WHITE PAPER

How 5G Will Impact Physical Networks and What You Should Do To Protect Equipment

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Published: April 2019

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Introduction

Fifth generation (5G) digital cellular networks have arrived. Carriers are beginning to deploy the first phases of 5G to provide enhanced download speeds, and a strong buildout is expected going forward.

5G will initially bring slightly faster speeds than 4G LTE but will eventually bring up to 20 times the speeds of current 4G for certain applications. That will rival current landline speeds. However, 5G is not just a speed upgrade. It is a fundamental change in network architecture, a shift to more software-defined networking, and designed not just for fast downstream data, but for much faster and higher capacity upstream data as well.

It is also important to understand that 5G is not a carrier-only upgrade. 5G will impact all physical networks, including enterprise-owned premise networks. If you are responsible for ensuring availability and speed of the network to business users, it is important to be aware of what 5G enables and how it may impact your network.

This white paper, by Chatsworth Products (CPI), summarizes the impact of 5G on the physical network, and highlights advancements in equipment storage and remote monitoring that will help to protect your network as you prepare to upgrade.

The Path to 5G

In early 2012, the International Telecommunications Union (ITU), a United Nations specialized agency that coordinates shared global use of radio spectrum and assists with the development of technical standards, started the effort to implement 5G by 2020. The International Telecommunications Union – Radio Communications Sector (ITU-R), Study Group 5, Working Party 5D, initiated International Mobile Telecommunications (IMT) systems for 2020 (IMT-2020)[1]. Study Group 5 developed a timeline for research, discovery, testing and implementation of 5G network by 2020.

5G Key Capabilities

The ITU-R IMT-2020 specification (Recommendation M.2083-0, 09/2015) defined specific usage scenarios and key capabilities for 5G (Figure 1).

Usage Scenarios

- Enhanced Mobile Broadband (eMBB) – an evolution of 4G LTE mobile broadband services that support more users, faster connection and higher throughput for access to multimedia content, services and data used in evolving immersive technologies such as Augmented Reality and Virtual Reality (AR/VR), and real-time, multi-player online gaming.

- Ultra-Reliable Low Latency Communications (URLLC) – uses strict requirements for throughput, latency and availability to support time-sensitive wireless remote control of industrial applications, robots and autonomous vehicles.

- Massive Machine Type Communications (MMTC) – supports very large arrays of sensors typically transmitting a relatively low volume of nondelay sensitive data, including some Smart Home and Smart City, Internet of Things (IoT) and Industrial Internet of Things (IIoT) devices.

Figure 1: 5G will enable many forms of IoT and direct machine-to-machine communications.

Performance Targets

Table 1 summarizes the original IMT-2020 specification targets for 5G, their importance to each usage scenario, and compares them to IMT-advanced (4G LTE Advanced).

Usage Scenario	Capability	Description	IMT-2020 target (5G)	IMT-advanced (4G-LTE Adv.)
eMBB	Peak data rate	Maximum achievable data rate	10 Gbit/s (dl typ) 20 Gbit/s (dl max	1 Gbit/s (dl) 500 Mbit/s (ul)
eMBB	User-experience data rate	Achievable data rate across the coverage area	100 Mbit/s (typ.) 1 Gbit/s (max.)	10 Mbit/s
eMBB	Energy efficiency	Data sent/received per unit energy consumption (by device or network)	Equal to 4G	
eMBB	Spectrum efficiency	Throughput per unit wireless bandwidth and per network cell	3x 4G (est.) 45-bit/s/Hz (dl) 20.25-bit/s/Hz (up)	1x 4G 15-bit/s/Hz (dl) 6.75 bit/s/Hz (ul) Indoor, per cell: 3-bit/s/Hz (dl) 2.25-bit/s/Hz (ul)
eMBB	Area traffic capacity	Total traffic across coverage area	10 Mbit/s/m²	0.1 Mbit/s/m²
eMBB URLLC	Mobility	Maximum speed for handoff and QoS requirements	500 km/h	350 km/h
URLLC	Latency	Radio network contribution to packet travel time	1 ms	10 ms
MMTC	Connection density	Total number of devices per unit area	10^6/km²	10^5/km²

Table 1: Summary of 5G performance targets from the original IMT-2020 specification.

Note: IMT-advanced values are extracted from 2008 report ITU-R M.2134 and recommendation ITU-R M.2012. IMT-advanced standards are 4GPP LTE-Advanced by 3GPP and IEEE 802.16m.

