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Wireless Investors Conference

The View from the Top

DAS and Small Cells Magazine

Cellular Network Primer
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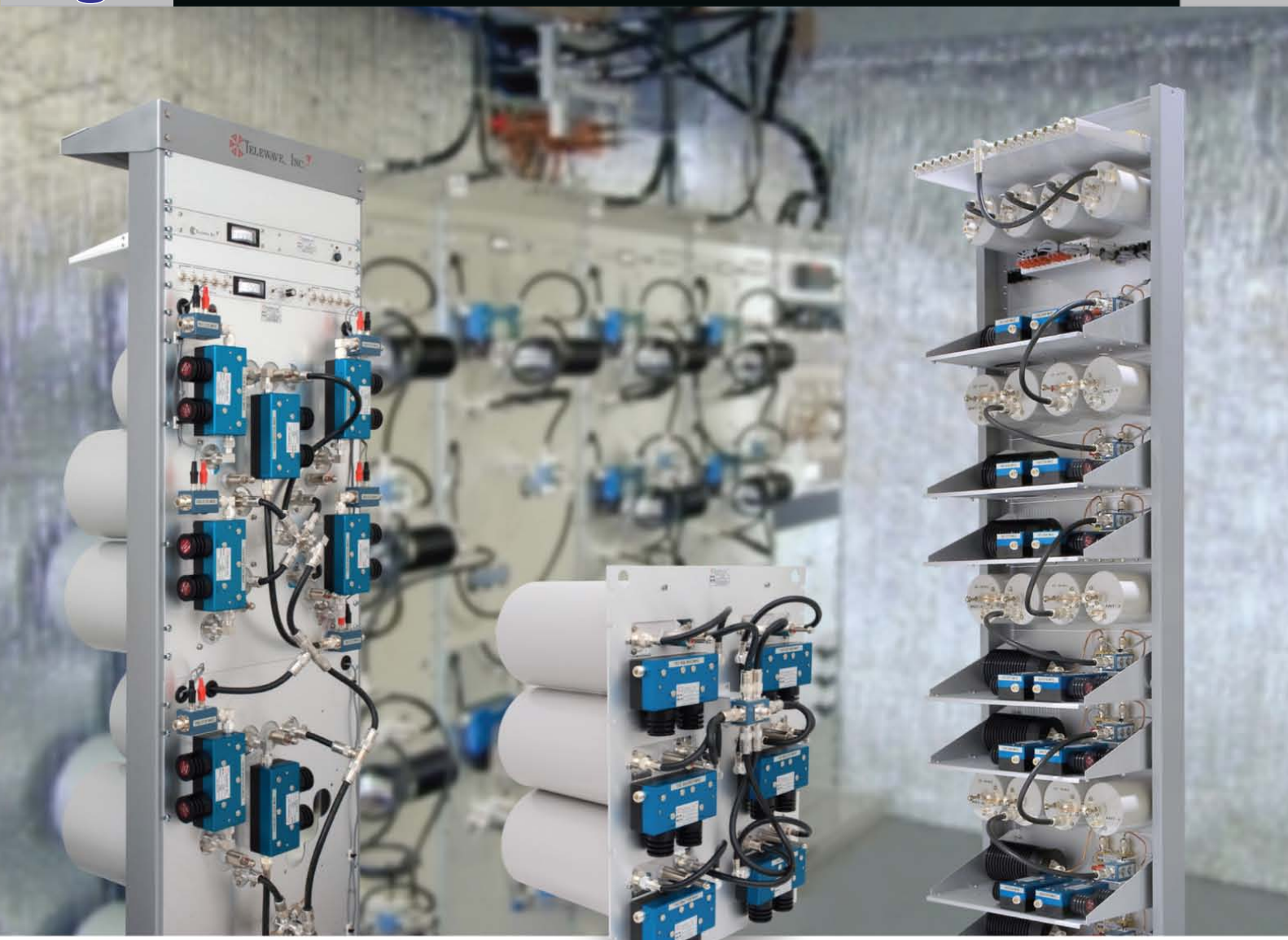

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December 2013 Vol. 10, No. 11

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on the cover

What's on the horizon? Industry leaders offer predictions and forecasts for the coming year and beyond in the annual Horizons section. See page 22.

Cover design by Scott Dolash

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5G—Too Soon?

Each December, *AGL* highlights predictions and forecasts in its Horizons section. This year's Horizons section begins on page 22. Our thanks to industry leaders who contributed prognostications this year, and to *AGL*'s J. Sharpe Smith, editor of the *AGL Link* and *AGL Small Cell Link* email newsletters, for compiling the forecasts. Four executives of tower companies (see "The View from the Top") are also represented, along with 10 financial world representatives (see "Wireless Investors Conference").

When 4G is not 4G

LTE, which stands for Long Term Evolution, achieves higher data throughputs by modulating the RF carrier wave with orthogonal frequency-division multiplexing. It allows the radio signal to carry more data compared with other modulation methods.

LTE Advanced helps to bring network performance up to speed, such as 1 gigabit per second. Which, by the way, was part of some standards organizations' definition of 4G, and by their definition, LTE is not quite 4G. For marketing purposes, it is 4G, but for engineering purposes, maybe not quite. LTE Advanced is intended to fix that.

With the use of advanced-topology networks and the ability to include the macrocells supported by tower owners and rooftop antenna-site managers along with picocells, femtocells and new relay nodes, LTE Advanced brings to the forefront optimized heterogeneous networks. The technology also can use bandwidths up to 100 megahertz wide to help with its support of high data rates.

Aside from the multibillion-dollar expense of upgrading their networks, all this pleases wireless carriers because it helps them meet customer demand, and it helps them to better compete with their landline counterparts. In turn, LTE and LTE Advanced please *AGL* readers, including tower owners, site acquisition specialists, tower erectors, equipment installers and carriers' antenna site managers because the 4G roll outs are delivering plenty of work to do and sales opportunities.

5G on the (distant) horizon

OK, that's fine for now, and next year, and maybe a year or two or three after that. But then what? 5G? Perhaps not quite so soon, but maybe in the early 2020s.

1G began in 1981, 2G in 1992, 3G in 2001 and 4G (fully compliant) in 2012. 5G could be about 10 years away.

On Oct. 30, Sprint announced Spark, a service that uses triband (800 MHz, 1.9 GHz and 2.5 GHz) devices. Spark will offer a peak speed of 50 Mb/s to 60 Mb/s. Sprint demonstrated 1 Gb/s service in the lab and said it is technically feasible to deliver more than 2 Gb/s per sector over-the-air speed. Spark uses frequency-division duplexing in the two lower bands and time-division duplexing with carrier aggregation in the higher band.

Flashback: In the 1880s, Hienrich Hertz used a spark gap to generate electromagnetic (radio) waves. In 1895, Guglielmo Marconi used a spark gap to demonstrate wireless communications. Spark may be the oldest word in wireless telecommunications. It's interesting that Sprint's new wireless technology is named the same as the oldest.

Meanwhile, don't be surprised if marketing starts referring to 5G service well before engineering codifies a 5G standard.

Wireless carriers should continue to seek ever-faster data throughput in the name of customer service. And when the 5G roll out comes, antenna site owners and equipment installers will be smiling. ■

By Don Bishop, Executive Editor
dbishop@agl-mag.com

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Infrastructure, regulatory and financial information for the antenna-siting community

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swap@agl-mag.com

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publisher's note

Here We Go Again...

Heading into the holiday season always has been my time for reflection and planning for the future — at least as much as I can possibly pretend to be able to plan for much in this industry. We always end the year with the December Horizons issue that takes a peek at the future and reflects on the events of the year. Our graphics guru, Art Director Scott Dolash, is the genius behind the *AGL* Tower of the Month center spread photo feature and always finds some great images for us. Scott also designed this issue's cover. Paul Wrablica, president of Telecom Realty Consultants and a friend of *AGL* who has been helpful to the magazine since 2004 in the months before its launch, captured the image used for this issue's Tower of the Month. Thanks for the great work, gentlemen.

Accidental publisher

It seems surprising to realize that Biby Publishing is nearly 10 years old, and *AGL* magazine will start its 10th year in January. Yep, 10 years of Biby Publishing and *AGL* magazine. This project started out as an educational outreach for the industry and to help municipal government decision-makers understand our antenna-siting industry. I think we've done pretty well, and we continue to make improvements in everything we do. As much fun as it's been, this accidental publisher has seen an opportunity to make some changes to the organization while continuing to ratchet up our content, topic coverage and industry outreach.

Name change

Publishing is a funny business. As an RF engineer, I have found publishing to be a lot of fun and completely different from anything I previously knew, but also full of a lot of new rules and traditions. Many of the rules and traditions I simply skipped when we started *AGL*. I didn't know any better. That's one nice thing about not knowing what you are doing. We are changing the name of the company that publishes *AGL* from Biby Publishing to AGL Media Group. It is just one of those growing up things, I guess. As I'm staring at 50 before too long, perhaps this is not a bad thing.

You may have noticed that Biby Publishing launched a new entity with a rebranding as AGL Media Group at the 2013 PCIA Wireless Infrastructure Show. We have heard good things about our new look and the expansion of our product offerings. I'm extremely happy to announce that Pat Troxell-Tant, CEO of Solution Seven,is working with the AGL Media Group team. Pat and Solution Seven are heading many of our new initiatives in 2014, including the new *AGL Small Cell Magazine*, two new e-newsletters, an increased focus on video interviews, a continuing expansion of the AGL Conferences, and the already successful launch of the new website, *www.aglmediagroup.com*.

If you've been in the industry more than a few minutes, you've probably had a chance to meet or work with Pat. She was largely responsible for the formation of the first state wireless association in Tennessee and the creation of the State Wireless Association Program. She is an overall industry force. Pat's background has focused on strong sales and marketing skills to grow companies within the wireless industry, and we're very excited to have her and the Solution Seven team working with us. The energy and professionalism is very welcome. I believe you will continue to be impressed with the publications and information you read and the events that you attend.

AGL Small Cell Magazine

We've resisted an inevitable change in the industry of moving to a purely digital publication. We enjoy publishing a magazine every month, and we love the results in print. In 2014, we'll be launching *AGL Small Cell Magazine* and, strangely enough, it also will be in print, at least for 2014. We'll see how 2015 shakes out. We also will relaunch two e-newsletters and rebrand them. The former *AGL Bulletin* becomes the *AGL Link*, and the former *DAS Bulletin* becomes the *AGL Small Cell Link*.

Something we'll be doing a lot more of next year is video. I have the pleasure of conducting most of the AGL Media Group video interviews you see on the website. We will conduct more interviews, webinars and video coverage of our conferences next year to bring you more information in greater detail from the best, most talented and knowledgeable people in the industry. You can receive this on our website all at a price you have to love: free. However, you know how it works; we survive on advertisers and sponsors. Companies trying to sell you stuff. And if you are in the industry, you likely do buy stuff, so it is not such a bad deal for any of us. If you like what we do, please pass the good word about our publications and our website to whomever you do business with. We have a really great group of companies sponsoring our events and advertising in the publications. These companies are why we can keep doing what we do. Thank you.

As an early morning person and avid NPR listener, I've heard Garrison Keillor for years end his short, daily early morning segment, "The Writers Almanac," with a tagline that makes sense for me to close with: "Be well, do good work, and keep in touch." ■

By Rich Biby, Publisher
rbiby@agl-mag.com

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Quick-Guide to DAS Companies

As a supplement to *AGL*'s January Buyers Guide, a list of DAS companies offers more detail to help you choose a vendor for your next project. Each service is coded numerically according to the legend below.

1. Site analysis	5. System engineering	9. System maintenance
2. Financing	6. System installation	10. Carrier coordination
3. Permitting	7. System management	11. RF analysis
4. System design	8. System monitoring	12. Concealment

Where shown, logos and company descriptions were provided by and paid for by each company.

5 Bars Inside
19200 Von Karman Ave., Suite 100
Irvine, CA 92612
Raylene Gonzalez
raylene.gonzalez@5barsinside.com
(949) 294-5274
www.5barsinside.com
Type of system: neutral host
Types of products: DAS, small cell, Wi-Fi
Types of services: 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11
Company description:
Five Bars Inside is a neutral-host DAS and Wi-Fi provider that offers total wireless connectivity by increasing coverage and capacity for both indoor and outdoor spaces. The company's team works with owners to design, build, operate, monetize and maintain indoor and outdoor wireless networks.

AFL
170 Ridgeview Center Drive
Duncan, SC 29334
Brian Wheeler
brian.wheeler@aflglobal.com
(678) 772-6627
www.aflglobal.com
Products offered: DAS, Small cell, Wi-Fi
Services offered: 1, 3, 4, 5, 6, 7, 8, 9, 10, 11
Other: Field support; continuous dispatch services; base station installation, integration and commissioning; Wi-Fi design, installation and maintenance; small cell installation, commissioning, support; and DAS and Wi-Fi structured cabling pre-plan design for new LEED construction.
Company description:
AFL is a vertically integrated solutions provider with expertise from the data center to wireless antenna. With over 1,600 associates across North America, AFL self-performs design, installation and support activities for macro, DAS, Wi-Fi and small cell projects. AFL takes the customer from design to commissioning.

American Tower
10 Presidential Way
Woburn, MA 01801
leasing@americantower.com
(877) 409-6966
www.americantower.com
Type of system: neutral host
Types of services: 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12
Company description:
American Tower is a wireless and broadcast communications infrastructure provider that offers access to more than 36,000 communications sites throughout the United States. The company's solutions include in-building wireless and outdoor DAS, small cell and Wi-Fi networks, other right of way options, managed rooftops, wireless and broadcast towers and services that speed network deployment.

Anritsu
1155 E. Collins Blvd., Suite 100
Richardson, TX 75081
Rob Robinson
rob.robinson@anritsu.com
(800) ANRITSU
www.anritsu.com
Types of products: test and measurement equipment and software for DAS, small cells and Wi-Fi
See ad on page 17

AT&T Towers
2300 Northlake Center Drive, 484
Tucker, GA 30084
Alicia Vines
ae426h@att.com
(405) 210-5082
www.atttowers.com
Type of system: neutral host
Type of product: DAS
Types of services: 4, 5, 6, 7, 8, 9, 10, 11, 12
Company description:
With greater, wider demand for anytime, anywhere wireless coverage, the AT&T portfolio, featuring AT&T neutral-host DAS, towers and rooftop coverage, offers more ways to meet the challenges customers face. With end-to-end support from its specialists, AT&T strives to make the entire process quick and easy.
See ad on page 11

AW Solutions
300 Crown Oak Centre Drive
Longwood, FL 32750
James Partridge
james.partridge@awsolutionsinc.com
(407) 260-0231 ext. 101
www.awsolutionsinc.com
Types of systems: neutral host, facility-owned, carrier-owned, public safety
Types of services: 1, 3, 4, 5, 6, 9, 10, 11, 12
Company description:
AW Solutions is licensed throughout the United States, Canada and the Caribbean, providing turnkey site infrastructure development and build-to-suit services to the wireless, iDAS, oDAS, wireline and fiber industry sectors. Services include project management, site evaluations and audits, site acquisition and land planning, engineering design and analysis, regulatory, construction management, construction, and warehousing and logistics.

Axell Wireless
15950 N. Dallas Parkway, Suite 400
Dallas, TX 75248
Matthew Thompson
sales.dallas@axellwireless.com
(972) 361-8038
www.axellwireless.com
Types of systems: neutral host, facility-owned, carrier-owned, public safety
Type of product: DAS
Types of services: 4, 5, 7, 8, 10, 11
Company description:
Axell Wireless is one of the largest DAS manufacturers in the world, specializing in both commercial and public safety DAS. Operating in the United States for over 40 years and owned by technology giant Cobham, Axell Wireless offers solutions for all bands and technologies, making Axell a one-stop shop.

Bird Technologies
30303 Aurora Road
Solon, OH 44139
Tom Boyle
tboyle@birdrf.com
(440) 519-2172
www.birdrf.com
Types of systems: neutral host, facility-owned, carrier-owned, public safety
Type of product: DAS
Types of services: 1, 4, 5, 8, 11

Black & Veatch
10950 Grandview St.
Overland Park, KS 66210
Kristi Klohs
Klohskm@bv.com
(913) 458-6271
www.bv.com
Types of systems: neutral host, facility-owned, carrier-owned, public safety
Types of services: 1, 3, 5, 6
Company description:
Black & Veatch provides nationwide network infrastructure deployment solutions and systems integration for DAS and small cells. These solutions include program and project management, site acquisition, architecture and engineering, zoning and permitting, tower structural analysis and modifications, procurement, logistics, construction and construction management. Black & Veatch serves as its clients' turnkey resource for network site development and modification projects.
See ad on page 43

C Squared Systems
65 Dartmouth Drive, Unit A3
Auburn, NH 03032
Scott Pollister
scott.pollister@csquaredsystems.com
Types of systems: neutral host, facility-owned, carrier-owned, public safety
Types of products: DAS, small cell, Wi-Fi
Types of services: 1, 3, 4, 5, 6, 7, 8, 9, 11
Company description:
C Squared Systems is an RF engineering, consulting and software development company specializing in providing services for complete wireless coverage from RF analysis to design and implementation to monitoring support. More than just alarming, SitePortal, a customizable Web-based software, was engineered by C Squared Systems to remotely monitor and manage complex multivendor environments.

buyers guide

1. Site analysis
2. Financing
3. Permitting
4. System design
5. System engineering
6. System installation
7. System management
8. System monitoring
9. System maintenance
10. Carrier coordination
11. RF analysis
12. Concealment

Cellular Specialties
670 N. Commercial St., Suite 202
Manchester, NH 03101
Carolyn McLaughlin
csisales@cellularspecialties.com
(603) 606-7709
www.cellularspecialties.com
Types of systems: neutral host, facility-owned, carrier-owned, public safety
Type of product: DAS
Company description:
Cellular Specialties delivers products that enable indoor wireless connectivity, anytime, anywhere. CSI's suite of products, designed for distributed antenna system (DAS) networks, include high-performance digital repeaters, DAS interface units (DIUs), PIM-compliant system components and antennas as well as E911 and location-based enhancement solutions.

Coleman Global Telecommunications
84 Merrill Road
Clifton, NJ 07012-1622
Marty Coleman
marty@colemanglobal.com
(973) 519-6416
www.ColemanGlobal.com
Types of systems: neutral host, facility-owned, carrier-owned, public safety
Product types: DAS, small cell, Wi-Fi
Types of services: 1, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12

ConcealFab
3265 Fillmore Ridge Heights
Colorado Springs, CO 80907
Mike Slattery
mslattery@concealfab.com
(719) 599-3400
www.concealfab.com
Types of products: DAS, small cell, Wi-Fi, backhaul
Type of service: 12
Other: 3-D product modeling for site renderings and photo simulations
Company description:
ConcealFab oDAS and small cell concealments integrate the industry's newest antenna and radio technology into a family of pole-top, side-arm and monopole solutions. Lightweight brackets and universal mounting plates work with all antenna brands. ConcealFab thermoplastic shrouds are ultra-RF-transparent for maximum signal strength.

Corning MobileAccess
13221 Woodland Park Road, Suite 400
Herndon, VA 20171
cmacontactus@corning.com
(703) 848-0200
www.corning.com/mobileaccess
Types of systems: neutral host, facility-owned, carrier-owned, public safety
Types of products: DAS, Wi-Fi
Types of services: 1, 4, 5, 6, 7, 8, 9, 10, 11, 12
Company description:
Corning MobileAccess provides distributed antenna system (DAS) networks, offering flexible cellular coverage solutions in the rapidly growing wireless market. Corning MobileAccess provides wireless operators and enterprises with in-building wireless infrastructure solutions that cover the needs of venues of all sizes. The Corning MobileAccess portfolio offers multiple-operator, multiple-service hybrid fiber coax solutions, as well as single-operator solutions that leverage existing enterprise LAN cabling to transport cellular service, both capable of supporting the full breadth of cellular technologies in use today.

Crown Castle
1100 Dexter Ave. N., Suite 250
Seattle, WA 98109
Mike Kavanagh
mikekavanagh@crowncastle.com
(206) 336-7383
Types of system: neutral host
Types of services: 1, 3, 4, 5, 6, 7, 8, 9
Company description:
As an owner and operator of shared wireless infrastructure and fiber-fed telecommunications small cell networks, Crown Castle has been designing, constructing, operating and marketing DAS networks at premier venues and locations nationwide. As the largest independent DAS operator in the United States, Crown Castle has 10,000 nodes in operation or under construction and rights to over 6,400 miles of fiber.

Dali Wireless
535 Middlefield Road, Suite 280
Menlo Park, CA 94025
Laura Hayes
lhayes@daliwireless.com
(604) 420-7760
www.daliwireless.com
Types of systems: neutral host, facility-owned, carrier-owned, public safety
Type of product: DAS
Types of services: 1, 4, 5, 6, 7, 8, 9, 10, 11
Company description:
Dali Wireless is a global provider of an all-digital radio frequency (RF) signal

1. Site analysis
2. Financing
3. Permitting
4. System design
5. System engineering
6. System installation
7. System management
8. System monitoring
9. System maintenance
10. Carrier coordination
11. RF analysis
12. Concealment

routing system, a whole new concept of distributed antenna system. The t-Series is a versatile and cost-effective solution for extending the coverage and capacity of wireless carriers indoors and outdoors.

Deltanode Solutions AB
30303 Aurora Road
Solon, OH 44139
Tom Boyle
tboyle@birdrf.com
(440) 519-2172
www.deltanode.com
Types of systems: neutral host, facility-owned, carrier-owned, public safety
Type of product: DAS
Types of services: 1, 4, 5, 8, 11

ExteNet Systems
3030 Warrenville Road
Lisle, IL 60532
Sean Page
spage@extenetsystems.com
(630) 505-3817
www.extenetsystems.com
Types of systems: neutral host, public safety
Types of products: DAS, small cell, Wi-Fi
Types of services: 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12
Company description:
ExteNet Systems designs, builds, owns and operates distributed networks for use by wireless carriers and venue owners in key strategic markets. Using distributed antenna system (DAS) networks, small cells, Wi-Fi and other technologies, ExteNet deploys networks to enhance coverage and capacity and enable superior wireless service in both outdoor and indoor environments. Primary markets addressed by ExteNet include outdoor distributed networks in a variety of densely occupied or heavily traveled settings, and a host of indoor verticals, including sports and entertainment venues, the hospitality industry, commercial buildings, and health care facilities.

Fiber-Span
3434 Route 22W, Suite 140
Branchburg, NJ 08876
Tom Cooper
tcooper@fiber-span.com
(905) 473-5496
www.fiber-span.com
Types of products: DAS, small cell, Wi-Fi
Types of services: 1, 4, 5, 6
Company description:
Since 1992, Fiber-Span has been singularly focused on providing wireless coverage solutions for some of the largest and most sophisticated RF on fiber and land mobile radio projects worldwide. Fiber-Span manufactures a full suite of patented and proprietary products including indoor and outdoor DAS solutions for delivering coverage across all RF frequency bands and service offerings.

Fullerton Engineering Consultants
300 N. Martingale Road, Suite 500
Schaumburg, IL 60173
Jeff Latzko
jlatzko@fullertonengineering.com
(224) 585-4430
www.fullertonengineering.com
Types of systems: neutral host, facility-owned, carrier-owned
Types of services: 1, 4, 5, 12
Other: architectural and engineering design.

H&M Networks
985 Jolly Road
Blue Bell, PA 19422
Bob Dundon
bdundon@henkels.com
(215) 283-7764
www.henkels.com
Types of systems: neutral host, facility-owned, carrier-owned, public safety
Types of products: DAS, small cell, Wi-Fi
Types of services: 1, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12
Company description:
H&M Networks, a division of Henkels & McCoy, is an integrator and engineering firm that focuses on DAS and Wi-Fi networks. H&M designs DAS systems for both in-building and outdoor applications. H&M operates on the iBwave platform, has designed or built over 1,000 systems, and has relationships with all the major carriers.

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19 Thompson Drive
Essex Junction, VT 05402
www.wirelessinfrastructure.com

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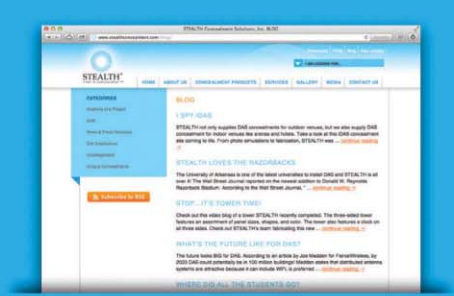

What's the concealment leader up to today? Keep current via our Blog, Twitter, Flickr, YouTube and LinkedIn accounts.

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3. Permitting
4. System design
5. System engineering
6. System installation
7. System management
8. System monitoring
9. System maintenance
10. Carrier coordination
11. RF analysis
12. Concealment

Types of products: DAS, small cell, Wi-Fi
Type of services: 4
Company description:
The Huber + Suhner group is a global supplier of components and systems for electrical and optical connectivity. The group has specialists with detailed knowledge of practical applications. Huber + Suhner offers expertise in radio-frequency applications, fiber optics, and low-frequency applications all under one roof, thus providing a basis for continual innovation that is focused on the macro cell, small cell and DAS needs of customers all over the world.
See ad on page 67

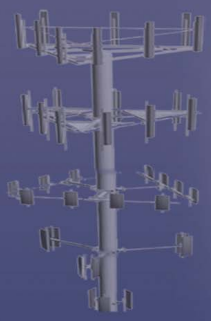
Independent Towers Holdings
1033 Watervliet Shaker Road
Albany, NY 12205
Kory P. Fretto
kfretto@independenttowers.com
(518) 608-4806
www.independenttowers.com
Types of systems: DAS, small cell
Types of products: DAS, small cell
Types of services: 5, 6
Other: build-to-suit development, owner-operator communications towers

Isotrope
503 Main St.
Medfield, MA 02052
Steve Riggs
info@isotrope.im
(508) 359-8833
www.isotrope.im
Types of services: 1, 3, 4, 5, 6, 7, 11
Other: public safety DAS
Company description:
Isotrope assists in the design, permitting, and build out of wireless communications facilities. The company's services include DAS design, benchmarking, scan tests, propagation maps, RF safety reports, regulatory compliance, interference studies, public hearings, expert testimony and project management.

Larson Camouflage
1501 S. Euclid Ave.
Tucson, AZ 85713
Tom Feddersen
Feddersen@Larsoncamo.com
(520) 792-1686
www.utilitycamo.com/products/das/
Types of products: DAS, small cell, Wi-Fi
Type of service: 12
Company description:
From iconic theme parks to football stadiums to citywide outdoor implementations, Larson has experience in concealed DAS and small cell design and fabrication. Larson offers several turnkey DAS and small cell products with integrated radio capability including light poles, branded monoliths, street sculptures and tree structures.
See ad on page 69

Microlab
25 Eastmans Road
Parsippany, NJ 07054
Danny Larsen
dlarsen@wtcom.com
(973) 386-9696
www.wtom.com
Types of systems: neutral host, facility-owned, carrier-owned, public safety
Type of product: DAS
Company description:
Microlab offers a wide selection of RF and microwave components to customers in the distributed antenna system (DAS) and in-building wireless solutions industry, the radio base station market and the medical equipment sector. Microlab's passive RF components share unique capabilities in the area of broadband coverage, minimal loss and low PIM.

Optiglow Systems
380 Holly Trail
Crownsville, MD 21032
William Imperato
wimperato@optiglow.com
(410) 409-8061
www.optiglow.com
Types of systems: neutral host, facility-owned, carrier-owned, public safety
Types of products: DAS, small cell, Wi-Fi
Types of services: 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12
Company description:
Optiglow Systems is a telecommunication infrastructure consulting firm that designs, builds, operates and maintains distributed antenna system (DAS) networks, small cells, Wi-Fi and public safety systems for wireless cell phone providers, enterprises and government agencies in office, industrial and retail buildings, hospitals, hotels, stadiums and campus locations. Optiglow is a product-agnostic systems integrator providing turnkey solutions on a nationwide basis. The company's extensive experience with wireless and IP technologies has positioned it as an adviser in the design, deployment, commissioning, maintenance and continuous monitoring services for voice, data and security systems.



