



Advanced Wireless Backhaul for the Smart Grid

Introduction

The information explosion is making possible the convergence of utility and telecommunications infrastructures. Bringing power generation, transmission and distribution close to consumers, the coupling of real-time, two-way information capabilities with delivery and consumption of power, the smart grid promises to boost energy efficiency while delivering it instantly where and when it is consumed.



There are two main reasons for creating the smart grid. First, today's numerous, disparate grids are outdated. In order to take advantage of advancing information technology, they must be modernized. Second, the benefits are substantial. The smart grid improves safety, increases efficiency, optimizes existing assets, enhances reliability, improves quality of power, reduces dependence on imported energy, minimizes environmental impact and contributes to national security. All stakeholders—utilities, consumers and the country at large—realize considerable value.

The smart grid is a bi-directional supply chain that employs information technologies to connect energy generation facilities to transmission and distribution networks and onto consumers. This bi-directional aspect does not exist in older power grid systems which are often inefficient and difficult to manage in the event of malfunction. Moreover, older systems cannot cope with the vast information flow of the smart grid.

The creation of the smart grid requires construction, on an unprecedented scale, of an automated, distributed and secure control system based on a high capacity, always available, flexible communication network. Ultimately, the network will require a packet-based transport infrastructure that supports secure and reliable transport of multiple applications while ensuring mission critical-grade quality with low latency and granular differentiation of services. Immediately, the network must support, and even enhance, the capabilities of legacy TDM (T1/DS1) services while providing a flexible and affordable path toward ongoing modernization.

In order to reap the substantial benefits of the smart grid, reliable and secure backhaul of its communication network is one of the most challenging tasks of forward-looking utility operators.



Herein, we look at the important smart grid applications, their requirements for advanced backhaul and Ceragon's product offering for meeting current and future demands of the smart grid network.

Wireless (Microwave) and Fiber Cable Deployments

Once deployed, fiber provides a tremendous amount of capacity that can satisfy demand for smart grid applications. However, there are considerable problems with fiber. Fiber deployment is a time-consuming and expensive activity—right-of-way permits and the labor intensiveness of trenching add significantly to the cost and the time required. The expenses for trenching and deploying fiber increase rapidly with distance, so, if you have to cover distances, fiber can cost too much.

In contrast, **microwave deployment usually costs a fraction of fiber**. It's easy to deploy, provided that you obtain the requisite spectrum permits. Deploying a microwave network over tens, or even hundreds, of kilometers/miles can be accomplished in just weeks.

Microwave is also quite flexible. While fiber is in the ground and, practically, cannot be moved, a microwave site can be moved or re-directed to accommodate traffic and topology changes in the network. These kinds of changes take only days or weeks.

In fact, even having the fiber in the ground does not guarantee problem-free transmission. Fiber breaks seem to be an all too frequent condition. In a particular large country, there are, on average, fourteen fiber breaks per 100km per year, adding up to a colossal 2,200 annual hours of network down-time. All fiber networks suffer breaks and these can be catastrophic to operations.

The reliability of microwave, on the other hand, is excellent. Network operators can rely on microwave to remain operational and to provide good service for very long periods of time. The MTBF of leading microwave systems is now in excess of 100 years.

Today's **microwave technology provides impressive capacity** that can be measured in gigabits and is often enough for most, if not all, smart grid applications. Innovative technologies, like Ceragon's multi-core radios, advanced modulation, and multi-carrier Adaptive Bandwidth Control empower operators to provide fiber-like capacities with all the benefits of wireless transmission.

Where it makes sense to deploy fiber, one still needs a high-capacity, reliable backup network especially for mission-critical applications. **Microwave is a great backup for fiber**. One fiber network alone is expensive to deploy, so it makes sense to use microwave to provide extra cost-effective network availability in case of fiber network failure. Today, there are many schemes for automatic switchover between fiber and microwave networks and this is a very practical solution that adds considerably to network reliability.



