The Emergence of Compact Base Stations in the New RAN Architecture Paradigm

New RAN Architecture Paradigm

As we move from 2G to 3G to 4G there has been an inherent trend in the radio access network (RAN) architecture of simplifying it, making it more compact and flat. The primary motive has been to enable mobile operators to maintain control on their network costs, while they deal with improving coverage and capacity. However, the sudden increase in data traffic volumes, courtesy smart devices like the iPhone, have made it difficult for operators to keep a lid on network costs while they try and keep up with incessantly exploding mobile data demand from burgeoning smart devices, applications, and changing user behavior.

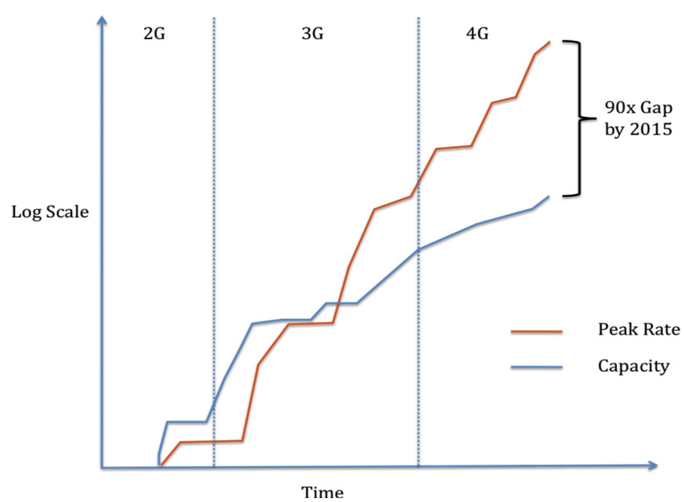
This calls for a new architectural paradigm that optimizes existing cell site infrastructure, most of which is macro layer enabled, but at the same time introduces new network layers at the micro-, pico- and femtocell level, that can effectively complement the macro layer.

This ABI Research white paper describes the emergence of this new paradigm and how compact base stations are ideally suited for this new marketplace. Its focus rests on macro, micro, and pico outdoor base station sites and does not cover indoor base stations or coverage needs.

Bandwidth Capacity Crunch and Metrozones

One key factor that is driving the new network paradigm is the bandwidth capacity crunch. As we move from 2G to 3G to 4G, the gap between peak and average bandwidth capacities is increasing. The size of this gap depends on numerous factors like the number of users in a cell, data usage patterns, location of the user in the cell, capability of smart phone device, and so forth.

Figure 1.1 Peak to Average Throughput Gap as we move from 2G to 3G to 4G



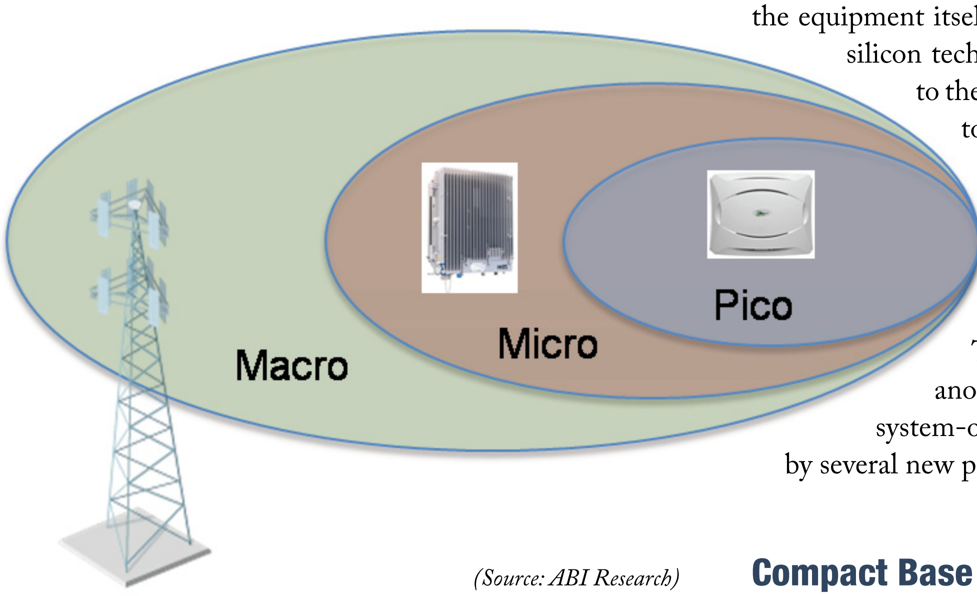
(Source: Agilent Technologies)

The peak to average gap is expected to grow to 90 times its current size by 2015 for 4G technologies as the density of users, smart phone capabilities, and data usage patterns put pressure on the network. This is expected to have a detrimental impact on the advertized bandwidth speeds from operators versus what is experienced in the real world.