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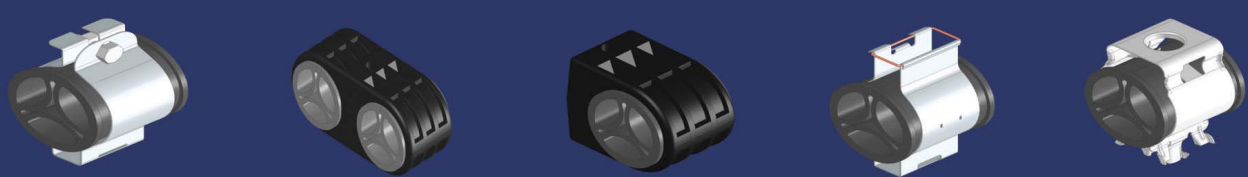

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13435 Estelle St.
Corona, CA 92879
Mark Peabody
sales@peabodyconcealment.com
(888) 511-6828
www.peabodyconcealment.com
Types of products: DAS, small cell, Wi-Fi
Types of services: 1, 4, 5, 12
Company description:
Peabody has been in the business of RF-transparent telecommunications (RFTC) equipment concealment since 1997. Peabody RFTC Concealment has firsthand knowledge working with the carriers and providers on making high-quality concealment systems. Prefabricated modular designs that install in hours save customers time and money.

RF Connect
37735 Enterprise Court, Suite 200
Farmington Hills, MI 48331
Jeff Hipchen
jhipchen@rfconnect.com
(248) 489-5800
www.rfconnect.com
Types of systems: neutral host, facility-owned, carrier-owned, public safety
Types of products: DAS, small cell, Wi-Fi
Types of services: 1, 5, 6, 8, 9, 11
Other: DAS consulting and outsourcing services
Company description:
RF Connect designs and deploys high-performance wireless networks. The company has designed and deployed thousands of indoor and outdoor systems in high-profile venues such as hospitals, airports, campuses, stadiums, arenas and tunnels. Whether single-carrier or multiple-carrier cellular, Wi-Fi, LTE, public safety, or virtually any other wireless technology, RFC provides intelligent, efficient solutions to meet the needs of even the most complex venues.

Radio Frequency Systems
200 Pond View Drive
Meriden, CT 06450
sales.americas@rfsworld.com
(800) 321-4700
www.rfsworld.com
Type of product: DAS
Company description:
Radio Frequency Systems (RFS) is a global designer and manufacturer of cable, antenna and tower systems, as well as active and passive RF conditioning modules, providing total-package solutions for outdoor and indoor wireless infrastructure. RFS serves OEMs, distributors, system integrators, operators and installers.

Solid
617 N. Mary Ave.
Sunnyvale, CA 94085
Dennis Rigney
sales@solid.com
(888) 409-9997
www.solid.com
Types of systems: operator-owned, facility-owned, carrier-owned, public safety
Types of products: DAS, backhaul
Types of services: 2, 4, 5, 7, 8, 9, 10, 11, 12
Company description:
Solid is a global communications technology innovator that enables cellular and public safety communications indoors and outdoors through RF amplification and optical transport solutions. The company's distributed antenna system (DAS) and backhaul products have been deployed at hospitals; Olympic, professional, and college sports venues; government, university and Fortune 500 corporate buildings; and metropolitan subways.
See ad on page 68

Stealth Concealment Solutions
3034-A Ashley Phosphate Road
North Charleston, SC 29418
Cindy Wishart
cindywishart@stealthsite.com
(800) 755-0689 ext. 124
www.stealthconcealment.com
www.coveryourdas.com
Types of systems: neutral host, facility-owned, carrier-owned, public safety
Types of products: DAS, small cell, Wi-Fi
Type of service: 12
Company description:
Camouflage antennas and improve the environmental landscape. Stealth Concealment Solutions has provided high-quality concealment solutions for the wireless industry since 1992. Stealth's aesthetically pleasing designs include custom rooftops, penthouses, church steeples, water tanks, bell towers, silos, louvers, trees, crosses, cacti and flagpoles.
See ad on pages 16 and 60

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Talley
12976 Sandoval St.
Santa Fe Springs, CA 90670
Pat Flynn
sales@talleycom.com
(800) 949-7079
www.talleycom.com

Types of products: DAS, small cell
Types of services: 1, 4, 5,

Tarana Wireless
2953 Bunker Hill Lane, Suite 100
Santa Clara, CA 95054
Luke Angelus
luke@taranawireless.com
(617) 413-4373
www.TaranaWireless.com
Type of system: carrier-owned
Type of product: small cell
Company description:
Tarana Wireless' universal wireless transport provides deterministic performance at full capacity across true non-line-of-sight (NLoS) and line-of-sight operation, delivering backhaul anywhere small cells are located. It combines ubiquitous coverage, high capacity and scalability, zero-touch provisioning and operation, and the lowest total cost of ownership of any NLoS backhaul solution.

Tempest Telecom Solutions
136 W. Canon Perdido, Suite 100
Santa Barbara, CA 93101
Elda Rudd
erudd@tempesttelecom.com
(805) 879-4829
www.tempestdas.com
Types of systems: neutral host, facility-owned, carrier-owned, public safety
Types of products: DAS, small cell, Wi-Fi
Types of services: 1, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12
Company description:
The experts at Tempest can take DAS and small cell projects from concept to reality. From engineering to design, business case approval to standardized

implementation criteria, system installation to optimization, project management to ongoing maintenance, Tempest DAS & Small Cell promises to deliver on time, on budget.

Tessco Technologies
11126 McCormick Road
Hunt Valley, MD 21031
John Celentano
celentanoj@tessco.com
(410) 229-1186
www.tessco.com
Types of products: DAS, Wi-Fi, backhaul
Types of services: 2, 4, 5, 10, 11
Other: site kitting, delivery logistics
Company description:
Tessco is a comprehensive source of equipment for building, using and maintaining wireless broadband voice, data and video systems. As a wireless equipment distributor, Tessco represents more than 300 manufacturers with over 25,000 products, all supported by technical services and training.
See ad on page 63

Trilogy Communications
2910 Highway 80 East
Pearl, MS, 30208
Angela Lourenco
alourenco@trilogycoax.com
(601) 933-7514
www.trilogycoax.com
Types of systems: neutral host, facility-owned, carrier-owned, public safety
Types of products: DAS, small cell, Wi-Fi
Types of services: 1, 3, 4, 5, 6, 7, 9, 10, 11

Westell Technologies
750 N. Commons Drive
Aurora, IL 60504
info@westell.com
(800) 377-8766
www.westell.com
Types of products: DAS, small cell
Types of services: 7, 8, 11
Other: system equipment
Company description:
Westell's DAS solutions are critical components in the overall DAS network, improving the efficiency, availability and reliability of the DAS site. Intelligent site management gives service providers a real-time view of overall network health, and an attenuation panel offers real-time adjustment of RF signals, power distribution and fiber management.

Shorter Antennas and More Concealments Are on the Way

By the AGL Staff

AGL interviewed Chris Hills, western regional sales manager for Stealth Concealment Solutions, at an AGL Wireless Infrastructure Conference. The following are his remarks, edited for length and style.

***AGL*: What does Stealth Concealment solutions do?**

Hills: We fabricate, engineer and in some instances install cell-site concealments. That consists of ways to make a traditional cell site more appealing from an aesthetic standpoint to put it into neighborhoods and areas where you don't want to see that big, 150-foot steel structure. But yet, despite the NIMBYs, everyone wants to use their cell phone in their backyard. We help the wireless telecommunications carriers build cell sites.

Stealth is a company that primarily hides cell sites. We take conventional cell towers and build an aesthetically pleasing solution that will better fit into the landscaping of a neighborhood or maybe even an industrial area where people want to use their cell phones in their backyards, but they don't want to see the tower. We conceal cell towers.

This is Stealth's 20th year in business. We started the concealment concept in 1992 and have grown to be about 50 employees strong.

***AGL*: What makes Stealth different from other concealment companies?**

Hills: We boast the highest RF transparency in the industry, meaning our material has less of an effect on the RF side of the signal. On the cell-site side of the construction, you can always turn the power up to blast through material, but it's the uplink, the little cell phone that you use that struggles with transmitting through that material that is not as RF transparent as ours. We have the best performance in the industry.

One of the key advantages that Stealth has over its competitors is its nationwide sales force. We use a network of manufacturers reps, as opposed to most of our competitors that are regional companies. We have some in California. We have some in the Northeast. No one can service the wireless industry like we can from a nationwide standpoint. We have people on the street in Chicago, Kansas City, St. Louis. When there's a site walk that is scheduled for the next day, we can put someone on the site quickly, as opposed to our competitors who would have to fly

Early concealments were rudimentary, like flagpoles. Now, carriers are requesting more complex solutions such as boulders.

A faux cactus conceals a cellular base station and antenna.

someone in, if they have someone who can jump on a plane immediately. Most of the time, they don't. That's one of our biggest advantages.

***AGL*: How does concealment affect the site performance?**

Hills: I'm comparing a traditional monopole with a tree pole. A flagpole, not so much. That's probably in the neighborhood of 15 percent.

***AGL*: What are the most popular concealments?**

Hills: Concealments have evolved over the past 20 years. It started with a rudimentary flagpole and an occasional tree. Now, we're getting into more complex solutions. For example, we're doing cacti. We're doing boulders. We're doing some indoor stuff like flowerpots and urns.

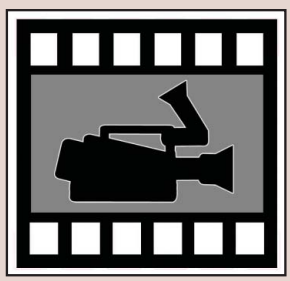
As the whole distributed antenna system (DAS) evolution comes along and small cells — the buzz phrase now — you're going to need ways to hide these antennas even on the inside. For example, some of the older stadiums that are 100 years old are basically a hole in the ground where they poured cement and placed bleachers and you have entrance tunnels under the bleachers, and that's it. You're very limited on where you can put antennas. Many stadiums only allow us to put them on the tunnel openings or section marker signs and things of that nature. That's what's evolved lately with DAS.

***AGL*: How has the industry changed with regard to concealment?**

Hills: The industry has matured because of the demand for concealment, largely due to the Internet. When we started building cell-site concealment in the early '90s, the Internet wasn't that prevalent. Your city planner or councilman didn't know what was available. The carriers certainly aren't going around asking, "Can I put up this 150 foot monopole, or would you like me to put up this 150-foot tree?" No. They're going to go with the easiest, most cost-effective solution and not educate the city planner. The Internet has done that for us, and we're seeing a lot of demand, even from rural municipalities, saying, "I saw on the Internet where you can build a water tank. That Petticoat Junction-looking water tank? We want one of those in our community."

***AGL*: What is the future of concealment?**

Hills: Cell sites are coming down in height and geographical coverage. You're going to need more sites, and more of them in residential areas. Five years from now, the next generation is not going to pick up the phone and call someone. They're going to pick up their iPad 10s and video chat with friends. Look at the data use on that. That's how they're going to communicate. We're going to need more and more of these antenna sites. They're all going to be shorter, and more of them will have to be concealed than ever. I think we're in a great position. I think the industry as a whole is in a great position. ■

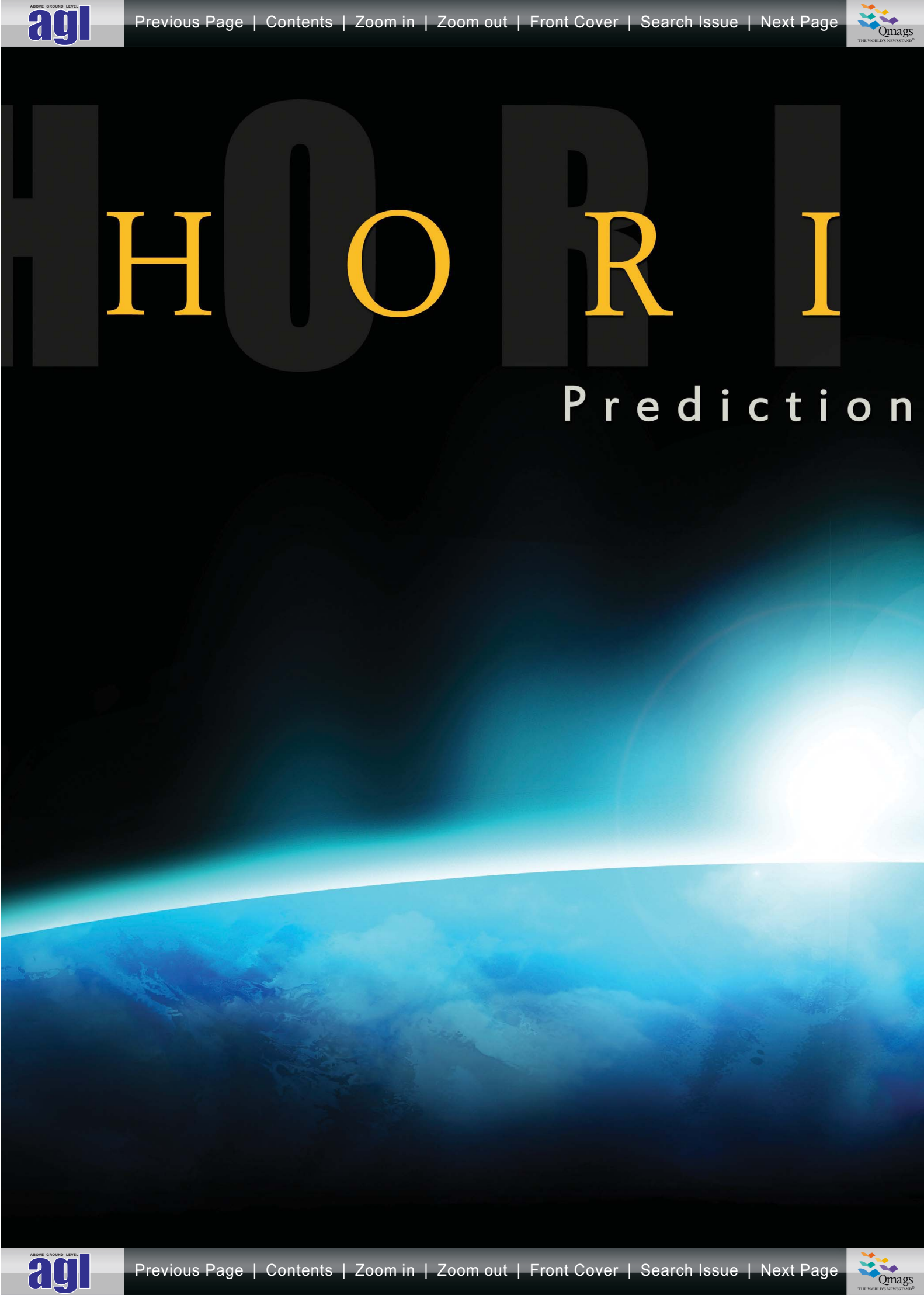


AGL Online Video

Watch Chris Hills' interview online at *www.agl-mag.com/aglvideos*.

HORI

Prediction



ZONES for 2014

The View from the Top

Executives of four large telecommunications tower companies assess the state of the industry and make predictions for antenna site development and company operations for the coming year.

By Don Bishop

Speaking in Orlando, Fla., on Oct. 9, 2013, executives of four large tower companies answered questions at a session named "The View From the Top." The occasion was PCIA's Wireless Infrastructure Show, and the executives were W. Benjamin "Ben" Moreland, president and CEO of Crown Castle International; Steven Marshall, executive vice president of American Tower and president of the company's U.S. tower division; Marc Ganzi, founder of Global Tower Partners; and Jeffrey A. Stoops, president and CEO of SBA Communications. Jonathan Adelstein, PCIA's president and CEO, was the host. The following are highlights from the session, edited for length and style.

Jeffrey A. Stoops: "PCIA succeeded in removing regulatory for the most part as the single longest delay point. Today's delays have more to do with availability of equipment and human resources."

Adelstein: What do you think of American Tower's purchase of Global Tower Partners?

Marshall: We picked up something like 6,500 towers, of which 500 are in Costa Rica, 15,000 rooftops, access to some DAS properties, some utility rights and 35,000 miles of railway access rights. When you combine those with American Tower's assets, we have over 50,000 communications site locations among towers, rooftops and DAS assets. We're able to offer superb one-stop shop solutions to carriers, so we're very pleased.

Adelstein: Marc, everybody wants to know, what will you do next?

Ganzi: We have a portfolio of towers in Mexico, and we'll be busy extricating those towers out of our existing platform and building an independent platform to run those towers. The idea is to continue to build and buy assets in Mexico with existing investors. It's a growing market. The plan is to continue investing in telecommunications infrastructure. We are more connected to other parts of the ecosystem beyond towers. Telecom infrastructure goes from data centers to backhaul to fiber to the cloud. As carriers move toward voice over LTE, the ability to move data traffic becomes more important. We'll look at other opportunities outside the tower world, but staying pretty close to home.

Adelstein: Where are we in the 4G build out? What's next as carriers finish their networks?

Stoops: LTE is still getting to full coverage. It is a good time to be in this industry because unlike prior technological upgrades where some of it was software-oriented, in every single case, LTE is an equipment-specific, equipment-intensive upgrade for our customers.

Moreland: We're seeing a return to collocations this year. Verizon and AT&T are starting now with the infill network, and we expect that from Sprint and T-Mobile as they complete their LTE builds.

Adelstein: Are you seeing a shift away from amendments and toward new collocations?

Stoops: We are. The trend continues where the incremental revenue that we're adding probably peaked in the fourth quarter of 2012 with amendments being the highest percentage of contribution that we had ever seen. Now, it's starting to constantly, gradually and steadily move toward true new collocation.

When you think about how carriers deploy their networks, it was all about speed and efficiency, which was the amendment process. That's how they got there quickest and cheapest. What followed in past cycles was the infill stage, which is satisfied by brand new tenancies. That's going to last for quite some time.

Marshall: Additional growth in data needs infrastructure to support it. We saw a lot of amendment activity during the last couple of years and less collocation. Despite a bit of a swing back toward collocation, there remains a lot of amendment activity and probably higher average amendment rates because of these amendments putting a lot more equipment onto existing rad centers.

Stoops: The new lease, brand new

collocation tenancy applications are for the largest equipment loads that we've ever seen.

Adelstein: PCIA, under previous Chairman Marc Ganzi, got legislation through Congress, Section 6409, allowing collocation by right. We've had progress with the shot clock and state legislation. The regulatory environment really seems to have improved. Has it made a difference in the speed at which carriers are able to deploy 4G?

Moreland: Absolutely. It provided a federal law backdrop for local zoning municipalities to get behind and, in some cases, just adopt as a matter of course. It's not universal, but the momentum is helping with collocation and amendments on sites. The speed and ease that we're able to provide to carriers is welcome.

Stoops: PCIA succeeded in removing regulatory for the most part as the single longest delay point. Today's delays have more to do with availability of equipment and human resources.

Ganzi: For some tower developers, it's no longer NIMBY, it's YIMBY, "yes in my backyard." It used to be towers were a blight on society, but now they're an integral part of the way we lead our lives. That's a big mind shift at a local level. It's a battle that took years to fight. It happened with showing up at zoning board meetings and educating people about the public benefits of wireless infrastructure.

If we can accelerate the carriers' network build outs and we can reduce cost, then we've really provided added value to our customers. That's why we worked hard on the Hill for years and years and years to get that legislation passed.

Adelstein: What do you see as some of the obstacles left? What do we focus on now?

Stoops: On the federal side, we're in pretty good shape. There always will be state and local flashpoints where we'll need to devote resources to expedite the ability to build infrastructure.

Adelstein: Will FirstNet make a material difference in the business? When do you anticipate FirstNet will start driving the business and revenue?

Marshall: I don't see any infrastructure activity until 2015 at the earliest. We could even see delays in that.

Moreland: I was pleased to hear that FirstNet's priority will be collocation on existing sites. We certainly stand ready to provide our portfolio

Ben Moreland: "I was pleased to hear that FirstNet's priority will be collocation on existing sites. We certainly stand ready to provide our portfolio sites as the most cost-effective and timely way to roll out a wireless network."

From the left: Steven Marshall, Marc Ganzi, W. Benjamin Moreland, Jeffrey A. Stoops and Jonathan Adelstein.

HORIZONS

Steven Marshall, executive vice president of American Tower and president of its U.S. tower division.

Marc Ganzi, founder, Global Tower Partners, which now is a subsidiary of American Tower.

sites as the most cost-effective and timely way to roll out a wireless network. Among other things, FirstNet has to sort out how the spectrum gets used and monetized, and then state government issues.

Stoops: FirstNet has the ability to access about $2 billion prior to the TV broadcast re-auctions. I'm guessing most of that will be spent on the heart of FirstNet's operations. The lion's share of the business and the deployments will occur only after the TV spectrum re-auctions happen and funding results. That step has its own set of timing and logistical challenges.

Ganzi: The turf war among local municipalities, counties and states wanting their own systems poses significant challenges. The easy part can actually be putting antennas on the air and getting the network going. If FirstNet can get the states and counties behind it, that makes for a 2015 or 2016 revenue-generation opportunity.

Thirty-five percent of FirstNet's antenna sites will be in the urban core, which means 65 percent of the rest of the country needs to be covered. That's a lot of geography to cover. As you move outside the cities, the real opportunity for tower developers is to provide infrastructure where there will be collocations and new tower builds.

Adelstein: What other business opportunities are next? Will Dish Network become the next tenant? Is any other new entrant on the horizon?

Moreland: Dish has been very public about its need and desire to have a wireless product. It has aggressively acquired spectrum, and Dish makes no bones about its interest in either acquiring or partnering with a wireless carrier to build a wireless product.

Stoops: Dish comes immediately to mind because it controls enough spectrum to make a difference not only with its own business plan but also to our industry with additional work. It's widely believed that when Dish does deploy, it will use network sharing, which hasn't been done to any great extent in the United States.

Marshall: The Dish spectrum will get deployed by somebody, either by Dish or by some other carrier. That will drive additional demand for infrastructure.

Carriers are spending billions and billions of dollars in refreshing, upgrading and expanding their networks because they see a fantastic future. New entrants will see the same. Softbank invested in Sprint because it sees an enormous opportunity in the United States. Maybe Dish will drive a lot more infrastructure investment. Meanwhile, other carriers will continue to invest in their platforms.

Moreland: The U.S. market has four large, active carriers, each spending incremental dollars of capex and driving incremental dollars of return. Each is in various stages of network roll out. Consumers demonstrate an insatiable appetite for multiple screens and maybe even connected cars. This will drive a lot of network and capital deployment. There is no better way to do that than with shared common elements of wireless infrastructure. Carriers are constantly thinking about how to manage costs as they spend billions of dollars on their networks. What we operate is the most efficient, cost-effective and quickest way to deploy additional network. That's a great place to be.

Marshall: In the past five years, America has come back from being a laggard in technological sophistication to being at the forefront of deployment. Europe invested in 3G before America, and now the American 4G deployment is way ahead of Europe's. In a short period, American carriers moved from

Marc Ganzi: "Thirty-five percent of FirstNet's antenna sites will be in the urban core, which means 65 percent of the rest of the country needs to be covered. ... The real opportunity for tower developers is to provide infrastructure where there will be collocations and new tower builds."

W. Benjamin "Ben" Moreland, president and chief executive officer, Crown Castle International.

laggard to leader on the world stage.

Moreland: And all through this time, we really haven't had a true new market entrant. We've been pretty busy with the folks that we have.

Adelstein: Railroads are under a statutory deadline by the end of 2015 to build out a positive train control, which can use as many as 20,000 new sites. Although some sites would be very short, it's quite an opportunity. Could transportation be a big driver for wireless service demand — trains and cars?

Ganzi: Wireless networks not only provide two-way communications between human beings but also machine-to-machine communications. The opportunity in positive train control could resemble the smart grid opportunity of two years ago. It was fringe leasing, where we didn't do a ton of leasing in smart grid but there was some anecdotal leasing with some major utility companies. We believe that trend will continue in the railroad industry as well.

One opportunity is to help railroads enhance their communications, which could enhance the cash flow profile of our sites. A second opportunity comes with having unique locations in places for railroad communications equipment that also help expand wireless carrier networks along railroad rights of way.

When trying to figure out new and unique ways to provide real estate to our carrier partners in areas where it's difficult to build and difficult to zone, we think about where railroad infrastructure sits. It's very much where consumers are doing business and consumers are leading their lives at night.

Stoops: SBA Communications partnered with Union Pacific to manage its infrastructure, and we've been working with them on positive train control. Many positive train control antenna sites may not be great sites for mobile wireless, but there will be a fair number where roads cross in populated areas, and building a larger piece of infrastructure for possible multitenant occupancy makes sense. Railroads have zoning exemptions and entitlements that will help speed the process. I expect to see some incremental positives coming out of train control.

Adelstein: How do you evaluate international business opportunities? And what do you see as the biggest opportunities for mergers and acquisitions (M&A)?

Marshall: For international investing, we build on the foundation we have in the United States, the skills and expertise, and our systems. We like to deploy the U.S. model to emerging markets that, in comparison, are further back in the life cycle of infrastructure development and bring incremental economic benefit to those countries while deriving value for our shareholders. In the past six years, we've gone into an additional 11 markets other than Brazil and Mexico.

We screen countries for political, financial and economic risk, and those with multiple carriers that need infrastructure. Usually, emerging markets have no tower companies to buy, so we seek to convince carriers to sell infrastructure assets or convince them to allow us to build assets

Jeffrey A. Stoops, president and chief executive officer, SBA Communications.

to share. I want to deploy capital at suitable risk-adjusted rates of return relevant to any particular country. Meanwhile, we always look to enhance our position in the United States.

Moreland: The North American market is the most attractive wireless

Jeffrey A. Stoops: "Every day brings a new capital allocation decision, U.S. versus international, if one or the other has the appropriate return. The return on international investment always is higher than what we would seek in the United States."

market in the world as measured by lots of different metrics. We added over 7,000 sites last year as well as

HORIZONS

10,000 DAS nodes and the small cell business we operate. We acquired the former NextG Networks. Meanwhile, we've looked at opportunities in South America and Western Europe. At the price points we saw, I have no news for you. We're firmly committed to our strategy of being a leader in the North American market.

Stoops: We gauge our international investments and risk-adjust them against the North American market, which is very attractive. The most important job we have is the allocation of capital. Shareholders like to see top line and EBITDA growth. To make sure we always had the largest or the right size of playing field to deploy capital, we moved international investment first in Canada, then in Central America and, most recently, in Brazil.

Every day brings a new capital allocation decision, U.S. versus international, if one or the other has the appropriate return. The return on international investment always is higher than what we would seek in the United States. We want to stay fully invested, so if investments in foreign or domestic towers aren't attractive enough, we may purchase our own stock. Another alternative for the capital is to pay down debt, which to us hasn't made much sense recently given the low cost of debt. It's all about managing the equation to produce the greatest value for shareholders.

Ganzi: The shared infrastructure model now is a global business. We share a common goal of capital allocation to achieve the target of returns for investors. The decision reflects where we can find good places at the right price to enter into relationships with good customers that can enter into long-term leases and then we can get the benefit of that business model, which is the recurring revenue model. If you think about the arc of where this industry has come in 20 years to where we are today, the tower industry is a global industry because carriers have accepted the shared infrastructure model across the globe. That makes it exciting for us. We didn't really have these problems 10 years ago. We didn't wake up every day and say, "Geez, should I invest in Africa? Or should I buy a tower business in Spain?" These are new problems. Not problems, but really new opportunities.

Stoops: Tower companies can take on additional assets with little additional incremental overhead expense. With that in mind, it's in all of our best interests to continue to grow with assets purchased at the right prices, but to continue to grow our portfolios.

