White Paper

Cable's Value Proposition for Small Cells

Prepared by

Alan Breznick
Contributing Analyst, Heavy Reading
www.heavyreading.com

on behalf of

ACCEDIAN
Experience • Performance

www.accedian.com

December 2015

Introduction: Small Cells, Big Impact

The much-anticipated small-cell era has clearly begun in earnest. With the rapid growth of smartphones and mobile data traffic, and the emergence of 4G/LTE (and soon 5G) wireless networks, mobile network operators (MNOs) are scrambling to install compact, environmental-friendly femto, pico and micro cells throughout their footprints to support that growth, boost their coverage and capacity, and maintain or even enhance subscriber quality of service (QoS) without breaking the bank or building new cell towers and fiber lines.

In fact, research firms estimate that millions of small cells have already been deployed in hard-to-reach areas around the world, and millions more cells will be deployed over the next few years. For example, the Small Cell Forum estimates that MNOs had already deployed 10 million small cells globally by 2015. About 25 million more could be deployed over the next three years.

Small cells offer numerous other benefits to wireless operators, including greater flexibility, higher capacity, reduced "cell edge" signal fade and offloading macro-towers to facilitate rollout of rich communications and VoLTE services. But small cells also present numerous technological, operational and economic challenges to carriers, including increased signal handoffs, signal interference problems, equipment interoperability issues, additional infrastructure to manage, maintain and optimize, longer backhaul chains and higher backhaul costs.

That's where cable operators come in. With their years of experience in backhauling traffic for the macro-cell networks of mobile carriers, cable operators can offer the technologies, infrastructure, fiber lines and flexibility to support backhaul for small-cell networks as well. In fact, cable operators can take advantage of their existing fiber-rich networks, which now connect tens of thousands of cell towers in the U.S. alone, to provide the same kind of secure backhaul service for small-cell deployments.

Cable providers can also leverage their hybrid fiber/coax (HFC) plant to deliver backhaul in residential areas and neighborhood (local) commercial areas, where many small businesses operate. Further, cable operators have access to power and rights-of-way in these locations, allowing them to provide not only backhaul, but also valuable real estate for small-cell installations. Cable operators' field deployment expertise also enables them to offer turnkey options, including small cells as a service (SCaaS), or installation and turn-up services for MNOs, as well as such infrastructure services as physical changes, break/fix, upgrades and preventive maintenance.

Of course, this task won't be easy. Like MNOs and other backhaul providers, cable operators face a number of key challenges in deploying small-cell backhaul services, including streamlining deployment procedures for agile and efficient installations, ensuring QoS meets strict SLA requirements and overcoming regulatory hurdles. But, with the proper technologies and integration and performance assurance solutions from vendors, cable providers can readily meet those challenges head-on.

This white paper explores the swiftly evolving small-cell backhaul opportunity for cable operators, starting in North America and Europe. It examines the key technological, operational and financial challenges that wireless providers and cable operators alike face in deploying small cells throughout their footprints, and spells out how these key hurdles can be surmounted with the right assistance from vendors. The paper also presents a revealing case study of Cox Communications' pioneering plans to introduce small-cell backhaul service in several U.S. markets this year.

Cable's Small-Cell Backhaul Opportunity

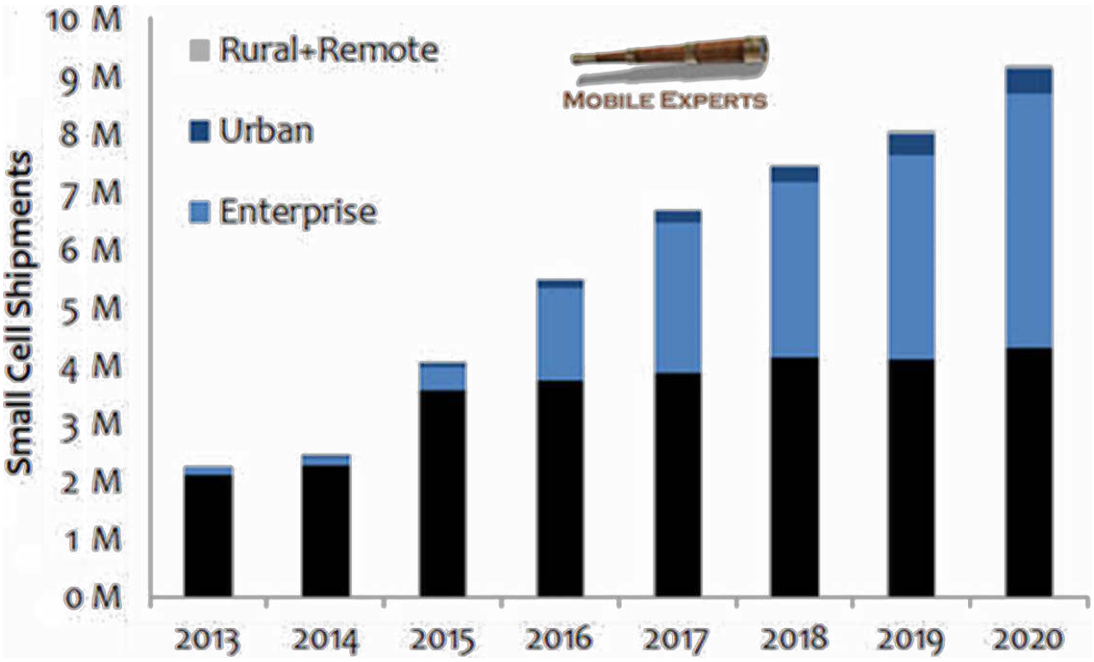
In this section, we will explore the vast potential of the emerging small-cell backhaul market for North American cable operators. With the deployment of 4G/LTE networks, mobile data traffic growing by leaps and bounds, and wireless access networks already straining to meet both the surging data demand from subscribers and their growing expectations of high-quality performance, mobile providers are increasingly finding themselves in a bandwidth bind.

