Mobile Edge Computing:
The Edge is the Future

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The Edge is the Future

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Executive Summary

Mobile data usage is on the rise – subscribers all over the world churn through gigabytes of streaming video, music, and social networking every month. Mobile network owners are scrambling to stay ahead of data demand by densifying their radio access networks with small cells. Wired network owners increasingly offer higher speeds to homes and businesses because mobile devices – smartphones, phablets, tablets and laptops – are all behind this surge in demand.

Mobile Edge Computing (MEC) is a new option for network owners. Its key value proposition is that it allows an operator to provide new services by opening up their RAN edge. It does this by placing smart nodes at the edge of a mobile network, for example, right where small cells would likely be placed. These smart nodes run virtualized software on general purpose server hardware housed within a secure form factor. The nodes can emulate parts of the core network, serve as reliable caching units, and/or run virtualized applications from any number of an operator's developer partners.

For the mobile operator, the benefits of MEC boil down to several factors:

- Potential to monetize in a different way that highlights the reach and power of the operator's network as it relates to content providers and their need for a digital distribution channel.
- Ability to provide a better "customer experience" through lower latency, higher throughput, and more diverse, localized and personalized services.
- Support for emerging, enhanced services such as Voice over LTE by having virtualization at edge assist with the strict quality of service requirements imposed by VoLTE, particularly on the X2 links between eNodeBs.

The MEC is led by a new Industry Specification Group (ISG) within ETSI which has been set up by Huawei, IBM, Intel, Nokia Networks, NTT DOCOMO and Vodafone. Since late 2014 when the MEC SIG was announced, more than 28 companies have joined the effort to create an open standard for mobile edge computing. The MEC SIG is already generating considerable interest in the market and participation in the effort continues to grow.

This whitepaper provides a brief overview of the challenges facing today's mobile networks and some of the current thinking about how those networks may evolve to 5G. We then consider how mobile edge computing will play a critical role both in making 5G a reality and improve the mobile customer experience for millions of subscribers around the globe.

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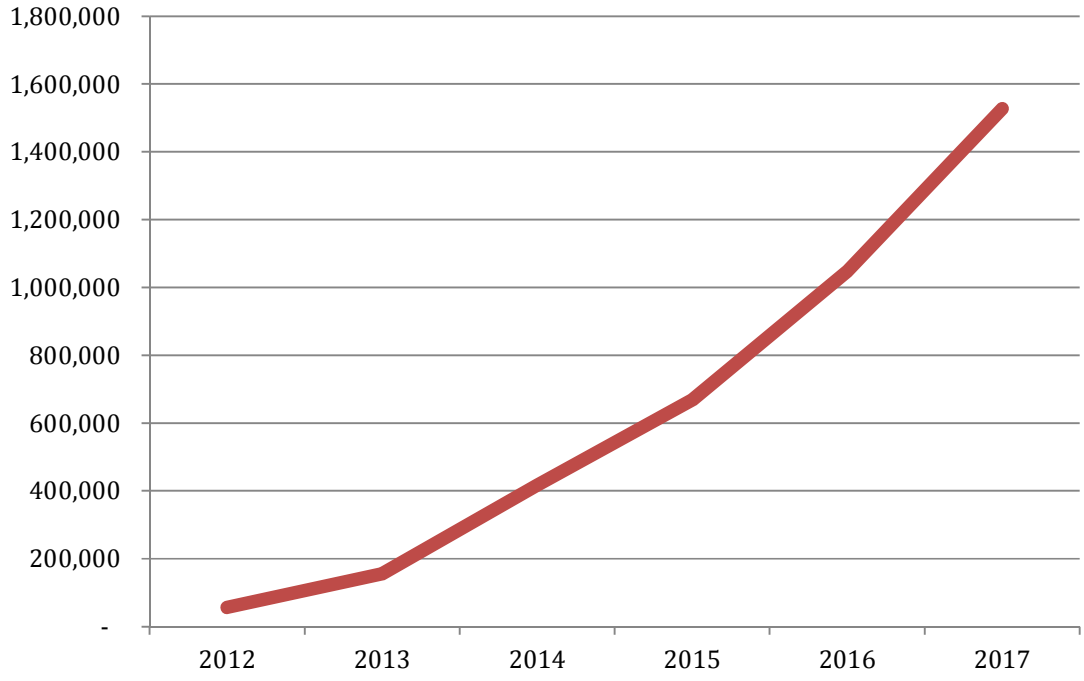
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Challenges in evolving mobile networks

By 2017, nearly 21 percent of the globe's population will use an LTE phone. The following chart shows *iG*R's forecast for the global LTE connections through 2017 – a 94 percent compound annual growth rate from 2012 to 2017. Globally, there will be about 1.53 billion LTE connections in 2017 – and approximately 7.4 billion people. Assuming one LTE connection per person for those 1.53 LTE connections, nearly 21 percent of the people around the world will be using LTE.