Moreland: We speculated for years that this business model could attract a cost of capital lower than our carrier customers' cost of capital. We're rapidly approaching that. Crown Castle has elected to convert into a real estate investment trust (REIT) as American Tower did. Global Tower Partners already was a private REIT. The REIT is a model that will introduce the wireless infrastructure business to a broader investor base, one that typically brings a lower cost of capital that more appropriately values the long-term, recurring, contracted revenue stream that we have.

The ability to redeploy capital in excess of the mandatory REIT distribution becomes increasingly important. With a larger REIT shareholder base, we have the opportunity to continue to lower the cost of capital as we increase the dividend requirement, and the net operating losses built up over time are exhausted.

We provide a clear path to the investment community as to what the business looks like long term. It's attractive for shareholders and for small tower developers seeking to monetize their investments. It's also attractive for our carrier customers. We can raise capital, both debt and equity, at an expected return that's lower than the return for the carriers themselves, and let them put their resources to work in a way to best grow their businesses and let us own and operate the shared infrastructure elements of their businesses. This happens in other

Marc Ganzi: "Having commercial real estate in the in the urban core by leasing not just the rooftops but also the sides of buildings and the insides of buildings is part of offering a variety of solutions to accomplish carrier objectives — micro cells, DAS, femtocells, Wi-Fi and macro cells."

industries such as oil and gas, and real estate. I'm encouraged that we're maturing to the point where we're getting to that stage. It's a nice turn of events for the industry, one that will continue to work globally, not necessarily just focused on the United States.

Adelstein: Are you seeing small cells and DAS as a small part of your business, but growing? Is the time coming when small cells can take advantage of the shared infrastructure business model, or is it a totally different business model?

Moreland: Crown Castle made a big statement last year with a billion-dollar investment in the small cell business. It is very much a shareable model in our view. The fiber, the intellectual property and the permitting are shareable elements.

We'll probably spend close to $200 million this year on new small cell construction, collocation and new build.

Small cell architecture is more complicated than a tower. Collocation can either be on the same pole in the same shared electronic box or it can be on the next pole over. Carriers will use small cells to add capacity where macro sites

are not sufficient. But small cells do not take the place of a macro site. Carriers prefer macro sites, but in a lot of urban environments capacity cannot be delivered by a macro site. We see tremendous small cell take up and adoption by carriers in those limited geographies.

Marshall: There's a lot of interest in small cells, but it isn't clear exactly what a small cell is. We are seeing people think about putting small cells supposedly on their towers on an underlay network. We're seeing people talk about just throwing small cells out to enterprise customers and saying, "Plug this in and you'll improve your wireless capacity and capability." We will continue to evaluate small cells and see whether the degree of opportunity is there for us and our shareholders.

We've been in the small cell business for a long time, particularly on the in-building wireless or indoor DAS side. We have 260 in-building wireless systems in some of the biggest U.S. venues. We have more in-building wireless and third-party systems than anyone else in the United States. We heavily invested in the niche. I spent more last year and this year and probably will spend more next year on in-building DAS systems than I previously spent in my six years with American Tower.

Nevertheless, small cells remain a small part of American Tower's revenue and EBITDA. Macro cells, macro towers are by far the biggest driver of revenue and EBITDA for us in the United States. I think it will continue to be so, despite the fact that we built one of the biggest DAS networks at Daytona in record time earlier in the year. We're investing more than we've ever done, but it's still a small part of our business.

Stoops: We have our view and our participation in DAS and small cells is our investment in ExteNet, a company that focuses on DAS, small cells and in-building wireless. In-building wireless is hot and has been for some time. It's expected to stay busy.

DAS seems to be gaining more traction. DAS in general, just for some structural reasons as to which players were really using DAS and which weren't, took a bit of a step backward when AT&T announced the T-Mobile acquisition at a time when certain projects were pending. We are now finally seeing some true small cell deployments. There was a huge gap a year ago between the buzz about small cells and what was really getting done. But that's starting to narrow, and as years go by, we'll be able to talk increasingly about actual true small cell deployments that

probably will be numerous.

Ganzi: It's increasingly apparent that carriers view small cells as a tool to extend the network closer to the subscriber, particularly in the urban core. Wireless device performance improves if you can shorten the distance from the antenna to the device.

To provide solutions to our carrier partners requires making available all of the tools. You have to offer DAS and in-building wireless systems along with towers and a significant commercial real estate portfolio because consumers hang out in office buildings, hotels, malls and restaurants where they use their communications devices. This is where they download documents, music and video. Having commercial real estate in the urban core by leasing not just the rooftops but also the sides of buildings and the insides of buildings is part of offering a variety of solutions to accomplish carrier objectives — micro cells, DAS, femtocells, Wi-Fi and macro cells.

Small cells are not new. They've been here for a long time. But we adapt. We change. We try to predict where our carrier partners need to go. That's critical for success. ■

The next Wireless Infrastructure Show will be held in Orlando, Fla., May 19–22, 2014. For information, visit *www.pcia.com.* Photography by Don Bishop.

Industry Leaders Give 2014 the Crystal Ball Treatment

Technological, regulatory and marketplace changes promise to shape, disrupt and grow various parts of the wireless communications industry. Here's what might be ahead for you in the new year and in the years that follow.

Compiled by J. Sharpe Smith

The Coming Year: Good for Tower Companies

Ronald G. Bizick II
Chief Executive Officer
Tarpon Towers

Our mid-sized tower business has never been stronger. We are expecting 2014 to continue to be very strong. Carrier activities, including new builds, collocations and amendments, have built up throughout 2013, and new projects appear to be well funded with numerous active search rings. AT&T and Verizon Wireless are fighting to keep ahead of each other and the rest of the pack with unprecedented activity in LTE, infill sites and new coverage. Also, Sprint and T-Mobile USA have fresh war chests and creative approaches to add subscribers, bringing new vigor to their 2014 projected activities. All four national carriers were actively upgrading their data networks throughout 2013 and, if the carriers execute their current plans (it seems likely that they will), all four will be simultaneously active in the new siting market for the first time in many years. We expect this build-up to continue, and the effect is already showing with our 2014 pipeline at record levels.

This much growth has made the tower acquisition market red hot, and we don't foresee it cooling down. Valuations in the middle market remain high for sellers as buyers remain bullish on future growth. We expect the buyers of AT&T's and Global Tower Partners' towers to quickly integrate their purchased towers and continue the acquisition trend by pursuing the remaining mid-size and smaller tower companies. Critical mass will remain an edge. Comparatively larger portfolios will command a premium as the herd thins, but smaller companies will continue to be pursued. The active acquisition market will help ensure that the robust cottage industry persists as local developers build towers throughout the country and sell to larger buyers, taking profits and refreshing capital for new projects.

The Great Tower Migration – 3G to 4G

Jake MacLeod
Consultant
Gray Beards Consulting

Forecasting the future of wireless communications technology needs a historical perspective for better accuracy. Technology is not the sole factor for success in the marketplace. Governmental regulation and the competitive landscape are the two other legs of the three-legged stool. Each of the legs depends on the others for market success. If one is lacking, the platform is unstable and the probability of market success is low. With that perspective in mind, let's examine several technologies and forecast their success or failure.

2G and 3G: Second-generation (2G) cellular technologies are on their last legs, given the natural evolution of wireless technologies. The 2G technologies are TDMA – GSM, TDMA (IS-136), CDPD, GPRS, EDGE, HSDPA and CDMA (IS-95), and 1XRTT. These technologies were introduced more than 12 years ago and have been the lifeblood for the carriers for many years. As the third-generation (3G) technologies were introduced into the NFL cities, the 2G equipment was forklifted and reinstalled in suburban and rural communities to expand carriers' service footprints and to extend the revenue-producing life of the capital asset.

Now that the 3G technologies have been widely deployed throughout the United States, the 2G equipment will be

taken out of service, refurbished and sold on the global market for use in underserved areas of the world.

3G to 4G technology transition: As with any transition from one technology to another, the carriers deploy the new technology carefully and methodically to ensure proper technical and operational management. The migration from 3G UMTS to 4G LTE (Long Term Evolution) is proving to be difficult, given that voice transmission is not yet fully baked into the LTE technology, so voice must be carried by the 3G technology until the carriers can be certain that the 4G technologies can reliably handle the voice communications. The migration will take some time as the carriers adjust their management parameters to accommodate the intricacies of the 4G orthogonal frequency division multiplexing (OFDM) systems in their operations support systems and business support systems (BSS) platforms. An additional level of complexity is encountered as a result of the fundamental difference in 3G CDMA versus the 4G OFDMA technologies. The hand up (3G to 4G) and hand down (4G to 3G) issues require inter-technology coordination and manipulation of operational parameters. A significant amount of trial and error regarding adjusting operational parameters will extend well into 2014. Only when the carriers are comfortable with the operational characteristics of the 4G OFDM technology and have all of the billing systems integrated in the BSS will the carriers significantly expand the 4G footprint.

Eventually, when the 4G bugs are defined and solutions enabled, the carriers will begin to deploy 4G in small cells and DAS systems. The time frame for this will likely be in 4Q 2014.

More Carriers Divest Towers, Network Densification Rules

Marc Ganzi
Founder
Global Tower Partners

We have seen a trend in North and South America of large wireless carriers divesting tower assets. This trend will continue and become more pronounced as it extends to Europe and parts of Asia. The days of carriers holding tower assets for strategic purposes are waning as the shared wireless infrastructure business model that started in the United States is being more accepted globally.

Densification is a key trend to watch in 2014. It is happening far faster than expected. AT&T and Verizon Wireless will lead the densification to solidify their 4G/LTE networks, but nobody should discount the relevance of a fully funded Sprint 4G build out, the effect of Softbank's culture and Softbank's desire to compete head-to-head with its larger rivals on the tower leasing market. This will lead to larger capex spends and ultimately enhanced network quality that will benefit consumers of wireless products.

2014 (and Beyond) Predictions

Jonathan L. Kramer
Founding Attorney
Telecom Law Firm

It doesn't take a crystal ball or a divining rod to determine that 2014 will be a sea-change year for the fundamental framework of wireless regulation and future trends in deployment that will inevitably follow those changes.

With two massive, open FCC dockets regarding broadband deployment and RF emissions safety, the commission is set to rock our world — with the word "our" being equally applicable to the industry and to state and local governments.

The easier of the two dockets, the RF emissions docket, seems headed to a rational conclusion: The basic legacy FCC RF emissions standards for base stations are unlikely to change in any material way, despite pleas from some segments of the public to the contrary based largely on incomplete information (or outright misinformation) about RF emissions.

Sometime in 2014, after the updated RF emissions rules are adopted, I believe the FCC will release a revised, updated and expanded guide on RF emissions safety to local governments and the public.

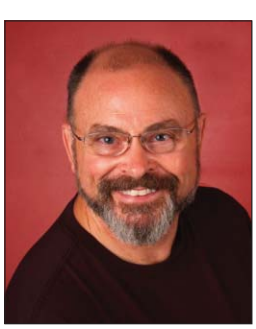
So answer me this: Why does the wireless industry still promote unnecessary and permit-delaying confusion regarding RF safety by constantly referring to RF emissions as radiation? It makes no sense to me, and a simple memo to the engineers, architects, designers and permit runners can start the healing by merely doing a word search for "radiation" and replacing it with "emissions." Doesn't "EM center" sound nicer than "rad center" or, worse still, "radiation center," without altering the basic meaning? I hope that 2014 will be the year that the word radiation exits our public vocabulary.

I saved my biggest, if certainly not the most troubling, predictions for last — my predictions for the Broadband Deployment Docket released by the FCC on Sept. 26, 2013. Everyone knew it was coming, yet the commission has gone beyond what some expected by asking us to comment on fundamental issues of whether the federal, state and local governments control local land use and safety codes, and how to torture the plain words of what many see as a fundamentally flawed, arguably unconstitutional federal cram-down. In many ways, the FCC is asking commenters for advice on ways to adopt even more restrictive interpretations that are likely no less unconstitutional. I predict that the 60-day comment and 30-day reply periods will be tolled, given the magnitude and fundamental structural and constitutional questions that are raised in the commission's docket. Hey, I'm a local government guy — I get to argue that the emperor has no clothes. Whether the emperor can be convinced of that will be seen around mid-2014 and on reconsideration in late 2014 or early 2015.

For my last and safest prediction, I predict federal judges will review the final broadband deployment rules sometime in 2016.

Top Tower Predictions for 2020

Ted Abrams
Wireless Consultant
Abrams Wireless



1. Towers and tower companies are recognized universally as blue-chip investments.

2. Tower demand continues.

3. Towers are recognized as essential infrastructure as important to society and the economy as bridges and railroads.

4. Antenna positions in the search ring above surrounding clutter continue to command the highest price per site.

5. Hardened tower compounds become hubs serving hundreds of small cells.

6. Tower asset monetization is exercised by every business that categorizes tower assets as noncore and nonstrategic.

7. Tower portfolio rationalization will take old, redundant steel out of the air — but ground space can be a different story.

8. Economies of scale continue to streamline processes and reduce costs of portfolio management.

9. Asset integrity management becomes increasingly important as tower owners eliminate defects and drive out unreliability.

10. Tower profiles change to incorporate more creative forms and artistic shapes in response to rising demand for pleasing aesthetics.

Think Small to Get Big Bandwidth

Peter Murray
Director of Wireless Solutions
CCI Systems

Network operators will continue the race to densify their networks. Small cells, Wi-Fi and DAS will continue to provide much-needed relief. Fiber to the cell towers and backhaul methodologies will also continue to be an important part of the solution.

The pressure to produce will stimulate multiple business models and some foolish behaviors. Neutral hosts make sense with DAS, but the smaller cells don't offer multiple-carrier options. Perhaps eventually they will. How will the smaller cells get backhaul in the outdoor environment? Does the incremental cost of deploying these technologies really make good business sense? Where is the demand really coming from? I suggest it's coming from teenagers who are tethered to their devices, posting video highlights of their every breath on their subsidized smartphones.

Licensed and unlicensed wireless capability in one access box is exciting, but 802.11 AC will offer more bandwidth at the access level. Will gigabit pipes be deployed behind this access methodology? Please.

The other day, while I was in my community pool, I noticed three people were taking photos and then texting or posting to Facebook the excitement of — not swimming. Good for them, but how do average revenue per user (ARPU) and earnings benefit from this behavior? It doesn't, and it will ultimately hurt the operators and help the manufacturers and integrators, to a degree. Ultimately, the ARPU and earnings growth in foolish forecasts will not materialize, and the manufacturers and integrators will eat their own young. I foresee budget cuts, layoffs and travel restrictions in Q3 and Q4 2014.

Rural Towers and Fiber Backhaul Will Grow in 2014

Cami Zimmer
Director of Communications
NewCore Wireless
with assistance from
Paul Vershure
Executive Director of Site Development and Construction Services
NewCore Wireless

1. Fiber builds, especially direct to tower sites, will remain a focus of large and small telcos to meet the never-ending traffic demand of the wireless industry. Everyone is scrambling to plow fiber to sites as the orders come in. This is great news for rural telcos looking for additional revenue to make up for continuing landline subscriber losses.

2. Rural area builds will continue to grow for wireless carriers of all sizes, especially in niche markets with large growth (western North Dakota and vacation destinations, for example). It is that old saying: People want coverage where they live, work and play. A lot of people play in those rural areas and will expect their carrier to play there, too.

3. Small cell and Wi-Fi deployment will continue to grow to keep up with customer demands in the urban markets. I doubt we will see much of small cells in the rural communities any time soon — macro sites remain sufficient.

4. Buy stock in the large tower companies because they probably have the simplest and best business case in the wireless world. No matter how poor their customer service seems to be, they still do extremely well.

5. Expect to see consolidation in the hosted core environment.

6. The part of the contractor industry focused on wireless will continue to see strong demand for its services. Contractors have done extremely well through the recession because of the continued growth of wireless. Wireless, overall, had a tough time in the early 2000s recession but did much better during the most recent recession. It has been a great industry to be in during the second go-around.

7. More mergers. Who, what? Who knows, but there will be more. (I will tell you at the end of 2014.)

8. Last but not least, a not-so-obvious prediction is that Verizon Wireless will partner with NewCore Wireless for 3G and LTE switching services.

Mainstream in 2014

Gordon Mansfield
Chairman
Small Cell Forum

The past 12 months have seen deployments of small cells continue to gain speed. As small cells move beyond initial deployments in the residential market, we are seeing them used in a diverse set of scenarios. In 2014, we are likely to see deployments in both enterprise and urban environments break through into the mainstream.

Operators have traditionally had limited success penetrating the enterprise market. With their innate ability to improve coverage and add capacity, small cells are as much of a boon to businesses as to residences. Mobile operators have seen an opportunity to use small cells as a platform to deliver value-added services. By leveraging the unique attributes of small cells, mobile operators can create enterprise networks, enable BYOD and even give mobile phones access to functionality usually reserved for the IP desk phone.

In 2014, we will see LTE deployments around the world continue to gain momentum, and although the technology itself is viewed by some as a panacea to overburdened networks, data volumes are growing more than ever. To meet ever-increasing demands placed

on their networks in busy urban areas, operators are deploying public access small cells in addition to utilizing additional spectrum being made available to serve this growth. By using small cells, operators are able to add vital capacity and coverage where it's needed.

We are also seeing an evolution in multimode small cells. When the modern small cell industry was born a little more than five years ago, much of the discourse surrounding the technology pitted it against Wi-Fi. Now, however, things have changed considerably. Rather than being either/or, cellular versus Wi-Fi, the two technologies are viewed as complementary — different tools for different jobs. Integration of Wi-Fi into small cell deployments is likely to become more commonplace in all types of small cell deployments, particularly enterprise and urban, with a view to delivering the highest-quality mobile broadband experience to consumers.

Through its release program, the Small Cell Forum is actively working to accelerate small cell deployments. Release 2, which has an enterprise theme, will be published in December 2013. Release 3, which considers urban deployments, will be published in February 2014. In the next five years, the forum's work, including its release program, will see small cell deployments become the norm, rolled out alongside macro cells as operators work to add capacity with the densification of their networks.

The Construction of FirstNet Towers and the importance of LA-

Michael Myers
Writer
Advancing Telecom blog

A lot is happening with the Los Angeles Regional Interoperable Communications Systems (LA-RICS), and FirstNet should take notice. There is the shortage of tower crews in the market, but another key topic needs to be addressed: civil construction.

More than 70 percent of the LA-RICS proposal relates to civil construction. Mainly, this is due to the need for less complexity in the first phase of its rollout, which essentially puts the focus on the build and the first stage of implementing the technology (that being LTE and microwave). Why is this a problem?

In the telecommunications industry, construction contractors, primarily the big engineering companies, are not competitive with the wireless carriers and the original equipment manufacturers (OEMs) because services rendered by carriers don't require complex hardening, as FirstNet does. Ultimately, this means the carriers can get by on the cheap by focusing on local turf players. Plus, when carriers make their OEMs the responsible parties for building their networks, the carriers can simplify their contracts through lump-sum service contracts tied to the sale of equipment. This means the carrier can call on the OEM any time they want, for whatever reason, using that fixed sum. It's kind of an all-you-can-eat business model.

Because OEMs are most concerned about profiting from the sale of their

In-building Wireless Market Constantly Changing to Meet Demand

Bob Butchko
National Business Development Executive
RF Connect

Because the wireless device is now, in many cases, your only device, users demand wireless connectivity as reliable as a landline that presents data-rich content as fast or faster than a wired laptop. Ironically, 80 percent of all voice calls and Internet connections are made indoors where the data-carrying signal is robust and unencumbered by the building itself. In-building distributed antenna system (DAS) networks have become the standard way to bring a reliable cellular signal into buildings. In a relatively short period, DAS has evolved from being a curiosity to become a luxury, then to become an amenity and, finally, to become a utility.

My world is all about designing and implementing in-building wireless DAS. Rest assured, the smartphone market will remain in a state of hyper growth into the foreseeable future. This means that everything in the in-building wireless market will be constantly adapting and changing to meet the demand.

Here are five predictions:

1. DAS as we know it today will take on additional roles becoming more

of a wireless utility network. Cellular, public safety, Wi-Fi, video security and just about any IP device will be able to ride on DAS.

2. New return on investment formulas will emerge, showing overwhelming evidence that customer satisfaction, increased sales in retail, decreased liability and increased client confidence in mass notification systems will be the by-products of a strong DAS coupled with innovative software applications.

3. As 4G/LTE becomes more entrenched, the macro system gets augmented by outdoor small cells, and as data becomes less expensive, Wi-Fi will take a back seat. 4G/LTE is a true wireless data network. It is faster than Wi-Fi, secure and reliable, and it has guaranteed levels of service.

4. The small cell will become the signal source for many indoor DAS installations. This will allow for the emergence of a much-needed, less costly mid-market DAS solution.

5. The role of a DAS systems integrator will change from a get-in-line, one of many bidders, to an outsourcing agent who advocates for the client and provides a one-stop-shop experience. This new business model will also marry infrastructure with applications to provide defined services or to solve specific wireless problems in unique ways.

RICS

gear, they tend to go cheap with their services portion (what they call delivery) by, confusingly, trying to apply paid services under the overheads of product development. When that happens, they are forced to bring in low-cost contractors to perform roles they can't afford to perform themselves. Unfortunately, the first to be scrutinized are their construction contractors. This is why we don't see major engineering firms such as Bechtel, Fluor and CH2M Hill building the carrier networks. They can't compete in the EFI (engineer, furnish and install) marketplace. Their overheads are too high to compete with the mom-and-pops. But now comes FirstNet.

FirstNet is a whole new beast. FirstNet needs the complex hardening characteristics that put it above the standard carrier design. Plus, FirstNet is not as concerned with profit as it is with enabling its self-fulfillment responsibilities covered by legislation passed to create the public safety broadband network. It also is concerned with attracting private equity to pay for the deployments. This means the small players will not, for the most part, be leading the construction effort. Those who do are known as turf players. When you have 20 construction crews delivering concrete, digging 30-foot holes for 70-foot towers, pouring concrete pads, delivering steel towers and installing vendor gear on top of the 70 foot poles while controlling an army of contractors and leasing, zoning and environmental crews, you can see why it takes a big engineering firm to ensure the deployment is done correctly.

Decreasing the Cost for Data

Tom Skidmore
Director
DAS and Small Cell Services
Black & Veatch

Wireless service providers continue to be pressured to decrease the cost per megabit or gigabit for wireless data to subscribers. This pressure on operating costs has a ripple effect through the wireless ecosystem that reaches equipment manufacturers, engineering services companies and, eventually, industry organizations to facilitate the sharing of best practices and educating venue owners.

In the equipment ecosystem, incumbent base transmitter station (BTS) equipment manufacturers have historically benefited from larger-scale R&D budgets and proprietary signaling between BTS sites and their central office switches. Now, these incumbents are developing much smaller form-factor BTS equipment commonly referred to as small cells. Small cells have the potential to greatly reduce the cost per megabyte or gigabyte of wireless data because of their lower cost, resulting in large part from the significantly reduced form factor.

This great potential for cost reduction is resulting in forecasts with extremely large potential deployment volumes. In turn, the potential deployment volume is attracting new entrants into the equipment ecosystem as they seek their fortune in the next big wave of deployments. In the future, you will see new equipment manufacturers with smaller R&D budgets bringing their products to market. The entry of new manufacturers will continue to drive down the cost per megabyte or gigabyte of data as they attempt to win market share with a better feature-to-cost ratio.

New companies will enter the distributed antennas system (DAS) manufacturer segment of the equipment ecosystem, too. The new DAS equipment manufacturers also will be seeking their share of the next big wave.

The ripple next hits the engineering service companies and system integrators. The skills and resources required for integration of a macro network-style BTS will be different in some ways from the skills and resources required for small cells. These service companies and integrators will need to retool and retrain some of their labor resources to adapt to the new deployment requirements for small cells.

Finally, industry associations will be affected by the ripple effect of the drive for lower costs per megabyte or gigabyte. These organizations that promote the development of deployment standards and device standards will need to provide guidance to their current membership or risk having members gravitate to other industry organizations that have kept up with the changes in equipment and services.

Mobility 2020: the Transition from a Wireless to a Mobile Ente

Ronny Haraldsvik
Senior Vice President
Chief Marketing Officer
SpiderCloud

A mobile enterprise has vast infrastructure and services implications for enterprise IT, hardware vendors and mobile operators. A mobile enterprise is not a destination, but an outcome of the transition from wired and wireless at work to always mobile-connected to the enterprise IT infrastructure, whether at work or on the go as part of an emerging global area network.

Blurring the lines between the enterprise and service provider networks will extend the edge of the mobile network from the operator's core into the enterprise premise. A mobile operator-managed ecosystem platform with presence inside the enterprise creates capex reduction opportunities for the chief information officers and creates a transition to a more predictable opex services relationship with mobile operators and partners, bridging the mobility value gap that exists between mobile operators and their business customers.

The shift to a mobilized enterprise fundamentally transforms the enterprise IT infrastructure from 80 percent capex to 80 percent opex. The mobile enterprise increases services revenue opportunities for mobile operators and builds a valued business partner relationship between operator and enterprise.

An important step to enable a stronger services presence within the enterprise is the deployment of a scalable small-cell system that can take on the role of a services platform point-of-presence inside the enterprise local area network (LAN).

Steps to build a trusted mobile services relationship start with deploy-

2014 Predictions

Seth Buechley
President
Solid

During the past 12 months, we at Solid have observed two fundamental trends in the wireless communications industry. First, out of the buzz surrounding small cells has emerged a more rational and pragmatic conversation for solving densification issues that applies a toolbox approach consisting of distributed antenna system (DAS) networks, small cells and Wi-Fi. Second, FirstNet, by virtue of having a board of directors with both cellular and public-safety stakeholders, has nudged the two industries closer together to explore converged solutions to disparate problems. It is these key trends that drive our predictions for 2014.

Network densification: Small cell deployments won't roll out as quickly as the industry suggests. This may sound self-serving, coming from a company that is best known for its DAS solutions. However, it's not about technology; instead, it's about the delays caused by the inherent complexity of obtaining approvals and permits from municipalities to place radios on street furniture.

Necessity spawns innovation, so to address street furniture and street pillar concerns, outdoor DAS and small cells are going to become smaller, lighter, greener and more powerful, and they will provide more frequency bands.

Single infrastructure will rule the day. Outdoors, we'll start to see street furniture that is capable of supporting DAS, small cells and Wi-Fi technology. Indoors, we'll begin to see next-generation in-building wireless solutions that take the form of a single, all-fiber, carrier-grade and enterprise-ready platform with fiber-fed antennas and power at the edge.

Finally, fiber owners become to the heterogeneous network what tower owners are to the macro network. There's no solution that offers the virtually limitless capacity of single-mode fiber, and carriers will rely heavily on fiber owners to empower them to deploy network densification solutions.

Public safety: Anyone familiar with Washington, D.C., knows that bipartisanship is a fact of life. In 2014, the inevitable will happen whereby FirstNet will grant the carriers access to D-Block spectrum. It fosters a win-win that satisfies the carriers' need for spectrum and delivers the interoperable ecosystem needed to make the vision of a nationwide LTE public safety broadband network a reality.

Meanwhile, FirstNet answers the question of whether it will drive the creation of fire codes that inform in-building public-safety communications requirements. With a focus on the public switched broadband network, the task of creating fire codes definitively and appropriately remains with the authority having jurisdiction (AHJ).

Last, location becomes the Holy Grail problem to solve for in-building wireless public-safety communications. Because Bluetooth and Wi-Fi can be turned off, those location solutions won't qualify as public-safety grade. Location won't be solved in 2014, but it's going to be a hot topic.

erprise

ment of a small cell system in a matter of days or weeks that can scale and deliver mobility services beyond basic coverage and capacity, and proof of consistently high throughput, consistently low call-drop rates and transparent reporting that builds trust. Another step is the addition of 3G/LTE/Wi-Fi and multi-mode small cells as capacity and technology needs evolve, without replacing the original system, which builds credibility. A third step is the introduction of per-employee/per-month applications services based on enterprise needs, such as Wi-Fi, private branch exchange integration, broadcast alerts and offers, location and context-aware services.

