VIAVI

DAS Deployment Overview

Streamlined approaches for DAS deployments

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Introduction

Global mobile data traffic is set to reach 52 million terabytes in 2015, an increase of 59% from 2014, according to Gartner, Inc. The rapid growth is set to continue through 2018 and beyond, as shown in Figure 1.
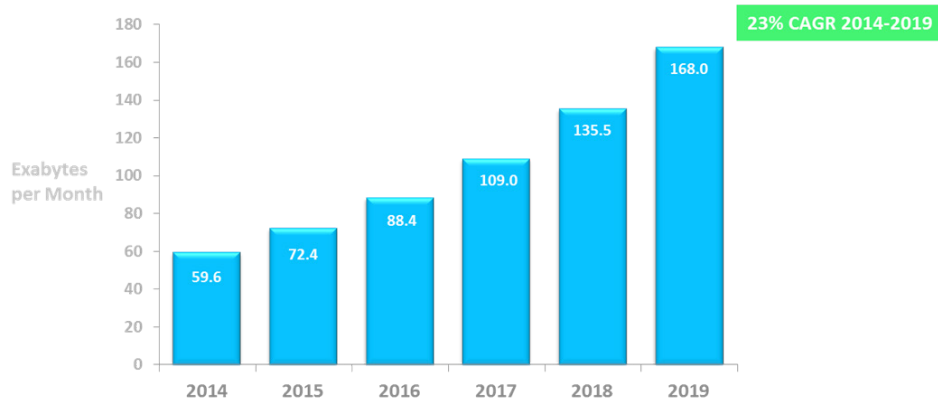

Figure 1. Cisco® VNI global IP traffic forecast, 2014 – 2019 (Exabyte=10^{18} bytes)

The introduction of new cellular technologies has significantly improved spectral efficiency; however, data demand has outpaced the spectral efficiency benefit. Cellular spectrum holdings cannot keep up with mobile data growth. For operators to meet data demand and retain profitability despite a falling cost per bit and increasing data levels, they must identify and seamlessly implement better, faster, and cheaper methods to improve network capacity and user quality of experience (QoE). Today, mobile subscribers have little tolerance for dropped calls and slow access to data and applications. They want access to the network from anywhere at any time without any disruption. Additionally, greater than 70% of data usage is from in-building environments. Macro networks cannot keep up with this growth, and operators need to look at other methods for delivering RF coverage and capacity, especially for in-building environments. A typical solution may require a combination of macro cell, small cell, and DAS. The success of this strategy depends on how well these different types of cell sites—such as macro, femto, metro, enterprise femto, DAS—work in concert with each other. This harmonious working of heterogeneous cell sites is called HetNet.

What defines a cell site as femto, pico, macro, and so on depends on a number of attributes such as power, coverage, utility, and market need. Table 1 shows a few criteria that have been commonly used over the years.

Table 1. Cell-type attributes

Cell Type	Subscribers	Coverage	Power Tx	Application
WiFi	<200	<100 ft	20 – 1000 mW	Home, single office/home office (SOHO), medium to large businesses, malls, hotels
DAS	<1800	>10,000 ft	<10 W	Venues, casinos, convention centers, etc.
Femtocell	4 – 6	<50 ft	10 – 100 mW	Home, SOHO
Picocell (E-femto)	32	10s of ft	100 – 250 mW	Medium businesses, offices
Metrocell	16 – 32	10 – 100s of ft	500 mW – 2 W	Large offices
Microcell/oDAS	32 – 200	100s of ft	5 – 10 W	City center, urban, large venues
Macrocell	<1800	miles	>10 W	Cellular coverage

Small Cell

Macrocell

Wi-Fi

Internet

Switching
Center

C-RAN

OAM

DAS/C-RAN

Internet Access
Front-haul
Backhaul
Wireless Backhaul
Device to Device link

100's MHz
Most 4G RAT with 5G compatibility

GHz

10's GHz

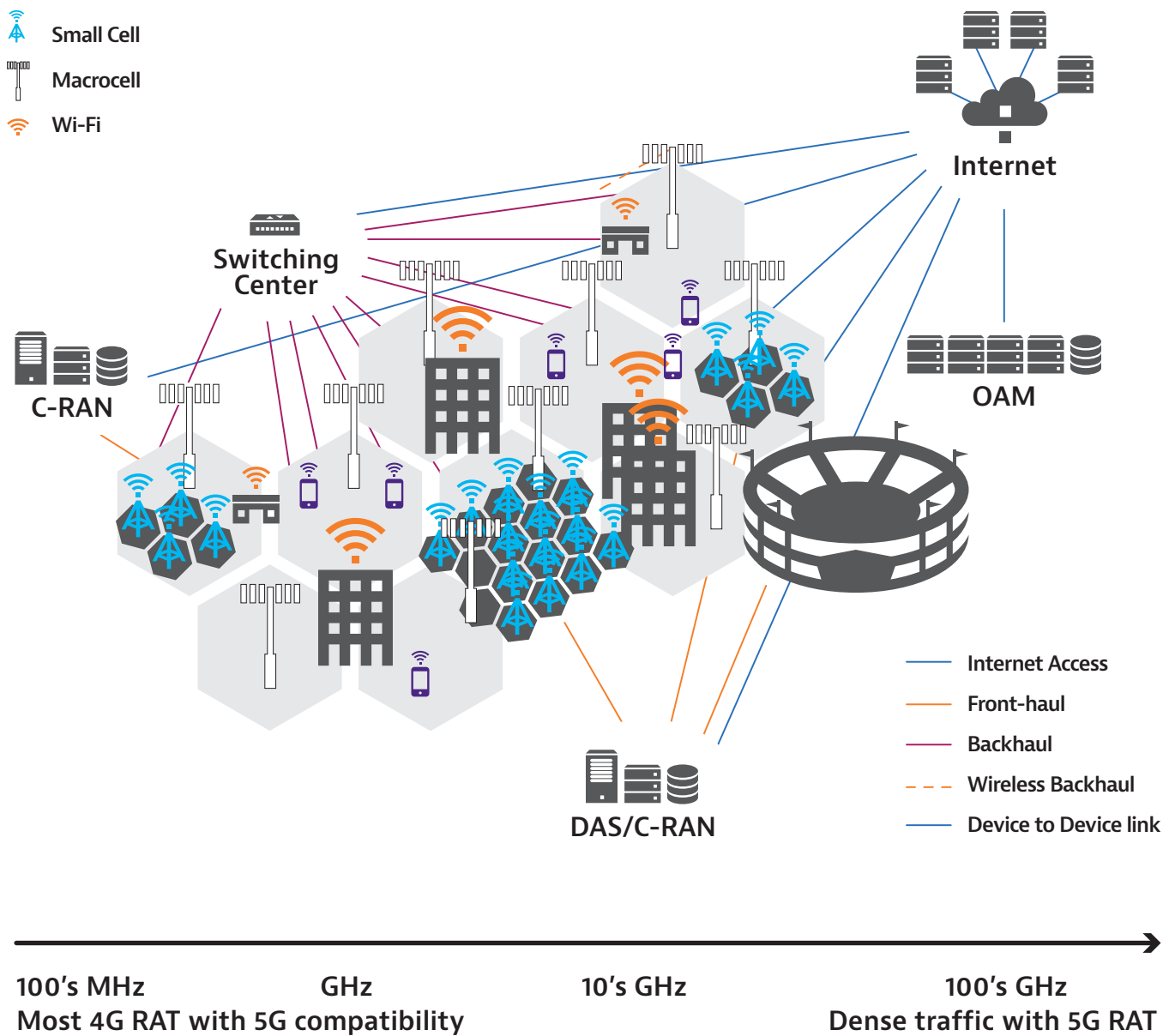100's GHz
Dense traffic with 5G RAT

Figure 2. Heterogeneous 4.5G+ network architecture

Figure 2 shows how a future heterogeneous network works as a network of networks. Operators continue to leverage their existing 4G investments in macrocells, DAS, and small cells along with newer technologies. Small-cell deployments will continue to increase at a much faster pace, and, importantly, their infrastructure will later work for 5G technologies. DAS deployments, being the most network agnostic, will increase as well but not as quickly. The business case, venue requirements, and solution flexibility are important factors for DAS deployments.

Distributed Antenna Systems (DAS)

In this paper we will discuss one of the key components of HetNets namely active DAS and the challenges, opportunities, and the streamlined deployment process for DAS.

Large service providers as well as venue owners (for example, stadiums, casinos, and malls) have been using DAS for the past two decades to improve network coverage in venues where the traditional macrocell approach does not work. As mobile networks migrate from 2G to 3G and 3G to LTE, DAS architectures have evolved from passive to active, in which repeaters are replaced with low-power remote radio heads connected through fiber optic cable to the DAS hub, resembling today's C-RAN macro architectures, as illustrated in Figure 3.

