DAS and Small Cell Update
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By Martha DeGrasse

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Introduction

Distributed antenna systems and small cells hold tremendous promise and tremendous uncertainty for the U.S. wireless industry. Mobile operators know they need to add capacity to their networks as LTE unleashes demand for mobile data, especially mobile video. But operators also need to stay profitable, and the cost of DAS and small cells has kept many potential projects in the planning phase.

The good news for operators is that businesses and municipalities are learning that they need to be proactive if they want to offer reliable access to high-speed mobile data. In-building deployments are finding new sources of financing from the companies that will use the services, and outdoor deployments are taking place in an improved regulatory environment.

This report will review trends in network densification both indoors and outdoors. Key focus areas include cost control through new network architectures and intelligent optimization, small cells as a service, and new business models for small cells and DAS.

Definitions

A distributed antenna system (DAS) consists of antennas, base stations, and a transport medium to connect them, typically fiber or cable. A DAS remote unit may be an antenna/amplifier or it may be a remote radio head that includes digital processing capabilities.

Passive distributed antenna systems are usually antennas linked by cable to a base station or head-end. Active DAS systems get an extra boost from fiber, antenna amplifiers, remote access hubs and expansion hubs. Passive DAS and cellular signal boosters are good solutions for many buildings, but larger venues like stadiums or hotels will usually need an active DAS.

Small cells is a term that is used broadly in the wireless industry to refer to a variety of solutions. According to The Small Cell Forum, ‘small cells’ is an umbrella term for operator-controlled, low-powered radio access nodes, including those that operate in licensed spectrum and unlicensed carrier-grade Wi-Fi. They typically have a range from 10 meters to several hundred meters.

The words “small cell” may be used to describe equipment that includes a baseband unit and functions as a miniature version of a cell tower, as well as equipment that is simply used to access the radio network. DAS remotes may at times be called small cells, and indoor access points that connect to controllers via fiber or cable may also be called small cells at times.

“Everyone’s got such a different definition of what a small cell is,” said analyst Earl Lum of EJL Wireless Research. “I would consider a small cell to have both the modem and the radio integrated into one unit, so it’s self-sufficient and all it needs is backhaul.”

Earl Lum, EJL Wireless Research

Small cells are starting to look more like distributed antenna systems as operators and vendors explore architectures that separate the baseband equipment from the access equipment in order to save space and money. By centralizing the baseband equipment and connecting it to the small cells via fiber or cable, operators can deploy smaller, less expensive access nodes.

The word “small” is also a relative term, as small cells come in several sizes. Femtocells are small cells that are used in homes or small businesses. They usually have a range of less than 100 meters. Picocells, or metrocells, have a range of up to several hundred meters, and microcells can cover more than a thousand meters.
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According to the analysts at Rethink Wireless, purchases of residential small cells will peak within the next couple of years. Urban small cells are expected to grow exponentially, and enterprise small cells are forecast to become the biggest part of the market. The vast majority of enterprise small cells are indoors.

**Indoor small cells**

Most mobile data usage occurs indoors, and most of it happens on Wi-Fi. Cell service providers can’t support all the activity that takes place on smartphones and tablets, but they want to keep as much of the traffic as they can handle. To do that, they need to provide reliable indoor coverage, even in crowded buildings that are not near a tower. The larger buildings may be candidates for an in-building DAS, but the hundreds of thousands of smaller buildings that operators want to serve are candidates for indoor small cells.

“Only about 2% of enterprise buildings actually have mobility in the building,” said Philip Sorrells, VP of strategic marketing at CommScope.

But a much higher percentage of the buildings that carriers will pay to cover have already gotten a system. The addressable market for carrier-funded indoor small cells is limited. Bringing better connectivity to the millions of people in office buildings who would love to see more bars on their

**Source:** Rethink Wireless

"Only about 2% of enterprise buildings actually have mobility in the building"

Philip Sorrells, CommScope
phones will require carriers to convert corporate customers into partners in the small cell investment process. Building owners and their enterprise tenants are getting a crash course in cellular, and one of the lessons they are learning is that technology is still evolving.

“They are very hesitant to invest in something that they may have to rip and replace in two years,” said Sorrells. “So the operators are approaching them in … a tentative way … trying to help the building owners understand the value of the investment and to bring them in at entry points that make sense for that size of building.” Sorrells expects to see significant traction in the enterprise segment during 2016.

Driving down the cost of indoor small cells

Mobile operators and enterprises can reduce the cost of indoor small cell deployments by streamlining the equipment and the installation processes, and by properly testing small cells to avoid high maintenance costs.

Vendors are working hard to deliver simple, scalable solutions that can be deployed by IT technicians who may have limited radio frequency experience. Centralizing control of the small cells is one way to keep the cost of each individual access point down. Standard Ethernet cable is used to connect indoor small cells to a central controller in the solutions developed by SpiderCloud Wireless and by Airvana, which is in the process of being acquired by CommScope.

Ericsson, Huawei and ZTE have all developed indoor small cells that function as antennas and amplifiers but do not include baseband processors. LAN cabling is typically used to connect the small cells to a remote base station.

Alcatel-Lucent, Ericsson and Nokia all offer small cells that are compatible with their macro base station equipment and include baseband processing units. These solutions require less interoperability testing than those from small cell specialists like SpiderCloud, Airvana, ip.access and Airspan, but they are also less flexible because operators can only deploy them with macro equipment from the same vendor.

Small cells as a service

Small cells as a service is a term that can have several different meanings. Ericsson uses the term to refer to a small cell network that can be shared by multiple operators and can integrate carrier-grade Wi-Fi. Other small cell vendors may use the term to describe a carrier offering that companies could pay for as an operating expense. Or, the word “service” can describe offerings like unified communications and mobile device management that are enabled by a small cell network.

iGR Research founder Iain Gillott said that many IT managers are uneasy with the concept of small cells that are remotely controlled by a mobile operator.

“IT managers do not want to lose direct control of the small cell environment,” said Gillott. “To an IT manager, the phrase ‘managed solution’ means that they retain some control and have a secure environment, while benefiting from a solution that reduces IT overhead and capital expense.”

![Interest in enterprise small cell solutions as a managed service by employee size of firm](chart.png)

**Source:** iGR Research
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Mary Devlin, Site Acquisition Specialist, Site Development
Virtualization

Small cell vendors are exploring network function virtualization (NFV) as a way to potentially bring down the cost of small cells, but this movement is in its infancy.

“Virtualization for small cells, as defined for macro, doesn’t really make sense economically,” explained Pierre Lynch, lead technologist of Ixia’s product management team. Currently, virtualization of the radio access network is defined by ETSI, the European Telecommunications Standards Institute.

“Their definition requires very high-throughput fronthaul to be able to get accomplished because of where they selected to do the virtualization,” said Lynch. “For a macro network that makes economic sense, but [not] for a small cell network.”