A 2013 research study by Exact Ventures describes a $100 billion emerging market opportunity for mobile operators in providing mobility services for enterprise customers. The research showed that enterprise customers could save 35 percent a year by adopting such operator-delivered managed and hosted services.

There will be challenges confronting enterprise chief information officers and mobility leaders in moving enterprises from wireless to mobile productivity, but there will be services

opportunities for mobile operators as they build coverage, capacity and a cloud/services presence to support the mobilized enterprise. Stay tuned. The move from wireless to a mobile enterprise is under way, and the changes and opportunities are significant.

Wireless Investors Conference

New builds? Slow. Stock price appreciation? Sluggish. Amendments? High and trending toward new collocations. Debt? It remains attractive, yet confined to large companies. Optimism? Easy to find here.

By Don Bishop

Speaking in Orlando, Fla., on Oct. 8, 2013, executives and directors of tower companies, a financial advisory firm, a venture capital fund, a bank and an investment bank answered questions at the Wireless Investors Conference, part of PCIA's Wireless Infrastructure Show. The conference moderator was Jonathan Atkin, managing director, RBC Capital Markets, an investment bank. Other speakers are identified on the next page. Here are remarks from the conference, edited for length and style.

Atkin: What operational activity is keeping chief financial operators at tower companies busy, and how is the leasing demand?

Brown: All four large U.S. wireless network operators are deploying LTE, and that has kept our folks incredibly busy over the last couple of years. We expect that level of activity is going to continue for some time. Thus, we're actively engaged in trying to meet the deployment demands of the customers.

Our small cell business has done well. We're going to invest about $200 million in it this year. We made two significant acquisitions over the last several years, NewPath Networks and NextG Networks.

We're wrapping up our integration with our purchase of rights to operate 7,200 T-Mobile USA towers that we announced shortly before this conference last year. It's almost entirely on all of our Crown systems internally. The experience of the customers isn't quite all the way to the legacy Crown sites, but it's getting close, and we're at the final stage of wrapping that up.

Cavanagh: SBA Communications is starting to expand more internationally, particularly in Brazil. We continue to focus on growing our U.S. portfolio, which we did substantially in 2012. Last year saw 66 percent portfolio growth. We spent time integrating the TowerCo and Mobilitie tower acquisitions, but we also have turned our attention on new Brazilian assets. We added 800 Brazilian towers late last year. We have an agreement with Oi, formerly Telmar, the largest Brazilian

telephone communications company, to buy 2,000 of its towers.

We focus on adding quality assets to our domestic and foreign portfolios, along with keeping our balance sheet in good shape. We completed a financing earlier this year, a $1.3 billion securitization at fixed rates of 3.25 percent over seven years. The availability of cash to the tower industry remains strong and at attractive rates.

Smith: American Tower is a global company with assets in 13 countries on five continents.

In the United States, we've never seen a better time for lease-up and the demand from the four primary carriers. AT&T and Verizon are building out LTE networks, resulting in heavy amendment activity for several years — 70 percent amendment, 30 percent new collocations. Verizon is ahead of the curve and will finish initial LTE deployment ahead of AT&T. AT&T probably will finish in 2014. Sprint and T-Mobile are active in building LTE networks. They are behind the other two, so they'll fill in the gap.

Having four carriers building networks at different stages of development helps push the growth curve out. That will give us lease-up ability for several years. And the carriers are building their initial LTE networks an inch deep and a mile wide, so they will have to infill those networks to handle increasing demand. When they do, we expect a switch from amendments to new collocations and new assets, and that will carry us for another couple of years. Network cycles are five- to 10-year cycles, so, there is no better time than now to be in the wireless industry. And we see that strong demand internationally as well.

Atkin: Marc, maybe you can add a rooftop perspective and comment about what has been driving some of the demand?

Ganzi: There were three core areas of growth for Global Tower Partners prior to the disposition. [Global Tower Partners, the company Ganzi founded and served as chief executive officer, was sold to American Tower.] One was a strong focus on growing our core portfolio to accommodate small cells. We had a differentiated strategy, focusing on re-creating tower economics on rooftop sites. Having 9,000 sites available to the wireless community for small cell and being able to deliver the same customer experience whether it's for a tower or a rooftop was important.

Speakers

In order from the left, as shown in the photo above:

Jonathan Atkin, managing director, RBC Capital Markets (moderator)
Clayton Funk, managing director, Med ia Venture Partners
Kevin Brynestad, managing director, Alpina Capital
Scott Gooch, director, Wachovia
Jay Brown, chief financial officer, Crown Castle International
Brendan Cavanagh, chief financial officer, SBA Communications
Rodney Smith, chief financial officer, U.S. Tower Division, American Tower
Marc Ganzi, founder, Global Tower Partners
Ric Prentiss, managing director, Raymond James & Associates
Ronald G. Bizick II, chief executive officer, Tarpon Towers

HORIZONS

We also continued to grow a vital railroad right of way business. Having rights of way up and down the eastern seaboard, crossing 12 of the top 20 metropolitan trading areas is an important distinction because it allows our customers to obtain access to thousands of miles of rights of way and key arteries and corridors for macro sites, small cells and other types of deployments, including DAS nodes along some railroad rights of way.

We've continued to build towers, and we try to build them where we're differentiated. We've chosen a partnership path with large utility companies to use their substations in suburbs. The battle for customers will be fought in urban cores during the day and in suburbs at night where people are hanging out, using their iPads and downloading music and content. We need real estate well positioned and close to that.

A second component of our business was international expansion. We closed a transaction in Panama, and that made us operational in Panama, Costa Rica and Mexico, where we have two important investments and great customers, Telefonica and Clark.

Meanwhile, we continued to focus on the balance sheet. We accessed the CMBS market and obtained financing with sub-3 percent pricing, at close to nine times leverage, which is almost unprecedented.

At the beginning of the year, we sold a small piece of our equity to a Dutch pension fund. I mention it to demonstrate the depth and the access of available capital to towers. The tower business is not a U.S.-based investor business anymore. More and more pension funds, sovereign funds and international investors look at towers as not only a safe haven but an area of growth. Everyone benefits from having depth in the investor community to access capital at all points of the capital structure. Whether you own 10 towers or 50,000 towers, we've never seen capital markets as receptive to the tower business as we see it today.

Prentiss: The network densification theme that you hear from all the carriers is important because they're moving to the new collocations. The new collocations are coming in at higher average rents than previous new collocations and maybe five times what amendment activity would bring. It's a nice revenue coming in.

Small cells seem like, yeah, they're coming, but nobody can really find them. It's always a lot of buzz, a lot of thoughts. I remember when lightRadio rippled through the CTIA and PCIA conferences, and you don't feel that same ripple. It will come. The carriers need to offload traffic. They need to have everything in the kit bag to make networks work, but every carrier we talk with says the macro is still their bread and butter; the macro is still what makes them unique; it's what provides ubiquity and mobility service. It still feels like macros are here for the long haul and macros remain one of the carriers' first choices.

Atkin: Ric, what's been going on with the stocks year to date? How has the group performed compared with others sectors you cover?

Prentiss: For anyone who owns these stocks as employees or as public investors, it's not been very good. Last year, American Tower was the laggard at only about 30 percent stock performance, and SBA and Crown had over 60 percent appreciation in stock prices in 2012. We expected a pause this year, but this has been more than a pause. It's been underperformance versus the major market. Interest rates are part of the reason. But with Marc talking about raising money at sub-3 percent, it's kind of hard to say interest rates are rising. The tower business is attractive to the debt market. The tower business can raise affordable money.

How good will business be in 2014 versus 2013? New amendment and collocation activity will help. People are moving beyond master leasing agreements as contracts that were pre-bought or pre-sold capacity. We have to watch how churn affects future numbers. It feels like the stock market is somewhat skeptical that 2014 can be another good year for the tower business. In 2013, the stock market has been asking, "How much better can tower stocks get in a rising interest rate environment?" Hopefully, the tower business will work its way through that and tower company stocks will have a good 2014.

Atkin: Ron and Kevin and Clayton, what opportunities and challenges do smaller developers face with new builds, lease-up and financing?

Bizick: The larger tower companies and the carriers have an inherent skill relationship that affords them the opportunity to do many things the smaller guys can't, such as build-to-suits, primary leasing arrangements, and swapping out for equipment that's coming down. Most small developers are developing towers, not buying. When Tarpon Towers started, we were able to deploy $45 million of capital in six months. That was while the

HORIZONS

public companies were struggling. That opportunity quickly closed as the public companies regained their health. We had to move toward a build strategy.

Plenty of equity capital is available for small developers. But they face a problem finding the right collateral when they go for debt. When you're trying to build towers as opposed to buying them, you're not starting with much more base. It's difficult to obtain any type of deal that makes sense. From a debt perspective, it's almost impossible. The equity is readily available.

Brynestad: At Alpina Capital, we talk with a lot of developers. Tower development is a great space right now. You have to grow organically, and it's the structure you're going after. You can get the equity. If you build 10 or 20 towers and you turn around and sell them, you see that equity is always expensive. You tend to be working for your equity sponsorship.

Although equity is absolutely paramount, you do need to layer in the debt. That's always the missing piece. Regional banks are beginning to understand the tower business. There's a familiar model: If I build it for $200,000 and I have one of the top four carriers as an anchor tenant and the potential for other carriers to use the tower, its value in the market is far greater than the development cost, whether it's $350,000 or $400,000. You have multiples when you start getting other tenants.

Meanwhile, although banks understand that their coverage is good, the problem is that small developers are always trying to reach down. If you only need $5 million, there is no debt sitting out there for that. If you would start at $10 million to $20 million, the industry would be well financed by those debt folks. Nevertheless, we are seeing some local banks that do understand, and they want to lend to the small developers. They see the protection behind it and the ability to grow. It's a dynamic business.

Funk: At Media Venture Partners, we define a middle-market tower company as one with 1,000 towers or fewer. Only three tower companies have more than 1,000. That leaves a couple of dozen companies in the mid-tier tower classification, a healthy group. People who have been in this business for a while continue to develop towers, sell them and develop again.

Clients tell us that opportunities to build towers have diminished, partly because of large build agreements some public companies have with Big Four carriers. But there's optimism that once the floodgates open for a T-Mobile and a Sprint and once AT&T and Verizon resume deploying sites to an extent that they may not be able to right now, the public tower companies may not be able to keep up with the demand. Some of the deployments will trickle down to the mid-market companies.

A lot of private equity is chasing opportunities to fund developers starting from scratch and recap companies, too. Tower development may be a little slower, right now, but there is optimism for the future.

Atkin: Ron, Clayton mentioned that network operators prefer carrier/tower company relationships that already exist in some cases and that smaller developers taking on more risk on a site acquisition process is affecting life. Don't the mom-and-pop's collectively do more new builds than the public guys?

Bizick: It hasn't changed the dynamic of risk that a developer our size takes on. The business the developer undertakes is done locally, using relationships with people who work for the carrier, people managing the build and what they know about zoning to get ahead of the design plan. It often is not a matter of having a search ring, it's having intimate knowledge of where the site needs to be and then securing the only game in town. RF has become a pinpoint matter. It's no longer a search ring. If you find that one spot, they're forced to work with you. The only financial risk the developer is taking is what it costs to acquire the property and put a leasehold option on it. Beyond that, I don't believe the process has changed much at all.

Brynestad: The smart build is the site acquisition, and it's the developer's capital at risk to obtain a permit, allowing you to get a lease signed by one of the carriers. That cost ranges from $10,000 to $50,000, on average, though it may be more. But once a developer has that kind of smart build plan, carriers are out there with their own techniques to find the holes not only from a coverage standpoint but also from a capacity standpoint. Developers have those two elements working in their favor. And once you get that, you're in pretty good shape if you have the permitting in place. ■

The next Wireless Infrastructure Show will be held in Orlando, Fla., May 19–22, 2014. For information, visit www.pcia.com. Photography by Don Bishop.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TOWER TYPE
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guest opinion

M2M Is Dead: Long Live the New M2M

By Iain Gillot

The wireless industry tends to have long market-development cycles, typically eight to 10 years. Consider location-based services: It was about eight years from when we first started discussion to widespread consumer use. Mobile data was around for a long time, and the next year was always going to be the year of mobile data. Now, of course, it really is here.

To me, it seems that machine-to-machine (M2M) falls into the same category. How many years have we been hearing about connected vending machines, washing machines, consumer devices and a myriad of other devices? A few years ago, many companies (vendors and mobile operators) were setting expectations that the world would be heavily unwired by now with M2M.

M2M is in use and there are many devices out there with connections — solar-powered parking meters that accept credit cards, mobile payment terminals, some newer home security systems and long-haul trucking are common applications. Video cameras that can be monitored from a smartphone are available to consumers. But many consumer devices are not monitored (my refrigerator still does not tell me we are low on milk, for example) and it is hard to say that M2M has hit critical mass in the lives of the average consumer.

Mobile operators have been pushing M2M for a while and have had some successes. But revenue is not high, and the fact is that most operators are more concerned with increasing their smartphone penetration than selling a few extra dog collars.

That said, things are likely to change significantly for M2M in the next few years. AT&T announced a couple of months ago that they will sunset their GSM/GPRS/EDGE network by January 2017, a mere 37 months from now. Contrary to what some believe, AT&T will not keep a few channels of GSM live to support its M2M business — this is simply not economical. As a result, the base network for M2M will be UMTS/HSPA. And Verizon Wireless is likely to decommission CDMA 1X by 2017 or 2018 (although no official date has been given).

At present, the costs for the GSM M2M modules exceed the costs for HSPA devices, but with additional volume and competitive pressure, the market should be close to parity in the next year or so. And for the operator, being able to reuse GSM/GPRS/EDGE spectrum for LTE will increase efficiencies significantly. The net result should be that an HSPA M2M module can be delivered for close to the cost of a 2G unit.

What does this mean for M2M? Goodbye narrowband, hello broadband. With HSPA, broadband apps and services can be delivered to machines, not just control and monitoring data. For example, the ubiquitous vending machine can not only tell its operator when it is low and needs replenishment, but also video clips could be refreshed at night for use on a display during the day — current ads and promotions could be updated daily.

And for the home security system, if the system is triggered, a broadband HSPA connection could deliver video from cameras showing the situation in the home to the monitoring center (this is possible today with Wi-Fi, assuming the bad guys do not cut the wired broadband connection).

These are just a few examples, but the point is that a broadband M2M connection increases the options of what can be monitored and delivered. Just as broadband connections enabled a range of new capabilities on smartphones, the same can now happen with M2M.

Some will point out that just because AT&T and Verizon are decommissioning their 2G networks does not mean that T-Mobile USA and Sprint will follow suit, and therefore T-Mobile and Sprint could steal the majority of the current narrowband business. But if AT&T and Verizon are able to use the 2G spectrum for LTE, competitive pressure is likely to force T-Mobile and Sprint to do the same as quickly as possible. Maintaining a 2G network to support a few thousand low-ARPU M2M devices makes little economic sense compared with moving completely to 3G and 4G networks to support as many smartphones and tablets as possible.

Broadband M2M is not a bad thing — it is an evolution in the market. And, just as happened with smartphones when broadband became more widespread, broadband M2M could be the impetus the industry needs to be truly ubiquitous and to build the Internet of Things. ■

Iain Gillot is the founder and president of *i*GR and *i*GR Semiconductor Research. His email address is *iain@iGR-inc.com*.

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PCIA Study Projects Enormous Job Growth Thanks to Wireless

The projected wireless broadband investment of $34 billion to $35 billion a year for the next five years is based on the huge growth in LTE subscribers and data traffic.

By Don Bishop

Jonathan Adelstein, president and chief executive officer of PCIA – The Wireless Infrastructure Association, spoke to an audience at an AGL Regional Conference in Chicago. Here are his remarks, edited for length and style.

AGL Photo / Carlo Silvio

PCIA president and CEO Jonathan Adelstein: "We're expecting $34 billion to $36 billion per year in the next five years in capital investments by the carriers. These investments will unleash up to $1.2 trillion dollars in economic development over the next five years."

PCIA's new study on the wireless industry shows its huge impact on the U.S. economy. You are the stars of this show because it's all about the jobs that you helped create and the economic growth that you helped create.

Economic development equals broadband. Jobs equals broadband. We're going to put some numbers on that for the first time as an infrastructure industry to say what we are contributing to the economy. These are points that we can use again and again as we fight to get this infrastructure sited and get it built out as quickly as we can to meet the demand.

Productive time

Whether you're checking the weather on the phone and learning whether to dress the kids warmly for the day, making a plan for a vacation while waiting for an oil change, downloading last quarter's earnings report so you can look at that while you're doing a conference call on another phone, or downloading an ebook, you're able to use your spare time to be productive. On any given day, all these chores might not get done if you didn't have wireless communications. And you don't need to plug anything into the wall, except to recharge. But from purchasing to scheduling, a modern person can do nearly every task over a wireless network.

Executive order

When President Barack Obama issued his executive order last year, the purpose was to expedite deployment of broadband on federal lands. He stated broadband access is essential to the nation's global competitiveness in the 21st century, driving job creation, promoting innovation and expanding markets for American businesses.

PCIA's report, "Wireless Broadband Infrastructure: A Catalyst for GDP and Job Growth 2013–2017" looks at the direct and indirect effects of wireless on jobs and on economic growth.

We're expecting $34 billion to $36 billion per year in the next five years in capital investments by the carriers. These investments will unleash up to $1.2 trillion dollars in economic development over the next five years. The study found that this will generate 1.2 million new jobs.

America has 340 million wireless subscribers, and 81 percent or 256 million are already using mobile broadband. We're approaching a period during which demand is about to outstrip sup-

ply in certain key areas. Spectrum in the next five years isn't likely to provide much relief. It takes at least three years for new spectrum brought into the market place to achieve any real offload of capacity and really more than that, up to five years. By that time, handsets get switched out and infrastructure gets switched out.

Mobile Internet

According to one recent study, the Internet will make the final move from primarily a wired, desktop environment to a mostly mobile medium this year. In just three years, an estimated 80 percent of the Internet access will be on smart and easily portable devices. Our report estimates that as a result, the U.S. workforce will be about 0.25 percent more productive over the next five years. That sounds small, but productivity is the key to economic growth.

The projected wireless broadband investment of $34 billion to $36 billion a year for the next five years is based on the huge growth in LTE subscribers and data traffic. Our study finds that the wireless broadband investment will have a direct impact on economic growth of as much as 0.55 percent per year, 2013 to 2017. That's roughly $87 billion worth of GDP growth every year for five years.

According to the report, up to 28,000 jobs will be created per year in the wireless infrastructure industry. And that comes out to over 122,000 jobs over the next five years.

Increase in GDP

Calculating the indirect economic impact is a bit trickier, but the findings see a rise from a baseline in 2013 of a 0.34 percent increase in GDP up to a 1.69 percent increase in 2017. This is huge. It represents an increase in economic activity from $54 billion in 2013 to $68 billion in 2017, which adds up to $806 billion over the next five years.

The indirect impact on employment is even more jaw-dropping. Our report estimates that between 2013 and 2017, an average of 250,000 jobs will be created every year as a result of this wireless revolution. So, the net total for job creation including direct and indirect

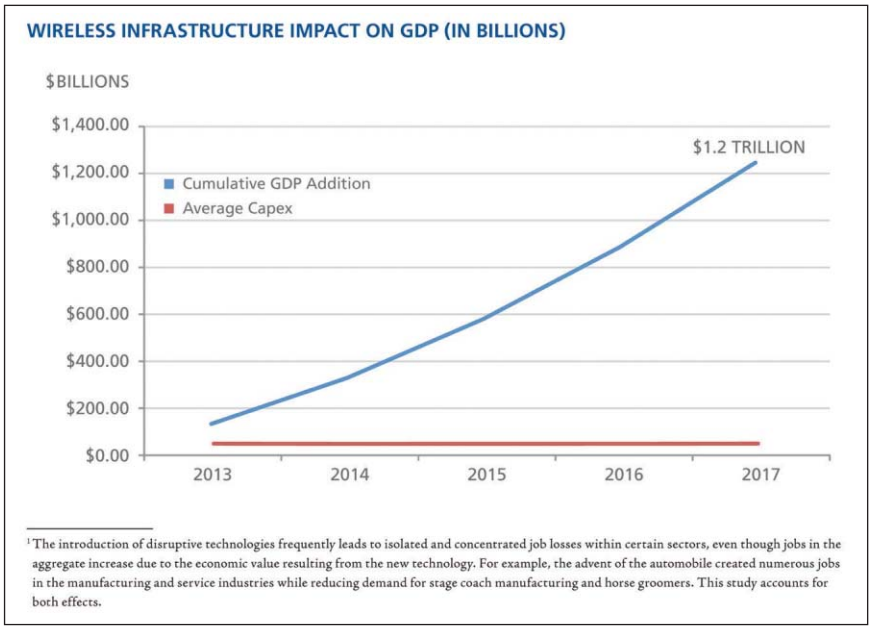

Figure 1. The PCIA study projects $1.2 trillion worth of gross domestic product (GDP) growth in the next five years because of wireless infrastructure. *Source: PCIA study*

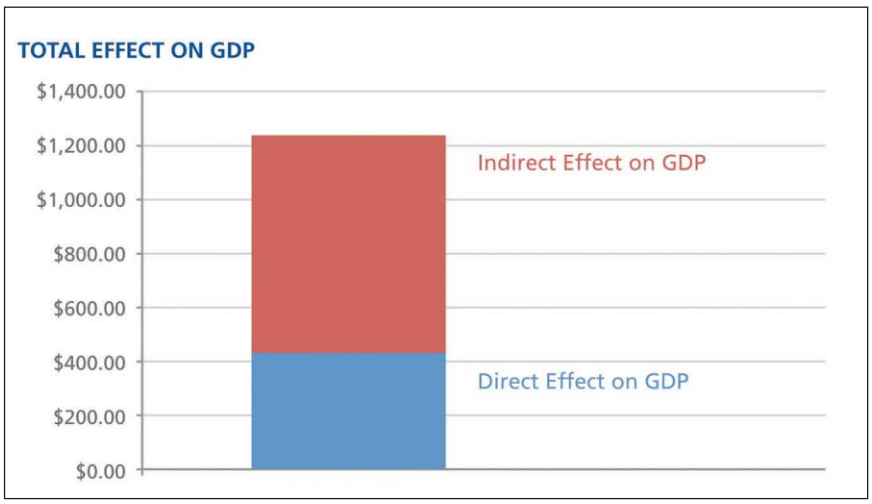

Figure 2. The effect of wireless infrastructure on the gross domestic product (GDP) includes a direct effort worth $400 billion and an indirect effect worth another $800 billion. *Source: PCIA study*

together is 1.2 million.

The report emphasizes how important it is to continue broadband development across the country. In order to pave to the way to this new normal, policymakers and politicians must continue to encourage the rapid deployment of nationwide ubiquitous and affordable wireless broadband by removing any barriers that hinder the acceleration of infrastructure deployment. Rapid network build out is

Policymakers and politicians must continue to encourage the rapid deployment of nationwide ubiquitous and affordable wireless broadband by removing any barriers that hinder the acceleration of infrastructure deployment.

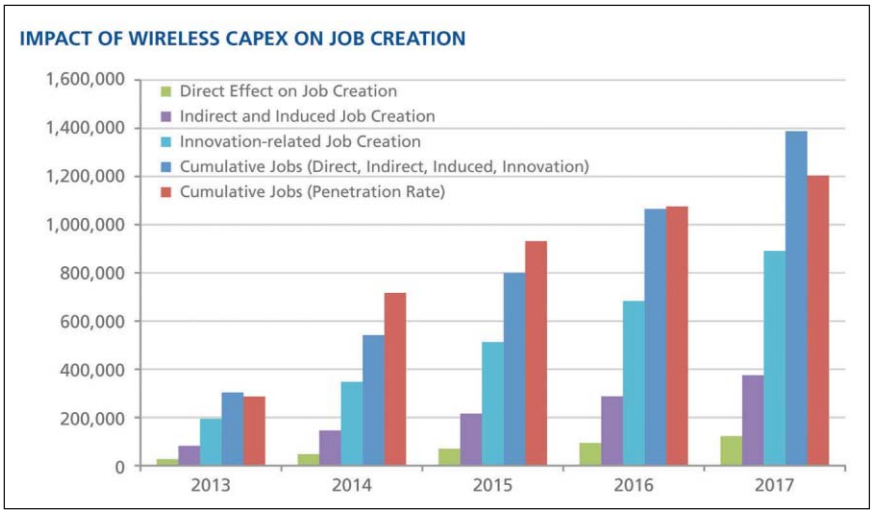

Figure 3. The effect wireless capital expenditures have on job creation is a combination of direct and indirect effects with a cumulative effect of creating as many as 1.4 million jobs by 2014. *Source: PCIA study*

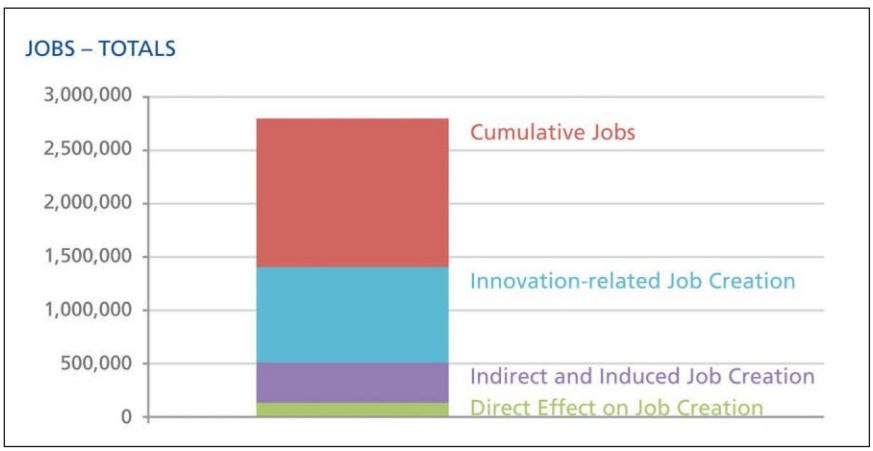

Figure 4. The net effect on jobs will be positive, after accounting for some job losses in certain sectors of the economy. *Source: PCIA study*

an employment and economic growth imperative.

The simple truth is that a 2.2 percent increase in GDP and 1.2 million jobs don't come about by magic. They only happen if we really recognize at federal, state and local levels how important it is to have robust, ubiquitous wireless broadband networks to meet the demands of the economy. This has to be recognized by FCC commissioners and local zoning board members. That's why we're taking our message of 4G policies for a 4G world on every level of government to local, state and federal officials.

Second-guessing

4G policies need to recognize that small cells and distributed antenna systems, which are going to be the face of next-generation networks, shouldn't be subjected to the same kind of environmental and historic preservation rules that towers are subjected to. 4G policies must state that carriers should not have to provide proof of need when deploying wireless facility. Why should a bureaucrat be second-guessing a decision of a company that wants to allocate a lot of capital to build expensive infrastructure? If the importance of wireless didn't make the need for that clear enough before, then this study should settle that debate.

4G policies have to facilitate the efficient use of existing support structures, be they towers, buildings, water tanks or utility poles, and that will encourage getting coverage and capacity delivered quickly with minimal impact and very efficiently.

When we go to local zoning boards and states, and when we go to Washington, we talk about health care, education, business development, economic growth and public safety. We talk about the need for an interoperable public safety broadband network and how important FirstNet is. You don't just build towers, DAS, antennas and wireless networks, you're building opportunities for education and health care, to grow this economy and to create jobs, not just in your industry but in a number of industries. You can be proud that what you're building is creating so much wealth and so many jobs in so many areas in our industry and beyond.

You don't just build towers, DAS, antennas and wireless networks, you're building opportunities for education and health care, to grow this economy and to create jobs, not just in your industry but in a number of industries.

