WHITEPAPER

5G Intelligent Edge

Published by

MOBILE WORLD LIVE

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Executive summary

5G is enabling service providers to address a broader range of customers than ever before with tailored solutions that can meet the most stringent performance requirements. Customer needs that were difficult, if not impossible, to address in the past can now be addressed with powerful and cost-effective solutions.

The new 5G capabilities with enhanced broadband, massive capacity and ultra-reliable low latency make 5G a compelling choice for not only connectivity, but also in support of advanced solutions requiring Artificial Intelligence (AI). Rather than competing with cloud services, intelligent 5G solutions can support and enhance these cloud services to enable the most efficient implementations that can scale cost-effectively.

This is leading to new opportunities at the 5G Edge, which is the crossroads where telecom, cloud and enterprise networks meet. The migration of intelligence from the core of the network to the edge is now enabling a new category of solutions that leverage the capabilities of 5G and the availability of compact, but powerful computational platforms combined with the latest AI solutions. These 5G Intelligent Edge solutions enable data to be processed and services to be hosted as close to the consumer as possible enabling faster, more responsive solutions as well as lightening the burden on upstream cloud service hosting and 5G network capacity.

5G Intelligent Edge solutions enable a broad range of applications supporting digital transformation initiatives in a variety of industries. As a leader in the 5G Intelligent Edge, Inseego has already helped customers address a diversity of challenges with powerful and cost-effective solutions. In this paper, we will present the 5G Intelligent Edge opportunity and highlight some of the use cases that exemplify what is possible.

What is the 5G Edge?

When someone mentions the "network edge", what do you have in mind? Depending on your background, the "network edge" can mean very different things.

For example, for many years, the telecom network edge was synonymous with the service provider demarcation point which defined where the responsibility of the service provider ended. For Internet networking, the network edge is where a device interfaces with the Internet and is thus synonymous with an edge device.

For enterprises, the network edge is synonymous with the WAN edge and is where the enterprise network connects to a third-party service. For cloud service providers, the edge is synonymous with cloud computing resources offered as close to the consumer as possible to reduce latency.

All of these definitions are correct from each of their perspectives, but also provide a preview of the confusion and complexity underlying the term "5G Edge." This is because the 5G Edge will be where telecom, Internet, enterprise networking and cloud computing will converge and will probably mean different things to different people depending on their background and perspective.

But the 5G Edge also incorporates many of these points of view into one concept. It is a demarcation point between the service provider and the consumer of that service. It will be associated with a device, or at the very least a virtual machine on a dedicated server host, where the enterprise connects to a third-

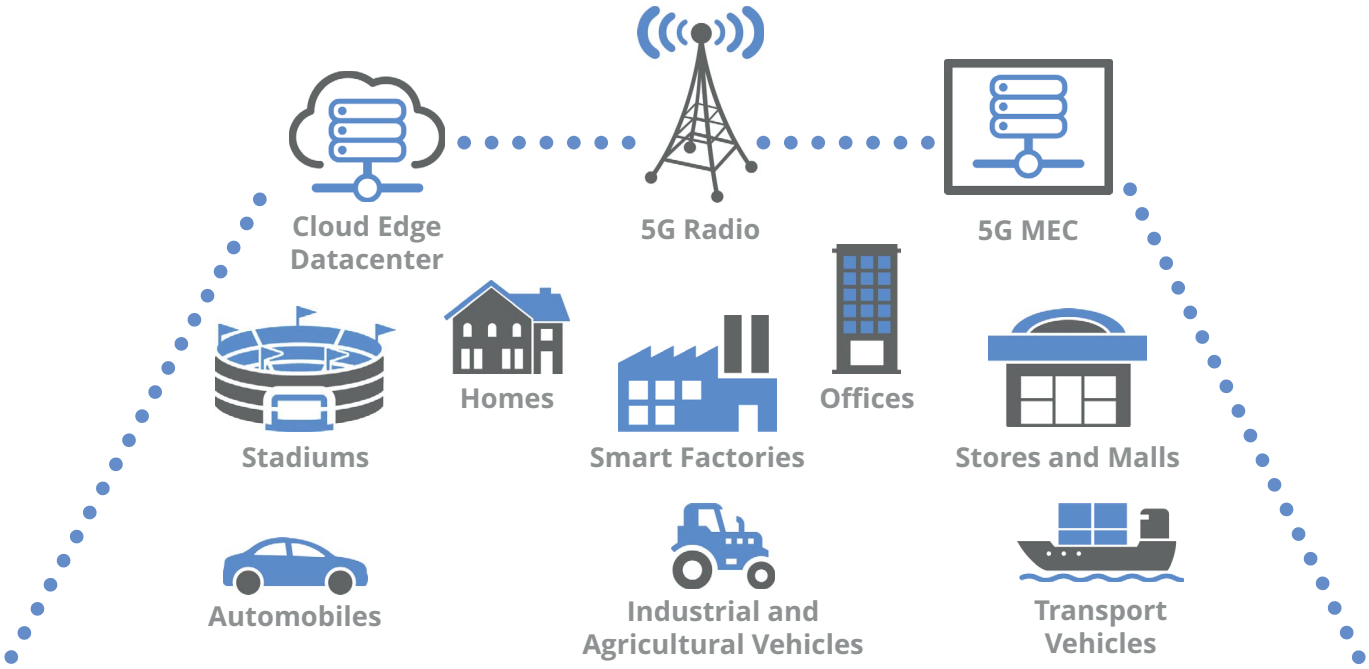


Figure 1: 5G Edge Location

party service. In many cases, it will also extend the cloud edge even further, offering cloud computing resources as close to the consumer as possible.