As Table 1 illustrates, upon full implementation, 5G is a significant improvement over 4G LTE, but implementation will require new spectrum, architecture, infrastructure and software.

Building the 5G Physical Network

To achieve these capabilities and fully support the usage scenarios, new 5G specifications and standards have been developed, and new spectrum is being made available for 5G in each geographic region.

5G Specifications and Standards

The air interface for 5G is defined by the 3rd Generation Partnership Project (3GPP)[2], a global collaboration between telecommunications standards associations.

3GPP has developed three 5G-specific standards, which include New Radio (NR), LTE-M and NB-IoT.

A fourth standard (NB-IIoT) is currently in development (Figure 2).

- **New Radio** - 3GPP specifications Release 15, developed in 2017 and 2018, defines the New Radio (NR) standard. NR defines FR1 and FR2 described in the section below on 5G spectrum, and a nonstandalone method (mixed 4G/5G with software) and standalone (full 5G) method of deployment. Deployments are beginning to support eMBB scenarios in existing networks and to build the first round of FR2 systems.

- **LTE-M** - 3GPP specifications Releases 12-14, developed between 2015 and 2017, defined the Long-Term Evolution-Machine Type Communications (LTE-M) standard, which supports the MMTC scenario. LTE-M enables low-power wide area network connections for machine-to-machine connections. It provides average 1 Mbit/s downlink and uplink rates with 10ms-15ms latency.

- **NB-IoT** - 3GPP specifications Releases 13 and 14, developed between 2016 and 2017, defined the Narrowband IoT (NB-IoT) standard, which also supports the MMTC scenario. NB-IoT focuses on indoor coverage with high connection density for low-cost, long-life sensors. NB-IoT provides much smaller uplink and downlink rates (250 kbit/s) and allows longer latency (1.6 – 10 s) as compared to LTE-M. It is for noncritical sensors that report small amounts of data in regular intervals.

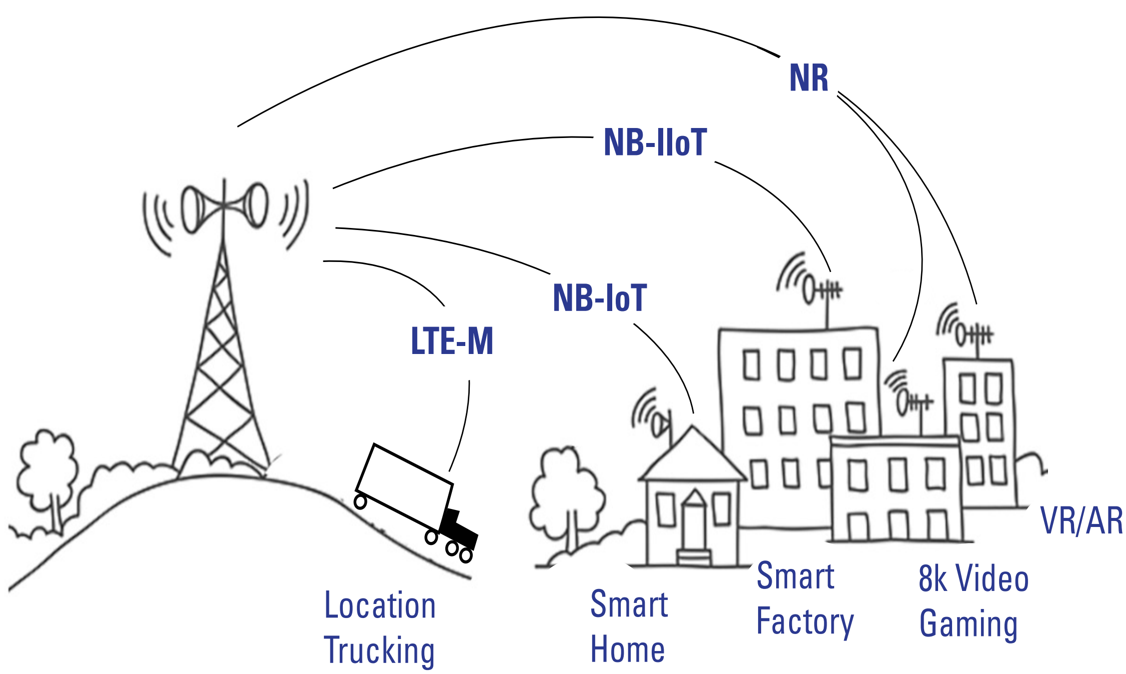


Figure 2: 5G will support faster download speeds for multimedia, connection of large arrays of sensors and direct machine-to-machine communications.

