Cel-Fi QUATRA Supercell™
Solving Enterprise Cellular Coverage and Densification Challenges when Off-Air Signal is Weak

By Paul Rigatti, Technology Director at Nextivity

Many buildings have poor cellular coverage or dead zones indoors, which is an issue for occupants considering that 80% of calls are made indoors. There are many factors that inhibit cellular signals, such as the size and construction of the building, environmental obstacles, and the location of towers. The number of users on a network (known as "loading") can also affect cellular coverage since networks are dynamic and grow or shrink based on inter-cell interference levels. This is why coverage may vary based on time of day, or day of the week.

Cellular service is increasingly mission critical. Inside hotels, apartment complexes, school campuses, government facilities, or office buildings poor coverage is not only inconvenient, it is a source of real frustration and concern for employees and guests. The key to addressing these issues lies with selecting the best technology.

Cel-Fi QUATRA, an active DAS hybrid, disrupted the in-building cellular coverage landscape for enterprise buildings because it delivers intelligence and active antennas not found in a typical passive Distributed Antenna System (DAS). QUATRA features the power of an active DAS at a price point that supports the middleprise (up to 1,000,000 sq. ft.).

Cel-Fi QUATRA solution configurations have been approved globally by regulators, the top four operator networks in the United States, and major carriers in Europe, Asia, North America, South America, and Australia.

Purpose and Intended Audience

This paper provides an in-depth look at the Cel-Fi QUATRA Supercell for commercial in-building cellular coverage, including how it works, and different use-case configurations. The paper is intended for mobile operators, integrators, installers, and interested business or IT professionals that want to better understand this hybrid solution to solve in-building cellular coverage problems for the underserved middleprise market.

What is a hybrid?

Cel-Fi QUATRA is a hybrid solution that combines the strengths of both passive and active DAS architectures. It can be deployed as a typical active DAS-style solution. QUATRA's remote units, called Coverage Units (CUs), are active omni-directional antennas that amplify the signal for each carrier independently, with up to 100dB gain, and use Power over Ethernet (PoE) to simplify installation.

Cel-Fi QUATRA can also be deployed like a passive DAS when a building's layout could be better serviced by an array of focused, targeted antennas. CUs can be deployed like bi-directional amplifier (BDA)-style remotes used to drive passive DAS branches connected by coaxial cables, while maintaining QUATRA's unique advantage of amplifying each carrier independently. This is unlike the traditional passive DAS application of one gain value set for all operators. This deployment option is particularly well suited for environments with irregular floorplans where RF coverage needs to be shaped to match building geometry.

The hybrid offers additional flexibility in the donor signal source, depending on the needs of the building. Cel-Fi QUATRA can be installed off-air or it can be tethered to a small cell to create a Supercell.

What is a Supercell?

A Supercell is created when the Cel-Fi QUATRA active DAS hybrid is tethered to the small cell of one or multiple carriers for the donor signal. A Supercell distributes uniform signal from the small cell throughout the building without coverage gaps or spotty coverage for one or multiple carriers simultaneously.

More densely populated sites can often benefit from the additional capacity delivered by a dedicated small cell donor. There are also several common situations when the macro signal doesn't penetrate into buildings that require a Supercell to resolve:

