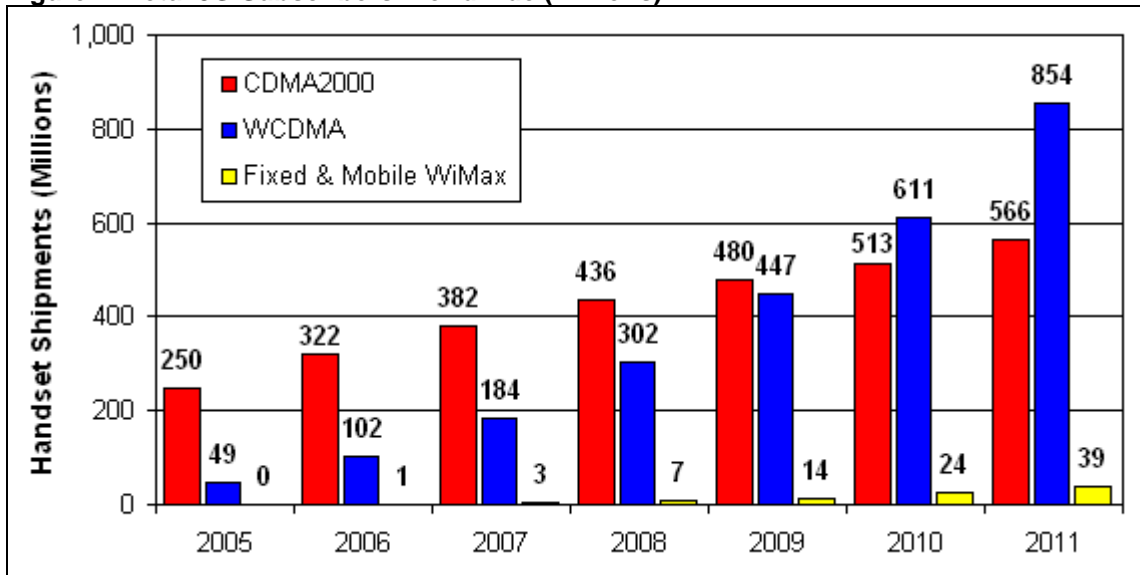
C. Market Potential

The market for in-home base stations, and the subsequent impact on the businesses of mobile network operators, depends on sales of 3G terminals and residential broadband penetration in a given market.

Without doubt, some vendors are extremely enthusiastic about the market potential, with one supplier interviewed for this report predicting an \$8 billion market worldwide by 2012, assuming volume shipments start in 2008 and that 3G penetration rises to 65 percent in developed markets. Others are much more conservative. It's difficult to say if the numbers are encouraging or not.

To take a high-level view of 3G subscriber numbers, around 100 million WCDMA chipsets shipped in 2006, according to Qualcomm, with expectations of 175 million units in 2007. Based on blended analyst estimates, shipments could reach more than 850 million annually by the end of 2011. Assuming even one percent of these subscribers buys a femto cell, this would give an annual market of 8.5 million units. At \$100 per unit, this would provide an annual market of \$850 million in 2011, not including core infrastructure or integration fees.

Figure 1: Total 3G Subscribers Worldwide (millions)



Source: Qualcomm (November 2006) based on blended analyst forecasts

III. Femto Cell Product Requirements

A. Air Interfaces

Most of the momentum behind femto cells comes from WCDMA and CDMA2000 interfaces, with WCDMA seen as the larger opportunity. There are multiple reasons for this:

- Because 3G systems are CDMA-based, femto cells can be deployed in the same frequency bands as macro cells. GSM and WiMax femtos will likely require dedicated spectrum, which can be difficult from a frequency-planning perspective.
- The majority of 3G networks are deployed in higher frequency bands than GSM, which results in worse propagation and therefore poorer in-building penetration. This is compounded by the requirement for stronger signal strength for many 3G applications such as high-speed data.
- In some markets, operators have invested large amounts of money in 3G spectrum and network infrastructure. Femto cells and the associated services represent one way to maximize return from that investment.

Backward compatibility with 2G is seen as important, however. Because GSM is the lowest common denominator – all 3G phones support GSM – it makes sense to consider GSM femtos where home-zone voice tariffs are the primary target application. Such products are easier to implement technically than 3G, since they use the same chipsets as those used in handsets and therefore are cheaper to produce. The drawback is that operators will have to allocate dedicated spectrum, in 200kHz segments, for GSM femtos, which, although possible in some cases, is problematic for heavily loaded networks.

Although it appears impractical to support GSM and WCDMA simultaneously on the same product, some vendors are developing product platforms that can be configured to operate with either air interface. The logic is that a device that can support 3G, which uses 5MHz channels, can be scaled down to support the narrow channel widths of GSM.

In CDMA2000 it is anticipated that femto products will have to support both 1xRTT for voice and EV-DO for data air interfaces. Clearly, it would be simpler to build EV-DO-only femtos and then rely on enhancements coming to market in EV-DO Rev. A to run VOIP services, but with very few compatible handsets in use, support for 1xRTT seems a hard requirement. Accordingly, this will have an effect on time to market and cost of CDMA2000 femtos.

B. Femto Cell Design Challenges

Even though 3G technology is now well understood, there are several technical hurdles to overcome in the implementation of WCDMA or CDMA2000 in femto cells. These include interference and power control, synchronization, and access control.

Interference & Power Control

Although CDMA systems are capable of coping with intra-system interference, the effect of femto cells on the macro network is still a major concern. Because the manual network planning processes used in the macro network cannot scale to support hundreds of thousands of femto cells, these devices must be self-provisioning.

This means femto cells will have to automatically adapt their power output to prevailing macro network radio conditions. This is critical to the performance of both the macro network and the indoor home network. From the macro network point of view the concern is that interference from femto cells will cause outdoor users to drop calls (for example, as you walk by someone's house); this interference can create what is sometimes called a "coverage hole." In other cases, most

likely at edge of a cell where the signal strength is weak, the concern is that macro users will see a stronger signal from a nearby femto cell (at a neighbor's house, for instance, where they don't have access), than from the macro network.

How femtos can meet this plug-and-play requirement and be guaranteed not to adversely affect the macro network represents one of the key technical challenges to system designers and is considered a key point of competitive differentiation. As a result nobody will say exactly how it is done, apart from that the basic methodology for femto cells to "listen" to the surrounding radio frequency (RF) environment to configure itself at switch-on, and then take ongoing readings to adjust itself over time. Several products also use data collected by handsets attached to the femto cell to assess power output requirements.