In fact, in a recent study, Cisco Systems found that mobile data traffic soared by 69 percent in 2014, as wireless users added nearly 500 million mobile devices and connections throughout the world. Further, the study predicts that advanced 4G will account for more than half of all mobile traffic by 2017.

In response, MNOs are increasingly turning to a combination of femto, pico and micro cells, known as a heterogeneous network (HetNet), to boost their coverage density without using up much space, especially in crowded urban areas and indoor locations. They are also increasingly turning to a mix of small and macro cells to meet their ever-growing customer demand.

As a result, mobile providers are expected to deploy tens of millions of small cells in their wireless networks over the next few years, especially as they increase their 4G/LTE coverage. For example, the Small Cell Forum projects that vendors will ship about 8 million small cells to telcos annually by 2018, about double the 4 million or so cells expected to ship in 2015. With an estimated 10 million cells already deployed across the globe by about 75 carriers, the additions should boost the total number of small cells deployed worldwide to more than 30 million over the next three years.

Figure 1: Projected Growth in Small Cell Shipments



Source: Mobile Experts

Breaking things down by region, North America, Europe and Asia/Pacific should "outperform" the overall market with "double-digit growth between 2015 and 2020," according to ABI Research. In the U.S. alone, such major mobile providers as AT&T, Verizon Wireless, Sprint and T-Mobile U.S. have all spelled out ambitious plans to blanket their regions with a wide array of small cells. For example, Sprint has talked about installing 60,000 to 70,000 small cells in its wireless network over the next few years, while AT&T plans to install 40,000 small cells under its Velocity IP program.

Having already made strong inroads in the broader cellular backhaul market in North America, U.S. and Canadian cable operators are in a unique position to capitalize on this promising business opportunity. For one thing, unlike traditional backhaul wholesale providers such as FirstLight, TowerCloud and Zayo, which focus purely on fiber to the tower, cable operators have dense yet flexible networks of fiber and coaxial lines covering both residential areas and many urban commercial centers. They don't just serve macro-cell sites, where the vast capacity of fiber can be more easily justified.

Further, cable providers have the centralized SLA monitoring tools in place to allow them to compete in the backhaul space. Fortunately, these monitoring tools can be easily extended to small cells, which will require similar accountability and performance reporting.

With small cells requiring far more endpoints (up to 10 per macro cell is common), many traditional backhaul wholesale providers will likely not be able to adapt and take advantage of this opportunity. In contrast, cable operators and other service providers catering to residential subscribers can do so, thanks to the enormous number of lines they already have in place and their expertise in delivering these edge services quickly. Think, for example, of the new cable subscriber whose service is usually installed just a few days after the order is placed.

Cable operators also appear well-positioned to compete in the rapidly emerging small-cell market because they have decades of experience in the trenches installing and maintaining wires and equipment in both indoor and outdoor locations. As will be shown in the Cox case study later in this paper, MSOs can backhaul traffic from indoor locations quite adeptly, due to the flexibility of their wide-reaching fiber and coaxial access networks.

Further, cable operators can boast the capability of managing small-cell deployments as a professional service for carriers. While MNOs still choose the small cells, determine their configuration and monitor the devices, cable providers can both install and maintain the small cells and deliver the backhaul service. Few of cable's competitors can make the same claim.

Unlike some wholesale rivals, cable operators have the potential capacity to provide backhaul service to small cells in outdoor as well as indoor locations. While outdoor deployments of small cells tend to be more challenging from both a radio and backhaul access perspective, pioneering MSOs such as Cox are starting to test ways to overcome those hurdles. So with large, well-trained field staffs already in place, cable providers are now developing the know-how and expertise that should enable them to compete in this area.

Also unlike some of their competitors, cable operators can offer critical alternative power sources to MNOs. While other providers can offer battery backup, the MSO advantage is that the HFC plant is already powered, and that power is backed up. So by connecting to cable plant power, the small cells inherently have backup power without requiring time-consuming coordination with local utilities or adding extra backup equipment.