“It is typical to link the data center to the radio unit with fiber, for instance, but that’s expensive and so folks are looking at other ways of partitioning the baseband,” explained analyst Nick Marshall of ABI Research. “There are multiple approaches. … The Small Cell Forum recently published its work on virtualization of the RAN and came up with multiple partitioning approaches for the baseband which would be suitable for small cells.”

“We’ve found clear benefits and drivers towards centralization and virtualization of the small cell network.”

Alan Law, Chairman, Small Cell Forum.

Testing techniques

Just as virtualization techniques that make sense for the macro network may not work for small cells, testing techniques also need to be adjusted for small cell environments.

“You want to have the same level of performance as a macro cell, but using the tools that would normally be deployed … for a macro cell to monitor and assure its performance are cost-prohibitive,” said Scott Sumner, VP of solutions development.
“This optimization that will be done automatically in many cases needs to have a feed of real-time metrics coming in from all parts of the network.”

Scott Sumner, Accedian Networks

and marketing Accedian Networks. “So the size, the power of your testing solutions, the operational expense, has to be sized right.” Sumner said that virtualized versions of the probes and field tests used to test macro sites can be appropriate for small cells.

“When you look at the evolution towards SDN, towards self-organizing networks, towards the dynamic pathing of traffic as networks move toward more full fabric instead of RAN and core, this optimization that will be done automatically in many cases needs to have a feed of real-time metrics coming in from all parts of the network so that you can [not only] detect issues but also fix them right away,” he said.

Sumner said that optimizing small cells can be more challenging than optimizing macro sites because often capacity can shift within a small cell network to meet user demand, and because handoffs happen very quickly. The complexity will increase significantly if operators start to deploy LTE small cells in the 5 GHz spectrum that is used for Wi-Fi.

Wi-Fi and indoor small cells

Nokia, Alcatel-Lucent and Ericsson all offer indoor small cells that include Wi-Fi connectivity chipsets. These vendors would like to see carriers bring their small cells to customers as all-in-one solutions, but they are learning that sometimes it is Wi-Fi, not cellular, that enterprises care about the most. Therefore, vendors are partnering with Wi-Fi access point makers.

Ericsson recently announced an alliance with HP, which owns Wi-Fi access point maker Aruba Networks. Ericsson plans to use Aruba’s Wi-Fi technology in future versions of its indoor small cell, and it will sell Aruba’s Wi-Fi networking gear along with its small cell portfolio. Likewise, enterprises that are buying servers or Wi-Fi access points from HP will be able to also purchase Ericsson’s small cells.

Other vendors are also partnering with Wi-Fi access point makers who can add small cells to their portfolio of solutions. SpiderCloud Wireless has partnered with Cisco and Alcatel-Lucent has partnered with Ruckus Wireless.

The Alcatel-Lucent/Ruckus partnership includes significant technical collaboration as well as co-marketing. The companies are using LTE Wi-Fi link aggregation (LWA), which aggregates both Wi-Fi and cellular on the downlink and uses cellular for the uplink. Alcatel-Lucent said that LWA can more than double download speeds relative to standalone network capabilities.

LWA is seen as a competitive technology to LAA or license-assisted access, which uses the 5 GHz spectrum for LTE transmissions. The 5 GHz spectrum is currently used for Wi-Fi, so Wi-Fi equipment vendors are concerned about interference from cell signals that could result from carrier deployments of LAA.

Indoor DAS

Some of us have had the experience of sitting at a ball game staring at a phone with no bars, while our friends chatted away happily on their phones. In highly congested areas, each carrier network may perform differently, and often the difference is a DAS.

Indoor DAS is a tried and true solution for airports, hotels and sports arenas. But even though operators, equipment makers and installers have worked on hundreds of distributed antenna systems, each DAS is a bespoke solution.

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has its own particular characteristics,” said Ray Hild, Galtronics’ VP for infrastructure in North America. “One size does not fit all.”

A single operator DAS will boost network performance for that service provider, while a multi-operator or neutral host DAS will improve service for several service providers, although the first provider on the DAS will often have the best service.

According to ABI Research, CommScope is the world’s leading vendor of DAS equipment. The company recently solidified its leading position with the purchase of TE Connectivity’s wireless funding models. Normally the carrier pays for the DAS and perhaps leases space to subsequent carriers who join the DAS, or leases space on the DAS from a neutral host provider who has taken the investment risk. Now carriers are looking for venues to help shoulder the cost of some potential DAS builds or upgrades.

“The venue will play the lead role in funding and owning the network. That means the venue owner must be able to negotiate with the carriers to plug into the network,” said Mike Collado, VP of marketing at SOLiD Technologies.

“Each build is unique and each building has its own particular characteristics.”

Ray Hild, Galtronics

“Over the last 12 months most of the spending in the U.S. DAS market specifically has been for upgrades.”

Mike O’Day, Corning
“Solutions within the ‘middleprise’ need to empower the venue to help themselves. This potentially looks like a carrier-approved / carrier-certified radio that the venue can purchase, but that the carrier needs to turn on.”

Collado sees this next tier of enterprise customers as a major opportunity for DAS vendors now that the largest venues already have systems. But these customers look at cellular connectivity as just one piece in the IT puzzle.

“Ideally, the infrastructure is converged, where a single backbone serves multiple services including commercial cellular, public-safety and IP (Wi-Fi),” said Collado. “This approach enables the infrastructure to stay in place while the end pieces get swapped out to avoid expensive rip and replace.”

DAS vendors and operators agree that building owners and their enterprise tenants will need to help finance DAS for many of the venues that want them. But that does not mean that carriers and neutral host providers will stop building DAS.

“A variety of DAS funding models exist, and we expect that to continue,” said CommScope’s Mike Melester. “Of course, each application is different and can dictate the use of different solutions. That is why CommScope continues to develop and invest in a variety of solutions to meet customer needs—whether it’s sector-splitting antennas, DAS or other small cell solutions for adding capacity.”

CommScope and Corning are examples of DAS vendors that are adapting to the changing demand for in-building solutions. CommScope has acquired TE Connectivity’s wireless business, which includes a digital DAS solution that can save money and space by connecting remote nodes directly to Alcatel-Lucent base stations without the need for head-end equipment. CommScope is also buying small cell vendor Airvana, which has developed a small cell solution that is a direct competitor to DAS. Airvana recently outfitted Gross Coliseum in Kansas (shown on the cover of this report) with a small cell system for Nextech Wireless. The carrier said the system was less than half the cost of a DAS.

Corning has leveraged its background in fiber optics to create an in-building solution that combines fiber backhaul for cellular, Wi-Fi and Ethernet. The company appears well-positioned as enterprises take a more active role in financing in-building cellular systems, because it offers a solution that also supports other enterprise connectivity requirements.