Smart Grid Applications

Smart grid applications can be organized into four areas for meeting the goals of efficient power delivery and information collection:

- Consumers applications
- Workforce applications
- Delivery applications
- Security applications

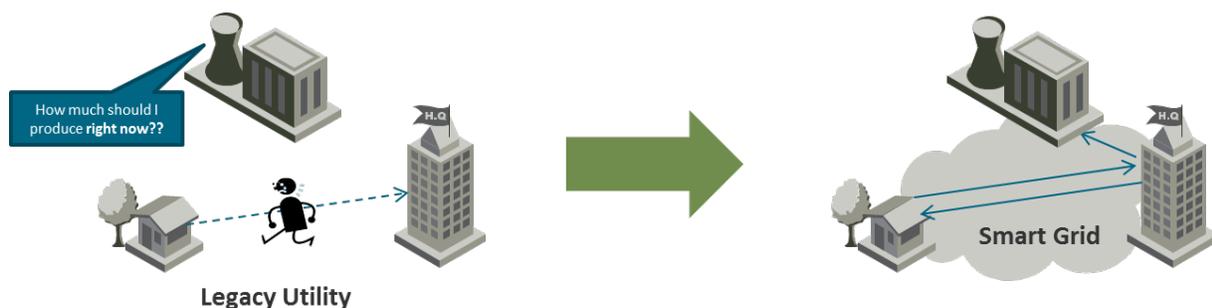
Ceragon offers advanced, cost-effective wireless solutions for each area.

Consumer Applications

Advanced Metering Infrastructure (AMI)

Chief among the consumer applications is the ability to read and tune power-consumption meters automatically and remotely.

In today's legacy grids, meters located at consumer end-points are passive, mere measurers of periodic power consumption. The meters are read locally by utility employees on foot who collect data for input into customer billing systems. Hand-held, automatic data collection devices somewhat automate the process, but they do not alleviate the substantial cost, time and tedium involved in the human effort of regularly visiting each and every meter.



Advances in technology now allow for installation of smart meters on consumer premises. Smart meters can monitor and report on consumer consumption instantaneously. Besides the immediate benefit of automating billing operations, reducing the size of the data-collection workforce, and decreasing the considerable time required for data collection and compilation, AMI enables a new level of benefits for both power utilities and consumers:

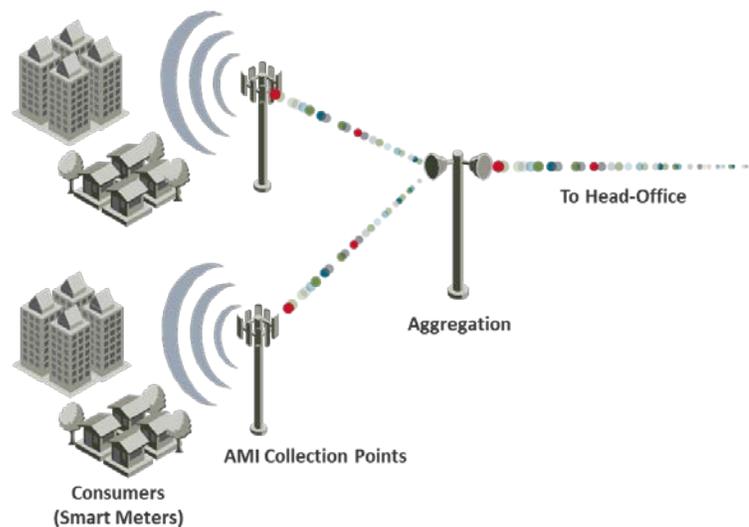


- **Real-time demand response:** The *generating edge* of the grid would be most efficient if it could produce just the right amount of energy at every given moment. Over-production of energy is inefficient and costly while under-production impairs service to consumers and can result in outages. Using the aggregated *real-time consumption* feedback of AMI, utility companies can instantaneously synchronize supply of power with consumption.
- **Smart energy consumption:** With the new ability to acquire real-time information on energy consumption on a per-customer basis, utilities can engage their customers with incentive plans (e.g., dynamic pricing per peak/off-peak hours) for smart energy usage. In addition, utilities can consider suitable *micro-generation* schemes for individual consumers (e.g., rooftop solar panels) and even directly control loads on customer premises allowing the utilities to alleviate peak demand toward more consistent and efficient power-usage schemes.

AMI Backhaul

Wireless AMI backhaul can be implemented in three stages:

- individual meters are connected to local collection points
- local collection points are backhauled to higher capacity aggregation points
- aggregation points are then backhauled to the utility's network operations center





In terms of information requirements over the smart grid, AMI makes relatively light demands on capacity and availability. Data from smart meters is concise and transmitted just every few minutes/hours. Furthermore, if, for any reason, a meter cannot report at this moment, it can hold its data until polled again.