Wireless broadband everywhere

If the kind of 4G policies I've talked about are enacted, we will expand wireless broadband everywhere. This is the core of PCIA's mission. Americans will continue to lead the world in wireless broadband as we're seeing today in 4G LTE. That means all the benefits that this report projects, the jobs, economic growth, the increased public safety, education and health care, won't just be potential benefits that I talked about in some study, but they'll be the real benefits that Americans will see. ■

Contact Waterford Consultants for a comprehensive report of this critical new ruling and the requirements for anyone that owns towers or is performing tower work.

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Managed Connectivity for Precision Network Views

Managed connectivity brings efficiency and automated documentation to a process that today is fraught with errors and costs, paving the way for a more efficient and cost-effective future.

By Davy Brown

With more than 300,000 cell sites and a million or more distributed antenna system (DAS) antennas out there, managing the physical layer infrastructure that feeds them is a major challenge. The move toward small cells is exacerbating this challenge as mobile operators deploy tens of thousands of these units to fill in coverage and capacity gaps. Mobile operators invest heavily in armies of technicians to turn up services and troubleshoot problems with all of this equipment. This work is complicated by a lack of clear visibility into network configuration, by site access restrictions and by the need to be prepared for any eventuality.

A managed connectivity system uses intelligent connectors and adapters combined with a database and management system to provide real-time reporting on the state of physical connections.

Managed connectivity provides automated, real-time visibility to physical layer connections within the network. A managed connectivity system uses intelligent connectors and adapters combined with a database and management system to provide real-time reporting on the state of physical connections. It brings the physical layer of the network under the same management visibility, discipline and control as the other network layers. Managed connectivity has significant implications for asset management, workflow management, and operating costs.

Flying blind

Large mobile operators have millions of network devices to inventory and manage. For many years, we have had network management systems that track activity at Layers 2–7 of the networking stack. However, operators have been forced to use manual, error-prone systems when it comes to documenting the physical layer. Typically, spreadsheets are used to track network configurations and equipment locations. Efforts to maintain manual documentation on the network require the time of dozens of network engineers to update documents. Over time, with each network change, network documentation can become increasingly inaccurate. Eventually, this lack of reliable information forces technicians to manually trace and verify connection and equipment locations before they do any work. This is a significant expense on the part of the mobile operator.

Use of manual documentation also has a big effect on the timeliness and cost-effectiveness of network changes. When a repair is necessary, the technician is dispatched to the tower, rooftop or customer premises without knowing for sure whether or not the equipment on the truck is adequate for performing the repair. Once at the site, the technician can spend up to 50 minutes of every hour just determining what the problem is, rather than fixing it, and if a part is needed that the technician doesn't have, it means another trip back to the dispatch center and a consequent delay in making the repair.

Multiply a single visit during which the technician wastes time determining what needs to be fixed by tens of thousands of service calls, and the magnitude of the problem becomes clear. Manual physical layer documentation prolongs time to repair, uses up network engineer time (in trying to maintain manual documents) that could be better spent elsewhere and increases the cost of service calls.

Automated documentation

Managed connectivity is a means of understanding the state of the physical network at all times. It is implemented through intelligent cable connectors, a monitoring system that tracks connection status through those connectors, a management system and a database. By using the management system, service and network administrators can know

when a problem arises and then schedule a work visit with a technician. With instructions delivered via smartphone, the technician knows in advance which piece of equipment needs service and precisely what the problem is. So, on arriving at the site, the technician can get to work immediately fixing the problem rather than poking around trying to determine what the problem is (see Figure 1).

Managed connectivity works with both powered and unpowered equipment. For powered equipment, the intelligent network connector reports its status back to the database over the IP network. The database stores records of all the managed connection points in the network. The connection status of managed connectivity connectors can be monitored by the management system. In addition, the management system includes a workflow manager that the network or service planners use to schedule jobs for service technicians, and that then directs the technicians via a smartphone application (see Figure 2).

Saving technician time is critical for cost savings, especially because the cost of sending out a technician can far outpace the cost of the small cell being serviced.

In the central office or mobile switching center (MSC), there's a device that monitors the cables and provides feedback to the database software. For the outside plant with unpowered equipment, managed connectivity works through radio-frequency identification (RFID) tags. The technician reads the RFID tag with an RFID reader pen, that pen is connected to the technician's smartphone via Bluetooth, and then the smartphone uses the 3G or 4G network to talk back to the management system. For example, if a technician's work order says to "go to small cell number 6673," when the technician gets there, the technician reads the RFID tag to confirm that the right piece of equipment is being serviced, and then the technician can proceed with the work order.

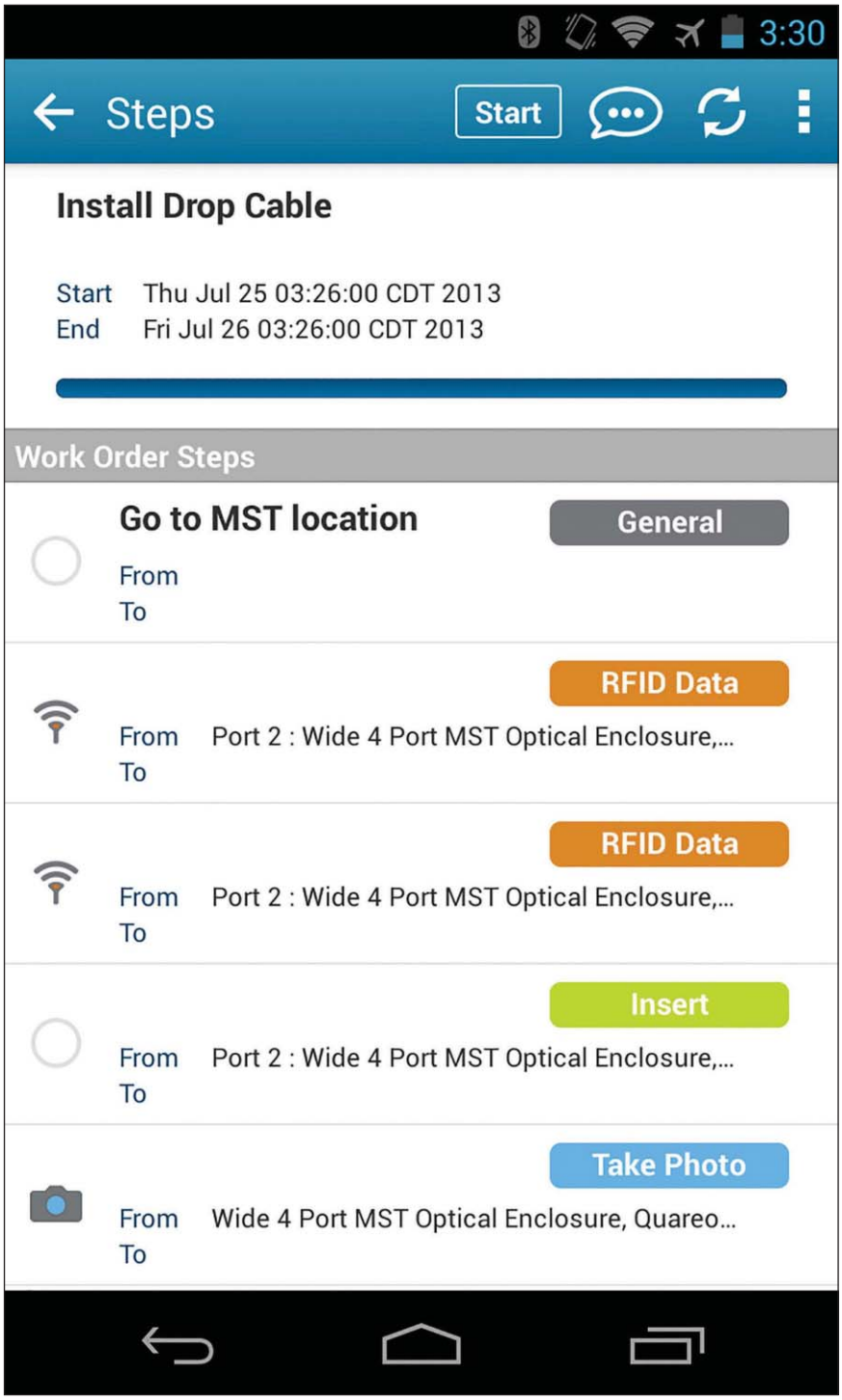

Figure 1. Technician instructions are delivered via smartphone.

Saving technician time is critical for cost savings, especially because the cost of sending out a technician can far outpace the cost of the small cell being serviced. Metrocells have electronics that cost perhaps $500 to $600, and it can cost $1,000 to $1,500 to send a

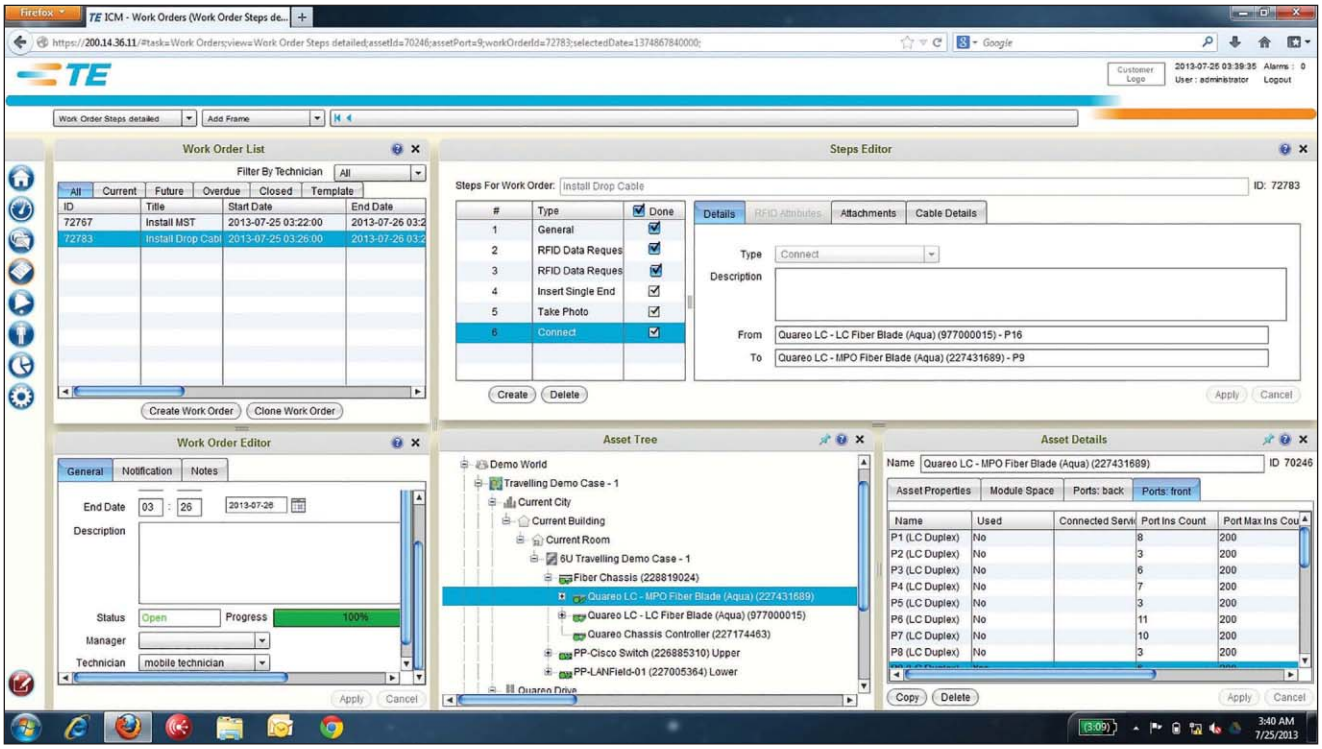

Figure 2: The managed connectivity system includes a workflow scheduler for job assignments.

technician to fix one. Making the most of that technician's time is of the utmost importance, and managed connectivity systems can save 70 percent or more of a technician's time at a given repair.

Benefits of managed connectivity

The benefits of managed connectivity include better asset management, improved visibility, alarming, and streamlined workflow management.

Asset management: When managed connectivity is used, a device becomes part of the network topology map as soon as it is connected. Rather than waiting for days or weeks for a configuration worksheet to be updated (and paying an engineer to update it), the network operator knows immediately that a new device has been added to the network, exactly what that device is, and exactly where it is.

Improved visibility: Managed connectivity provides a self-documenting view of the network, what's connected and what's not connected. Network administrators can easily view the network and tell its health all the way from the MSC to the antenna.

Alarming: Because a managed connectivity system always knows what is or is not connected, it can issue alarms to report a problem in the network as soon as it occurs. This helps expedite repairs.

Workflow management: The managed connectivity system includes a workflow manager, so managers can schedule jobs directly from the system that tracks the problems. Each technician can be sent out with precise information about what the problem is and where it's located, all via smartphone. In addition, the operator may be able to send lower-level technicians to jobs where the only problem is a disconnected cable, thus saving on personnel costs.

Today, managed connectivity is relatively new, but it's not hard to see how it will expand.

The future of managed connectivity

Today, managed connectivity is relatively new, but it's not hard to see how it will expand. Eventually, we will see managed connectivity extend to all of the elements in the network. Currently, managed connectivity solutions encompass network elements from the MSC to the macro network antenna. Eventually, they will include picocells and microcells so that the entire network is visible and easily repaired.

Network connections are constantly changing with the advent of LTE, small cells and continual scaling to accommodate more subscribers. Mobile operators can save money and do a better job of managing workflows by implementing managed connectivity systems that can help pinpoint the location of a problem in the physical plant. Managed connectivity brings efficiency and automated documentation to a process that today is fraught with errors and costs, paving the way for a more efficient and cost-effective future. ■

Davy (David) Brown is chief technology officer, TE Connectivity. He works with telecom and wireless business leaders to steer the development organization to deliver products that support TE's strategic goals, and he participates in TE technology initiatives.


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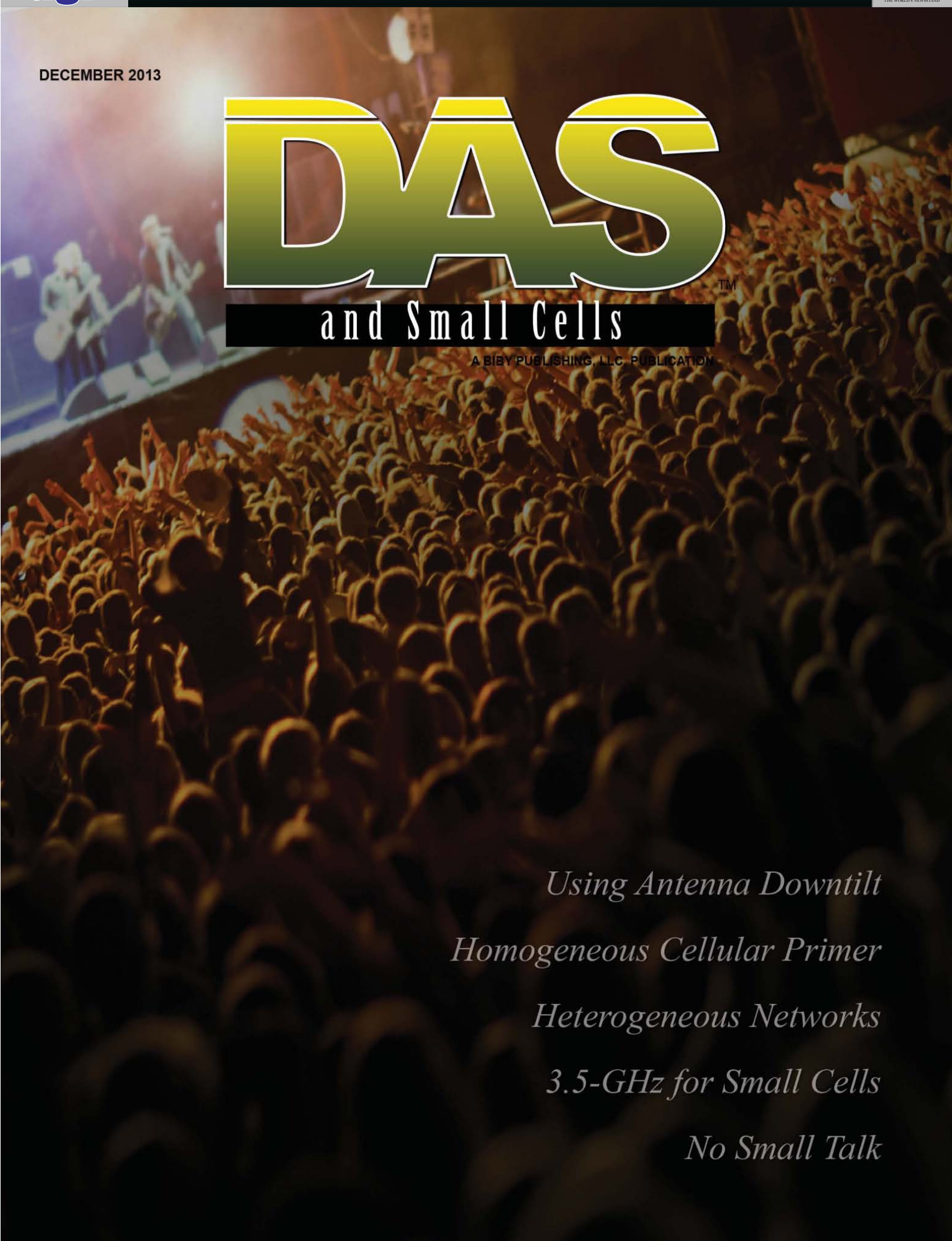

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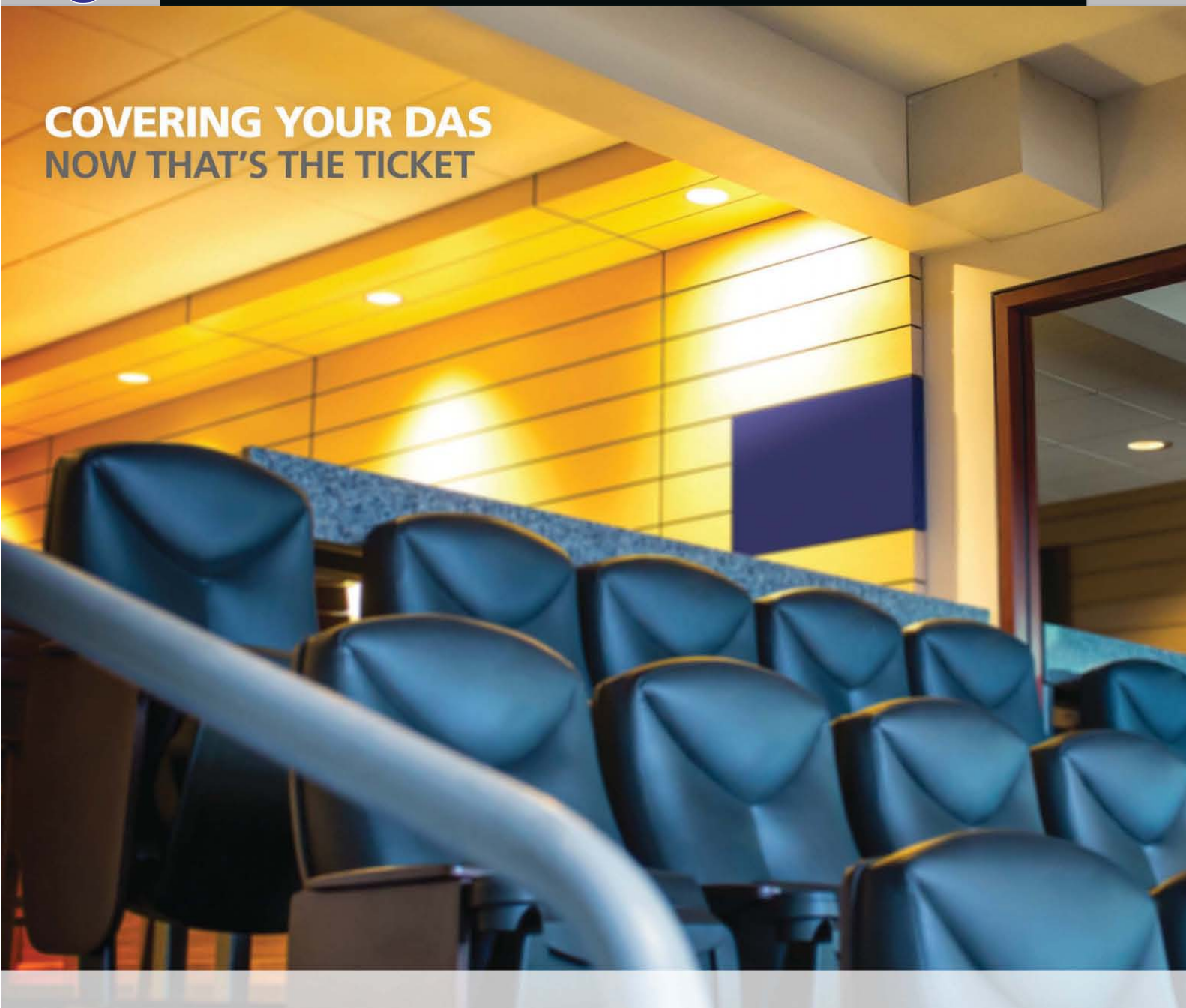
No Small Talk



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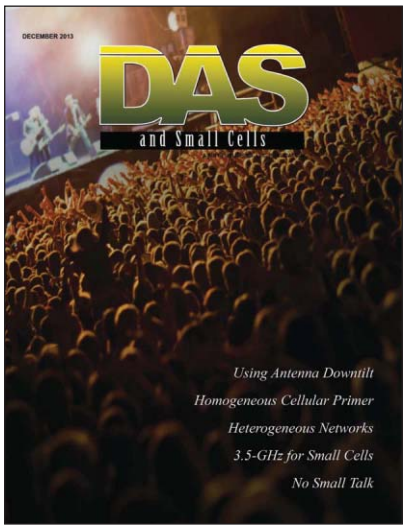

on the cover

In-building wireless systems serve arenas where audience members at concerts and sporting events expect wireless connectivity.

Cover design by Scott Dolash

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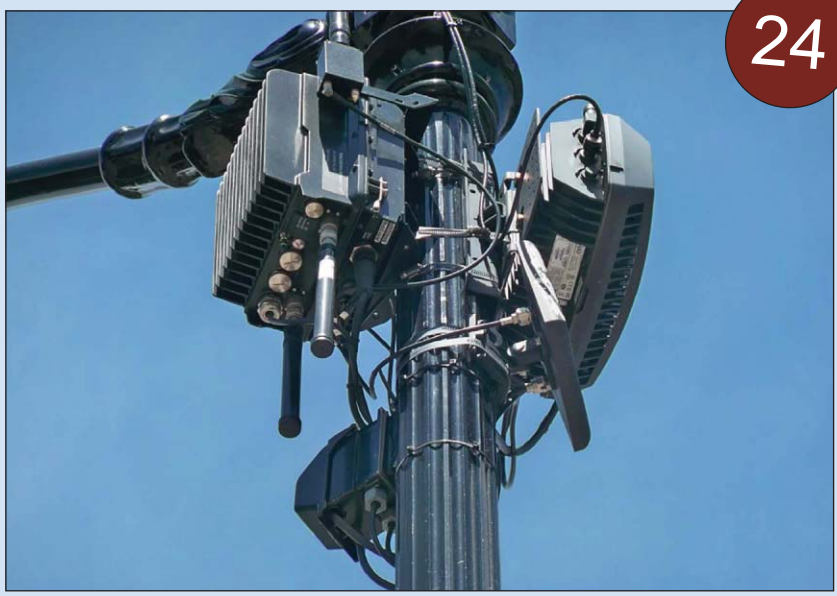

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IT Is the New Wireless Infrastructure Manager

IT groups are about to get slammed with the responsibility for managing both computers and communications. They are about to become information and communications technology (ICT) groups.

Not that IT hasn't already been indoctrinated. Worker mobility has been enabled for at least 10 years, and IT departments have been deciding who gets what hardware and software, and that was that. IT departments are comfortable with exercising iron-fisted control over integrating specific communications devices and applications in their enterprises.

That will change as small cell infrastructure is deployed and as it removes device control from the enterprise. IT departments will instead be charged with integrating BYOX hardware and managing the tetherless communications within, across, and in and out of the macro network and the enterprise. That's unfamiliar territory for the IT industry. The juggernaut of open networks (networks that will integrate every conceivable hardware and software platform) will become the new challenge for IT departments.

The new ICT organizations will be designed to seamlessly support licensed and unlicensed wireless, platform-independent hardware, unified communication (UC), bring your own anything (BYOX) and any application the programmers can dream up. For the first time, IT departments are shaking in their boots. They are going to have to find ways to integrate mobile commerce with social media, enterprise software, middleware, storage, the Internet and audiovisual systems, all while mitigating risk and locking down the network from hackers and well-meaning authorized users. In addition, they will have to find a way to enable and manage employee-owned assets while supporting free-range roaming with the common, proprietary and emerging applications (PC-based soft phones, for example) — whew!

And, as usual, technology is coming to the rescue. Today's networking hardware is orders of magnitude more sophisticated and intelligent than that of only a decade ago. Highly integrated system-on-a-chip (SoC)- and system-in-a-package (SiP)-based hardware incorporates all the technology layers IT departments will need to manage this new frontier. SoCs for small cells will integrate hardware and software on a single platform. Enterprise resource planning software and integrated voice and data communications applications are becoming so sophisticated and integrated that they can manage the data and have integrated wireless communications system management at the core. Solutions are coming fast.

As with all emerging/morphing technologies, many scenarios on how the change for IT will play out are possible. Many variables remain to be defined for small cells, heterogeneous networks, LTE, UC, BYOD/X, carrier Wi-Fi roaming and seamless handoffs.

The reality check will come when the small cell rollout gains momentum in the next year or so. By now, IT departments should be well on their way to getting their arms around the new ICT. It will require a change in IT department thinking and acceptance that IT departments will no longer have the lock-down control to which they are accustomed. Instead, they will become gatekeepers of tomorrow's organizational information platforms. ■

By Ernest Worthman, Editor
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Using Antenna Downtilt to Improve Mobile Network Coverage

Downtilt is a useful tool in the RF engineer's toolbox that can help optimize coverage and network performance, but it won't always help in the presence of RF shadowing and scattering.

By Andy Singer

Network planners for LTE systems such as cellular and public safety systems are currently considering how to design and implement network topologies that include the use of small cells such as microcells, picocells and femtocells. As network planners review optimization of these small cells and the need to focus RF energy in small, specific areas, they will use downtilt to optimize many of these sites. With the next phase of LTE system architecture being designed by network operators, a review of downtilt and how to calculate the optimal amount would be useful for these planners.

As shown in Figure 1, a signal is transmitted toward the horizon. Although this angle is generally desirable, there are applications where we would prefer that less energy is radiated above the horizon and more of it is focused to areas closer in or below the horizon. Thus, downtilting is the action of focusing the antenna's radiated energy so that it is directed below the horizon. This helps to reduce energy above the horizon and provides better coverage in the RF-shadowed areas directly below the site. By focusing the energy at the horizon and to areas below the site, instead of having more energy radiated at angles above the horizon, we have increased the efficiency of the system, minimized co-channel interference and improved coverage.