Although no two active DAS installations are the same, a typical deployment is driven either by a direct connection to a radio base station, donor macro cell, or baseband unit. Often, multiple RF feeds are combined and then passed to a master distribution unit. The master distribution unit then feeds remote units via a variety of media—fiber, 75 ohm coax, or twisted pair. The remote units in turn feed the antenna systems via 50 ohm coax. Multiple antennas can be fed from a single remote unit via splitters, as shown in Figure 4.
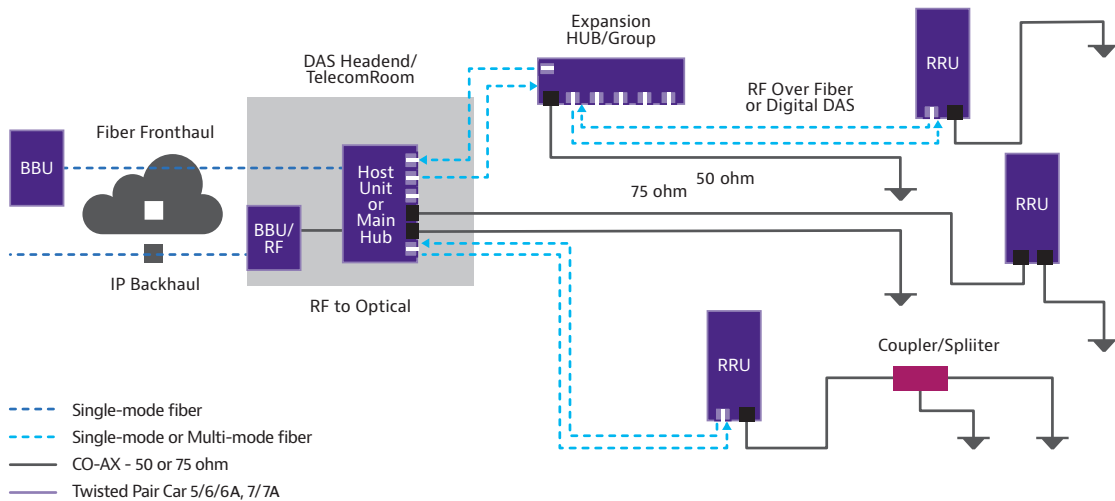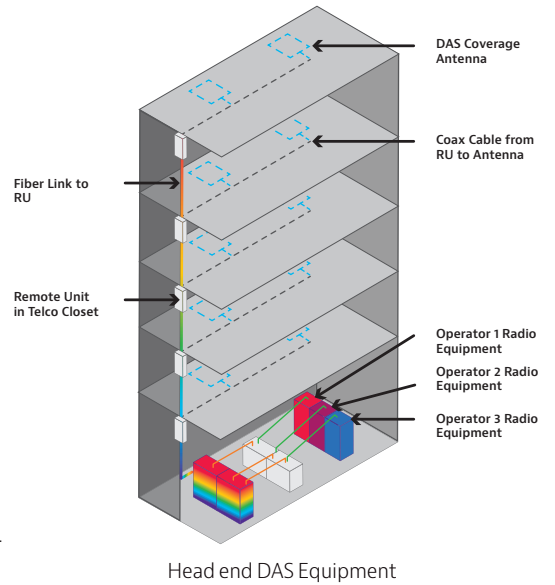
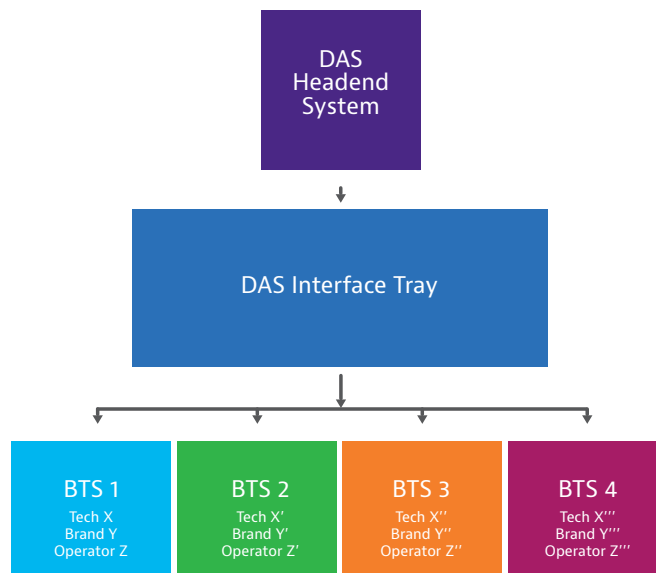Head end DAS Equipment

Figure 3. Typical DAS architecture

Figure 4. Reference diagram for DAS RF junction (also known as the main hub)

One of the key reasons active DAS has been so successful is its ability to offer a technology agnostic solution for multiple operators at the same time. Combining multiple operators with different technology significantly improves the DAS business case and makes it attractive for neutral hosts and venue owners. One of the key requirements for any in-building solution is to minimize the aesthetic impact to the venue. Today venue owners are very interested in making sure their patrons don't have a poor wireless experience, but at the same time they don't want to deploy too much hardware in their buildings, impacting their aesthetic appeal. The best way to strike that balance is to offer a solution that is neutral to multiple operators offering better QoE without being unsightly for the patrons. DAS seems to be an ideal solution for this purpose, because it not only solves some of the problems mentioned but it may also help with the business case as the cost to deploy DAS can be divided between multiple operators.

Key DAS Components

Headend Radio Equipment

Wireless carrier-provided headend radio equipment, like that shown in Figure 5, provides the RF signal source (input) to the DAS.

Figure 5. DAS radio headend

Common Junction Point with Attenuator Trays

The DAS common junction point combines multiple BTS types with a multiple radio access technology (RAT) onto a single DAS system. Attenuation trays like the ones shown in Figure 6 provide attenuation to an RF signal before the signal is fed to the DAS headend system, which also levels and equalizes performance for all base stations.
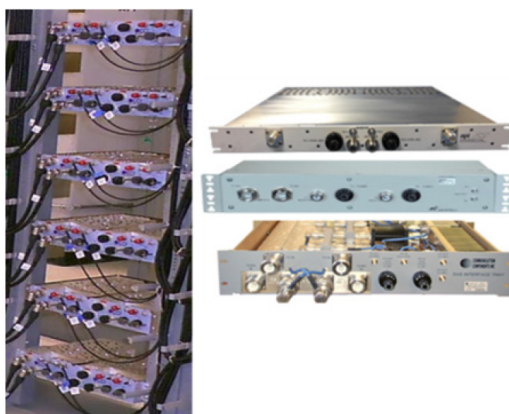
Figure 6. Example of attenuation trays at the headend

Fiber Headend Equipment

At the head end of the DAS, the main hub digitizes the RF signal coming from the different service providers and then distributes it to other hubs and radio heads via a high-bandwidth fiber optic network, see Figure 7. Digitizing the signal on the fiber allows the signal to be transported over much longer distances with minimal losses as opposed to passive DAS.

Figure 7. Example of fiber equipment at the headend

Remote Access Units

Remote access units (RAU) convert a fiber signal back to RF and feed it to the antenna, see Figure 8.

Figure 8. Example of a remote access unit

Splitters/Combiners

Splitters or combiners do just that, they split or combine the RF signals between two or more cable paths, see Figure 9

Figure 9. Splitter and combiners

Coverage Antennas

Coverage antennas transmit and receive (Tx/Rx) multiple RF bands simultaneously between the coaxial cable and the mobile, see Figure 10.

Figure 10. DAS coverage antennas

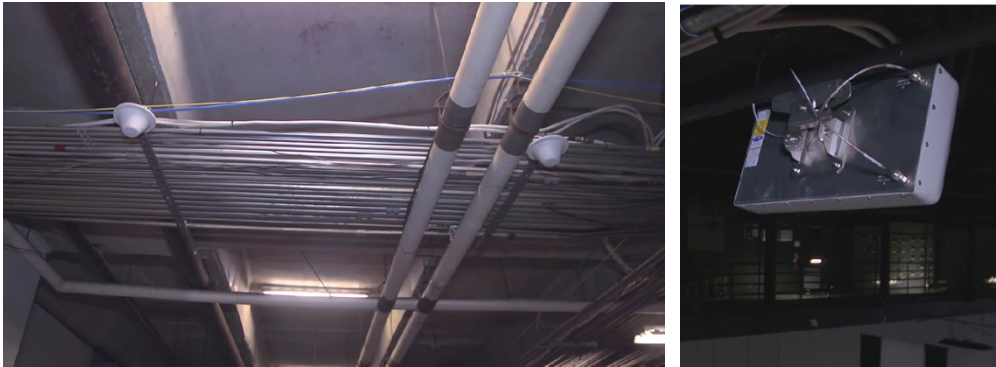# DAS Ecosystem and Its Challenges

DAS architectures can vary significantly and use a wide variety of physical media for connectivity, creating a complex environment which, if not tested, validated, managed, and optimized, can detrimentally affect an end user's mobile experience and can significantly reduce the service provider's ROI. Unlike traditional cellular networks, DAS has a complex ecosystem, as Figure 11 illustrates. Multiple parties may be involved in the DAS deployment further increasing it complexity and cost.

Consultant/Firms

· Educates the end-user & contractors

· Develops and publishes the bid spec

· Evaluates bid responses

Buidling Owner

Electrical Contractors

DAS Integrator

· Interfaces with all ecosystem players to ensure successful deployment of the DAS

· Designs, implements, & supports the DAS

· Coordinates carrier funding and integration

COMMSCOPE   axell   TE
CORNING MobileAccess Wireless Solutions
Comba   SOLiD TECHNOLOGIES