As individual AMI data is neither mission-critical nor voluminous, end-to-end availability and latency requirements are relaxed. Hundreds, even thousands, of individual smart meters can report their periodic status data to a collection point via existing infrastructure (like copper wire) that is already available in domiciles, factories, buildings and other types of consumer facilities, or by any other wireless access technology like Wi-Fi, WiMAX, 3G mobile networks and LTE/4G.

Transmission between collection points and aggregation points requires more capacity than local collection, but is comfortably within the capabilities of cost-effective wireless (microwave radio) communications. With wireless, communications between multiple collection points and an aggregation point can be quickly and cost-effectively set up virtually anywhere.

Since some collection points might be located in urban environments where line of sight is not always available, data transmission can be performed effectively by means of non-line-of-sight (NLoS), point-to-multi-point (PtMP) radio connectivity.

Workforce Applications

Mobile Workforce Management

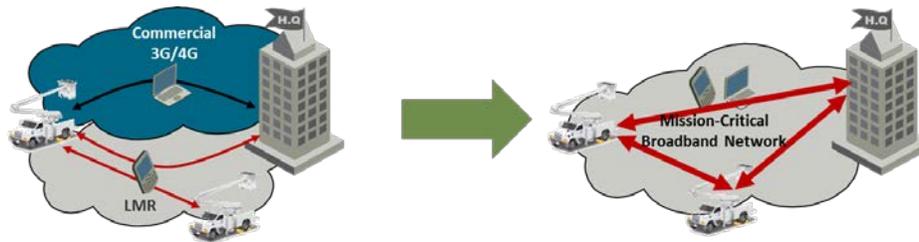
Power utilities employ a considerable workforce of highly mobile managers and technicians who service the entire span of the power grid from generation facilities to consumers. Utilities need their mobile workforces to be in constant touch with headquarters and control centers. Workers in the field need real-time access to data stored in distant data centers.

While traditional Land Mobile Radio (LMR) networks might be sufficient for the voice-only communications of field personnel, much more capacity is required now. Field personnel now carry smartphones, tablets and other advanced mobile data devices. Vast quantities of data, supervision, control, security and other applications need to be available at the technician's fingertips while out in the field.

Mobile Workforce Management can include many applications that require high volumes of on-demand data such as customer lists, visit schedules, maps and real-time grid status reports. These applications demand high capacity of always-available networks in order to make efficient use of the workforce. To date, this need for mobile data can be served by commercial 3G mobile networks, but



these networks cannot provide mission-critical, secure and assured service; Mission-critical broadband connectivity is needed.



Power Delivery Applications

Substation Automation

Substation automation is the practice of collecting data from different components of substations (e.g., circuit breakers, transformers, capacitor banks). It includes extraction and analysis of significant volumes of information from the components and controlling operations of substations, transmission networks, distribution stations, etc.

Legacy Supervisory Control and Data Acquisition (SCADA) systems are very limited in the data they can collect, their scalability, and the control functions they offer. Modern SCADA systems, comprising many types of intelligent electronic devices (IEDs), provide much higher management and control capabilities and thus much more two-way information flow. A new protocol, IEC 61850, aims to standardize substation automation and includes Ethernet as its transport protocol, not available on legacy networks. IEDs continue to get smarter and their information needs continue to grow. Smart grid SCADA systems require increasingly high-capacity and flexible data communications.

Grid Monitoring

Teleprotection is an intelligent interconnected system of relays that monitors the flow of electricity in transmission lines. It rapidly isolates faulty parts of the transmission network in order to prevent widespread blackouts. To function, it requires constant comparison of voltages and current characteristics between the relays in order to detect faulty behavior as early as possible.

Both SCADA and teleprotection applications are highly mission-critical to power providers. While not requiring copious quantities of network capacity, they do require very low and symmetrical latency as well as mission-critical availability since the result of not performing the right action at the right time may be costly and even hazardous to human life.



Another important constraint imposed by these applications is backwards compatibility. Albeit inferior, legacy SCADA and teleprotection systems will remain operational until they are gradually replaced by modern systems in a long process which will take years to complete. Since these legacy versions are based on TDM communications, viable TDM support and cost-effective evolution is required alongside seamless evolution to the packet-based smart grid.