Passive DAS and signal boosters

An active DAS may be beyond reach for many companies, even though they may need more coverage than they can get from a small cell. Analyst Earl Lum of EJL Wireless Research sees a significant opportunity to connect enterprises that are too large to be supported by a small cell but not large enough to attract carrier investment in a DAS.

“You have still a huge opportunity for passive DAS,” he said. “You’re using a repeater source to borrow capacity from a sector of a cell site and just light up the inside of a building and you’re not worried about capacity or anything – you’re just trying to get some signal inside the building. The building owner has to pay for it; it’s not being paid for by the operator. There’s not a signaling source that the building owner has to buy or the operator has to buy, so the cost per square foot is substantially
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For buildings that are less than 100,000 square feet, cell signal boosters may be effective and cost even less than a passive DAS. Cell signal boosters, also called cellular repeaters, perform three functions. They receive, amplify and then rebroadcast existing cell signals. A cell signal booster will not be a good solution if the signal outside a building is already weak. But if signal deterioration occurs indoors, a cell signal booster can be a very good alternative to a distributed antenna system. Boosters use on-premise power, and they typically cover the bands of all the leading U.S. wireless carriers. In essence, they can perform like a multi-operator passive DAS.

“A signal booster system set up in a building of whatever type is a passive DAS system in itself,” said Curtis Burkhart, director of sales and marketing at Surecall. “So it’s cable, antennas, amplifier without any other need for a fiber connection to a tower or carrier-specific connectivity of any type, or backhaul. I think a lot of purists out there would say that we don’t qualify as a true passive DAS or as a DAS system at all. But as they say, the proof is in the pudding. … Installers are deploying literally hundreds of the Force 5s across the country every month now.” The Force 5 is a 5-band amplifier that supports 3G and 4G.

Some cell signal boosters can also be integrated with small cell networks. A small cell could be used to increase capacity and the cell signal booster can provide the increased coverage.

**DAS and small cells come together indoors**

Indoor small cells are expected to grow more quickly than indoor DAS, as operators and building owners look for less expensive ways to boost indoor capacity.

Analyst Joe Madden of Mobile Experts said that even when operators choose to deploy a DAS, they may use small cells as signaling sources.

“The new trend now is, instead of doing one of those big macro base station cabinets as a signal source, they can use a small cell … with a low power output to feed into that DAS system and support one sector of the DAS. So now instead of a big rack, you’ve got a little box.”

Madden said that six or seven small cells might fit into the same space previously occupied by a rack of DAS head-end equipment. He added that the small cells do not need to come from a single vendor, and that this can make it easier for a DAS to support multiple operators.

Eliminating large DAS head-ends in high-end buildings is one way to cut the cost of in-building systems. Analyst Earl Lum of EJL Wireless sees remote headend architectures as a convergence of DAS and small cells.

“Today in DAS, the majority of the DAS has to have a head-end room inside the building, which takes up a lot of room and it’s really expensive if the building is in a dense metro area like Manhattan or Chicago downtown or wherever,” he said. “If you can move the head-end room away to some cheaper part of the city and run fiber back to each of the buildings that you want to connect, and have all of the signaling equipment from the operators in that one building, that’s essentially a baseband hotel or a form of C-RAN.” Lum said that Verizon Wireless will use a remote head-end architecture like this to cover the Super Bowl in 2017.

**In-building networks and the wireless workforce**

As data usage and network deployments move indoors, infrastructure service
providers need new skill sets from the wireless workforce.

“It’s not the guy who’s climbing the towers outside … it’s more the IT-type competencies basically that are coming into play,” said Greg Rogers, head of Ericsson’s mobile broadband engagement practice. “I need a person who can interconnect the networks, someone who can connect the indoor network to the outdoor network.”

Ericsson hopes to get ahead of the curve by developing skill sets internally, but the company also expects to work with new subcontractors on small cell and DAS deployments.

“What we’ll see is a new set of vendors starting to come in because it is a new set of competencies,” said Rogers. He added that RF engineers are well-advised to develop an understanding of in-building RF coverage and Wi-Fi, as emerging small cell solutions like Ericsson’s RBS 6402 support both and are expected to work with an enterprise’s existing Wi-Fi plans when deployed.

IT professionals might also be well-advised to learn about RF, but an operator cannot assume that an installer will have RF expertise in-house. Vendors recognize this, and are trying to design solutions with the IT professional in mind.

“What we’re doing is trying to drive toward a platform of solutions that look like and feel like IT-type technologies,” said CommScope’s Philip Sorrels. “An IT technician who is used to doing Wi-Fi or used to setting up computer networks or platforms – they’ll look at this technology and say, ‘Hey, I get this, and I can install it and run it seamlessly.’” Sorrells added that CommScope’s access points can recognize the required frequency band, meaning that the IT technician does not need to know which access point is for which band.

### Outdoor small cells

Outdoor small cells have been slow to take off, and it is clear that not all operators and infrastructure providers agree on the potential here. Within the last year, AT&T has backed off a commitment to deploy 40,000 small cells and SBA Communications has sold its stake in ExteNet Systems, saying that small cells and DAS represent a “lower margin, capital-intensive business” and that the company saw “10, 20, 30 reasons why we simply prefer the macro site business.”

ExteNet was purchased by another tower company, Vertical Bridge, which clearly has a more optimistic view of outdoor small cells and DAS. Tower giants Crown Castle and American Tower also remain bullish on outdoor deployments, and carriers are definitely testing the waters.

Sprint has encouraged vendors with news that it plans to deploy 70,000 strategically located small cells. Verizon is deploying 4,000 small cells in San Francisco. The nation’s largest carrier has earmarked half a billion dollars for small cell deployments this year, and is expected to target Cincinnati, New York and Boston.

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**In-building radio node shipments**

*Source: Mobile Experts*
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Fiber is one reason that outdoor small cells are beginning to make economic sense to operators. As more dark fiber becomes available for backhaul, operators are able to plan deployments without trenching streets.

“With the growth of fiber, we are doing a tremendous amount of both outside plant and inside plant fiber work,” said Jeff Ebihara, national director of business development at NB+C. NB+C serves operators primarily on the East Coast, and Ebihara said he sees a lot of outdoor small cell and DAS activity tied to fiber backhaul.

In San Francisco, Verizon was able to leverage dark fiber and utility poles that belong to the public utility. The baseband equipment is housed in an undisclosed remote location, and fiber will connect each small cell to the baseband.

C-RAN architectures like the one Verizon is deploying may be able to significantly reduce the cost of outdoor small cells. Vendors have been working hard to deliver solutions like these in order to jumpstart the small cell market.

“For three years we’ve been chasing technology,” said Surya Bommakanti of Ericsson, Verizon’s small cell vendor for the San Francisco project. “We don’t need to chase technology anymore, we’ve got the technology. What we really need to be figuring out is the most effective deployment model both in terms of the business model as well as just the logistics of creating small cell deployments in the right places.

