WIA Wireless Infrastructure Association

Wireless Infrastructure By The Numbers

2022 Key Industry Statistics

Published Q1 2023

This white paper was prepared for WIA by iGR.

Content

Executive Summary

Throughout the United States, wireless infrastructure keeps consumers and businesses connected, contributes significantly to the country's productivity, and propels America to become an increasingly mobile-first society. Wireless infrastructure comprises different types of towers, cell sites, antennas, radios and other equipment as well as fiber and data centers that enable cellular mobile networks, fixed wireless access, and in-building wireless networks. These networks use a wide range of spectrum including millimeter-Wave (mmWave), Citizens Broadband Radio Service (CBRS), C-Band, and other cellular bands.

This report quantifies the size of the nation's wireless infrastructure sector, including cell towers, indoor and outdoor small cells, macrocell sectors, annual

spending, and the American jobs that support this critical resource.
The U.S. wireless & mobile industry spent $11.9 billion building additional capacity and coverage into the nation's wireless networks in 2022. This does not include spending on spectrum or maintenance and ongoing network operations. In total, network operating expenses for U.S. wireless and mobile networks in 2022 topped $46 billion.

The following key statistics show the strength of the U.S. wireless infrastructure industry at the end of 2022:

- **142,100 cellular** towers were in operation;
- **209,500 macrocell sites,** not including small cells, were deployed;
- **678,700 macrocell sectors,** not including small cells, were in operation;
- **452,200 outdoor small cell nodes** were deployed;
- And **747,400 indoor small cell nodes** were in use, including private CBRS networks, DAS, small cells and mmWave and other licensed frequency bands.

Deploying and operating this infrastructure translates into jobs: **401,100 people or full-time equivalents were employed in the U.S.** to build, maintain and operate the nation's wireless and mobile networks, supporting 4G/LTE, 5G, indoor and outdoor networks and private networks.

As the numbers suggest, cellular towers and macrocell sites support more than one network operator. The efficiencies associated with colocation on U.S. wireless infrastructure has been a key reason for the success of the wireless ecosystem as a whole – this simply means that network equipment from multiple operators is deployed on the same physical tower, small cell or building. Colocation has many benefits, from improved economics to reduced environmental impact of infrastructure.

WIRELESS INFRASTRUCTURE BY THE NUMBERS

401,100
Wireless Infrastructure Jobs

$46B
Spent on Cellular Network Operation in 2022

142,100
Cell Towers

209,470
Macrocell Sites

678,700
Macrocell Sectors

747,400
Indoor Small Cell & DAS Nodes

452,200
Outdoor Small Cell Nodes

$11.9B
Spent on Cellular Network Construction in 2022

Wireless Infrastructure Association

Wireless Infrastructure Key Statistics

The country's wireless infrastructure keeps consumers and businesses connected across 50 states and nearly 3.8 million square miles, helping to drive the country's GDP of $23 trillion. But what is the scale of cellular infrastructure? How many towers, cell sites, sectors, and small cells are used? How many are employed to build and maintain the cellular networks?

Towers

An estimated 142,100 cellular towers were operating in the United States at the end of 2022. This figure comprises only the towers that support cellular networks and does not include towers used exclusively for municipalities, other government, emergency services, educational or other users. To be included in this count, a tower must host a cellular cell site (other non-cellular equipment may be hosted as well).

Importantly, outdoor small cells are not included in this count (outdoor small cells are detailed later in this report) – this number represents towers only. The Federal Communications Commission defines a small cell as being less than 50 feet from ground level – therefore, we define a tower as being any free-standing tower structure over 50 feet in height. Several designs are in use, such as monopole, guyed, and stealth towers.

Note that in 2022, the majority of towers in the U.S. are owned and operated by independent tower companies, with mobile operators owning a small minority. In the late 1990s and early 2000s, mobile operators started a process of divesting their tower assets (prior to this, the towers were owned by the operators) and the independent tower companies grew significantly. This model has benefited carriers as it freed up capital to invest in their businesses, including expanding their networks.

