Improving 4G coverage and capacity indoors and at hotspots with LTE femtocells

Nokia Siemens Networks

White Paper

Contents

Executive summary

3GPP placed another stepping-stone on the path to the all-IP network when it standardized the Evolved Packet System (EPS) with Rel-8. The advanced Evolved next generation Packet Core (EPC) provides the architectural underpinning. And the Long-Term Evolution (LTE) radio access network delivers powerful broadband performance, makes the most of radio resources, and cuts latency and per-bit costs.

3GPP formulated LTE to make mobile communication a more satisfying experience for users, driving demand for streaming, gaming, social networking, and other multimedia services. The LTE femtocell is a key ingredient. Also called the Home Evolved Node B (HeNB), this low power, high-performance access device operates in licensed spectrum, providing low-cost coverage and capacity for small areas over public Internet backhaul. Usually deployed in homes and businesses, it can also cover hotspots indoors and out.

Radio waves fade faster at higher carrier frequencies, making it hard to serve indoor subscribers with outdoor macro base transceiver stations (BTS). This requires smaller cells, so femtocells are sure to figure prominently in LTE's future. Committed to both breeds of LTE femto, Time Division Duplex LTE (TD-LTE) and Frequency Division Duplex, Nokia Siemens Networks staged the first demo of a TD-LTE femto prototype in 2009. This paper looks at how LTE femtocells work and what they can do, and presents a viable solution for service providers.

1. What LTE femtocells can do

Business requirements, customer demand, and higher frequency band allocations compel service providers to roll out smaller LTE-based cells. Burgeoning data traffic and capacity demand are outpacing revenue growth, creating a capacity-cost dilemma. Data traffic's growth curve will remain steep in the years ahead, so service providers must find ways of cutting per-bit costs, extending margins, and leveraging new services to boost revenue.

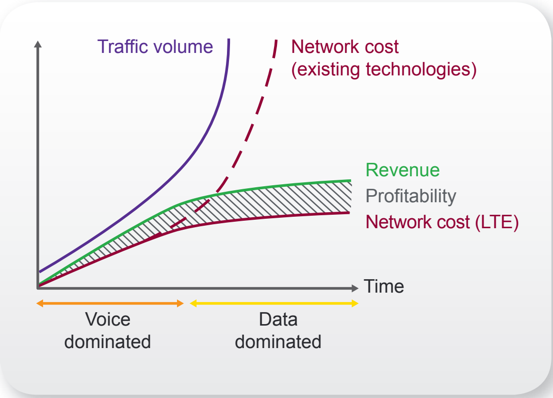

Figure 1: The capacity-cost dilemma

With far less overhead for power supply, backhaul links, and site acquisition, femtocells drive down total cost of ownership. Designed for plug-and-play deployment and provisioning, they enable providers to

- Quickly ramp up new services
- Tap new revenue streams
- Capitalize on value-added services and family contracts

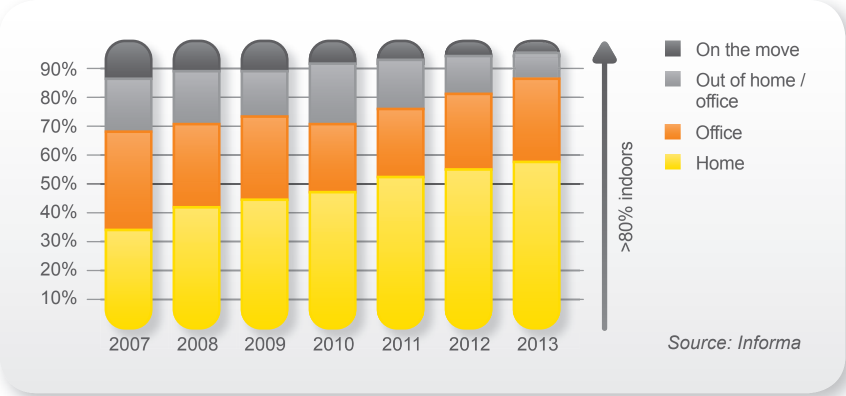

Figure 2: Mobile data traffic´s phenomenal growth indoors

1.1 Improving coverage, lightening the load

The relentless advance of smart phones, broadband-enabled laptops, and other data-hungry devices has mobile data traffic doubling from one year to the next. Much of it originates at home and in the office, and devices outdoors are hard-pressed to meet indoor bandwidth demand. It will take a lot more macrocells to deliver deep indoor coverage and sophisticated services. But most service providers want to reuse legacy sites, and adding new sites is not always feasible.