The bottlenecks truly are: sites, backhaul,
Site acquisition costs, power and backhaul are usually cited as the three main constraints that can delay or even derail a small cell project. CommScope’s Philip Sorrells points out that the box has a fourth corner: the potential small cell needs to be carefully evaluated in the context of the overall network before a commitment is made.

“Ultimately at the end of the day, the performance from that small cell … needs to have a high enough quality level that it really impacts the overall performance of the network without creating interference,” said Sorrells. Rigorous testing is the process that insures that performance.

“Now that we’re adding small cells into the mix … we’re adding additional elements into the chain of the backhaul itself, so adding an additional step, adding additional processing, latency, and all this can make achieving the same kind of performance over a small cell more challenging than the macro itself,” said Accedian’s Scott Sumner. Outdoor small cells also face more potential interference from the macro network than do indoor small cells, and this adds another important element to the testing process.

“You won’t necessarily have the same vendor for your small cell coverage as the macro, so you have an interop challenge there, far more than with indoor small cells,” said Ixia’s Pierre Lynch.

Before small cells even hit the streets, they undergo extensive testing in the lab. Engineers need to test small cell interactions with user equipment and with the operator’s core network.

“We … test a small cell from both sides,” said Lynch. “We’ll simulate the subscribers over the radio interface … and then conversely we’ll sandwich that test and replace the EPC and everything behind it to make the test easier and more manageable and repeatable.”

Vendors agree that small cell technology is ready for prime time outdoors. Now the challenge is finding affordable ways to get the show on the road. Operators can identify the network hot spots that could benefit from a small cell, but getting that site deployed can be an arduous process.

“A lot of that is going to hinge on whether there is actual real estate there to put something,” explained Steve Kemp, CommScope’s manager of small cell site solutions. “It’s going to be a permitting process. It’s probably going to go through several iterations of trial and error vis-à-vis the photo simulations that have to be done to see if everybody’s going to be happy with the look and feel.”

Kemp said that site acquisition and development costs are among the expenses that may be underestimated when a small cell project is first evaluated. He said operators are finding that the cost of equipment, installation and site development are all comparable.
RCR Editorial Webinar: DAS and Small Cell Update

Featuring Pierre Lynch, Lead Technologist of Ixia’s Product Management Team

With traffic from mobile devices growing faster than the Earth’s population, operators worldwide face massive opportunity. Small cells and distributed antenna systems (DAS) are an efficient and economical solution for enhancing the customer experience, improving retention, slashing cost, and unlocking new revenues.

Small cells will carry nearly half of all mobile network data traffic by 2016, and . . . offload more than 200 exabytes of data per year by 2017.¹

By 2020, SNS Research predicts HetNets will account for more than $350 billion in mobile data service revenues.²

Watch Ixia’s Pierre Lynch discuss small cell testing strategies and ramifications

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Panelist:
- Martha DeGrasse, Editor, RCR Wireless News
- Alan Law, Vodafone, Chair of Small Cell Forum
- Scott Sumner, VP Solutions Development and Marketing, Accedian
- Earl Lum, President, EJL Wireless Research.
- Pierre Lynch, Lead Technologist of Product Management Team, Ixia
- Raymond Hild, Vice President, North America, Galtronics

² Signals and Systems Market Intelligence and Consultancy Solutions, The HetNet Bible (Small Cells and Carrier WiFi) – Opportunities, Challenges, Strategies and Forecasts, 2013 – 2020 © 2013 SNS Research
“Proportionately it’s probably a third equipment, a third installation and then probably a third everything else, like three times through the permitting cycle at $3,000 a throw,” he said. “So there’s quite a bit of money that is everything else.”

“Everything else” can be managed best by upfront planning. Vendors are working hard to help operators with this process. Nokia and Alcatel-Lucent (which are planning to merge) have both developed databases that using mapping technology to help carriers cross network hot spots with locations that could support small cells. The databases catalog supporting structures like utility poles, as well as the availability of power, backhaul, and potential problem structures like gas lines.

“Over the past few years, the architecture has migrated from DAS nodes (which can be seen as a higher power version of the amplifier in an indoor DAS node) to remote radio heads,” said Madden. “A remote radio head includes the digital processing for up/down conversion, as well as CPRI-based operational/maintenance features which help the major OEMs and operators to manage and maintain the system. Remote radio head units generally work more seamlessly with the macro network.”

Even when a radio equipment maker supplies the DAS node, traditional DAS vendors will supply antennas and cable for a typical outdoor deployment. Antenna vendor Galtronics said that these equipment makers can expedite the zoning and permitting processes by creating form factors that can accommodate several RF configurations. If a zoning entity approves a form factor, it can be used repeatedly for different deployments within the approved area.

Some urban DAS deployments call for non-traditional antennas, or for concealment solutions that can disguise antennas as part of the landscape.

“We were approached by a major tower company to come up with a whip-type antenna, a 2-inch and 4-inch whip,” said Ray Hild of Galtronics. “Because at some point in time in this massive urban jungle you run out of places to put things, zoning or otherwise. It’s important that the OEM be receptive and creative.”

**Outdoor DAS**

Some industry veterans say that outdoor DAS was conceived by an executive who was frustrated because he could not get a signal on his drive home from work through Topanga Canyon in Los Angeles. For years, outdoor DAS has been a steady part of the wireless landscape without ever seeing breakout growth. Nor is outdoor DAS expected to take off in the years ahead.

Roughly 30,000 outdoor radio nodes are shipped each year, according to analyst Joe Madden of Mobile Experts. Madden estimates that more than half the nodes currently deployed are remote radio heads made by equipment vendors like Ericsson and Alcatel-Lucent.
Backhaul for outdoor DAS and small cells: Operators focus on fiber

Outdoor small cell and DAS backhaul solutions include point-to-point fiber, point-to-multipoint fiber, microwave and Ethernet over copper (DSL). The most cost effective deployments are often those that leverage existing fiber.

Even the wireless carriers that are deploying fiber-to-the-home may turn to other providers for dark fiber.

“Getting dark fiber out there, getting the small cells in there, that’s the direction we’re headed,” said Verizon Wireless’s Brian Mecum, VP-Network for the western United States. “That’s what’s going to give us our ability to deliver to our customers on the promise of reliability.”

Dark fiber is fiber that is not currently in use (lit). Infrastructure providers often lay more fiber than a given project requires in order to avoid the expense of trenching twice. The extra fiber becomes an asset that they hope to “light up” for customers in the future.

Major owners of dark fiber in the United States include Zayo, American Fiber Systems, Lightower Fiber Networks, Level 3 Communications, Allied Fiber, and CenturyLink. Regional fiber owners include Alpheus Communications, Birch Communications, PEG Bandwidth, Lumos Networks, FirstLight Fiber, and Unite Private Network.

