By Michiel Lotter, CTO and VP of Engineering at Nextivity

In-Building Cellular: Matching User Experience Expectations with Technology Selection

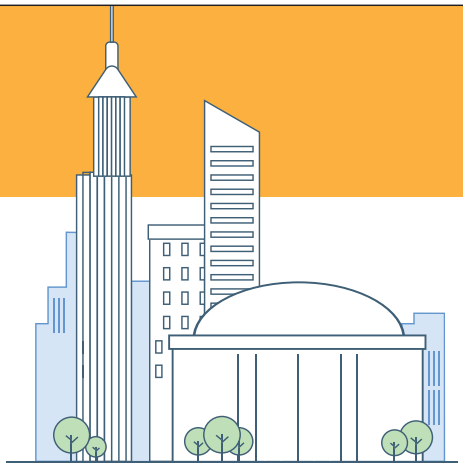
Today, in-building cellular coverage is an important part of the conversation when a new building is constructed or an existing building is upgraded. Long gone are the days when a case needed to be made for providing a good cell phone signal in commercial spaces.

However, the conversation around in-building cellular coverage has become muddled with senseless acronyms, biased industry agendas pushing solutions that may not be well suited for specific applications, and products that fail to meet expectations. Having a clear understanding of the requirements of each market segment is key. Of course, the baseline requirements for each segment may be different today compared to five years out, particularly with the rollout of 5G networks.

In this paper, we examine the in-building cellular coverage system requirements for the enterprise and their evolution over the next five years. We also dive into the various technologies on offer by vendors to ensure there is clarity around which are essential.

IBC Market Needs

Characteristics of in-building cellular coverage systems across market segments.



LARGE ENTERPRISE: > 500K ft²

REQUIREMENTS	
HOST:	Neutral host and multi-technology
FOCUS:	Most functionality — willingness to push the envelope *(e.g. 5G ready, MIMO etc)*
DATA RATE:	Generally large enough to garner operator involvement
SOURCE:	Almost always fed by a local signal
TURNAROUND:	Longest *(months to years)*
COST:	$$$$$

MIDDLEPRISE: 50K – 500K ft²

HOST:	Neutral host and single technology *(cellular)*
FOCUS:	User productivity and not a large feature set
DATA RATE:	Make reliable calls/texts and have an adequatet data rate *(around 10Mbps would be adequate)*
SOURCE:	Mostly operated as an off-air system with some local signal
TURNAROUND:	Quick *(weeks to months)*
COST:	$$

SMB: < 50K ft²

HOST:	Operator specific cellular
FOCUS:	Productivity
DATA RATE:	Make reliable calls/texts and have a decent data rate *(around 5Mbps is functional)*
SOURCE:	Always off-air donor
TURNAROUND:	Quickest *(days to weeks)*
COST:	$

User Experience Expectations

Consumer wants and needs are fundamental to determining the requirements for in-building cellular coverage in enterprise and middleprise applications, as noted in the above infographic. For middleprise applications, we claim that 10Mbps throughput is adequate. But how can we make such a claim? Even if we are correct, what about the future? It's conceivable that the required data rate to achieve customer happiness increases significantly over time, thus moving the goal posts for the service level needed from in-building cellular coverage systems. After all, 5G is promising gigabit data rates.

In the next five years, video traffic will be the driving force of throughput expectations, based on user demand . The data rate requirements for video provided by YouTube are shown below. Today, most video viewed on smartphones is consumed at 360p resolution, but this is quickly rising to 720p . We foresee this trend continuing, with 1080p video streaming becoming popular in years to come. Using the 1080p number as an anchor, the throughput level target of 10Mbps for middleprise in-building cellular coverage solutions in the next five years seems to be a reasonable target.

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.

Type	Video Bitrate, Standard Frame Rate (24, 25, 30)
2160p (4k)	35-45 Mbps
1440p (2k)	16 Mbps
1080p	8 Mbps
720p	5 Mbps
480p	2.5 Mbps
360p	1 Mbps

Technology Selection

From the infographic above, one of the main differences between middleprise solutions and large enterprise solutions is the willingness of consumers to pay for features that push the technological envelope. In the case of the middleprise, the building owner may very well be funding the total cost of the in-building cellular coverage system and could be looking to maximize the ROI on this investment. However, the ROI comes from happy, long-term tenants paying their monthly rental bills. Therefore, it stands to reason that any dollar spent on an in-building cellular coverage system that does not incrementally lead to happier tenants is a dollar that could have been better spent elsewhere.