Lightening the macro network's traffic load frees up capacity. One very efficient and cost-effective way of doing this is to deploy femtocells. As a fringe benefit, the femtocell improves radio performance, treating users to a more gratifying experience.

1.2 Resolving the high-frequency quandary

Again, higher-frequency waves have a harder time penetrating buildings, making life a lot tougher for service providers deploying LTE, say at 2.6 GHz rather than 700 MHz. Femtocells improve coverage and extend capacity in homes and businesses, and the side effects are very welcome indeed.

For one, walls shield the femtocell, attenuating interference with the macro network. For the other, the geometry of rooms creates a rich and angular multipath environment that maximizes multi-input multi-output gains. This helps LTE achieve peak modulation rates and spectral efficiency, creating the perfect conditions for delivering premium services to demanding customers.

2. Places for LTE femtocells to go

LTE femtocells provide cost-effective solutions mainly for indoor residential and enterprise applications, as well as for select outdoor hotspots. The big differences between the three are transmission power, user numbers, type of backhaul connectivity, and access mode (open, closed, or hybrid). Also, business femtocells may have to serve as de facto private networks for the company and its customers. Dual-mode 3G/ LTE femtocells could be the way to go for service providers seeking to spare subscribers the hassle of separate boxes and the wait for LTE adoption.

2.1 At home
Residential femtocells generally cover one household with a radius of about 25 meters. Service providers or subscribers can furnish these plug-and-play devices. Digital subscriber line (xDSL) cable and a passive optical network (xPON) already installed in the house connect the devices to the core network. Operating mainly in closed and hybrid access modes, they support seamless mobility with the surrounding macro layer. Only user equipment (UE) within the closed subscriber group can camp on a femtocell in closed access mode. Accommodating between 4 and 8 concurrent users, and perhaps up to 20 in connected mode, these femtocells are managed by a system based on TR069 protocols, connected to the radio access network's management system.

2.2 At work
Enterprise femtocells must interwork to ensure service continuity and seamless handover, which may call for the X2 interface. It will probably take 'light' network planning to deploy these plug-and-play devices. The data transmission link currently in place connects these devices to the core network, but it may have to evolve for a better LTE user experience.

Companies want simple, secure local services. Service providers want to keep huge loads of enterprise packet traffic off their core network. A local breakout for data traffic satisfies both demands. Accommodating between 32 and 64 concurrent users, enterprise femtocells are managed by the service provider's enterprise management system, possibly with a TR069 system serving as the front end to femtocells.

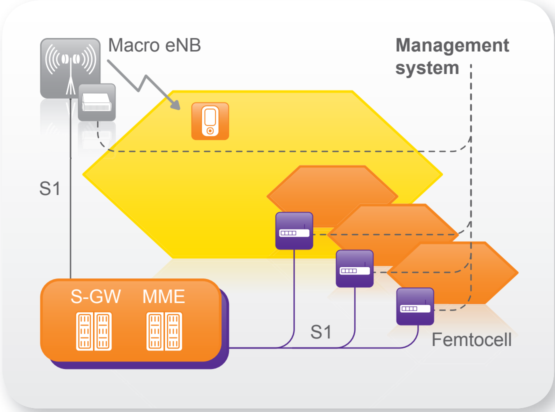

Figure 3: A simplified diagram of LTE femtocell network architecture

2.3 In public
Public femtocells cover buildings such as airports, railway stations, shopping malls, and large plants, or outdoor hotspots. They need dedicated backhaul links, probably deployed by the service provider, and may accommodate hundreds of concurrent users, if necessary. The macro network's management system will most likely also manage the public femtocell, often called a picocell.

3. The importance of being flat: LTE femtocell architecture

The LTE EPC bases on flat IP architecture, and so do femtocells and macrocells' architecture and interfaces. There is no need for new interfaces between LTE femtocells and EPC elements. The femto gateway is optional.