Cable Contractors

· Installs DAS cable infrastructure

· Leverages their contractors/end-user relationships

WBE
Corporate Technology Solutions

The Customer

DAS Equipment Vendors

· Maufactures the DAS compontents

· Supports the integrators with product training

· Deliver DAS certification trainings

Wireless Carriers

· Set the design standards

· Provides the RF source

· Participates in funding

at&t   verizon
VimpelCom   Claro
中国电信 CHINA TELECOM   oi

Distribution

· Supplies inventory locally

· Facilitates local training & education

· Works with partners to generate opportunities

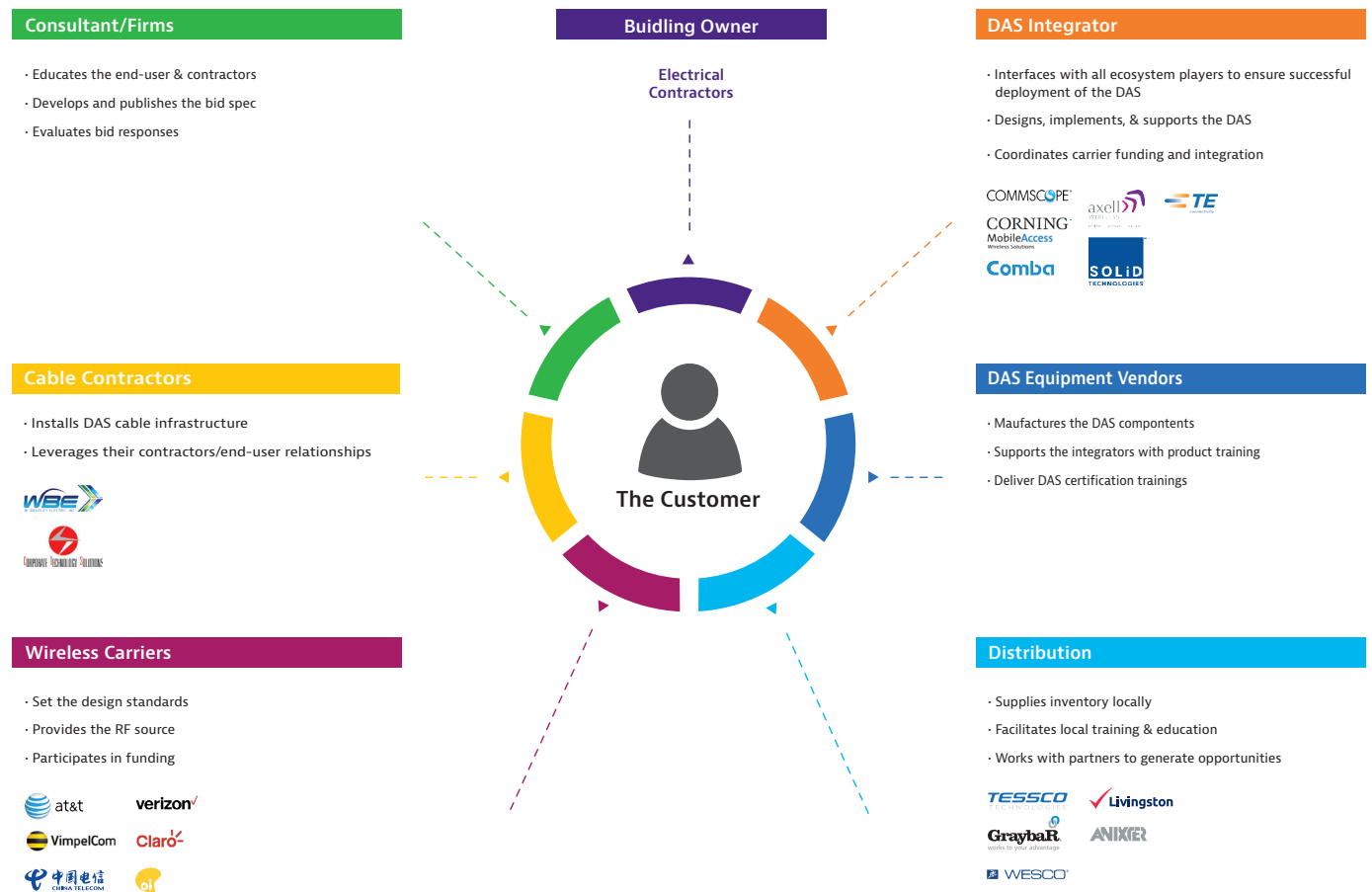TESSCO   Livingston
GraybaR   ANIXTER
WESCO

Figure 11. DAS ecosystem

The industry uses different models to deploy DAS: venue-owned, carrier-owned, shared cost, and neutral host. The model used truly depends on ROI, ease of deployment, venue location, and accessibility. As discussed earlier, one of the key reasons for venue owners to choose DAS over other solutions is its ability to offer multiple operators' services using the fewest visible antennas, because it can serve several service providers from one antenna, a key benefit that truly helps the DAS use case.
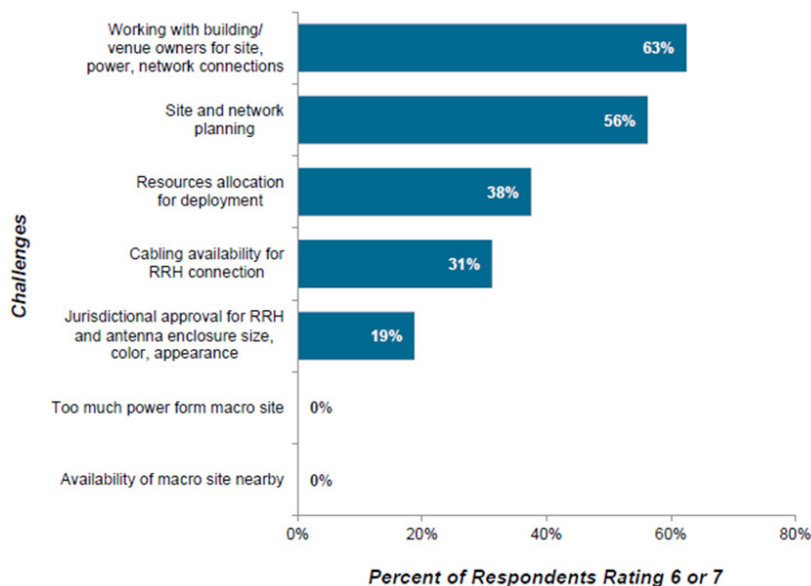

Figure 12. DAS deployment challenges (source: Infonetics)

Figure 12 shows how service providers from the world's top 20 DAS users rated DAS deployment challenges on a scale of 1 to 7, where 1 is not an issue, 4 is somewhat of an issue, and 7 is a strong challenge. The results show the percentage of respondents rating each aspect a challenge.

The data shows that respondents consider working with building/venue owners for site, power, and network connections and site and network planning to be major DAS deployment challenges. These are similar to the challenges of deploying small cells in buildings. Typically, service providers don't own the venue but need to address coverage issues by assessing the best system in their HetNet toolbox (for example, DAS, small cells, carrier WiFi) to do the job.

In a similar study related to DAS deployment barriers, Figure 13 clearly shows that the cost of DAS is the biggest barrier. Seventy five percent of respondents (up from 69% last year) rated deployment costs as a barrier, with fiber cabling requirements a distant second (31%).
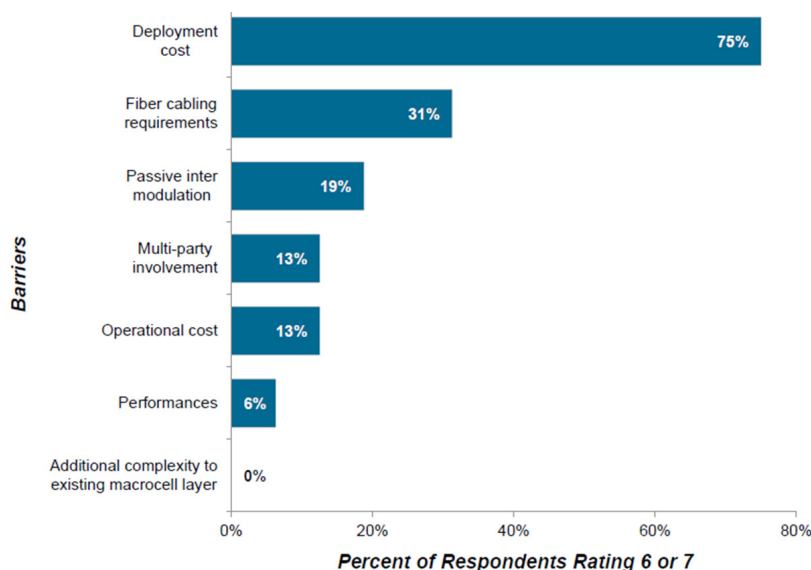

Figure 13. DAS deployment barriers

To deploy modern DAS system installers should be familiar with installation and testing of both fiber and coax mediums. Besides the headend, remote access units (RAUs) like WiFi access points will also require power, another consideration in DAS deployments. From a deployment stand point, every fiber installation program should include cleaning and inspecting the connectors, checking continuity with a visual fault locator (VFL), testing cables for insertion loss with a light source and power meter to determine if all fibers are okay. Recording this data will help in the final test after the cable has been installed by comparing losses before and after installation to see if any damage occurred during installation.

Dirt is the number one enemy of fiber optic connectors because it can cause loss and reflectance and even damage to connectors. Inspect every connector before you make a connection with it. Check the connector and the receptacle it will be plugged into as either or both may be dirty. Remember to always keep protective caps on all the connectors except when cleaning, inspecting, or testing. After installation, retest the cable again to ensure no damage occurred during installation. Insertion loss testing and perhaps OTDR testing will be required.

For the coax testing, take similar steps to ensure connector losses and splitter losses are all within link budget specifications.

DAS Deployment Tools

Streamlining the DAS deployment process can significantly help service providers and partners in the ecosystem significantly reduce costs. Today a lot of manual steps are required in the deployment process that add to the complexity of DAS deployment, increasing the chances of human error thereby delaying the time to launch. In this paper we will analyze those challenges and identify some of the key solutions that can be leveraged to improve the overall DAS deployment process.

The next sections identify some of the essential tools required by the installers, technicians, and engineers performing DAS deployment.

RF Cables, Connectors, and Adapters

Different DAS vendors may use different types of RF connectors and adapters, as shown in Figure 14. Having a good understanding of all the connectors used in this space and building complete kits with all the right types is essential to preventing time lost at the site. Here are some of the key components:

- SMA-type adapters and cables

- QMA-type adapters and cables

- N-type adapters and cables

- DIN-type adapters and cables

SMA Male   DIN to N Adapter set   QMA to SMA

DINN Male to SMA Male Cable   N Male to SMA Male Cable   N Male to SMA Female

Figure 14. RF connectors, cables, and adapters used during DAS deployment

Torque Wrenches

Tightening connectors to the proper torque value is essential; technicians should never use just their hands to tighten connectors. Proper torque on the connector is both required and will help minimize passive intermodulation (PIM) issues and losses. Low torque will allow gaps and PIM from the center connector. High torque will damage the center connector, again, causing PIM.

Ensuring that the right type of torque wrench, see Figure 15, is used for the right type of connectors is a must during DAS installation.

7-16 DIN   SMA Type   N Type

Figure 15. Torque wrenches

Power Splitter

Figure 16. Wideband 4:1 splitter used during commissioning

Antennas

Figure 17. Wideband antennas

Wideband antennas like those shown in Figure 17 are used with continuous wave (CW) transmitters and with receivers during commissioning as well as to collect RF data. Care must be taken to ensure antennas support the frequency bands under test.

Fiber Cable and Connector Cleaning Kit

Contamination like dust, dirt, and fiber-coating debris as well as the silica find their way to connector surfaces and will offset the fibers and degrade performance making a fiber connector cleaning kit like the one shown in Figure 18 essential.

Figure 18. Example of a fiber connector cleaning kit

Spectrum Analyzer

The spectrum analyzer like the one shown in Figure 19 will be used heavily during DAS installation and commissioning and must have the necessary sensitivity and dynamic range to measure the noise floor accurately. Its –125 dBm or better receive sensitivity should be used. Use the spectrum analyzer to ensure return loss (RL) and execute distance-to-fault (DTF) tests for each segment of coaxial cable ensuring that the measurements are within specification. The test ensures that no faults are present in the coax and that all connectors are properly terminated. This test must be performed on each individual coax cable at the:

• Remote unit (remote out to the coverage antennas).

• Head end side (radio equipment end point to attenuation trays) and (attenuation trays to DAS equipment RF headend).

A spectrum analyzer kit must contain a calibration kit, precision 50 ohm load, and adapter set for different connector types, as identified earlier.

