Small Cell Technology, Big Business Opportunity

The continually growing popularity of accessing applications and associated content located within data centers over mobile networks continues unabated, with no signs of slowing in the coming years. This growth is forcing Mobile Network Operators (MNOs) to continually expand their mobile networks, which creates a significant and timely opportunity for improvements to the mobile backhaul technology currently being used. As MNOs update their Long Term Evolution (LTE) and LTE Advanced (LTE-A) wireless networks to accommodate the growing demand for packet-based mobile data services, a concurrent upgrade to the mobile backhaul part of their networks is required to handle the ever-increasing bandwidth demands of mobile end-users, whether man or machine, with the latter related to the burgeoning Internet of Things (IoT) and associated Machine-to-Machine (M2M) communications over mobile networks. The proliferation of apps among mobile smartphone users— including email, video on demand, gaming, and social media— indicates that increased pressures on mobile networks will only be exacerbated in coming years. MNOs not properly prepared to address these infrastructure challenges and changes risk falling behind the competition in this hypercompetitive environment.

The Need for (More) Speed

As wireless networks are increasingly located between application end-users and associated content, the network becomes the dominant factor that ultimately dictates the overall Quality of Experience (QoE). This means mobile networks, as well as backhaul networks connecting end-users to data centers, must be fast, reliable, and cost-effective. Traffic from the large macro towers to the Mobile Telephone Switching Office (MTSO) is increasingly carried over Ethernet-based optical networks, where bandwidth increases are easily addressed by upgrading from 1GbE today to 10GbE and even higher rates in the future.

However, increasing available bandwidth on the air interface side, via antennas and radios, is more difficult than increasing optical backhaul network bandwidth.

Wireless vendors again are pushing up the Shannon limit, and are thus having a difficult time in cost-effectively extracting more bits per hertz over available wireless spectrum, meaning a new method of wirelessly accessing the global network infrastructure is required. As shown in Table 1, there has been a steady increase in wireless access speeds as cellular standards have evolved, but the theoretical upload and download speeds are rarely achieved, and in most cases, are much slower due to a variety of factors, including large distances from mobile devices to macro cell towers, line-of-sight obstructions, indoor usage, transmission signal interference, and mobile device performance limitations. One method of achieving faster wireless speeds is to bring the end-users and their mobile devices closer to the mobile network radios for vastly improved access performance.

	Standard	Download	Upload
2.5G	GPRS	114 Kb/s	20 Kb/s
2.75G	EDGE	384 Kb/s	60 Kb/s
3G	UMTS	384 Kb/s	64 Kb/s
	W-CDMA	2 Mb/s	153 Kb/s
	HSPA 3.6	3.6 Mb/s	348 Kb/s
	HSPA 7.2	7.2 Mb/s	2 Mb/s
Pre-4G	HSPA 14	14 Mb/s	5.7 Mb/s
	HSPA*	56 Mb/s	22 Mb/s
	WiMAX	6 Mb/s	1 Mb/s
	LTE	100 Mb/s	50 Mb/s
4G	WiMAX 2	1 Gb/s	500 Mb/s
	LTE Advanced	1 Gb/s	500 Mb/s

Figure 1. Wireless standards evolution and comparison

	Home Consumer	Enterprise Business	Small Cells		
			Indoor Public Space	Outdoor Urban Public Space	Rural Public Space
Name	Femto Cell	Femto Cell Pico Cell	Pico Cell Micro Cell	Pico Cell Micro Cell	Pico Cell Micro Cell
User Access	Closed	Closed/Hybrid	Open Public	Open Public	Open Public
Installed By	End-user	End-user Network Operator	Network Operator	Network Operator	Network Operator

Figure 2. Small cell category summary

One viable method is known as small cells, although the associated business implications are anything but small. A small cell brings the radios physically closer to end-users to improve coverage and capacity, and is seen as a viable wireless access technology option, allowing MNOs to retain and even attract new customers. MNOs around the world are experiencing intense ongoing competition related to retaining and attracting new mobile customers, where winners cost-effectively and reliably expand coverage and available capacity to differentiate based on an improved and better overall QoE, which is increasingly seen as table stakes to discerning end-users.