3.1 Standardized from the start
Engineered to make the most of LTE standards, LTE femtocells are in step with the LTE schedule and fit for day-one deployment. They integrate seamlessly into the EPC infrastructure using the same interfaces defined for the macrocells, so the same EPC can support both femtocells and macrocells. Nokia Siemens Network, a driving force in standardization efforts, will continue to chart LTE femto's course.

3.2 Network architecture
There are several ways of connecting the LTE femto access point (FAP) to the core network, depending on if and how an LTE femto gateway is put in place. If the setup lacks a femto gateway, S1 interfaces connect LTE femtocells straight to the Mobility Management Entity (MME) and Serving Gateway (SGW). In setups with a control plane (CP), the femto gateway only aggregates CP traffic from multiple FAPs to the MME. In setups with a CP and user plane (UP), the femto gateway aggregates both CP traffic from femtocells to the MME and UP traffic from femtocells to the SGW.

The macro EPC is easily shared when rolling out femtocells, especially on a small scale or at fewer points in the network. Service providers can introduce an LTE femto GW, or later migrate from a 3G femto GW or dedicated MME/SGW to enable mass deployment.

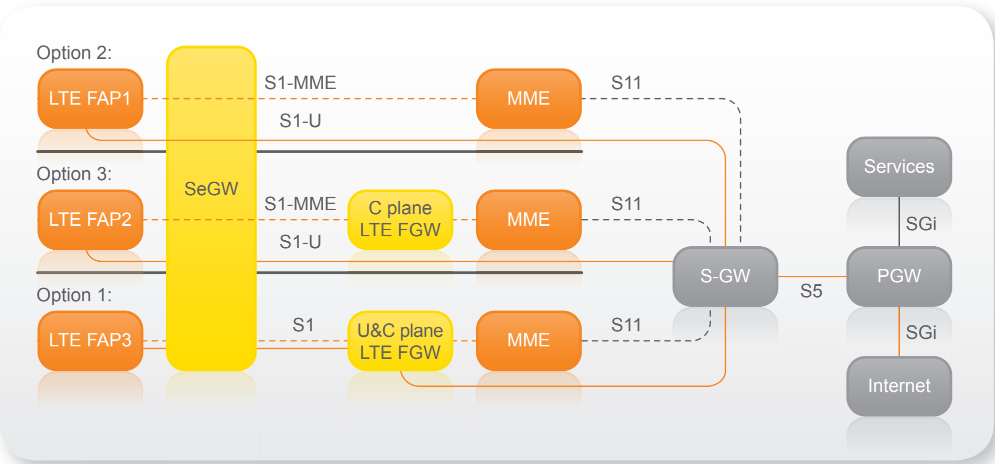

Figure 4: Variations on a theme: LTE femto network architecture

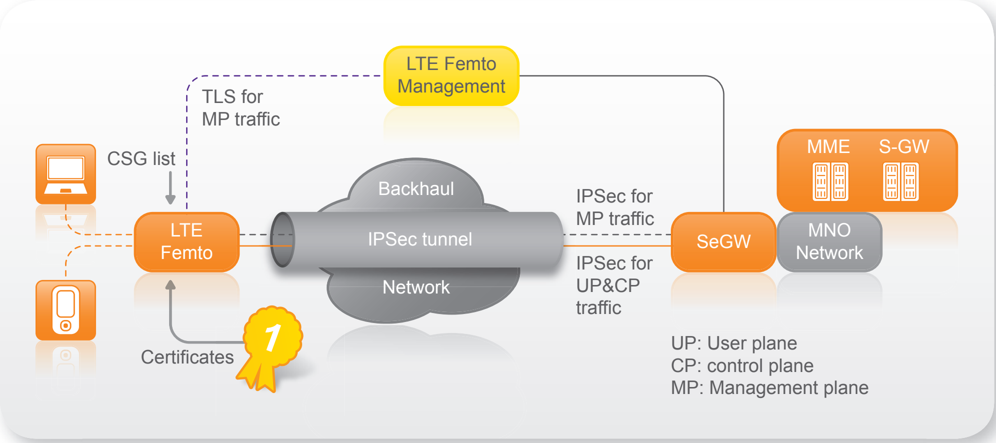

Figure 5: LTE femto security in action

3.3 Security architecture

Security risks jeopardize the local femtocell as well as the network connected via public backhaul. These threats include