Figure 19. Example of a spectrum analyzer

CW Signal Generator

Low-power transmitters, like those shown in Figure 20, that can transmit over current 700, 850, 1900, and 2100 MHz, etc., commercial bands and signal generators that can support more than two bands will reduce the equipment needed at the site, especially for DASs that support more than two bands. A signal generator is an essential tool used during the design and commissioning phases of the DAS deployment process.

Figure 20. Example of CW transmitters

RF Scanner/Receivers

Figure 21. RF scanners

A wideband scanner, like those shown in Figure 21, that can support LTE FDD/TDD, UMTS, GSM, 1xEV-DO, cdma2000, spectrum analysis, and CW technologies with ability to scan multiple bands simultaneously is another necessary tool.

Fiber Cable Test Tools

As indicated earlier, fiber cable test tools like those shown in Figure 22 are essential to validate that all fiber interfaces are meeting the required link-budget targets. A large variety of tools are available that can perform fiber inspection, optical time-domain reflectometer (OTDR) tests, insertion loss tests, and more.

Figure 22. Fiber test tools

In-Building Walk Test Kit

An in-building RF data collection solution is required during multiple DAS deployment phases. Small form factors and the minimum number of cables connected to the scanner and devices should be strongly considered when determining a Walk test tool to minimize failures and to reduce fatigue caused by extended in-building walks. An in-building kit should include these items:

- Tablet or a laptop

- Scanner (small form factor)

- Multiple phones

- Scanner batteries

- Scanner antenna

- Scanner battery charger

- Phone chargers

- SIM cards per technology

- Backpack

What Should be Tested?

Fiber Test
- Fiber inspection
- OTDR
- Optical power

RF Coax Test
- Sweep test
  - Cable and connectors
- PIM

System Test
- Baseline noise measurements
- Parameter normalization
- CW testing
- Noise sensitivity

RF Air Link Test
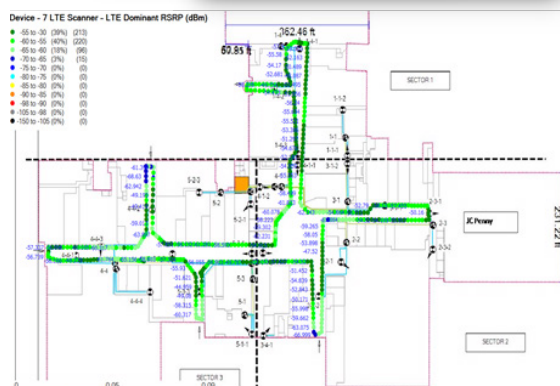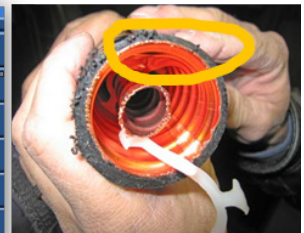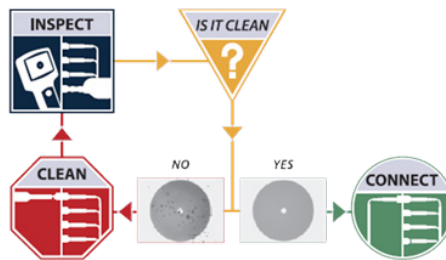- RF signal and interference
- Antenna validation report
- RF throughput

Figure 23. DAS testing requirements

DAS Deployment Phases (approximation)

Deployment Step	Resource	Tools
Design & RF Survey	RF Engineer	IBWave CellAdvisor/Scanner CW Transmitter
Installation	PM Construction Crew Technicians	Design Docs CellAdvisor FTTA
COMMISIONING — Validation od DAS Completion	PM Construction Crew RF Engineers	Sweep Test Report OTDR Report PIM Results
Baseline Measurement	Construction Crew RF Engineers	CW Transmitter CellAdvisor
DAS Parameter Normalization CW Testing	RF Engineers	CW Transmitter CellAdvisor
Maximize Sensitivity	RF Engineers	CW Transmitter CellAdvisor
RAN Integration Pre Optimization Testing	RF Engineers Cell Technicians	Walk Test RF Solution
On Air Optimization Acceptance	PM RF Engineers	Walk Test RF Solution

Figure 24. DAS deployment steps

Benchmarking and Survey

An RF scanner (iBFlex or DRT) can be used to establish a good baseline for RF coverage at the venue, which can be very useful in determining the effectiveness of the DAS deployment later and controlling RF from macro cellsites at the DAS venue.

As part of the RF survey, at a minimum the following information should be captured:

- In-building transmitter tests (if possible) — To analyze complex RF environment path losses using CW transmitters and a Viavi spectrum analyzer and use Rx data to optimize prediction models used in the design tool.

- Installation considerations and pictures — To document key equipment locations, installation concerns, and notes directly on the building floor plans for easy reference and design translation.

- Code and safety documentation — To maintain customer, industry, and government safety regulations.

- Building environment (dense, open floor, etc.) and floor plans should be updated.

- Roof mount area and access.

- Head-end equipment room details.

- Power and wall space.

Design

Design is a crucial phase in the DAS deployment because it determines where the antennas should be installed and the power levels that will be set for the DAS. A proper design requires collecting RF survey data for use in tuning the prediction models. Using an in-building RF design tool, such as iBWave or RAN plan, can help to complete a proper DAS design. Engineers may need to walk the venue several times to avoid physical obstructions or challenges to properly installing the antenna. Failing to perform this exercise can limit RF coverage and may cause PIM issues.

After the design is complete, a design package, in the form of an Excel spreadsheet, is delivered indicating the location of each antenna, the length of all cables, the loss limits for each length, and the proper attenuation associated with each antenna link. The spreadsheet can be very complicated; therefore, errors that can occur during manual updates are a major cause for concern. Large venues can have hundreds of antennas connected through hundreds of fiber and coax cables.

Key design outputs:

1. Design drawings, like the one shown in Figure 25, are highly detailed and accurately depict equipment placement, including riser diagrams and floor-by-floor layouts.

Figure 25. DAS design
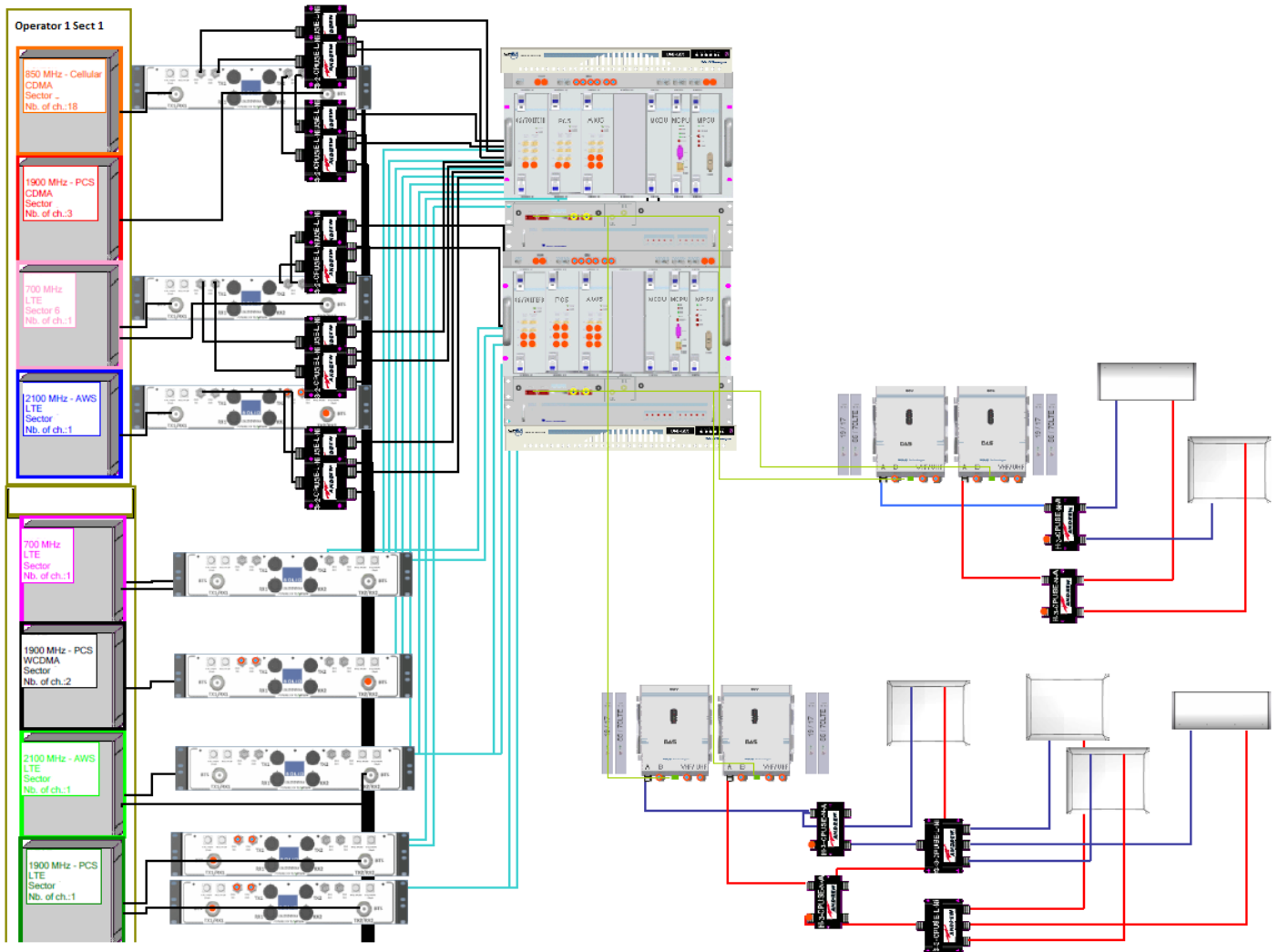
2. RF "heat" maps, like the one shown in Figure 26, are a color-coded representation of predicted RF levels received.
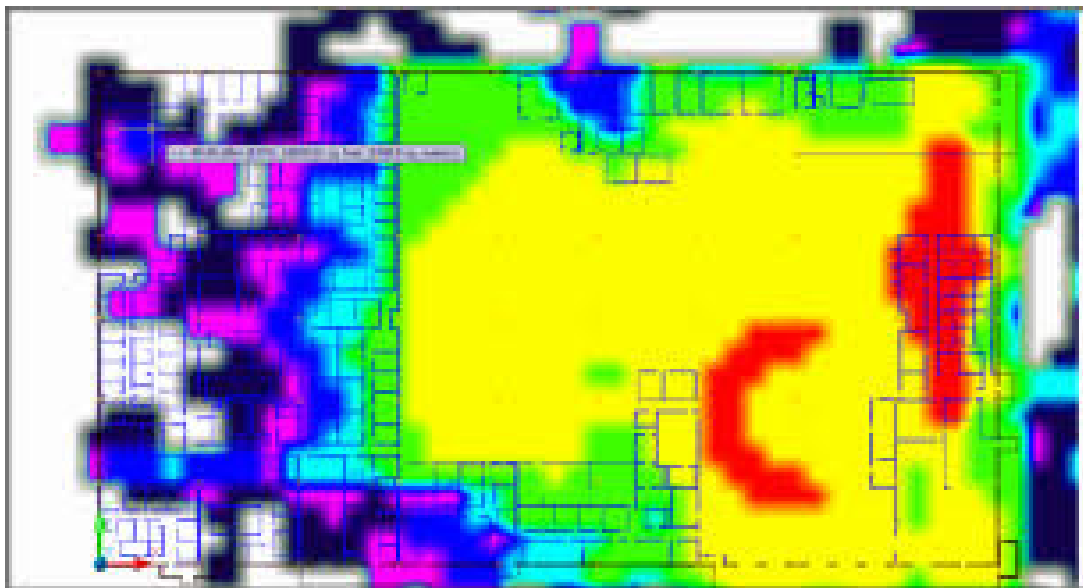

