

Enterprise



Running for Coverage: A Review of Femtocells

Peter Thornycroft

Femtocells and Wi-Fi

Femtocells are short-range radios used to extend the cellular network into homes and office buildings. While there is enormous enthusiasm over their prospects, deployment is still at a very early stage. Many operators are evaluating femtocells in the lab, several are in early trials but only a handful are currently offering commercially available femtocell service to their customers. While the potential benefits have been comprehensively promoted, the technology is not yet proven, and the use cases and economics are not well-understood.

This note offers a Wi-Fi infrastructure vendor's view of femtocells. While femtocells differ from Wi-Fi access points in some ways, they seek to solve many of the same problems and are often considered to be competitive solutions. Thus a Wi-Fi viewpoint will be informed by knowledge of many key issues, but with a detachment not shared by many in the cellular infrastructure business. At least, that is our hope.

This note offers a comprehensive but swift survey of market requirements and state-of-the-art technology. It probes the claimed benefits to both operators and consumers and suggests how fast the market may develop. Following this, femtocells and Wi-Fi access points are compared and contrasted, and the final section identifies how the two technologies may coexist in the future home. The scope is mainly on the residential customer, but many of the issues are applicable to enterprise wireless strategies.

Femtocell technology

A 'femtocell' is a 'mini base station' including a radio unit like that in a cell tower for a mobile operator's network. It is designed to provide short-range coverage, ideally extending through a house or apartment but not radiating much outside that area. It is small, about the size and shape of a Wi-Fi access point, and is designed for self-installation by the consumer. An Ethernet connection allows the femtocell to use a DSL or cable modem to backhaul voice and data calls across the consumer's Internet connection to the cellular operator's core network. Thus the femtocell allows the mobile operator to extend its mobile network into the home by using the consumer's Internet connection.

The most important reason to deploy a femtocell is to compensate for poor cellular coverage. Mobile operators themselves estimate that perhaps 10% of subscribers don't get good cellular coverage at home, and since over 70% of U.S. households now have a broadband connection, femtocells are well-positioned to fill that gap. Femtocells may be used in this way to fill gaps in the macro cellular network, but some vendors suggest that the technology will become so inexpensive that next-generation mobile networks will be built around thousands or millions of femtocells, with only a few macro cells to cover outdoor areas. We will examine some proposals later in this note.

The radio in the femtocell is controlled by the mobile operator's core network, and it operates with standard mobile phones with no special modifications. When a roaming subscriber arrives home, their phone will sense poor macrocell coverage and automatically hand over to the femtocell, passing across calls in progress in similar fashion to macrocell handovers.

Current status of femtocell technology

A myriad of issues affect femtocells at this stage of their evolution:

All operators require zero-touch installation, so naturally the equipment vendors claim to comply, no matter what the actual situation. In practice, close-to-zero-touch installation should not be so hard to achieve. The buying process will see the consumer pick out a femtocell in a shop, take it home, power up and connect it to the Internet, in this respect similar to a Wi-Fi access point. However, at that point the femtocell must seek out and connect to the operator's core network, identify itself and its location, report its neighboring macrocells and decide the RF channel it should operate on. In turn, the network must identify the new subscribers this new femtocell is meant to serve. As with all service provider equipment, these provisioning steps must scale to thousands of new femtocells installed per day, with minimal calls to customer service and even fewer technician dispatches: zero-touch installation with zero tolerance for errors.

The femtocell's location must be determined and reported to the operator's network. The obvious reason for this is to ensure emergency calls are directed to the correct dispatch center (known as a public safety answering point or PSAP in the U.S.) and comply with U.S. E911 regulations by automatically identifying the street address of the caller. This is surprisingly difficult to achieve. GPS positioning is universal and accurate, but notoriously unavailable when under a roof, the natural habitat of the femtocell. Triangulation on the macro network is already proven, but what if the femtocell were to be placed in an area with no macro network coverage, as presumably many will be? Another potential solution identifies the location by the IP address of the Internet connection, but this is not completely reliable, except perhaps for combined fixed-mobile operators who control the whole Internet chain. The method most likely to avoid lawsuits when calls go astray is perhaps to ask the femtocell customer for a home address at point-of-sale, but as a despondent planner recently remarked, femtocells will have a tendency to move over time.