Finally, cable providers can offer the advantage of having "right of way" to install strand-mounted small cells, or to mount cabinets on existing poles, in areas where small cells are of the greatest interest: residential and commercial centers, small towns, etc. Obtaining the municipal permits to place a small cell on a pole can take more than a year, especially if there are historical or environmental factors at play. In contrast, an MSO can install a small cell on a wire anytime, using the existing right of way that it already possesses.

Not surprisingly, then, many mobile providers are quite interested in teaming with cable operators on small-cell backhaul deployments. In a survey conducted by RCR Wireless last year, for instance, 45 percent of mobile providers looking for small-cell partners said they would turn to MSOs for backhaul assistance. Plus, 20 percent of this sample said they would turn to cable operators for "full service" small cells.

Figure 2: Cable's Key Assets in the Small-Cell Space

Asset	Details
Dense, flexible networks covering both residential and business areas	Cable's HFC networks range far and wide, catering to far more than just the macro-cell areas served by fiber providers
Centralized SLA monitoring tools already in place	Established initially for the backhaul space, these monitoring tools can be easily extended to the small-cell market
Expertise in delivering edge services to customers quickly	Cable operators have decades of experience providing services to residential subscribers
Installation experience in both indoor and outdoor locations	Cable providers have been installing and maintaining wires in both types of locations for dozens of years
Capability to manage small cells as a professional service	Cable operators can both install and maintain the small cells and deliver the backhaul service
Ability to offer alternative power sources, like battery backup	Cable's HFC networks are already powered with electricity and leverage batteries as a backup source
Already have rights of way to city streets and utility poles	Cable operators have already negotiated for the rights to lay wires under the streets or string them from pole to pole

Source: Heavy Reading

Key Challenges of Deploying Small Cells

As alluded to earlier, service providers of all stripes face a number of key technical, operational and other challenges in working with MNOs to deploy small cells and deliver backhaul service. Even though small cells require the same or even higher levels of performance as macro cells, the backhaul challenges differ greatly because of the sheer volume of small cells that must be served, as well as the added backhaul transport and processing latency introduced by further hops to user equipment. As a result, the margin for error is much smaller, hurting sync, voice, control plane and media streaming, and ultimately impacting both the network's QoS and the customer's quality of experience (QoE).

Indeed, the potential challenges of small-cell deployment are numerous, including many that are not pertinent or unique to MSO solutions. The long list of small-cell backhaul challenges includes:

- Longer backhaul chains, which threaten QoS
- More service endpoints/access points to serve and monitor
- Greater need to monitor control plane traffic with more frequent handoffs, automated interference optimization and coordinated multipoint access (CoMP)
- Multi-vendor equipment interoperability conflicts
- Gaining rights-of-way and access to power (in short time frames) for outdoor deployments
- Deploying backhaul to buildings for indoor small cells and distributed antenna system (DAS) installations
- Intense cost pressures on deployment, monitoring and operational expenses
- Potential for RF interference over the HFC plant, specifically in the 600 MHz and 700 MHz spectrum
- Utilizing DOCSIS as a backhaul platform
- Providing power to the small cell location

While all of these issues have an impact on the delivery of small-cell backhaul, many of them are not cable-specific. In this section, we will delve into the ones that are most pertinent to cable operators.

Many of the technical challenges revolve around the cable industry's HFC plant and its flagship DOCSIS platform for broadband service. While cable operators mainly rely on metro Ethernet service over high-performance fiber lines to serve cell towers for backhaul transport, they will likely not be able to rely on purely fiber connections to serve all of the small cells that mobile providers plan to deploy throughout their markets.

That likelihood poses a looming technical challenge for cable because DOCSIS-based service over HFC lines simply cannot meet the same high performance standards as data service over all-fiber networks. Consider the use of the HFC DOCSIS platform for small-cell backhaul. While such performance issues as packet delay, jitter and signal loss may not cause big problems for DOCSIS-based HFC networks, such other backhaul service requirements as control signaling performance may prompt concern because these requirements are notably more stringent for 4G/LTE

networks. So, when one small cell hands off a signal to another, the longer the handoff process takes, the more likely it is that the resulting signal handover will fail.

Since HFC plants were designed primarily to deliver video, latency is another key concern. Although buffering has its benefits for video distribution, it can be highly detrimental for mobile signaling and real-time applications such as VoLTE. Fortunately, as we'll discuss later in this paper, careful monitoring can ensure that latency falls within expected norms at turn-up, and also identify traffic bottlenecks in the network where network elements can be tuned to meet latency requirements.

Site provisioning of small cells represents another major challenge for cable operators. Although pole mounts and rooftops make for highly desirable locations for operators because they enable signals to propagate in more directions, these locations often can't be used for small cells because of the coverage needed or the limited range of the cells. The same limitations go for the sides of buildings, which usually have the further restriction of only 180-degree signal coverage. In addition, environmental noise and signal interference can cause problems as well.