This means that the 5G Edge can be located in a cloud-edge data center, in the home, in the office, in a factory, a store, a stadium or even in a moving vehicle. It is wherever there is a consumer with a need that can be addressed with a combination of 5G connectivity and intelligent processing performed as close to the consumer as possible.

5G Edge services and solutions

The words “service” and “solution” are often used, but sometimes can add to the confusion, especially with respect to the 5G Edge. A distinction needs to be made between 5G services and other services. For example, an enterprise will already subscribe to services from telecommunications service providers and cloud service providers, which can include separate service for mobile telephony, broadband connectivity, SD-WAN services as well as a broad range of cloud-hosted services.

In the case of 5G services, we are referring to services that rely on 5G mobile networks typically offered by a telecommunications service provider. However, these 5G services can include, cooperate with, or enhance the experience of services hosted or offered by cloud service providers or other telecommunications service providers.

This is where the distinction between services and solutions become relevant. A solution addresses a specific challenge for the customer and can be based on a 5G service offering. For example, a “solution” can be a specific technology or approach used to deliver the 5G service or a combination of a 5G Edge device leveraging 5G services which enhance cloud services. A 5G service can therefore be a packaged solution that is offered to many customers with the potential to tailor the service to a particular customer need to provide a specific solution.

The emergence of the 5G Intelligent Edge

5G provides new capabilities that make it the natural convergence platform for multiple packet-based services. The functional decomposition of 5G network functions and Multi-access Edge Computing (MEC) provides a new level of flexibility and adaptability in meeting service requirements. The ability to tailor the performance of 5G services to specific consumer needs using network slicing and virtualization enables 5G to address a broad range of applications with strict performance requirements.

The 5G Edge will take advantage of these 5G capabilities to offer solutions to specific challenges that have been difficult to address in the past. But the 5G Edge will also take advantage of other trends that will enhance the value of solutions.

Migration of intelligence to the 5G edge

One of these trends is the general migration of intelligence from the core of the network to the network edge. This is best illustrated by cloud services where cloud computing resources have migrated from core, hyperscale data centers to cloud-edge data centers closer to the consumer. This improves latency and reduces the amount of data to be transported back to hyperscale data centers. But it also enables intelligent processing of data at the edge of the network.