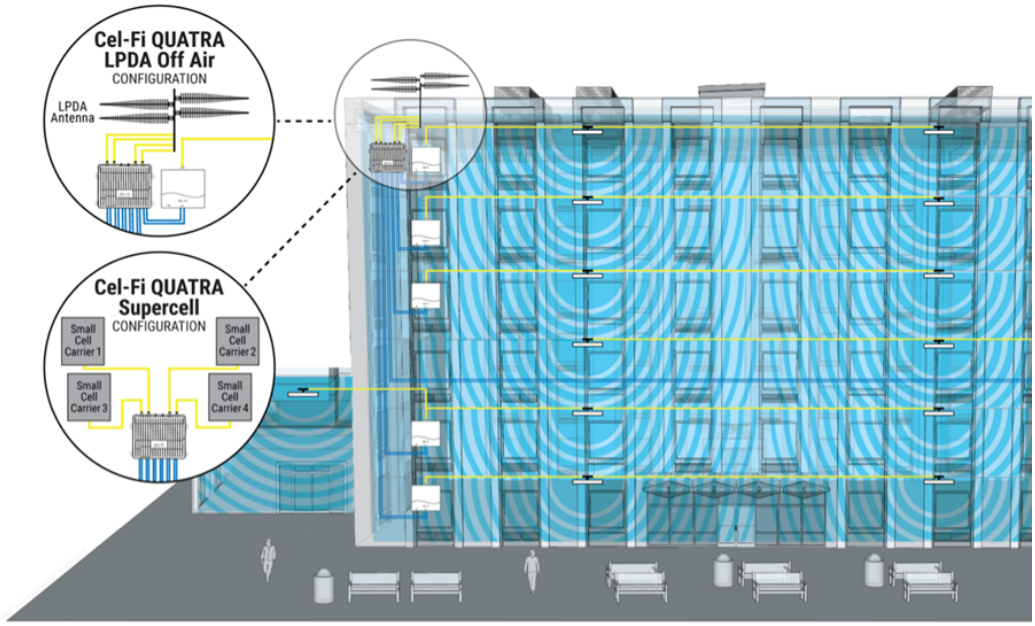
- Congested macro network in metro areas resulting in insufficient capacity and/or poor signal-to-noise ratio
- Buildings taller than the 25-30 ft macro sites generally installed in metro areas
- Pilot pollution from too many visible cell sites with no dominant donor cell
- Extremely weak signal outside the building in rural, mountainous, or other areas with external obstacles
- No place to attach external donor antennas at optimum locations or building owner won't allow them
- LEED or shielded buildings or rooms and energy efficient windows in combination with any of the other scenarios above
- Carrier reluctance to approve a rebroadcast agreement due to concerns with overloading the macro network

For several years, many of the major carriers have offered enterprise small cells as the solution to these situations. While a small cell can deliver the additional signal capacity to a building, small cell deployment has not been as easy a fix as the plug-and-play initially promoted. Depending on the carrier and the deployment model, users may require a dedicated data feed for each small cell, which is a recurring expense, normally incurred by the owner (not the carrier). Interference between multiple small cells in a space, coverage gaps on the edges or between the coverage bubbles of each unit, technical complexity, slow delivery times, and high costs have all severely reduced the volume of small cell deployments that were initially projected. Additionally, a small cell supports a single operator, and many poor coverage scenarios require solutions for more than just one carrier.

The Cel-Fi QUATRA Supercell eliminates these issues.

CEL-FI QUATRA Supercell Configuration

A Cel-Fi QUATRA Supercell is comprised of one or four small cells, one Network Unit (NU), which is the head end or hub of the system, and up to six CUs per NU (depending on the QUATRA system deployed). The CUs have full transmit power available without suffering from coaxial distribution power loss. Each CU can drive a passive DAS branch with up to six (6) antenna drops.



COVERAGE UNITS (CU)

- Up to six (6) per NU for Q4000
- Up to six (4) per NU for Q1000
- Power over Ethernet
- Horizontal ceiling or vertical wall mountable

NETWORK UNIT (NU)

- Built-in or external donor antennas
- Accepts small cell donor inputs (to one or more Cel-Fi QUATRA systems)
- Powers entire system
- Self-configuring
- Cel-Fi WAVE Enterprise management

Multiple NUs can be installed for larger buildings, each connected to up to six CUs. Each NU can be tethered to one to four carrier small cells. Virtually any small cell can be used with QUATRA, as long as the supported bands of the small cell match the bands supported by QUATRA. There are several QUATRA band variations available, covering the most popular ones.