Macrocell Overlay to Clusters of Small Cells

In order to curtail the impact of this bandwidth capacity crunch and mushrooming network costs for operators, the macrocell network needs to be overlaid with picocells and microcells which offload some of the network load as well as ensuring service continuity and enhance user experience. Smaller cells can bring a 1600x increase in capacity[1] as compared to other methods like improving spectrum efficiency, increasing cell site power levels etc. The cost of adding macrocell overlays using picocells and microcells is minimal compared to that of using macro base stations for the same purpose. While the cell size diameter in dense metropolitan areas is approaching 500m or less, operators will benefit from using cheaper picocell and microcell architectures instead of deploying traditional base station equipment.

Figure 1.2 The Importance of Macro, Micro, and Picocells in the New Network



(Source: ABI Research)

Although picocells and microcells are considered as fill-ins in today's network, they need to be seen as essential elements in any future blueprint. These can be considered as clusters of small cells built into the network architecture. Instead of the network growing organically with network usage, operators could pay the price if they do not engineer their networks with picocells and microcells from the start. The best example is AT&T in the US who has been facing network issues, most of which is coming from their Iphone customer base, where expectations have not been able to meet network capability.

Based on simulations it has been found that in order to meeting the capacity demands for 3G/4G between 8-14 picocells and/or 3-6 microcells will be required per macro cell site.

Optimizing Site Equipment

While macrocell overlays are important, existing site costs can be reduced and network performance improved by upgrading macro base-station equipment. With each technology iteration there is a move towards compact and flatter architectures. While there is consolidation of network boxes, like the collapsing of base station controllers with the base station itself in 3GPP Rel 8, the trend is toward continuing to optimize the equipment itself, a trend that is driven by advances in silicon technology. Moving RF equipment closer to the antenna installed on the tower, referred to as remote radio head (RRH), is part of that trend. The primary motive is reducing power consumption at the site, as well as reducing maintenance and installation costs.

The remaining baseband unit (BBU) is another target of highly integrated silicon system-on-chip (SoC) technology, as evidenced by several new product announcements recently.

Compact Base Stations

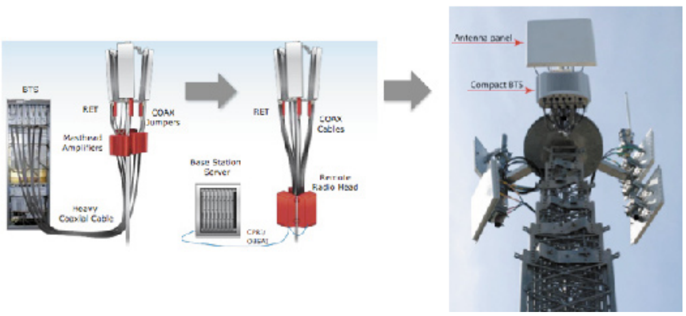
The emergence of compact base stations is an outcome of the underlying trends in the new RAN architecture paradigm. It is aimed towards specific pain points in current RAN architecture, namely the need for

- macrocell overlays and eventually clusters of picocells and microcells

- optimizing existing macro layer equipment

As Figure 1.3 illustrates, the architecture has evolved from traditional integrated base stations to distributed remote radio heads and is now moving to a compact and passively cooled base station architecture.

Figure 1.3 Evolution of Traditional, Distributed and Compact Base Stations



(Source: Ubidyne, Purewave)

Site Classification

The compact base station is a scalable platform that can fit into multiple site classifications, ranging from picocell to microcell and macrocell applications. Each site has its own specific equipment characteristics that are required for that specific site. In this ABI Research white paper we summarize this new class of equipment under the term "Compact BTS."