Synchronization

CDMA base stations have strict synchronization requirements in order for users to handoff between sectors or cells without dropping a connection. In GSM or WCDMA networks the base station can typically reference a network clock via a T1/E1 line. For femto cells backhauled over residential broadband IP links there is no such luxury, and a new synchronization solution is required. Broadly speaking there are three options for deriving a timing reference:

- Eavesdrop on the GSM or WCDMA macro network, which is elegant and has a lot of appeal but requires the femto to be placed where there is macro network coverage and may incur equipment costs if a dedicated GSM receiver is required
- Use a GPS receiver, which adds expense – possibly up to \$15 of equipment costs – and may not work well indoors
- Network-based timing either based on the Internet Engineering Task Force (IETF)'s Network Timing Protocol (NTP) or the Institute of Electrical & Electronics Engineers (IEEE)'s 1588 standard, which look most likely to be used

Access Control

Femto cells can be provisioned for open access, where any subscriber to that network can use the device, or closed access, where only pre-registered users can have access. Control over who accesses a closed network at face value looks quite simple – only those phone numbers registered with the service should be granted access. In reality it's more complex.

The major issue is how to stop handsets not registered to a femto cell from requesting access. This is undesirable because access will not be granted and a number of access requests would require lots of signaling requests to be sent over the home broadband link to the operator's core network. In busy locations this could potentially overwhelm the backhaul or the service provider's Authentication, Authorization, and Accounting architecture.

Proprietary mechanisms to address access control are typically kept secret and in some cases are closely linked to the interference and power-control algorithms discussed above.

C. Collapsed Radio Access Network (RAN) Architecture

Instead of replicating the hierarchical architecture of today's 3G networks, femto cells are sometimes being designed with a flat all-IP architecture in mind. To this end, vendors are integrating functionality from the radio access – radio network controllers (RNCs) – and core network – Serving GPRS Support Node (SGSN) and Gateway GPRS Support Node (GGSN) – into the access point itself. Such designs are sometimes referred to as "collapsed RAN" or "collapsed stack" architectures. The logic behind collapsed architectures looks compelling – after all, why re-create a legacy architecture that is expensive and living on borrowed time? How best to get to this new architecture is wide open for debate, however.

At one end of the spectrum, there's an argument that femto cells should port as directly into the existing network architecture as possible, since this requires minimal additional investment or changes to working practices, and then evolve the products and architectures from there. At the other end, it's argued that deploying the service on a fully collapsed architecture will be far more efficient. Options for integrating femto cells with the core network are discussed in **Section IV**.

D. Form Factors & Price Points

Initial 3G femto cell products are almost certain to be offered as standalone access points and then integrated with home modem or router equipment over time. One advantage of an integrated product is that it will be easier to prioritize voice traffic over the IP backhaul link than if the 3G femto is connected to an existing home router.

Almost regardless of form factor, the evolution of the femto cell market will be determined by the price, flexibility, and size of the components, which go to make up the device's equipment costs in turn will determine the end-user price. Obviously, these devices must be very low cost – ideally as cheap as a WLAN access point.

At \$50 for an 802.11g WiFi router or \$90 for a more advanced Multiple Input, Multiple Output router, it's difficult to see 3G femto cells being competitively priced in the near term. Several vendors claim a price of \$100 per unit can be achieved when or if volume production kicks in (i.e. units of 500,000 or more), with some saying this price point could be reached by the end of 2008. Others are more skeptical.

Unstrung Insider believes a more realistic, yet still aggressive, target is \$200 to \$300 per device by the end of 2008. This would include the cost of the network infrastructure, which as a rough guide would cost around \$40 per femto device using a RAN-based integration, \$25 using Unlicensed Mobile Access (UMA) integration, and \$15 to \$20 using IP Multimedia Subsystem/Session Initiation Protocol (IMS/SIP) integration.

Aside from volume production, two other factors will drive pricing: the capabilities of devices and the integration of discrete components into systems-on-chip style products. In terms of device capability, at the low end, femto cells with support for R99 and basic HSDPA (up to 3.6 Mbit/s) functionality could come in significantly cheaper than more advanced devices that support full-rate HSDPA at 14 Mbit/s and High-Speed Upload Packet Access (HSUPA) at 5.4 Mbit/s and require more expensive components.

At present it is not clear if basic or more advanced products will be preferred by the market, and this uncertainty is causing some system and silicon vendors to delay their product plans while they conduct further market research. This uncertainty, of course, presents an opportunity for the supplier that can deliver advanced performance at low-end price points.

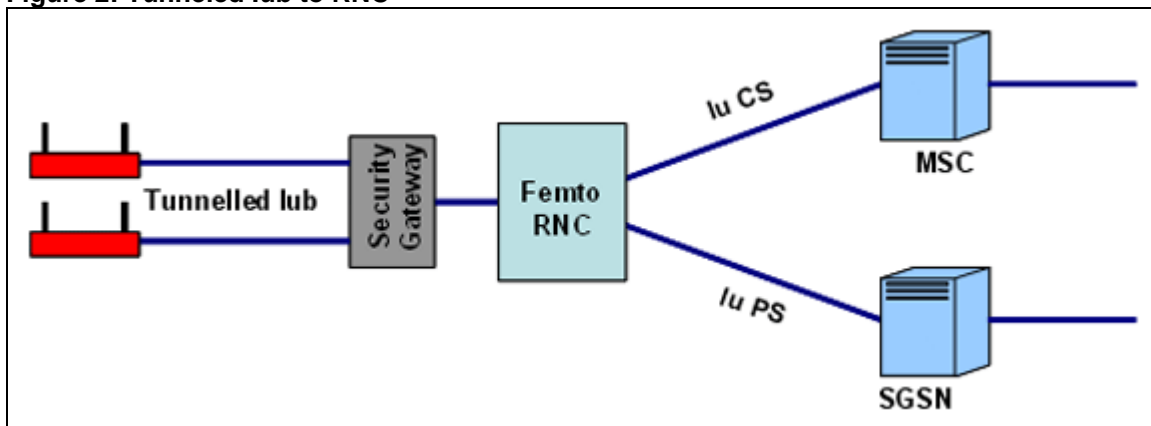
IV. Core Network Integration

The means by which femto cells are to be integrated with the mobile core network is critical for the success of this concept. Several of the proposed architectures roughly mirror the integration mechanisms already adopted for WLAN, while others are closer to the traditional RAN-based architecture. For a more detailed discussion of these architectures, see the previous *Unstrung Insider* report entitled **Mobile Network Security: The Threat of Convergence & IMS** (Vol. 5, No. 5, May 2006).