Size the Solution to the Need

Different coverage needs and building layouts will drive the requirement for the deployment. A Cel-Fi QUATRA Supercell provides the flexibility to support a variety of configurations to meet the needs of most middleprise buildings, even when no macro signal can penetrate the building or is too weak to use as a donor.

Some office spaces only need coverage for the one or two carriers the company subscribes to for the cell phones it supplies to employees. Other venues may have multiple tenants or guests, so they require good coverage for all major carriers. Some buildings receive sufficient signal from one carrier but not another. These factors can be evaluated during an initial site survey, so the necessary small cells can be specified and acquired from the carriers.

In a venue with an open setting, high ceilings and low (or non-existent) interior walls, a single high-power, centrally positioned Cel-Fi QUATRA CU can provide coverage to a very large area. This is the simplest and fastest way to install a coverage node, because the units can be quickly mounted, and Cat 5e cable plugged-in, to provide power (through PoE) and signal.

But in an area with many obstacles or other blockers to interior coverage propagation, an installer may want to pinpoint coverage with easy-to-deploy and inexpensive passive antennas, rather than multiple CUs. In this case, the Cel-Fi QUATRA CU can be

used, like a BDA, as the remote source to power and drive a passive DAS. Coax cable can be run from the CU's external antenna ports to antennas to distribute coverage. In addition to QUATRA's higher-gain over a traditional passive DAS, each of the four internal amplifiers are automatically gain-controlled independently, allowing each band to get to maximum downlink power.

While the hardware cost of deploying passive antennas rather than multiple CUs is considerably lower, the installation is more complicated and therefore requires more planning and RF engineering. Improper installation or set-up can lead to poor or inconsistent results, leading to a bad customer experience. This must be factored in when the system integrator evaluates the right solution for the environment and works to meet budgetary needs.

A certified installer can use the Cel-Fi QUATRA BOM Estimator Tool (https://www.cel-fi.com/support/bom-estimator/) prior to a site survey for automated configuration and output of suggested network elements. This portal-based tool, based on standard 802.1x RF propagation models, eliminates time-consuming manual calculations that integrators generally need to do when initially designing an in-building solution. Instead, an estimate can be built from data supplied over the phone or via email, even as a pre-sale service, before the site survey, to develop a preliminary bill of materials (BOM).

Installation

A site survey can be performed to determine the optimum system design for the venue. The integrator installs and maintains the system using the Cel-Fi WAVE platform, a cloud-based management interface with an easy-to-use dashboard for system optimization, alerts and alarms, and software updates.

Once the small cells are installed and the system is mounted appropriately, standard Cat 5e (or better) cable is used to connect the NU with each CU. Many commercial buildings are wired with Cat 5e (or better) cabling, further simplifying the installation and reducing installation costs. If using a CU as the source to drive a passive DAS, coaxial cable is installed to connect the antennas. When powered on, all network and system optimizations are performed automatically.

In developing Cel-Fi QUATRA, Nextivity leveraged its proprietary processor technology and digital architecture that powers its family of Cel-Fi cellular coverage solutions. The digital architecture that underlies these proven solutions provides both the intelligence and scalability required to deliver and optimize indoor cellular coverage.

The intelligent architecture self-configures and self-optimizes, making the qualified installer's job easier. The system intelligently adjusts and adapts to changes in the environment or network, eliminating interference and always maximizing performance once installed. This reduces maintenance costs and alleviates the typical demands on staff to maintain a traditional active or passive DAS.

The smart digital architecture includes many features such as: automatic gain control to maximize system power, uplink power control, advanced digital echo-cancellation and feedback control, uplink muting, and signal qualification (channels are individually qualified for boosting, so noise or very poor signals won't be amplified and won't degrade the network).

These smart systems have been designed in conjunction with operators to improve indoor coverage without the network interference problems and installation complexity associated with other types of systems, like repeaters or traditional DAS. Cel-Fi QUATRA is proven to be unconditionally network safe, which ensures there is no network interference, and can be deployed confidently.