Location is also important to determine what RF channel and power settings the femtocell should use, to fit into the macro network and avoid interference. The U.S. licensing plan is administered by the Federal Communications Commission (FCC) on the basis of small areas in the order of 50 miles across. Each area has a number of channels available, and these are licensed by different operators, so the result is a patchwork: a particular operator may have different channels, even different spectrum bands in adjacent geographic areas. The use of licensed frequencies by mobile operators usually guarantees immunity from interference from other radio transmitters on the same channel. The first consideration must be to prevent the femtocell from transmitting on a channel licensed by a competing Operator, which could lead to considerable strife. To ensure this, the operator must know the femtocell's location to ensure it selects only from channels licensed to that operator in that area. Once the legal channel range is established, a particular channel must be chosen for best fit with the macrocell network, as a femtocell on the same channel as an overlapping macrocell will lead to interference. After emergency call location, this is the second reason the femtocell's location must be accurately known.

The location problem becomes more difficult because femtocells will travel with their owners, despite operators discouraging the practice. At one extreme, moving a femtocell across international boundaries will almost certainly violate the licensing regime (contrasting with a Wi-Fi access point, which would be compliant with local RF regulations almost everywhere in the world). But even locally, there will be potential disruption to the operator's channel plan and business plan. Femtocell deployments further the mobile operator's advance in fixed-mobile substitution, the phenomenon where increasing numbers of households discontinue their fixed phone line and use the mobile network exclusively for their voice

communications. The optimum business plan would be to adjust the charges for calls made from the home so the cost to the consumer is attractive compared to a fixed line alternative. But, ever cautious over revenue leakage, operators are concerned that consumers will become over-exuberant, installing femtocells in offices and other locations where they should be paying full price for calls.

Operators are divided about open or closed usage models for femtocells. An open installation accepts calls from any subscriber to the network, which has the potential to overload a subscriber's Internet connection with public freeloaders, and to leak revenue from the operator, depending on the tariff. Alternatively, if a femtocell is to be configured for use of only one subscriber or one family, administrative mechanisms must maintain a subscriber list for each femtocell, and other usage must be restricted, presumably with the exception of emergency calls for which there is a universal carriage requirement.

Inter-cell interference and frequency planning present particularly tricky problems when femtocells are used in the network. Mobile operators already perform wonders to squeeze maximum coverage and minimum interference out of a very limited slice of spectrum. Interference results wherever cells using the same channel overlap, and it is liable to affect quality of service in the affected area. Femtocells must integrate with the network's channel plan for their location, causing difficulties because of the inevitable situations where channel shortage dictates that they must share the channel of an adjacent macrocell. Also, the scale of femtocell deployments (should they become successful) will introduce several orders of magnitude more transmitters than today's network of cell towers, transforming an already difficult management task into something significantly more challenging. Already vendors are suggesting that channel determination is decentralized to each femtocell, as current mobile networks cannot handle this level of calculation. Additionally, closed femtocells that serve only named subscribers will appear as coverage holes to other subscribers, and worse, they may also interfere with adjacent macrocells, even on adjacent channels, further exacerbating quality of service issues.

Quality of service in its broadest sense of customer satisfaction is a continual concern of mobile Operators. When applied to femtocells, there are two new aspects. Since standard RF interfaces are used, over-the-air performance is well understood except that the low transmit power of femtocells may mean that phones are operating at the edge of coverage much of the time. Indeed, many of the issues reported in early trials arise from coverage that is insufficient to light up the whole house, particularly difficult in multi-storey dwellings with concrete floors. The second source of QoS concern is over the broadband Internet connection. A single voice conversation will take a few hundred kbps of bandwidth, and Operators would prefer to see femtocells allow up to four simultaneous conversations, requiring 500 kbps or more of low-loss, low-delay capacity on the DSL line. This bandwidth may be nominally available, however some early trials showed that voice conversations were interrupted when family members simultaneously exercised the Internet connection for Web and video downloads while making femtocell calls. While it may prove easy for fixed and mobile Operators to coordinate Internet QoS with femtocells, cellular-only Operators are reliant on services beyond their control, with concomitant concerns about service calls and customer satisfaction. It seems clear that a successful femtocell design will need to monitor and adapt to the instantaneous bandwidth, packet loss and delay characteristics of the Internet connection.