Figure 26. Design heat map

3. Bill of Materials (BOM) development — Determining accurate material quantities

4. Design package — Scope of Work, Bill of Materials, Link Budgets, and Design Drawings, shown in Figure 28

Figure 27. Example of a DAS design document

Construction Phase

After the project information is generated by the various teams involved in the design, the generation of a BOM, and the resources, a complete project worksheet with the necessary requirements is sent to the project manager at the site, who works with the construction and deployment team to execute the DAS deployment.

These are the documents delivered:

• DAS RF design sheets (RFDS)

• IBwave design or DAS design from the design tool

• DAS detailed drawings

• DAS link budget spreadsheets

• Detailed project plans

Construction is the most challenging and resource-intensive phase because it requires installing the DAS headend equipment, along with hundreds of fiber and coax cables, and connecting it to the remote radio unit (RRU) and antennas. It is essential to certify every cable and to check all connections. Depending on operator requirements, these tests must be executed during this process:

1. Fiber Test measurements

Example:

Fiber Strand Label			Loss 1310 nm		Loss 1550 nm		
Receiving Remote ID	Fiber Pair	UL-DL	Forward (dB)	Reverse (dB)	Forward (dB)	Reverse (dB)	Link Length (km)
1-1	1	1	0.450	0.450	0.358	0.450	0.3942
1-1	1	2	1.020	1.020	0.864	1.020	0.3974

2. Coax Sweep/Cable Distance-to-Fault test

Example:

Test Point	Description	Frequency Band	Remote Amplifier ID	Distance to Fault Pass/Fail Threshold (dB)	Measured Distance to Fault - Marker to Peak (dB)	Pass/Fail
RAU to antenna port	System — cable w/ passive components	698 – 960 MHz (low band)	1-1A	15.5	18	Pass
RAU to antenna port	System — cable w/ passive components	1710 – 2200 MHz (high band)	1-1A	15.5	20	Pass
RAU to antenna port	1 System — cable w/ passive components	698 – 960 MHz (low band)	1-1B	15.5	18	Pass
RAU to antenna port	System — cable w/ passive components	1710 – 2200 MHz (high band)	1-1B	15.5	20	Pass

3. PIM test

4. DAS system health reports

Checking all the plumbing eliminates expensive, time-consuming troubleshooting when problems arise in later stages. It also helps to ensure on-time system turn-up so providers can start generating revenue, and it shortens troubleshooting times later by providing a good baseline. Significant resources and coordination are required to implement this phase, so the lack of highly trained personnel and robust tools can result in longer deployment times and budget overages.
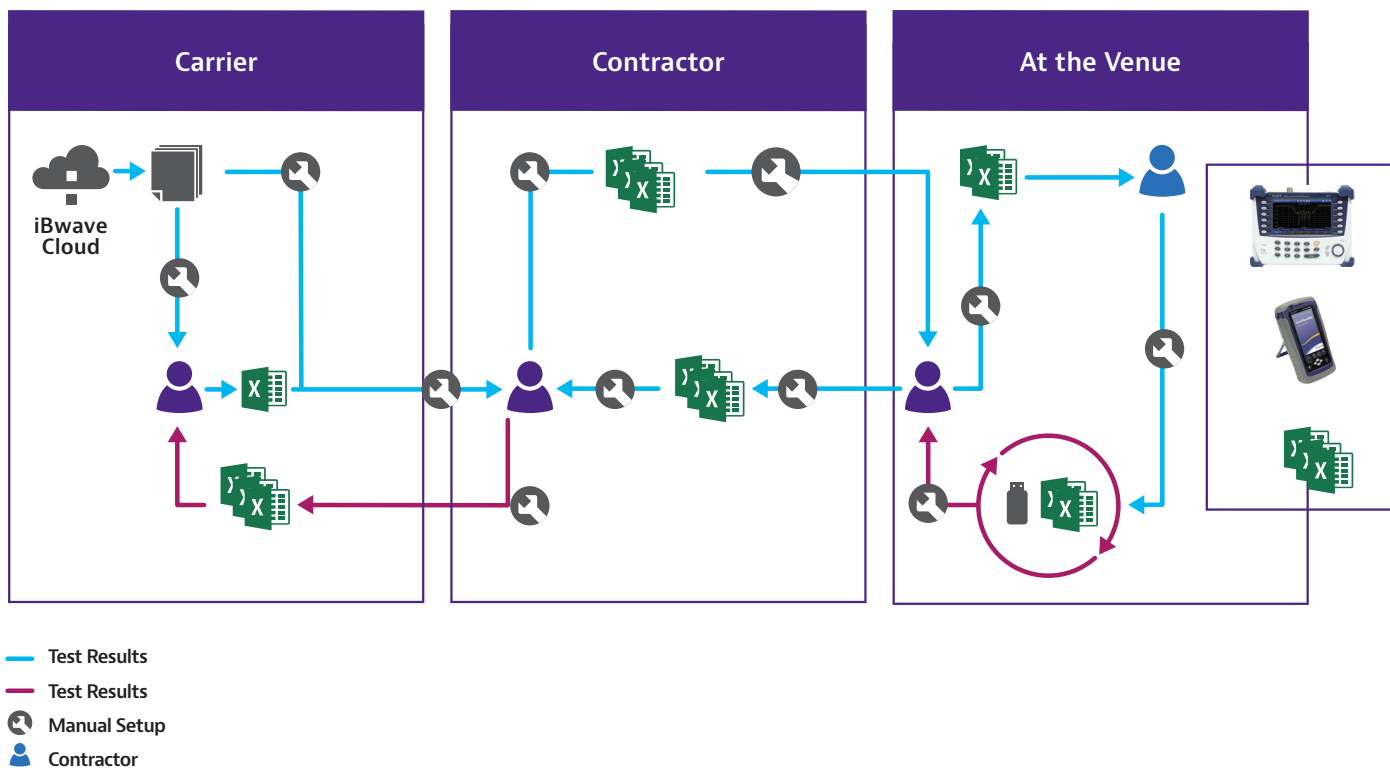
Figure 28. Typical DAS Installation and commission process

As Figure 28 shows and as summarized below, the current deployment process can present several challenges.

- Manually creating the Project Design/Test Plan documents

- Manually communicating changes and updates to the design documents

- Manually collecting test results and associating them with installation tasks

- Manually evaluating results (pass/fail)

- Manually updating test plans and progress reports (Excel sheets)

- Lack of real-time insight into project activities or ability to share status information with all parties

- Excessive manual updates cause inaccurate and opportunities for test result errors and omissions

- Delays in deploying tasks to contractors and in test execution

- Lost or misplaced results submissions from contractors (for example, USB file transfer, e-mail, FTP, dropbox, and others).

- Manually completing an audit — Are all tasks completed, results present, and tests passed?

Service providers and contractors can streamline the DAS construction and commissioning process by centralizing the whole DAS construction process workflow using a cloud-based solution that connects instruments, contractors, project managers, RF engineers, and the deployment teams, enabling them to manage and track all installation/commissioning tasks in real time. A streamlined DAS workflow process like the one shown in Figure 29 ensures technicians carry out the right tests using correctly configured test instruments based on the design document specifications. Also, the accurate results collection mechanism enables any contractor to perform any task seamlessly.
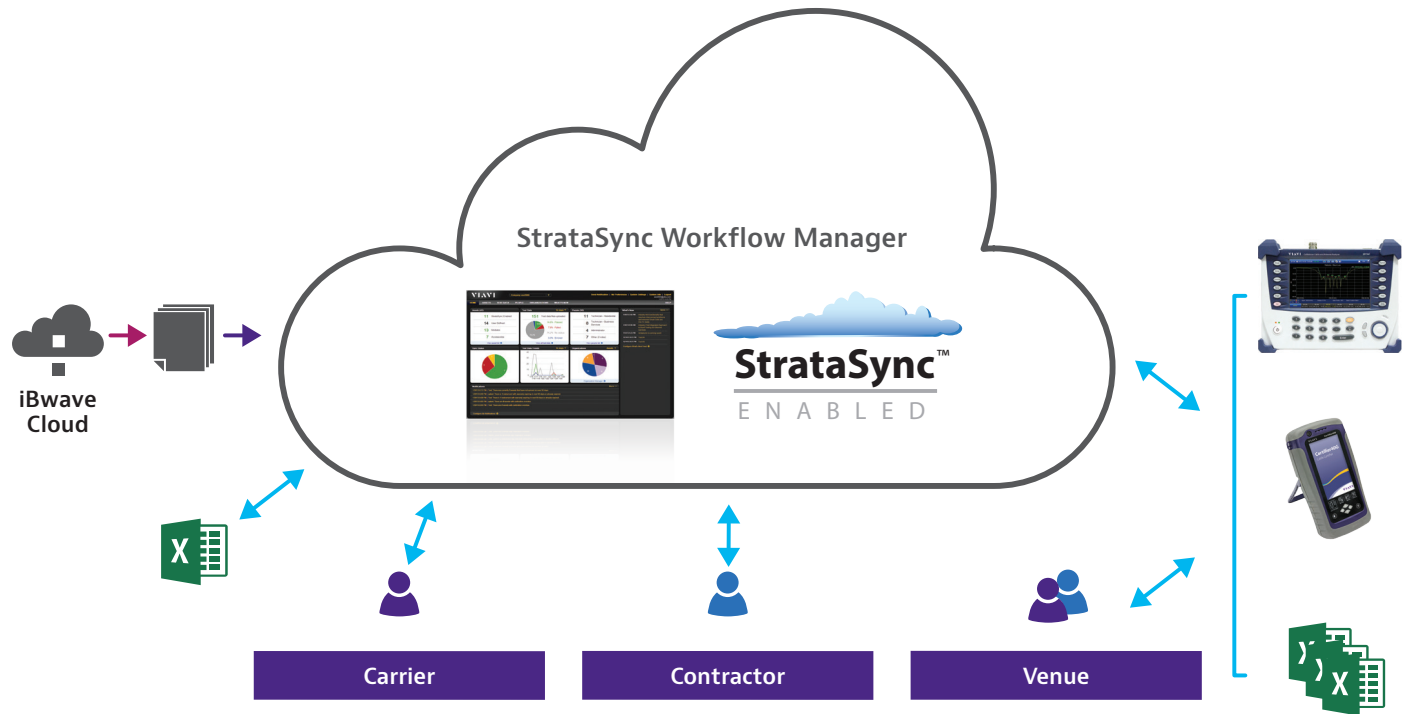
Figure 29. Streamlined deployment approach