Moreover, for a large percentage of those people LTE will be their primary way of accessing the Internet. As LTE grows more dominant, and as mobile networks become more dense and heterogeneous, the distinction between the "mobile" and "wired" Internet will become largely academic. The advent of new technologies, such as mobile edge computing (MEC), will help shift that paradigm.

Figure 1: Global LTE Connections Growth, 2012-2017



Source: *iG*R's Global Connections Forecast, 2015

*iG*R's forecast for global mobile data usage grows from a "mere" 1.5 million terabytes per month (TB/month) in 2012 to 8.8 million TB/month in 2017. A large portion of this traffic will be driven by the adoption of LTE. Mobile operators the world over already report that on their fledgling LTE networks, which in all cases still run side-by-side with 3G networks, the preponderance of

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data traffic is on LTE and not 3G. Note, of course, that the total number of 3G connections greatly exceeds the total number of LTE connections.

Mobile Data Growth Drivers

The growth in total mobile data usage is driven by several factors:

- More subscribers: Although this trend is slowing in North America, there are still some individuals without mobile phones.
- More data connections, including the Internet of Things (IoT) which covers everything from smart thermostats to smart meters in a refinery. These IoT solutions tend to transmit small amounts of data, but there is a potential for higher-bandwidth applications (e.g., video surveillance).
- Connected Car has the potential to increase both connections and data usage through "rear-seat" applications that might stream video, etc., to passengers.
- More data consumed per user: Increasingly, those with smartphones consume a large portion of their "Internet content" on mobile devices. All of this content is getting bigger and better as 8+ megapixel photos are snapped and sent, 1080p video is shot and posted, Netflix and YouTube videos are watched, and music streamed – in addition to all the other traffic that flows over mobile data networks everyday.

Evolving Mobile Networks

Total mobile data usage grows both because more people are using the cellular network more and because they use it more every day. To compensate for the non-stop increase of mobile data traffic, mobile operators are doing several things:

- Refarming spectrum as fast as they can from 2G to 3G and then to 4G.
- Carrier aggregation – an approach made possible in the 3GPP standards.
- Network densification – putting more network equipment in more places, which increases environmental, size and power considerations across the network. In the future, dense networks will critically important in the rollout of 5G. (Based on what equipment vendors and carriers are saying today, *iG*R expects that the first deployments of 5G will begin in the 2020 timeframe – a mere five years from now.)

The GSMA and the Next Generation Mobile Networks Alliance (NGMN) have both published whitepapers detailing their visions for what 5G will be. The NGMN whitepaper cites multiple use cases for 5G, including: broadband access in dense areas; broadband access everywhere; higher use mobility; support for massive sensor networks; and broadcast-like services. 5G will incorporate LTE and its future versions, but will use different network topologies and architectures.

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With respect to MEC, the NGMN whitepaper cites “Smart Edge Nodes” (page 107) as a technology building block for 5G networks. The paper defines smart edge nodes as network equipment that sits at the edge of the network that can actively carry out some of the core network functionalities such as context-aware dynamic caching. The paper also states that these nodes would run virtualized software on general purpose servers.

Year-in, year-out, mobile operators need to be able to deliver higher throughput and lower latency in more places at far lower cost per GB. The ongoing shift to LTE helps improve cost efficiencies, but that is always balanced against the need to continually invest in the network.

With 5G, the mobile network will need to be able to deliver bigger payloads to mobile devices cost effectively. At the same time, there is also a need for reduced latency to further improve the customer experience along with all of the 5G-centric use cases mentioned earlier. Mobile edge computing and densification is one way to help provide these gains, but mobile operators can also move content closer to the edge of the cellular network.

Today, these examples are not possible on mobile networks. Content or application servers are not collocated with any equipment in the mobile operator’s network. But, the above scenario becomes possible if carriers move toward implementing MEC.