With each site-specific classification scheme comes a specific set of requirements, such as cell size, max. number of subscribers, total required site capacity, and so forth. In turn, these requirements drive the definition of the capability set of a suitable Compact BTS for that type of site, *e.g.,* the RF output power, which is largely determined by site location and targeted cell size. Finally, the capability set then determines suitable Compact BTS specifications, such as type of PA, heat dissipation, physical form factor, and so forth.

Table 1.1 shows the typical characteristics required for different site classifications.

Deployment Scenarios

The deployments of pico-, micro-, and macrocells vary and are meant to service a certain operator need. Macrocells are deployed on specific cell sites within a cabinet or on rooftops typically using a cabinet or climate-controlled enclosure.

Compact BTS are more flexible, as they do not need shelters or cabinets, and can thus service different needs depending on deployment needs and site classification.

Traditional Macro Sites and Remote Radio Heads

Traditional macro sites are on rooftops or at a designated cell site that has a tower mast installed with a cabinet enclosure. This is the most common cell site classification and is the traditional approach to building mobile networks. Traditional macro sites typically have the baseband and radio units enclosed in a cabinet enclosure with the antenna on a tower mast. The cabinet is then connected using a coax cable. This architecture is being transformed with the introduction of remote radio heads (RRH).

Table 1.1 Site Characteristics for Compact BTS in Pico-, Micro- and Macrocells

Characteristics	Picocell (outdoor)	Microcell	Macrocell
Capacity (carriers)	1 carrier, 1sector	1-3 carrier, 1-3 sectors	3-6 carriers, 3 sectors
Output Transmit Power	1-2W	2-5W	10W and above
Coverage Radius	0.5-1 km	1-3 km	1-25 km
Size (average)	20x30 cm	40x30 cm	50x60cm
Weight	2-4 kg	4-6 kg	10-15kg
Typical Deployments	Indoor and Outdoor, Lamp posts, Building Walls, Utility Poles	Building Walls, Roof tops, Outdoor, Utility Poles	Tower masts, Roof-tops, Outdoor

(Source: ABI Research)

RRH combine multiple elements of the RF portion of the base station in a single box. Typical RRH consists of the LNA and the Power Amplifier, TDD Switch or Duplexer, Up and Down Converters, Analog to Digital and Digital to Analog Converters, I/Q Optical Interface, and some degree of OA&M processing.

RRH typically supports a single sector and attaches onto the tower mast adjacent to the antenna, and connects to the baseband at the bottom of the tower enclosed in a cabinet. This connection is made with a fiber optic cable. The primary aim of this architecture is to reduce losses from antenna to RF portion improving performance and lowering power consumption.

New Compact BTS architectures can allow for the RRH to be combined with a baseband processing unit in a single passively cooled unit, eliminating the need for a shelter or cabinet enclosure at the bottom of the tower. This brings on additional savings on the site, and further improves performance. With this new architectural paradigm, multimode, multi-frequency, software defined capability becomes mandatory as maintenance and upgrade of equipment on the tower mast is cost prohibitive.

New Sites: The Metrozone

Picocells are deployed both indoors (inside buildings) and outdoors to offer uniform coverage and capacity, while microcells and macrocells are typically deployed outdoors, with the exception of indoor DAS systems, not considered in this white paper. Due to their small size and weight, picocells are typically seen deployed on lamp posts or on building walls. Microcells are slightly heavier boxes and therefore typically do not go onto poles or lamp posts. These are also mounted on the side of buildings or on roof tops.

With the role of picocells and microcells moving from that of fill-ins to that of providing primary coverage and capacity in a network there are some additional characteristics that need to be included like that of multi-mode support, multi-frequency support, flexibility in capacity and power, and redundancy features. Compact BTS are expected to service these needs for new Metrozone sites, which fall under the micro or pico category.

Base Station Metrics

The new RAN architectural paradigm uses different base station metrics compared to traditional 2G and 3G base stations (illustrated in Table 2.1). There is a marked difference in the equipment size, equipment cost, power consumption, installation, and TCO that will allow operators to largely decouple network costs from exploding network traffic. Table 2.1 clearly demonstrates the advantages of moving towards using more Compact BTS.