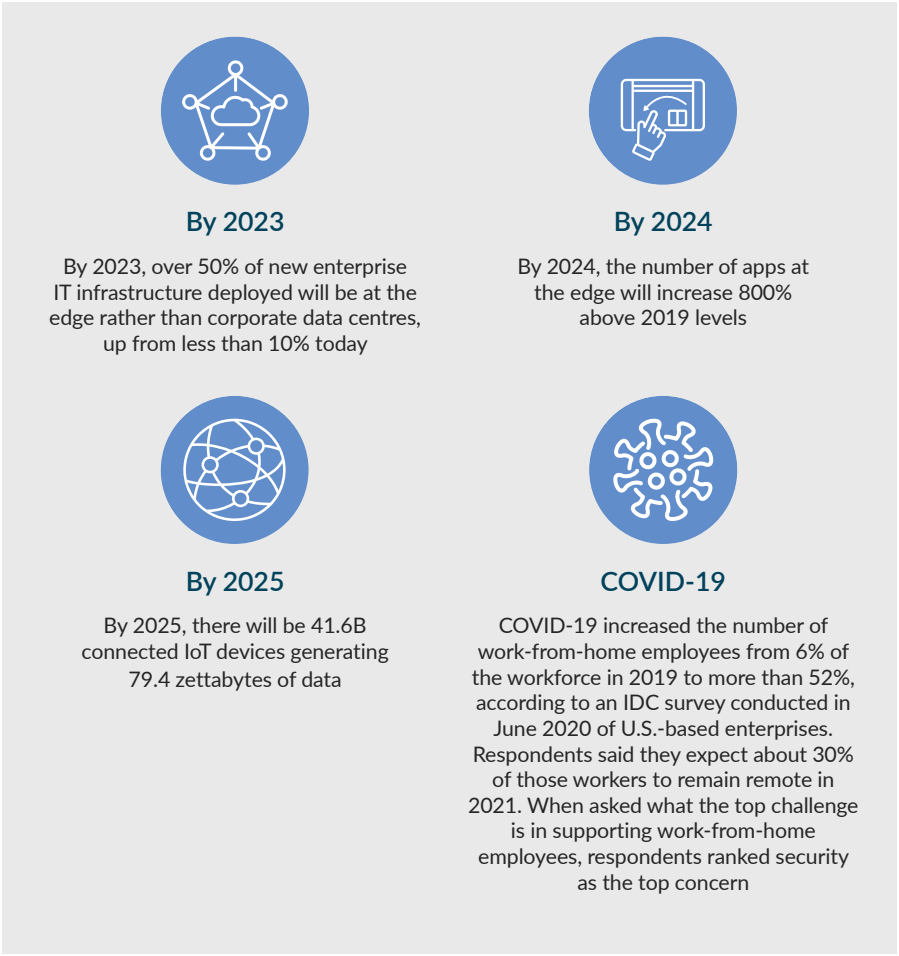
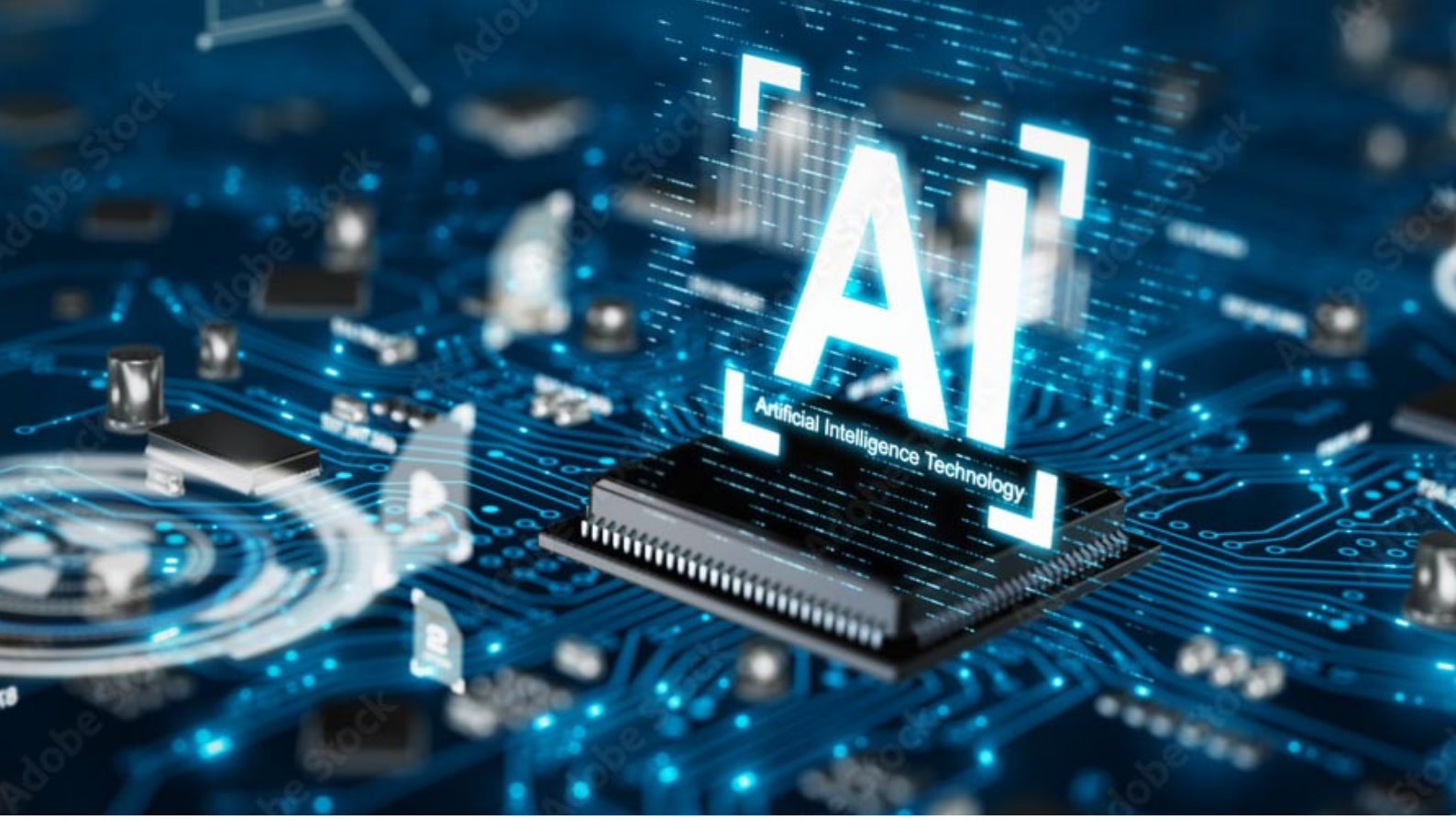


Figure 2

Source: IDC, Rise of the Intelligent Edge Era



In 5G networks, an example of intelligence moving to the edge is the MEC. The MEC is similar to a cloud-edge where it is possible to host a variety of virtual services. The difference between a cloud-services edge and MEC is that the MEC is 5G-aware and provides facilities to take advantage of 5G capabilities. The MEC provides a virtual computing infrastructure that is designed to support mobile edge services. It includes hosts with compute, storage and network resources as well as facilities for authentication, authorization and traffic management. The infrastructure is managed with controlled spin-up and termination of mobile edge services.

The MEC can be centralized closer to the core of the network, but can also be distributed at the edge of the network and any point in between, depending on the needs of the service. This allows the data associated with a 5G service to be processed and stored centrally for non-real-time services or closer to the consumer for real-time services.

The potential of artificial intelligence at the edge

Another trend, however, adds even more intelligence to the 5G Edge. Artificial Intelligence (AI) algorithms are now available to intelligently and efficiently analyze large amounts of data. Cloud service providers are already providing "AI-as-a-Service" offerings, such as AWS Greengrass and Microsoft Azure's IoT Edge. Telecom service providers are taking note and planning their own AI-as-a-Service offerings that leverage 5G capabilities.