A. Tunneled Iub to RNC

Perhaps the least disruptive way to integrate femto cells would be use the same mechanism already used for pico cells today, through integration with existing or dedicated RNCs via a tunneled Iub interface, as shown in **Figure 2**.

Figure 2: Tunneled Iub to RNC



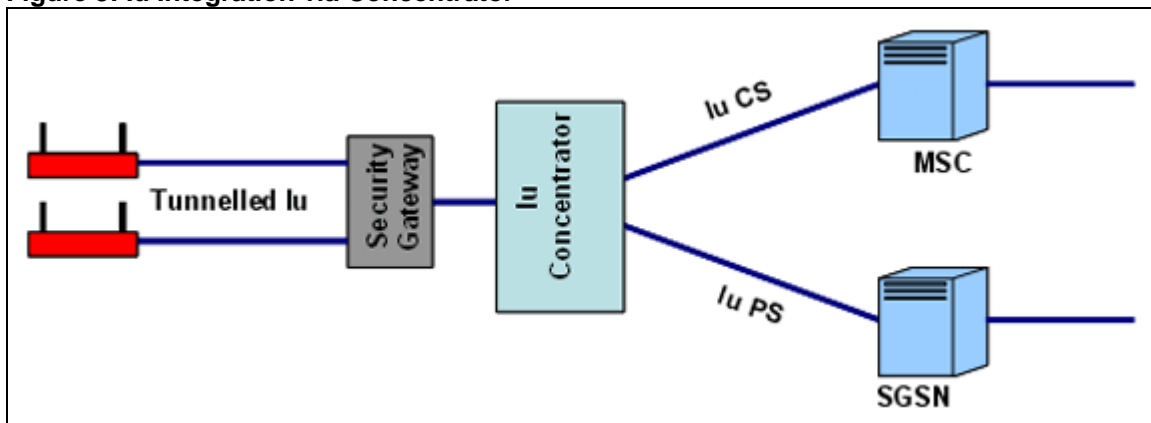
Source: *Unstrung Insider*

The drawbacks of this approach are that it locks the operator into using femto cells and RNCs from a single vendor, and it perpetuates the legacy network architecture.

B. Iub Interface via Concentrator

By integrating the RNC into the femto device, a collapsed RAN architecture can be deployed such that tunneled Iub interfaces from the femto cells can be aggregated by a concentrator device and then ported into the core network, as shown in **Figure 3**.

Figure 3: Iub Integration via Concentrator



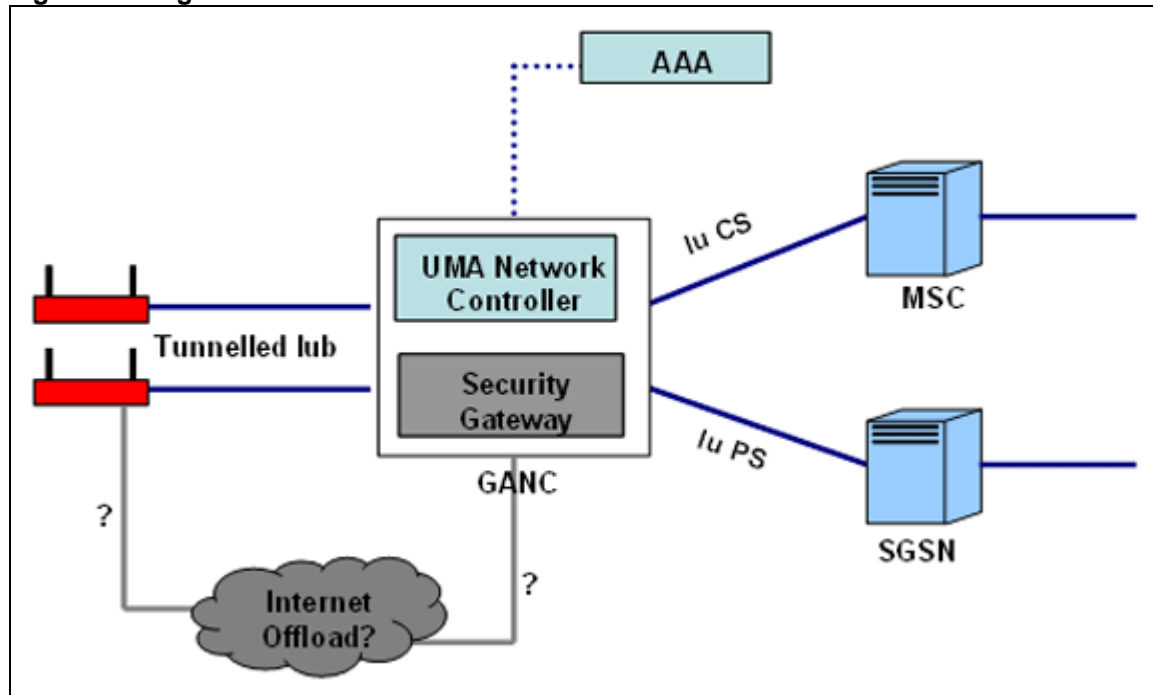
Source: *Unstrung Insider*

The primary drawback of this approach is that it would be difficult to perform call control. Another drawback would be that this architecture is similar to using RNCs, in that additional core network equipment is required.

C. UMA/GAN Architecture

One of the more straightforward approaches to integrating femto cells with the mobile core network would be to use the UMA/Generic Access Network (GAN) architecture, which reuses most of what has been developed for UMA – as shown in **Figure 4**.

Figure 4: Integration With UMA/GAN



Source: *Unstrung Insider*

One drawback of this architecture is that it perpetuates the legacy mobile packet core based on SGSNs and GGSNs, which is expensive and constrains bandwidth. A partial solution to this problem could be to offload Internet traffic before it hits the packet core, either at the Generic Access Network Controller (GANC) or directly from the femto cell itself.