Additionally, the Institute of Electrical and Electronics Engineers (IEEE), 1914 Working Group[3], developed the IEEE 1914.3 Standard for Radio Over Ethernet Encapsulations and Mappings amendment and the 1914.1 Standard for Packet-based Fronthaul Transport Networks amendment to address the need to improve fronthaul networks, the connections which span between cell sites and centralized baseband locations, to achieve 5G performance targets.

- **IEEE 1914.3 Standard for Radio Over Ethernet Encapsulation and Mappings** – the IEEE 1914.3 amendment standardizes packet formats, allowing wireless cellular network traffic to travel across Ethernet broadband networks including a management model and control messages.

- **EEE 1914.1 Standard for Packet-based Fronthaul Transport Network**s – the IEEE 1914.1 amendment standardizes network architectures and new requirements for the fronthaul networks in Cloud Radio Access Network (C-RAN) or Virtualized RAN. This includes deployment scenarios, user data traffic, management and control plane traffic, data rates, timing and synchronization, network slicing and quality of service. It also introduces Massive Multiple Input Multiple Output (MIMO) technologies for fronthaul.

5G Spectrum, Bandwidth and Modulation

Per 3GPP NR, 5G will operate in two new radio frequency ranges. Frequency range 1 (FR1) is below 6 GHz, has a maximum single-channel bandwidth of 100 MHz and a maximum modulation format of 256-QAM. 4G LTE supports a maximum single-channel bandwidth 20 MHz channel and 64-QAM. Note that with 4G LTE, carriers can aggregate five 20 MHz channels to create a 100 MHz channel, and LTE-Advanced already uses 256-QAM. Regardless, 5G in the below 6 GHz spectrum, when using channel bandwidths above 20 MHz, provides better throughput than single-channel or aggregated 4G LTE or LTE-Advanced.

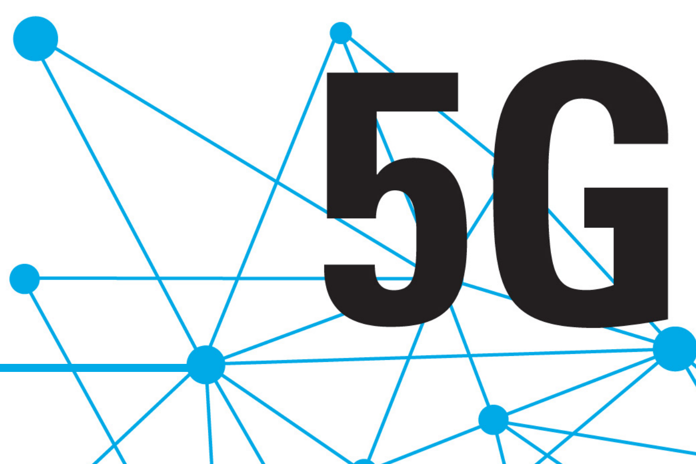
Frequency range 2 (FR2), also referred to as millimeter wave (mmWave), is between 24 GHz and 86 GHz, has a maximum single-channel bandwidth of 400 MHz, a minimum single-channel bandwidth of 50 MHz, and a new modulation format. FR2 (mmWave) will support the very high peak data rates of 10 Gbits/s and 20 Gbits/s but will require more infrastructure buildout to deploy (Figure 3).

U.S. Cellular Wireless Frequencies (MHz)

	600	700	800	850	1700	1900	2100	2300	2500	2600	3600	5200	24000 to 86000	
2G			X	X		X								
3G				X	X	X	X							
4G LTE	X	X		X	X	X	X	X		X	X	X		
5G FR1	X								X					
5G FR2													X	X

Figure 3: 5G FR2 mmWave will use new bandwidth for cellular wireless transmission.

Note: 1700 MHz is 1.7 GHz. 5G FR2 will only occupy some of the frequencies between 24 and 86 GHz. This graphic attempts to show that 5G FR1 will coexist in the current cellular wireless range (below 6 GHz), but 5G FR 2 is a completely new range, well beyond current frequencies.