At the 5G Edge, AI can be used to enhance and offload AI-as-a-Service offerings by bringing AI capabilities as close to the 5G service consumer as possible. This resembles the migration of cloud services to the edge where AI can be considered an example of a cloud service that now can be migrated to the on-premises 5G Intelligent Edge device.

AI at the edge can take several forms. AI basically entails analysis of data to make a decision and thereafter alert the user or take a pre-defined automated action. An example of this is security. AI at the 5G Edge can be used to secure 5G Edge devices and the sensitive traffic that is being transmitted and received via those devices. This can include detecting and preventing network and device intrusion attacks on 5G Edge devices. This can also be extended to protect Internet of Things (IoT) devices from being hijacked if they are connected to 5G Intelligent Edge devices.

Other use cases include centralized management of 5G Edge and IoT devices and intelligent processing of video content. To understand the power and value that 5G Intelligent Edge solutions can provide, let's take a closer look at the capabilities provided by 5G and how these can be leveraged to provide intelligent solutions.

5G is designed to meet the strict requirements of multiple services

Mobile networks have been traditionally focused on providing high-quality voice, which means strict control of latency and jitter performance. However, as consumption of data services has increased, especially high-quality video services, increasing raw bandwidth and capacity has become more important.

4G LTE provides high-quality voice as well as high-speed broadband access, which enabled a whole set of new applications to be addressed by mobile networks. However, it also highlighted the difficulties of meeting multiple contending service needs with a single network architecture. The basic trade-off is between latency and capacity. By centralizing processing functions, it is possible to efficiently and cost-effectively support a large number of services. However, latency suffers as it takes longer to transport data from consumers to centrally located data centers.

5G is designed to address this issue by enabling multiple services with contending performance requirements to share the same network infrastructure. This is achieved by virtualizing network functions and abandoning the static network architecture of the past. Instead of dedicated equipment hosting specific network functions at specific geographic locations, network functions are virtualized and can thus be instantiated and migrated to any suitable server host platform in any location.

What this requires is the availability of server host platforms at various geographic locations. Similar to cloud services, very large data centers hosting thousands of servers will be located at central locations, but will be supplemented by smaller data centers to cover regional areas and then edge data centers closer to service consumers.

Since the various functions required to deliver a mobile service are now de-composed and virtualized, they can be separately instantiated at any of these locations. All of them can be instantiated centrally or at the edge or at any suitable data center in between.

Since the functions have been virtualized as separate software instances, they can be scaled to meet the needs of a single service user or multiple users. This allows a service with specific performance requirements with respect to speed and latency to be created by linking together the right combination of 5G mobile virtual network functions and instantiating them in the most appropriate geographic locations.

This combination is often referred to as a “network slice” as the network capacity is “sliced” into virtual functions dedicated to a specific service that are connected together and instantiated when and where they are required. Multiple “network slices” with very different performance needs and characteristics can thus be supported by the same 5G network. As a service consumer, this allows a service to be tailored to precisely your needs, which can be exploited at the 5G Edge.

The multi-service 5G edge

With the introduction of 4G LTE, mobile broadband services became a valid alternative enterprise connectivity option. Software-Defined WAN (SD-WAN) solutions enabled mobile broadband to complement fixed broadband and MPLS services as either a backup connectivity or offload option. Mobile hotspots and routers enabled enterprises to leverage mobile broadband for LAN and WAN connectivity. With the 10x improvement in speeds and capacity offered by 5G, these connectivity options become even more interesting.

But broadband connectivity is just one need that can be serviced by the 5G Edge. Rather than branch offices sending all traffic to headquarters before it is redirected to the appropriate cloud service provider, modern SD-WAN solutions now allow branches to send cloud traffic to the nearest cloud edge data center at the 5G Edge.

The same principle can be used for various other services. For example, data collected from millions of IoT sensors can be transported over mobile connections and processed in cloud edge data centers at the 5G Edge. In the future, autonomous vehicle communication will be facilitated in the same manner, where 5G connectivity will be essential.

So, whether the 5G connectivity is dedicated, as in the case of autonomous vehicles, or one of many options, as in SD-WAN, the processing of data occurs in cloud edge data centers at the 5G Edge.

Extending the 5G Edge even closer to the service consumer

While moving intelligence to the edge has improved performance considerably, there can be further scope for improvement. The principle is still the same; keep data local as much as possible.

This provides an additional evolution in the migration of services, such as cloud services, from being centrally processed in hyperscale data centers to cloud edge data centers and now to the customer premise thanks to 5G Intelligent Edge solutions.