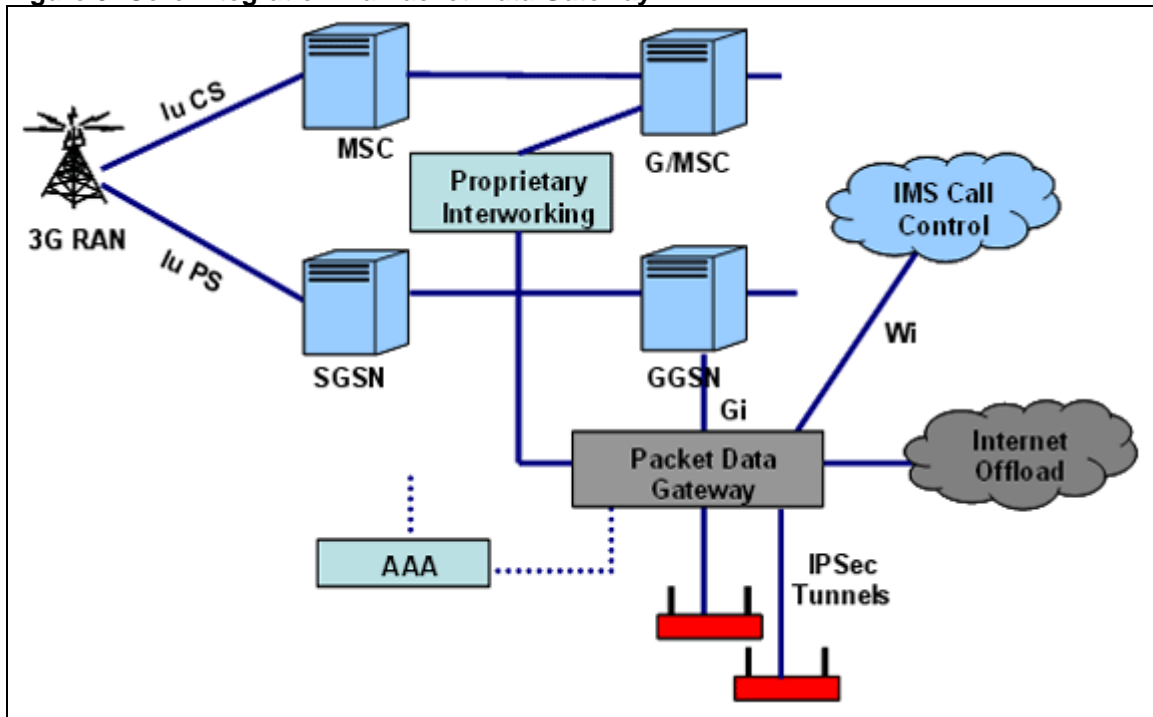
Note also that existing UMA/GAN standards are for GSM only, and that the corresponding specifications for UMTS are only now being worked out by the 3rd Generation Partnership Project (3GPP). Since it should prove relatively simple to complete this work, the standards could be finished by around the end of 2007 or early 2008.

D. SIP-based via Packet Data Gateway (I-WLAN)

Femto cell integration via a packet data gateway (PDG) using SIP-based call control is widely considered the preferred target architecture for femto cell integration, as it aligns with the overall vision of an IMS-based architecture, and is therefore likely to be the cheapest and most future-proof solution over the long term.

The problem with this target architecture is that it is relatively new, with crucial elements such as call control still not adequately standardized. As a result, some vendors are proposing using proprietary signaling gateways to overcome the issue in the short term, while maintaining support for legacy terminals.

Figure 5: Core Integration via Packet Data Gateway



Source: Unstrung Insider

V. Company Profiles

A. Public Mobile Infrastructure Suppliers

Alcatel-Lucent (NYSE/Euronext Paris: ALU)

The merger of Alcatel and Lucent, combined with the acquisition of Nortel's UMTS business, at the end of 2006, created a business unit with several overlapping product lines. In the femto cell market, both Lucent and Nortel had initiatives underway prior to the merger, while Alcatel had been less advanced with its efforts. The net result is that the Lucent and Nortel efforts have been merged, with the original Lucent program appearing to have prevailed over the former Nortel program. The femto cell architecture and product set will retain Lucent's Base Station Router (BSR) branding and use the name "femto BSR."

Femto Product: The original BSR products were targeted at the micro and pico market, which Lucent had identified as segments where it could most effectively use its new BSR architecture to break into the UMTS infrastructure market.

BSRs are based on a collapsed stack architecture where the RNC, SGSN, and GGSN are integrated into the base station itself. The original products, however, are oversized for the femto market – the pico product weighed about 4 kg – and new, smaller devices specifically targeted at residential users are under development. In the short term this will be a digital signal processing (DSP)-based product, although the firm says it is evaluating options for more integrated, off-the-shelf, baseband hardware that could drive equipment costs down over the medium term.

Many of the BSR features developed by Lucent's Bell Labs division, such as self-configuration and automatic power control, are said to be portable to femto form factor devices and are based on algorithms already field tested in existing BSR deployments.

Architecture: The BSR architecture is based on collapsing the key mobile network functions into the base station node. This concept represents the leading edge of commercial system design today and, as such, could be important to operators looking to accelerate the move to all-IP mobile networks. In addition to the femto cell, the BSR architecture comprises:

- A Home Agent to support IP mobility across access domains
- A Home Unit Server to configure femto cells when they register on the network that supports up to 500,000 femto BSRs
- A BSR Voice Gateway (BVG), which acts a type of media gateway and supports up to 50,000 femto BSRs
- A BSR Signaling Gateway (BSG), which interfaces to Signaling System 7 (SS7) signaling environments and supports up to 50,000 femto BSRs

The entire femto architecture will be demonstrated at the 3GSM trade show in February 2007, with a view to starting operator field trials by the end of the year and introducing commercial products in early 2008.

Unstrung Insider Verdict: It's a bold move by Alcatel-Lucent to go directly to the collapsed, flat IP architecture and drop much of the work the former Nortel division had been doing on an RNC-based architecture. The upside is that this is probably the most field-ready, IP-based architecture on the market today, and it is well aligned with the desired target architecture of many carriers in the longer term.

The downside of this strategy could prove to be time to market, since many operators are uncomfortable moving to all-IP, SIP-based solutions until features such as Voice Call Continuity

are adequately standardized by 3GPP, while the RNC-based architecture and femto cells from Nortel were likely closer to commercial readiness.

Andrew Corp. (Nasdaq: ANDW)

Andrew is best known as a supplier of base station subsystems and in-building coverage systems. However, it also has a small play in base station equipment through the acquisition of Kevab, a startup from Sweden focused on micro and pico Node B products. The micro Node B is a two-carrier 10W design, while the pico Node B is offered in a single-carrier 300mw design. Both pico and micro products are sold via original equipment manufacturer (OEM) partners including Huawei, Nokia, Nortel (prior to the acquisition by Alcatel-Lucent), ZTE, and others. These partners then integrate the base stations with their own RNCs.

These products are likely to ship in volumes of tens of thousands of units in 2007, with 100,000 units possible if the things go extremely well for the company this year. This would make Andrew one of the largest suppliers of small Node Bs worldwide. With a price tag of approximately €3,000 per unit for the smallest pico cell (supporting 20 simultaneous users), these products are inappropriate for the home market.