The built-in intelligence of the system means that a Cel-Fi QUATRA Supercell can be installed considerably faster than other enterprise solutions on the market.

SUPERCELL ADVANTAGES

The Supercell configuration — i.e., Cel-Fi QUATRA connected to a small cell donor — has three key advantages over a small cell installed alone. These are:

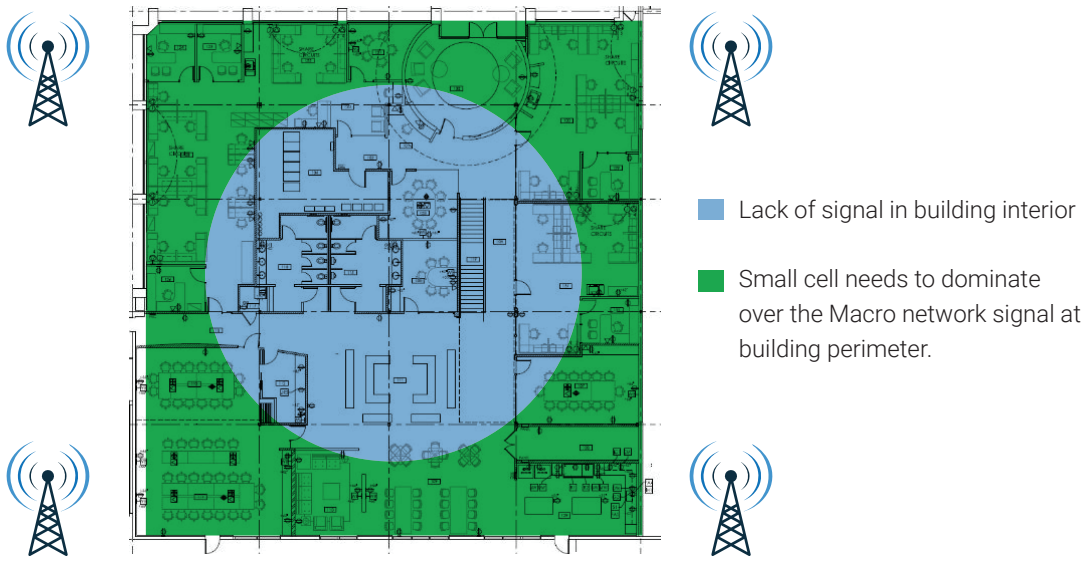
1. Small cell dominance
2. Elimination of problems related to multiple small cell interference
3. Reduced small cell overhead and OPEX resource requirements (fewer small cells are required for the space)

SUPERCELL DOMINANCE

Larger or more densely populated installation sites can often benefit from the network capacity delivered by a dedicated small cell. This means three things to the operator (and the enterprise):

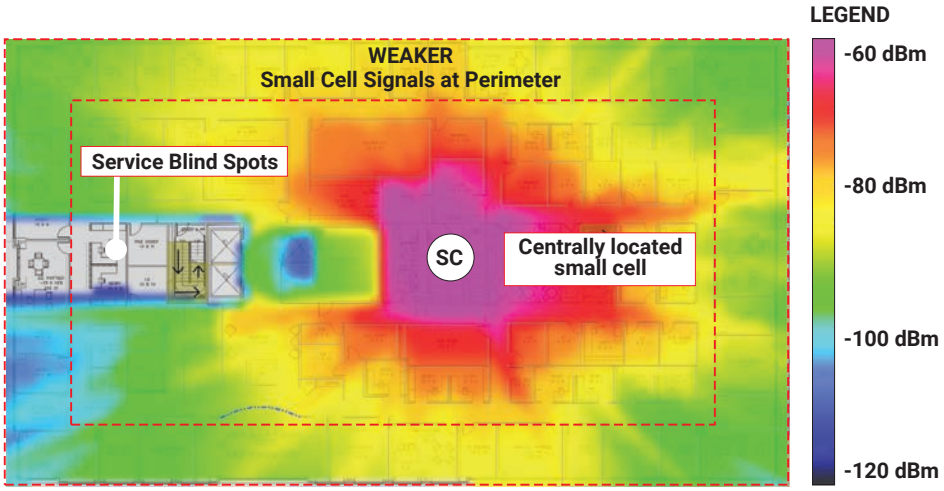
1. The installation should provide enough signal dominance (power) over the outside macro network so that in-building calls stay in-building on the small cell where they belong.
2. The local small cell off-loads traffic from the macro network, freeing up capacity for other macro network subscribers.
3. If the site suffers from network interference problems, such as pilot pollution in a high-rise building where too many cell sites are visible and interfering with each other, small cell dominance must be able to overcome the interference signal energy that is present.