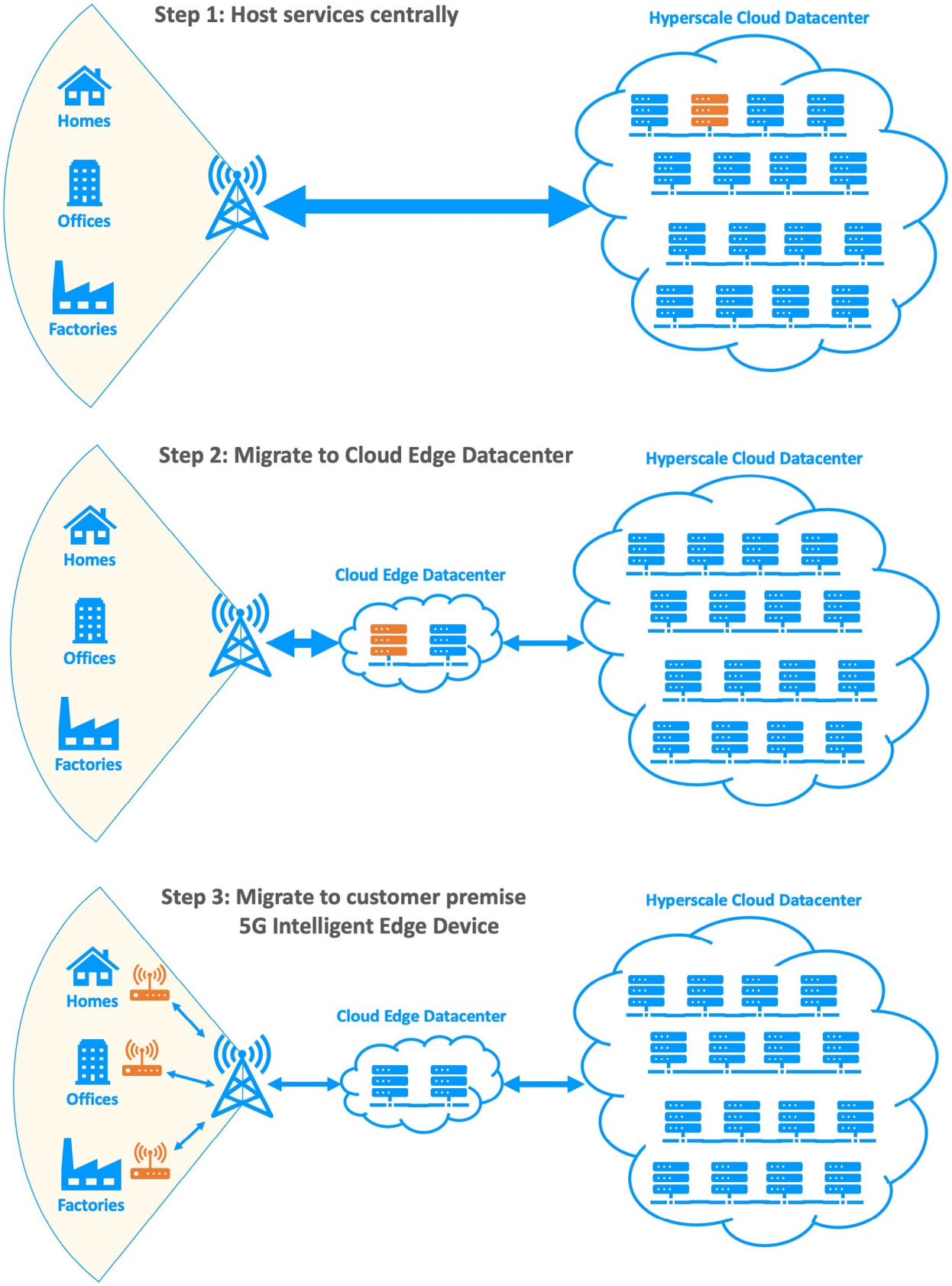


Figure 3: Three steps in migrating services and intelligence as close to the consumer as possible

The 5G Intelligent Edge opportunity

The introduction of 5G, combined with the availability of powerful, yet affordable and compact computing capabilities, is enabling new solutions. A new generation of 5G Intelligent Edge devices is now being introduced that not only provides 5G connectivity, but also intelligent offload and support of services with AI capabilities.

Inseego, a leader in 5G and IoT device-to-cloud solutions, is transforming what's possible with 5G with a portfolio of products that spans Fixed Wireless Access, mobile hotspots and IoT modems, routers and gateways. An example of these is the new 5G Edge device, the Customer Premises Equipment (CPE) in the Inseego Wavemaker™ 5G portfolio, which delivers fast 5G speeds, higher bandwidth, and low latency with enterprise-grade edge security.

The Inseego Wavemaker portfolio includes high-performance 5G connectivity solutions with multiple Wi-Fi 6 ports for the LAN. They also provide considerable computational power based on quad- and octo-core ARM chips capable of multiTera Operations per Second (TOPS). With ample memory and hard-disk storage, the devices provide a computational platform that can support AI processing of offloaded service tasks.

Video surveillance example

To understand the potential and value that 5G Edge devices can deliver, we can consider a video surveillance example. We are all now familiar with security cameras at various locations. These cameras are now IP-based and provide improved quality with High-Definition (HD) resolution. This enables smart cloud-based services where security camera footage can be analyzed in real-time for a variety of purposes. This could be to detect intrusions or recognize a number plate on a vehicle.