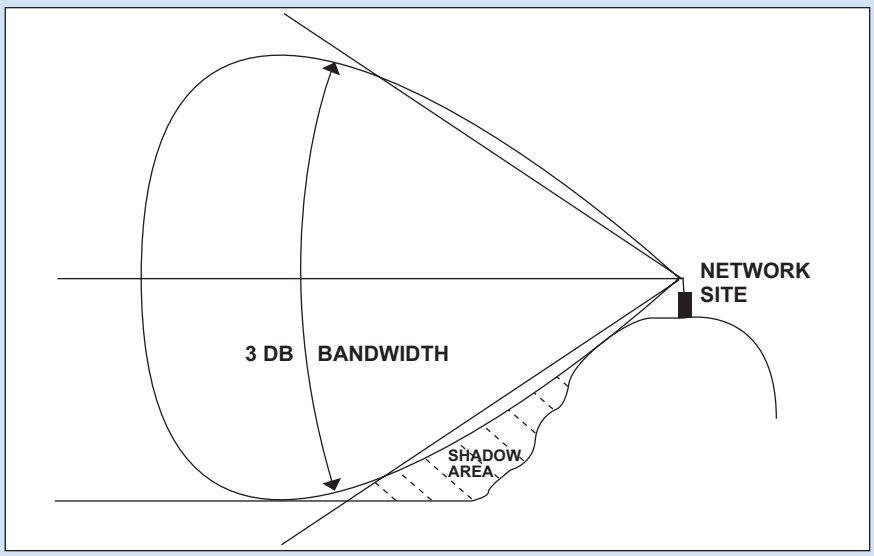

Figure 1. An antenna with its primary lobe directed toward the horizon.

There are two methods by which downtilt can be implemented — mechanically and electrically. A mechanical approach is more commonly used with sector antennas. The antenna is simply mounted with the use of a downtilt clamp, and the clamp is adjusted to provide the desired angle of downtilt measured in degrees. Although this method works with sector antennas, you probably would not want to use this method with omnidirectional antennas because it would cause the opposite side of the antenna to radiate with uptilt into space, overshooting the coverage area.

Electrical downtilt is achieved by introducing an electrical phase shift to each radiating element of the antenna. In dipole arrays, downtilt is achieved by inserting coaxial delay sections in each dipole's feed line. Where a patch array is utilized with micro-strip technology, the delay can be introduced on the strip-line surface or via discrete phase shifters. Either method causes a progressive phase shift, allowing the antenna pattern to electrically tilt downward.

Not only are mechanical and electrical downtilt achieved via different methods, the end results are also different. For example, when a sector antenna is mechanically tilted, the horizontal pattern becomes distorted. As the amount of tilt is increased, the pattern becomes more oblong instead of exhibiting sector antenna's usual cardioid pattern. Electrical tilt preserves the cardioid shape.

The vertical pattern also must be considered. If an antenna has an upper lobe at 20 degrees above the horizon, and if you mechanically tilt the antenna downward 20 degrees, this lobe would now be on the horizon. When electrically tilting the antenna, the antenna designer will often utilize techniques to suppress the first upper lobe to avoid this possible issue.

With this understanding of what downtilt is, let's use trigonometry to apply it in a real-world situation. It's not difficult. Think back to a mnemonic from high school. At my school, we learned it as Soh-Cah-Toa. The tangent of an angle can be calculated if we know the opposite and adjacent sides of the triangle. See Figure 2, which shows a typical mountaintop site for reference. If we examine the site, we can make a comparison with the triangle. The height represents the opposite side of the triangle, and the distance to the coverage area represents the adjacent side of the triangle. Using our trig from school, we know that the unknown angle is equal to the inverse tangent of the height, divided by the distance.

To calculate the primary illumination area, we need a formula for D_{min} and D_{max}. D_{min} is the half-power beamwidth (HPBW) and first intersects the ground where the gain is down 3 dB. D_{max} is the point on the other side of the main beam where the signal is down by 3 dB. This footprint is known as the primary illumination area. The goal is generally to place the service area within this footprint. D_{min} is defined by the angle of the downtilt plus 0.5(HPBW); D_{max} is the downtitlt angle minus 0.5(HPBW). These formulas then become:

$D_{min} = H/\tan(\text{downtilt} + 0.5(\text{HPBW}))$

$D_{max} = H/\tan(\text{downtilt} - 0.5(\text{HPBW}))$

To convert the answers to distances in miles, divide the result by 5,280 feet.

Figure 3 is a simple Quick BASIC program I wrote in 1990. You should be able to easily program it into any desired language. The user inputs the antenna model number, the 3 dB beamwidth and the height above average terrain at the appropriate prompts. The program then generates a listing from 0 to 24 degrees of downtilt, showing the primary illumination area. This allows you to experiment with different beamwidths to help find the optimal solution. Note that the angle is divided by 57.3 to convert degrees into radians.

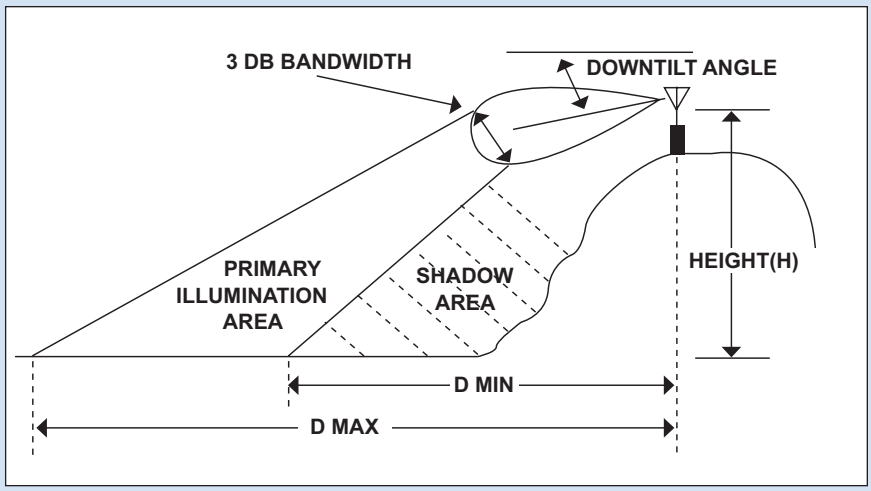

Figure 2. Downtilt directs the primary illumination area where it is most needed.

Downtilt can be highly useful, but keep in mind it is not a cure-all. RF scattering, especially in urban areas, can give results not predicted by simple models. Additionally, if the root cause of poor coverage is RF shadowing by a large hill or building, downtilt will not resolve it because it is a tool, not a miracle-worker. As long as these limitations are understood, downtilt is a useful tool in the RF engineer's toolbox that can help optimize coverage and network performance. ■

Andy Singer, president and chief executive officer of Singer Executive Development, was one of the original developers of the remote-tilt antenna system concept. He has both BSEE and MBA degrees and is on the board of directors of several organizations.

```
1     REM DOWNTILT.BAS WRITTEN BY ANDREW SINGER
2     PRINT "COVERAGE DISTANCE CAN BE AFFECTED BY MANY FACTORS."
3     PRINT "THIS PROGRAM, SERVES ONLY AS A GUIDE."
4     PRINT "FOR CHOOSING DOWNTILT VALUES." : PRINT
5     LPRINT "COVERAGE DISTANCE CAN BE AFFECTED BY MANY FACTORS."
6     LPRINT "THIS PROGRAM, SERVES ONLY AS A GUIDE."
7     LPRINT "FOR CHOOSING DOWNTILT VALUES."
8     REM ** CALCULATION BASED ON FLAT EARTH. **
9     REM ** HEIGHT REFERS TO ELEVATION ABOVE AVERAGE TERRAI . **
10    INPUT "PLEASE ENTER ANTENNA MODEL NUMBER" ; ANTENNA$
20    INPUT "PLEASE ENTER HEIGHT" ; H
30    INPUT "PLEASE ENTER ANTENNA 3 dB BEAMWIDTH" ; BW
40    LPRINT : LPRINT "ILLUMINATION DISTANCE IN MILES FOR " ; ANTENNA$; "AT"
      ; H; "FEET"
50    LPRINT : LPRINT "DOWNTILT   DMIN     DMAX" :  LPRINT
60    FOR DOWNTILT = 0 TO 24 STEP 1
70    DMIN = ( H / TAN((.5 * BW + DOWNTILT) / 57.3)) / 5280
80    ANGLE = DOWNTILT - .5 * BW
90    IF ANGLE <= 0 THEN 110
100   DMAX = (H / TAN((ANGLE) / (57.3)) / 5280: IF DMAX > 100 THEN 110 ELSE 120
110   LPRINT USING "### ########.## & &" ; DOWNTILT;  DMIN;  "   "; " >HOR" : GOTO
      139
120   LPRINT USING "### ########.## #####.##" ;  DOWNTILT;  DMIN;  DMAX
130   NEXT DOWNTILT
140   INPUT "WOULD YOU LIKE TO RUN ANOTHER (Y/N)" ; ANSWER$
150   IF ANSWER = "Y" OR ANSWER = "y" THEN 10 ELSE END
```

Figure 3. This program (it's written in BASIC, but it should be adaptable to other programming languages) helps to simplify downtilt calculations. The program prompts the user for the antenna model number, the height above average terrain and the 3-dB beamwidth of the antenna.

Intelligent, Optimized and Homogeneous Cellular Network Primer

The wireless world has progressed to text, data, video and multimedia. Innovators are trying to develop infrastructure that provides whatever users want, when they want it and anywhere they want it.

By Ernest Worthman

In today's rather jumbled and disjointed cellular infrastructure, some interesting indicators give us a glimpse of the present state of wireless networks and what is coming down the road. Statistics reveal that fewer than 10 percent of cells handle 90 percent of data traffic, and 80 percent of data traffic is indoors. Other statistics, prognostications and data, some measured, some extrapolated and some assumed, are real eye-openers on how to handle the 10+ monthly exabytes of network data that is expected by 2015. As we tunnel into the next-generation wireless infrastructure, these statistics form the basis of the industry's concern that we are close to data gridlock, and the industry needs to put into place an intelligent, optimized and homogeneous cellular infrastructure.

No matter what technology, what operational support system (OSS), what kind of software hardware, glue logic, interconnect or interface, the consensus is that tomorrow's global wireless network will have to be made up of intelligent networks.

First step: optimizing networks

Optimizing the 10 percent of cells that handle the 90 percent of data traffic will have a significant effect on the global network data rate. Off-loading the 80 percent of indoor data traffic onto small cells will have an equally significant effect on the global data pipelines.

Various techniques are available for optimizing cells. Tilt optimization and sectorization optimize cell coverage and increase cell efficiency. Interference mitigation techniques optimize power levels and improve data throughput.

These techniques have long been used for macro cells, but with advancements in technology, they can be scaled to be effective with smaller cells. Optimization can only do so much to improve bandwidth. It is just the beginning. Alone, it is not nearly enough to supply the anticipated bandwidth demand.

Next step: adding intelligence

Once optimization has been done, the cells are ready for the next step — making them intelligent. Signal manipulation in the digital domain and adding smart, software-controlled hardware under an open OSS can make cells self-aware. Then, many possibilities open up. Intelligent cells will be the networks of tomorrow and the backbone of heterogeneous networks (hetnets).

Small cells range in size from femto to metro. Multiple-component versions (generally micro and metro) can have one or more base stations and multiple transmission components. They may use multiple-input, multiple-output (MIMO) communications. Femtocells and picocells generally have only a single base station with a multiple-input, single-output platform. Technology implemented in small cells and their interconnected layers makes them come together in a homogenous global network.

Before adding intelligence to a cell is even on the radar screen, cells must be made as efficient as physically possible. Cell placement is all about location, especially with licensed macro deployments. With small cells, licensed and unlicensed, failure to research the deployment environment can be disastrous. Intermodulation interference, RF interference, spectrum sharing and other possible interference must be considered when choosing cell locations.

For efficiency, hardware within the cell must be carefully located, including base stations, antennas and remote radio heads. Carefully selecting interconnect components and routing helps to minimize attenuation and insertion loss.

Other efficiency factors are more integrated into the cell's intelligence layers, such as spectrum sharing, power control and data services, which are built into the cells' operating systems.

Much of the intelligence in cells is embedded in network and application services. One approach is to deploy this intelligence at the access point via smart

soft radios, which can radically alter the traffic profile. If the access point can intelligently route traffic in real time, it provides two significant benefits: less backhaul traffic and faster, more efficient data throughput. The access point can analyze the I/O traffic and intelligently route and manage it based on available spectrum resource and destination.

Intelligent routing usually involves various layers of technology or techniques. One is caching, which has been used in computer data management for years. Caching is an effective way to achieve fast data transfer. The trick is to be able to do the prediction, and this works best in cases where redundancy can be expected. This type of caching is called predictive. It works by having the network, via any number of methods, search for and download popular content during off hours. The data downloaded is stored and ready to deliver when the requests come in. This works well for standard sources such as YouTube where algorithms can go to the same place and assess data based on standard query criteria. This also works well for static data that is commonly requested, such as restaurant or street guides.

A second caching method is called proactive. It is more of an afterthought type of caching in which the network sees a lot of requests for particular data and then downloads it. Caching also lessens the demand on backhaul.

Another technique to add intelligence to a cell is the use of content awareness. A content-aware network can analyze and understand a packet's contents. It also can recognize the type of application or service to which a packet belongs. It does this by analyzing the header and the payload layers of the packet. Algorithms then adapt the data to the end user device and optimize it for efficient routing. This is especially applicable to video, which is easily recognizable and has a wide range of codecs that can optimize it.

Self-organizing networks

Once intelligence has been integrated into the cells, the next step is to make them self-aware. Systems of this type will elevate cellular technology from 4G to 5G.

Traditional cellular deployments are essentially one-dimensional. The same is true for unlicensed technologies such as Wi-Fi and the Family Radio Service. There are fundamental technological incompatibilities between these and other services. GSM versus CDMA and data versus voice are examples. No single technology can seamlessly interconnect them under a common platform.

Heterogeneous networks are about to change all of that. Using intelligent cell hardware and software based on self-organizing network (SoN) principles, discrete technologies will be integrated in hetnets, making them multidimensional. If open-systems architecture principles are followed, as recommended, multiple vendors, multiple technology layers, multiple operators and multiple architectures and wireless systems of all kinds (3G, 4G, LTE, Wi-Fi, VoIP, mobile

video, multimedia) eventually will be seamlessly integrated into an efficient, optimized global wireless network. Hetnets will be forward-compatible with present and yet-to-be-developed applications and technologies.

SoNs have been employed in optical and Ethernet networks for quite some time to create intelligence-based homogeneous networks. The same intelligence model must be applied in hetnets, and intelligence will be the glue that will bind SoNs and hetnets.

Because the SoN model has been so successfully implemented in operational support systems and Ethernet, there is already a realistic model to draw upon. Although wireless has its own unique set of issues, scaling SoN principles and technologies to wireless is expected to have few roadblocks. The most significant roadblock isn't found in the task of implementing intelligent technology, it is found in the economic segment and involves getting all the players to buy into the compatibility argument.

SoNs are comprised of intelligent cells plus a layer of self-management and intelligent interconnect. These combinations are referred to as hetnets. However, SoN-based hetnets won't just be a group of single, intelligent cells. They also will integrate the technology to make the hetnets self-aware, self-healing and self-configuring, thus enabling the ultimate goal of seamless, self-managed intercell networking.SoNs contain nodes that are self-configuring, self-optimizing and self-healing. The importance of these three platforms is pivotal. They are the key elements that will enable next-generation wireless networks and eventually will be found in all cell sites. So far, such wireless networks are scarce, and much of this technology remains in development and field trials. The final solution for wide-scale deployment may differ somewhat from the development and field trial versions, but the basic premise has been established.To date, most SoN implementations are OSS or network management-centric. This is more of a hybrid approach because the high-level management of the network is still centralized to a certain degree, as opposed to being fully distributed. Eventually, the architecture will embed the algorithms for self-monitoring and regulation into the nodes (network elements). This solution will enable automatic optimization and healing decisions at the node level and will be a fully distributed system, although there probably will be some level of central control for the foreseeable future.

Embedded functionality at the node is essential for the node to fully implement the three critical functions previously mentioned. This allows the node to accurately run the algorithms based on actual conditions at the node and not from a central site that bases decisions on assessments of peripherals.

Types of SoNs

Currently, the most developed platform

of SoNs is the centralized solution. The other option is distributed. The centralized version (referred to as C-SoN), places the concentrated intelligence higher up the layer ladder to the higher-order network nodes or the network OSS. Although this makes the network less agile and self-controlling, today's technology isn't mature enough to allow a fully distributed network to exist on a large scale. But this has some definite advantages in some situations because it allows a higher-level overview of more of the edge elements where most of the problems occur. Centralized networks can manipulate loading, power and distribution across a wider geographic area, which in some cases is preferred. However, C-SoNs require paying attention to internetworking because they are self-contained networks. These networks require manual interconnect with other C-SoNs and the macro infrastructure.

In a fully distributed SoN, (referred to as a D-SON), self-managing functions are distributed among the network elements at the edge of the network. Today, they are typically ENodeB elements.

ENodeB is short for E-UTRAN Node B, also known as Evolved Node B. It is the evolution of the element Node B in UTRA of UMTS. It is the hardware that is connected to the mobile network that communicates directly with mobile handsets. ENodeB uses the ETRA protocols OFDMA for the downlink and SC-FDMA for the uplink on the LTE-Uu interface. The earlier version NodeB uses UTRA protocols WCDMA or TD-SCDMA on its Uu interface.

Technology has not advanced to the point at which fully autonomous global wireless networks are practical. However, on a smaller scale, this platform provides a peek into what eventually could be scaled up. Distributed SoNs have shown that they can function relatively autonomously within their cell when all the equipment is from the same source.

Hybrid SoNs contain elements of both configurations to varying degrees.

True heterogeneous networks require that vendors find a way to blend all of the different layers that hetnets will contain. The most promising track is to develop open standards within which all vendors can work. Such open standards allow vendors to develop products for all layers of the network and the best of breed can be implemented without fear of compatibility problems.

Next on the list is coexistence with macro cells. Macro cells need to be part of the hetnet, but that may be difficult to implement. Ownership of macro cells is well defined and regulated. There are major issues with this that involve a number of metrics, most of them having to do with matters of finance and control.

Interference management in hetnets will be much more complex than in macro networks. The interference characteristics common to macro cells are found within the hetnet, plus small cell interconnect and small cell interference problems. In small

cell networks, many more cell borders must be taken into consideration, both within the small cell and within the macro cell. This combination introduces orders of magnitude more complex intermodulation interference and distortion problems because of the variety of signals that can exist at the edges of macro and small cells, and because of their composition. With licensed wireless, the well of knowledge is deep, and there are no surprises at the cell fringes anymore.

With small cells and homogeneous networks, the variables at the edge are much more varied. It is going to be both an art and a science to locate hardware and choose signal-manipulating software for small cells. Much attention will be required for optimal implementation of attributes such as automatic power adjustment and resource scheduling to keep the fringes clean and interference-free. This is where antenna positioning and configuration are key in combination with hardware and software.

The fifth factor for small cell efficiency lies in the backhaul. The backhaul path requires careful planning and strict performance management. If backhaul is not planned and implemented well, the benefits of the hetnet can be undermined, and bottlenecks can be created that will ripple thought the entire hetnet and seriously affect throughput.

Small cell backhaul

For all that they promise, hetnets will create a significant problem for backhaul, which must provide connectivity at sufficient capacity and quality of service. Backhaul is perceived as the most critical factor for small-cell platforms.

Microwave is the largest carrier of backhaul. But there is concern that this platform will become overburdened as small cells and hetnets proliferate and integrate with each other. The concern about microwave is the sheer number of sites needed to support the looming large-scale deployment of small cells. There are also problems with the technology. Existing microwave frequencies in the 6 GHz to 42 GHz band cannot support discrete antennas at the street level of many small cells. Higher frequencies (60 GHz to 80 GHz) are being considered, but propagation limitations at those frequencies mean their application to small cell networks needs more investigation.

The preferred solution is fiber-optic cable, but it cannot be installed everywhere. Some combination of backhaul technologies may be used, and perhaps some technologies such as earth-orbiting satellites, perhaps those long-forgotten low earth-orbit (LEO) satellites may be used.

Creating an invisible, self-managed, wide-bandwidth wireless infrastructure is a lofty goal. Applying technologies such as SoNs to create hetnets represents the latest attempt to reach it. Virtually every trick in the book will have to be used to make it happen. ■

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hetnets

Heterogeneous Cellular Networks

Wireless data systems are going to run out of bandwidth, and when they do, the result will be a data gridlock. Heterogeneous networks (hetnets) promise to relieve this datageddon and keep data moving smoothly. **By Ernest Worthman**

Macro cellular networks are on the verge of overload. Wireless data traffic volume is increasing exponentially. The latest data-hungry smartphones, tablets and portables, and the ever-increasing number of applications for them, cannot be borne by current cellular systems, not even 4G systems. Figure 1 shows the relationship between devices that are data driven and the equivalent bandwidth load that the device puts on a system, compared with a simply voice-only cellular radio.

By the end of this year, video data is expected to account for 64 percent of mobile data traffic. New applications for telemedicine, high-definition and real-time interactive gaming, and mobile education systems will further clog the wireless infrastructure. To cope with the data growth, new and innovative approaches such as small cell networks and heterogeneous platforms are being developed and deployed.

Figure 1. The bandwidth used by 3/4G devices, vs. 2G voice-only cellular radios.

Network types

Homogenous networks support multiple broadband wireless access technologies and global roaming across systems constructed of individual access technologies. What makes this possible is a common core network (CCN).

The CCN enables heterogeneous networks (hetnets), also referred to as coherent heterogeneous integrated cellular (CHIC) networks that will support all applications, devices and infrastructures that have open access. The CHIC network provides wide-area, high-data-rate wireless connectivity by combining air interfaces and backhaul access technologies with devices, applications, and service providers into a single, protracted, interconnected network. CHIC networks are loosely confederated, and they resemble Internet Protocol models.

Hetnets will connect small cells from femto to metro and provide the interface to the macro network. One example of an emerging cellular model is shown in Figure 2.

Because hetnets contain uncontrolled deployments (Wi-Fi in particular), traditional propagation studies are not useful. Hetnets contain a large number of femtocells, most of which will be deployed at the consumer's whim.

Femtocells

The smallest of cells, femtocells are the most likely to create havoc within the hetnet. Femtocells represent a special case because other members of the small cell family, pico, micro and metro cells, are more likely to be deployed with forethought and awareness of the global wireless infrastructure. The larger forms of small cells can be integrated into the hetnet without most of the problems that femtocells can have.

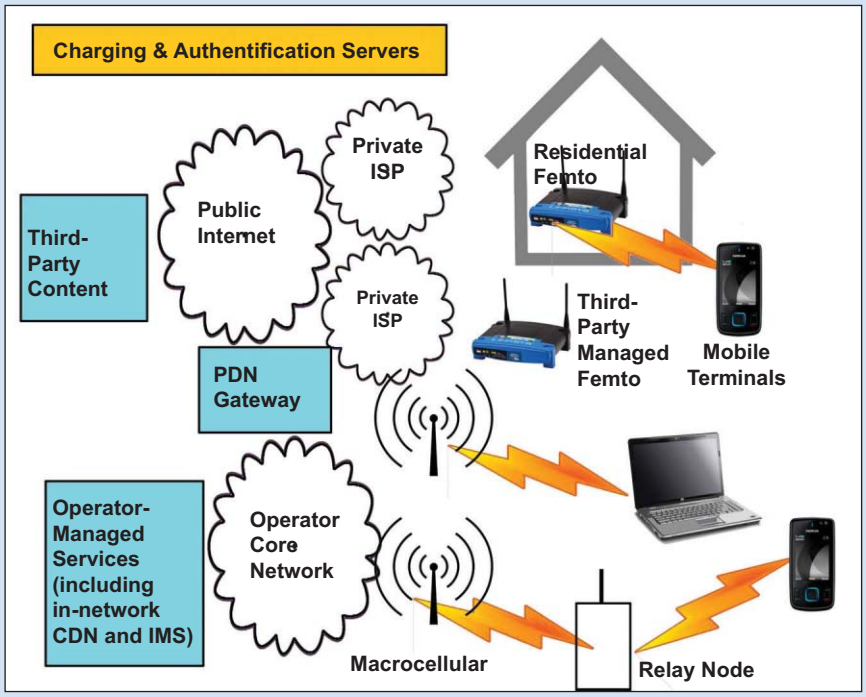


Figure 2. An example of a CHIC-based cellular network with hetnet considerations.

A consumer may place one or more femtocells in a home or place of business. If it stays put, it is easier for the hetnet's intelligence to integrate its coverage pattern; however, at any given moment, the consumer can move the cell around, turn it off, remove it or move it to another location. The dynamic realignment that moving a femtocell represents will affect traffic control within the hetnet and create interference. Figure 3 shows some of the conditions that cause femtocell interference in Hetnets. The first graphic (a) represents the standard macrocellular model with three-way sectorization. This configuration is designed with fixed TX/RX components and known propagation models within hetnets. This means that interference can be minimized and will not change within the cell or the hetnet. Graphic (b) is a series of femtocells within a hetnet capable of interfering with each other and with macrocell segments as well. Graphic (c) presents how an intelligent CHIC network works. It dynamically configures itself to minimize interference with other femtocells and within the hetnet.

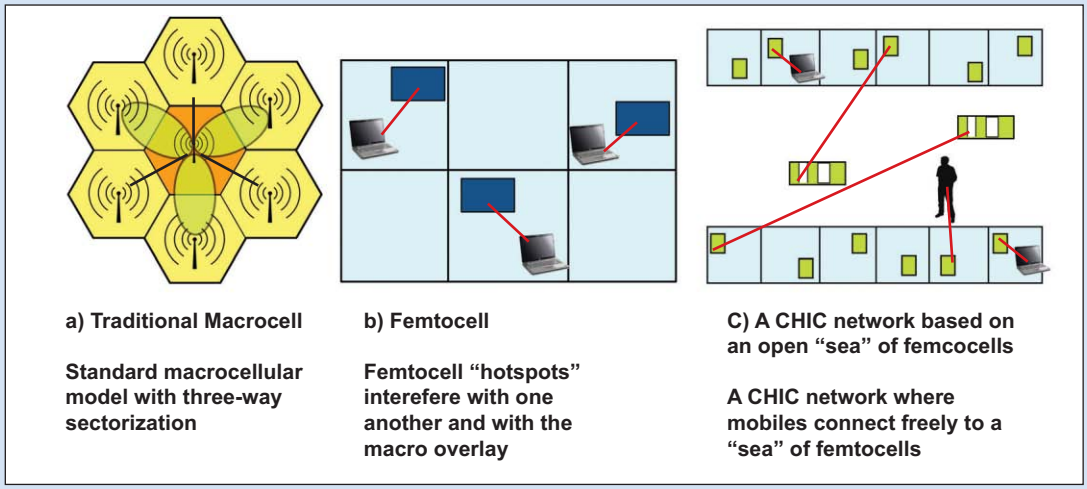


Figure 3. Interference issues in hetnets and how a CHIC solution resolves them.

To compensate for femtocell interference and ad-hoc conditions, two common strategies can be employed (see Figure 4). One relies on power management strategy and the other implements time or frequency management. The upper graphic represents the power control with reuse approach. This approach links the transmit power to time and frequency. Power control is a mechanism used to exploit both spatial reuse and power conservation opportunities. Increasing the transmitting power overcomes interference at the desired receiver but consumes power and creates additional interference at other communicating nodes. Reducing transmitting power reduces interference at other communicating pairs and saves the sender's power consumption, but results in a lower signal-to-noise ratio (SNR), which can become a problem at the edge of the network. Power reduction works best with low-interference systems.

The second method is orthagonalization. This approach makes the transmission more dynamic by linking it to different times or frequencies, rather than trying to control everything with power. The system analyzes available frequencies and bandwidths and chooses the best time or frequency for the transmission. This is a better solution when interference is unpredictable. It is the basis of the 802.11 standards where transmit conditions are dynamic and unpredictable. Both methods can be implemented in the same system with intelligent activation, depending on interference conditions and cell intelligence.

