Creating, Deploying and Managing a Software-Defined Mobile Edge (SD-ME) Cloud

VERSION 1

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Introduction

Enterprises Deploying Edge

Digital transformation in Enterprises is well underway. Enterprises are investing in infrastructure, connectivity, bandwidth, applications and the Cloud in order to get their businesses ready for the digital world. Digital transformation refers to the process of using digital technologies to create new, or modify existing, business processes, culture, and customer experiences to meet changing business and market requirements. This reimagining of business in the digital age forms the crux of digital transformation. Competition in any industry is based on speed, precision in delivery, prompt and competent customer service, marketing, cost management and efficient manufacturing, and companies are spending liberally to make the leap. Worldwide spending to accelerate digital transformation is likely to be a significant portion of the $4.3 Trillion in Information & Communications Technology in 2020, according to IDC¹.

¹ Worldwide ICT Spending to Reach $4.3 Trillion in 2020 Led by Investments in Devices, Applications, and IT Services, According to a New IDC Spending Guide. Feb 20, 2020

https://www.idc.com/getdoc.jsp?containerId=prUS46047320
According to IDC - IT spending will make up more than half of all ICT (Information, Communications and Technology) spending in 2020, led by purchases of devices (mainly mobile phones and PCs) and Enterprise applications. However, when combined, the three IT services categories (managed services, project-oriented services, and support services) will deliver more than $750 billion in spending this year as organizations look to accelerate their digital transformation efforts. The application development and deployment category will provide the strongest spending growth over the 2019-2023 forecast period with a five-year compound annual growth rates (CAGR) of 11.1%, as shown in Figure 1 above.

5G Performance without Upgrading
Digital transformation is being driven by new video, collaboration and productivity applications that demand high performance, low latency and superb quality. The conventional wisdom is 5G will usher in these new applications on mobile devices, and until then, none of this digital transformation will truly be possible.

Alef’s Software-Defined Mobile Edge (SD-ME) platform can enable this new class of applications today on mobile devices without requiring any of the costly infrastructure upgrades to 5G. SD-ME is able to do this through a Software-Defined Mobile Edge computing architecture that handles high performance and low latency applications at the Edge close to the point of consumption by bringing connectivity and computing together in one programmable and open software architecture. By separating the control and user/data planes, which is the 5G imperative, SD-ME is able to accomplish the efficiencies and performance promise of 5G in a small footprint environment at the Mobile Edge today.

Edge is Hot, and it is Predicted to be a Huge Market
Edge computing is hot. Leading companies like Microsoft, Amazon, VMWare, Dell, HP, Intel, Nokia, Ericsson and many startups including AlefEdge have announced strategies and products to serve the burgeoning need for Edge computing and services as Enterprises consider evolving their Cloud computing usage and deployments to this new Edge architecture.

Chetan Sharma Consulting estimates that by 2030, the Edge Internet economy will be over $4.1 Trillion worldwide\(^2\); please see Figure 2 below. The initial growth will come from the Edge serving existing use cases, and will gradually accelerate and be driven by new use cases as deployment becomes more widespread, technology maturation occurs and developers are able to take advantage of an SD-ME architecture through the use of open APIs and services.

In addition, Chetan Sharma Consulting predicts the economic impact of the Edge will be bigger than the cloud and similar to that of Internet and the mobile industry. It will influence all industry sectors and will

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\(^2\) Edge Internet Economy by Chetan Sharma Consulting. How big is the Internet Economy, p 26. 2019.
help create new streams of innovation and disruption, new industries and companies, and new jobs and ecosystems.\textsuperscript{3}

The Promise of the Mobile Edge – Edge Enhanced apps and Edge Native apps
The mobile edge can enhance existing Cloud applications that require speed of delivery, low latency, targeting, high performance and ultra-high definition quality. It can also usher in a whole new class of applications such as AR/VR, autonomous cars, live streaming of video, Stream Processing of simultaneous video streams, Industry 4.0 and others. It will be applications - both existing Edge apps as well as Edge enhanced apps - that will drive this growth as illustrated in Figure 3 below.\textsuperscript{4}