Macrocell Sites

Macrocells typically cover large geographic regions (i.e., miles in radius), and are loaded with different antennas and radios that allow mobile network operators (MNOs) to provide service across multiple spectrum bands. Most macrocell sites are located on towers and two or more MNOs share the tower. This is called colocation, discussed later in this report.

A total of 209,500 macrocell sites were in operation at the end of 2022, not including small cells. This figure includes macrocells mounted on towers and roof tops and refers only to macrocells used for cellular and fixed wireless access networks. Cell sites used exclusively for municipal, government, and emergency services networks are not included in this count.

The majority of macrocells are deployed on towers, with a smaller number on rooftops or other structures.

Macrocell Sectors

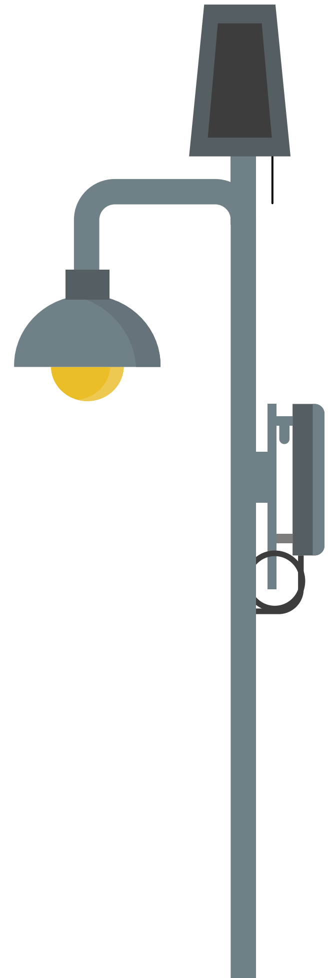
Each macrocell site is split into sectors – there are typically three or more sectors per macrocell. In the case of a three-sector cell site, each sector covers essentially one-third of the macrocell and includes its own radios, antennas and base-station equipment. Each sector will use one or more frequency bands.

Approximately 678,700 macrocell sectors were operating at the end of 2022, not including small cells. Again, this figure refers only to macrocell sectors used for cellular and fixed wireless access networks. Cell sites used exclusively for municipal, government, and emergency services networks are not included.