Table 2.1 Base Station Metrics by Technology

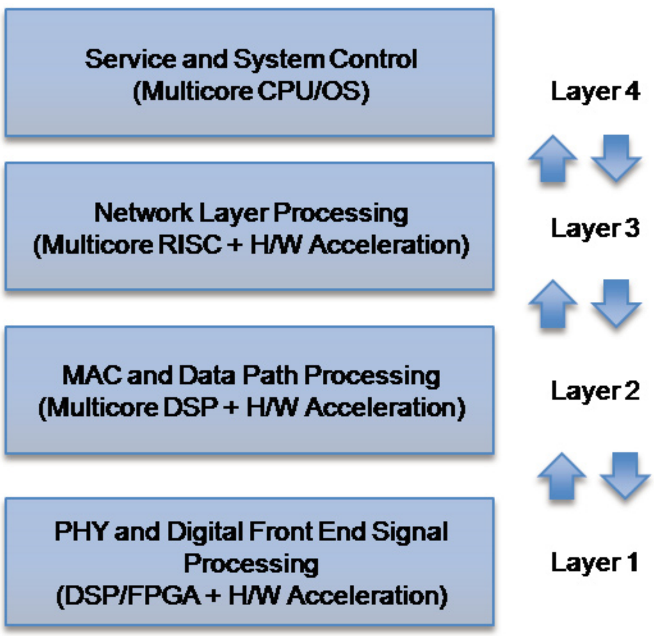
Characteristics	Traditional 2G BTS	Traditional 3G BTS	Next Generation 3G/4G BTS	
Equipment Type	Integrated Cabinet	Integrated Cabinet	Distributed (Cabinet + RRH)	Compact BTS
Macro, Micro, Pico	Mostly macro base stations with micro base stations as fill-in	Mostly macro base stations with micro base stations as fill-in	Mostly macro cells	Macrocells, Microcells and Picocells
Base Station Equipment Cost (including equipment, antennas, cabinets)	$50,000-$60,000	$50,000-$60,000	Approximately 5% more than integrated base station	Between $2000-$15,000 for a pico, micro or macro Compact BTS
% of Shelter/Cabinet Costs	10-20%	10-20%	5%	0%
Equipment Size	Heavy and Bulky	Heavy and Bulky with compact single-cabinet version (Micro)	Compact RRH with a 1U/2U BBU rack unit	Small and Compact. Pizza Box or Wireless router size
Power Consumption	1000-1500W	500-1000W	20% lower power consumption due to RRH compared with traditional integrated cabinet BTS	Pico – 15-50 W Micro – 40-120 W Macro – 120-180W
Installation and TCO	30-40% additional costs from equipment cost	20-30% additional cost from equipment cost	Lower site rental cost but additional cost of fiber connection to RRH	No shelter or fiber/coax connectivity costs

(Source: ABI Research)

Chipset Approaches for Compact Base Stations

With new metrics required for next generation compact single box base stations, chipset suppliers are using different approaches to achieve those metrics. The two key approaches in use are the DSP/ASSP/FPGA and the SoC approaches.

Figure 2.1 Compact base station Chipset Processing Layers



(Source: Ubidyne, Purewave)

DSP/FPGA/Network Processor Approach

In this approach the baseband processing is split between different processing elements and a separate RF chipset is then connected to the baseband processing unit. Typically DSPs are used to handle uplink and downlink processing for Layer 1. Then, FPGAs are used for the network interfaces for the RF and backhaul transmission ends. FPGAs are also used for high-end processing tasks such as turbo decoding, DFT, FFT, RACH, and so forth. RISC processors or Multicore DSPs are used for Layer 2 and higher such as MAC scheduling, RLC, board control and so forth. While this approach is the most common bottleneck issues occur when transferring data between the DSP, FPGA, and Network Processor elements, especially when dealing with processing intensive technologies like LTE that use MIMO or have higher bandwidths.

System on Chip (SoC)

With advancement of semiconductor technology and smaller geometries, chipset vendors have been able to combine multiple elements that are separated across DSP, FPGA, and Network Processor on their multi-core chipset platforms. While the baseband elements are combined on the SoC, the RF chipset is separate, while the RF interface element is integrated within the chipset itself. The bottleneck in this approach is the data backplane that connects the various baseband cores of the chipset. However, the bottleneck is reduced because all the processing is done on the same chipset.

Some of the leading vendors working on a single chipset platform include Mindspeed Technologies, Texas Instruments, Freescale, Xilinx, and DesignArt Networks. Texas Instruments and Freescale are traditional DSP vendors in the wireless base station space pushing for a single-chip DSP solution, while Xilinx is a FPGA vendor pushing for a single FPGA solution. Mindspeed and DesignArt are non-traditional chipset vendors combining multiple elements of the SP/FPGA/Network Processor approach on a single-die solution.