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What is Mobile Edge Computing?

In September 2014, the MEC industry initiative published a whitepaper which defined MEC as "IT and cloud-computing capabilities within the radio access network in close proximity to mobile subscribers."

The whitepaper goes on to say that MEC:

- Offers application developers and content providers cloud-computing capabilities and an IT service environment at the edge of the mobile network. This environment is characterized by ultra-low latency and high bandwidth as well as real-time access to radio network information.
- Transforms base stations into intelligent service hubs that are capable of delivering highly personalized services directly from the very edge of the network while providing the best possible performance in mobile networks.
- Runs on servers deployed at any of the following sites in the mobile operator's network: at the LTE macro base station (eNodeB), at the 3G Radio Network Controller (RNC) or at a multi-technology cell aggregation site. MEC platforms should be deployed on high-volume IT hardware with standardized components so that maintenance can be rapid and cost-effective.
- Introduces three new management layers: one for the hosting infrastructure, one for the MEC application platform and one for the software applications and services which are hosted on the platform. The MEC server provides computing resources, storage capacity, connectivity, and access to user traffic and radio and network information.

Implementing MEC

The whitepaper goes on to state that there are two different ways to implement MEC.

- Macrocells: Vendors building this equipment would embed secured computing and virtualization capabilities directly into RAN elements. This integration of applications with radio equipment allows operators improve mobile users' experience by reducing latency, improving quality of service and/or providing customized services. Tight integration with radio equipment also makes it easier for applications/services to understand traffic characteristics and needs, deal with local radio conditions, get device location information, etc. This integration might help enable new IoT/M2M scenarios, big data/analytics, smart cities, etc. The key here is that with MEC embedded within the macrocell, the mobile operator can deliver new network features, accelerate over-the-top (OTT) services, and potentially enable a variety of new high value services. And by hosting and processing

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those services locally, the operator adds a flexible, uniquely customizable lever to their mobile network.

- Small Cells: As previously mentioned, small cells refers to both indoor and outdoor equipment, as well as DAS and, in some cases, even WiFi.
    - With respect to the intersection of small cells and MEC, the actual MEC hardware may or may not be directly integrated into the radio equipment given where the actual deployment happens – there is not a lot of space in a box strapped to the top of a light pole.
    - If the MEC server is hosted in a separate server/enclosure, that MEC would serve as a gateway between the radio network equipment and the MEC server on which multiple services run (through lightweight virtualization). These services might be unique to the particular location in which the small cell is installed or they could be more general services.
    - As an example, the integration of Wi-Fi as a trusted network as part of the mobile operator's core requires heavy compute power and communication with authentication resources inside the operator's core. Rather than perform the computations at the core, they could be handled with the MEC server. This might help speed AAA and therefore improve the user's experience of the network.

MEC and Virtualization

Virtualization is critical to the concept and implementation of MEC. The MEC hosting infrastructure consists of hardware resources and a virtualization layer. The virtualization manager provides, in brief, an Infrastructure as a Service (IaaS) capability. The IaaS controller provides a security and resource sandbox for the applications and the platform. Virtual-appliance applications run on top of an IaaS and are delivered as packaged operating system Virtual Machine (VM) images.

MEC applications from vendors, service providers, and third-parties would be deployed and executed within virtual machines that run on the MEC platforms. A single MEC platform can run multiple VMs. And it should help keep the lease cost down for each individual MEC application provider.

Note that mulit-core processors such as the Intel® Xeon® processor product family that feature hardware-based virtualization enhancements are required at the edge to perform the many tasks required for virtual machines. Intel® Atom™ processors and other smaller, or mobile-focused CPUs may not be up to the task of running multiple VMs day in, day out. Having a CPU with 10 or more cores is important to run as many applications as possible.

Finally, recall that these MEC servers will run at the edge of the network, which typically means exposed on utility poles, lamp post, etc. One key requirement

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for those MEC nodes would be support for IP65 (i.e., complete protection from dust, oil, other non-corrosives, water, contact with enclosed equipment).

With Network Functions Virtualization (NFV), entire classes of network node functions can be virtualized into building blocks that may be connected or chained together to create communication services. The MEC will therefore enable applications and services (Layer 4 and above) to be hosted "on top" of the base station or the RNC.