Femto Product: Andrew is evaluating the femto market potential and looking to identify product requirements. It has identified two possible product types and has largely completed the feasibility and design work. One option under evaluation is a "Femto Pro" style product, which would have capacity for 15 to 20 voice users with 100mw power output, and would be targeted at the small business market. This would cost in the region of €800 to €1,000 in volume.

Another option is a "Femto Home" product that would support three to six equivalent voice channels, with 30mw power output, and would support High-Speed Packet Access (HSPA). The vendor believes a \$200 price point is achievable in high volumes (between half a million and a million units of production). However, it cautions that silicon suppliers are not yet capable of delivering chipsets that will deliver the required price/performance. The firm believes it will be sometime towards the end of 2008 or in 2009 before silicon really meets market requirements.

Architecture: To a large extent the femto architecture would likely be determined by the design choices of Andrew's OEM partners.

Unstrung Insider Verdict: Andrew is one of the largest suppliers of pico cell equipment worldwide, but freely admits the market hasn't ramped as fast as it would have liked. As a result, its diligent and cautious evaluation of the femto cell market is understandable. This, combined with conditions in its main subsystems and components markets, makes it fairly obvious that the company cannot afford to take risks in the same way as a venture-funded start-up can. Yet this procrastination could end-up costing Andrew since many of its natural, big-vendor OEM partners are already shopping for femto technology partners.

Ericsson AB (Nasdaq: ERIC)

As the world's leading provider of cellular infrastructure and with growing ambition in wireline access and what it calls "multimedia networking," the femto cell concept looks an ideal fit for Ericsson. Indeed, the company has long been able to point to prototype femto designs and limited edition production devices as evidence of its capability.

Femto Product: Ericsson has both GSM and WCDMA femto initiatives underway. The GSM product, to be announced in February 2007, is an integrated home gateway combining a GSM base station, a WiFi access point, a home router, and a DSL modem. The GSM part of this product uses the same chipset (with some additional software) as is used in Sony Ericsson mobile phones and therefore adds very little additional cost to the home gateway.

By integrating the GSM femto device into the home gateway it is possible to prioritize mobile voice traffic over the backhaul link. In this way the operator has greater control over call quality. How important this feature will be is yet to be seen. VOIP calls without prioritization from the computer today typically work well enough for most home users, but this apparent satisfaction may be the result of different set of user expectations. Services offered over low-speed DSL, many of which have only a 128kbit/s uplink, could particularly benefit from prioritized VOIP, believes Ericsson.

Ericsson also has a 3G femto device under development. The product based on commercial DSP and Field-Programmable Gate Array (FPGA) silicon will support 7.2Mbit/s HSDPA and will initially be offered as a standalone 3G access point that plugs into a home router. Per market requirements, the device will be self-configuring and have automated power control. Ericsson believes it has an industry-leading solution to this problem and claims that it can reduce the interference zone around a 3G femto to just one meter.

Nevertheless, the firm believes the potential problems of femto interference with the macro network have been underestimated by some competitors. It is advising operators to initially deploy 3G femtos on a different RF carrier to the macro network if possible. The logic is that this removes the risk of interference during initial deployment. Then, when the operator comes to build out the macro network on that second carrier, in the event that there is any interference users on the macro network can fall back to the initial carrier.

The 3G femto is currently in prototype form, with Ericsson targeting operator trials in mid 2007 and production devices in early 2008.

Architecture: The GSM femto cell will integrate into the core network via a dedicated femto base station controller (BSC), which will act as a concentrator for a large number of femto devices. This is in line with most GSM pico implementations today. The 3G femto will follow a similar architecture and use a dedicated, low-cost RNC for femto aggregation. Ericsson believes this is the most reliable and workable way to integrate femtos into the core network in the short term. This "lub over IP" approach may have some advantages, including synchronization, but because lub is so low in the protocol stack this potentially limits the flexibility of the architecture.

Unstrung Insider Verdict: Several sources in the operator and vendor community have indicated that Ericsson's 3G femto development program lags the market leaders, expressing surprise at this given the firm's leadership in macro 3G equipment. One reason why Ericsson, like other large vendors, may have been cautious about this market is that even optimistic sales projections would barely make a meaningful contribution to the firm's revenues. Another reason is that femtos will likely attack its core revenue base in macro infrastructure. It's difficult for any successful company to make an early decision to cannibalize its own revenues. Of course, it would be perilous to underestimate Ericsson. As the company's interest in in-home multimedia services grows, this type of femto product could become an important competitive advantage.

Motorola Inc. (NYSE: MOT)

Motorola has not been public about its plans for the 3G femto market, although its enthusiasm for FMC is well known from its advocacy of UMA. In theory, this should translate into support for femto cells.

Femto Product: In early 2006 Motorola introduced its AXPT 3G access point. The device is targeted at enterprise applications and offered 3.6 Mbit/s HSDPA when demonstrated in February 2006. By October 2006 the product was still under trial, and the company has not provided an update on the status of this product since. Based on a collapsed architecture, the AXPT integrates the base station, RNC, and SGSN into a single node. With up to 20 simultaneous users and weighing in at 10 kg, the AXPT is oversized for the residential market.

Architecture: The AXPT connects to an AXPT Concentrator in the operator's network, which in turn connects to an mobile switching center (MSC) and packet core. How exactly this core integration works in practice is unclear and several sources outside the company claim there are significant integration hurdles to overcome with this architecture.

Unstrung Insider Verdict: Our impression is that Motorola will not persevere with attempts to downsize the AXPT for femto applications, and we understand that the firm is actively evaluating OEM possibilities. This has not been confirmed by the company. Looked at from the perspective of Motorola as a whole, especially the Connected Home, Devices, and Networks divisions, femto cells look like an attractive and complementary market.

NEC Corp. (Nasdaq: NIPNY; Tokyo: 6701)

In partnership with Siemens, NEC has established a reasonable position in WCDMA infrastructure and has won business directly in Europe with 3 Group companies and in Japan with NTT DoCoMo. With the Siemens joint venture under threat from the Nokia-Siemens merger, NEC is looking at how to expand under its own initiative and sees 3G femto cells as an opportunity to break into accounts where it currently has no presence.

Femto Product: NEC has revealed little about its product plans except to say that details will be announced shortly. What it will say is that it is working on a collapsed-stack architecture that will integrate RNC and/or SGSN/GGSN functionality.

Architecture: The collapsed stack overlay architecture is critical if NEC is to win business with operators where it currently has no presence. The firm will not reveal details about its preferred integration method, but it does say that it has its own PDG that it will use for this purpose. This suggests either a UMA-based architecture or IMS/SIP.