The SoC single-chip approach is better equipped to meet the challenges for Next Gen RAN equipment those of which are described in Table 2.2 below.

Table 2.2 List of Hardware Requirements for Compact BTS Equipment

Challenges	Hardware Requirements
Multimode Capable	Software-defined reconfigurable chipset
Multi-frequency Capable	Wideband, multi-carrier with support of flexible RF Components
Low Latency	Reduce data transfer bottlenecks on chip
High Throughput and Bandwidth	MIMO capable, higher channel bandwidth support
Cell Size Heterogeneity	Scalability across macro, micro and pico form factors – same operational SW and service network behavior.
Low Power Consumption	Support of high-output, discrete PA and low-cost PA-IC technologies, overall reduction in power loss of base station subsystem
Low TCO and Installation	Very low MTBF and system complexity, SW-automated installation and operational support (e.g. SON). Full in-field SW-upgradability on all layers.

(Source: ABI Research)

Single-chip SoC Approaches

A number of vendors are working towards a compact base station architecture, mentioned below.

Mindspeed Technologies

Mindspeed is a semiconductor technology provider that focuses on communications markets for enterprise, metro, access and wide area networks. In the wireless baseband space, Mindspeed offers a baseband SoC known as Transcede 4000 that are targeted at WCDMA, LTE, and WiMAX base station markets. Transcede is a multi-core processor that uses a combination of DSP cores, RISC processor cores, and ASIC/co-processor cores, combined with hardware accelerators. The Transcede 4000 series processor provides L1, L2, and L3 processing including PHY, MAC, and network layer processing. It also has two IP/Ethernet interfaces and 4 TDM interfaces.

Transcede is available in two variants: 600 MHz and 750 MHz, which have a power consumption of 12 and 15W respectively. The 600 MHz processor can handle processing needs of 3 sectors of 10 MHz 2x2 MIMO. The 750 MHz processor can handle 2x2 MIMO for 20 MHz bandwidth. Both of the chipsets are also good for running HSPA supporting 144+ HSPA active users on one chipset with a full duplex data rate of 40 Mbps.

The Transcede processor is multimode and software defined, two essential characteristics for compact base stations. ZTE is known to be trialing Transcede's 4000 series processors for its WCDMA, LTE, and WiMAX base stations.

Texas Instruments

Texas Instruments (TI) is known for its DSP (Digital Signal Processing) solutions that are specialized processors used in high-end signal processing applications, one of which is wireless base stations. In February 2010, TI announced a new multi-core SoC architecture with a CPU performance of 1.2GHz that can be applicable for wireless base stations, media gateways, and video infrastructure equipment. Instead of using separate FPGAs and ASSPs, TI suggests transferring all the baseband tasks onto a single multi-core DSP. The company's latest approach is using a 4-core architecture for wireless base stations, although it can go up to 8 cores. Each core will be able to achieve floating point computations of 32 GMACS or 16 GFLOPS. The floating point capability is useful in 4G with MIMO applications and layer 2 scheduling as well as non-requirement of conversion of code to fixed point, thus speeding up tasks. With this new chipset TI has introduced a multi-core navigator system that deals with hardware queues and scheduling. There are additional methods used to make internal data transfer on the chip itself more efficient.

TIs traditional multi-core SoCs for wireless infrastructure are known as the 648x series and includes 3 chips: TCI6487, 6488 and 6489. The new chipset is more of an architectural change, but the first chipsets are only likely to be available towards end 2010. TI's multi-core chipset is also multi-standard capable and support technologies from WCDMA to LTE and WiMAX. It can also fit into multiple form factors from picocells to macrocells.

Freescale

Freescale is another leading baseband processor vendor in the wireless base station space. Freescale's latest chipset is a 6-core DSP solution known as MSC8155; it provides 6 GHz of performance and uses specialized hardware accelerators to handle high bandwidth 3G and 4G technologies and Turbo/FEC coding that were earlier performed on FPGAs. The solution also comes with Serial RapidIO interfaces for high throughput data transfers. The chipset will become available in Q3 2010.