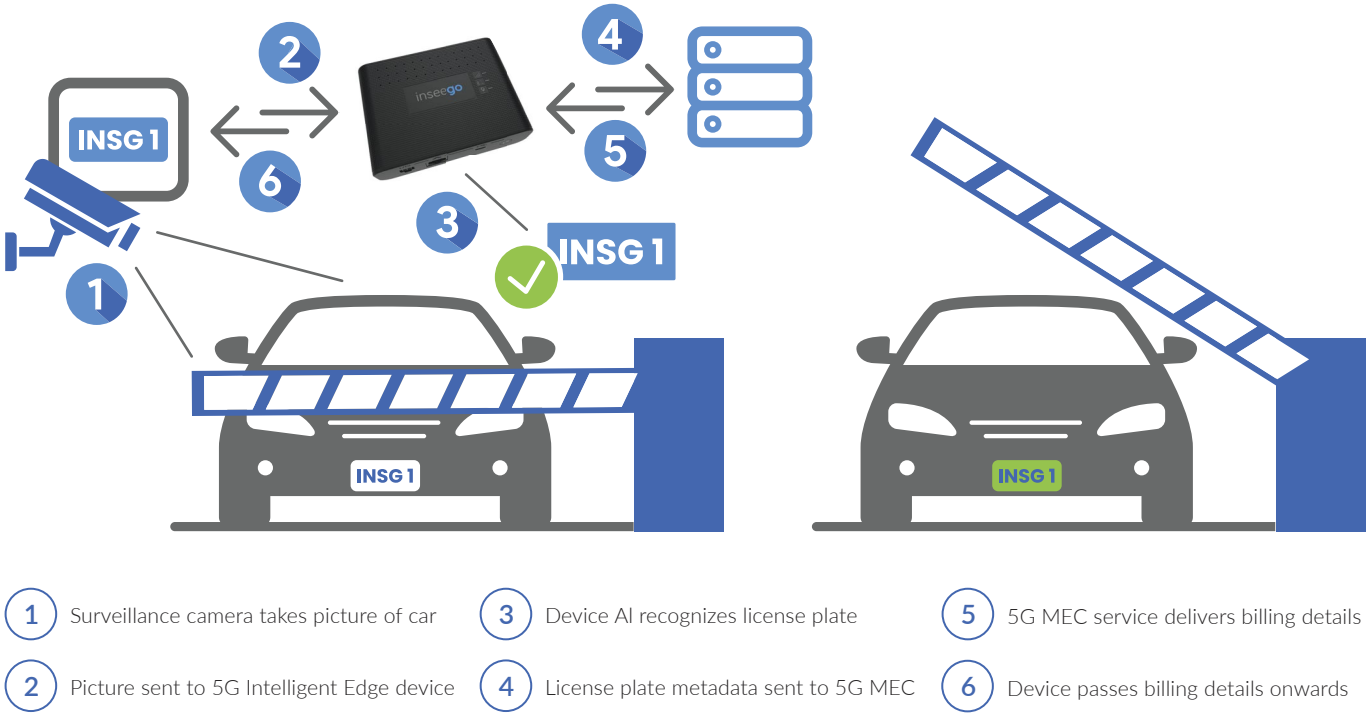


Figure 4: Recognizing a license plate and sending license plate data to 5G MEC for charging

While these new capabilities provide a lot of value, there are also challenges. As the resolution of IP-based security cameras improves from Standard Definition (SD) to HD and further to 4K/8K resolutions, the amount of data that needs to be sent for analysis grows exponentially. This is both expensive and time-consuming. It should also be noted that the 5G MEC functions used to process the video stream could be located close to the antenna, but that is not a given. If real-time response is not needed, then this function could just as easily be located more centrally close to the network core. This will inevitably increase the cost and time for processing video streams.

If, on the other hand, the real-time video stream can be processed locally, then only relevant data need be exchanged with the remote cloud service. Various AI algorithms and functions are now available that can be executed locally on the device enabling video streams to be processed locally. This enables only relevant clips or meta-data to be exchanged with the MEC processing functions, thus reducing the overall load, cost and time to process video streams.

Smart offload of data processing on 5G Edge devices

The video surveillance example is just one of many potential applications of 5G Edge offload. The basic principle is the same; process data as locally as possible to reduce the burden on the rest of the network and in so doing reduce overall cost and time needed to process data.

This opens a number of potential high-value use cases for a variety of organizations. In the following we will look at some examples of how 5G Edge devices can bring value across a variety of industries.

Video surveillance for smart cities, fast response and smart retail solutions

In the earlier video surveillance example, we saw how a 5G Edge device hosting an AI application can recognize license plates. This same principle can be used for a variety of other smart city applications.

For example, Inseego teamed with a leading provider of intelligent traffic systems and a leading 5G mobile network operator in the UK to support 4K CCTV surveillance for traffic monitoring and control.

Another example is fast response for emergency services. In Los Angeles, Inseego teamed with T-Mobile and the County of Los Angeles Fire Department to enable 4K CCTV video surveillance of remote areas prone to forest fires. The ability to deploy wireless devices quickly in the right locations enabled reliable and low latency communication of emergencies.

A more advanced example of intelligent video processing involved a major UK retail chain where Inseego teamed with a leading UK mobile operator to enable analysis of shopper behavior and to monitor shelf inventory. This is just one example of how intelligent video analysis can be used to improve retail operations. It can also be used to count the number of customers, map customer flows and even recognize returning customers (or shoplifters).

Managing and securing IoT and fleets

When we think of IoT, we often think of smart meters or home devices that can be controlled from our smartphone. However, IoT is much broader.