Commissioning and Verification Phase

The typical commissioning phase requires these tests:

- Completely test and validate DAS construction

- Measure baseline system noise

- Perform DAS parameter normalization and CW testing (DL and ULCW measurements)

- Minimize noise (maximize sensitivity)

- Commission RF levels

Validate DAS Readiness for System Verification Testing

After completing the DAS installation, the project manager at the venue will deliver the test results to the PM and RF engineers before the RF engineers begin working on the baseline. The performance engineer validates that the DAS infrastructure installation is complete by:

- Confirming that the DAS is fully connected from the demark to the antenna

- Receiving passing coax cable sweep reports

- Receiving passing fiber test result reports

- Receiving PIM measurement reports

- Receiving an alarm-free DAS System Health report

Measuring the System Noise Floor Baseline

With DAS fully powered on, measure the baseline noise for each path between the RAN equipment and DAS equipment for each system sector and band, taking into consideration the simulcast radios, see Figure 30.
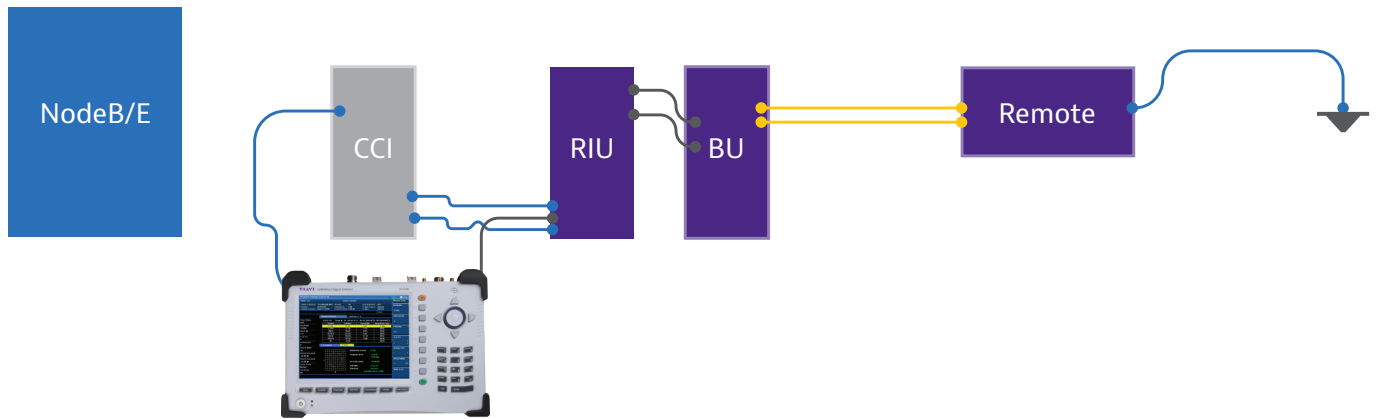
Figure 30. Baseline system noise floor measurements

- Uplink attenuation for both the DAS interface equipment and remote equipment should be set to minimum or the system default to establish a true baseline noise floor measurement.

- Using CellAdvisor measure the in-band CLEAR channel, which shows the true system baseline without any on-channel user bias.

- Taking a baseline noise floor measurement using a spectrum analyzer with the DAS fully powered up is required at the equipment demark for each sector and band. The channel selected should fall within the frequency range for the tested band.

- Record all measurements in the workbook provided by the design engineer.

Note: Based on average measurements, record the levels, take a snapshot of the noise floor, and save them in a file with the proper naming convention for the sector, technology, and band serving that sector.

Example:

Frequency Band (MHz)	Technology Reference	DAS Sector ID	Frequency	Number of Remotes Per Sector	Measured Noise Floor (dBm)	Pass/Fail
700	LTE 5 MHz	1	698 – 716 MHz	4	−107.47	
700	LTE 5 MHz	2	698 – 716 MHz	4	−104.19	
700	LTE 5 MHz	3	698 – 716 MHz	4	−107.1	
Cell 850	UMTS 3.84 MHz	1	824 – 849 MHz	12	−105.9	
PCS 1900	CDMA 1.25 MHz	1	1850 – 1915 MHz	12	−102.81	
AWS 1700	LTE 10 MHz	1	1710 – 1755 MHz	12	−104	

Figure 31. Spectrum analysis
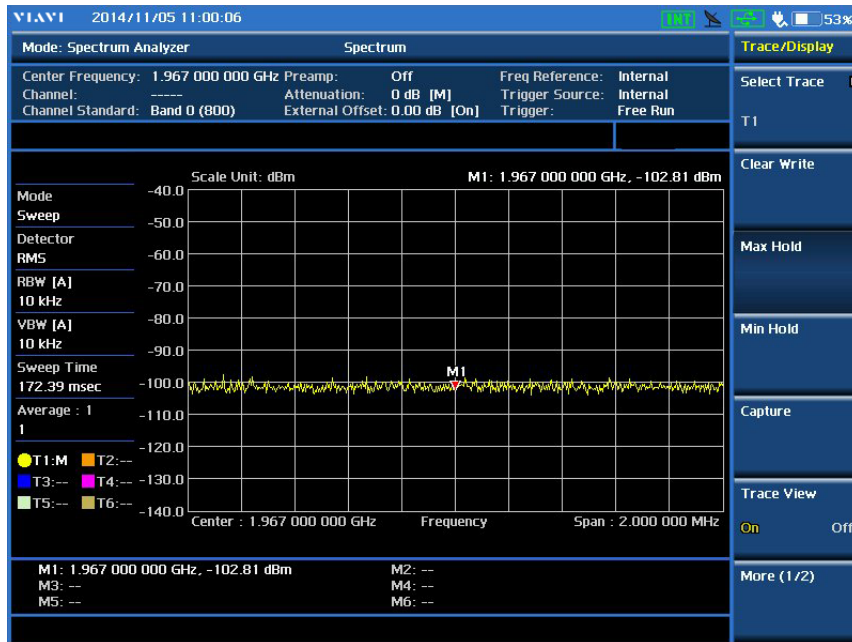
Downlink Functionality Testing

At this point, the DAS equipment should be validated as functional and ready for RF continuity testing. Perform this test to verify that all active and passive DAS equipment is installed correctly and is functioning properly to meet the design link budget. Perform this test before the Post-Build CW testing.

- Headend Loss Measurement procedure

  – Normalize all losses through test jumpers and connect the CW transmitter to DAS interface where RAN equipment would connect, indicating the demark point.

  – Using a spectrum analyzer, such as CellAdvisor, measure the headend system loss.

  – Measurements are recorded in the worksheets

Note: The Headend Loss measurement is required to validate RF continuity and losses through the entire RF signal-conditioning path at the headend between the demark and fiber card.

- Downlink Measurement procedure

  – Normalize all losses through the test jumpers prior to connecting to the DAS system.

  – Inject a CW test signal at the headend interface based on the maximum OEM power requirement, which should allow for maximum output power of the remote.

  – Collect a received signal strength reading of the main beam from all the antennas connected to this remote (from a safe distance away to avoid saturation) using a spectrum analyzer, such as CellAdvisor.

  – Record readings in the commissioning workbook and verify that the link budget has been met by comparing the readings to the calculated values expected for each antenna locations shown in worksheet.

  – If any fiber/coax swaps or remote amplifier failures are present, notify the on-site construction contractors before proceeding to any coverage testing.

  – If the measured signal strength (RSSI) is off by more than 5 dB from the calculated link budget or the antenna plumbing does not match the design, notify the on-site construction contractor to check for faulty, loose, or incorrect cable connections or a defective remote amplifier, see Figure 33.