The 5G Challenge

The main challenges of supporting 5G are related to the use of FR2 mmWave spectrum and increased bitrates. Cellular wireless signal range is limited by factors of radio frequency propagation and link budget. mmWaves suffer faster attenuation (signal loss over the distance traveled). They also will not penetrate most building materials. This means there will need to be more nodes in a given geographic area to provide the promised coverage and performance (Figure 4).

Factors impacting range:

- Height of antenna (line of site propagation)
- Frequency of signal used (attenuation)
- Timing limitations of technology
- Power of the transmitter
- Data rate of subscriber device
- Directional characteristics of antennas
- Reflection and absorption by buildings and vegetation
- Local geography
- Weather conditions
- Regulations

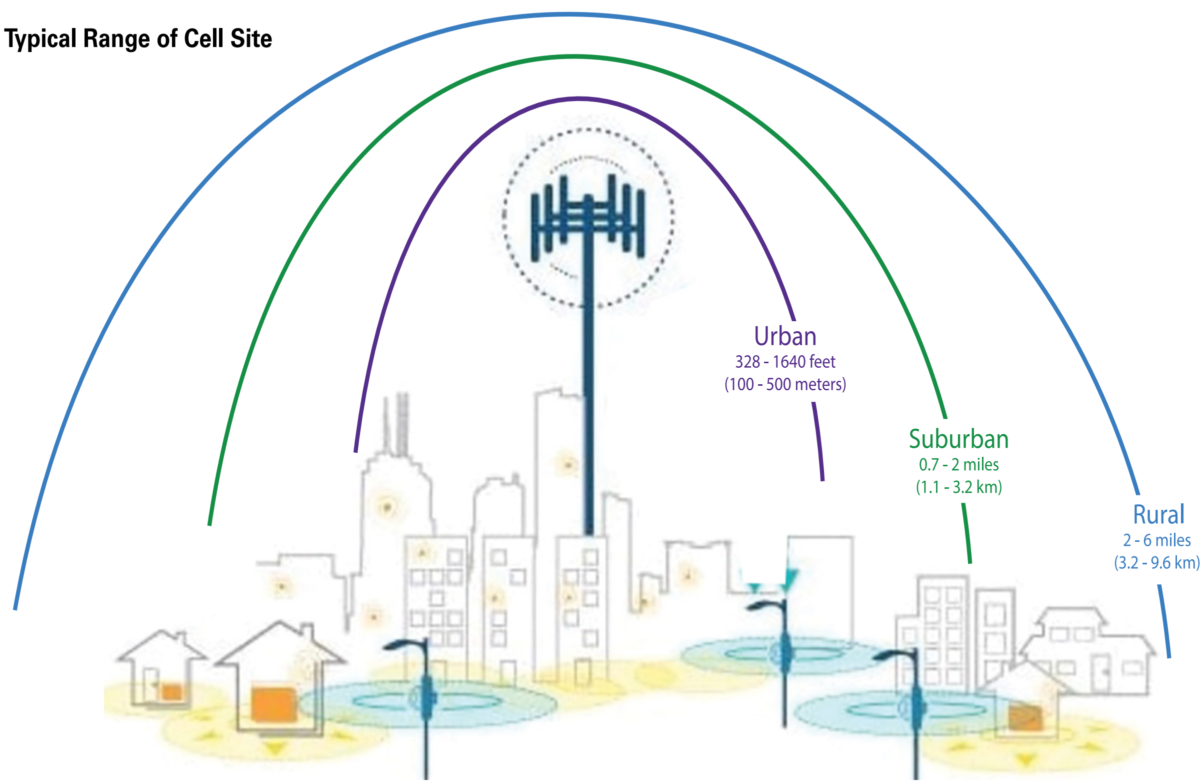


Figure 4: 5G will use mmWave spectrum. These higher frequency waves will attenuate faster, requiring network densification and other techniques to provide coverage and high quality of service.

New Technologies that Make 5G a Reality

To solve the signal challenges and deliver reliable connections, 5G networks will combine several technologies.

- **Massive Multiple Input Multiple Output Antennas** – network densification or the use of large numbers of Multiuser MIMO (MU-MIMO) antennas, which increase sector throughput and capacity density. Each MU-MIMO antenna supports multiple users, is individually controlled and may embed radio transceiver components. This is an extension of current MIMO antenna methods.

- **Beamforming** – signal processing to shape transmission waves to maximize area coverage. 5G mmWave signals will require clear line of sight. This method can be used to shape a signal in a particular direction when standard transmission coverage is not optimal or to connect with/between specific sites/devices.