Xilinx

Xilinx is a leader in FPGA devices and provides components for wireless base station platforms. Xilinx's FPGA solutions are typically used in collaboration with other DSP or ASSP products in a base station platform. However, for next gen 4G platforms such as LTE, Xilinx has introduced its latest Virtex FPGAs as being capable of supporting all the digital radio processing instead of being supported on different DSP and ASSP chipsets. The Virtex-6 LX75T is able to combine all the various tasks such as L1, L2/L3, and above on a single chipset. The Xilinx chipset is also technology agnostic and can support multiple technologies like LTE and WiMAX.

DesignArt Networks

DesignArt Networks is a fabless semiconductor company that focuses specifically on wireless radio access network infrastructure equipment. It provides system-on-chip (SoC) platforms for 2G, 3G, and 4G networks, such as GSM, HSPA, WiMAX, TD-SCDMA, and LTE. DesignArt networks aims to provide low-cost scalable single-SoC product solutions for various RAN applications – targeting base stations, mobile backhaul (PtP) and RRH product solutions with the same SoCs.

Currently, DesignArt is offering the DAN2000 SoC platform that aims at the mobile WiMAX RAN market. Two products are available in the DAN2000 family: the DAN2200 for Femtocell applications and the more scalable DAN2400 for all other product solutions. Released end of 2008, the DAN2400 platform is just now being installed in WiMAX networks globally, in what could be considered some of the first product examples for Compact BTS equipment.

Recently, DesignArt announced the DAN3000 SoC product family, planned for availability in Q3 2010. The DAN3000 family delivers more than 1 Gbps in PHY and MAC performance, with much extended PHY and digital front-end (DFE) SW capabilities. It is a fully SW-defined multi-carrier, multi-sector, and multi-technology capable platform that can support both FDD and TDD standards. It has a larger number of ARM, RISC, and DSP cores in support of what the company claims to be true 4G capacity and service capabilities. The DAN3000 family is designed for the support of up to 16 carriers, with a combined maximum channel bandwidth of 40 MHz or 80 MHz, for the evolution from 2G to FDD- or TD-LTE, and eventually to IMT-Advanced technologies. The DAN3000 provides multi-sector support, *e.g.*, with an option of 4 LTE or 8 LTE sectors from a single SoC, consuming less than 5W.

The multi-standard, multi-mode approach allows DAN3000 to support a combination of GSM/HSPA and FDD-LTE concurrently, or alternatively TD-SCDMA/WiMAX and TD-LTE. DesignArt also provides integrated wireless backhaul and multi-hop relay SW for its chipsets, essentially allowing for standard LTE relay and non-standard in- or out-of-band self-backhaul.

Compact BTS Shipment Forecasts

The forecasts in this section focus on 3G and 4G technologies such as HSPA, LTE, and WiMAX.

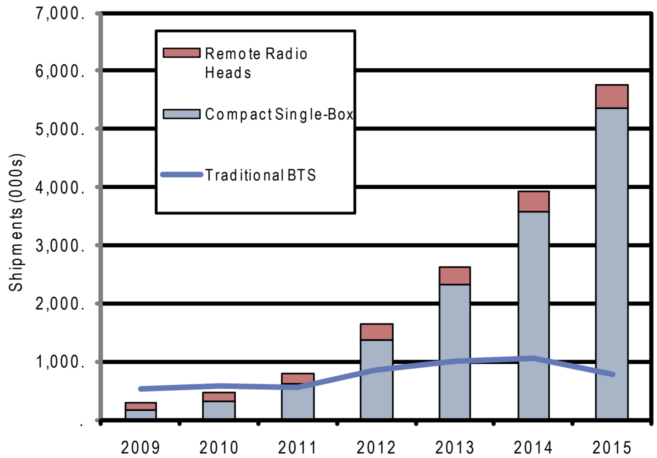
The changing network architecture paradigm suggests a shift in the architecture of base stations from traditional base stations (integrated cabinet radio heads) to distributed base stations (remotely mounted radio heads) and towards the growing use of Compact BTS units as described in Section 1.2.1.