Smart meters are an example of the massive IoT that 5G was designed to address with billions of devices sending small amounts of data. But there are also IoT applications, such as drones and fleet management, which are more demanding with larger data volumes and lower latency requirements. These demands increase as we begin to address critical IoT applications like

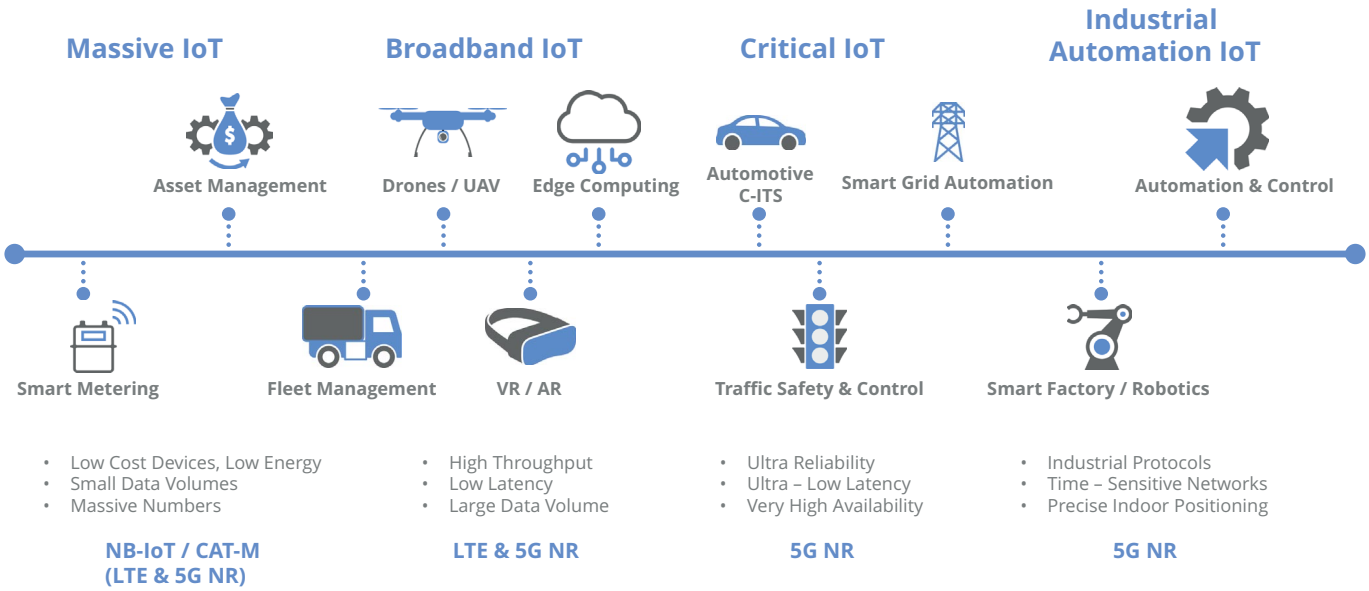


Figure 6: Broad range of IoT applications and requirements

automated vehicles, traffic monitoring and control as well as demanding applications such as smart grid automation and Industrial automation.

A common need across all of these applications is the need for device management and, most importantly, device security. According to the Netscout Threat Intelligence Report, IoT devices are typically attacked within 5 minutes of connecting to the Internet . According to Deloitte, 70% of IoT devices are configured using factory-set default usernames and passwords.

Managing lots of devices that can also be moving is a complex task. Ensuring that all these devices are available, operating correctly and are updated with the latest software is a major challenge.

Inseego 5G Edge devices can include management solutions, such as Inseego Connect™ that enable centralized management of large pools of devices with monitoring and analysis capabilities. This allows remote management of large pools of devices as well as easier upgrade of device software, which is important to ensure that they are operating correctly as well as ensuring that

devices are secure.

5G Edge devices can also include security solutions, such as Inseego Secure™, to secure both the device itself, but also all connected IoT devices. For the security solution to be effective, it needs to address all aspects of the attack from first detection to preventing data extraction.

The many recent examples of critical infrastructure that have been compromised show the vulnerabilities that can lurk within the environment. For example, in the recent Colonial Pipeline ransomware case, the breach exploited a single VPN password that was no longer active, but could still be used to breach the network . Once inside, vulnerabilities in other software as well as a large number of compromised IoT devices enabled the hackers to gain control of the network. The breach resulted in the payment of a $4.4m ransom on top of the disruption of fuel supply to over 50 million people.

Managing how software is deployed, the status of IoT devices and their location as well as ensuring that security can be enforced at the edge will become critical as we become more dependent on IoT devices.