Several other companies are quickly becoming major owners of fiber. Verizon and AT&T are both deploying fiber to support their high-speed Internet offerings. Google Fiber is currently live in Austin, Kansas City and Provo, with Charlotte, Raleigh-Durham, Atlanta, Nashville, Salt Lake City and San Antonio next on the list. Tower giant Crown Castle has recently become a significant fiber owner through its acquisitions of Sunesys, Access Fiber Group and 24/7 Mid-Atlantic Network.

“Fiber is the horizontal tower,” said Crown Castle CEO Ben Moreland. “Small cells are fed by fiber. So we are typically building fiber-based systems that are brought back to a hub site where they have all the base stations. On occasion though, we have found it to be more attractive, more economically efficient, to actually acquire some fiber instead of building.”

Conclusion

The distinction between DAS and small cells is blurring as operators deploy indoor small cells that include antennas but not modems, and DAS remotes outdoors that are actually remote radio heads. Mobile operators, municipalities and enterprise customers are all less focused on categorizing solutions than they are on solving specific problems, and throughout the ecosystem there is agreement that each connectivity issue is unique. Vendors are learning that individual problems require customized solutions, and that it helps to have a variety of tools in the toolkit. To that end, savvy vendors are acquiring new skill sets and even acquiring competitors to broaden their offerings.

Vendors see tremendous opportunities in-building, but growth hinges on the development of new business models. In short, building owners and enterprises need to help fund wireless equipment if they want more cellular capacity in their buildings. These customers are already investing in cell signal boosters and Wi-Fi access points, but DAS and small cell vendors hope to see this extend to their equipment as well. Fortunately, new network architectures such as the centralized radio access network have the potential to make solutions more affordable for building owners.

Outdoor DAS and small cells will continue to be funded primarily by the wireless carriers. Verizon Wireless and Sprint have both made commitments to new outdoor small cell deployments this year. Again, the centralized radio access network is emerging as a cost-effective architecture, with Verizon Wireless choosing this approach in San Francisco.

Analysts and operators remain split on the long-term outlook for small cells and DAS. Some see these deployments rivaling macro sites within a few years, while others are convinced that DAS and small cells will both remain niche markets, and that operators will only deploy strategically to address discrete network problems. Even if the second scenario plays out, the demand for mobile data could create enough “network problems” to necessitate widespread deployments of small cells and DAS.
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Trileaf Corporation
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Contact: Scott Muschany
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UCI specializes in the construction and installation of communication infrastructure for cellular, PCS, CLEC and fixed/mobile broadband based networks. UCI Construction Services offers turn-key solutions by providing network to transport needs. Providing network and microwave design, implementation and maintenance of customer owned back-haul infrastructures.

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Universal Network Development Corporation, a telecommunications engineering and consulting company, was incorporated under the laws of the State of California on May 15, 1980. This company, was incorporated under the laws of the State of California on May 15, 1980. This company is owned and operated by Cinthia Kazee. UNDC is a certified Minority and Woman-owned small business enterprise. We are 8(a) certified by the Small Business Administration.

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White Buffalo Environmental offers Phase I, NEPA, environmental assessments, tribal and agency consultations. Count on the company to meet your timelines and budget. White Buffalo Environmental has experienced telecommunications environmental professionals. Since 1998, the company has provided expert services to major and independent companies from single projects.

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Contact: Dr. Gemma K. Frock
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We conduct hands on training with real life scenarios to ensure you have the best understanding. We conduct various classes for Fall Protection and Rescue at our in-door training facilities in Baton Rouge, LA and Houston, TX; or at your location. We specialize in training programs for employees whose work involves special hazards in areas beyond easy access and rapid emergency aid. We focus on workers who must negotiate terrain which presents unique hazards in any line of work or industry.

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Parsons is 100% owned by the Employee Stock Ownership Trust. Parsons is a leader in many diversified markets with a focus on transportation, environmental/infrastructure, defense/security, and resources. We conquer the toughest logistical challenges and deliver design/design-build, program/construction management, and other professional services packaged in innovative alternative delivery methods to federal, regional, and local government agencies, as well as to private industrial customers worldwide.

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Pacific Safety Solution LLC

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PMI’s Vertical Specialist program exists to establish a group of excellent, experienced athletes in various rope related sports and rope access skills across the USA.

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brandon@techsafetylines.com
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TES Inc. is your “Go To” expert for fall protection, rescue and access for work at height, confined space and technical rescue. We offer our customers the opportunity to communicate, train and find the resources to accomplish the task at hand.

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Tower Safety Consulting (formerly Tower Safety International) has been training individuals, Fortune 500 companies, major defense contractors, the United States Military as well as many other Government agencies for the last 15 years. We specialize in offering OSHA mandated safety training for construction workers, maintenance personnel, telecom engineers and design personnel regardless of their hands on involvement in working on elevated structures.

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Vertical Systems International Inc. (VSI) is dedicated to providing safe solutions for industries that have workers exposed to fall hazards and extreme conditions, whether in the mountains or on industrial structures. VSI is the expert in consulting and training for Fall Protection, Tower Climbing, Confined Space, Rope Access, Wilderness Mountain Safety and Technical Rescue throughout the world.

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info@airhopcomm.com
airhopcomm-web.com
Founded in 2007, AirHop is a privately held startup that develops advanced RAN intelligence software critical to the next wave of the mobile Internet. AirHop’s eSON products are the first to completely address the installation, operation, performance, and multi-vendor support challenges of multi-layer, small cell and HetNet deployments.

Airvina
Hardware
250 Apollo Drive
Chelmsford, MA 01824
Contact: Josh Adelson
978-250-3000
info@airvina.com
www.airvina.com
Airvina provides 4G LTE small cell solutions for residential, small/medium business, enterprises and public spaces.

Alcatel-Lucent
Hardware
15401 Commerce Park Dr.
Brook Park, OH 44142
Contact: Bruce Carmichael
440-232-6060
sales@allfasteners.com
www.allfasteners.com
Fasteners to the tower industry, Ajax Oneside, A490, A325, V bolts, U bolts, steel for tower modifications.

Ambor Structures Inc.
Hardware
PO Box 3763
St. Paul, MN 55101
Contact: Andrew Murray
651-414-1276
andrew.murray@amborstructures.com
www.amborstructures.com
AN Structures provides pre-engineered and custom designed communication tower packages, especially well suited to international Broadband Deployments and Two-way applications. These tower ship very economically internationally.

Athena Wireless Communications
Hardware
12425 W. Bell Rd, Ste. 144
Surprise, AZ 85378
623-242-7224
sales@athenawave.com
www.athenawave.com
Athena designs and manufactures SiGe-based millimeter-band wireless Gigabit backhaul links and SoC-based LTE small cells for wireless telecommunication operators, governments and private enterprises around the globe.