Cells, Cells, and More Cells

As is typical in emerging technologies, small cells mean different things to different people. There is overlap as to what is classified as femto cells, pico cells, micro cells, WiFi cells, and small cells, with the latter often assumed to encompass some or all of the former terms. Figure 2 provides a summary view of these terms to help set the reference for what is to be referred to as small cells discussed in this paper.

Small Cell Mobile Network Fit

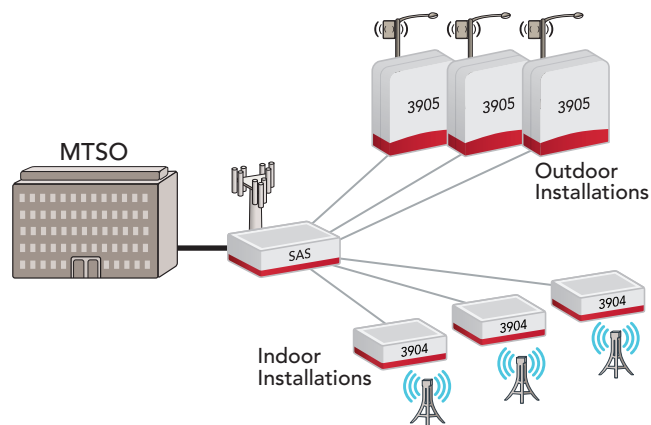There are two ways to deploy small cells within existing mobile network architectures. Small cells can be homed back to existing macro cells, as shown in Figure 3, with aggregated small and macro cell traffic backhauled to the MTSO. This results in increased capacity requirements onto the backhaul links currently feeding the macro cell, especially as more and more small cells are deployed. This network architecture will likely be the most popular method of rolling out small cells, as it results in shorter small cell backhaul links, meaning MNOs must endure fewer right-of-way negotiations, which are typically very time-consuming and very costly to close.

Alternatively, small cells can be homed directly back to the MTSO, as shown in Figure 4, which results in longer distance backhaul links. This leads to more difficult and costly right-of-way negotiations, especially if protected dual small cell backhaul links are employed. The advantage of this architecture is that deploying small cells will not affect the capacity requirements of the existing macro cell backhaul links. In all likelihood, a combination of these two small cell backhaul network architectures will be deployed based on specific network requirements, deployment constraints (indoor or outdoor), and optical fiber availability.
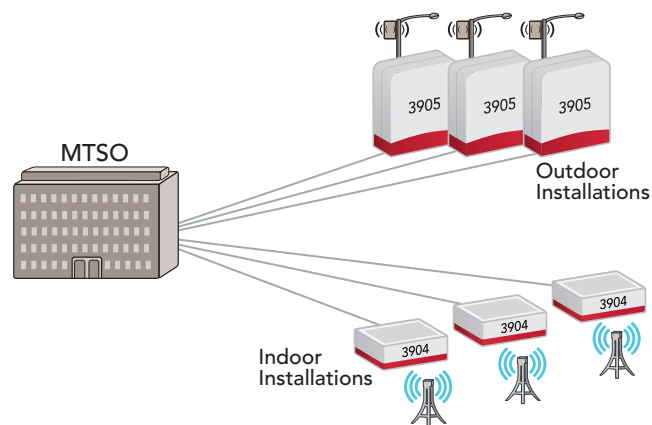

Figure 4. Small cell backhaul traffic homed directly to the MTSO

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Figure 3. Small cell backhaul traffic homed to macro cell tower

It should be noted that, regardless of which of the small cell backhaul network architectures is deployed, they both result in increased capacity for end-users due to improved overall mobile network coverage and proximity to the smalls cells. This means more network traffic can be driven into the MTSO sites and over metro networks toward the data centers, where applications and content are being accessed. These increased demands placed upon existing metro networks will continue to drive the adoption of 100G.

Benefits of Small Cells

MNOs can derive numerous benefits by deploying small cells. From a coverage perspective, they may experience improved service extension to targeted rural areas, indoor locations, and downtown concrete canyon not-spots. There is also a reduced need to deploy more macro cell towers, which are time-consuming, costly to deploy and operate, and typically entail deployment issues related to economic, environmental, regulatory, and time-to-market perspectives. Small cells are far easier and faster to deploy compared to macro cells, and typically do not experience the side effects associated with deploying the latter. Since small cells will be installed in a wide variety of physical environments, such as on masts, poles, strands, the sides of buildings, or within the building itself for indoor applications, small cell equipment must have highly flexible mechanical mounting options to ensure simple, rapid, reliable, and cost-effective field deployments on a wide scale.