- **Small Cells** – low-powered cellular radio access nodes that will supplement existing macro sites and micro cells. This is a way to increase density in highly populated urban areas and to improve coverage indoors.

- **Radio Convergence** – sharing cellular and Wi-Fi channels enabling multiple radio access technologies. This method has already been explored with 4G LTE Licensed Assisted Access (4G LTE-LAA) and provides high performance results in dense urban areas. It will be improved with 5G as speeds and packet techniques are coordinated through C-RAN in the Ethernet networks.

- **Edge Computing** – moving compute and storage closer to network users to run C-RAN software and to cache data to reduce network latency. Edge computing will improve user experience and enable faster machine-to-machine communications.

Physical Network Changes that Support 5G

As a result of new technologies, 5G will include some new approaches in the buildout of the physical networks.

- **More Antenna Sites (Network Densification)** – Massive MIMO Antennas means more antenna sites. You will see antennas on light poles along highways and on the sides of buildings in urban areas. The typical installation includes an antenna mast and may also include a small separate power electronics enclosure to provide power and network connections. Municipalities will designate the size, style and placement of antennas and any associated enclosures. Access to power and fiber cable or right of way with line of site for wireless fronthaul will be critical. Although the Federal Communications Commission (FCC) issued a declaratory ruling (FCC-18-133)[4] to help accelerate wireline broadband deployment, you may need to source custom antennas and custom enclosures to match the municipal requirements.

- **New Small Cell Locations** – Small cells will be located indoors and outdoors. Placing small cells will also require connection to power and network, and possible consideration for thermal management. It will be important to secure the network and power connections and the small cell. Additionally, if located outdoors, enclosures will need to be environmentally rated. Use of composite enclosures instead of metal enclosures will reduce signal interference.

- **Adapting Enterprise-Owned Wi-Fi and DAS** – Radio convergence will require additional routers, compute and data storage in carrier and enterprise networks. When updating enterprise networks for Wi-Fi or DAS upgrades, consider methods for radio convergence, as well as simultaneously upgrading other enterprise technologies such as Power over Ethernet (PoE). Note that IEEE will issue 802.11ax[5] in 2019 to further increase Wi-Fi bandwidth and throughput.

- **Edge Data Centers** – moving compute and storage closer to users will mean the creation of computer rooms and edge data centers inside urban areas. These will be smaller, more dispersed sites, not the typical large cloud or colocation environments. They will be interconnected and may not require the robust, highly redundant architecture of previous central office configurations or ANSI/TIA-942[6] data center Tier 3 concurrently maintainable site and Tier 4 fault tolerant site infrastructures. However, they may also need to be placed in harsh environments such as on rooftops, in a space previously used as an office space, in warehouses, or in shipping containers nearby to cell sites. Carriers may need to utilize environmentally rated enclosures with remote monitoring and access control to house compute and storage.

  Carriers will also want to consider compute platforms that can be deployed quickly and do not require specialized technicians. Standard computer and storage equipment is designed to mount into 19" EIA equipment racks similar to those used in most cloud and colocation data centers.

  However, Open Compute Project racks[7] are another option that use direct current power and may retrofit into central office sites. Alternately, Open19 Project compute platforms[8] offer an easy way to prestage and deploy compute quickly in 19" EIA racks without complex system compatibility concerns. It allows you to buy computers from multiple sources, but all systems have a uniform racking and connection method. Regardless, facilities and enclosures that house computer and data storage equipment will also need to address power and cooling for the equipment.

Alternately, there is a new type of edge colocation service provider focused on developing infrastructure to provide faster connection of carrier microsites to Internet Exchanges like VaporIO, EdgeMicro and DataPoints edge colocation data centers. Service providers are also offering software services.

- **More Fiber to Connect Sites** – higher data throughput means more data transport. Additional fiber will need to be placed to interconnect antennas, small cells, enterprise networks and edge data centers.