- Attacks from the Internet directed against the FAP
- Subscribers who compromise the FAP to snoop out others or invade the network
- Entities masquerading as an FAP to strike out against the network

Many countermeasures protect the femtocell and network. The service provider can limit access to the FAP, for example, by using a closed subscriber group (CSG) list. FAPs may be locked to prevent access from unregistered locations, and authenticated with public key certificates. Internet Protocol Security (IPSec) can protect S1 and OAM traffic, creating the platform for a trusted environment.

3.4 Management architecture

Self-organized network management is the key to enabling plug-and-play deployment. To this end, LTE femtocells automatically

- Connect after power-on
- Identify the femto device
- Configure settings
- Optimize the setup

A security gateway or transport layer security protects all management plane messages. As specified by the Broadband Forum, the TR-069 protocol and TR-196 data model, inserted between the FAP and femto management system, ensure interoperability.

LTE femtocells benefit from SON features stipulated in 3GPP's LTE standard, particularly from data provided by user equipment to help the system automatically generate and adapt the various configuration files.

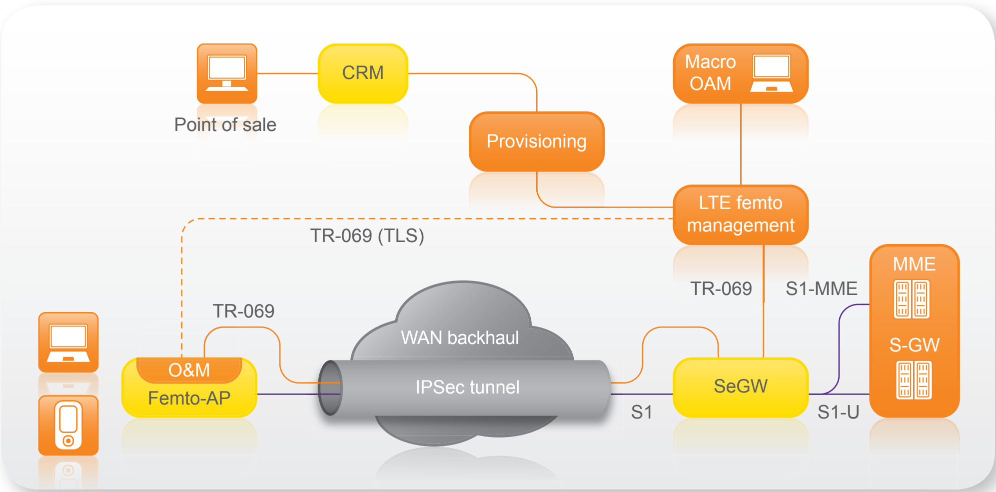

Figure 6: A look at the management structure

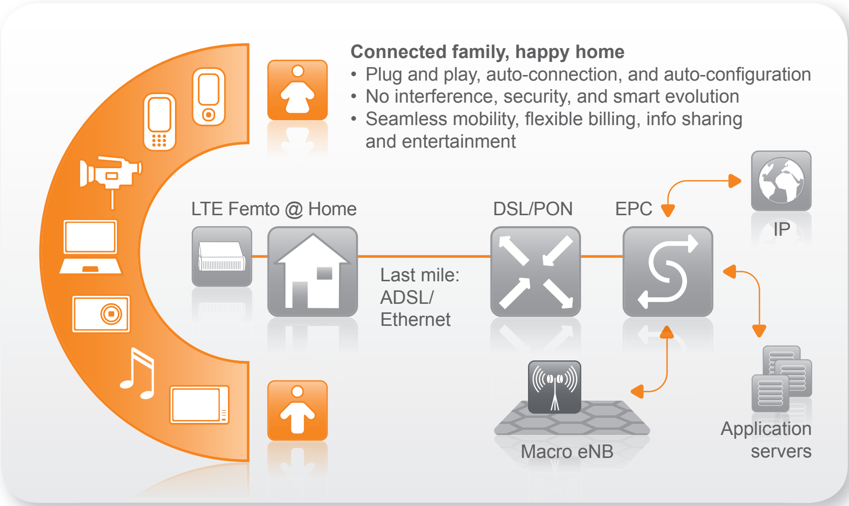

Figure 7: Smart @ Home services enabled by an LTE femto portal

3.5 Femtozone services

Femtocells provide a portal to in-building services and automations. These femtozone services include high-bandwidth services for the connected home as well as context-aware, location-based services. They also make the transition to and from the macro network smooth, and enable flexible billing.