Small cells increase service coverage by situating radios physically closer to increasingly powerful mobile devices, which enables significantly increased capacity to end-users, be they man or machine. Small cells will also allow for macro cell congestion relief by offloading wireless capacity, especially as end-user bandwidth demands continue to increase. This lengthens the lifespans of deployed macro cells and minimizes the need to deploy more macro towers closer to end-users simply to increase coverage and capacity. Small cells can also improve the Time To Market (TTM) for new services and lower the cost per bit. Increased capacity can be used as a significant service differentiator and a key enabler of innovative new high-bandwidth services.

Reliable, packet-based small cell backhaul networks, coupled with improved coverage and associated higher capacity available to end-users, result in an overall improved QoE, leading to higher customer satisfaction and the ability to offer new and differentiated services for innovative new revenue streams. Improved QoE facilitates customer retention and can be used to attract new customers away from competitors saddled with legacy networks starting to show their age. Increasingly, end-users are accessing their applications and content hosted in distant data centers, meaning demands placed on the mobile network infrastructure will show no signs of abating for years, if at all. As small cell deployments proliferate, end-users should experience the highly coveted side benefit of improved battery life resulting from reduced transmitter-receiver distances from smart mobile device to more small cells.

Side Effects of Small Cells

The majority of small cell traffic will be homed to existing macrocells and then aggregated along with the macrocell backhaul traffic itself, meaning backhaul network from the macrocell to the MTSO must be upgraded to avoid bottlenecks effecting the

Small Cell Network Backhaul

Packet-based optical networks best serve small cell backhaul while ensuring simple, rapid, reliable, and cost-effective deployments to facilitate access to web-scale data centers and the application services they provide.

Business Challenges
- End-users are demanding improved mobile network coverage, access speeds, and overall QoE

- Wireless coverage is lacking in many areas, thereby limiting download speeds

- MNOs must rapidly and reliably scale their networks in a highly cost-effective manner

Technology Solutions
- Small cells allow MNOs to better utilize available wireless spectrum by offloading macro cell traffic

- Rich packet OAM allows for proactive and reactive mobile backhaul network health management

- Ethernet-based optical networks are simpler to own and operate compared to competing backhaul options

end-to-end network performance, and ultimately the overall end-user experience. Although it's not expected that actual small cell traffic will approach a full 1 Gb/s for quite some time, given the limited number of supported users per small cell coupled with current 4G LTE smartphone performance, the links from small cell to macrocell will be via cost-effective 1GbE physical interfaces allowing for future growth. This means that the backhaul network from the macrocell to the MTSO should be upgraded from existing 1GbE to 10GbE to ensure sufficient aggregate capacity is available across the entire backhaul network.

Wholesale Mobile Backhaul Network Demarcation

Most MNOs acquire backhaul network bandwidth from third-party or internal wholesale providers (the latter from different business units within the same corporation), meaning that a clear network demarcation point between the mobile and wholesale networks is required to ensure rigid SLAs are guaranteed at all times (Figure 5). To ensure rigid SLAs can be guaranteed in the first place, and over time, a broad set of packet Operations, Administration, and Maintenance (OAM) tools is required for standards-based traffic monitoring (packet loss, throughput, delay, and jitter) passing between the demarcated wholesale and mobile networks. Web-based SLA portals allow MNOs to monitor purchased backhaul network services from their wholesale providers for improved peace of mind. Wholesale providers leverage strong packet OAM capabilities and offer SLA Web portals to their customers as key services that help differentiate them in the hypercompetitive marketplace of backhaul network services.