Avlite
Component
Bracnet Ltd.
Hardware
House:26, Road:28, Block: K, Banani Dhaka
arahimbdd@yahoo.com
www.bracnet.net
ISP & Nationwide Data Connectivity Company.

Buckingham Mfg. Co., Inc.
Accessory

BTI Wireless
Hardware
6185 Phyllis Drive, Unit D
Cypress, CA 90630
Contact: Ron Poulin
714-856-9604
ronp@btiewireless.com
www.btiwireless.com

Cablcon
Hardware
379 Executive Drive
Troy, Michigan 480083
Contact: Dan Tomica
248-703-6493
dtomica@cablcon.com
www.cablcon.com

Carrier IQ
Component
640 W. California Avenue, Ste. 100
Sunnyvale, CA 94086
650-625-5400
bbergeret@carrieriq.com
www.carrieriq.com
As market leader in mobile intelligence, Carrier IQ provides mobile operators and device vendors with actionable analytics and insights into the real mobile customer experience.

Carwell Specialty Coatings
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408-943-7100
info@cavium.com
www.cavium.com
OCTEON Fusion Family, the industry’s most powerful, small cell Base Station-on-a-chip family are specifically designed for LTE & 3G multi-mode small cell base stations, including picocell and micro base stations.

Cell Blocks Inc.
Hardware
PO Box 1167
Jackson, CA 95642
Contact: James Fey
510-418-4322
philcolflesh@cellblocksinc.com
www.cellblocksinc.com

Cellite Solutions
Hardware
1720 I Ave NE
Cedar Rapids, IA 52402
Contact: Amber Kramer
319-826-3404
amber@cellitesolutionsllc.com
www.cellitesolutions.com

CITCA LLC
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Comarcom
Hardware
7 Hazeck
Tivon, Israel 36011
+972 (0)4 9531638
gary@comarcom.biz
www.comarcom.biz
Comarcom designs, manufactures and markets VEGA, very high gain antenna, the most cost effective solutions to meet Radio Access Network coverage challenges.

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San Jose, CA 95131
Contact: Kevin Geary
866-802-7961
sales.nam@comba-telecom.com
www.combausa.com

Com cellForRowAtIndexPath
 struct {
  CGSize size;
  UIView *view;
} _cell;

cba compliant
 com calculations
 for

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4 Westbrook Corporate Center, Ste. 400
Westchester, IL 60154
708-236-6634
bill.walter@commscope.com
www.commscope.com
CommScope has played a role in virtually all the world’s best communication networks. We create the infrastructure that connects people and technologies through every evolution. Our portfolio of end-to-end solutions includes critical infrastructure our customers need to build high-performing wired and wireless networks.

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Farmers Branch, TX 75234
866-770-3207
www.customcableconnection.com
sales@customcableconnection.com
Cable Assembly House.

Dali Wireless, Inc.
Hardware
535 Middlefield Road, Ste 280
Menlo Park, CA 94025
Contact: Johnny Truong
916-934-2583
information@daliwireless.com
www.daliwireless.com
Dali Wireless is the global provider of an all-digital RF ROUTER® platform. This revolutionary platform transcends the capabilities typically associated with traditional Distributed Antenna Systems (DAS) to deliver more data throughput and value at the lowest Total Cost of Ownership.

Dantel Inc.
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559-292-1111
info@dantel.com
www.dantel.com
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www.dantherm.com/us/

Delta Node
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3030 Aurora Road
Solon, OH 44139
Contact: Tom Doyle
866-695-4569
sales@birdrf.com
www.birdrf.com

DEUS Rescue
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Dialight Corporation
Equipment

Dillon/Quality Plus, Inc.
Equipment

Eagle Comtronics
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7665 Henry Clay Blvd.
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800-448-7474
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www.eaglecomtronics.com
Eagle Comtronics has been a recognized leader in RF (Radio Frequency) communication and filter manufacturing since 1975. Known for industry changing innovations in Filter technology.

Electro Wire
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933 East Remington Rd
Schaumburg, IL 60173

Elk River, Inc.
Accessory

EnerSphere Communications, LLC
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2950 Mt. Wilkinson Pkwy. SE
Atlanta, GA 30339
404-449-4729
info@enersphere.com
www.enersphere.com
EnerSphere develops, sells and leases modular composite pole technology with integrated outdoor Small Cell infrastructure that serves the mobile communications, electric utility and municipal markets.

ERICO, Inc.
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Ericsson
Equipment

Essentia
Equipment
One Mallard Pointe,
11020 David Taylor Drive, Ste. 103
Charlotte, NC 282262
Contact: Caroline Dalpiaz
704-360-3647
caroline.dalpiaz@essentia-inc.com
www.essentia-inc.com

Etheretronics Inc.
Equipment
5501 Oberlin Drive, Ste. 100
San Diego, CA 92159
619-847-9855
amccray@ethertronics.com
www.ethertronics.com
Etheretronics develops antenna and RF Front End system solutions for 3G and 4G (LTE and LTE-Advanced) mobile devices, as well as solutions for M2M, IoT and Distributed Antenna Systems (DAS).

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254 E Hacienda Avenue
Campbell, CA 95008
408-688-0200
info@exaltcom.com
www.exaltcom.com
Exalt Communications is the leading innovator of next-generation point-to-point and point-to-multipoint systems for private networks and Internet infrastructures.

Fairview Microwave
Equipment
1130 Junction Dr. Suite 100
Allen, TX 75013
972-649-6678
shaun@fairviewmicrowave.com
www.fairviewmicrowave.com
Fairview Microwave offers immediate delivery of RF components including attenuators, adapters, coaxial cable assemblies, connectors, terminations and much more.

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Athens 15344
302103000000
info@fasmetrics.com
www.fasmetrics.com
FASMETRICS S.A. offers a revolutionary robotic antenna platform that dramatically changes how an antenna network operates and behaves. It increases the capacity and quality of broadband services, sharply reduces costs and keeps your customers loyal.

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Oriskany, NY 13424
Contact: Kirk Donley
315-736-2206
www.fiberinstrumentsales.com

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Yokneam 20692
972-495-91717
info@fibrolan.com
www.fibrolan.com
Fibrolan is an experienced vendor of Optical Access Equipment, for the Telecom (fixed and mobile) and Government markets.

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Columbia, MD 21020
Contact: Beau Aero
312-260-6055
info@fieldsense.com
www.fieldsense.com

FIMO USA
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Innovative Systems provides voice, video and OSS/BSS telecommunications services to wireless and wireline companies with over 1200 systems in service. The APMAX delivers voice services including Unified Messaging, Mass Notification, Conference Calling, Web Portal Customer Care and many other enhanced voice services.

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Vista, CA 92081
760-631-6789
www.treescapes.com
www.treescapes.com
Manufacturer of cellular, surveillance and sound system concealment products, including replica tree wraps for rooftop and hillside sites.