4. What to consider when deploying LTE femtocells

4.1 Allocating spectrum

LTE femtocells can use all bands defined by 3GPP. They do not require dedicated frequency spectrum, but dedicated bands can mitigate interference. Able to perform consistently regardless of band, even at higher frequencies, LTE femtocells are cost-effective means of providing high capacity in smaller areas. They can also employ spectrum used less frequently today, such as time division duplex sub-bands and, in some instances, even guard bands.

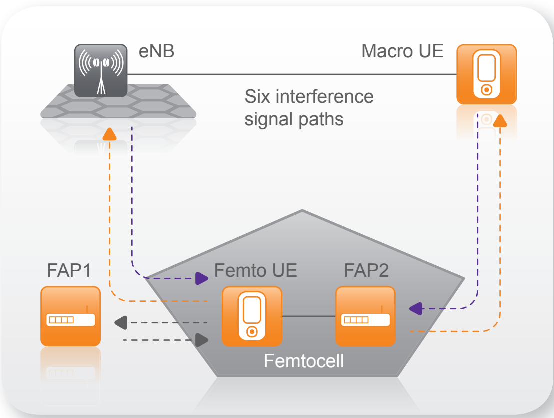

Figure 8: LTE femto interference paths

4.2 Dealing with interference

Whereas engineers can carefully plan and roll out BTS and allocate frequencies to prevent interference in macro networks, deploying femtocells 'ad hoc' requires new mitigation techniques. The level of interference in the six possible paths – femto to macro, macro to femto, and femto to femto (uplink and downlink) – depends largely on whether cells share spectrum, causing co-channel interference, and whether access is open or closed (limited to a CSG).

All six interference paths come into play in co-channel setups. Using a dedicated channel narrows it down to just the femto-to-femto interference paths. High interference is usually attributable to the UE and less-than-ideal cell selection. Downlink interference may be high, for example, if the UE connected to the eNB at the macro edge is not on the femto CSG list. The UE served by the FAP interferes with the uplink at the cell's edge.

Autonomous interference management schemes can mitigate this interference to enable uncoordinated deployment; that is, without prior network planning. 3GPP autonomous interference mitigation features such as adaptive maximum output power control and macro-aware UE power capping help ensure acceptable performance, and deployment with a dedicated band or 'escape carrier' can make it robust. 3GPP is also discussing enhanced inter-cell interference coordination (eICIC) schemes.

4.3 Backhauling

The xDSL, xPON, or cable link installed in the customer premises connect LTE femtocells to the network. In homes, this is usually an xDSL link. In businesses, it is the fiber or Ethernet link carrying the enterprise network's data traffic. Backhaul availability and bandwidth are critical, and fixed broadband access can provide it. Experts expect higher fixed Broadband access speeds to match LTE femtocells' requirements to be coming soon.

4.4 Synchronizing

LTE femtocells will support ±0.25ppm frequency/ clock synchronization, which is less stringent than a macro eNB's specification for accuracy. The TD-LTE femtocell requires ±3us phase synchronization (in relative time), or ±1.33us plus propagation delay in network listening mode and at distances greater than 500 meters. Absolute time-of-day synchronization may also be required for management purposes.

Synchronization options include Timing over Packet, Global Positioning System/Global Navigation Satellite Systems (GPS/GNSS), and network listening over the air. Each has its advantages and drawbacks: The GPS signal may not penetrate indoors. Legacy xDSL or xPON devices may not support IEEE1588 V2 protocol processing. The macro BTS signal may not reach the indoor femtocell. The cost of supporting all these modes is prohibitive, so one should serve as the main method, say 1588-V2, and another such as GPS or network listening as the backup.