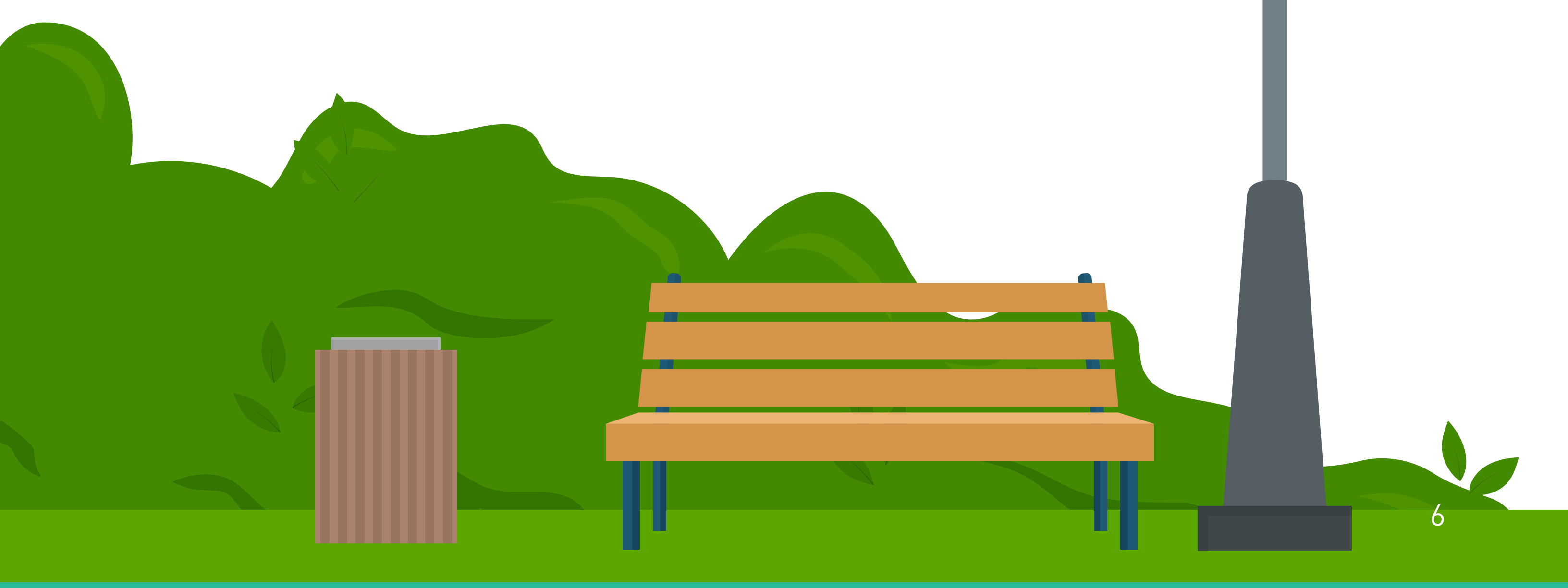
Outdoor Small Cells

Outdoor small cells, which the FCC terms "small wireless facilities," are typically deployed by mobile operators and cable multiple system operators (MSOs) to provide coverage in local areas, fill in dead spots and enhance capacity in high traffic areas.

In 2022, 452,200 outdoor small cell nodes had been deployed. Note that multiple nodes are usually deployed on a single small-cell pole or enclosure. This number includes licensed cellular bands (including C-Band), millimeter-Wave (mmWave) and Citizens Broadband Radio Service (CBRS) spectrum, as well as cells used for fixed wireless service and mobile. Outdoor Wi-Fi hotspots are not included.



Mainly due to the pandemic and the resulting changes in mobile bandwidth demand, the deployment of small cells from 2020-2022 lagged the original forecasts. The market is starting to accelerate, and more outdoor small cell deployments are expected in 2023 and beyond. As a result, the number of outdoor small cells is expected to rise in the next few years.



Indoor Small Cells And DAS

Indoor small cells are used to provide coverage and capacity in large buildings such as stadiums, airports, convention centers, hotels, office buildings, and multiple dwelling units, among other locations.

A total of 747,400 indoor small-cell nodes were in operation at the end of 2022. This includes private CBRS networks, distributed antenna systems (DAS), mmWave, and other licensed frequency bands – and comprises multiple nodes per system and per building. This number does not include indoor Wi-Fi access points for private or public networks.

As with outdoor small cells, in-building wireless deployment, including small cells and DAS, lagged during the pandemic – there were simply fewer people inside large commercial buildings demanding mobile bandwidth.

Demand for in-building wireless solutions is increasing as more people have started to return to work in the office and sporting events have resumed. As a result, the number of buildings with in-building wireless solutions installed is expected to increase in the next few years.

Success Of Colocation

Colocation on wireless infrastructure has been a key reason for the success of the infrastructure as a whole and a key driver for the success of the U.S. wireless industry. Colocation has many benefits, from improved carrier economics to reduced environmental impact of infrastructure.

Colocation is defined simply as putting multiple network or computing resources on the same physical infrastructure.

In the case of cellular towers and small cells, this means the ability to deploy multiple radios, spectrum bands, and multiple operators on the same infrastructure. Rather than each mobile operator having to build or lease a single tower, the same physical tower is shared between multiple operators.

Colocation is not always feasible in areas lacking sufficient existing infrastructure such as rural areas. However, even in rural areas, the possibility of an infrastructure provider recovering revenue from multiple wireless mobile operators increases the likelihood of a tower being built, and the ability of multiple mobile operators attaching to the same tower improves the economics for carriers to justify expansion into more remote areas.

With colocation, the economics of tower construction and maintenance can be shared over multiple operators. This may include not only the actual tower itself, but also ancillary systems such as backup power, shelters and cabinets, and cell site security.

The ability to collocate on existing towers, therefore, means that individual mobile operators are able to focus their capital on what they do best – designing and deploying the best mobile broadband networks in the world.