Further, the growing deployment of small cells could cause signal interference problems for cable operators themselves, especially with LTE service deployments in the 700 MHz range. Indeed, such interference issues have steadily been on the rise since 2011, when mobile carriers started ramping up LTE service around the world.

Another tricky potential challenge for cable operators is more regulatory than technical or operational in nature. While cable's HFC strands and poles are fairly ubiquitous in most metro areas throughout the U.S., they may not always be so readily available for small-cell use. That's because operators may need to renegotiate their local franchise agreements with municipalities and counties to offer or install small-cell service, or at least work out new arrangements with local regulators so they can put up the cells, string up more wires or dig more trenches in the streets.

Similarly, cable providers often must hammer out new pole-attachment agreements with local utilities to reach new locations with their HFC networks. Both of these requirements can add significant delays and costs to the small-cell deployment process, especially if the municipalities and/or utilities are not willing to negotiate changes or are looking to squeeze substantially more money out of cable providers.

Finally, cost efficiency in operations and equipment will be key to making a successful business case for small-cell backhaul. Because each small cell serves significantly fewer subscribers than a macro site, the cost of deployment and ongoing backhaul must be proportionally lower. MSOs will succeed if they can deploy volumes of connections very efficiently, which will require great attention to detail at all levels of service deployment, using automation to eliminate long install times, human error, and any additional steps that increase complexity in operations. Small cells will need to be turned up fast and done right the first time, leveraging cost-efficient hardware and software.

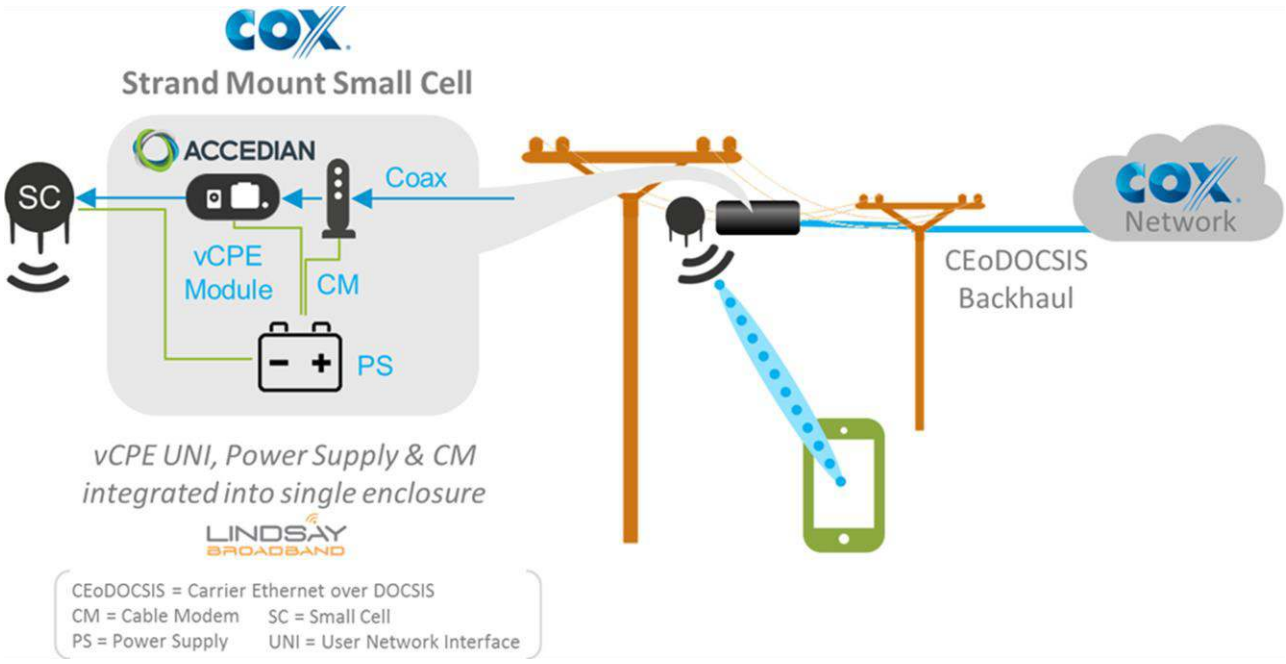
Overcoming the Challenges

Fortunately, the major deployment challenges described in the previous section, while potentially quite daunting, are not insurmountable. This section focuses on how cable operators can overcome these hurdles to entering the market, enabling them to deliver small-cell backhaul service and even deploy the small cells themselves. In particular, we will explain how new vendor solutions such as those offered by Accedian Networks and Lindsay Broadband may help operators address such technical challenges and integrate the various kinds of small cells effectively into their existing backhaul networks.