Security Applications

Peripheral Site Security

Utilities are mission-critical infrastructures, serving and affecting the lives of millions of people daily. In fact, even a single substation may serve tens of thousands of people. Some substations are located in unprotected residential neighborhood or remote, sparsely populated rural areas making them easy targets for attack, looting, vandalism and sabotage.

With the proliferation of cyber terrorism, smart grid networks are constantly in the sights of domestic and foreign adversaries. Utility facilities and substations have strategic significance and can become the targets of terrorist attacks. As a result, site security and video surveillance is a growing sub-application in the utilities market.

The smart grid supports much tighter, automated security measures with networked sensors, video surveillance and warning and alarm systems. These security devices and applications generate high volumes of data that must be continuously transported to control centers. Real-time security applications require very high capacity and 24/7 availability.

Information Security

Consolidating multiple application-specific networks into one multi-service communications network increases the risk on the security of the information. The thousands of devices (sensors, meters, controllers, etc.) connected to the network must be protected from infiltration and eavesdropping for untoward, illegal and harmful purposes. Therefore, extensive security measures must be deployed in order to protect the network itself and its flow of vital, sensitive information.

Ceragon Solutions for Smart Grid Backhaul

The requirements of the growing volume of smart grid applications are diverse. Different types of network access technologies are used for different applications with varying capacity, coverage and footprint constraints, as well as latency and availability requirements. While mobile networks' 4G/LTE holds the promise of a unified access technology for these applications, the lack of sufficient LTE infrastructure, its high deployment costs and the lengthy deployment plans in most areas for this



nascent technology necessitate the use of additional access technologies such as WiMAX, Wi-Fi, RF mesh and commercial 3G networks. Taken together, these technologies can be used to construct and operate the smart grid.

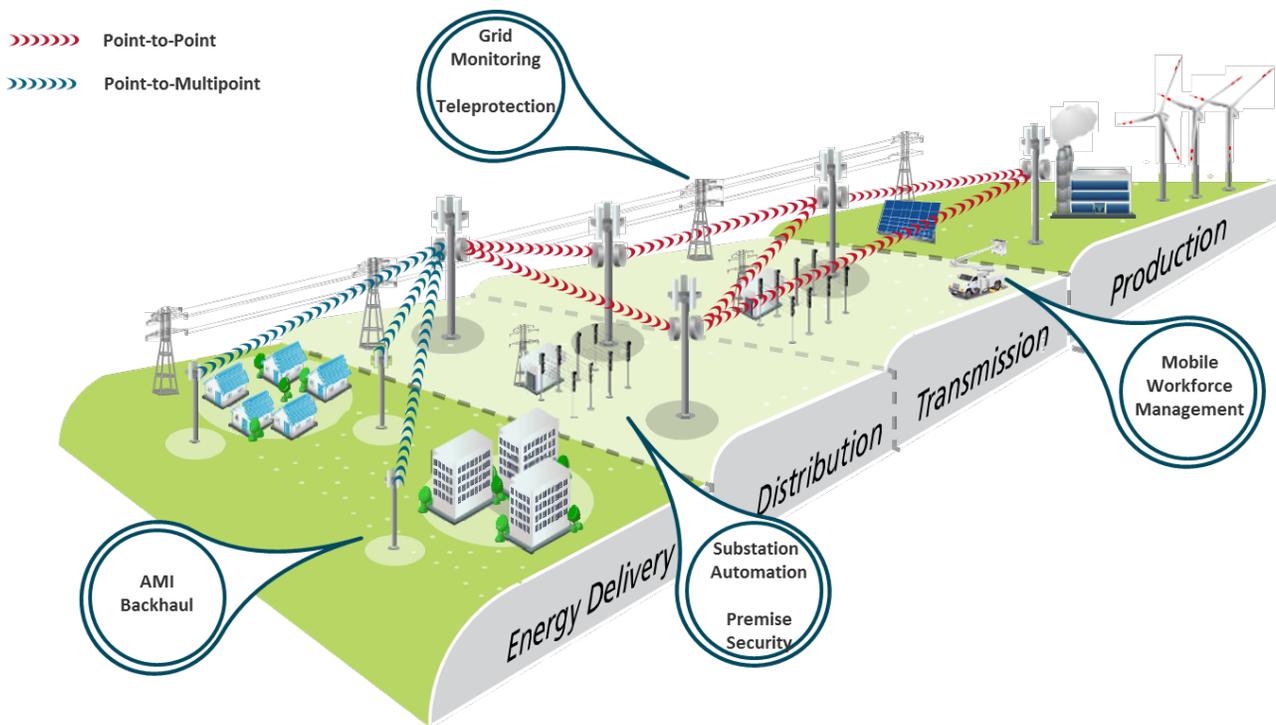
Ceragon's comprehensive solution portfolio addresses the myriad requirements of power utilities as they evolve their legacy networks to reap the benefits of the smart grid. The array of Ceragon products provides high-capacity, flexible, microwave backhaul solutions that are deployed within the transmission and distribution segments of the network. A low-CAPEX, quick-deployment alternative to fiber optics, Ceragon's wireless products meet stringent latency and availability requirements while reducing operating costs and expediting the operator's return on investment. Ceragon solutions constitute the lowest total cost of ownership in networking.