Not all towers or small cells have all mobile operators on them – each operator's network is different and has different geographic needs based on spectrum used, bandwidth demands, etc. As shown in this report, the number of macrocells is higher than the number of towers – this means that multiple macrocells are deployed on a single tower. In an urban or suburban area, it is not unusual to see two, three or more mobile operators on a single large tower. But in a more sparsely populated rural area, the rate of colocation will be lower.

Colocation also applies to small cells – in some cases, two operators' equipment may be deployed on a single small cell pole or roof top. This depends on the location and size of the small cell but given the difficulty with deploying outdoor small cells in urban areas (due to access, zoning and permitting, fiber, and power access, etc.), more small cell colocation is expected as the outdoor small cell market develops.

The U.S. colocation model has been very successful, so much so that it is being emulated in other regions. Europe is a good example – traditionally, each operator in a European market has deployed, owned and operated the majority of its own towers. This has led to situations where three towers may be built side-by-side on the same hilltop, which is inefficient and may detract from the overall aesthetics.

This situation is starting to change in Europe as mobile operators are starting to divest their physical tower assets to independent tower companies, which then look to colocation to improve the economics of their operations.

Finally, colocation also applies to in-building wireless solutions – DAS installations used in stadiums, hotels, hospitals, convention centers, airports and other large buildings share a single antenna installation among multiple mobile operators, reducing the cost of deployment and operations.

This also means less wiring and antenna equipment is needed in the building, which is important where space may be limited or sensitive areas where radio signals must be strictly controlled (such as the surgery area of a hospital).

2022 Wireless And Mobile Infrastructure Spending

2022 Build Spending

The U.S. wireless & mobile industry spent $11.9 billion **building additional capacity and coverage** into the nation's wireless networks in 2022. This figure is only for the deployment of new and upgraded networks, including the cost of network equipment, installation, construction of new towers and sites, engineering and design and associated network deployment costs. The cost of building and deploying private CBRS networks and in-building wireless networks is also included.

The $11.9 billion can be further divided by RAN, front/backhaul and core spending:

- RAN comprises the majority of the network build spending at $9.5 billion – this is base station equipment. In fourth-generation LTE technology, this is the eNodeB and in 5G, the gNodeB. Tower modifications, site costs and small-cell costs are also included. RAN costs associated with virtualization and Open RAN, such as commercial off-the-shelf (COTS) hardware are included in this figure.
- Spending on new or upgraded fronthaul and backhaul (essentially the fiber networks connecting the RAN to the 4G and 5G core) totaled $1.6 billion in 2022.
- Finally, spending on new 4G and 5G core network equipment in 2022 amounted to $815 million. Edge compute also has a role here for both applications and content at the edge of the network, but also to support RAN and core software.

Importantly, this does not include any spending on spectrum, and it does not include any spending on maintenance or ongoing operations. According to an analysis by Inside Towers, total capital expenditure by the U.S. MNOs (which includes spending on spectrum, capitalized operational and maintenance items and some non-network items) was forecast to reach $48 billion in 2022.

2022 Operating Spending

Operating expenses for U.S. wireless and mobile networks in 2022 totaled $46 billion. This includes spending on tower and small-cell leases, network equipment maintenance, fiber and backhaul leases, power expenses, and associated network operations costs. Again, this is for both outdoor and in-building wireless networks, including private CBRS networks.

This figure does not include any expenses for billing, customer care, or support costs associated with the subscriber base.

2022 Wireless And Mobile Infrastructure Employment

A total of 401,100 people or full-time equivalents were employed in the U.S. wireless infrastructure sector at the end of 2022 to build, maintain and operate the nation's wireless and mobile networks, including outdoor cellular networks, private CBRS networks, in-building wireless and fixed wireless access networks.

All employees at the tower companies are included in this calculation, since their workforces, by definition, are directly involved in the deployment and support of the mobile networks.

This figure does not include all the people employed by the mobile operators, original equipment manufacturers (OEMs), and construction companies as a whole, but includes those involved directly in the deployment, maintenance, and operation of the mobile networks. Specific job functions include:

- Network engineers to design, test, build, and operate the networks;
- Network equipment engineers for design, manufacturing, and deployment;
- Tower and small cell design, construction, deployment and maintenance;
- Fiber and backhaul design, construction, deployment and maintenance;
- Legal, financial and support functions associated with network design, deployment, maintenance, and operations.