The primary drivers for this transition will be the increasing demand for data services, the increasing gap in peak and average throughput for 3G/4G technologies, and the cost savings in deploying Compact BTS equipment in terms of both OPEX and CAPEX. Advances in multi-core chipset technology (explored in Section 2) allow for the development of multi-mode Compact BTS platforms that can bring femtocell-like cost and deployment efficiencies to macro-, micro-, and picocell architectures, and will kick start this transition around 2011 to 2012. While it is assumed that operators will initially deploy Compact BTS equipment as in-fills on the pico- and microcell layer, they will quickly transition to being deployed as a fundamental part of the network rollout. An additional market opportunity will be transitioning high-output remote radio head installations on the macrocell level to the deployment of multi-technology Compact BTS equipment.

Global Shipments

Chart 3.1 compares base station shipments for Compact BTS equipment (as described in Section 1.2) with traditional base stations that have an integrated radio unit within the cabinet.

Chart 3.1 3G/4G Shipments for RRH, Compact and Traditional BTS – Global Forecast 2009-2015



(Source: ABI Research)

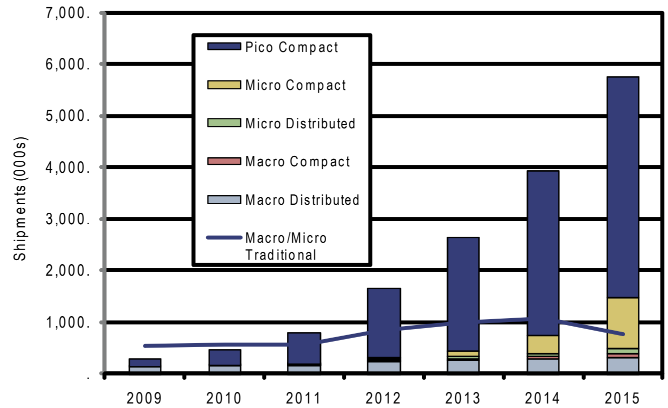
Also compared are remote radio heads, which will replace traditional base station shipments in the forecast period. Remote radio heads will primarily be deployed in the macro base station layer with a gradual move towards a Compact BTS architecture which will attach as a single box on the top of a tower, a wall or lamp post. Compact BTS equipment will outpace shipments for remote radio heads and traditional base stations, reaching 5.3 million units by 2015. By 2015 it is expected that traditional base stations will start to decline giving way to both distributed and Compact base stations.

Shipments by Classification and Technology

Charts 3.2 and 3.3 showcase the breakdown of 3G/4G base station shipments by technology and site classification. The site classification is across macro, micro. and pico and further divided by type of base station such as traditional, distributed, and compact. In total the seven categories are:

- Macro Traditional and Micro Traditional: Traditional macro and micro base stations that have the baseband and radio head in a cabinet
- Macro Distributed and Micro Distributed: Distributed macro and micro base stations that use remote radio heads
- Macro, Micro, and Pico Compact BTS: The new category of compact, single-enclosure base stations.

Chart 3.2 3G/4G Shipments for Distributed and Compact BTS by Site Classification: Global Forecast 2009 to 2015



(Source: ABI Research)

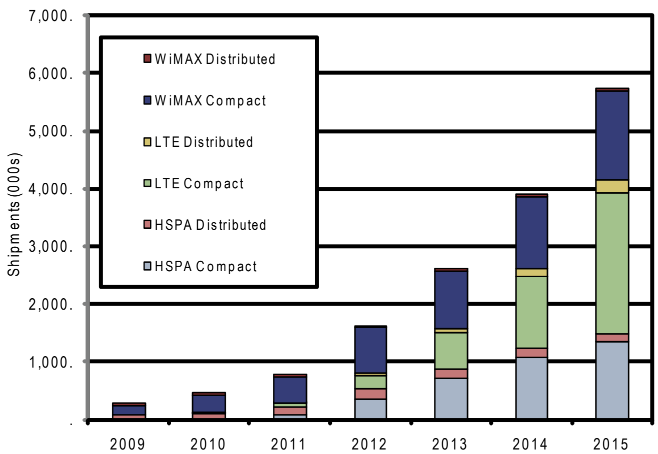
Within pico it is assumed that no distributed architecture exists, where traditional discrete pico base stations will be immediately replaced by Compact BTS equipment, due to the much lower cost, size and deployment flexibility of the equipment. Indoor pico base stations are not included in these forecasts, with the focus solely on outdoor picocells.