All this will require a robust deployment architecture and SD-ME provides Enterprises one today to take advantage of, without having to wait for costly upgrades to 5G.

\begin{figure}[h]
  \centering
  \includegraphics[width=\textwidth]{edge-internet-economy-growth.png}
  \caption{Edge Internet Economy reaches $4.1T by 2030. Chetan Sharma Consulting}
  \end{figure}

\textsuperscript{3} Edge Internet Economy by Chetan Sharma Consulting. How big is the Internet Economy, p 28. 2019
\textsuperscript{4} Edge Internet Economy by Chetan Sharma Consulting. Edge Internet Economy Segmentation, p 27. 2019
Figure 3 – Growth in Edge is driven by Applications and Services.
Challenges with Mobile Edge Deployment

Deploying a Mobile Edge architecture requires some careful considerations, chief of which are described below.

How can an Enterprise unleash the full power of the Edge?

As the Chief Digital Officer (CDO) or Head of IT, you might be wondering – “as an Enterprise that generates a bunch of mobile traffic, how best can I take advantage of SD-ME?” Traffic aggregation, local breakout to avoid long, costly and slow routes across the Internet, availability of Edge enhanced and native Edge apps, ease of deployment, low Total Cost of Ownership, high availability of SD-ME and security are going to be the CDO or Head of IT’s prime considerations.

What Hardware should an Enterprise Deploy?

SD-ME delivered via an OpEx model being championed by Alef, ensures Enterprises will not have to install costly servers, maintain them, worry about restoring them when they are down and upgrade them as the cost/performance curve inevitably shifts away from them and new hardware becomes available at more attractive price points. Instead, by deploying SD-ME through an OpEx model, Enterprises ensure that any hardware and other infrastructure (such as switches, cloud virtualization software etc.) concerns are taken off their list. SD-ME uses the best available bare metal available in Data Centers worldwide, and comes pre-deployed by Alef, available close to Enterprise locations in various global locations.

To Virtualize or Not?

SD-ME is deployed in a completely Cloud native environment, in a virtualized or fully containerized environment. Abstracting the hardware layer reduces the dependency on any one hardware manufacturer. Virtualization or containerization also allows for a DevOps or CloudOps model with CI/CD to be embraced from a software development and deployment perspective. A good SD-ME provider is constantly adding new features to the network function and/or application layers, and having a fully Cloud native environment helps in the speedy development and delivery of such new features. Also, software being in VMs or containers allows for easy separation of those software components at the Edge that really impact performance and targeting, versus components that are still part of the SD-ME architecture, but are not as critical for performance and can remain in an Origin or Hypercloud environment.

To Automate or Not?

Automation occurs in many important areas of Alef’s SD-ME stack and is crucial to its ease of deployment and excellent customer experience. The first is Installation Automation, which refers to the automated installation of SD-ME components both at the Edge location as well as Central site for the control plane elements. Integration Automation, which is next, refers to the automated way in which Enterprise wireless traffic is integrated into the SD-ME stack as well as the automated way in which
Enterprises latch onto the closest Micro Edge location determined by lowest RTT and latency. A third area of automation is sending Automated Software Updates to Edge locations as new Alef SD-ME versions become available. Licensing of APIs and Edge Services is another area of critical automation in which Alef is leading. A good SD-ME solution will pay acute interest in, and carry out, automation in each of these areas.

