The DNA of Small Cells

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INTRODUCTION

According to the definition put forward by Wikipedia, deoxyribonucleic acid (DNA) is a molecule that encodes the genetic instructions used in the development and functioning of all known living organisms. But what exactly does this have to do with the small cells used in today's mobile networks? Because each small cell deployment has its own characteristics based on a fixed list of components, the DNA correlation is relevant. Now, before we go about sequencing cellular networks, let's take a look at their morphology.

Macrocells form the core of the cellular network. Macrocells typically have a range of several kilometers and cover three transmission and reception sectors. Due to the large coverage area, the capacity of this cell is limited at the edge. Given that large volumes of users are able to connect to macrocells, the capacity is divided between all active users. As a result, the throughput falls rapidly well below users' expectations.

To help alleviate some of the congestion, smaller, more cost-efficient cellular base stations known as femtocells were developed. With the deployment of femtocells within larger micro/metro cells, a revised delivery mechanism was created to reduce congestion and provide better quality of experience (QoE) to all users. As shown in Figure 1, small cells range in size, with some as small as residential femtocells covering a range of 20 m for four to twenty users, and a capacity of 40 Mbit/s (depending on the broadband access). Small cells can also be as large as micro/metro cells with a range of 2 km for more than 100 users, and a capacity of 100 Mbit/s.

Small cells will play a key role in the increased capacity of mobile networks. Although macrocells and small cells will continue to be deployed in cellular networks, their design will be relatively different. For starters, small cells should not be mistaken with small-footprint macrocells. To ensure that large number of network elements would be provided to service providers at a minimum cost, a number of compromises were made in order to create small cells.

	LTE Cell Type	Typical Cell Range	Typical Power (Tx) Output	Capacity (in Mbit/s per km^2)	Typical Number of Users
	Macrocell	800 m to several km	3 x 40 W	24+	>256
	Micro/Metro Cell	700 m – 2 km	2 x 5 W or 10 W	50+	>100
Small Cell	Picocell	300 – 500 m	2 x 1 W or 2 W	260+	30 –100
	Femtocell – Enterprise	100 m	100 – 250 mW	1 Gbit/s	32 – 64
	Femtocell – Residential	20 m	10 mW	40+ per household	4 – 20

Figure 1. The Cell Types Available in LTE Networks

ANATOMY OF A SMALL CELL

Figure 2 presents a block diagram of a small cell. The design of a small cell must respect its requirements for power, footprint, capacity (voice and data) and coverage. The processor and related management port form the core of every network element. Multiple challenges are inherent to designing small cells at a very low cost, which usually means that processors are selected in line with the cost target of the network element. Fortunately, new system-on-a-chip (SoC) processors help meet these requirements at the design stage.

In the case of small cells, the RF modulator/demodulator uses the required scheme to connect with mobile devices. Accordingly, service providers require that small cells support two modes of operation, namely 2G/3G or 3G/4G. Although many baseband processors are missing the hardware capability required to support two modes of operation, this capability can be implemented using SoC processors.

The next important aspect of small cell design is connectivity. A small cell must have input interfaces for clock synchronization, backhaul connectivity through wired or wireless access, and finally, power.

The least problematic of these blocks is the one representing power. Based on the application in question, power can be AC or DC, and is usually not difficult to supply. The most important blocks are the two representing network and clock input. Depending on the RF technology used by the small cell, the clock input will have to supply frequency synchronization or frequency and phase synchronization. Also, based on the technology adopted, small cells may require greater clock input accuracy than macrocells.

Subject to the network technology being used to supply backhaul connectivity to the small cell, it may be possible to leverage it in order to provide clock synchronization in addition to backhaul bandwidth.

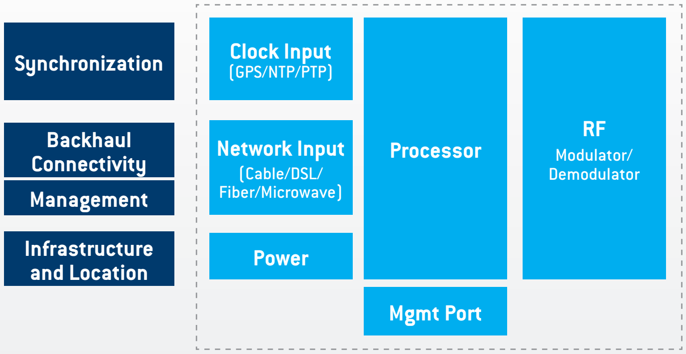


Figure 2. Anatomy of a Small Cell and Related Challenges

The navy-blue boxes shown in Figure 2 are aligned with the connectivity boxes, and represent the various challenges inherent to small cell deployment. These challenges will differ for each deployment, as will the manner in which they are addressed, hence our reference to “the DNA of small cell deployment.”