Consider the potential RF interference challenge. CableLabs and cable operators have already worked to resolve this issue by conducting stringent plant testing and developing ways to manage the ingress. In addition, vendors have designed solutions to prevent any interference problems. For example, Lindsay Broadband has crafted a stainless steel connector for the small-cell gateway platform that's specifically geared toward blocking out RF Interference (mainly 600-700 MHz) from the MNO's small-cell radio feeding back through the RF plant. This solution has been tested thoroughly by CableLabs for electromagnetic interference (EMI) protection.

Or take the site provisioning challenge described earlier, for example. To overcome the hurdle of where to install the small cells and run the connecting wires, cable operators can make use of innovative strand-mounting methods that vendors have developed for the industry. These methods allow MSOs to avoid relying on pole attachments, the sides of buildings, rooftops and other structures, drastically cutting the deployment costs and time constraints for providing the backhaul service (over both fiber and DOCSIS HFC networks) and deploying the small cells themselves.

Figure 3: Outdoor Deployment Scenario for Small Cells



Source: Accedian Networks

In addition, these strand-mounted methods are often subject to less regulatory oversight by local franchise authorities. Thus, they allow for a more streamlined deployment process in a zoning-friendly way, enabling a more cost-effective solution.

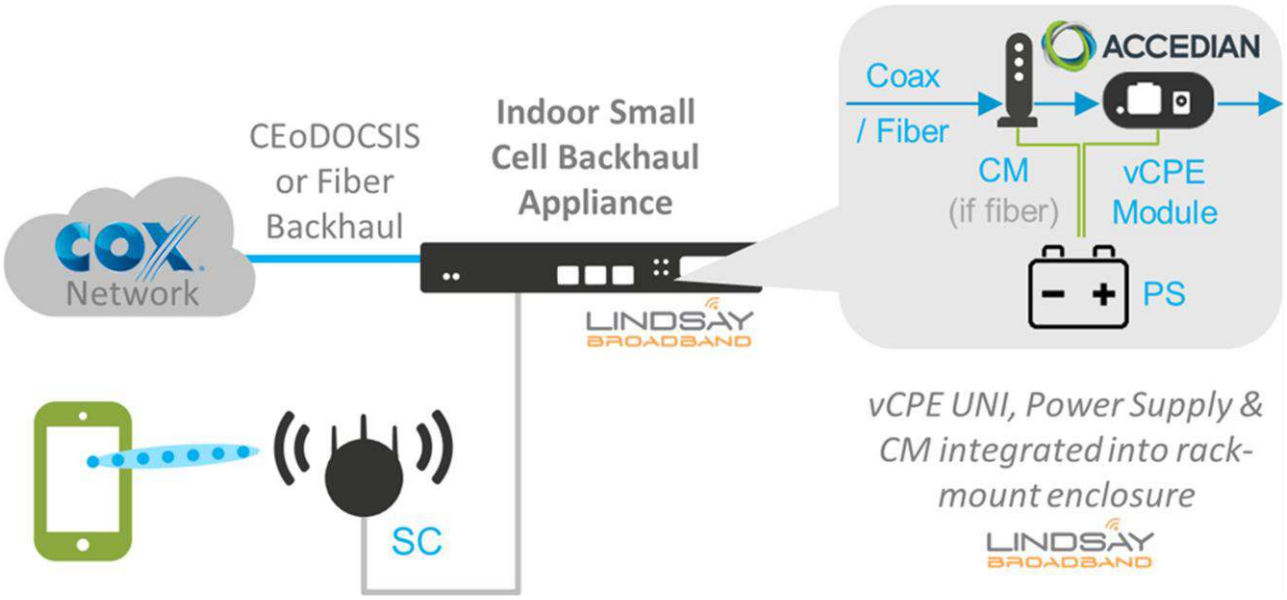
Hardened strand- or pole-mount enclosures can tap into the existing cable power plant and HFC connectivity to provide an efficient backhaul appliance that contains everything needed to connect, turn up, monitor and maintain connectivity to a small cell: a cable modem, NFV-powered (virtualized) compact network interface device (NID), a power supply and potentially the small cell itself.

Cable operators can also utilize the same installation techniques that they already use for macro cells, with the same technician-friendly look and feel as their existing strand equipment, because no new knowledge is required. Plus, operators can leverage automation to eliminate human error and cut down the time needed for complex small-cell and backhaul configuration on site, freeing technicians to focus on physical connections and installation.

With about 60-70 percent of small cells expected to be deployed indoors rather than outdoors, cable operators and vendors are also working hard to develop innovative backhaul solutions for indoor locations. In this case, they are taking advantage of the fact that cable providers have already done extensive indoor wiring in indoor locations where small cells seem well suited, such as business parks, commercial buildings, shopping malls, large apartment buildings, etc.

Leveraging such existing infrastructure, cable operators can provide backhaul service for small cells or DAS installations, which in many cases include coarse wavelength division multiplexing (CWDM) for front-haul service. Similar to outdoor applications, turnkey backhaul appliances, which combine fiber or HFC connectivity and a NID, can facilitate rapid installation while assuring SLA-grade performance.