In the case where a job function is split between the wireless and mobile telecom industry and another industry (for example, landline telecommunications or utilities), only the portion of the job associated with the wireless infrastructure industry is included in this figure.

Wireless infrastructure employment does not include any employment for billing, customer care, retail sales or support costs associated with the mobile operators, FWA providers or cable MSOs.

Conclusion

Wireless infrastructure, comprising cellular towers, small cells, networks, and the associated services and hardware, supports critical services that keeps the nation's consumers and businesses connected, driving the country's economic prosperity and social well-being.

Wireless infrastructure enables cellular mobile networks, fixed wireless access, and in-building wireless networks, using a wide range of spectrum including mmWave, CBRS, C-Band and the cellular bands.

The deployment of this essential infrastructure is responsible for creating more than 400,000 high-quality American jobs.

Methodology

The source for all data, unless otherwise stated, is iGR based on iGR's ongoing detailed wireless industry research.

Network Spending

- iGR's network cost model is based on the amount of data the network is expected to be able to support and deliver; initially this is primarily LTE though the amount of data carried on 5G is increasing rapidly.
- The cost model is based on the estimated cost required to add 1 GB of data capacity to the network and then to operate that capacity. Since the capacity of the network is known (based on the network technology), the cost of network buildout is dependent on the subscriber growth and the data usage of each subscriber. These known/estimated variables provide the total GB the network is likely able to deliver.
- Note that these costs do not include the cost of spectrum; the build spend is only associated with the cost of purchasing the necessary equipment and installing it in the network.

RAN: This is base station equipment. In LTE, this is the eNodeB and in 5G, the gNodeB. Tower modifications, site costs and lease costs are also included. Small cell costs and remote radio heads are also included over the forecast period as the industry moves to small base stations. RAN costs associated with virtualization and Open RAN, such as COTS hardware, are also included.

Front/Backhaul: This is the connection from the base station or radio to the core network. For today's wireless network, front/backhaul is provided by fiber.

Core, Including Edge/Data Center/Central Office (CO): For LTE, this is the Evolved Packet Core (EPC) including the serving gateway, packet gateway, MME, HSS, AAA, and PSCF. This has migrated to the new 5G virtualized core over the forecast period.

Edge compute also has a role here for both applications and content at the edge of the network but also to support RAN and core software. For 5G, this means storage, servers, content and application processors located at or near the cell site; this could be in a local data center, CO, or in a specific edge computing housing at the cell site or the cloud.

Employment Estimates

The wireless infrastructure employment number was calculated by iGR using both a top-down and bottom-up approach:

1. Defined the companies involved in each aspect of wireless infrastructure: mobile operators, tower companies, equipment OEMs, construction companies, etc.
2. Ranked the companies in order of size and obtained employment numbers for public companies.
3. Estimated the employment for private companies using existing research and public sources, where available.
4. Estimated the percentage of employees, for each company, directly in the deployment, maintenance and operation of the mobile networks. Specific job functions included are:
    - Network engineers to design, test, build and operate the networks;
    - Network equipment engineers for design, manufacturing and deployment;
    - Tower and small cell design, construction, deployment and maintenance;
    - Fiber and backhaul design, construction, deployment and maintenance;
    - Legal, financial and support functions associated with network design, deployment, maintenance, and operations.
5. For companies such as tower companies, all employees were included since by definition the whole company is involved in the build and support of wireless infrastructure. In the case where a job function is split between the wireless and mobile telecom industry and another industry (for example, landline telecommunications or utilities), only the portion of the job associated with the wireless infrastructure industry is included.

6. This detailed methodology was then compared with a top-down analysis using data from the U.S. Bureau of Labor Statistics (BLS). Data on individual job functions for the telecommunications industry and specifically wireless communications was then sourced.
7. This BLS data was then segmented into individual job functions – the jobs associated with the direct build and support of wireless infrastructure were then summed.
8. Using these two approaches resulted in two employment estimates that differed by less than one percent.
9. Note that this methodology was specifically developed in order to be repeatable to provide tracking over subsequent years.