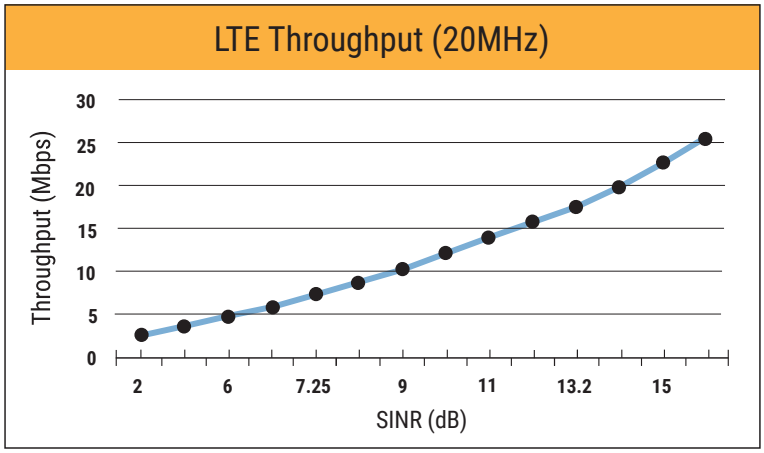
When in-building cellular coverage solutions are pitched to building owners, it is easy to take some of the new technological features and sell them to the building owner as critical. After all, this will lead to the higher overall project costs which technology providers expect of their sales teams. However, it is seldom in the building owner's interest to jump to the most feature-rich solution.

MIMO

MIMO (Multiple Input – Multiple Output) technology is a mainstay of LTE and LTE-A networks. MIMO technology has the potential to double or even quadruple data rates available to end-users without requiring additional spectrum to support the data rate increases. This is achieved by using multiple antennas at the base station as well as on the handset. Today, increasingly more LTE base stations deploy four transmit antennas, while handsets may use two or four receive antennas.

The important question to ask in the context of in-building cellular coverage for the middleprise is what the improvement in data rate would be for users with MIMO technology, and the cost of this improvement. Remembering that our throughput target is 10Mbps, it can be delivered in one of two ways. Using a single receiving antenna, a SISO (Single Input – Single Output) channel would need to deliver 10Mbps of throughput. Using two receiving antennas, a MIMO channel would need to deliver

5Mbps of throughput through two spatial channels. From an end-user point of view, it matters little which method is used to deliver the service. Assuming a 20MHz LTE carrier (typical for urban deployments where most middleprise systems will be deployed), a SISO system would require a donor SINR (signal-to-interference-plus-noise ratio) of approximately 9dB to achieve a 10Mbps throughput level. A MIMO system could achieve the same throughput level with a SINR of approximately 6.5dB.



However, to support MIMO in an in-building cellular coverage system, the amount of hardware (and therefore the cost) in the system must essentially be doubled as the signals from the two donor antennas must be carried as independent signals to all MIMO server antennas to keep the MIMO channel intact. Thus, when MIMO is pushed as a must-have technology, building owners are being asked to double their equipment cost so that users of the in-building cellular coverage system may enjoy video in 1080p versus 720p. For a cost-conscious building owner, this is not a great investment to make—especially since good donor antenna selection and placement can significantly improve the donor SINR for a SISO system at a fraction of the cost of a MIMO system.

Based on this analysis, we conclude that MIMO is not a must-have technology for a middleprise in-building cellular coverage system.

CBRS

Citizen Broadband Radio Service (CBRS) is a shared spectrum allocation in 3.5GHz bands, and is touted as a disruptive force for in-building coverage. In the context of a five-year vision for middleprise in-building cellular coverage, it would seem as if CBRS may not be enough of a dominant force to become a must-have for the middleprise. The reason for this thinking is that the CBRS band is a shared band with different tiers of access. From a carrier's point of view, that is not as valuable as the dedicated spectrum for which they paid billions of dollars. Under certain conditions the CBRS spectrum may be extremely valuable (for example, a large event that needs temporary additional network capacity), but it will always be an augmentation of dedicated spectrum. Thus, if the goal of the middleprise in-building cellular coverage system is to provide access to carrier services, only dedicated spectrum will guarantee service. Consequently, access to CBRS spectrum through a middleprise in-building cellular coverage system is not a requirement for providing coverage for mobile network operators.

This position on CBRS may seem somewhat simplistic given the amount of press CBRS has received. Could such a simplistic view be wrong? While it is possible that our assessment of CBRS for the middleprise may be wrong, it is not probable. By way of example, look at the OnGo program from the CBRS Alliance, which states : "In-Building: OnGo provides secure, cost-effective LTE coverage indoors, where it's needed most, supporting new Private LTE and IoT applications." While we agree that CBRS offers a great spectrum platform for organizations to roll out private LTE network services, support for these private networks is not the main concern of the middleprise building owner.