Example:

Test Case Frequency	DAS Sector	Antenna ID	Downlink Transmit Power in TFLN Card	System Gain	Ibwave Calculated Passive Loss/Gain	Distance from Antenna to Receiver (ft)	Free Space Path Loss	Calculated Signal Under Antenna	Measured DL Signal Strength Under Antenna (dBm)	Pass/ Fail 5 dB Variance
700	1	1-1-1	−2	32	−4.19	10	39.05	−18.24	−16.56	−1.68
2100	1	1-1-1	−2	32	−2.01	10	48.59	−25.60	−30.37	4.77
850	1	1-1-1	−2	32	−4.17	10	40.74	−19.91	−14.84	−5.07
1900	1	1-1-1	−2	32	−1.56	10	47.72	−24.28	−26.72	2.44
2100	2	2-1-2	−2	32	−5.21	10	48.59	−28.80	−43.32	14.52
1900	2	2-1-2	−2	32	−4.77	10	47.72	−27.49	−43.06	15.57
850	2	2-1-2	−2	32	−7.43	10	40.74	−23.17	−37.38	14.21
700	2	2-1-2	−2	32	−7.45	10	39.05	−21.50	−28.45	6.95
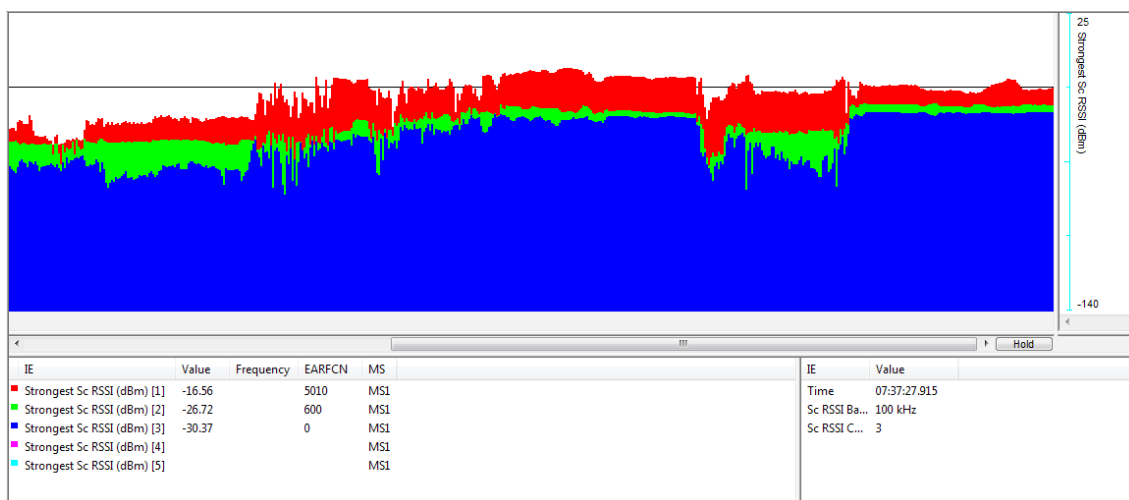
Figure 32. RSSI measurement

Uplink Functionality Testing

Perform thee Uplink Functionality test to verify that all active and passive DAS equipment has been installed correctly and is functioning properly to meet the design link budget. This test confirms that the uplink is functional and that the sensitivity is set properly.

- Set the active DAS uplink to achieve unity, or as close to unity, system gain from the remote to the head-end interface.

  – Normalize all losses through test jumpers prior to connecting to the DAS remote.

  – Inject a low-power CW tone (−50 to −60) into one remote per DAS sector per band.

  – Connect the spectrum analyzer, such as CellAdvisor, to DAS interface and measure the signal. If any gain or loss is noted, increase or decrease the variable software attenuation on the uplink until it measures the same as the signal level being injected.

  – Adjust the system gain/loss to be as close as possible to unity and then log the system loss in the spreadsheet.

- Total System Uplink Measurement procedure

  – Connect the over-the-air antenna to the CW transmitter and set the Tx frequency to be a clean frequency within the receive-band frequencies deployed on the DAS. Perform this test for one remote per sector.

  – In the previous step, the uplink gain from the remote to the DAS interface was adjusted to unity. Perform this test again within a 30 ft radius of the antenna connected to that particular remote.

  – Inject +10 dBm signals over the air from the CW transmitter with the antenna pointing towards the DAS antenna (line of sight).

  – Measure the UL RSSI at the DAS headend UL RF port by connecting the spectrum analyzer and setting the marker's frequency at each CW signal frequency used for the UL test.

  – Perform this test on one remote at a time by turning off the remaining remotes that are simulcast to the same sector.

  – Test each MIMO remote separately for each MIMO path, or use two different frequencies to define each path.

  – Record readings in the commissioning workbook and verify whether they meet the link budget.

If the measured signal strength (RSSI) is off by more than 5 dB from the calculated link budget, or if the antenna plumbing does not match the design, notify the on-site construction contractor to check for faulty, loose, or incorrect cable connections or a defective remote amplifier.

Example:

Test Case Frequency	DAS Sector	Antenna ID	Uplink CW Power OTA (dBm)	Free Space PL	Ibwave Calculated Passive Loss/Gain	Total System Uplink Gain	Uplink Measurement Headend Location	Expected UL Signal Measurement (dBm)	Measured UL Signal Strength (dBm)	Pass/ Fail 5 dB Variance
2100	1	1-1-3	10	56.55	−8.21	0	Demark	−54.76	−22.00	−32.76
850	1	1-1-3	10	48.69	−8.19	0	Demark	−46.88	−42.00	−4.88
1900	1	1-1-3	10	55.68	−7.53	0	Demark	−53.21	−20.00	−33.21
700	1	1-2-1	10	39.05	−4.19	0	Demark	−33.24	−33.00	−0.24

Post-Build CW Testing

Perform Post-Build CW testing after successfully completing the Uplink and Downlink Functionality testing. The DAS must be free of alarms and in compliance with the uplink and downlink RF design link budgets before starting Post-Build CW testing. This test confirms whether the DAS network meets the design coverage criteria.

- Inject a CW signal at the headend RF interface using the maximum expected power into the DAS per the DAS OEM specifications.

- The input power at the headend causes remotes to come to full power.

- Obtain a clean frequency on each frequency band using a spectrum analyzer, such as CellAdvisor, or a scanner with spectrum analyzer functionality.

- If testing multiple sectors simultaneously, ensure the availability of multiple clean frequencies and assign one per sector.

- Walk test and collect signal strength measurements for all the frequency bands in the area that is covered by the sectors being tested.

- Test the LTE MIMO by injecting signals separately at each path with different frequencies and walk testing it to measure the output signal for each path.

- Post-process and analyze data using RF walk test solution

Calibrate/Minimize UL Noise (Maximize Sensitivity)

The purpose of this step is to make the necessary final gain/attenuation setting adjustments to the DAS OEM measurements.

Measure the noise floor and adjust the DAS equipment parameters to optimize the sensitivity of the overall system. This can be accomplished by incrementally adding each simulcast remote and measuring its noise contribution. Repeat this step until all simulcast remotes have been added for that sector.

Turn on each simulcast remote, repeating until all simulcast remotes have been added for that sector. Adjust the attenuation until the noise floor begins to rise and then back off.

Some noise rise should be present in a DAS system, however, this procedure minimizes noise while keeping the uplink sensitivity high.

Frequency Band (MHz)	Technology Reference	Sector ID	Number of Remotes/Sectors	Measurement Location	Measured Noise Floor No Remotes	Measured Noise Floor Remote n Added
700	LTE 10 MHz	1	6	Demark	−106.56	−106.02
700	UMTS 3.84 MHz	2	6	Demark	−104.45	−101.19
700	LTE 5 MHz	3	6	Demark	−106.07	−105.01
Cell 850	CDMA 1.25 MHz	1	6	Demark	−105.28	−105.71
PCS 1900	LTE 5 MHz	2	6	Demark	−101.83	−100.65
AWS 1700	LTE 5 MHz	3	6	Demark	−103.13	−102.68

RAN Integration (Commission RF Levels)

Integrate the RF link coming from the RAN (NodeB/eNode/DAS) testing and ensure alarm-free RAN and DAS alarm connectivity.

Downlink Measurements										
DAS Sector/Zone	Channel Identifier	700 RS (dBM) at Demark	Composite Pwr RS at Demark (CH Pwr)	External Attenuation before DAS POI	700 RS into BIU	Composite RS Power into BIU	BIU MDBU Expected Max	Additional HE Insertion Loss	Final Total DL Attenuation	BIU UL Attenuation Setting
1A	5230.0	−18.0	−2.0	10.0	−28.0	−12.0	0.0	0.0	10.0	28.0
1B	5230.0	−18.0	−2.0	10.0	−28.0	−12.0	0.0	0.0	10.0	28.0
2A	5230.0	−18.0	−2.0	10.0	−28.0	−12.0	0.0	0.0	10.0	28.0
2B	5230.0	−18.0	−2.0	10.0	−28.0	−12.0	0.0	0.0	10.0	28.0

DAS Sector/Zone	850 CPICH (dBm) F1 at Demark	850 CPICH (dBm) F2 at Demark	Composite CPICH at Demark	External Attenuation before DAS POI	850 CPICH F1 at RIU	850 CPICH F2 at RIU	Composite Power into RIU	RIU Conditioner Expected Max	Additional HE Insertion Loss	Final Total DL Attenuation
1.0	30.0	30.0	33.0	10.0	20.0	20.0	23.0	32.0	0.0	10.0
2.0	30.0	30.0	33.0	10.0	20.0	20.0	23.0	32.0	0.0	10.0
3.0	30.0	30.0	33.0	10.0	20.0	20.0	23.0	32.0	0.0	10.0

Pre-Optimization Basic Call Testing

After validating the completed installation and commissioning the DAS OEM infrastructure, RF engineers should perform basic walk testing. to verify that every node/remote is functioning properly/processing calls and that coverage objectives are met. The RF engineer should make voice and data calls at every node/remote passing near each antenna and collect data in the general coverage objective area.

This test requires a scanner (DRT, IBFlex, or similar) and UE to measure the DAS signal for each CDMA/EV-DO/UMTS/LTE (MIMO) band along the walk route, ensuring to pass near each antenna.

- Set the scanner to scan applicable bands for each CDMA/EV-DO/UMTS channel and LTE MIMO.

- Set the phone and software to perform call and data testing on the desired technologies and bands

  – Data testing includes download and upload to an FTP server for both 3G and 4G. Using Rubix, post-processing can be done in real time; however, testing must be repeated for each frequency band. If there are multiple bands for the DAS on 3G and 4G, this can be achieved by having multiple phones with each phone locked onto a particular band.