Equating Network Spending To Capital Expenditure In Financial Statements

Many mobile operators release capital expenditure statistics in their quarterly and annual financial results. These numbers are reported in accordance with Generally Accepted Accounting Principles (GAAP) and each company's own policies with respect to how they book revenue, costs, assets and liabilities, among other items. All that reporting is subject to third-party and Securities and Exchange Commission scrutiny. Reconciling public companies' reported financial results with these network spending numbers is difficult because it is hard to derive network build and operating expenditures purely from the mobile operators' financial statement, for the following reasons:

- Some operators do not break out their mobile-only capital expenditures from the total, especially those that have extensive landline and fiber networks. The "network capital spending" figure from some operators includes other items aside from wireless network spending.

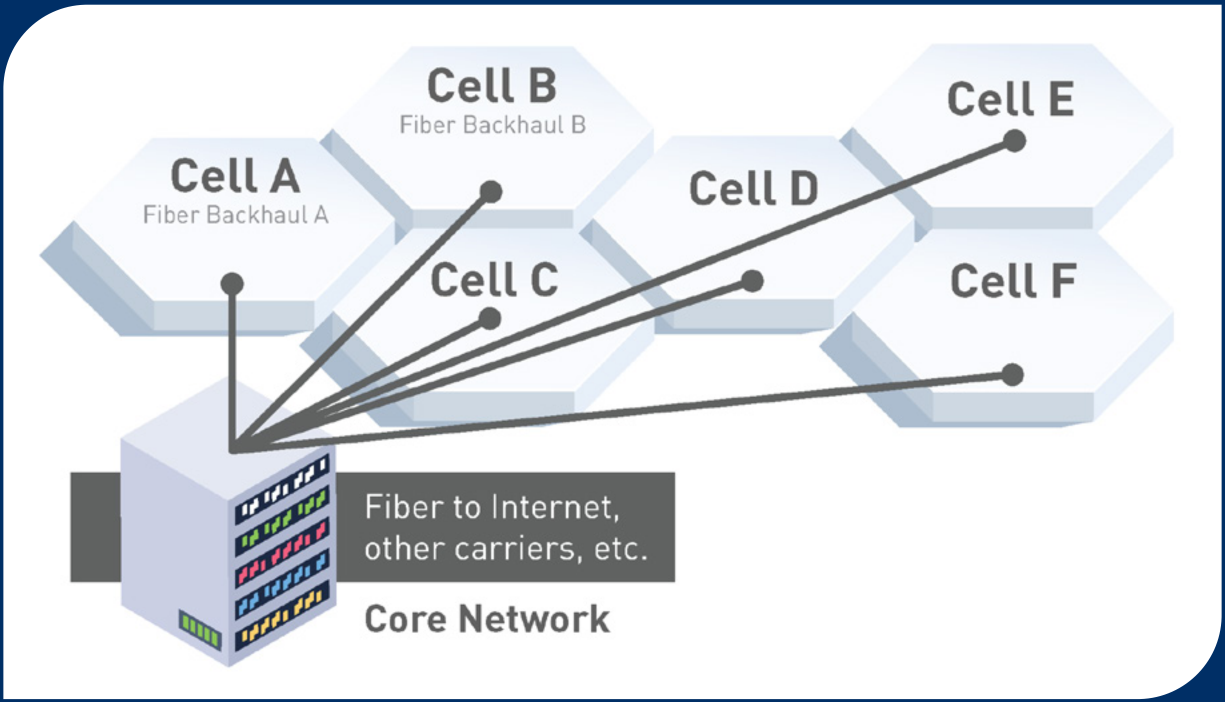
- Operators may include other non-network items in their capital expenditure statistics. For example, some mobile operators include the cost of building new retail stores in the capital expenditure numbers. Other non-network items are also likely included.
- Due to the details of some contracts, some operators have included future maintenance costs in network capital expenditures.
- Depending on how operators interpret accounting rules, other items not related to network building, operation or maintenance may be capitalized.
- Some operators include spectrum spending in their capital expenditures.
- Thus, it is important to understand that due to accounting policies at the various mobile operators, the infrastructure build spending forecast presented in this report cannot be directly equated to the capital expenditure numbers released by the mobile operators in their quarterly and annual financial results.