In the typical example below, the building suffers from a lack of signal at its interior, while the perimeter areas of the building are being adequately served by competing macro cells.



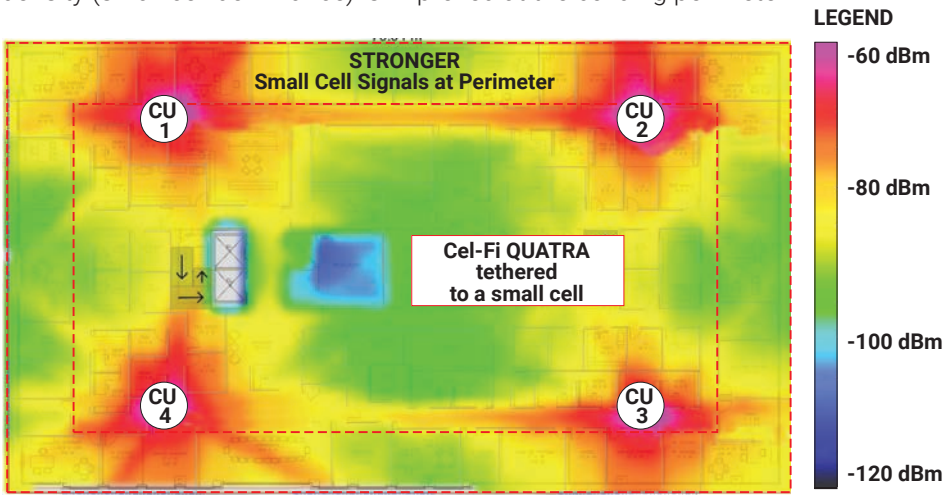
Small cell competes with the Macro network.

If a small cell is installed in the center of the building, its signal power falls off as callers get closer to the perimeter. This results in service being handed-off to the outdoor network, which defeats the purpose of adding small cell capacity.



WEAKER small cell signal at perimeter.

Now consider the Supercell case which distributes local capacity in a more uniform fashion. The result is that more areas are covered, and power density (small cell dominance) is improved at the building perimeter.

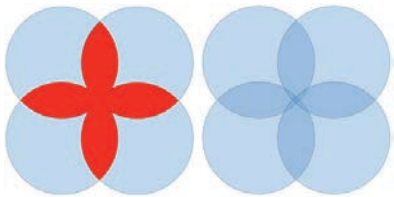


STRONGER small cell signal at perimeter.

In this case, the result is a 14dB improvement for the perimeter offices, plus better coverage overall throughout the venue. This helps to ensure that local cell phones will be properly served by the local system, and that the macro network will be properly off-loaded as the operator intends.

Potential Interference from Multiple Small Cells

Similar to macro network cells, small cells may interfere with each other where they overlap, causing reduced performance. The Supercell configuration resolves this problem by creating a large single composite cell and eliminating hand-off regions between multiple small cells.