By hosting applications on a network edge platform, lower latency may be provided for services like video streaming, video conferencing, audio streaming, and VoLTE. Other potential use cases include:

- Integrating wireless sensors for M2M/IoT with vertical back office solutions.
- Information capture for analytics and big data, such as network context information (radio conditions, networks statistics, etc.).
- Providing lower latency services through running them closer to end devices; this part is similar to CDNs.
- Location awareness: An app/service on the MEC can leverage low-level signaling information to determine the location of each connected device. Examples of use cases might be location-based services (e.g., connecting subscribers with local points of interest, businesses and events), analytics, etc.

Security

Obviously, one of the biggest hurdles facing MEC is security. The cloud/IT applications alluded to here would have granular access to data that is not only proprietary to the mobile operator, but secret/private/confidential to the mobile operator's subscribers. In addition, this information and how the applications make use of it, if at all, would likely be subjected to regulator and/or legislative scrutiny and restrictions.

According to the MEC whitepaper, "the MEC platform not only needs to fulfill 3GPP-related security requirements while providing a secure sandbox for applications, i.e., isolating applications as much as possible from the burden of having to relate to all the implications of 3GPP security, operator security policies and local regulatory rules."

Moreover, the physical security of the MEC server would also be a concern. Mobile operator base station sites are typically not as secure as private data center operations. These sites would either have to be made more secure or the MEC deployment model would have to be restricted to fewer, more secure locales. And, of course, the physical security of the node itself would be paramount as the equipment would likely be outside. With general interest from carriers in moving toward a C-RAN network architecture, this latter approach might well be doable.

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Benefits of MEC

For the mobile operator, the benefits of MEC boils down to several factors:

- Potential to monetize in a different way that highlights the reach and power of the operator's network as it relates to content providers and their need for a digital distribution channel. The mobile network operators (MNOs) could increase their revenue by charging based on the resource usage (storage, NW bandwidth, CPU, etc.) of each content provider, if such resource usage could be obtained via specific APIs in MEC server.

- Provide better services to customers – lower latency, higher throughput, more diverse, localized and personalized services. Application-aware cell performance optimization for each device in real time can improve network efficiency and customer experience. Physically closer servers and tight RAN integration can help reduce video stalling and increase browsing throughput.

- Video caching, specifically the ability to store video content at the edge of the network, reducing transport costs and improving customer experience.

- Support for IoT/M2M applications and services, which tend to transmit small amounts of data but may also include higher-bandwidth applications such as video surveillance.

- Reduction of the volume of signaling offloaded to the core network, which could reduce OPEX for the MNOs, as compared to hosting all enhanced services in the mobile core. A distributed caching technology can provide backhaul and transport savings and improved QoE. Content caching has the potential to reduce backhaul capacity requirements by up to 35 percent. Local Domain Name System (DNS) caching can reduce web page download time by 20 percent.

- Other benefits would be to include the ability to open the edge to more application designers for over-the-top services and/or DVR services offered by a cable operator. In the case of an OTT provider, with MEC servers, their service would likely feel faster since requests for new programs and/or "fast forward or rewind" functions would not have as far to travel. A cable operator might be able to move the DVR from the set-top box to the edge of its network, which would potentially allow the operator to offer more storage to its customers.