- Record and present the following data for each zone and area, see Figure 33 for examples of RF measurements:
  - 3G Voice and Data
    - Ec/RSCP phone and scanner
    - Ec/RSCP per UMTS/EV-DO/CDMA channel
    - Mobile Tx power
    - Mobile Tx adjust
    - Dominant PN/PCI
    - Ec/Io best server (voice and data separately), both scanner and phone
    - FER% (EV-DO and CDMA)
    - BER% EV-DO
    - DL throughput (EV-DO/HSPA)
    - UL throughput (EV-DO/HSPA)
  - 4G LTE
    - Dominant PCI, both scanner and phone
    - RSRP per PCI, both scanner and phone
    - CINR, both scanner and phone
    - UE Tx Pwr
    - RSRP per MIMO path from scanner
    - LTE rank indicator
    - Application-level throughput UL/DL
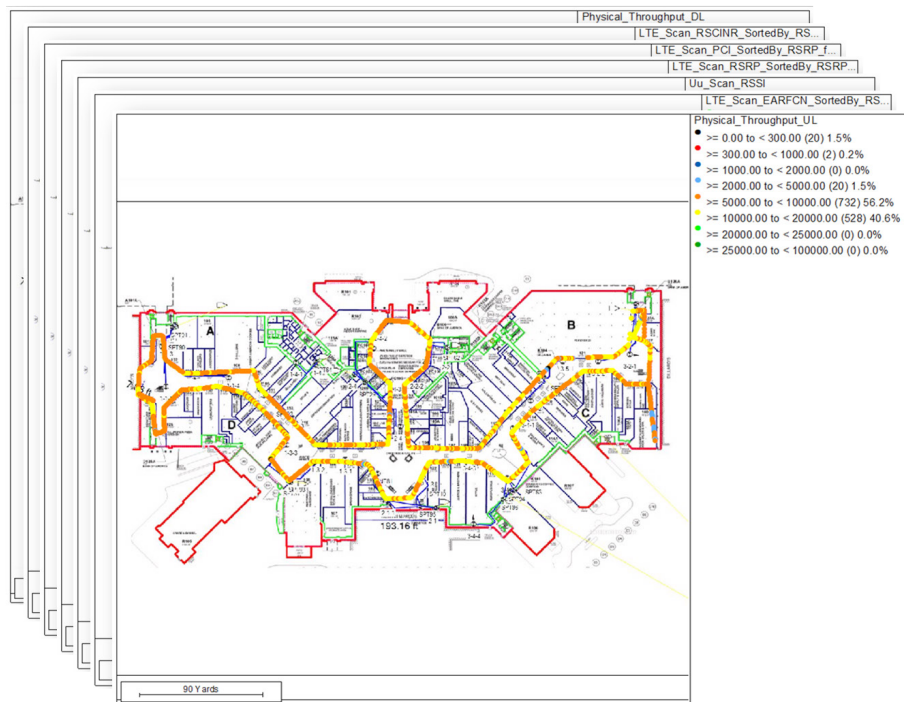   - Modulation scheme

Figure 33. RF measurements

Certain efficiencies can be realized by improving the RF walk test process with less resource-intensive solutions available on the market today. The following are the necessary steps in the current data collection process shown in Figure 34:

- Request venue access for testing.

- RF engineer/technician collects data (8 to 12 hours).

- RF engineer/technician uploads the data to the server (1 to 2 hours).

- Back office engineer downloads the data (2 to 3 hours).

- Back office engineer post-processes the data to validate if all the data is present and reports can be generated (4 to 16 hours), data is analyzed and KPIs reviewed with the design engineers.

- Missing data or discovering data anomalies will require a site revisit.

- The whole process may need to be redone either the next day/night, if site access is not an issue; or a team can be redeployed when site access is granted.

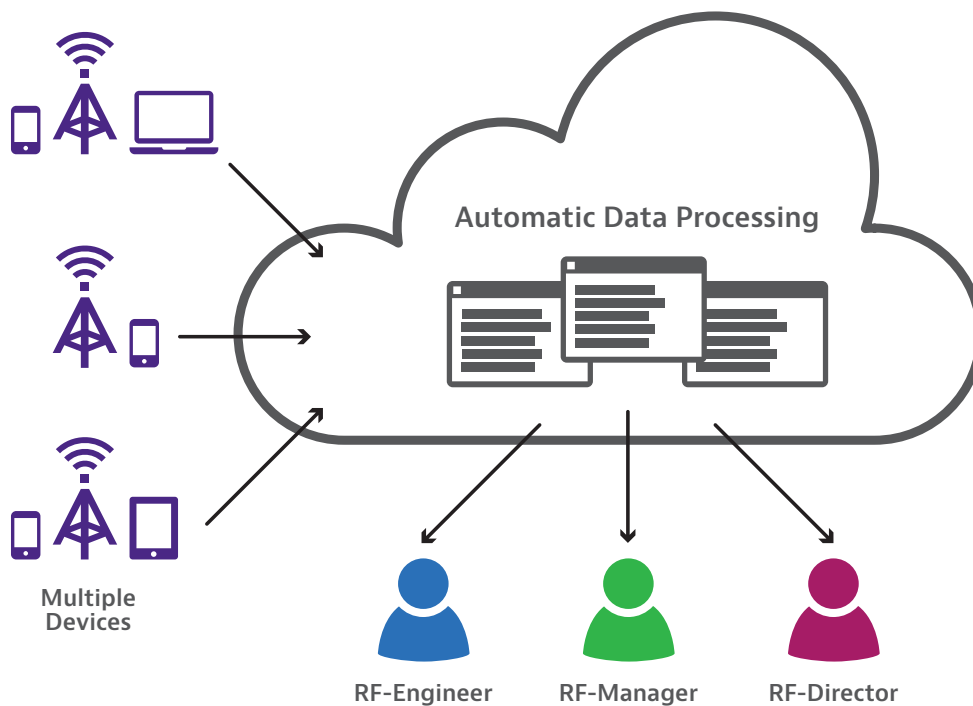Figure 34. Current walk testing and analysis method

Figure 35. Cloud-based real-time post-processing

Optimization

After analyzing the data and making the necessary network and parameter changes, additional walk tests may be performed. The closeout package is created after achieving the throughput, SINR, RSSI, RSRP, UE Tx power, and other KPI target values, including all the necessary plots and measurements, and is delivered to the project PM.

Acceptance

Acceptance is achieved after all parties (neutral host/venue owner and service providers) agree with the delivered report.

Maintenance

To ensure optimal end-user QoE, it is essential to continuously monitor the performance of the DAS venue. If any performance issues are reported, teams may be asked to revisit the venue to collect and analyze data and to identify actions for troubleshooting any performance-related issues.
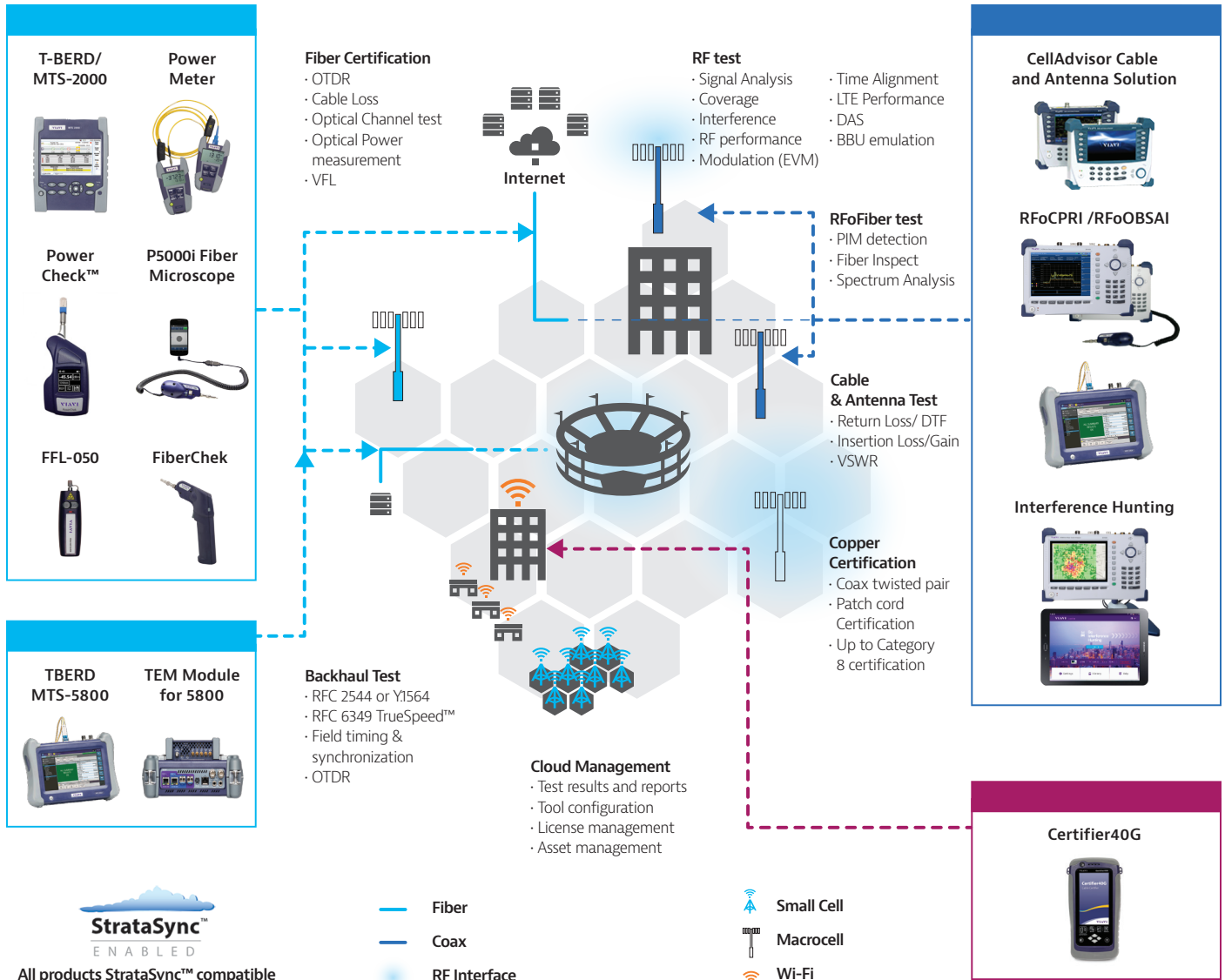
Summary

As wireless networks continue to evolve from a typical macro to a heterogeneous network, service providers and their partners are being challenged to find efficient and smarter ways to install, commission, and optimize them. Traditional methods for deploying and troubleshooting networks are no longer sustainable. Operators are under significant pressure to reduce their OpEx while simultaneously deploying networks at a much faster pace to keep up with the mobile data growth, especially in the in-building environment.

As discussed in this document, DAS network deployment is a fairly complex process, requiring a lot of expert resources and coordination among various teams. Identifying opportunities to streamline the process using advanced tools can greatly reduce the overall deployment time and optimize the overall DAS network.

Viavi Surround the Antenna Solutions

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Fiber Certification
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· Cable Loss
· Optical Channel test
· Optical Power measurement
· VFL

Internet

Backhaul Test
· RFC 2544 or Y.1564
· RFC 6349 TrueSpeed™
· Field timing & synchronization
· OTDR

Cloud Management
· Test results and reports
· Tool configuration
· License management
· Asset management

RF test
· Signal Analysis
· Coverage
· Interference
· RF performance
· Modulation (EVM)
· Time Alignment
· LTE Performance
· DAS
· BBU emulation

RFoFiber test
· PIM detection
· Fiber Inspect
· Spectrum Analysis

Cable & Antenna Test
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