THE DNA OF A SMALL CELL DEPLOYMENT CAN BE SEQUENCED AS BSIM

Without going into a long lecture on molecular biology, suffice to say that most DNA structures can be described as double helices created from an alignment composed of the nucleobases adenine, thymine, cytosine and guanine (which are recorded using the letters A, T, C and G). Given that the DNA sequence can be transcribed as ATCG, we could in turn transcribe small cell DNA as BSIM, based on the components of its core structure (shown in Figure 2), i.e., backhaul connectivity (B), synchronization (S), infrastructure and location (I), and management (M). As discussed in the latter part of this white paper, each component of a small cell deployment greatly influences the overall design, giving it unique characteristics.

Backhaul Connectivity

Backhaul connectivity to the small cell can be challenging from both an engineering and cost perspective. A very large proportion of the OPEX associated with small cells relates specifically to backhaul deployments. If the backhaul network could somehow be shared, with bandwidth dynamically provisioned to the small cell requiring the most capacity before being sent on to others as needed, the benefits would help make a business case for small cells.

Looking forward to the future of small cell backhaul data rates, we are in for an explosion. The typical backhaul rate for Wi-Fi hot spots is around 2 Mbit/s, with a maximum of 8 Mbit/s even if the connection to the devices is possible at higher rates. Accordingly, 3G and 4G service providers will not want to limit their small cell backhaul link, and will therefore likely be requiring 42 Mbit/s for 3G, and 100+ Mbit/s for LTE cohosted within the same small cell. These speeds will raise the issue of whether the backhaul network should be designed for maximum rates or for typical average demand levels.

This in turn raises the question of what technology should be used for small cell backhaul. At the outset, small cells will be deployed in densely populated areas where macrocells alone cannot provide the best wireless broadband connectivity to users. With the previously cited rate for 3G and 4G, fiber could be leveraged for backhaul connectivity. The fiber availability in some cities is excellent, but may be restricted in others. Low-cost access to fiber to the small cell will help make the business case more appealing; however, that will all change if fiber is not available at a decent price, or even worse, if it is not close enough to a particular small cell.

Other operators may “fiber-feed” a neighborhood cabinet, and then use bounded and vectored DSL lines or other techniques to connect to the small cell at rates of up to 100 Mbit/s over copper pairs. This will only be possible if copper is routed to the small cell location.

Another trend associated with small cell backhaul is the use of wireless. Although there are many issues related to deploying wireless small cell backhaul, there are also significant benefits. In consideration of the large number of small cells to be deployed, the skill level of the personnel tasked with installing them, and the short installation time required, there is a clear need for a simple and flexible solution. Knowing where the small cells need to be located, and completing the installation using power alone (without the need to physically bring the backhaul service to it) creates a tempting business case.

Small Cell Synchronization

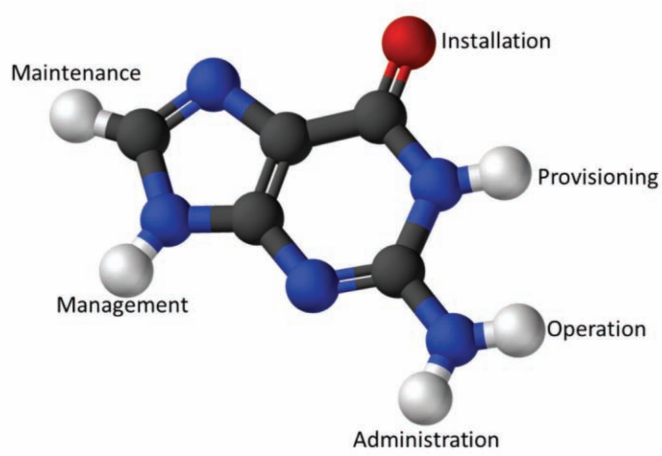
Another issue inherent to small cell backhaul is synchronization. Depending on the small cell technologies deployed, there will be different requirements for synchronization. In a metro cell environment, two technologies are widely deployed: classic GPS to all nodes and IEEE 1588v2, also known as precision time protocol (PTP). Having a global positioning system (GPS) antenna inside each small cell would be costly, and therefore impact the deployment business case. There are also issues with GPS, especially in urban areas. In particular, reflection and jamming of the GPS signal can cause outings that would not be tolerated in a small cell environment.

Using PTP, it is possible to distribute frequency and phase to the small cell through the backhaul connection. Unfortunately, PTP deployment is also prone to issues. The design and performance characteristics of the backhaul network will have a direct impact on the PTP performance and influence its network architecture. In addition, the distribution of the PTP signal must be symmetrical, because asymmetry in the distribution will cause inaccuracy in relation to the small cell’s internal clock. Proper traffic engineering of the backhaul network will minimize asymmetries and ensure effective performance of the small cell. Different deployment decisions will need to be made based on the knowledge and control of the backhaul network design and reliability.