Figure 4: Indoor Deployment Scenario for Small Cells



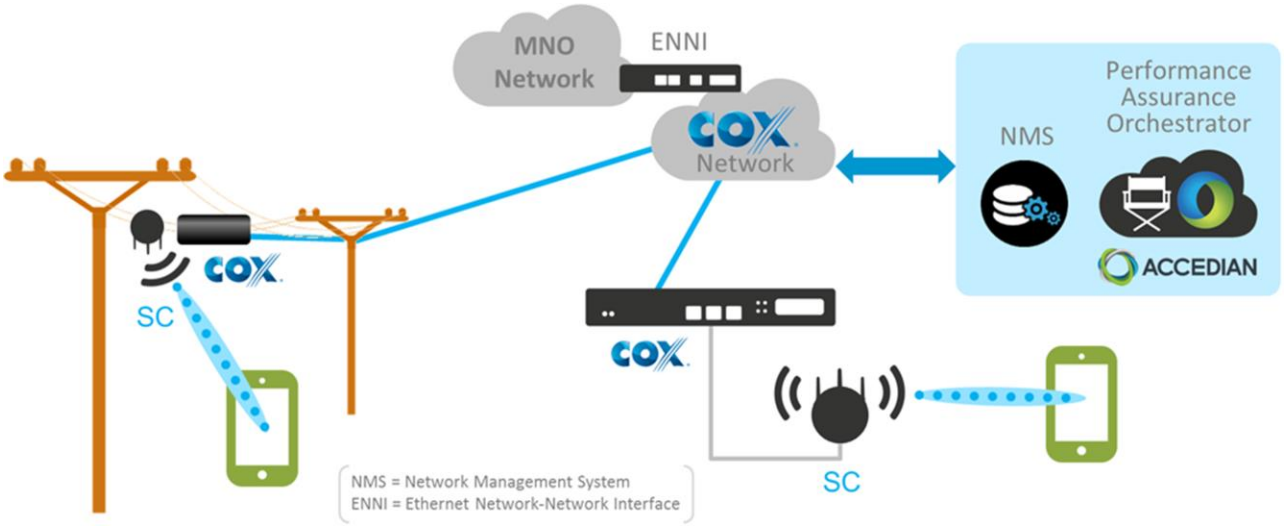
Source: Accedian Networks

Moreover, cable operators can respond to the market challenges by expanding beyond their traditional distribution role in the cell backhaul market. Instead of just backhauling cell traffic, they can install the small cells themselves and offer a value-added small-cell managed service to their MNO partners. Plus, they can offer power and maintenance services, and ongoing monitoring and network management.

Further, cable providers can offer turnkey installations, providing the location for the small cells, installing them for the MNO and then supplying the backhaul service. By using centralized provisioning, performance assurance and SLA reporting automation, MSOs can streamline the installation, operations and maintenance of their backhaul offerings, allowing their existing team of technicians to easily install these connections with only minimal additional training and procedures.

Leading the small-cell charge in the U.S. cable industry, Cox Communications is pursuing both of the last two approaches. The following section delves into these efforts in detail.

Figure 5: Overall Small Cell Deployment Schema for Small Cells



Source: Accedian Networks

The Cox Case Study

More than any of its MSO peers, Cox Communications is leading the cable industry's charge into the swiftly evolving small-cell market. Cox, the third largest cable operator in the U.S. with more than 4 million residential and business customers, launched a pilot small-cell managed service in Phoenix, Arizona, in June 2014 and plans to roll out commercial service more broadly in other locations shortly.

An early cable pioneer in the macro-cell backhaul market, Cox has been exploring the potential of small-cell technologies for some time. The large MSO began testing small-cell backhaul service in indoor locations two years ago, and in outdoor locales in June 2014.

Working in conjunction with two key equipment vendors, Accedian Networks and Lindsay Broadband, Cox has also been seeking innovative ways to turn small cells into a big business. Besides offering conventional backhaul service to wireless providers, the cable operator is looking to develop small cells as a managed service by coming up with locations for the cells and installing the cells itself.

"We think it's a pretty significant opportunity," says Bill Jesser, senior manager of product development for Cox. Indeed, Cox officials figure that each of the major U.S. wireless carriers will be looking to install hundreds of thousands of small cells in outdoor locations over the next few years.

Cox, which already serves all of the major U.S. wireless carriers with macro-cell backhaul service, has been pursuing its interest in small cells on two major fronts – indoor and outdoor. It has also been experimenting with both HFC lines and all-fiber lines, as well as Ethernet and IP, for small-cell backhauling. "We've tried to make the small-cell toolbox as broad as possible," Jesser says.