Big New Business Opportunities

Besides the improved customer retention and attraction benefits afforded by small cells relative to the improved capacity, coverage, and overall QoE they offer, there are also benefits related to innovative new business opportunities. Improved capacity allows for new, high-definition video streaming services to end-users, leading to new revenue-generating opportunities that may not be possible on existing capacity-constrained mobile networks in certain geographic locations and markets. The insatiable thirst for multimedia-based social media apps, some of which have not even been developed yet, will only continue to drive increased mobile network demands. This will be exacerbated by new smartphones supporting more powerful processors and more pixels on larger screens, which together create the perfect storm of increased mobile network bandwidth growth.
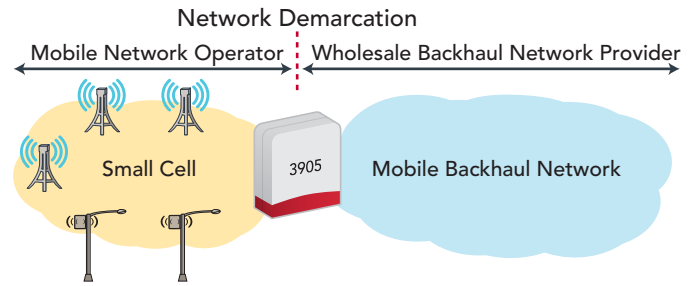

Figure 5. Mobile network to wholesale backhaul network demarcation

Improved coverage and capacity enables new services that arise in response to the impending wave of traffic soon to be unleashed onto mobile networks is related to the IoT, which is expected to expand to tens of billions of deployed traffic-generating devices in just a few years. Applications and associated services enabled by the IoT are related to smart cities, smart oil fields, networked vehicles, smart parking, traffic congestion alleviation, smart lighting, weather monitoring, smart electricity grids, alarm systems, and many more, most of which have not even been envisioned yet. What is known is that, due to convenience and the nature of IoT applications themselves, wireless connectivity over mobile networks will lead to growing wireless traffic demands that are daunting to mobile network planners and architects.

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Once social media and IoT traffic is transmitted wirelessly over the airwaves and reach small cells, it is transmitted over wireline networks to and from data centers. This means the traffic-carrying capacity of backhaul networks from small cell to macro cells and the MTSO must be upgraded. As 4G network technologies are inherently packet-based, backhaul networks based on packet-over-optical networks allow for the seamless traffic handoff to and from data centers where much of the content being transmitted resides. Thus, when deploying small cells, MNOs must incorporate backhaul upgrades that address increased wireless capacity to ensure the backhaul does not become a bottleneck leading to poor QoE.

Reliable and Rapid Rollout Is Necessary

Besides improved coverage, capacity, and overall associated QoE, one of the primary advantages of smalls cells is a much faster TTM than deploying more macro cells and the towers they entail. However, to improve coverage on a wide scale,

far more small cells—as much as 20:1—must be deployed as macro cells. This means they must be designed for rapid, reliable, simple, and low-cost deployments, along with very strong troubleshooting via standards-based OAM tools. Rich packet OAM tools allow MNOs and wholesale mobile backhaul service providers to remotely and quickly isolate issues in their backhaul networks, either proactively or reactively, to resolve problems and maintain a differentiated QoE. Without such tools, operators must deploy field technicians to troubleshoot issues, often requiring special equipment needed to access small cells mounted in dangerous, hard-to-reach locations, such as on the top of a pole in bad weather. Remote troubleshooting capabilities, coupled with secure and encrypted WiFi management ports, further facilitate the rollout and ongoing maintenance of small cells in a very cost-effective manner.

From CAPEX and OPEX perspectives, the simplicity and affordability of Ethernet-based connectivity are major reasons this protocol is quickly becoming the protocol of choice in all parts of the global network; the mobile backhaul network is no exception. Ethernet is a well-understood protocol that offers a rich set of packet OAM tools available that ensure backhaul services meet or exceed the strong SLAs MNOs have come to expect from traditional TDM-based E1 backhaul network services. The requirements published by the Metro Ethernet Forum (MEF), along with Carrier Ethernet 2.0 certification, increasingly makes Ethernet-over-optical networks the technology pairing of choice for mobile backhaul services.

Web-scale Wireless Access Coverage

The rise of web-scale IT architectures has challenged traditional hardware and software architectures and allowed for previously unheard-of capacities and processing powers being housed in today's data centers. It has allowed some of the world's largest content providers to grow to serve billions of end-users in a flexible, reliable, and previously unachievable cost-effective manner. Web-scale data centers mean that introducing new services to more users have become faster and easier than ever before. As open source software and dynamic bandwidth between data centers connect multiple physically distinct data center into an essentially limitless virtual data center without walls, the capability of future data centers and services they can support is essentially limitless. Small cells allow the mobile network to improve in both coverage and capacity, which facilitates web-scale architectures even further as wireless access to these data centers that house applications and content increasingly becomes the dominant network access method of choice.

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