Unlike other small cells, femtocells

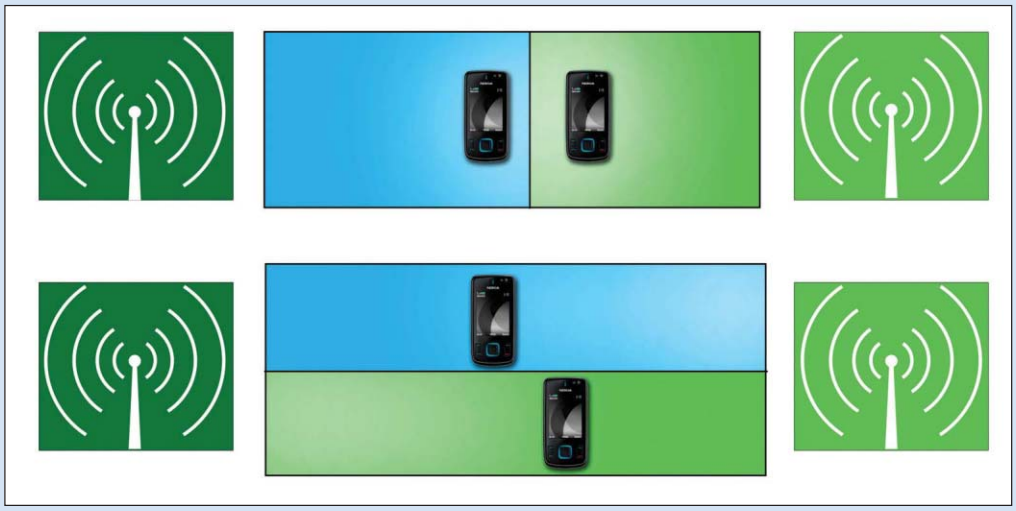


Figure 4. Two commonly used interference management strategies. The top graphic uses the same frequency but varies power to mitigate interference. The bottom graphic uses frequency management (dynamic frequency allocation) to mitigate interference.

are not generally connected to the operator's core network. This makes for interesting bedfellows in a macrocell-sharing environment. Femtocells have limited or no backhaul signaling for interference mitigation.

A wireless over-the-air (OTA) signaling scheme used in place of backhaul brings some problems with it. For femtocells within a macrocell's propagation footprint, OTA signaling can be unreliable because of large power disparities that cause the femtocell's signal to be lost in the noise floor. If a large number of femtocells are operating in the macrocell's coverage zone, some of their OTA signaling can be lost or misunderstood by the macrocell.

The best way to mitigate cross-tier interference is to use an under-the-radar overlay (see Figure 5). Unorthodox but viable, this scenario uses a device's short-range links to cancel signals from the macrocell transmitters and operate transparently within the macrocell. This method removes the necessity of coordinating across tiers and only reduces the macrocell's transmission rate by a few percentage points. It also improves the data rate in the femtocells.

It works by partitioning both the uplink (UL) and downlink (DL) into subbands. Using standard fractional frequency reuse (FFR) methods, the macro transmit power is varied across the subbands. This creates different reuse patterns and interference conditions unique to each subband. It allows femto links to transmit in one or more subbands, keeping interference within the subband and out of the macro network. If a load-spillage power control method is implemented, femtocell transmitters can identify the interference effect in each subband and optimize power distribution across the subbands accordingly. Figure 5 is an example of such a scheme. It shows typical locations of macro UEs (MUE1–4) in each subband, along with possible locations for short-range links (SR1–7). SR1–3 can operate in either the UL or DL and does not require interference cancellation (IC). SR4 and 5 would operate in the DL with IC of the DL signal from the macrocell base stations. SR6 and 7 operate in the UL with IC of the macro UE transmissions.

For interference coordination, MUE1 and MUE3 use f0 because they are close to the base station. MUE2 and MUE4 use f1 and f2, respectively. SR1 uses f0 because it is at the macrocell edge. Close to the base station, SR2 or SR3 can use a band not used by the base station.

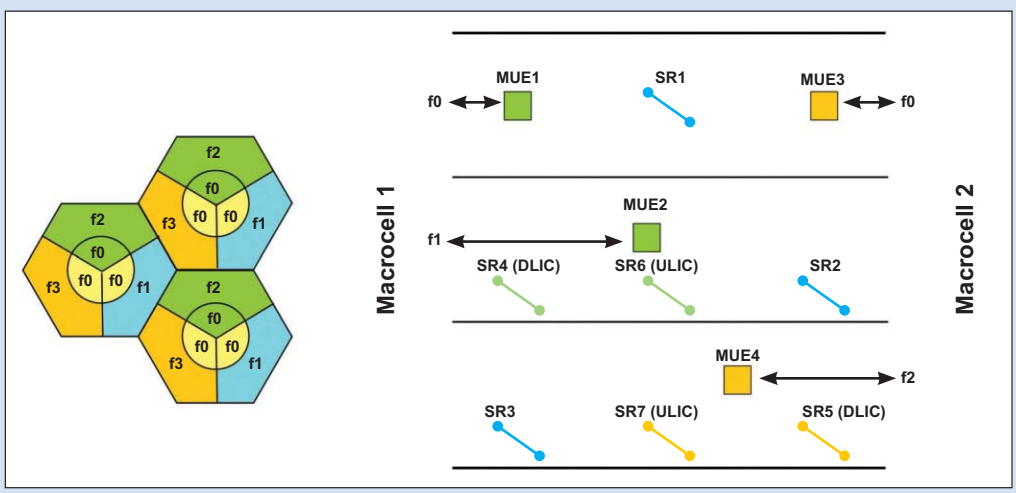


Figure 5. Interference mitigation via link control.

Interference

For interference cancellation, because SR4 is close to macrocell 1, it will receive the DL signal on f1 strongly. Also, the signal on that subband will typically be at a low rate and can be easily decoded to perform IC. The same situation applies to SR5.

SR6 and SR7 are subject to strong uplink interference. They perform IC for the uplink.

To function efficiently and effectively, heterogeneous cells will require a different architecture to be all that they can be. Current topology implements an evolved packet core (EPC) approach. Although it is effective at today's data rates, it will have problems as data rates burgeon.

The EPC has considerations that make it work under current conditions. It offers a constant IP point of attachment that makes the user mobility transparent to the public Internet. It is optimized to handle mobility procedures such as handover, access control and paging with significant cross-layer design. It simplifies the design of terminal with centralized processing, with the terminals only providing measurement reports.

Tomorrow's hetnet architecture will have to be more flexible and fluid. One proposed methodology is called edge. Edge networks offer better scalability. EPC handover has been designed with the assumption that the air interface would be the bottleneck and would rely on extensive, fast messaging in the core network. However, this plan is not optimized for intelligent hetnets and it probably would perform poorly in heterogeneous networks where access points could have limited backhaul or could add significant delay to the core network.

Also, edge provides the ability to support the emerging cellular standards (selected IP traffic offload [SIPTO] and local IP access [LIPA]) that support providing an IP point of attachment directly at the base stations as opposed to a constant attachment such as with EPC. If mobility is support for those protocols, edge networking can provide the basis for a more scalable architecture without a costly dedicated core network, and mobility can enable flexible integration of much more varied backhaul access technologies. Edge will offer services such as caching, content delivery networks (CDNs), adaptive video transcoding, low-latency network virtualization and cloud computing.

Cooperation in hetnets

For the next generation of cellular sites to interface successfully, cooperation is the magic word. Although there have been significant improvements in efficiency within cells, problems still exist at the cell edges. For heterogeneous networks to provide a seamless, consistent information exchange, these problems must be resolved.

The problem is that stations at the edge transmit at a much lower data rate than stations at the center (10:1 for Wi-Fi). Packet transmission for stations at the edge takes much longer and, there are higher interference levels at the cell edge. All of this translates into bottlenecks that affect the entire network.

One solution is to implement cooperative communications via a relay, often called a third node, to improve marginal transmission. Relays process overheard information and forward it to a destination. This results in improved network performance and higher spectral efficiency because then edge nodes can transmit at higher rate. Within hetnets, such relays can be provided by pico and femto base stations; thus, they can intrinsically improve hetnet performance.

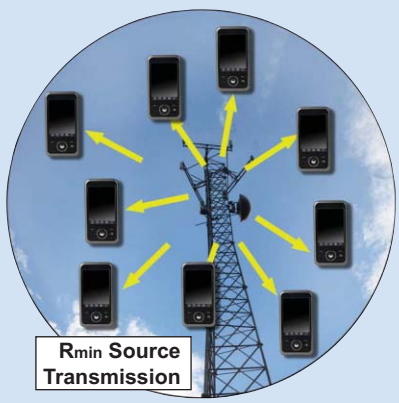


Figure 6. Standard cooperative video multicast.

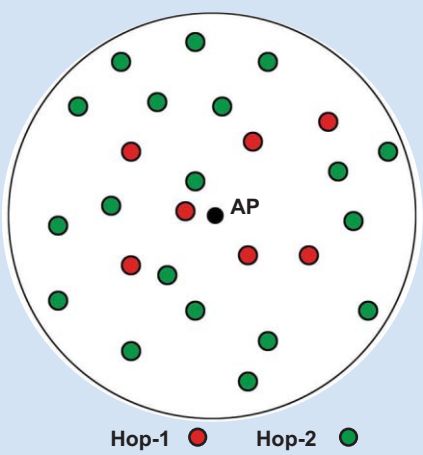


Figure 7. Cooperative video multicast with R-DSTC.

The same cooperative multicast with randomized distributed space-time coding (R-DSTC) is dynamic. The source transmits the data stream at a faster rate. As nodes receive the data, they become relays and forward the data to the next hop.

Cooperative video multicast

Video is becoming a huge burden on cell bandwidth. To maintain cell data rates with integrated video, the video must be multicasted. Traditionally, video is transmitted and received within a cell from a single base station (see Figure 6). With cooperative multicasting, a relay condition exists (see Figure 7).

In the standard multicast, the source transmits at the lowest transmission rate and in a steady data stream to each channel. The entire transmission is sent at the rate of the slowest receiver. This is done so all the receivers, regardless of channel quality, can receive the signal. Although this technique works well, it limits the network's performance and wastes the capabilities of high-end receivers. It can also hog bandwidth.

The same cooperative multicast with randomized distributed space-time coding (R-DSTC) is dynamic. The source transmits the data stream at a faster rate. As nodes receive the data, they become relays and forward the data to the next hop. The data

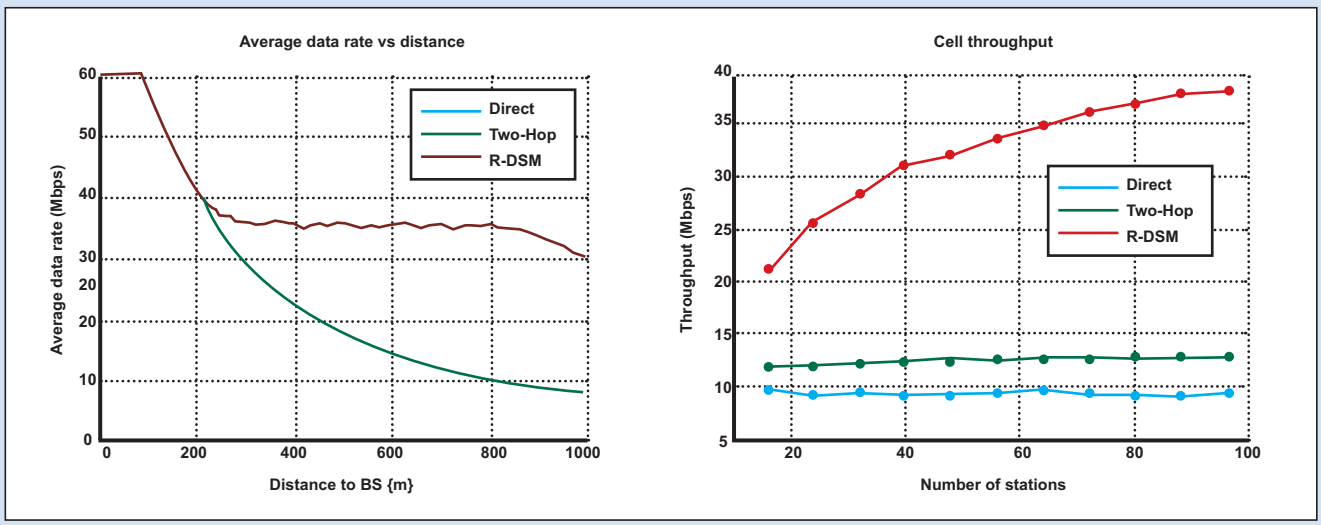


Figure 8. Comparison of throughput using RDSM techniques vs. direct and two-hop methods.

is sent in packets and assembled at the receivers from multiple sources. Slower receivers buffer the data and the faster devices work at an optimized rate. This has the effect of optimizing bandwidth, and the higher-quality channels can receive data at a rate compatible with their capabilities.

The R-DTSC technique is based on randomized distributed spatial multiplexing (R-DSM) in which the channel capacity between the relays and the destinations scales linearly with min(N,L), where N is the number of relays. Therefore, the more relays, the better the transmission quality and subsequent data rate. RDSM dramatically improves data rates as the number of stations increases (see Figure 8).

In the downlink, the macrocell base station fetches user data packets to a cluster of pico/femtocell BSs via their backhauls and allocates frequency/time slots for the downlink data and broadcasts to all base stations under it.

Other adaptive video options

Video, as the dominant traffic on the wireless Internet, can be optimized for the wireless bottleneck via video transport optimization.

There are some new system-level approaches to realizing practical cross-layer optimizations. They include using new visual perception metrics in end-to-end transport, multi-user resource allocation in highly congested environments and cooperation models and incentives for hetnets (cell, broadcast and Wi-Fi) that leverage metadata and side information in the transport layer. The system-level approaches also include video processing optimizations with video frame rate up-conversion (FRUC), super-resolution and error concealment, along with saliency and video analytics such as face detection and tracking for video conferencing to identify priority regions for unequal error protection. A third system-level approach uses novel network architectures to lower the barrier and dramatically increase the number of network attach points (co-op clients/P2P, caching, heterogeneous cognitive networks and vehicular P2P).

Additional approaches such as compression, video scaling and optimizing the various video parameters such as signal-to-noise (SNR) ratio can be applied.

Handover in hetnet small cells

Another issue that must be understood in small, particularly femto and picocells, is handover. In such cells handover occurs much more frequently than in macro cells. This is due to a number of factors including smaller base station (BS) coverage area because each BS is a lower power unit. There is higher signaling overhead for the same reason. In a cooperative hetnet environment, there are separate signalling and data paths. While the macrocell orchestrates handover and allocates radio resources, the pico/femtocells handle the user data. This significantly improves throughput via the following process:

The macrocell base station tracks the locations of the mobile stations and makes predictions for the handover and which pico/femtocell base stations the mobile station is moving to.

In the downlink, the macrocell base station fetches user data packets to a cluster of pico/femtocell BSs via their backhauls and allocates frequency/time slots for the downlink data and broadcasts to all base stations under it. Pico/femtocell base stations cooperatively transmit to the mobile stations using R-DSTC.

In the uplink, the macrocell base station broadcasts the allocated frequency/time slots for the mobile stations. Any pico/femtocell base station that successfully decodes an uplink user packet forwards it to the macrocell base station via its backhaul.

All of this is enabled by applying various schemes of simulcasting,

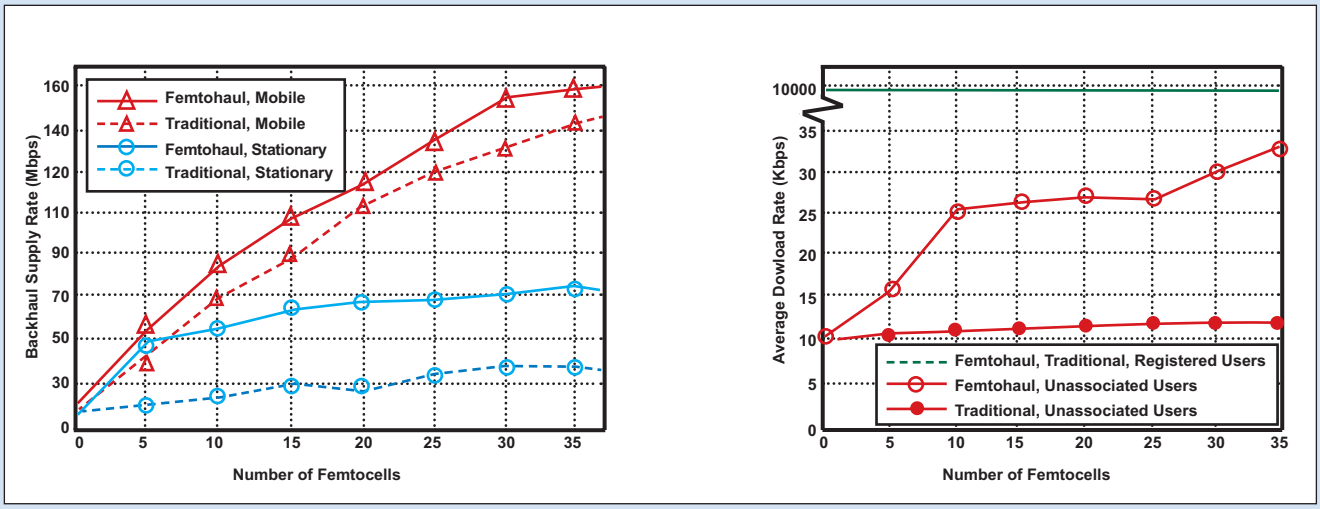


Figure 9. Comparison of data throughput rates for femtohaul technology vs. other femtocell transmission schemes.

using the latest generation of radio hardware. video conferencing to identify priority regions for unequal error protection. A third system-level approach uses novel network architectures to lower the barrier and dramatically increase the number of network attach points (co-op clients/P2P, caching, heterogeneous cognitive networks and vehicular P2P).

Additional approaches such as compression, video scaling and optimizing the various video parameters such as signal-to-noise (SNR) ratio can be applied.

Femtohaul

Another proposed novel solution, femtohaul, uses femtocell backhaul to carry non-femto user traffic by forwarding it through a relay. The channel allocation mechanism is based on orthogonal frequency-division multiple access (OFDMA) WiMAX. This sets up a policy for the base stations to schedule user transmissions and greatly increases the data rate in relation to the number of femto base stations (see Figure 9).

Millimeter wave

Recent advances in CMOS processes made millimeter wave bands (30 GHz to 300 GHz) a possibility for wireless personal communications. For example, global spectrum regulators have agreed upon several gigahertz of license-free wireless personal area network (PAN) frequencies centered on 60 GHz as a position in the radio-frequency spectrum.

Higher frequencies pose challenges that do not necessarily scale linearly as frequencies increase, such as propagation loss, free-space loss, atmosphere gaseous losses, precipitation attenuation and foliage blockage. Signal scattering, bending, propagation losses caused by rain, foliage and building materials would affect hetnet operation at higher frequencies. Although millimeter waves are attractive for mobile use because of small component sizes and power requirements, attenuation at such frequencies is higher in most materials. On the plus side, more antennas can be integrated into the devices, higher MIMO gains can be realized and highly directional antennas can be integrated to mitigate interference.

Overall, as frequencies at millimeter wavelengths are evaluated, it can be expected that some will prove to be suitable for small cell applications.

Conclusion

The future network architecture will have to be a heterogeneous environment with a conglomeration of macro-, metro- pico- and femtocells integrating Wi-Fi and ad hoc architectures. Femtocells, in particular, are the carrier's Trojan horse and will require some special considerations. Macrocells will act more like traffic managers with most of the data being handled by hetnet small cells. The global layer that will make all of this possible will be cooperative networking. It will be the umbrella that will empower user end devices, small cells and macro cells, Wi-Fi access points and other yet-to-be-dreamed-of platforms to provide a heterogeneous, seamless and ubiquitous wireless communications infrastructure. ■

Another proposed novel solution, femtohaul, uses femtocell backhaul to carry non-femto user traffic by forwarding it through a relay. The channel allocation mechanism is based on orthogonal frequency-division multiple access (OFDMA) WiMAX.

This article was adapted from a tutorial developed and presented at a Virginia Tech wireless symposium by Shivendra S. Panwar, professor, Polytechnic Institute of New York University. The author thanks the professor for his assistance and for supplying data for the article.

The Promise the 3.5-GHz Band Holds for Small Cell Systems

With variable power and collocated incumbents, the 3.5-GHz band poses interference problems for small cell systems. Intelligent, computer-controlled digital radios can mitigate interference for small cells.

By Ernest Worthman

Experts predict that by 2020, required wireless capacity will increase by as much 1,000-fold compared with the capacity demand during 2012 and 2013. The current cellular data network, even with 4G/LTE, cannot possibly provide the bandwidth and capacity that predictions say will be needed.

Anticipating the demand, and in an attempt to open spectrum for small cells, the FCC has proposed to refarm spectrum in the 3.5-GHz band, a 100-megahertz slice from 3.55 GHz to 3.65 GHz. The FCC issued a proposed rulemaking to take the spectrum from military and satellite users to create a new citizens broadband service. The service would be allocated for small cell and spectrum sharing.

The Fast Track Report within the National Broadband Plan initiative recommends that 100 megahertz of spectrum (3.55 GHz to 3.65 MHz) could be made available for commercial wireless broadband by 2015.

Spectrum under consideration

The FCC considers 3.5 GHz to be an ideal frequency for small cells. Most incumbents are government users such as high-powered Department of Defense (DoD) radar, and nonfederal Fixed Satellite Service (FSS) earth stations for receive-only, space-to-earth operations and feeder links. Just below 3.5 GHz are high-powered ground and airborne military radar operations. Even though the band is somewhat crowded, studies of the propagation characteristic of signals at this frequency make it extremely attractive for small cell coexistence with the incumbents.

The band was first investigated for suitability of propagation for macro cells. Propagation was found to be inadequate for reliable signal coverage of the area typically served by a macro cell. To place macro cells on this frequency would require them to be much closer than they are at lower frequencies and would make deployment cost-prohibitive. Precisely because of the limited propagation, the band seems ideal for small cells.

The FCC put forth a set of comprehensive policy recommendations that would open up 500 megahertz of spectrum for wireless broadband access by 2020. Of that, 300 megahertz between 225 MHz and 3.7 GHz would be assigned exclusively for mobile broadband use by 2015. The initiative opened up a tremendous opportunity for the small cell market. Some problems with incumbent users and users of adjacent frequencies would restrict the hardware that could be used.

The Fast Track Report within the National Broadband Plan initiative recommends that 100 megahertz of spectrum (3.55 GHz to 3.65 MHz) could be made available for commercial wireless broadband by 2015. The report included concerns about interference and how it could be mitigated to protect incumbents and small cells.

Because of the band's propagation characteristics, protecting DoD radar and FSS operations from the propagation footprints of small cells would require geographic studies. New systems would need protection from co-channel interference caused by high-powered military in-band ship-borne radar and adjacent-band DoD ground-based radar. Although low-power propagation is limited, radar systems in this band overcome propagation losses with high-power transmitters and high-gain antennas. Because many radar systems are mobile, the need for careful evaluation of propagation characteristics is vital.

The FCC seems to think that,

with sufficient modern frequency manipulation, the 3.5-GHz band offers frequencies suitable for small cell deployments.

The techie talk

Small cell signal propagation in this band is favorable for dense deployment of small cells and offers a reduced risk of harmful interference to geographically or spectrally adjacent users. Additionally, its limited propagation range greatly increases frequency reuse and available network capacity. Signal propagation at 3.5 GHz is viable at least to some degree for non-line-of-sight use, allowing for flexible network topologies. In short, given its characteristics, the 3.5-GHz band appears to be a good candidate for small cell uses, if it isn't crippled by incumbent uses.

The 3.5-GHz band's propagation limitation can work to a small cell's advantage. Assuming ideal free-space line-of-sight conditions, a 3.5-GHz signal would decay faster than a signal in lower frequency bands. Range at 3.5 GHz is reduced by 29 percent compared with broadband radio service in the 2.5-GHz band. It is reduced by 45 percent compared with the 1.9-GHz PCS band and 75 percent compared with cellular bands at 850 MHz and 950 MHz. Range reduction would be greater with buildings and other obstructions because attenuation characteristics of obstructions increase logarithmically as frequency increases.

Limited propagation would allow radio systems to operate in closer proximity to each other than they could in lower-frequency bands. With appropriate geographic separation and other mitigation techniques, this should enable greater sharing opportunities with incumbent systems. Resilient and flexible technologies such as spectrum access systems (SAS) and spectrum-sensing technology should be implemented to ensure this result. Such technologies also raise the possibility of even greater spectrum sharing among various commercial systems.

Mitigating technologies

Spectrum access systems (SASs) are designed to be implemented where multiple RF systems are in close proximity, as would be the case with small cells in the 3.5-GHz band. SAS is modeled after the TV whitespace (TVWS) database requirements. It can port current database technology and can be used to achieve dynamic frequency assignment while mitigating interference among devices in the same frequency band. SAS can also integrate spectrum scheduling, which is where intelligent, individual wireless systems are aware of each other's existence within the same RF band. Spectrum scheduling system layers modify how wireless systems time-share the bandwidth. Couple that with the SAS database method, and it appears as though the 3.5-GHz band offers an excellent option for small cells. Some possibilities for system scheduling include:

Limited propagation would allow radio systems to operate in closer proximity to each other than they could in lower frequency bands. With appropriate geographic separation and other mitigation techniques, this should enable greater sharing opportunities with incumbent systems.

Architectural methodologies: Design the entire system to be spectrum agile. This approach will modify components of the wireless systems for coexistence, such as modifying base stations or mobile handsets to enable spectrum agility.

Structural methodologies: Build in interoperability technologies at the beginning of the protocol design stage, and leverage existing protocol mechanisms, such as protocol messages, conditions or signal-processing schemes to coordinate channel access schedules.

Temporal methodologies: Share at the macro scale, which requires setting up an advance timetable at an hour or day level for various wireless systems to operate without getting into each other's ways, or share at micro scale, which requires protocols to multiplex the spectrum resource at millisecond levels, close to the hardware clock speed.

Spectral methodologies: Use a monopoly, which allows a wireless system to occupy the spectrum completely for the protocol operations, or use a commonwealth, which allows multiple systems to fragment the channel in frequency domain.

Once the system scheduling is in place, an SAS, which incorporates a geolocation-enabled, dynamic database to manage access across a number of access planes, can be implemented. The SAS will analyze geography, time and frequency, and would use other technological coordination techniques. Coupled with spectrum scheduling, SAS can be an extremely attractive spectrum-sharing and collocation solution.

Considering an SAS for the 3.5-GHz band raises new issues. It would require a new generation of the existing dynamic database technology, which would involve planning and testing. It would have to include an appropriate data security scheme to protect sensitive federal information. Whether the existing TVWS database model can be modified to accommodate the 3.5-GHz band is uncertain.

Spectrum sensing

Able to use a variety of innovative technologies, spectrum-sensing devices employ a mechanism that detects the presence of RF signals and dynamically guides the transmitters to hop to another channel whenever a particular set of conditions occurs. When implemented, a transmitter's spectrum-sensing mechanism would constantly monitor available radar or small cell channels. When a transmission is about to occur

and if a signal is detected, the sensor associated with that signal would look for another available channel to use. It is a rather simple idea, but to function efficiently, all the systems involved would have to have some measure of intelligence.

Other mitigation techniques

To prevent interference among adjacent and same-tier users, other mitigation techniques can be used that are not as sophisticated as SAS and spectrum sensing. They are applicable to older systems in which adding intelligence may not be feasible. Proven techniques include duty cycle and average power to limit interference between users, simple spectrum sharing (CDMA, TDMA) technologies, automatic power control, embedded mitigation techniques such as channel coding with forward error correction (FEC), adaptive modulation and coding schemes, multiple-input multiple-output (MIMO) communications, beaconing technology or the capability to switch to other spectrum bands authorized for use in the event of harmful interference from new and incumbent users.

Femtocells are typically deployed in residences and small businesses. Picocells are typically used in larger public indoor spaces. Microcells and metrocells are generally used for larger outdoor and larger enterprise deployments.