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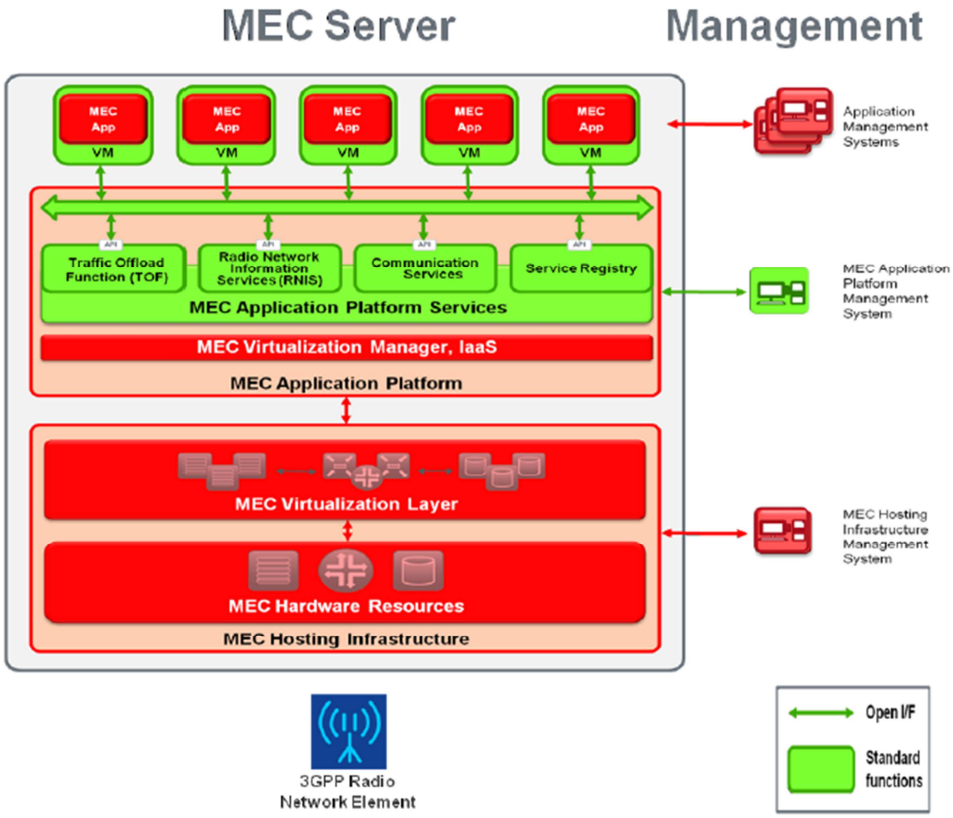
Requirements for successful MEC deployment

MEC's core value proposition is that it allows an operator to provide new services by opening up their RAN edge. In turn, this means new revenue streams that are fundamentally different from the "speeds and feeds" services that are the current market focus. With MEC, an operator's competitor saying they offer more data for less dollars per month will be about as relevant as "free long distance calling" is now.

MEC offers cloud-computing capabilities and an IT service environment at the edge of the mobile network. And it offers an ultra-low latency, high bandwidth and real-time access to radio network information. However, all of these capabilities have to be built into the hardware of the base station itself (or into a "box" that is collocated with, and connected to, the base station).

The following figure illustrates the base components of a MEC server. All of the green-highlighted components are essentially software components running on hardware.

Figure 2: MEC Server Building Blocks



Source: Mobile-Edge Computing – Introductory Technical White Paper, Sept. 2014

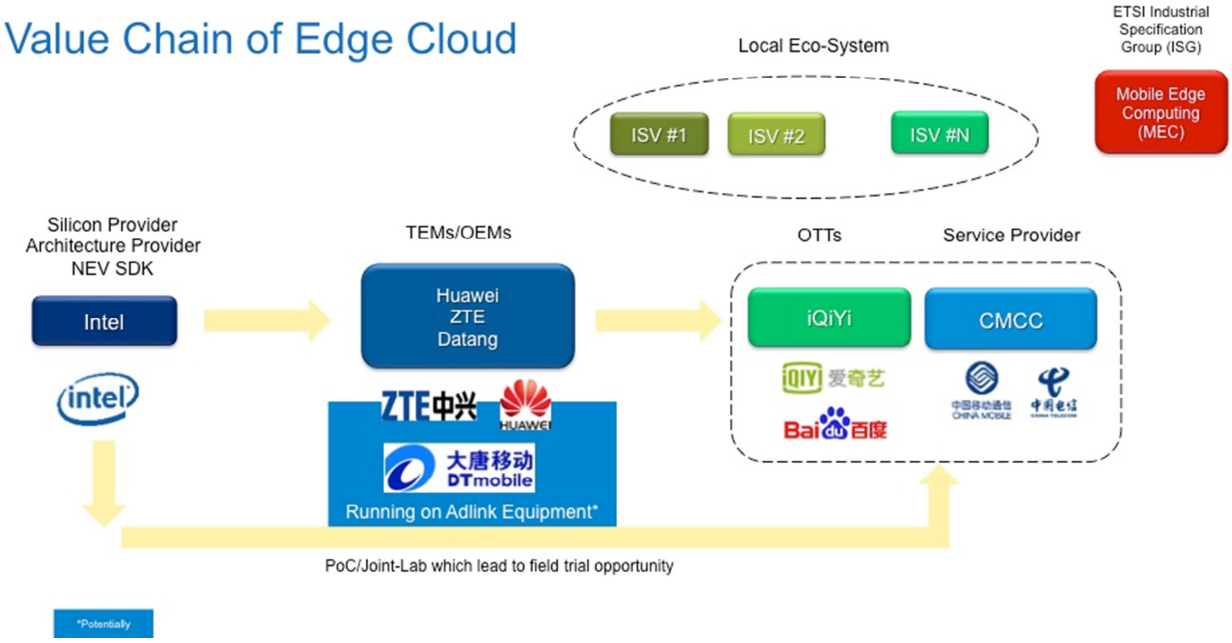
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Fundamentally, the MEC hardware must be cost effective, particularly if it will be deployed at multiple points in the carrier's edge. One way to push costs lower is to use off-the-shelf hardware and leverage NFV and virtualization. For example, the MEC Virtualized Infrastructure Manager provides Infrastructure as a Service (IaaS) facilities and therefore supports flexible and efficient, multi-tenancy, run-time and hosting environment for the MEC Application Platform services.