Picocell Compact BTS equipment will make up the largest proportion of the Compact BTS market, with microcell Compact BTS growing in share significantly, but more slowly. By 2015, picocell Compact BTS shipments are expected to reach 4.3 million units, while microcell Compact BTS will reach 0.9 million shipments. Picocell Compact BTS are ideally suited to reduce the gap between peak throughput and average throughput, are the most flexible in terms of cell site selection, and are also the lowest cost amongst all three categories. The rise of microcell Compact BTS will be primarily due to the market extension of traditional micro base station deployments, and their evolution towards much more cost-effective microcell Compact BTS.

Microcell Compact BTS equipment will probably also be used as "hubs" in the backhaul architecture of picocell Metrozones, where they provide high-capacity wireless backhaul facilities to surrounding picocell clusters.

Chart 3.3 shows that the shipments are split by technology. WiMAX will dominate shipments in the earlier part of the forecast period, due to a larger established footprint and an active ecosystem of vendors that are working on compact base stations; however by 2015, LTE and HSPA compact base stations will make up the majority of the shipments.

Chart 3.3 3G/4G Shipments for Distributed and Compact BTS by Technology: Global Forecast 2009 to 2015



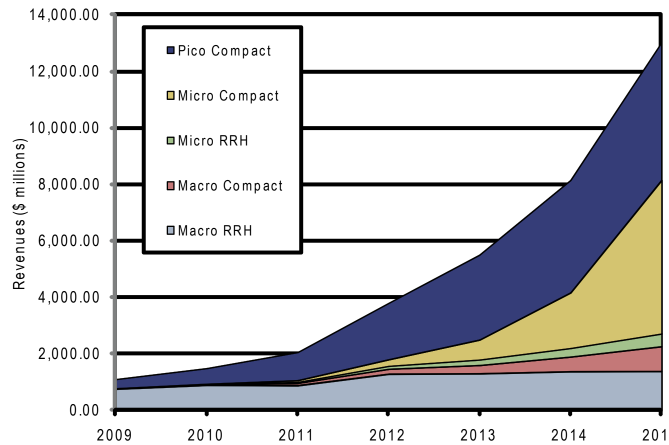
(Source: ABI Research)

Revenues by Site Classification

The total revenues for pico-, micro-, and macrocell Compact BTS equipment and distributed base stations for 3G/4G are expected to reach $13 billion by 2015 as shown in Chart 3.4. This number represents the total revenue opportunity for the new RAN architectural paradigm and is expected to kick start a brand new and incremental market in the 3G/4G wireless infrastructure space, with a large opportunity for chipset suppliers and OEMs that cater to this emerging market.

Microcell Compact BTS equipment will take a larger proportion of the revenues due to their higher cost than picocell Compact BTS. By 2015, microcell Compact BTS revenues are expected to reach $5.4 billion, while picocell revenues will reach $4.9 billion.

Chart 3.4 Revenues for 3G/4G RRH and Compact BTS by Site Classification: Global Forecast 2009 to 2015

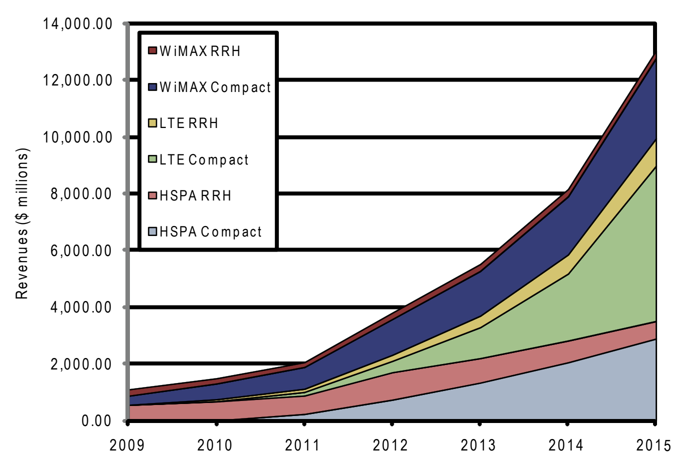


(Source: ABI Research)

Revenues by Technology

LTE Compact base stations (pico-, micro-, and macro) will make up the largest proportion of the revenues by 2015 reaching $5.5 billion. Both HSPA and WiMAX compact base stations (pico-, micro-, and macro) will see each of their revenues reach $2.9 billion.

Chart 3.5 Revenues for 3G/4G RRH and Compact BTS by Technology: Global Forecast 2009 to 2015



(Source: ABI Research)

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