**What Architecture to Deploy for the Edge?**

There are many competing architectures for deploying Edge computing. Such architectures range from a Mobile Edge Computing appliance with integrated hardware commonly referred to as Multi Access Edge Computing (MEC), to SAE Gateways at the Edge, to S-Gateways at the Edge to SD-ME at the Edge. SD-ME from Alef is the only architecture that provides for low TCO, ease of APN management, and provides for true mobility across private networks and between the private network (where it is deployed) to the wider public network a user may roam into. Edge Mobility, Edge Roaming, Edge Orchestration, Edge Elasticity – true product differentiators and value generators of Alef’s solution - are possible only with Alef’s SD-ME based 3GPP architecture. These characteristics truly separate a Mobile Edge deployment from an excellent one, and make it ready for mobility, high application performance, low latency, great security and low TCO.

**Edge Cloud Considerations – How to Connect Multiple Edge Locations?**

Connecting disparate Private Edge locations into an Edge Cloud is critical in order to provide mobility, extensibility, and pervasive application availability. Connecting Private Edge networks requires the ideas of Edge Mobility, Edge Roaming and Edge Orchestration to be incorporated. Only Alef’s SD-ME addresses each of these ideas in detail. **Edge Mobility** refers to session persistence when the user moves from one Private Network to another. **Edge Roaming** refers to the availability of compute and application resources no matter where the user is – in their own Private Network, roaming into another Private Network tethered to the same neutral host ePC or roaming into a Public Network. **Edge Orchestration** refers to maintaining application state awareness no matter where the user is, so the application moves with the user. **Edge Elasticity** refers to the dynamic movement of Microservices from one Edge location to another as demand for them fluctuates. All of these capabilities are provided by Alef’s SD-ME stack and create significant value for an Enterprise looking to take advantage of Mobile Edge solutions consistent with their Digital Transformation strategies.

**What about the Hypercloud, i.e. current Origin Cloud?**

Providing an onramp to the Origin or Hypercloud is an important consideration for Mobile Edge solution providers and Alef takes this very seriously. The reason is simple – Enterprises rely on a bevy of applications and databases that still reside in the Cloud at their favorite or multiple Hypercloud providers such as AWS, Azure, Google Cloud, Salesforce Cloud, IBM, Oracle, Box.com and others. While applications that require the power, availability and constancy of the Edge will be moved to the Edge and served from the Edge, the Mobile Edge computing platform will have to provide fast connectivity to the Origin cloud in order for Enterprises to access some of their applications that will continue to reside
there. This is where Alef’s SD-ME shines, as with SD-ME’s local breakout capability, mobile traffic destined to the Origin cloud can be peered at the GTP layer with an IXP that has already set up a peering fabric with the heaviest trafficked sites in the world. This ensures fast RTT for uplink traffic requests that would otherwise go through the P-gateway of the ePC and into the Internet to be satisfied, and the resulting downlink traffic to be routed back after many hops, back to the user.
Alef’s Key Areas of Innovation
Alef invented SD-ME as a way to accelerate Digital Transformation that is well underway in Enterprises, without costly upgrades to existing access infrastructure to 5G or Wi-Fi 6, and without the need to invest in costly Edge computing infrastructure thanks to its as-a-service model. Some of the key aspects of Alef’s innovation are described below.

Alef’s SD-ME is the Software Stack for Edge Computing
For SD-ME architecture to be functional - a mobile access layer (like LTE or Wi-Fi), a Data Center, hardware and software are necessary. Alef is the software provider in this value chain and has the entire software stack to build the Mobile Edge Internet using SD-ME. Alef’s SD-ME software stack can be divided into 3 layers - Mobility and Gateway, Cloud, and Application Enablement. The Mobility and Gateway layer consists of various network services to process and route incoming mobile traffic to intelligently determine what can be served from the Edge as well as setting up a session and creating CDRs and IPDRs to be recorded in Alef’s central site. These central site services are tied to certain packet core functions related to the control plane that have been brought into Alef’s SD-ME architecture, but centralized. Alef’s Cloud layer enables Private Edge networks to be connected seamlessly together to provide connectivity and mobility across Private Edge networks and into the Public network. The Application Enablement layer provides an application framework to easily deploy Mobile Edge applications to satisfy the most stringent of latency requirements at the Edge. All of these layers work symbiotically and seamlessly in the SD-ME stack. Another hallmark of Alef’s SD-ME platform is every layer is open and programmable, and has connectors and APIs to take advantage of some of the best software out in the marketplace from 3rd party providers.