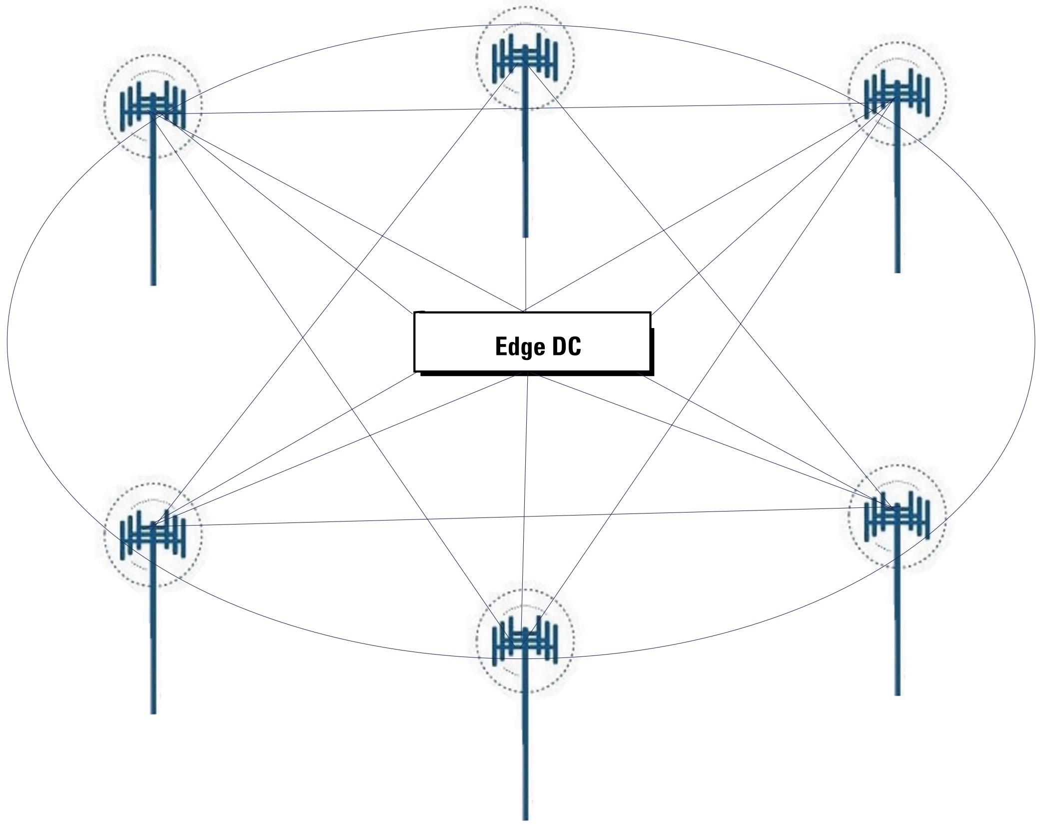


Figure 5: 5G will result in more microsites, especially in dense urban areas. The arrays of antennas will be interconnected to edge data centers for local compute and faster access to Internet Exchanges.

Fast Fact

For more details on networking changes in enterprise-owned networks, download the white paper Four Technologies That Will Affect Your Enterprise Network, and How To Support Them In Your Premise Networks at https://www.chatsworth.com/white-papers.

Selecting the Right Enclosure for 5G

Although not the most complicated component of the physical network, enclosure solutions are the first line of defense in protecting your electronics, information and communications technology (ICT) equipment. Here are a few key considerations when selecting enclosures to store and secure equipment in your physical network.

1. Enclosure Type

Enclosure type refers to the level of environmental protection the enclosure provides. Enclosures can be specified according to the National Electrical Manufacturers Association (NEMA) Standard 250 Enclosures for Electrical Equipment[9] or the International Electrotechnical Commission (IEC) Standard 60529 Ingress Protection Marking[10] to designate a level of environmental protection against particulate or liquid penetration and for corrosion resistance.

Indoor enclosures in controlled environments, such as computer and equipment rooms are often open to allow airflow (Figure 6). Enclosures located outside of these controlled spaces need a degree of protection against particles and liquid penetration (Figure 7). If located near chemicals or salt air, the enclosure will also need corrosion protection.

Figure 6: Example of a Type 1 (IP20) enclosure (cabinet) typical of the style used to house compute and data storage equipment in controlled environments such as data centers and computer rooms. Doors are vented to allow front-to-rear airflow. In some instances, ducting is used to guide hot air away through the top of the cabinet. Photo of CPI F-Series TeraFrame® Gen3 Cabinet with patented Vertical Exhaust Duct.

Figure 7: Example of a Type 4 (IP66) industrial enclosure typical of the style used to place compute or networking in harsh environments. This type of enclosure is completely sealed when closed to prevent penetration of dust and liquid. It can be fitted with a cooling unit when used to store compute or network switch equipment. Photo of CPI RMR® Free-Standing Enclosure.