Mitigation steps could require specific control outside of intelligent frequency management. Certain conditions could require permanent and absolute interference mitigation. In that case, hard limits such as minimum/maximum emission bandwidth, limits to power spectral density and edge of band, out-of-band emission (OOBE) limits could reduce or prevent interference with adjacent channels. Initial analysis suggests that for small cell operations at 3.5 GHz, fixed station transmit power should be limited to 200 milliwatts (23 dBm) with a maximum gain of 7 dBi for any external antenna. Assuming negligible cable and insertion loss, this makes the maximum EIRP 1 watt (30 dBm), which probably would be the baseline regulatory condition to which intelligent small cell networks are designed.

Femtocells

The cell with the smallest footprint is called a femtocell, and its range is about 10 meters. Coverage increases in order with picocells, microcells and metrocells that reach from 10 meters to several kilometers. In reality, these are baseline numbers and, of course, can vary widely from installation to installation. Femtocells are typically deployed in residences and small businesses. Picocells are typically used in larger public indoor spaces. Microcells and metrocells are generally used for larger outdoor and larger enterprise deployments.

Small cell technologies are not limited to unlicensed frequencies such as Wi-Fi. They are utilized in the full range of licensed and unlicensed mobile technologies, such as those standardized by the Third Generation Partnership Projects (3GPP and 3GPP2), and the Institute of Electrical and Electronics Engineers (IEEE). Small cell technologies can integrate 4G/LTE technology.

There are three classes of femtocells:

Class 1: This class of femtocells emerged first and femtocells are the best-known technology in the class. Femtocells in this class deliver transmit power and deployment similar to Wi-Fi access points, typically 20 dBm of EIRP or less for residential or small enterprise application. The end user normally installs this class of device.

Class 2: Using somewhat higher power, typically 24 dBm of EIRP to support longer ranges, this class of device generally is installed by the operator but may be installed by an end user in an enterprise environment. Class 2 femtocells must be deployed with the network operator's assistance.

Class 3: The higher transmit power level of Class 3 devices delivers longer range to provide a larger coverage footprint for more users. Typically, operators deploy Class 3 femtocells outdoors in an open access mode to authorized subscribers. Class 3 femtocells can be deployed indoors, in large enterprise applications such as public buildings, malls, or sports venues. It can be deployed outdoors in built-up areas to deliver distributed capacity or to cover voids, or in rural areas to meet specific coverage needs.

Class 2 and Class 3 femtocells aren't difficult to regulate, but Class 1 femtocells are. Why? Because 70 percent of Class 1 femtocells are self-deployed consumer installations with the consumer being the site owner and manager.

Trying to regulate wireless at the consumer level can be difficult, if not impossible, as the FCC learned with citizens band radio. Other small cell devices generally are deployed by organizations or enterprises, and their installations can be better regulated.

Trying to regulate wireless at the consumer level can be difficult, if not impossible, as the FCC learned with citizens band radio. Other small cell devices generally are deployed by organizations or enterprises, and their installations can be better regulated. Femtocell regulation is different from

other small cells.

With 3.5-GHz femtocells, despite their RF emissions being mostly confined indoors, the possibility for interference with nearby or critical incumbents exists.

Femtocells are low-power wireless access points that operate in licensed spectrum and that connect mobile devices to a mobile operator's network. Femtocells can use residential DSL or cable broadband connections, or they can use wireless connections. The wireless access has to have some regulation because a femtocell is a miniature base station that backhauls to the operator's core network. For femtocells to be consumer-proof, the regulation is carefully built into the device itself.

Femtocells use standard over-the-air wireless qualifying protocols, including GSM, WCDMA, LTE, Mobile WiMAX and CDMA. They are designed to use other current and future protocols standardized by 3GPP, 3GPP2 and the IEEE/WiMAX Forum.

Licensed operators manage the femtocells. They only operate within limits the licensed operators set. Although femtocells have a high degree of intelligence to ensure that they operate at power levels and frequencies unlikely to cause interference, operators, not the end users, set the limits. An operator is able to deny service to individual femtocells or users. This control is maintained whether the femtocell is owned by the operator or the end user. The use of such protocols allows femtocells to provide service to users that they can access from almost any location as part of a wide-area network.

Because sensitive and critical users in the 3.5-GHz band must be protected from interference, regulating 3.5-GHz femtocells presents one or two problems unique to the frequency band. One problem is that femtocells are portable, and the second is that unlike other small cells, femtocells cannot be subjected to geographic restrictions. A consumer can take a femtocell along in a motor home or on a boat. Used mobile, femtocells cannot be kept out of another user's coverage area. There is no way to keep the user from moving a femtocell to another fixed location within a carrier's licensed coverage area.

Because femtocells register with the network, when one moves to a new network, the network operator can apply special restrictions for that area on top of the femtocell's programmed interoperability.

The femtocell can be made to self-regulate. It can be programed on the fly to make it subordinate to any licensed operations in its frequency band. When the femtocell senses a pre-programmed frequency is in use, as by radar in a nearby band, it automatically limits its transmit functions to keep it from interfering. It either reduces power or transmits where no signal is sensed. This is the most reasonable approach. Another option is to program into the femtocell some kind of notification to the user that the femtocell is in an area of potential conflict and offer the user other options. If the user doesn't respond, then the unit can turn itself off or go into some sort of mitigation mode.

Conclusion

Small cells are expected to be used for more than 70 percent of new cell site deployments. For small cell deployments to proceed flawlessly, interference, coexistence and interoperability problems should be resolved early on.

The 3.5-GHz band has unique problems with variable power and with high-priority collocated incumbents that need to be protected from interference. Therefore, new occupants at 3.5 GHz have a different challenge compared with frequency bands filled with commercial users.

Fortunately, deploying generic RF sites is well along the maturity curve and problems involved with generic RF sites are moot. Meanwhile, technology holds many of the answers with the availability of intelligent, computer-controlled digital radios that can mitigate interference, even in new frequency bands. That bodes well for the deployment of 3.5-GHz wireless broadband access services, at least from a regulatory perspective. ■

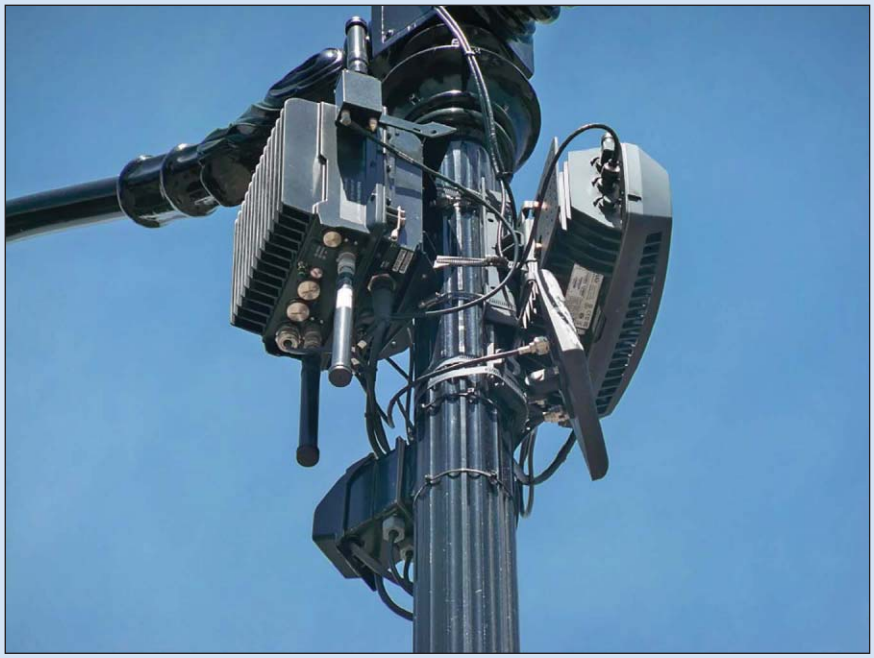
No Small Task

Small cells offer a viable solution for boosting mobile capacity. But first, providers must tackle a number of implementation challenges.

By Omar Flores

Global demand for high-bandwidth service over mobile networks shows no imminent sign of slowing. Industry analysts such as Earl J. Lum of EJL Wireless Research estimate that by 2018, mobile broadband subscriptions will reach 6.5 billion, up from about 1.8 billion today, cited by the *Ericsson Mobility Report*. Broadband data traffic is expected to grow exponentially over the next few years, increasing two to three times year-over-year through 2017.

Mobile service providers continue to build out their LTE/4G networks, and Wi-Fi has been useful in offloading traffic where capacity is thin. Yet, over the next few years, demand probably will exceed the ability of macrocells and existing Wi-Fi access to deliver adequate quality of service, particularly in the world's largest cities.



Augmenting macrocells with small-cell layers, primarily in dense urban areas, has emerged as a widely accepted solution for adding capacity to existing and future LTE networks. A 2013 report from Senza Fili Consulting declared the support for small cells "nearly universal" among providers and vendors. In the future, heterogeneous networks (hetnets) consisting of macrocells, small cells (microcells, picocells and femtocells) and Wi-Fi access points are likely to serve urban subscribers simultaneously.

Augmenting macrocells with small cell layers, primarily in dense urban areas, has emerged as a widely accepted solution for adding capacity to existing and future LTE networks.

Major mobile carriers in the United States, Europe, South Korea and Japan have all publicly announced plans to deploy small cells, with mass deployments planned for 2014 through 2017. In fact, *AGL* reported in September that South Korea (SK) Telecom has already deployed a system of 200,000 LTE small cells. An estimated 6.5 million new microcells are expected to be deployed globally over the next six years, compared with about 5 million towers currently deployed.

Small cells present an enormous opportunity for providers and vendors to capture new revenue, while subscribers look forward to enhanced services and improved reception. But before anyone can begin reaping the rewards brought about by small cells, the infrastructure must be deployed. Implementation of the small-cell layer presents a number of challenges to providers, vendors and municipalities alike.

The 3M Communication Markets Division has identified and categorized five major challenges associated with the deployment of microcells. For the purposes of this article, a microcell is defined as a public access small cell deployed in an

outdoor urban space. This type of small cell is also referred to as a metrocell. Vendors for the wireless segment are working on solutions to address these pain points in order to help providers successfully deploy small-cell layers and meet capacity demands in the coming years.

Deployment cost

Rolling out microcells in densely populated urban areas will pose new constraints not typically experienced with the construction of traditional macrocells. Deployment will involve a host of resource-intensive tasks, including site acquisition, designing cells for each unique environment, laying cable in developed urban areas, and securing permits from local governments to attach equipment to public infrastructure such as lampposts and public buildings.

One thing is certain: No one-size-fits-all solution will work in every city or in every neighborhood within a city. For example, wireline backhaul may be readily available in some areas but not for others. Some communities will require equipment to be disguised for aesthetic purposes while others will not. This unavoidable lack of uniformity will complicate installations and strain efforts to realize cost savings through economies of scale compared with macrocell site development. In addition, initial deployment cost will require an initial investment in new hardware and technology optimized for the small cell in order to achieve long-term service reliability and minimize ongoing maintenance costs.

For the time being, the mass deployment of small cells remains a costly proposition. Therefore, vendors are challenged with developing products and services that can help providers meet the challenges of urban deployment and long-term network stability while reducing capital and operating expenditures.

Backhaul and fronthaul

Obviously, small cells require backhaul to link them to the core network. Small cells typically backhaul to an aggregation point, which then connects with the operator's core backhaul network. Certain small-cell designs will also require what is now commonly referred to as fronthaul. Several remote radio heads can be clustered around a single baseband unit and connected with it via either wireline or wireless fronthaul. Each radio head forms its own small cell.

When deploying small cells, the provider must decide between wireline (fiber or copper cable) or wireless (microwave) backhaul. It makes sense for providers to leverage their existing copper or fiber plant. The problem is that small cells need to go where they need to go — in the midst of the greatest mobile broadband traffic — which isn't necessarily near a cabinet. In the absence of nearby fiber or copper plant, providers can choose to lay new cable, which, with current technology, requires trenching, micro-trenching or directional boring through and under streets and sidewalks.

Should laying new cable prove to be cost-prohibitive, wireless backhaul poses a viable second choice. A wireless backhaul solution is relatively inexpensive because it avoids the cost, installation time and permitting complexities associated with running cable. However, a wireless backhaul connection is usually not as inherently reliable as a hardwired connection. Line-of-sight requirements, susceptibility to interference and the availability of bandwidth are some of the issues the provider must grapple with when deploying wireless backhaul.

A multitude of small-cell backhaul technologies are under evaluation by

Municipal street lights are popular perches for small cells. *Photo by Stephen King, 3M*

Low-altitude interferers, such as seasonal foliage, can affect small cell performance.
Photo by Stephen King, 3M

various vendors and providers. Ultimately, most small cell networks will evolve using a mix of both wired and wireless backhaul and fronthaul, depending on the local constraints, according to the Small Cell Forum.

RF performance

Developing interference management solutions optimized for the small cell is one of the key challenges providers and vendors must meet before the mass deployment of heterogeneous networks begins. Small cells face a number of issues in terms of RF performance. For instance, the power imbalance between the macrocells and microcells increases the risk of co-channel interference. In addition, because microcell sites are intended to be mounted at a height of 5 meters or less above grade, they face continuously changing ground clutter, signal contamination found at low altitudes. Ground clutter can be caused by metal structures, large vehicles, seasonal tree foliage and even ocean swells. Radio-frequency interference (RFI) generated by electronic devices prevalent in the urban environment can also affect small-cell performance.

Security and monitoring

As mentioned previously, small cells will predominantly serve densely populated areas where mobile traffic is the highest and network capacity is often spread thin. Network equipment may soon be found gracing utility poles, lampposts and building exteriors in the world's largest cities. Although equipment will surely be mounted out of arm's reach, it will be much more exposed than macrocell equipment, which is generally tucked behind locked gates and razor-wire fences. Therefore, small cell equipment is more vulnerable to vandalism and tampering.

Monitoring is also a concern. Current monitoring and testing practices developed for the macrocell network may not scale to support the needs of dispersed small cells. Base station functionality can be monitored by a dedicated piece of equipment installed at the macrocell site. But installing monitoring equipment at each small-cell site poses severe cost challenges. In addition, deploying field technicians to small-cell sites to perform tests and validate network performance will be costly and impractical due to the sheer number of them expected to be deployed (6.5 million over the next six years, as mentioned earlier.) Monitoring technologies and methodologies optimized for small cells topologies will need to be developed.

Aesthetics

Microcells deployed in public spaces will affect the visual aesthetics of communities. The development of small form-factor base station nodes, radio heads and antennas optimized for small cell sites will help minimize visual impact. Even so, novel ways of disguising equipment will be in demand. Vendors are challenged with developing novel ways to mask small cells while not interfering with their functionality.

The challenges and tremendous opportunities posed by small cell deployment make this an exciting time in the mobile communications industry. Smartphones and tablets have changed the way people consume media, and global demand for high-bandwidth services over the mobile network shows no signs of slowing.

Even as LTE/4G networks continue to be rolled out, mobile operators are gearing up to deploy small-cell layers in order to add capacity in high-traffic areas. Over the next few years, service providers and vendors will work together to develop new technologies and designs to meet the challenges associated with small cells. Their efforts will result in better service for more customers and increased revenues for operators and vendors alike. ■

Omar Flores is business development manager, 3M Communication Markets Division.

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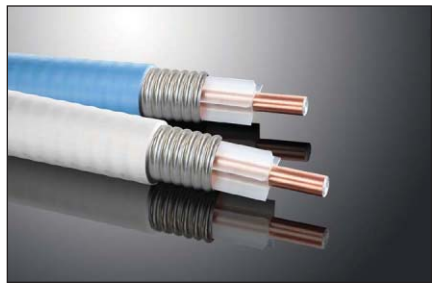
DAS and small cell cable



Radio Frequency Systems offers its ICA LITE, 0.5-inch aluminum plenum-rated wideband coaxial cable as a cable solution for DAS and small cell installation. The cost-effective, lighter-weight alternative to copper cabling is designed to support in-building wireless applications. It has compatibility with existing connectors, tools and hanging hardware. It is available in blue jacket (CA12-50JPLL) and white jacket (ICA12-50JPLLW) models. It utilizes Star-Dielectric Spline technology, which provides uniform support throughout the length of the cable and eliminates electrical and mechanical problems in tight bending areas. **www.rfsworld.com**

RF Antenna Alignment Tool

Aligning antenna installations at DAS and small cell sites is made easier with the **3Z Telecom** RF aligner. The device is a compact GPS-based alignment tool that facilitates precise azimuth, tilt, roll and above ground level (AGL) measurements. The device can be used for a multitude of directional antennas. It features a universal antenna-mounting system for quick antenna attachment and release. It is user-friendly and compact for easy transport up any tower. It saves all measurements so recordkeeping and reporting are available by attaching it to any host device with a USB port. **www.3ztelecom.com**

GPS-empowered Triplexer

123eWireless' multiband triplexer, the 123eGplex, is an outdoor solution for wireless applications where a GPS signal is required. This device enables the use of an existing transmission line on a tower or a DAS installation to triplex wireless signals at 698 MHz to 900 MHz, 1710 MHz to 1950 MHz and the GPS band at 1500 MHz to 1600 MHz. The triplexer is designed for GPS antenna direct mount, which improves frequency response by using fewer connections within the GPS antenna run. It features DC pass for powering the GPS antenna amplifier while blocking DC current on the 698-MHz and 2100-MHz bands. **www.123ewireless.com**

Antenna Site Concealment

ConcealFab, a supplier of oDAS and small cell concealments, integrates the newest antenna and radio technology into a variety of concealment solutions. ConcealFab integrates antennas, radios, brackets, connectors and cabling into a family of production-friendly solutions including pole-top, side arm and integrated monopole concealments that facilitate zoning approvals and shorten time to market. High-strength, lightweight mounting brackets affix to light poles and utility poles and come with optional ultra-RF-transparent thermoplastic coverings and shrouds for rapid deployment across urban and suburban landscapes. Modular RF-transparent rooftop and base station enclosures are available in both penetrating and ballasted (nonpenetrating) mounting configurations to satisfy various installation requirements. **www.concealfab.com**

Hidden Antenna Solutions

With DAS and small cell concealment solutions for virtually any antenna, **Stealth Concealment Solutions** can make antennas aesthetically pleasing and reduce the potential for theft and vandalism by making the site technology invisible. Stealth can design and build virtually any installation at colleges, football stadiums, arenas, hotels and most any enterprise requiring hidden antennas. The concealments not only cover DAS and small cell antennas, they also provide branding opportunities. **www.stealthconcealment.com**

DAS Systems Diplexer

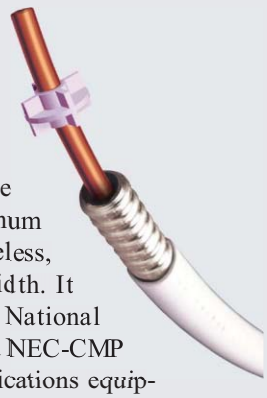
A hybrid diplexer for DAS deployments from **Microlab** features low PIM, low loss and high isolation, characteristics that are desirable for efficiently combining RF signals, particularly in active and passive DAS deployments. The new CM-20 is an integrated 4 x 2 hybrid multiband combiner with a unique design that combines two low-band signals within 698 MHz to 960 MHz with two high-band signals within 1710 MHz to 2170 MHz. **www.microlab.fxr.com**

product showcase — das and small cell products

Routers for DAS

Dali Wireless' t-Series RF router for DAS and small cell wireless is comprised of a family of network elements. It includes the tHost unit, the low-power quad-band t30 remote unit, and the high-power dual-band t43 remote unit. The system offers 164 MHz in each of the uplink and downlink paths on the same single fiber. It supports 700-MHz LTE, 850-MHz cellular, PCS and AWS. It also accommodates 1Gb/s IP backhaul. For APAC and EMEA installation, the system also supports 900 MHz, 1800 MHz, 2100 MHz and 2600 MHz. Software options include network and capacity management systems for true dynamic capacity allocation. The Dali system offers a long network reach and high data throughput to reduce the total cost of ownership. **www.daliwireless.com**

6 GHz Plenum Cable



Trilogy Communications offers air-dielectric AirCell 6-GHz plenum cable for DAS and small cell installations. The AP6012J50 is a good plenum cable for in-building wireless, offering a 6-GHz bandwidth. It meets the most stringent National Electric Code, UL-910 and NEC-CMP requirements for communications equipment. It is manufactured in the United States.
www.trilogycoax.com

Low-power Fiber-optic Remote

Axell Wireless' model MBF-20 is a low-power fiber-optic remote unit that operates as part of the company's second-generation LTE-ready fiber DAS. The unit is used to provide wireless coverage in complex and confined environments such as high-rise buildings, tunnels and metro systems. The remote unit supports technologies and bands including 700-MHz LTE (upper and lower bands), 800-MHz SMR, 850-MHz cellular, PCS (including the G-block for Sprint) and AWS. It features a compact, 18-pound form factor and can be installed quickly and easily on a wall or in a rack. Its design helps to minimize the signal-to-noise ratio, resulting in one of the lowest noise figures on the market. It also offers a plug-and-play configuration and a Web-based GUI for fast and easy deployment and management.
www.axellwireless.com

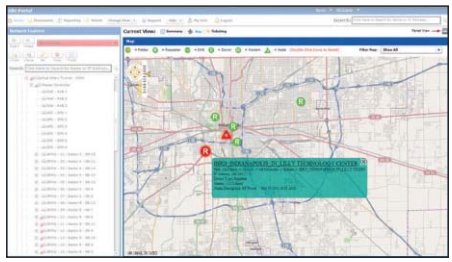
RF Power Tappers

Pasternack Enterprises offers low-loss power tappers that are used to either evenly or unevenly sample or split RF signals in in-building wireless and outdoor DAS applications and in Wi-Fi systems. 2-way, 3-way and 4-way body styles are available with type N or 7/16 DIN connectors. The devices feature a ruggedized, sealed construction using an air-dielectric structure without solder joints. They have connectors with O-rings for IP65/67 installations. They are available in a variety of split ratios from 2:1 to 1000:1 (4.8 dB to 30 dB) and operate from 376 MHz to 6 GHz. The equal split tappers cover wireless bands from 376 MHz to 2.7 GHz, making them suitable for in-building wireless. The devices admit continuous DC through the main line while passing RF power with minimal ripple and insertion loss. The low-PIM signal tappers have a maximum power rating of 700 watts and are IP65/IP67- and RoHS-compliant.
www.pasternack.com

RF Spectrum Analyzer

The AirMagnet Spectrum ES spectrum analyzer manufactured by **Fluke Networks** and distributed by Alliance is a portable, affordable, professional-grade RF spectrum analyzer that speeds DAS and cellular deployments. Rich spectrum graphs with next-generation visualization and enhanced in-field productivity features provide the intuitive network visibility needed to validate and troubleshoot at every project stage. The unit scans frequencies between 698 MHz and 2690 MHz and supports 2G/3G/4G platforms. The unit features automated classification and location of RF interference sources, automated location-specific carrier and technology spectrum scan setup to verify and troubleshoot at every stage of the project lifecycle. These features help ensure offload deployment and troubleshooting are done quickly and accurately.
www.flukenetworks.com
and
www.alliancecomm.com

Remote Site Management Software



SitePortal from **C Squared Systems** is a customizable Web-based site hardware monitoring software for small cells and other telecom sites. SitePortal allows users to access a common remote monitoring and management tool to view site metrics. The software can monitor a wide variety of devices associated with wireless communication towers, remote shelters, equipment bays or any remote installation. Such installations include telecommunications equipment, wireless access points, security and access devices, environmental sensors, generators, building automation mechanisms and other systems. Available collected data includes aggregated notifications, managed faults and alerts, defined system parameters, run reports and troubleshooting device results. The software allows the addition of notes and consolidates documentation. It can be used to set permission access and share knowledge. It easily integrates with active equipment using SNMP, contact closures, ping, ASCII Data, SYSLOG reports or other custom queries. For equipment without on-board remote access capabilities, data capture devices and wireless routers can be added to gather pertinent information.

www.csquaredsystems.com

product showcase — lighting and monitoring

Medium-intensity Red Beacon

For tower and building lighting, **ITL** offers the IFH-1700 medium-intensity red beacon. The device uses LED technology and advanced optics to achieve a compact, energy-efficient, L-864(L) product. The beacon is self-contained and comes ready for installation with a 10-foot cable attached. The IFH-1700 features an aluminum top and base and a clear acrylic cover. The beacon is designed for long-term maintainability with field-replaceable LED boards, and power supply board and a light engine.

www.itl-llc.com

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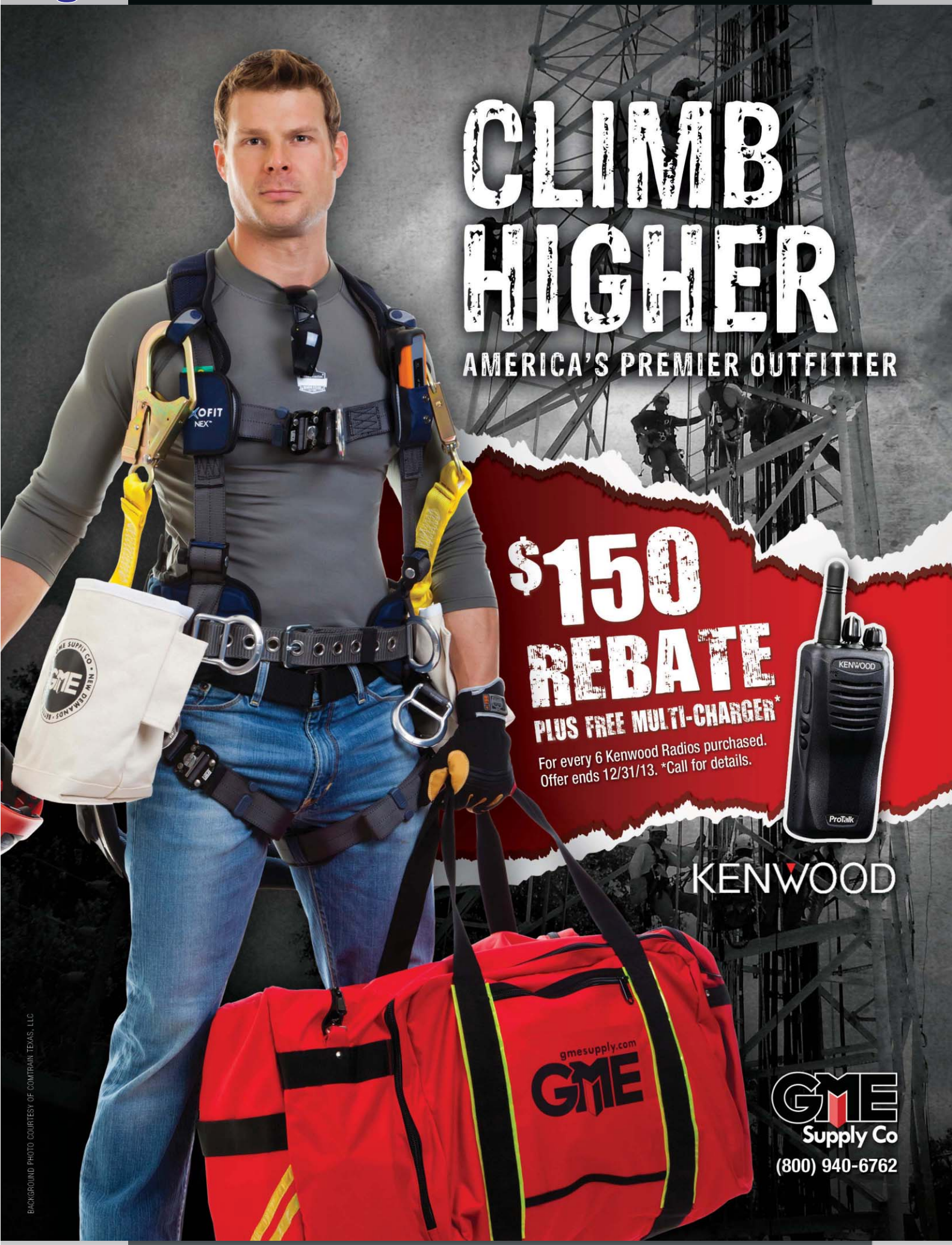
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