CUPS – at Every Layer. Software Defined
Each one of the software layers – Mobility, Cloud and Application Enablement – follows Software defined principles. Alef has implemented CUPS (Control plane User Plane Separation) in addition to CDPS (Control Plane Data Plane Separation). The control plane is centralized while the user and/or data planes are localized. This is implemented in every layer of Alef’s software stack - gateway, cloud and application. Data plane processing applies to Software Defined Networks (SDN). Whereas, Alef performs user plane processing in addition to data plane processing at the application level. User plane processing means keeping track of the state of the user, and what to serve from each Edge location, and at what quality, to that user. The advantage of a CUPS and CDPS architecture is we reduce a great deal of complexity in the network. The centralized Control Plane is used to set up a session while the localized Data and User Planes allow for the SD-ME solution to deliver low-latency and high performance to the end user. Further, separating these layers allows Alef to keep the footprint in the Edge site very small and light, positively and dramatically impacting the TCO.

Hardware Abstraction
Hardware abstraction is critical to achieve independence from any specific hardware provider. While there is a slight performance penalty for moving away from deploying SD-ME directly on bare metal
hardware and over a virtualized or containerized Cloud native environment, abstracting the hardware layer allows Alef to deploy its software on Bare Metal as a Service (BMaaS) environments in both Micro and Metro Edge Data Centers. This allows Alef to focus on its core software competency of creating virtualized network and application services relevant to mobility and Edge computing in order to deliver a premium experience to Enterprise end users. In order to overcome any loss in performance from hardware abstraction, Alef employs libraries such as DPDK, which is the Data Plane Development Kit that consists of libraries to accelerate packet processing workloads running on a wide variety of CPU architectures. Alef also employs SRIOV (single root input/output virtualization), which in virtualization, is a specification that allows the isolation of PCI Express resources for manageability and performance reasons. A single physical PCI Express bus can be shared in a virtual environment using this specification.

Full Application Development Environment
Alef’s vision is to create a completely programmable open API software stack at every layer to allow developers to take advantage of the powerful SD-ME environment it has created. Alef has connectors and services available for developers to port their applications over to the SD-ME stack to take advantage of the power of the Edge. In the future, Alef will provide a full network services and application development environment or plugins to existing ones such as Mulesoft’s Anypoint platform. If an existing application is containerized or virtualized, it will be very easy to deploy it on Alef’s SD-ME stack.

Full Automation
Automation is vital to quickly deploying Alef’s software stack and onboarding Enterprise customers. We pride ourselves in fully automating the installation of software into the virtualized Edge compute environment. We automate the creation of the virtual machines and or containers through our centralized controller, and make available for installers a user interface (UI) that makes it easy for any installation team to merely execute a Shell script to perfect the installation. We refer to this set of automation rules as Installation Automation.

Alef also champions Integration Automation, which is the automation required to automatically onboard Enterprise wireless traffic be it from Wi-Fi or LTE networks, and in the future, 5G networks. These automated SD-ME deployments can easily be managed from a centralized console. Typically, the Cloud infrastructure layer will be managed by the central controller of Cloud companies such as VMWare and Red Hat. For example, VMWare’s vCloud Director is the central cloud controller for its virtualized Edge instances. This is part of their SDDC (Software Defined Data Center) architecture. Alef will leverage this automation layer of the Cloud Infrastructure layer as well as automation from BMaaS providers such as Packet and Zen Layer as well on the compute layer to get an integrated Private Edge system automation and administration view. Finally, Alef has its automation to deploy updates to APIs, software and other services and any associated licensing at every Edge site.
Keep using your Cloud Applications

For an Enterprise already committed to and using Cloud applications in a multi Cloud environment that includes AWS, Microsoft Azure, Google Cloud, Salesforce Cloud and others, having application availability from the Origin or Hyper Cloud is critical. Alef provides an onramp to the Hypercloud through local breakout of wireless traffic directly to a peering location at an IXP located in a Metro Edge Data Center. This is a core SD-ME capability that Alef provides Enterprises to protect the latter’s investments in current Cloud applications as well as to provide maximum application performance. This results in bandwidth savings as such traffic is managed and served locally with high SLAs, as opposed to using expensive leased lines to reach the Hypercloud.