Table 2 provides a simple guideline to protection ratings for common enclosure applications.

NEMA 250 Type Rating	**IEC 60529 IP Rating**	**Standard Material, Construction and Finish**	**Application**	**Degree of Protection**
Type 1	IP 20	Mild steel, welded,painted	Indoor use in controlled environments, data centers, equipment rooms, office spaces.	Minimal protection against particulate or liquid penetration.
Type 12	IP 55	Mild steel, welded, painted	Indoor use in warehouse or manufacturing environment.	Medium protection against particulate and liquid penetration.
Type 4	IP 66	Mild steel, welded, painted	Indoor or outdoor use.	High protection against particulate and liquid penetration.
Type 4x		Composite or stainless steel	Indoor or outdoor use.	High protection against particulate and liquid penetration and corrosion protection.

Table 2: Environmental protection ratings and their recommended applications.

Fast Fact

For more details on enclosure selection for controlled environments, warehouse, manufacturing and outdoor spaces, download the white papers Key Elements of a Successful Data Center Cabinet Ecosystem and Extending the Network Into Nontraditional Spaces: an Enclosure Selection Guide for IT Systems Administrators That Support IoT at https://www.chatsworth.com/white-papers.

2. Power Distribution and Remote Monitoring

Enclosures that house compute, data storage or network equipment require multiple power connections for equipment. A rack-mount Uninterruptible Power Supply (UPS) and Power Distribution Unit (PDU) are primary options. UPSs condition utility power and include a battery to provide ride through power if utility power is lost. UPSs typically have a few connections for equipment. In larger configurations, a room-level UPS may condition power and PDUs are used in each enclosure to provide multiple connections for equipment. UPS and PDUs offer optional remote monitoring of power. Monitoring power helps you optimize site utilization. PDUs may also offer remote control of power (the ability to toggle power to outlets and equipment) to reset equipment, remote environmental monitoring to ensure proper conditions and integrated remote access control to protect unauthorized access to equipment (Figure 8).

Figure 8: Rack-mount PDUs distribute power to equipment within the enclosure and can provide remote power monitoring and outlet control. Photo of CPI Switched Pro eConnect® PDUs.

3. Thermal Management

Environmental enclosures are sealed to protect equipment from particles and liquid penetration and may require a cooling unit to remove heat generated by equipment. Similarly, a heater may be required in very cold environments. Alternately, when equipment is placed in a more traditional equipment room, airflow management accessories should be used to separate hot and cold air within the enclosure and the room. This allows adjustments to the cooling system that improve cooling efficiency and reduce overall cooling cost.

Figure 9: Electronic locks restrict access to equipment and will provide an audit trail of each access attempt. Photo of CPI Electronic Access Control solution.

4. Access Control

If access to your facility is tightly controlled, you may not need to add access control to your enclosures. Otherwise, remote enclosures need to be secured to protect equipment. In the case of computer enclosures, an electronic access control system will maintain a digital log of access attempts to enclosures and allow fast assignment or removal of access authorization rights. Electronic access control simplifies key management and provides a record of access attempts (Figure 9).

5. Modification and Kitting

There are several standard enclosures for protecting small electronics, access points, computers and network switches. However, your site or application may require the modification of an enclosure to include a different door, latch and lock, equipment-mounting bracket, method of attachment, custom openings, finish or color. Some enclosure manufacturers offer modification services and custom design engineering. Kitting is also an important service. Assigning custom part numbers and kitting accessories will help you with rollouts to coordinate enclosures to the correct regions and equipment.

Conclusion

5G will enable a wide range of new applications including more AR/VR devices for connected learning, multisensory technologies such as remote surgeries in connected hospitals, and higher yields for sensors in agriculture, to name a few. Anticipate strong buildout of telecom infrastructure to support the new 5G physical network. That buildout will include network densification with small cells and microsites and new edge data centers to provide compute and storage.

Each site will need one or several enclosures to protect electronic equipment. Enclosure selection includes consideration of how to power and cool equipment and how to control access to equipment.

CPI is a proven expert in the design, manufacture and customization of enclosures. Our expertise includes thermal management and remote monitoring for enclosed equipment. We offer solutions for indoor and outdoor applications and staff applications engineers to assist with rapid selection, modification and customization of enclosures to match specific requirements. Please contact a CPI Technical Support Specialist (techsupport@chatsworth.com) for more details.

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