The network interface, and indeed the overall system architecture for femtocells is not close to standardization. There is general agreement that it will not be possible to tunnel femtocell traffic directly back to today's core cellular networks: there is no interface there capable of terminating and controlling vast numbers of femtocells. Vendors are advancing a wide range of proposed architectures and interface standards; some are suitable for current networks while others are built for an IP multimedia subsystem

(IMS) core, and there are many subsets of architectural design for each category. This variety might be expected at this stage of development, as the femtocell concept is still fluid, but the lack of a network interface standard will fragment the global market for femtocell vendors, reducing vendor choice for operators, who typically promote competition between equipment vendors in order to reduce procurement risks and optimize pricing. The choice of architecture is complicated, as mobile networks are not yet based on IMS, but will migrate to it over the next several years, and because the interested startups have considerable intellectual property and patents in this area, and are not ready to forfeit the associated commercial opportunity. The recently founded Femtocell Forum has a goal to encourage vendors and Operators to converge on a smaller number of options.

The RF interface should be one of the strengths of femtocells, as the mobile phone has a well-defined over-the-air protocol. In fact, network operators upgrade regularly, both to offer subscribers new services and to encourage phone upgrades. Phone upgrade cycles are good for phone companies because ultimately the customer pays, but network equipment costs such as femtocells are at least partially borne by the operators. The roadmap for global system for mobile communications (GSM) operators includes today's predominantly 2.5G networks, 3G which already includes a number of incremental steps, and the emerging long term evolution (LTE) standard. The ideal femtocell would be software-configurable for all these, also for CDMA standards, and potentially support multiple standards simultaneously. Sadly, the cost of such processing power is currently prohibitive, even if it were feasible with today's technology. Thus equipment vendors must choose particular combinations, which will each appeal to a subset of global operators, shrinking their potential market and economies of scale. Operators selling a femtocell to consumers should be careful to allow for a future marketing campaign where they explain why these units are now obsolete, and a new purchase is required.

The cost of consumer units and core network upgrades is a key unknown in femtocell economic models. Most operators are already indicating they do not want to subsidize the purchase of femtocells, so the subscriber will have to pay the full cost. Meanwhile the femtocells in limited production today use brand new chips with no production volume, and as one large vendor noted, the startups involved in the production chain must recover their R&D costs and accelerate profitability by establishing significant margins. One analysis suggested that if the chip/device/OEM/retailer chain involves four companies, each adding €30 of value at a 30% gross margin, the final price of a unit would be €116. This is an argument against over-reliance on OEM relationships and procurement chains involving multiple startups and new components, yet these appear to be unavoidable in the early stages of the femtocell market.

Regardless of vendor OEM chains, operators are disinclined to be held to target retail prices, but indicate \$200 or €100 as a goal. Even current price estimates, based on considerable future volume, present a significant barrier to overcome before operators will take femtocells seriously. It is safe to assert that any femtocell sold to the public in 2008 and 2009 will result in either the femtocell vendor or the operator taking a significant financial loss.

Femtocells must meet significant levels of voice and data performance to be accepted by the consumer. In the voice dimension, performance equates to call quality, but mobile operators' data services, already a 10% share of revenue, must be available on femtocells just as readily as from the macro network. The newest 3G phones are advertised with data capability in excess of 2 Mbps, and as access to these services in the home is considered a primary application, operators are keen to see this level of performance is not compromised when service is provided from a femtocell. Preliminary trials indicate that this is a serious

effect, as femtocell-provided data services in early trials compare unfavorably with Wi-Fi from the same Internet connection.

Wi-Fi access points work with any Internet connection and Wi-Fi client, but operator-independent femtocells do not exist. Initially each femtocell will bear a particular operator's logo, and will work only for that operator. Until there is a de-facto standard for the network interface (see above), a universal design will be impossible. An operator-independent femtocell would appeal to consumers, since they could keep the same unit when they change operators, similar to GSM subscribers outside the U.S with their mobile phones. However, this would be to the femtocell operator's disadvantage. Operators expect femtocells to provide an advantage by delivering capabilities competitors cannot easily match, even offering pricing plans to encourage whole families to use the same operator and share the same femtocell. These goals are predicated on an operator-specific femtocell, and would be negated if the consumer could purchase a femtocell from one operator, but quickly switch its service to a competitor.

Benefits to the mobile operator and the consumer

The main benefit of femtocells is to improve in-home coverage, but as vendors dig deeper into their marketing toolboxes they have unearthed many other interesting ramifications of the technology.