Mirroring the deployment strategy of most MNOs, Cox moved ahead on the indoor front first partly because it offers a more controlled environment with fewer variables. In contrast, outdoor locations require temperature/environmental hardening and other extra components. "Outdoor is trickier than indoors," Jesser says. "We actually had indoor and outdoor as one initially, then decided to put off outdoor as a later phase of the project." In addition, indoor coverage is where the market need is greater: In-building mobile coverage is poor, and up to 80 percent of all cellular calls originate indoors, as reported by AT&T in August 2015. Thus, many MNOs started with indoor small-cell/DAS deployments for both simplicity and need.

With this strategy in place, Cox started testing indoor small-cell backhaul service for a major U.S. wireless carrier in December 2013. In this trial, the MSO has been backhauling traffic from a major downtown Phoenix office building equipped with 16 larger small cells, or what some carriers call "metro cells." For the trial, it has leveraged a NID from Accedian that provides performance assurance, and a hardened chassis from Lindsay Broadband that encapsulates both the NID and the cable modem and protects them both from harm. This integrated appliance also simplifies installation – a single 1U rackmount unit simply requires a coax or fiber connection to the network, and provides a Carrier Ethernet service port that connects directly to the small-cell gateway or DAS controller.

Satisfied with the trial results, Cox quietly went commercial with the small-cell backhaul service in June 2015, making it the first U.S. MSO to do so. Thus far, it says, it has not run into any major technical issues. "It's been performing great," Jesser says. "In one and a half years, we haven't had any issues at all." As a result, Cox is now just

looking for its major wireless customer to approve the expansion of the service to more office buildings. "We're still waiting for the orders to come rolling in," Jesser says. "We're ready for them."

On the outdoor front, Cox has been testing small-cell managed service in Rhode Island since the middle of 2014. In that trial, the cable operator has been working with small cells mounted on utility poles to serve its MNO customers, similar to how it serves macro cells. Cox has also provided turnkey deployment services and is sending power to the small cells via the battery backed-up HFC plant.

Now Cox is undertaking a trial in Las Vegas that is leveraging innovative strand-mounting of dozens of small cells to backhaul mobile traffic for a major U.S. wireless carrier. In this venture, the MSO is again teaming up with Accedian and Lindsay Broadband on the NIDs and hardened enclosures for the NIDs and cable modems. Cox officials view the hardened boxes as a critical differentiator for cable because they offer the ability to provide power, backhaul and service assurance in a small strand-mountable enclosure. Cox is also providing the powering for the small cells.

In Las Vegas, Cox's is making use of a strand-mounting approach to bypass costly, heavy regulated pole attachments and get the small cells up and running much quicker than before. "We're really excited about the strand-mounted solution," Jesser says. "We can get a small cell on the air a lot quicker."

Figure 6: Example of Cox's New Strand-Mount Installation for Small Cells

Source: Cox Communications

Besides backhauling small-cell traffic, securing the locations for the cells and installing the cells, Cox also aims to provide powering and backup power to its carrier customers. The cable operator is working once more with Lindsay Broadband to offer a battery backup solution to MNOs by converting its 90-volt AC electrical power over its coaxial lines to 48-volt DC signals suitable for small cells. "We can leverage our HFC plant for powering," Jesser says. "That's a great differentiator for the cable companies, because MNOs like to have small cells on battery backup."

Cox officials believe that outdoor small cells may eventually produce more revenue because of the variety of services that can be offered. But the sheer number of indoor small cells will likely outnumber outdoor cells. Also, there are typically many indoor small cells with a single point of backhaul, while outdoor cells are more often deployed on a one-to-one basis.

Cox's managed small-cell service also offers operational efficiency benefits. The solution encompasses: Carrier Ethernet service creation; policy enforcement; integrated turn-up testing; performance monitoring and fault isolation, covering the full service lifecycle from provisioning through ongoing performance and SLA monitoring, to troubleshooting and optimization.

Accedian says the integration of its solutions into Cox's centralized network management and operations support systems (OSS) automates the steps required to activate and assure the service, allowing rapid installation while eliminating the risk of human error. It contends that this operational efficiency, originally developed for macro-cell backhaul, is a key reason why Cox's offering is cost-competitive and fast to deploy, with reliable, differentiated performance.

As mentioned earlier, cable operators are uniquely positioned to provide power, colocation space, backup power and turnkey network deployment services. Cox has teamed with seasoned vendors to provide turnkey deployment services. These services include RF design, site selection, site acquisition, construction and installation, and testing and integration. The partnership with vendors enables Cox to be a one-stop-shop for small-cell services and streamlines the process for MNOs because there is a single company responsible for the entire network.

After the small cells have been deployed, Cox offers infrastructure services to ensure the ongoing care and feeding of the network. These services include intelligent remote hands for making physical site changes or rebooting equipment. Cox also offers break/fix services for damaged equipment and hardware upgrades for protection against obsolescence, as well as preventive maintenance services. Cox can leverage its fleet of bucket trucks and extensive outside plant maintenance crew to perform these tasks, resulting in a lower cost to the mobile operator.