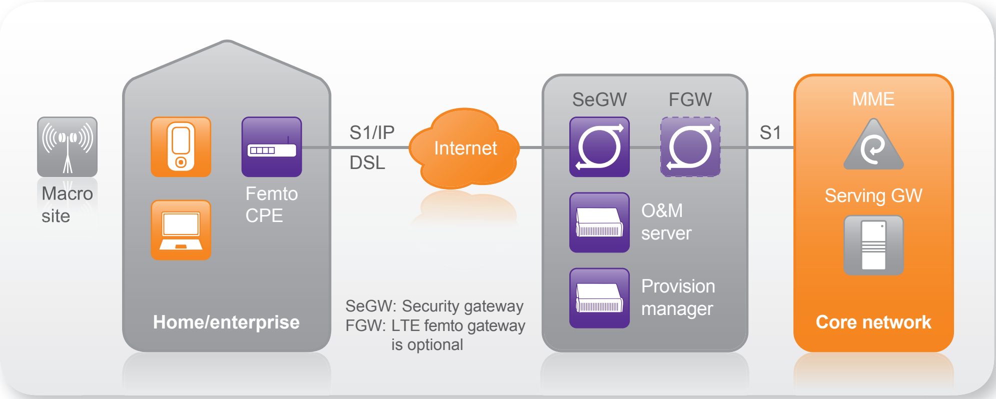

Figure 9: Nokia Siemens Networks' LTE Femto Solution

4.5 Managing locations

Some use cases such as emergency calls and positioning applications, for example, device-to-device communication, need to know an LTE femtocell's location. This is why location management features include the ability to detect and verify the FAP's location.

With a radius of about 25 meters, an LTE femtocell is small enough so that its position is tantamount to that of the UE it serves. Femtocells may be located via GPS/GNSS. The service provider's management system can also identify the xDSL line to pinpoint the residential femtocell.

LTE femtocells operate in the licensed frequency band, so different frequency policies in different regions prevent any 'anarchical' use. A location locking function powered by GPS positioning, xDSL ID tracking, neighboring macro radio scanning, or other technique precludes use from unregistered locations.

5. Why Nokia Siemens Networks?

Nokia Siemens Networks is leading the way in LTE femto, performing the world's first demo of a TD-LTE femto concept in Q3 of 2009, followed by the May 2010 release of a prototype. With lab tests and field trials underway in 2011, the commercial version's debut is slated for 2012. Chipset availability will be a factor in the timing, as most vendors intend to release LTE femto chipsets by Q1 of 2012.

With this solution in the works, Nokia Siemens Networks aims to implement the 3GPP Rel9 femto standard using network architecture that is open, scalable, and flat. The subsequent 2013 version is expected to build on the Rel10 standard. The company's experience in mobile radio access, core, and residential broadband access networks runs deep, enabling it to offer peerless integration and support services.

This solution will factor all the indispensable functional entities discussed in this paper into the femtocell equation – the FAP, SeGW, Femto Network Management System, and the Provision Manager. The LTE femto gateway will be optional.

The FAP or Customer Premises Equipment (CPE) provides all transmission and control functions for one femtocell. Sited in the home or business, it will connect to the EPC via an S1 interface. A FAP shares the same functions as an eNB, although with added CSG support. It communicates with the SeGW across an IPSec tunnel, via the customer's broadband wireline access. The SeGW may be a separate physical entity or co-located. It will provide security association(s) for the backhaul link connecting the FAP and core network.

The TR069 standard and TR196 data model provide the framework for the LTE femto management system. Nokia Siemens Networks has a proven 3G Femto O&M server and provisioning manager, and a 4G version in the works. Comprised of an MME, a Serving and PDN Gateway, a Policy Control and Charging Rule Function, and a Home Subscriber Server, the EPC also supports femto features. Femtocells can be served by the same EPC deployed for the macro network.

Engineered to make the most of all these features and attributes, this solution will provide precisely what service providers need to deliver low-cost coverage and capacity to homes, businesses, and hotspots. Readers wishing to learn more about this LTE Femto solution are asked to please contact Nokia Siemens Networks.

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Order-No. C401-00681-WP-201101-1-EN

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