Since 3G mobile networks use higher frequencies and different modulation than 2G, they generally have shorter range for voice calls and even worse building penetration. Also, many Operators have built-out 3G coverage and hence are now encouraging subscribers to upgrade to 3G service. Femtocells can be linked to 3G either to provide subscribers another incentive to upgrade (they can improve their in-home coverage, but only if they upgrade to 3G), or defensively to compensate those subscribers who find their previously marginal home coverage becomes unusable following a 3G upgrade.

The most significant reason for consumers to upgrade their mobile to 3G is for higher data rates, and the multimedia services these enable. Data services suffer the same range and building penetration effects as voice, but more so: it is possible that over 50% of 3G homes will receive less than 384 kbps rates indoors, but a few steps outside the building will transform this to 1 Mbps or more. While many measures can be of marginal help, ultimately the only way to reach large numbers of subscribers with high-data rate services is to reduce the cell size, which implies adding more base stations. Since macrocell sites are very expensive to identify and build, user-sited femtocells hold the solution. Further, marketers have identified usage of data service in the home as a significant requirement, and femtocells will increase data rates in the very places they are most needed.

Today's cell towers are backhauled to the operator's core network by lines or radio with bandwidth of the order of 1.5 - 2 Mbps. As 3G takes off, such a cell will start to serve many users simultaneously demanding data services, swamping the backhaul connection and forcing an expensive upgrade of network infrastructure if service levels are to be maintained. But femtocells offer data services without loading these links – consumers pays for their own Internet connections, typically of many Mbps, and the operator's traffic can ride the wire without charge.

Similarly, in areas where the user population has overwhelmed the macro network with traffic, open femtocells can be judiciously added to relieve the pressure without requiring new cell tower infrastructure.

The initial cost estimates for femtocells are alarmingly attractive: as vendors run the numbers, it turns out that a network of femtocells could be orders of magnitude cheaper to build than a traditional macro network. Although much of this is based on optimistic volume-pricing, the effective range of a femtocell and forward-looking pricing estimates, it certainly appears that a 2G Operator wishing to introduce 3G could do so by scattering femtocells as an overlay to the 2G network at a much lower cost than a traditional macrocell upgrade.

Taking this concept a step further, if femtocells are indeed a cheaper way to build a network, why use macrocells at all? As the chairman of the Femtocell Forum recently remarked, mobile technology can build large cells and small cells, so why would the consumer need anything else? Small femtocells in the home and larger femtocells serving outdoor areas can answer all our communication needs, whereas competing technologies (e.g., Wi-Fi) are only short-range and so only a partial solution.

The developers of femtocell hardware and software are mainly startups hoping to establish a footprint and become a de-facto standard. These vendors rely on silicon from other startups with no volume production, so initial pricing is high, although forward price estimates are rosy. Established, large suppliers of mobile network equipment are observing the startups, establishing loose partnerships and generally getting to understand the market and the technology, but are not expecting to make significant sales for some years.

Meanwhile, in the year or two that femtocells have progressed from a vision to prototype form, operators have looked at the opportunity enough to be intrigued, but have identified a list of significant concerns discussed above that are barriers to deployment, as we have discussed above. To date, most operator activity has been in the lab, with a handful of small-scale trials. Sprint's Airave offering is the first commercial trial of femtocell capabilities, in this case with CDMA, and even Sprint admits it is a speculative exercise, a project to gain enough experience to move to a larger-scale rollout.

Femtocells compared to Wi-Fi access points

When compared to Wi-Fi, it is clear that femtocells fall short in many areas, but offer a number of potential advantages. The discussion below offers a comparison in a few areas where the two technologies would be considered competitive.

The cost and pricing model for Wi-Fi is understood and successful. Chipsets are sub-\$5, access points sell for \$30 and consumers are happy to buy them at that price. It is unclear what value consumers will assign to femtocells. One view suggests that when offering a femtocell as the solution to poor coverage, the operator is asking the subscriber to pay for its lack of investment in the macro network, implying that the subscriber would be reluctant to pay anything to remedy the operator's shortcoming. However the consumer eventually values femtocells, and trials have not yet proven any of the value models, even at optimistic market growth estimates they will take years to approach Wi-Fi access point volumes and price points.

Consumers are comfortable with Wi-Fi. There is a support system for the technology and products that, while imperfect, demonstrably succeed. How will the consumer feel about bringing home a 'cell tower'? Will there be concerns about RF radiation? Will expectations for call quality, effective range and data services be different for femtocells than for Wi-Fi? Indeed, will the consumer care or understand that femtocells and Wi-Fi access points use different technology, and how will this affect consumer acceptance of the newcomer technology?