The first and most important point to understand about 5G is that it is not one thing. It is a name for a set of services which may be delivered using multiple physical network topologies. Therefore, a statement by an in-building cellular coverage vendor that they "support 5G" is somewhat meaningless. From an in-building cellular coverage point of view, the two most important ways in which the service can be delivered is mmWAVE and sub-6GHz.

mmWAVE 5G

mmWAVE 5G refers to 5G networks operating at very high frequencies such as 28GHz and 39GHz. The advantage of these high frequencies is that extremely large amounts of bandwidth are available at these frequencies, making it possible to deliver extremely high data rates to end-users. However, the higher the operating frequency of a network, the worse the propagation characteristics of the signals.

In the case of mmWAVE signals, line-of-sight operation is required to get any decent level of data throughput. In the context of a middleprise in-building cellular coverage system, this means that every user in a building must be able to see a server antenna to get the full benefit of the 5G mmWAVE network. If this is not already a too costly endeavor, the amount of bandwidth that must be available to carry the signals to each of the server antennas for all operators is gigantic—especially as MIMO technology is a critical part of the mmWAVE 5G system. Therefore, the only way to connect server antennas is through fiber with its associated cost profile.

Based on our view of the middleprise requiring around 10Mbps throughput to satisfy user requirements over the next five years and the massive cost of mmWAVE in-building coverage systems, it seems as if the need for mmWAVE support for the middleprise may be beyond our five-year horizon.

Sub-6GHz 5G

The delivery of 5G services in bands below 6GHz seems to be of much greater relevance. However, LTE remains by far the most important technology for the next five years. The GSMA predicts that in the USA, only 50% of connections will be 5G connections by 2025 . Also important to remember is that each one of these 5G capable phones will also be LTE capable—and LTE will be able to deliver services that far exceeds our minimum requirement of 10Mbps throughput. Therefore, within our five-year horizon, it seems as if 5G may not be a required feature for middleprise in-building cellular coverage systems. That doesn't mean that middleprise in-building cellular coverage vendors and building owners should completely ignore 5G; but it does make sense for the 5G focus to be on supporting the natural evolution of services within currently supported bands from 3G to 4G and then to 5G.

Prior to the roll-out of 3G, 2G technology occupied all carrier spectrum. As 3G technology became more prevalent, 2G networks were cut back until they eventually disappeared. The same is happening to 3G technology as 4G proliferates; and the same will happen to 4G technology as 5G proliferates.

What stays constant throughout is the spectrum. It is owned by the mobile network operator who will do all it can to maximize the revenue it can derive from that spectrum. Therefore, the most sensible approach to 5G from the point of view of a middleprise in-building cellular coverage solution would be to ensure that whatever equipment is deployed today has the ability to carry 5G signals within the same spectrum as the 4G signals carried today. This ensures that building owners don't end up with the equivalent of "dark fiber" or unused DAS (distributed antenna system) components in their DAS systems as networks evolve.

Taking all of this into account, the most sensible 5G strategy for a middleprise is to pick equipment that will withstand a transition from 4G waveforms to 5G waveforms within the existing bands being provided inside the building. This should ideally include TDD LTE bands, which are not commonplace in middleprise systems today.

Conclusion

Predicting the future is somewhat like playing the lottery—while you are unlikely to select all the winning numbers, you continue to play each week in case you are that one-in-a-million person who does get it right. Given the five-year horizon for the predictions we are making this document, we are confident that our characterization of the middleprise in-building cellular coverage space will prove to be accurate. While 10Mbps data rates may turn out to be 15Mbps, such differences are not material to our understanding of the requirements of in-building cellular coverage for the middleprise.

In summary, here is our characterization of what is required from an in-building cellular coverage system for the middleprise over the next 5 years:

- Support for at least one or two dedicated bands for all major operators in one system
- SISO
- Capable of using off-air donor as well as small cell donors
- Capable of optimizing the SINR of donor signals to maximize throughput
- Capable of supporting a transition from 3G to 4G to 5G within the supported bands.

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

About the Author

Mr. Lotter has 25 years of experience in the field of wireless communication. Prior to joining Nextivity he was the Senior Director responsible for platform development in the Mobile Communications BU at Broadcom, which he joined as part of the firm's acquisition of Zyray Wireless of which he was a co-founder and Vice-President, Engineering. Prior to Zyray he spent 8 years with Alcatel Networks. Mr. Lotter holds a Ph.D. from the University of Pretoria in Electrical Engineering. Additionally, he has authored and co-authored a number of journal and conference papers, as well as two books on wireless communications and is the named inventor or co-inventor on 31 issued patents with several more pending.