Fortunately, it is possible to validate the capability of the backhaul network using connected test instruments to thoroughly test up to the small cell. By validating the PTP packet network synchronization services, emulating PTP clients, generating and analyzing messages between master/clients, and verifying the clock quality level and inter-frame delay variation (IFDV), service providers can be sure that their PTP synchronization network is up to par.

Infrastructure and Location

Despite not being very technical in nature, acquiring a place to hang a small cell is as much of a challenge as providing backhaul connectivity or network synchronization. Right of way and available power to the small cell are just a few of the many factors delaying project launches. The location of a given small cell is very important, especially since it is vital to removing congestion within the network. Therefore, the inability to properly position the small cell will impact its performance.



Management

The last and most important component of any network deployment is management. In the context of the DNA of small cell deployment, management will consist of all engineering and operational aspects related to a given small cell deployment. As shown in Figure 3, management therefore encompasses the provisioning, installation, operation, administration, maintenance and management of the small cell network. Without delving into the details and specifics, all of these elements can be considered important factors that are crucial to delivering and maintaining a small cell network.

With infrastructure and location, management is the most likely component to be the determining factor in the success of small cell deployment. The ability to rapidly provision and install the backhaul connectivity, coupled with the vast number of small cells, makes it possible for service providers to reduce the amount of OPEX spent on deployment. If the deployment process is properly implemented and the installation crews have the tools and knowledge required to accomplish their tasks, service providers will be able to bring a high-quality network into service. By adding a state-of-the-art monitoring system, service providers will have the means to detect network issues and act on them immediately, thus minimizing the time required to repair networks.

TESTING AND MONITORING SOLUTIONS TO BE USED DURING THE LIFECYCLE OF A SMALL CELL NETWORK DEPLOYMENT

From installation to maintenance, the lifecycle of a small cell network can get complex. Various optimized solutions can be leveraged to provide an advanced test architecture that will help reduce and ultimately eliminate complexity.

The first solution relates to backhaul connectivity. If fiber is leveraged for the backhaul connectivity to the small cell, it will need to be characterized. Having access to confirmation that the fiber is correctly installed and a record of its properties at installation can be very useful, especially if any issues arise down the road.

As applicable to any fiber connection, a large majority of the issues detected during the lifetime of the fiber network are connector-related. Inspection tools ensure that connectors and adapters are clean and exempt of defects, and for this reason, the cleaning procedure is the starting point for accurate network testing. Link characterization is also applicable to copper connectivity. Again, a TDR trace of the copper circuit will be extremely useful during troubleshooting.

The next step in the installation process consists of validating that the backhaul services are working according to design. Measurements based on ITU-T Y.1564 ensure that the Ethernet services and network synchronization are working as planned.

Once a service is turned up, the monitoring system continuously collects, correlates, analyzes and visualizes critical quality of service (QoS) and QoE data from the network core to the small cell using numerous methods, including industry-standard protocols such as Y.1731 and two-way active measurement protocol (TWAMP). This process enables operators to identify, diagnose and quickly resolve network and service issues before customers are affected, thereby guaranteeing performance and customer satisfaction.

When providers leverage best-effort data delivery systems (such as Ethernet) for their services, real time service-level agreements (SLAs) are a requirement. A correlation and analysis software engine equipped with performance and quality information capable of producing advanced analytics and visualization (real-time dashboards, historical reports and customer portals) is needed to manage and continually meet SLAs. By generating reports that address the needs of a broad audience ranging from technical to executive-level experts, they provide the business intelligence needed for the organization to be successful.

By continually monitoring the performance and quality of Carrier Ethernet and IP transport, in addition to real-time IP services, monitoring systems are the most powerful, scalable and versatile solutions currently available.

Finally, a cloud-hosted advanced test infrastructure consisting of connected smart test instruments, applications and asset management functions enables automation of day-to-day work. Based on a set of standards-based measurements, but enhanced with greater functionality, this advanced test infrastructure improves on the methods and procedures used by service providers to reduce costs associated with inefficiencies. A cloud-based test management system provides an automated, secure environment that links test instruments together and centralizes captured data across the organization. With its powerful correlation engine, an advanced test infrastructure makes it possible to convert captured data into actionable information through customized test-data reporting and features that streamline test operations from build-out to maintenance.

SUMMARY

The technology related to small cell deployment is not very complex, given that most of it was previously validated during the deployment of macrocells. Similar to the DNA content in cells, the BSIM components that make up the DNA of small cell deployment are known and understood. The increasing complexity of a small cell deployment is exemplified by the vast number of small cells to be deployed. When addressing each component of a deployment, service providers need to simplify the process to ensure that OPEX costs are kept to a minimum, thereby ensuring the commercial success of the deployment.

Understanding the DNA of small cell deployment is a core factor to success. Likewise, access to an advanced test architecture and monitoring system can be catalytic to this success.

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  ISO 9001 2008 Printed in Canada 14/04