Will consumers be concerned about being locked into one operator with their femtocell, and when changing operators will the need to buy a new femtocell prove frustrating? Wi-Fi access points are independent of the service-provider unless they are integrated with DSL termination or set-top boxes. They can be readily transported and re-installed at will.

Wi-Fi access point interfaces are clearly defined, allowing multi-vendor interoperability and driving innovation as designers seek novel and profitable new uses for Wi-Fi. It is difficult to see this competitive, innovative model translating to the femtocell world where each device will be specific to, and sold via a particular operator: the operators become gatekeepers in dictating new features, an economically inferior business model.

It is arguably more difficult to implement good quality of service and deterministic multi-media behaviour on Wi-Fi than on mobile technologies, both because of the better control from using licensed spectrum and because Wi-Fi products initially had no QoS. However, the IEEE 802.11 working group ratified 802.11e for QoS in 2005, and Wi-Fi phones, both single-mode and dual-mode implementing this standard are now readily available. Voice over Wi-Fi is already a mission-critical service for many organizations. Current work in the industry is towards video and IPTV over Wi-Fi, services that are already possible but will be improved and fine-tuned over the next few years. Meanwhile the best mobile network video service, DVB-H, does not scale beyond a tiny screen.

While Operators' exclusive use of licensed spectrum is usually seen as a benefit, it becomes a disadvantage in the home. The concern noted above, where femtocells must learn exactly where they are located, and transmit only on the channels licensed to the parent operator, is one of the most significant unsolved problems. Indeed, while femtocells are restricted to a single location, Wi-Fi access points can be mobile, so a personal access point can be set up almost anywhere in the world and operate legally, backhauling traffic over the Internet to the home network. Further, Wi-Fi QoS is proven even under conditions of RF interference such as exist in the real world, whereas early trials show the performance of femtocells overlapping with macrocells on the same channel is problematic.

Mobility is another area where Wi-Fi lags cellular technologies, but the gap is quickly closing. Enterprise Wi-Fi installations routinely hand over calls between access points, using techniques borrowed from the cellular world but standardized for Wi-Fi. This is not usually a requirement in the home, where a single Wi-Fi access point can provide sufficient coverage, but here the ability to hand over calls into and out of the cellular system becomes important, matching the capability of femtocell-macrocell handover. This is a challenge that fixed-mobile convergence (FMC) techniques, pioneered by a number of startups and incumbents in Wi-Fi, stand ready to solve. FMC research over a number of years is culminating in large-scale trials of solutions such as unlicensed mobile access (UMA), a GSM standard for supporting dual-mode Wi-Fi / cellular phones and handing over calls. UMA is in commercial service world-wide with operators such as BT, Orange and T-Mobile. The most significant barrier to this technology, the availability of dual-mode handsets, has been overcome, and UMA phones are now available from Nokia, RIM (BlackBerry), Windows Mobile vendors such as HTC, and Linux phone vendors, providing a basis for Google's Android software from the Open Handset Alliance (OHA). Even the iPhone has a Wi-Fi interface, although this does not yet support VoIP

Wi-Fi clients cover a much broader range of products than mere phone devices. Wi-Fi is embedded in an extraordinary range of consumer devices, from PCs where it is now the default communications interface (Apple's MAC Air lightweight PC has only Wi-Fi, no wired Ethernet) to digital cameras, game consoles

and printers, among others. This is due to the ubiquity of Wi-Fi home access points, interoperability guaranteed by strong standards, and the low cost of silicon due to huge volume production. Wi-Fi is used by the nascent home media center market, connecting devices throughout the home for photo, music, video and TV services. Many DSL and cable TV vendors are integrating Wi-Fi with their termination and set top boxes. It will take some time, very new thinking, and new business models for mobile operators to embed their interfaces in such a variety of devices, even if the consumer is prepared to accept them.

The ongoing cost models are very different. With Wi-Fi, there is nothing to pay after purchase: use of the air for Wi-Fi is free. But any device accessing an operator's licensed femtocell must be registered in some way, and will attract a monthly subscription fee. And choosing a particular operator's femtocell will immediately reduce the range of clients to those compatible with that operator's network. These are all considerations the consumer will weigh as part of the purchase decision, and Operators are beginning to quantify consumer preferences.