Interop Technologies
Hardware
PO Box 41875
Nashville, TN 37204
Contact: Katie Taylor
615-256-6030
taylor@itl-llc.com
www.itl-llc.com

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444 E. State Parkway, Suite 123
Schaumburg, IL 60173
888-472-3458
sales@iscointl.com
www.iscointl.com
Solutions maximizing performance of the RF uplink through spectrum conditioning to mitigate interference, manageability to react to spectrum dynamics, and spectral awareness tools.
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<thead>
<tr>
<th>ITL, LLC</th>
<th>Component</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>ITrinity</strong></td>
<td>Hardware</td>
</tr>
<tr>
<td>Bulse Grange</td>
<td></td>
</tr>
<tr>
<td>Saffron Walden</td>
<td></td>
</tr>
<tr>
<td>CB11 4JT</td>
<td>+44 01799 252200</td>
</tr>
<tr>
<td><a href="mailto:debra.wilkins@itrinegy.com">debra.wilkins@itrinegy.com</a></td>
<td></td>
</tr>
<tr>
<td><a href="http://www.itrinegy.com">www.itrinegy.com</a></td>
<td></td>
</tr>
<tr>
<td>ITrinity provides network profiling and network emulation for de-risking application performance out in the field for Satellite, Virtual, WAN/LAN, Mobile, Radio over IP etc.</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>JDSU</th>
<th>Hardware</th>
</tr>
</thead>
<tbody>
<tr>
<td>430 N McCarthy Blvd.</td>
<td></td>
</tr>
<tr>
<td>Milpitas, CA 95035</td>
<td>408-546-5000</td>
</tr>
<tr>
<td><a href="mailto:info@jdsu.com">info@jdsu.com</a></td>
<td><a href="http://www.jdsu.com">www.jdsu.com</a></td>
</tr>
<tr>
<td>JDSU serves markets that are at the heart of what's important, making virtually every network in the world faster and more reliable. JDSU leads the fastest-growing segments of the optical-networking market: tunable XFPs, transport blades, and reconfigurable optical add/drop multiplexers (ROADMs).</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>JMA Wireless</th>
<th>Hardware</th>
</tr>
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<tbody>
<tr>
<td>7645 Henry Clay Blvd</td>
<td></td>
</tr>
<tr>
<td>Liverpool, NY 13088</td>
<td>315-431-7126</td>
</tr>
<tr>
<td><a href="mailto:dlawrence@jmawireless.com">dlawrence@jmawireless.com</a></td>
<td></td>
</tr>
<tr>
<td><a href="http://www.jmawireless.com">www.jmawireless.com</a></td>
<td></td>
</tr>
<tr>
<td>Kaipac</td>
<td>Hardware</td>
</tr>
<tr>
<td>724 Canyon Drive</td>
<td></td>
</tr>
<tr>
<td>Coppell, TX 75019</td>
<td><a href="http://www.kaipac.com">www.kaipac.com</a></td>
</tr>
<tr>
<td>Kimberly Steel Solutions</td>
<td>Accessory</td>
</tr>
<tr>
<td>9138 County Road 65</td>
<td></td>
</tr>
<tr>
<td>Foley, AL 36535</td>
<td>Contact: Jeff Osborne</td>
</tr>
<tr>
<td>866-320-2197</td>
<td><a href="mailto:josborne@kimberlysteelsolutions.com">josborne@kimberlysteelsolutions.com</a></td>
</tr>
<tr>
<td><a href="http://www.protectivecages.com">www.protectivecages.com</a></td>
<td></td>
</tr>
<tr>
<td>Protective steel cages and enclosures for cell towers, switch gear, etc.</td>
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<table>
<thead>
<tr>
<th>L-Com</th>
<th>Component</th>
</tr>
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<tbody>
<tr>
<td>Laird</td>
<td>Hardware</td>
</tr>
<tr>
<td>1751 Wilkening Ct.</td>
<td>Schaumburg, IL 60173</td>
</tr>
<tr>
<td>Contact: Gus Basualdo</td>
<td>954-240-2036</td>
</tr>
<tr>
<td><a href="mailto:gus.basualdo@lairdtech.com">gus.basualdo@lairdtech.com</a></td>
<td></td>
</tr>
<tr>
<td><a href="http://www.lairdtech.com">www.lairdtech.com</a></td>
<td></td>
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<tr>
<td>Lattice Communications</td>
<td>Component</td>
</tr>
<tr>
<td>Launch 3</td>
<td>Hardware</td>
</tr>
<tr>
<td>134 Myer Street</td>
<td>Hackensack, NJ 07601</td>
</tr>
<tr>
<td>877-878-9134</td>
<td><a href="mailto:sales@launch3.net">sales@launch3.net</a></td>
</tr>
<tr>
<td><a href="http://www.launch3telemcom.com">www.launch3telemcom.com</a></td>
<td></td>
</tr>
<tr>
<td>Launch 3 Telecom is an international distributor of new, used, and refurbished telecom equipment. Launch 3 carries all major manufacturers such as Andrew, Cisco, Alcatel-Lucent, Tyco, Katherin Scala Division, Powerwave, and many more.</td>
<td></td>
</tr>
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<table>
<thead>
<tr>
<th>LBA Technology</th>
<th>Hardware</th>
</tr>
</thead>
<tbody>
<tr>
<td>3400 Tupper Drive</td>
<td>Greenville, NC 27834</td>
</tr>
<tr>
<td>252-757-0279</td>
<td><a href="mailto:lbagrp@lbagroup.com">lbagrp@lbagroup.com</a></td>
</tr>
<tr>
<td>lbatechnology.com</td>
<td></td>
</tr>
<tr>
<td>Fabricates lightning mast protection systems, sophisticated radio antenna tuning &amp; coupling systems, provides transmission &amp; shielding system design-build integration &amp; markets test equipment for the RF sector.</td>
<td></td>
</tr>
</tbody>
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<thead>
<tr>
<th>LNA Solutions, Inc.</th>
<th>Component</th>
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</thead>
<tbody>
<tr>
<td>LOCIO International</td>
<td>Hardware</td>
</tr>
<tr>
<td>2 Countryside Dr</td>
<td>Pelham, NH 03076</td>
</tr>
<tr>
<td>888-509-3669</td>
<td><a href="mailto:sales@locointl.com">sales@locointl.com</a></td>
</tr>
<tr>
<td><a href="http://www.locointl.com">www.locointl.com</a></td>
<td></td>
</tr>
<tr>
<td>LOCO International is the leading global provider of new and refurbished networking equipment, computer systems, computer parts, and test and measurement equipment. We buy and sell electronic hardware, test equipment, networking and computer parts at reduced prices.</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Lyncle XIT Grounding</th>
<th>Component</th>
</tr>
</thead>
<tbody>
<tr>
<td>Matsing</td>
<td>Hardware</td>
</tr>
<tr>
<td>12 Mauchly, Unit O</td>
<td>Irvine, CA 92618</td>
</tr>
<tr>
<td>Contact: Tony DeMarco</td>
<td>714-504-5964</td>
</tr>
<tr>
<td><a href="http://www.matsing.com">www.matsing.com</a></td>
<td></td>
</tr>
<tr>
<td>Maximum Signal LLC</td>
<td>Hardware</td>
</tr>
<tr>
<td>3843 Union Road, Suite 15 , #139</td>
<td>Cheektowaga, NY 14225</td>
</tr>
<tr>
<td>716-818-5896</td>
<td><a href="mailto:maximumsignal@aol.com">maximumsignal@aol.com</a></td>
</tr>
<tr>
<td><a href="http://www.maximumsignal.com">www.maximumsignal.com</a></td>
<td></td>
</tr>
<tr>
<td>Melody Wireless Infrastructure</td>
<td>Hardware</td>
</tr>
<tr>
<td>60 Arch Street</td>
<td>Greenwich, CT 06830</td>
</tr>
<tr>
<td>Contact: David Bacino</td>
<td>203-302-1790</td>
</tr>
<tr>
<td><a href="mailto:dbacino@melodypartners.com">dbacino@melodypartners.com</a></td>
<td></td>
</tr>
<tr>
<td><a href="http://www.melodywireless.com">www.melodywireless.com</a></td>
<td></td>
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<tr>
<td>Midsun Speicalty Products, Inc.</td>
<td>Component</td>
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<tr>
<td>Midwest Unlimited LLC</td>
<td>Accessory</td>
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<tr>
<td>Miller Fall Protection By Honeywell</td>
<td>Accessory</td>
</tr>
<tr>
<td>MPS Civil Products (MacLean Dixie)</td>
<td>Component</td>
</tr>
<tr>
<td>MSETCL</td>
<td>Hardware</td>
</tr>
<tr>
<td>Parakash Ganga, BKC, Bandra(E)</td>
<td>Mumbai, India 400062</td>
</tr>
<tr>
<td><a href="mailto:singhbp64@yahoo.com">singhbp64@yahoo.com</a></td>
<td>mahatransco.in</td>
</tr>
<tr>
<td>Multiwave Sensors Inc.</td>
<td>Component</td>
</tr>
<tr>
<td>Narda Safety Test Solutions</td>
<td>Component</td>
</tr>
<tr>
<td>National Strand Products, Inc.</td>
<td>Component</td>
</tr>
</tbody>
</table>
OTL Solutions
Hardware
4920 Louis-B. Mayer
Laval, QC H7P 0H7
Contact: Michel Lavallee
800-647-9110
info@otlsolution.com
www.otlsolution.com