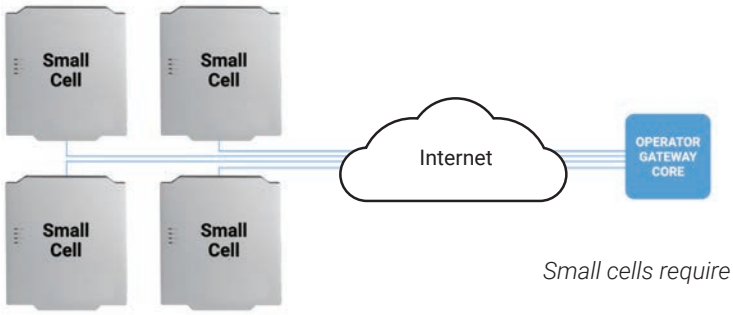
Small Cell Interference Zones

Supercell Seamless Service

The Supercell Advantage

Small Cell Overhead and Opex

Each small cell must have its own high-bandwidth backhaul that connects it to the operator's gateway/core network. A dedicated data feed of between 20 and 50 Mbps is typically recommended for a small cell's backhaul. Therefore, additional small cells result in an increase in cumulative backhaul requirements and OPEX that should be considered. Some enterprises will have plenty of overhead bandwidth and can draw from that with small cells, while others will need to increase bandwidth, which comes at a cost. Each small cell comes with guidance on the bandwidth consumption, so the enterprise can easily determine if current bandwidth is sufficient.



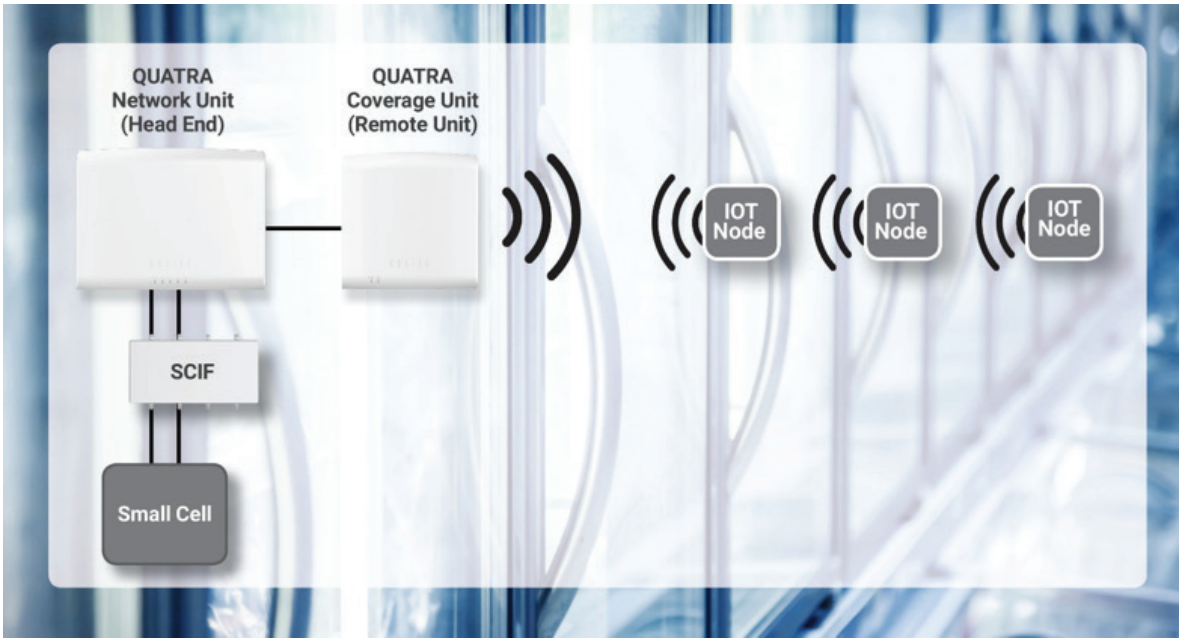
Small cells require backhaul.

Cel-Fi QUATRA Supercell AND IoT

LTE-based cellular Internet of Things (IoT) solutions are new on the market, with the commercial deployments starting to ramp up substantially. Cat M1 LTE is gaining a lot of momentum in IoT, based on support from the traditional wireless mobile network operators. These technologies are subject to similar in-building penetration challenges and resulting coverage problems as cellular. For example, many reviews of Apple's LTE-based iWatch product cited LTE coverage as an important metric in the usability of the product, impacting its performance and customer satisfaction.