The future of femtocells and the home communications network

The femtocell concept, and the considerable research and development that has resulted in early trials of femtocell technology offers some exciting glimpses of one version of the mobile operator's future network. There is considerable interest in the industry, but a realization that many obstacles need to be overcome before the technology gains widespread success.

Wi-Fi is indisputably the technology for the in-home wireless network. The majority of homes in developed countries already use a Wi-Fi network for Internet access, and multimedia home entertainment devices using Wi-Fi are in mass-production, even though they are still early in the adoption cycle. A number of FMC architectures use the home Wi-Fi access point to deliver the same benefits as femtocells, although this market, too, is in its early stages. But Wi-Fi is already entrenched, has high production volumes, low prices and good consumer acceptance, and is likely to grow in time into this wider role of communicating photos, music, TV and voice around the home. This is the environment the femtocell must penetrate, and it seems a daunting proposition: Wi-Fi already has a significant network effect, and mobile operators must choose whether to be part of that network, or to maintain their separate technology island.

But the mobile operator still controls two vital levers with the subscriber. Firstly the principal phone number is key to the subscriber's identity. Non-mobile forms of FMC cannot replace this number, although when the mobile network supports reliable, high-bandwidth data services it will become possible for voice service providers to tunnel through it with VoIP and offer an alternative. The second key advantage is that only mobile operators can provide wide-area coverage, and any new entrant would need to invest capital in the order of \$10 billion to build out a new national U.S. network with cellular, WiMAX or other technology.

While an exclusive spectrum license has been seen traditionally as the key strength of a mobile operator, this paper has shown that it is at the least a two-edged weapon in the case of femtocells, and realization of this effect has sparked some interesting ideas in the communications industry. Analysts and others are suggesting various combinations of Wi-Fi and femtocell technology may give consumers the best mix of services, quality, and price. A simple device might combine a Wi-Fi access point and femtocell, although more interesting integration is possible. When an operator also provides wired Internet service, the combined unit could add a DSL termination. There is scope for these integrated service providers to deliver a complete Internet, phone and TV service to the consumer.

Operators also have the network management and support capabilities to provide a superior level of customer care and remote troubleshooting compared with today's retail Wi-Fi support model. In most areas, they have an established and trusted brand, so femtocells may offer an opportunity to penetrate the home with more devices and services.

It will take some years, but the possibilities exposed by inexpensive femtocells in conjunction or competition with Wi-Fi access points promise considerable disruption to existing business models, to the ultimate benefit of consumers.

About Aruba Networks, Inc.

People move. Networks must follow. Aruba securely delivers networks to users, wherever they work or roam. Our unified mobility solutions include Wi-Fi networks, identity-based security, remote access and cellular services, and centralized multi-vendor network management to enable the Follow-Me Enterprise that moves in lock-step with users:

- Follow-Me Connectivity: Adaptive 802.11a/b/g/n Wi-Fi networks optimize themselves to ensure that users are always within reach of mission-critical information;
- Follow-Me Security: Identity-based security assigns access policies to users, enforcing those policies whenever and wherever a network is accessed;
- Follow-Me Applications: Remote access solutions and cellular network integration ensure uninterrupted access to applications as users move;
- Follow-Me Management: Multi-vendor network management provides a single point of control while managing both legacy and new wireless networks from both Aruba and its competitors.

The cost, convenience, and security benefits of our unified mobility solutions are fundamentally changing how and where we work. Listed on the NASDAQ and Russell 2000® Index, Aruba is based in Sunnyvale, California, and has operations throughout the Americas, Europe, Middle East, and Asia Pacific regions. To learn more, visit Aruba at <http://www.arubanetworks.com>.

© 2008 Aruba Networks, Inc. *AirWave®*, *Aruba Networks®*, *Aruba Mobility Management System®*, *Bluescanner*, *For Wireless That Works®*, *Mobile Edge Architecture*, *People Move. Networks Must Follow.*, *RFProtect*, *The All Wireless Workplace Is Now Open For Business*, and *The Mobile Edge Company®* are trademarks of Aruba Networks, Inc. All rights reserved. All other trademarks are the property of their respective owners.

WP_FEMTO_US_080418



1344 Crossman Ave. Sunnyvale, CA 94089-1113
Tel. +1.408.227.4500 | Fax. +1.408.227.4550 | info@arubanetworks.com
<http://www.arubanetworks.com>