Unstrung Insider Verdict: All signs point to NEC cutting an OEM deal with a startup supplier. 3Way Networks or Ubiquisys would be the prime suspects. NEC appears seriously committed to the femto concept, and working with a startup could be the winning combination of innovative technology, big-company backing, and a hunger to win business from incumbent 3G vendors.

Nokia Siemens Networks

Although **Nokia Corp. (NYSE: NOK)** says it is "closely following the 3G home access market developments," with its Networks division and **Siemens AG (NYSE: SI; Frankfurt: SIE)**'s communications division currently involved in a merger process, it appears that decisions on how to attack the femto cell market are on the back burner.

Femto Product: Both companies have some experience of this market through OEM agreements with privately held, specialist pico cell vendors. Siemens has a relatively longstanding relationship with ip.access for GSM, while Nokia recently announced a relationship with RadioFrame Networks.

Architecture: Nokia believes that it is important to avoid technology fragmentation in the way femtos are integrated at the core. "Further technical optimization and cost efficiency enhancements are achievable through specification improvements within 3GPP in view of 3G home access for example in the areas of access control, mobility, synchronization, and operation and maintenance," says the firm in a written response to questions.

Unstrung Insider Verdict: Based on industry sources, it appears that what was Nokia Networks will lead this initiative in the merged company. Several sources confirm that Nokia is currently evaluating OEM suppliers. We believe RadioFrame is probably best positioned here, but providers such as 3Way, ip.access, and Ubiquisys also have a shot.

Other Vendors

There are several large mobile infrastructure suppliers that have not yet shown their hand in the femto market. **Samsung Electronics Co. Ltd. (Korea: SEC)**, for example, told *Unstrung Insider* that it has a development program underway for CDMA2000, but it has not yet provided further details. Sources outside Samsung believe it may have a chipset under development and would be looking to support both 1xRTT and EV-DO in the same femto cell; some sources, however, suggest that an in-house chipset could simply be a gambit to extract better pricing from Qualcomm on base station modems.

Other vendors yet to declare include **Fujitsu Ltd. (OTC: FJTSY)**; **Huawei Technologies Co. Ltd.**; **LG Electronics Inc. (London: LGLD; Korea: 6657.KS)**; and **ZTE Corp. (Shenzhen: 000063; Hong Kong: 0763)**. Sources indicate these companies are in the early stages of evaluating OEM possibilities.

B. Private Mobile Infrastructure Vendors

3Way Networks Ltd.

Founded in August 2004 by former technology and sales executives at pico cell maker ip.access, 3Way employs 15 people and was profitable on revenues of £1 million (\$2 million) in 2006. The company is self-financed to date, with some support from high-net worth individuals. It is considering outside investment to expand, as it plans to grow to 30 or 40 employees during 2007.

3Way is active in three main markets today: mobile operators, military, and transportation, with the latter two markets accounting for nearly all its revenue. It sees mobile operators as the largest market opportunity by far, however. 3Way's business model calls for the firm to license its software to larger OEMs or to sell femto cell line cards to third-party manufacturers; it does not anticipate selling direct to operators.

Femto Product: 3Way offers a 3G femto cell on a printed circuit board, which uses a mixture of FPGA and DSP silicon and can be used by OEMs to create their own products. It also offers a Layer 1-7 software stack that it will license on a per-unit basis to OEMs wanting to use their own hardware, and it will port the software to this hardware for a one-time fee. This focus on a complete software stack is unusual, in that an OEM might normally buy silicon with Layer 1-2 capabilities and then develop the rest of the stack itself. 3Way claims the advantage of its approach is that the entire stack (not just the Layer 1-2 modem) is optimized for small form factor, low-cost hardware. It should also speed time to market for its OEM partners, although the downside is that it will be harder to differentiate against other 3Way customers. For specialist military and transportation markets, 3Way offers ready-made femto and pico products, since volumes are lower in these markets and pricing supports better margins.

Architecture: 3Way offers a collapsed stack architecture and was founded on the principle of SIP/IMS-based integration with the core network. Given the slow pace of IMS's adoption and standardization IMS, in the near term 3Way expects the focus to be on integration via the lu interface to the SGSN, with voice integration and call control handled by a SIP Interworking Function, which has been developed in association with its partner Telesoft Technologies.

Unstrung Insider Verdict: 3Way clearly has an interesting approach, although it needs a major customer or OEM partner reference to lend weight to its claims. Assuming its claims ring true, however, it could make a good fit for a silicon company looking to move up the value chain and provide OEMs with a more complete solution.

Airvana Inc.

Airvana declined requests to be interviewed for this report, but several sources say the firm is working on a CDMA2000 femto product and perhaps even a WCDMA product. The move in

femto cells would make sense for Airvana; With a successful business selling EV-DO line cards and software to OEM partners, the firm has the resources to expand into new markets. It could also be motivated by a desire to IPO, which would be helped if it could show it operates in multiple growth segments. It would also help to reduce reliance on Nortel, its largest customer, as some rumors say Nortel is working on its own EV-DO line cards to recapture some of this margin.

A femto product would fit well with two of Airvana's other recent business development initiatives. Its air-to-ground communications systems explicitly require a femto- or pico-type product on board aircraft, while its Universal Access Gateway product can be positioned as a PDG for secure IP access to the mobile core. It's not clear if, or how, Airvana would support the 1xRTT flavor of CDMA since it has so far not played in this market.

AirWalk Communications Inc.

AirWalk is based in Texas and was formed in 2003. In October 2006 the firm closed a \$16 million Series B financing round led by Sevin Rosen Funds, bringing total investment to \$23 million. It currently employs around 30 people, but has plans to double its headcount in 2007.

Femto Product: The firm has confirmed that it is actively working on femto products supporting both 1xRTT and EV-DO. It won't reveal many details about its product plans except to say that its devices will use separate RF chains for the RTT and EV-DO but a single digital baseband processing unit. In this way it can reduce costs and differentiate from vendors that must integrate two base stations into one box to deliver a femto cell capable of both 1xRTT and EV-DO.

Architecture: AirWalk was one of the first companies to adopt a collapsed RAN architecture for its base station products and has always focused on backhaul over IP. Given that it has already developed, tested, and sold equipment that integrates BSC and RNC functionality into the base station, it looks well positioned for the femto market.

Unstrung Insider Verdict: AirWalk looks the most innovative company in the CDMA2000 femto market and has a great opportunity to establish itself through this application. In the absence of a low-cost CDMA base station modem supplier, however, it faces a challenge in getting to the low price points the market needs.

ip.access Ltd.