Appendix: A Primer on Wireless Infrastructure

Basic Architecture

How are the nation's cellular networks constructed? The following graphic provides a basic overview of what a cellular network looks like. Each cell comprises a tower (or small cell) with radios, base stations and antennas. The size of each cell varies according to the spectrum used and network design. Each cell is connected, usually by fiber, to the mobile network operator's (MNO's) core network. There is usually one core per market (often centered in a city) and is hosted at a local data center. Each core network is interconnected with the MNO's other cores.

Figure: Basic Mobile Network Architecture



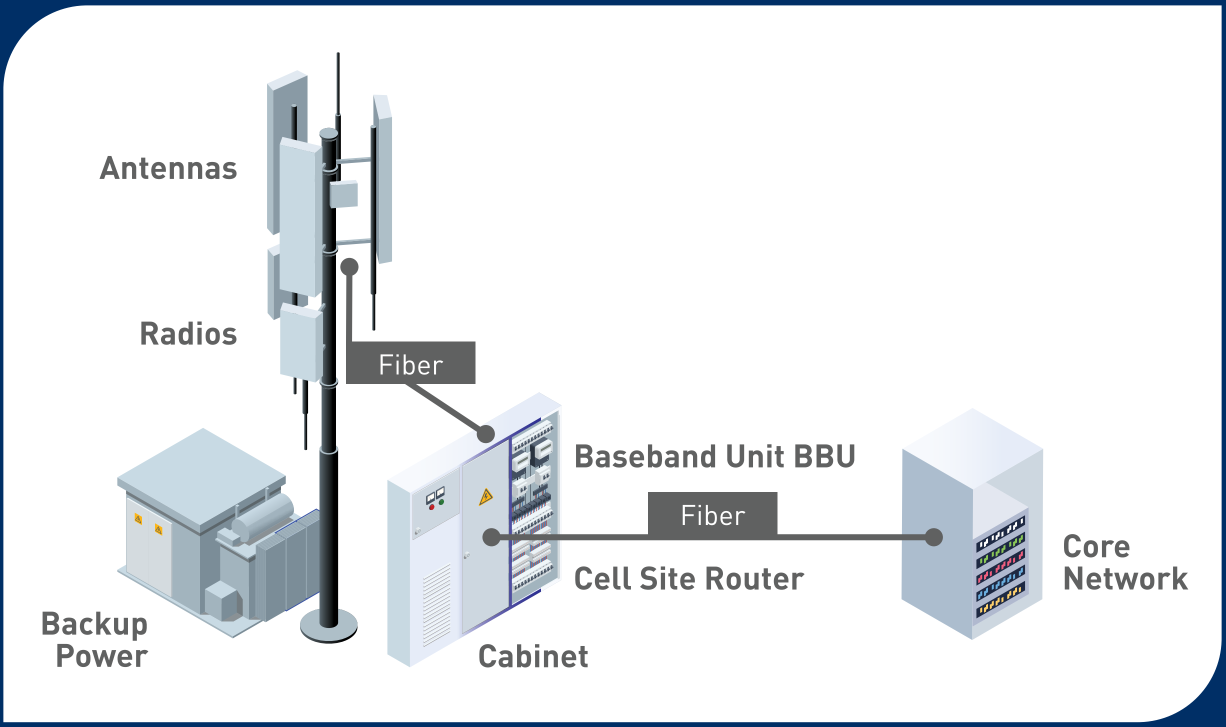
Source: iGR, 2022

Macrocells

To increase the network capacity and support more simultaneous users, cells are split into sectors. Macrocells are typically split into three sectors (but there could be more). Each sector acts as a cell site with its own equipment.