The following figure shows one view, based on an Intel MEC presentation, of the value chain of the Mobile Edge Computing Cloud – everything from the ETSI SIG to the silicon provider (Intel) to the OEMs, who either manufacture the equipment themselves or white-label it through a third-party such as ADLINK. The service providers who would deploy the equipment in their networks and then license access to the MEC equipment to either OTT vendors and/or Independent Software Providers (ISVs) are also shown.

Figure 3: The MEC Cloud Value Chain



Source: Intel / ADLINK, 2014; slightly modified by *iG*R, 2015

Viewed in the above context, it is easy to see how critically important minimizing the cost of the MEC hardware is to a successful MEC deployment. There are multiple moving parts – OEMS, OTT, ISVs, operators, etc. – that all touch the value chain at one point or another.

And even beyond the above example, cost is also important with respect to environment, safety and/or regulatory requirements – particularly if the MEC hardware will be deployed within a small cell enclosure, collocated as an attachment on a small cell site, or even just deployed in a macrocell enclosure at the base of a tower. Operating costs, failure rates, replacement/upgrade

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requirements, backhaul, power use, etc., all factor into the total cost of both the initial deployment as well as the total cost of ownership. The cost of rolling a truck to all of those different locations would also vary – having to physically touch 100 small cells would be more costly than visiting a single macrocell site.

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Who is involved in MEC?

The MEC is lead by a new Industry Specification Group (ISG) within ETSI, which has been set up by Huawei, IBM, Intel, Nokia Networks, NTT DOCOMO and Vodafone. Since late 2014 when the MEC SIG was announced, more than 28 companies have joined the effort to create an open standard for mobile edge computing. The MEC SIG is already generating considerable interest in the market and participation in the effort continues to grow.

ETSI plays an active, integral role in the development and implementation of many extant telecommunication standards, including GSM, UMTS and LTE, independently and with partners in other regions. Not only have these specifications have been successfully adopted worldwide, but they form the basis of today's evolving cellular communications infrastructure. In addition, ETSI is currently working on the development of standards relating to cloud and Internet technologies as well as end-to-end network architecture.

The MEC ISG aims to unite the telco and IT-cloud worlds, providing IT and cloud-computing capabilities within the RAN. The ISG MEC will specify the elements that are required to enable applications to be hosted in a multi-vendor Mobile-edge Computing environment.

ETSI also has an active ISG working on Network Function Virtualization (NFV) which is tasked with leveraging IT virtualization technology to consolidate multiple types of network equipment into standards-based, high-volume servers, switches and storage which could be located in data centers, network nodes and at the end user's premises. Using NFV, entire classes of network functions can be virtualized into building blocks that may be connected or chained together to create communication services.

The scope of work on MEC will be highly focused and complement the work on NFV. MEC will enable applications and services (Layer 4 and above) to be hosted "on top" of the mobile network elements, i.e. above the network layer. These applications and services can benefit from being in close proximity to the customer and from receiving local radio-network contextual information.

The ISG MEC will produce interoperable and deployable Group Specifications. The ISG MEC will deliver results in different releases, whereby the scope of the first release will be tightly controlled to ensure delivery within 18-24 months (with the start date being in late 2014).