U.K.-based ip.access is a pioneer in the femto and pico cell market. It was founded on the principle of using IP access networks to backhaul traffic from very small base stations in order to extend operator coverage at low cost. The firm was set up in 1999 as a spinoff from U.K. handset technology company TTPCom, which was the majority owner until ip.access raised £8.5 million (\$17 million) of outside financing in March 2006. When Motorola acquired TTPCom in June of 2006, Motorola's venture arm became ip.access's largest shareholder, with a roughly 40 percent stake. The company is now working on a financing deal that will reduce Motorola's holdings.

The firm has lots of announced and unannounced customers – of which T-Mobile has the highest profile – and an OEM agreement with Siemens. It employs 100 people and had revenues of £8 million (\$16 million) in its last financial year, with a target to double sales in the current year.

Femto Product: ip.access announced its 3G access point in September 2006. The device, based on picoChip silicon and software, offers HSDPA and will be used in customer trials from mid 2007 and will be available commercially from early 2008. Per market requirements, it supports auto-configuration and automatic power management, and it will offer seamless handover with 3G macro networks.

Although ip.access does not use a fully collapsed architecture, much of the RNC functionality is integrated into the femto cell. In the GSM segment, the firm offers a 200mw NanoBTS pico cell

product that sells for €1,000 to €2,000 and is targeted at the small business market and locations such as coffee shops or public transport hubs.

Architecture: For GSM, ip.access offers a RAN-based architecture with dedicated BSCs and management system. One strength of the product line is that the BSC has been widely tested against MSCs and SGSNs from several major equipment suppliers.

For 3G integration the firm is proposing what it calls a "split-lub" approach that sees much of the RNC functionality integrated within the femto cell and allows local offload for Internet traffic yet maintains the call control model provided by the existing core network. How exactly this works is unclear to *Unstrung Insider* at this time, but ip.access claims to have learnt from years of experience trying to integrate with existing networks. It says it will make this modified interface available to third parties in the near future.

The firm also proposes using secure Real-time Transport Protocol (RTP) and Secure Sockets Layer (SSL) security instead of IPSec tunnels to encrypt traffic over the Internet link. It says this had proved the most workable solution over its years of experience with the problem.

Unstrung Insider Verdict: Given its long association with this market, its ongoing revenue stream, and its close, long-term relationships with mobile operators, ip.access should be ideally positioned for entry into the emerging femto cell market. It is one of the few vendors with experience on real-world deployment in this sector.

picoChip Designs Ltd.

picoChip was founded in the U.K. in 2002 to commercialize a multicore processor design said to be well suited to wireless signal processing. The firm has now raised \$40.5 million in funding. The pitch is that this multicore processor is not only less expensive than a DSP with comparable performance, but also that it ships with production quality baseband software and thus can drastically reduce time to market for equipment manufacturers. This is proving attractive in the WiMax market, where picoChip has a number of major customers and partnerships and looks well suited to the 3G femto market.

Femto Product: The basic femto product is a programmable processor complete with WCDMA baseband software and an embedded microprocessor. The single-chip architecture contrasts with designs based on FGPA and DSPs that typically have higher component counts and equipment costs. It is also said to be particularly suitable for collapsed-stack femto cells, since the RNC, SGSN, and GGSN functions can be done on the chip.

Announced customers for its 3G femto product are ip.access and Ubiquisys. picoChip is also active in the WiMax femto market and in June 2006 it announced a partnership with Korea Telecom to co-develop a WiMax femto cell.

Unstrung Insider Verdict: picoChip is the standout silicon play in the femto cell market. It is often name-checked by its direct competitors, potential customers currently using other silicon suppliers, and mobile network operators, many of which have positive things to say about the company's products and innovative technology. The company has yet to snag, or at least has yet to announce, a big-name customer in the 3G market, but there's every chance that one of its smaller customers will end up as a technology partner to a major infrastructure supplier or consumer electronics vendor.

RadioFrame Networks Inc.

Founded in 1999, RadioFrame is emerging as a success story in the in-building wireless market. It had revenues of \$80 million in 2006 and has a headcount of 220. Much of its success to date has come from supplying Sprint/Nextel with indoor iDEN products backhauled over IP.

While Sprint/Nextel has been clear that it intends to continue to invest in the iDEN network in the medium term, it would seem logical for RadioFrame to also look at other long-term growth markets. This would especially help perception of the company when it plans to IPO. In April 2006 the firm announced a reseller and distribution agreement with Nokia Networks for its S-Series GSM/EDGE pico cells. Potentially this could carry over into the 3G femto market, although neither party has discussed this publicly.

Femto Product: Apart from the iDEN equipment, the key product on the market today from a femto cell perspective is the single-carrier S-Series GSM/EDGE device. Although this is more of a pico cell than a femto cell, it provides some clues about the direction it will take for 3G femtos.

Specifically, the use of an Abis-over-IP interface between the GSM base station and the core network points to the use of an equivalent RAN-based architecture and the use of lub over IP for 3G. One reason for this is that RadioFrame believes there is a lot of unused capacity in deployed RNCs and that it makes sense to take advantage of this. Another reason is that the lub interface aligns with the requirements of potential OEM partners looking to integrate femto cells with their own infrastructures. RadioFrame doesn't discount the value of a collapsed RAN design, and says this will likely be a second-phase feature.

Architecture: The GSM products integrate into the network via a concentrator that terminates IPsec tunnels and aggregates traffic prior to forwarding it to third-party BSCs via the Abis interface. Although the 3G femto product and architecture is still unannounced, it looks set to follow the same model using an lub interface.

Unstrung Insider Verdict: RadioFrame looks to have good momentum and upcoming (and yet unannounced) products look likely to make it extremely competitive in the 3G femto market. While it has lots of experience to back its decision to go with RAN-based core network integration, this could be a weak spot if collapsed stack femto vendor solutions prove successful quickly enough.

Ubiquisys Ltd.

Corporate: Formed in 2004 and based in the U.K., Ubiquisys has raised \$12 million in funding. Headcount is now at 50, up from just 12 six months ago. It has announced a series of business development deals including a tie-up with a leading European home gateway supplier (possibly Thomson, although this is unconfirmed) and with a large cellular equipment vendor (possibly NEC, although this is also unconfirmed). In anticipation of shipping product, Ubiquisys also announced a manufacturing deal with Sony Europe in November 2006.