Each macrocell site contains specialized equipment, as shown in the following graphic. The majority of macrocell sites are deployed on a tower, but they can also be located on building roofs, inside church steeples, on water towers and in some areas of the country on electric transmission infrastructure, well above power lines.

Figure: Equipment At Every Cell Site



Source: iGR, 2022

As shown on page 21, each macrocell site includes the following equipment:

- **Tower:** There are several designs (monopole, guyed, stealth), but all cellular equipment is usually high up on the tower. Most municipalities have strict ordinances on what equipment can go where.
- **Radios located at top of the tower:** Modern cell sites locate the radios (which transmit and receive the radio signal to and from the end users) near the antennas. This cuts down on interference and signal losses.
- **Antennas:** These are usually inside an antenna array, which houses multiple antennas that work across independent RF bands. Separate antennas for each frequency band and for transmit and receive are required. Antennas are connected directly to radios, usually by short coaxial cables. Active antenna arrays are units that fully incorporate antennas and radios inside of one unit.
- **Baseband Units (BBUs):** These are the processing units that translate the signals telling the radios what to transmit. In most pre-5G installations, these units are deployed at the cell site. For newer 4G LTE sites and 5G technology, the BBUs have a new standardized architecture that allows them to be split into a distributed unit (DU) and a centralized unit (CU). Depending on what the MNO requires, these units can either be deployed at the cell site itself or at a more central location, or both.
- **Cell site router:** The router connects all the fiber inputs/outputs to the BBU, enabling connectivity to and from the site.
- **Fiber connectivity:** Typically, redundant fiber links are used to provide connectivity to and from the cell site. These fiber links connect users to the internet and the MNO's equipment back to its core network.
- **Core:** The Evolved Packet Core (EPC) and/or 5G Core (5GC) provide the control necessary to manage each user in the network, as well as policy and security enforcement and billing/rating.

- **Backup power:** All macrocell sites are connected to some type of backup power (e.g., battery bank, diesel generator). There is a growing trend to connect small cell sites to backup power.

Outdoor Small Cells

In heavily congested areas or in areas where there are cellular dead spots, mobile operators may deploy an outdoor small cell. This essentially uses the same technology as on a macrocell but is deployed at a smaller scale on a pole at street level, the roof or side of a building, on street furniture (such as street poles, traffic signals or signs) or on utility poles.

Various definitions for small cells are used in the industry, but to keep things simple this paper defines an outdoor small cell as any "small wireless facility" (SWF) that is deployed outdoors at or below 50 feet from ground level and is used for mobile/cellular voice/data connectivity. SWF is the acronym used by the FCC to distinguish between small cells and other types of outdoor cellular deployments (e.g., on macrocell towers/sites).

Various technical solutions may be deployed as outdoor small cells, including outdoor distributed antenna systems (DAS), a metrocell or a remote radio head (RRH). Small cells may incorporate multiple nodes and spectrum bands – in essence, a small cell node is equivalent to a sector on a macrocell site.

In-Building Wireless

This market is characterized by DAS and/or indoor small cells that provide wireless/cellular service inside a building and/or on a campus. Good examples include office buildings, colleges/universities, stadiums/arenas, convention centers, medical facilities, hotels, casinos and warehouses.

All the equipment required at a macrocell site is also required inside a building. This is the typical process associated with deploying an in-building wireless (IBW) system:

- The building owner contracts with a third party to build and operate a wireless network. The third party is a company that has expertise in installing in-building networks.
- The third party builds the network to MNO specifications using MNO spectrum bands. The MNO provides a "signal source" (equivalent to a base station), which is installed inside the building, as well as a connection to their core network. The in-building network then functions as a part of the MNO's network and the MNO will balance its outdoor, macrocell-based network to not interfere with the in-building installation.
- The IBW network is tested and certified by MNOs as necessary. Note that most IBW systems host two or more MNOs, though single-MNO IBW systems exist.

In-building wireless networks usually co-exist with Wi-Fi networks – they complement each other and use separate equipment.

The Wireless Infrastructure Association advocates for the deployment of wireless infrastructure across the United States, representing the companies that make up the wireless infrastructure ecosystem.

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