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ADLINK's Extreme Outdoor Server



ADLINK Technology, a leading global provider of cloud-based services, intelligent gateways and embedded building blocks for edge devices that enable the Internet of Things (IoT), provides a new product called the Extreme Outdoor Server. This latest technology is the first high-performance mobile edge computing platform specifically designed for extreme environments and outdoor telecom/networking applications.

Based on the Intel® Xeon® processor E5-2400 v2 product family, the Extreme Outdoor Server MEC platform enables Telecom Equipment Manufacturers (TEMs) and Application Providers to deliver datacenter performance at the edge of the network. Offered in single- and dual-socket configurations, the Extreme Outdoor Server provides IT and cloud-computing capabilities within the Radio Access Network (RAN) in close proximity to mobile subscribers. This offers a service environment characterized by proximity, ultra-low latency, high-bandwidth that allows content, services and applications to be accelerated, maintaining a customer's high-level Quality of Experience (QoE).

ADLINK's MEC platform provides computing resources, storage capacity, connectivity and access to user traffic and real time radio and network information. This allows operators to offer context-related services that can differentiate the user experience and be monetized. In addition, since the data is processed at the edge in the RAN environment, the Extreme Outdoor Server reduces backhaul costs and improves the infrastructure's efficiency with more intelligent and optimized networks. Secondly, with the onset of NFV infrastructure, having datacenter performance at the edge of networks can enable specific VNF functions closer to the consumer, improving QoE.

Attributes such as shock and vibration resistance, -40˚C to +55˚C wide temp range, IP65 water and dust ingress rating make the ETOS-1000 an ideal solution for outdoor and extreme environments. The Extreme Outdoor Server even reduces maintenance costs with worry-free, weather-resistant high-speed connections for copper or fiber and the elimination of fans and filters.

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The Extreme Outdoor Server can utilize ADLINK's application ready intelligent platform (ARiP) software, which includes PacketManager, remote management functions, and system management APIs for application developers. The ARiP enables customers to focus primarily on development of their customized application instead of the cloud platform building blocks.

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Methodology

*iG*R relied on the following sources when writing this whitepaper:

- The Mobile-Edge Computing whitepaper published by the founders of the Mobile-edge Computing (MEC) industry initiative in September 2014
- Discussions with vendors in the industry
- *iG*R's primary research, reports and forecasts
- Secondary research

Disclaimer

The opinions expressed in this white paper are those of *IGR* and do not reflect the opinions of the companies or organizations referenced in this paper. All research was conducted exclusively and independently by *IGR*.

About ADLINK

ADLINK Technology is enabling the Internet of Things (IoT) with innovative embedded computing solutions for edge devices, intelligent gateways and cloud services. ADLINK's products are application-ready for industrial automation, communications, medical, defense, transportation, and infotainment industries. Our product range includes motherboards, blades, chassis, modules, and systems based on industry standard form factors, as well as an extensive line of test & measurement products and smart touch computers, displays and handhelds that support the global transition to always connected systems. Many products are Extreme Rugged™, supporting extended temperature ranges, shock and vibration.

ADLINK is a Premier Member of the Intel® Internet of Things Solutions Alliance and is active in several standards organizations, including PCI Industrial Computer Manufacturers Group (PICMG), PXI Systems Alliance (PXISA), and Standardization Group for Embedded Technologies (SGeT).

ADLINK is a global company with headquarters in Taiwan and manufacturing in Taiwan and China; R&D and integration in Taiwan, China, the US, and Germany; and an extensive network of worldwide sales and support offices. ADLINK is ISO-9001, ISO-14001, ISO-13485 and TL9000 certified and is publicly traded on the TAIEX Taiwan Stock Exchange (stock code: 6166).

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About the Intel® Internet of Things Solutions Alliance

From modular components to market-ready systems, Intel and the 350+ global member companies of the Intel® Internet of Things Solutions Alliance provide scalable, interoperable solutions that accelerate deployment of intelligent devices and end-to-end analytics. Close collaboration with Intel and each other enables Alliance members to innovate with the latest technologies, helping developers deliver first-in-market solutions.

About *iG*R

*iG*R is a market strategy consultancy focused on the wireless and mobile communications industry. Founded by Iain Gillott, one of the wireless industry's leading analysts, we research and analyze the impact new wireless and mobile technologies will have on the industry, on vendors' competitive positioning, and on our clients' strategic business plans.

A more complete profile of the company can be found at http://www.iGR-inc.com/.

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