- **High availability, reliability and resiliency:** Smart grid networks must service mission-critical applications. Therefore, backhaul systems transmitting critical information to and from the field need to be resilient and reliable. This translates into technical requirements such as extraordinarily high MTBF with equipment redundancy and resilient network topologies.
- **Powerful signal strength:** High transmit power gain allows for deployment of longer links and the use of smaller antennas reducing capital expenditure, tower load, leasing expenses and maintenance costs.
- **Differentiated services:** The use of a common infrastructure for applications with differing capacity, latency and availability requirements necessitates a regimen of effective control over the quality of service (QoS) and dynamic provisioning of services by scenario. The QoS engine should be tightly integrated with the microwave equipment in order to cope with dynamic link conditions which affect capacity and prioritization of traffic.
- **Ultra-low latency:** Mission-critical information flows must be transmitted in real time with no hesitation. Low latency is required from all network equipment all the way through the transport network.
- **Future-ready while supporting legacy:** During the migration phase from today's networks to the smart grid, legacy and new services will co-exist. Backhaul networks will need to be flexible to support simultaneously TDM and Ethernet in the migration phase. Over time, they will need to migrate smoothly to all-Ethernet with support for remaining TDM services.
- **Compactness:** Since there is a wide variety in types of premises for hosting network equipment, the physical footprint in equipment shelters can already be substantial. The new



communication equipment added to these systems as the networks are migrated forward must be compact taking up minimal rack space and requiring little additional power for operation.

- **Security:** With the proliferation of cyber terrorism and crime, smart grid networks are constantly in the sights of domestic and foreign adversaries, and sophisticated criminal elements. Networks must be secure at all levels, from protected management interfaces that block access from unauthorized users, to payload encryption that ensures that mission-critical data cannot be collected or altered by hostile forces.



Depicted above is the topology of a smart power grid showing the appropriate types of microwave deployments.

From the production site (on the right) to and through the transmission network all the way to distribution substations, high power, long distance, point-to-point microwave links provide cost-efficient and reliable connectivity. Mobile workforces can be accessible via cellular and WiMAX networks maintaining contact with central operations that dispatch work crews based on real-time performance information from the field.



Substations communicate in real-time with operation centers providing automatic monitor and operation information. High speed, long distance microwave links provide ample bandwidth for automatic, remote control.

Substations can also serve as aggregation points for clusters of meters that communicate via efficient point-to-multi-point networks in licensed and unlicensed bands.

FibeAir® IP-20A



Ceragon Networks' new **FibeAir® IP-20A** responds to the needs of forward-thinking utility operators with an eye on improving today's operations with smooth evolution to tomorrow's smart grid. As the optimal wireless backhaul solution for mission-critical networks, FibeAir IP-20A enhances today's TDM-based utility networks and grows with them as they evolve into broadband packet networks supporting the smart grid.

Compact in form—2 radios in 2U, 4 radios in 3U—and featuring ultra-high power transmission, FibeAir IP-20A provides high-capacity wireless backhaul in heavy-use environments. It spans the longest distances while requiring minimal space and modest power consumption, perfect for remote deployments.

From urban to rural settings, faultless operation is essential since everybody relies on continuous, efficient supply of power. FibeAir IP-20A's resilient architecture with no single point-of-failure and with a wide variety of protection configurations ensures uninterrupted service for smart grid applications. FibeAir IP-20A's all-indoor architecture and remote configurability via Ceragon's user-friendly Network Management System simplify maintenance and operations providing complete network visibility with minimal effort and cost.