In an LTE-based IoT infrastructure, a Cel-Fi QUATRA Supercell offers several advantages:

1. It is transparent to the network. There is no additional latency or setup required. A device could be installed in a concrete bunker, yet the device would appear on the network as if it was sitting in a wide-open coverage area without any structural obstacles. For mission-critical business solutions that rely on real-time communications, this is an important option.
2. Unlike mesh networks, connected devices that are inside the coverage bubble of a Cel-Fi QUATRA Supercell are not required to do any additional networking, so they can be much lighter weight in terms of capability, and power consumption. They can operate as intended, waking only when prompted, or on a timer. This delivers the 10-year battery life desired by the IoT industry.
3. Buildings with IoT solutions being serviced by a Cel-Fi QUATRA Supercell have a lot of flexibility, since nodes can be added or subtracted without any special setup or configuration. Connected devices can be fully mobile and not reliant on tethering from a cable or network connection.



Unlike other options (e.g., simply adding an antenna to the IoT router), using Cel-Fi QUATRA will not only connect the IoT node connected in a high-speed low latency connection, all LTE services, like voice calling, will be improved. For an IoT application that doesn't have outside cellular service, a Supercell can be a great way to provide coverage to the IoT devices.

Driving Down Cost and Complexity for the Middleprise

A large enterprise may be able to support the return on investment or net operating income and associated costs of a traditional DAS solution that requires extensive RF design, engineering, and costly maintenance, as well as extensive budget and contract negotiations with multiple vendors, integrators, and the operators themselves.

But the cost of a fully installed, traditional DAS solution at $2- $3 per square foot typically puts it out of range for most middleprise venues. Simpler solutions such as femtocells and Wi-Fi calling are available but do not have the reliability, quality of service, or management capabilities that a business requires. Venues that range in size from 50,000 to 1,000,000 sq. ft. are particularly challenged with the price/performance gap, because they are too large for affordable consumer-grade solutions and too small for high-performance DAS.

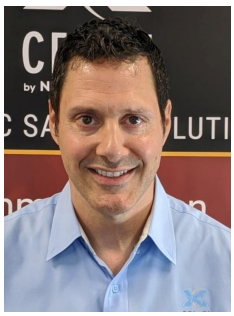
A Cel-Fi QUATRA Supercell addresses this gap with a flexibility tailored for middleprise usage requirements, configurations, and ease of installation and maintenance. This translates into an exceptional total cost of ownership for the middleprise, and faster deployment times.

Conclusion

The industry has struggled to provide affordable indoor cellular coverage solutions for middleprise venues up to 1,000,000 sq. ft. with poor or no macro signal—until now. Existing consumer-grade solutions have been limited in performance, a BDA passive DAS cannot connect to a small cell for the stronger donor signal required, and active DAS has been too complex and costly. The Cel-Fi QUATRA Supercell is the first to meaningfully address the obstacles to indoor coverage for the middleprise in locations with inadequate donor signal.

Configurations are flexible and can be scaled to the unique needs of each venue, future-proofing the system for company expansion. With Cel-Fi QUATRA intelligence and toolsets, installations are highly optimized, helping to make the certified installer's job easier, and keeping the CAPEX and OPEX of the system at an affordable level for most middleprise budgets.

Cel Fi QUATRA is available through distributors around the globe. For more information, visit www.cel-fi.com/QUATRA. To become a certified partner, visit www.cel-fi.com/partnership.



About the Author

Paul Rigatti is a Solutions Architect and Technical Sales Director at Nextivity, Inc. Previously, he spent 10 years as an engineer and consultant deploying cellular infrastructure end-to-end. From mobile devices to the RAN to the core, Paul has worked with Qualcomm, Ericsson, and Broadcom on the ground in 23 countries.