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401 E Las Olas Blvd, Ste. 1520
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Contact: Nelsy Arellano
954-525-1906
narellano@neptunouusa.com
www.naapsolution.com

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211 W. Washington St, Ste. 2000
South Bend, IN 46601
Contact: Todd Kneller
574-288-3832
tkneller@nelloinc.com
www.nelloinc.com

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info@phoenixcon.com
www.phoenixcontact.com
Phoenix Contact develops and manufactures industrial electrical and electronic technology products that power, protect, connect and automate systems and equipment for many industries.

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gabe@primuselectronics.com
www.primuselectronics.com

Primus Electronics
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Contact: John Lavalette
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john.lavalette@prysmiangroup.com
na.prysmiangroup.com

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3611 NE 112th Ave
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Quest Controls
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208 9th Street Drive West
Palmetto, FL 34221
Contact: Robert Vachris
941-224-1005
rvachris@questcontrols.com
www.questcontrols.com

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Rochester, NY 14615
Contact: Joseph Veni
408-687-1093
joe.veni@quintelsolutions.com
www.quintelsolutions.com

Northstar Battery Company
Hardware
4000 Continental Way
Springfield, MO 65803
Contact: Al Aflague
530-503-5053
al.aflague@northstarbattery.com
www.northstarbattery.com

Nextivity
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12230 World Trade Drive
San Diego, CA 92128
Contact: Joe Schmelzer
858-485-9442
jschmelzer@nextivityinc.com
www.cel-fi.com
Nextivity Inc. is a leading developer of indoor cellular coverage technology which optimizes the experience of wireless subscribers and increases Radio Frequency (RF) network capacity for mobile operators.

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Van Nuys, CA 91411
818-780-9701
info@opticalzonu.com
www.opticalzonu.com
Manufacturers of carrier-grade RF-over-Fiber interconnect links for small cell and DAS deployments.

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tkneller@nelloinc.com
www.nelloinc.com

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401 E Las Olas Blvd, Ste. 1520
Fort Lauderdale, FL 33301
Contact: Nelsy Arellano
954-525-1906
narellano@neptunouusa.com
www.naapsolution.com

Northstar Battery Company
Hardware
4000 Continental Way
Springfield, MO 65803
Contact: Al Aflague
530-503-5053
al.aflague@northstarbattery.com
www.northstarbattery.com

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Optica Network Technologies, LLC
Accessory

Optical Zonu Corporation
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15028 Delano Street
Van Nuys, CA 91411
818-780-9701
info@opticalzonu.com
www.opticalzonu.com
Manufacturers of carrier-grade RF-over-Fiber interconnect links for small cell and DAS deployments.

OTL Solutions
Hardware
4920 Louis-B. Mayer
Laval, QC H7P 0H7
Contact: Michel Lavallee
800-647-9110
info@otlsolution.com
www.otlsolution.com

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Middletown, PA 17057
717-944-1300
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www.phoenixcontact.com
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Accessory

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Hardware
PO Box 129
Ostrander, OH 43061
www.precisiontowerproducts.com

Preformed Line Products
Accessory

Primus
Hardware
4180 E Sand Ridge Rd
Morris, IL 60450
800-435-1636
gabe@primuselectronics.com
www.primuselectronics.com

Primus Electronics
Component

PRINOTH
Component

Pro-Tec Mobile Communications
Hardware
1641 North Pinal Ave.
Casa Grande, AZ 85122
520-836-4681
protecmobile@aol.com
www.protecmobile.com
Motorola, Kenwood Dealers

Prysmian Group
Hardware
PO Box 39
Claremont, NC 28610
Contact: John Lavalette
800-879-9862
john.lavalette@prysmiangroup.com
na.prysmiangroup.com

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3611 NE 112th Ave
Vancouver, WA 98682
Contact: Denise Kegley
360-859-5016
dkegley@pulseelectronics.com
www.pulseelectronics.com

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Hardware
208 9th Street Drive West
Palmetto, FL 34221
Contact: Robert Vachris
941-224-1005
rvachris@questcontrols.com
www.questcontrols.com

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