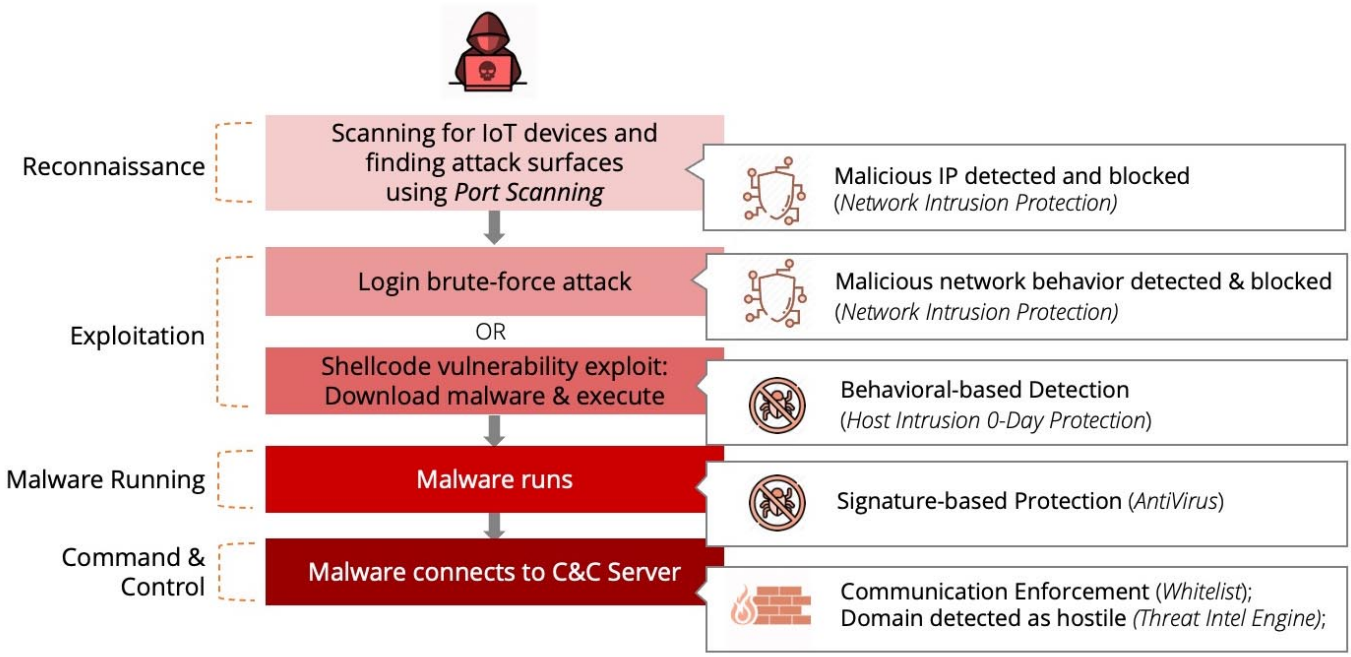


Figure 7: Comprehensive security capabilities at the edge stop IoT attacks

[1] *Source: IoT Brute Force Attacks | NETSCOUT*
[2] *Source: in-tmt-IoT_Theriseoftheconnectedworld-28aug-noexp.pdf (deloitte.com)*

Inseego portfolio of 5G Intelligent Edge solutions

Inseego is an industry leader in wireless solutions for operators, enterprise customers and consumers and is also leading the way in 5G Intelligent Edge solutions. The Inseego Wavemaker™ product range provides both indoor and outdoor 5G solutions supporting both sub-6 GHz and mmWave connectivity. Dual-band Wi-Fi 6 technology with connectivity for up to 128 devices makes Inseego Wavemaker™ 5G Edge devices suitable for applications which rely on IoT devices.

Inseego Wavemaker devices can support a wide range of AI processing algorithms and other automated tasks. These capabilities are leveraged in two Inseego software solutions available with all Inseego Wavemaker devices; namely Inseego Connect™ and Inseego Secure.

Inseego Connect

Inseego Connect is a multi-tiered configuration and monitoring platform for device management of Inseego devices through a single pane of glass. Inseego Connect supports remote configuration and monitoring of device health. With Inseego Connect it is possible to analyze and track device usage, including geographic location for devices on the move.

Inseego Secure™

Inseego Secure offers a cloud-based AI-powered platform designed to defend edge devices from security breaches and malware attacks. It provides two levels of protection based on Network Intrusion Detection and Prevention as well as algorithms to detect anomalous behavior, which are continuously learning and adapting to the target environment. With Inseego Secure™ on Inseego Wavemaker™ 5G Intelligent Edge devices, both Inseego devices and all connected devices are secured in compliance with key industry standards such as PCI DSS, ARPA and ISO 27001.

Take advantage of the 5G Intelligent Edge

5G opens up new opportunities to improve and enhance existing services and solutions. With 5G Intelligent Edge solutions, it is possible for service providers to address specific customer needs with powerful solutions as close to the consumer as possible. By leveraging the intelligence and power of 5G Edge devices, enterprise customers can achieve more with less by processing as much data as possible locally. The ability to efficiently monitor and manage thousands of IoT devices while ensuring that they are secure at all times is now a necessary capability as proven by recent high-profile attacks.

Inseego is already delivering this future today with a comprehensive portfolio of 5G Intelligent Edge hardware and software solutions. To find out more visit: Advancing Industries with 5G and 4G LTE | Inseego Corp.

[3] *Source: Colonial Pipeline Cyber Attack: Hackers Used Compromised Password - Bloomberg*

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Inseego Corp. (Nasdaq: INSG) is an industry leader in smart device-to-cloud solutions that extend the 5G network edge, enabling broader 5G coverage, multi-gigabit data speeds, low latency and strong security to deliver highly reliable internet access. Our innovative mobile broadband and fixed wireless access (FWA) solutions incorporate the most advanced technologies (including 5G, 4G LTE, Wi-Fi 6 and others) into a wide range of products that provide robust connectivity indoors, outdoors and in the harshest industrial environments. Designed and developed in the U.S., Inseego products and SaaS solutions build on the company's patented technologies to provide the highest quality 4G and 5G connectivity for service providers, enterprises, and government entities worldwide.

Find out more at inseego.com

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