Femto Product: Ubiquisys's ZoneGate femto cell was demonstrated in public for the first time in February 2006 and is currently being readied for operator trials in anticipation of a commercial launch in early 2008. As with most products in the report, it is said to support the required self-install and automatic power control features.

The baseband and microprocessor functions are handled by picoChip's pico-array product and thus support HSDPA with an upgrade path to HSUPA. The concept is based entirely around the collapsed stack architecture, which is offered in both a collapsed RAN version for a UMA-style architecture and a version with fully integrated SGSN/GGSN for IMS/SIP integration.

Architecture: The firm has identified UMA and IMS/SIP as the most attractive architectures for core network integration. On the UMA side it has partnered with Kineto Wireless, while on the IMS/SIP side it has announced a partnership with Tatar Systems. The firm does not anticipate ever needing an "lub over IP"-style interface.

Unstrung Insider Verdict: No question, Ubiquisys is a hot startup. Despite its small size, it is one of the vendors setting the agenda in terms of femto cell product design and capability. Top-tier investors – e.g. Accel Partners and Atlas Venture – give it instant credibility.

Startup Corporate Summary

The table below summarizes key corporate and funding information for the privately -held vendors profiled above.

Figure 6: Privately Held Femto Cell Equipment Vendors

Vendor	Founded; Location	Funding to Date	Value & Date of Last Round	Lead Investors	Head- count	Revenues
3Way Networks	2004; Cambridge, U.K.	Mostly self- financed	N/A	High net-worth individuals	15	\$2M
AirWalk	2003; Dallas, Texas	\$23M	\$16M Series B, October 2006	Sevin Rosen Funds, TL Ventures, Alta Berkeley, Duchossois Technology Partners	30	Not disclosed
ip.access	1999; Cambridge, U.K.	\$17M	\$17M Series A, March 2006	Intel Capital, Rothschild & Cie Gestion, Scottish Equity Partners	100	\$16M
picoChip Designs	2002; Bath, U.K..	\$41.5M	\$21M Series C, June 2005 (plus add-on in February 2006)	AT&T, Atlas Venture, Intel Capital, Pond Venture Partners, Rothschild, Scottish Equity Partners	>50	Not disclosed
Radio- Frame Networks	1999; Redmond, Wash.	\$78M	\$41M Series E, 1Q06	COM Investments, EVP/Eastven, Ignition Partners, Innovacom, Samsung Ventures, Sprint Nextel, VantagePoint Venture Partners	220	\$80M
Ubiquisys	2004; Swindon, U.K..	\$12M (plus seed funding)	\$12M Series A, September 2006	Accel Partners, Advent Venture Partners, Atlas Venture	50	Not disclosed

Source: Unstrung Insider

Research Analyst: Gabriel Brown (brown@unstrung.com)

Editor: Richard Martin (martin@unstrung.com)

Support: www.unstrung.com/insider (insider@unstrung.com)

SUBSCRIBER LICENSE AGREEMENT

Any Unstrung Insider report ("Report") and the information therein are the property of or licensed to Light Reading Inc. ("Light Reading") and permission to use the same is granted to annual or single-report subscribers ("Subscribers") under the terms of this Subscriber License Agreement ("Agreement") which may be amended from time to time without notice. When requesting a Report, Subscriber acknowledges that it is bound by the terms and conditions of this Agreement and any amendments thereto. Light Reading therefore recommends that you review this page for amendments to this Agreement prior to requesting any additional Reports.

SUBSCRIPTION RENEWAL

For convenience, subscriptions purchased by credit card will be auto-renewed at the end of the subscription term. Prior to that auto-renewal you will receive a notice that will include instructions for updating your subscription or payment information and for opting out of the auto-renewal process.

OWNERSHIP RIGHTS

All Reports are owned by Light Reading and protected by United States Copyright and international copyright/intellectual property laws under applicable treaties and/or conventions. Subscriber agrees not to export any Report into a country that does not have copyright/intellectual property laws that will protect Light Reading's rights therein.

GRANT OF LICENSE RIGHTS

Light Reading hereby grants Subscriber a personal, non-exclusive, non-refundable, non-transferable license to use the Report for research purposes only pursuant to the terms and conditions of this Agreement. Light Reading retains exclusive and sole ownership of each Report disseminated under this Agreement. Subscriber agrees not to permit any unauthorized use, reproduction, distribution, publication or electronic transmission of any Report or the information/forecasts therein without the express written permission of Light Reading. Subscribers purchasing site licenses may make a Report available to other persons from their organization at the specific physical site covered by the agreement, but are prohibited from distributing the report to people outside the organization, or to other sites within the organization. Enterprise Level Subscribers, however, may make a Report available for access on computer intranets or closed computer systems for internal use under their service agreements with Light Reading.

DISCLAIMER OF WARRANTY AND LIABILITY

Light Reading has used its best efforts in collecting and preparing each Report.

LIGHT READING, ITS EMPLOYEES, AFFILIATES, AGENTS, AND LICENSORS DO NOT WARRANT THE ACCURACY, COMPLETENESS, CURRENTNESS, NONINFRINGEMENT, MERCHANTABILITY, OR FITNESS FOR A PARTICULAR PURPOSE OF ANY REPORTS COVERED BY THIS AGREEMENT. LIGHT READING, ITS EMPLOYEES, AFFILIATES, AGENTS, OR LICENSORS SHALL NOT BE LIABLE TO SUBSCRIBER OR ANY THIRD PARTY FOR LOSSES OR INJURY CAUSED IN WHOLE OR PART BY OUR NEGLIGENCE OR CONTINGENCIES BEYOND LIGHT READING'S CONTROL IN COMPILING, PREPARING OR DISSEMINATING ANY REPORT OR FOR ANY DECISION MADE OR ACTION TAKEN BY SUBSCRIBER OR ANY THIRD PARTY IN RELIANCE ON SUCH INFORMATION OR FOR ANY CONSEQUENTIAL, SPECIAL, INDIRECT OR SIMILAR DAMAGES, EVEN IF LIGHT READING WAS ADVISED OF THE POSSIBILITY OF THE SAME. SUBSCRIBER AGREES THAT THE LIABILITY OF LIGHT READING, ITS EMPLOYEES, AFFILIATES, AGENTS AND LICENSORS, IF ANY, ARISING OUT OF ANY KIND OF LEGAL CLAIM (WHETHER IN CONTRACT, TORT OR OTHERWISE) IN CONNECTION WITH ITS GOODS/SERVICES UNDER THIS AGREEMENT SHALL NOT EXCEED THE AMOUNT YOU PAID TO LIGHT READING FOR USE OF THE REPORT IN QUESTION.