Evolution of the Wireless Base Station - Meeting LTE Capacity and Coverage Requirements

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The wireless base station has evolved from a bulky rack-full of equipment to multiple form factors targeted at different deployment scenarios. Fourth generation technologies like LTE, and end user behavior which are driven by mobile Internet, set specific capacity and coverage requirements that network operators strive to meet within budgetary constraints to enable a profitable business case. Today, base stations now come in different forms presenting the operator with different deployment options, each with its pros and cons.

In my opinion, the most significant development that occurred in the design of base stations is the acceptance of operators to deploy outdoor remote radios. Operators were historically averse to deploying active equipment on tower-tops since it implied loss of redundancy (or higher expense to achieve redundancy) and higher risk of service interruption (due to environmental elements such as lightning).

As this barrier is broken, there is more tolerance to integrate baseband functionality into the remote radio to form pico and micro base stations that present a simple, low cost form-factor which fits well into the 4G deployment model driven by high capacity requirement and ubiquitous coverage expectation.

Today, two different base station architectures have emerged, each with its own variants and points of differentiation: the first is the split architecture with indoor baseband unit and remote radio module (i.e. distributed) base station, and the second is the all-outdoor, zero-footprint base station.

Distributed Base Stations

The modern split-architecture base station has evolved to combine multiple sectors in one indoor unit platform (such as a pizza box or a shelf in a small chassis). The base station architecture is often based on standards like CPRI and OBASI which define the functional modules of the base station (e.g. baseband, power, transport, control and remote radio modules in OBSAI) and the interfaces between these modules to facilitate integration and interoperability between third-party vendors.

By including multi-sector operation into one indoor unit, cost is reduced by sharing components and sub-systems (e.g. power subsystem) that otherwise would have to be replicated if each sector was designed in a separate physical unit. The interface between the indoor and outdoor unit is often optical fiber which has the advantage of high-bandwidth, low loss, and sufficient mechanical flexibility to allow deployment of the remote radio at large distances from the indoor baseband unit (several kilometers).

A variant of the split architecture base station is based on standardized chassis like microTCA. This architecture is capable of holding a higher number of base stations or sectors and is used often as a ‘distributed antenna system’ (DAS) where remote radios can be deployed in multiple locations (a deployment scenario often referred to as 'base station hotelling').

This type also allows ‘infrastructure sharing’ where several operators share the base stations. These deployment scenarios save capital (e.g. civil works) and operational expenditures (leasehold, support and maintenance expenses).

Distributed base stations typically provide high output power, support multiple frequency carriers (hence large capacity), and serve large number of subscribers due to high baseband processing power and provisioned memory capabilities – the baseband processors are often programmable devices such as FPGAs and DSPs. Distributed base stations are typically classified as ‘macro’ base stations.

Single Form-Factor Architecture

Single-form factor base stations integrate baseband and radio functionality into a single mechanical enclosure that functions as a single sector. This architecture eliminates interface components and cables between indoor and outdoor units and integrates common subsystems required for the baseband and radio functions, such as power and mechanical components.

The absence of indoor module obviates the need for temperature control systems required for distributed base stations (e.g. heaters and AC units). Furthermore, an outdoor unit weighing less than about 15 kg allows for a ‘one-man’ install which reduces deployment time, complexity and expense.

Single form-factor base stations typically feature lower output power than distributed base stations, mainly as more components (baseband processors, memory, etc.) in the outdoor unit increase the thermal load and push against the limits set by the desire of low weight and small volume mechanical unit. They are also provisioned to support a smaller number of subscribers. The baseband processor is typically a System on Chip (SoC) which allows for cost reduction by integrating several functions required in a base station (such as synchronization, different types of standardized interfaces, memory, etc.).

In all, higher integration and small form-factor provides the network operator with a low capital and operational expense deployment model.

LTE Deployment Models

Capacity and coverage requirements for LTE indicate the necessity of deploying a high-density grid of base stations. In an urban area, six 1-Watt base stations mounted at 12 meters above ground provide equivalent coverage to a three-sector base station of 10-Watt output power mounted at 30 meters, but with 6-time the capacity.

As output power capabilities of single form-factor base stations increase, they are becoming competitive from an overall business case perspective with distributed base stations, notwithstanding backhaul requirements (a very important element to be addressed in a future posting). Noting that the throughput capability of both types of base stations is the same – it is a function of air interface capabilities – a number of deployment options become available to operators which allow leveraging the low-cost, quick deployment benefits of single-form factor base stations or the high scalability of distributed base stations.

As the wireless base station evolves, the trend would be towards greater power and integration for single form-factor base stations to further improve the business case, and for greater scalability and capacity for split-architecture base stations to remain competitive on cost. Along this continuum, different types of base stations will carve a niche for certain applications such as coverage and capacity fill, or indoor enterprise use case.

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