"We have seen strong interest for a unique managed small-cell solution from the MNOs," said Jeremy Bye, VP of carrier services for Cox. "Cox is very excited to be successfully delivering our turnkey service that addresses the MNOs' business needs, including access, power and transport, with a fast and cost-effective solution."

Future-Proofing for 5G & Beyond

As asserted throughout this paper, MNOs are largely focused on deploying 4G/LTE technologies throughout their wireless networks today. Seeking to expand coverage areas, increase coverage density, boost QoS and keep scaling their networks to meet the relentless bandwidth demands of their subscribers, MNOs are increasingly relying on small cells to fill coverage gaps and meet higher performance requirements. But even as they move ahead with their 4G deployments today, MNOs are preparing for tomorrow's network demands as well. In the short term, operators are pointing toward the launch of LTE-Advanced, which will extend the capacity and reach of LTE even further in some areas, while simultaneously demanding even tighter performance requirements.

Looking further out into the future, the wireless industry is also starting to prepare for the introduction of 5G, possibly by the end of the decade. Although no standard for 5G has been defined yet, these sophisticated networks will likely dwarf even the vast bandwidth capacity of today's 4G networks. In fact, market analysts expect 5G to offer an order of magnitude higher bandwidth than 4G, supporting 100 percent device densification and the Internet of Things (IoT), among other things. As a result, the advent of 5G will undoubtedly require a great deal more small cells to achieve the much higher data rates expected. In addition, they will likely require even higher backhaul performance standards, including up to 1 millisecond (ms) latency bounds, tighter packet loss and higher availability limits.

With the push toward 5G, industry experts expect to see other new developments in the future, including the following:

- The introduction of multiple classes of service monitoring, as a growing number of applications, including IoT and VoLTE, are introduced into the mix
- The ability to monitor application-layer/QoE for per-session/policy-based performance assurance, traffic prioritization, dynamic performance optimization, session-level troubleshooting, etc.
- The development of both dynamic network provisioning (elastic bandwidth) and adaptive performance monitoring
- New adaptations of both SDN and NFV: assured, distributed NFVI (D-NFV and mobile edge compute, MEC) for local VNFs processing, performance monitoring for chained services, gateways for fog computing, security assurance, lawful intercept in virtualized networks, etc.
- CoMP backhaul and related low-latency X2 interface requirements
- The development of Sync as a Service
- The adoption of dynamic performance optimization, etc.

All of these trends will clearly bring new bandwidth, latency, monitoring and other challenges for MNOs and MSOs alike, highlighting the need for operators to keep updating and future-proofing their networks to be prepared for the demands of tomorrow. Consider Cox, which is pursuing a proven path to assure the migration toward the SDN/NFV-powered backhaul networks of the future – whether offered by itself or as a virtual private network as a service (VPNaaS) – by establishing pervasive performance visibility and centrally controlled provisioning. Such real-time performance information will be an essential element for the self-organized, SDN-controlled, dynamic networks that will serve the backhaul needs of emerging 5G networks, the IoT, and other applications that have not yet even been dreamed up.

Conclusion

Now that the small-cell era has definitely begun, cable operators have a great opportunity to turn these compact femto, pico and micro cells into a booming business. With millions of small cells already deployed around the world and millions more on the way, MSOs have the chance to leverage their wide-ranging HFC networks, well-trained installation teams, plant-powering capabilities and growing backhaul expertise to build a promising new revenue stream for years to come.

Cable operators are also well-positioned to compete successfully in the emerging small-cell market because of the next-gen technologies that they are developing and beginning to deploy. These technologies include the new gigabit-enabling DOCSIS 3.1 spec and Converged Cable Access Platform (CCAP), which combines the data processing functions of the cable modem termination system (CMTS) and video processing functions of the edgeQAM modulator in one super-dense, highly efficient device or architecture. In addition, cable operators are poised to deploy various flavors of passive optical networking (PON) technology over their networks, which will also boost data speeds and bandwidth capacity.

Of course, like all other would-be small-cell service providers, cable providers face a number of looming technical, operational and other challenges in entering this market. As spelled out earlier in this paper, these challenges include delivering high-performance backhaul service over DOCSIS on coax lines, conducting site provisioning for small cells, battling potential signal interference problems, negotiating new pole attachment agreements and dealing with regulatory matters. These issues will all take time, money, effort and patience to sort out.

But, as this paper also shows, cable operators can overcome these challenges and join the small-cell movement, especially with the help of vendors with key tools such as integrated backhaul appliances; automated service provisioning, monitoring and maintenance; and real-time SLA reporting. Following the model now being established by Cox, MSOs can find ways to support MNO deployments of both indoor and outdoor small cells and provide a potpourri of related services, such as site provisioning, cell installations, management services and alternative power options. It's not just about backhaul anymore.

In other words, cable operators can potentially have a big impact in the small-cell world, if they make the proper commitment to the market. Sometimes, good things really do come in small packages.