In order to cope with cyber terrorism, FibeAir IP-20A is endowed with multiple layers of protection including intercept-resistant, narrow-beam microwave communications, secure authentication and management and virtually unbreakable payload encryption, compliant with NERC-CIP requirements. It delivers secure, dependable, eavesdrop-free communications.

FibeAir IP-20A uses a latency-optimized radio design employing sophisticated hierarchical Quality of Service capabilities. It offers prioritized traffic handling that encourages differentiation of services and guarantees mission-critical communication where high levels of delay cannot be tolerated. Ultra-low latency also translates into longer radio chains, broader radio rings, and shorter recovery times.

FibeAir® IP-20C HP



For new sites where all-outdoor installation is feasible, **FibeAir® IP-20C HP** is the optimal solution for efficient, reliable and secure backhaul. It features similar capabilities to the FibeAir IP-20A (capacity, availability, high transmit power, resilience, low latency, Hierarchical QoS, flexibility, security) while breaking records for compactness. Its unique multi-core architecture enables transmission of up to 1Gbps radio throughput over a single channel in a single all-outdoor box with extremely low power consumption.

FibeAir IP-20C HP's versatility makes it ideal for a wide variety of deployment scenarios. As a software-defined radio, it can be remotely configured to quadruple capacity, double link distance and reduce power consumption. It is easily and quickly deployable compared with fiber, allowing smart grid operators to achieve faster time to service, lower total cost of ownership and long-term peace of mind.

FibeAir IP-20C HP is ideal for all the new smart grid applications that take advantage of high-capacity packet technology including grid monitoring, teleprotection, substation automation, premise security, and mobile workforce management.

FibeAir 2500



FibeAir® 2500 is the optimal solution for point-to-multipoint applications like backhaul for AMI. It is deployed as a base unit with multiple compact subscriber units that can be installed virtually anywhere. Delivering high capacity over a single radio unit, it saves on tower space, eases maintenance and reduces total cost of ownership per Mbps.

FibeAir 2500 provides the highest spectrum efficiency available in the sub-6GHz band facilitating transmission of greater throughput over narrower channel bandwidth. It reduces spectrum license fees and increases frequency planning flexibility.

Offering a variety of powerful subscriber units (SUs), FibeAir 2500 enables service capacity from 5Mbps up to 100Mbps per SU. The base unit, or hub, can be located on the premises of the closest substation where it aggregates transmissions from multiple meter collection points each with a subscriber unit. With up to 250Mbps of total capacity, FibeAir 2500 provides cost-effective aggregation for numerous AMI collection points. It operates effectively in sub-6 GHz licensed and unlicensed bands for low-cost operation over long distances, including the 4.9 GHz band reserved for public safety and critical infrastructure.

With today's packetized video, no other solution is more suitable for backhauling vast volumes of video data from a geographical perimeter than the FibeAir 2500 point-to-multipoint solution. Along



with the high capacity required by video applications, it also supplies the capacity and reliability to serve additional surveillance and other security applications. FibeAir 2500 uniquely secures available bandwidth per end-user for guaranteed service levels.

Summary

The smart grid applies the advancements in smart devices and modern networks to the efficient provision of power to a national audience of consumers. Ceragon provides the most cost-effective microwave solutions to enhance existing network services while providing the smooth, cost-effective path to the smart grid.

About Ceragon

Ceragon Networks Ltd. (NASDAQ: CRNT) is the #1 wireless backhaul specialist. We provide innovative, flexible and cost-effective wireless backhaul and fronthaul solutions that enable mobile operators and other wired/wireless service providers to deliver 2G/3G, 4G/LTE and other broadband services to their subscribers. Ceragon's high-capacity, solutions use microwave technology to transfer voice and data traffic while maximizing bandwidth efficiency, to deliver more capacity over longer distances under any deployment scenario. Based on our extensive global experience, Ceragon delivers turnkey solutions that support service provider profitability at every stage of the network lifecycle enabling faster time to revenue, cost-effective operation and simple migration to all-IP networks. As the demand for data pushes the need for ever-increasing capacity, Ceragon is committed to serving the market with unmatched technology and innovation, ensuring effective solutions for the evolving needs of the marketplace. Our solutions are deployed by more than 430 service providers in over 130 countries.

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