Innovation Brings About Mobility and Enables Roaming

Companies like VMWare that have created a virtualization and containerization environment called SDDC, have made it easy for SD-ME companies such as Alef to deploy software on top of Cloud native functionality using either their Hypervisor or Kubernetes layer. While a certain degree of miniaturization of the SDDC layer in Micro Edge locations does provide some Cloud native functionality and services to Enterprises and deployers of SDDC, merely having some SDDC functionality on a bare metal compute layer is insufficient to unleash the power and promise of the Edge. This is where Alef’s Software-Defined Mobile Edge comes in and provides the software layers of network and mobility services as well as Application layer functionality to deploy new and existing Edge applications. Mobility is an important capability to ensure Private Network users can easily cross over and “roam” into other Private Networks with full guest privileges, as well as into Macro/public carrier networks, and continue to have their Edge services available. We refer to this constancy as Edge Roaming, and we bring this level of innovation to the Edge.

Coordination Between Edge Cloud Instances

Proper coordination between different Edge Cloud instances is critical to ensure the user has a smooth experience with regard to session handoffs as he/she traverses across the Private Network and crosses over into an adjoining Private Network or into a Macro Public network. This is referred to as Edge Mobility. Session handoff is critical so the Edge compute session can continue uninterrupted. Edge Roaming is the ability for a user to roam outside his/her immediate Private Network into another Private Network tethered to the same neutral host ePC or into a Public Network also tethered to the same neutral host ePC and part of a Roaming marketplace. With Edge Roaming, a user will be registered as a guest in these guest networks and have Edge compute and application resources available. This requires accessing the user’s traffic on 3GPP interfaces such as S1 and S8, which is part of Alef’s innovation.

Application Constancy - Orchestration

Application constancy refers to the user’s application state being stored and resumed as the user moves from one Private Edge site to another. This is referred to as Edge Orchestration, another of Alef’s core value propositions and product differentiators. Edge Orchestration requires maintaining the user’s application state and refers to the movement of microservices with the user. It is mobility management at the application layer, i.e. maintaining session and application states across Edge sites. Mobile devices
connect to multiple Private Edge sites at the same time. These Private Edge sites are distributed geographically. Each Private Edge site has multiple containers, but not all microservices in a given Edge site are relevant to a given application session. Private Edge sites connect to multiple mobile devices at the same time. We have “many to many” associations between mobile devices and Edge sites which change as a function of time. Managing these dynamic associations and state transfers as a function of time is what we refer to as Edge Orchestration, one of Alef’s core areas of Intellectual Property.
Future Innovation

There are several areas of innovation Alef is engaged in. A few of these are listed below.

EdgeOps™

DevOps refers to the practice of operations and development engineers participating together in the entire service lifecycle, from design through the development process to production support. DevOps is also characterized by the operations staff making use of many of the same techniques as developers for their systems work. These techniques can range from using source control to testing to participating in an Agile development process. DevOps has a set of values, principles, methods, practices and tools.

There are three primary practice areas that are usually discussed in context of DevOps⁵:

- Infrastructure Automation – create your own systems, OS configs, and application deployments as code.
- Continuous Delivery – build, test, deploy your applications in a fast and automated manner.
- Site Reliability Engineering – operate your systems; monitoring and orchestration, but also designing for operability in the first place.

DevOps can be implemented on an Enterprise premise or as a service. When it is deployed as a service, it is referred to DevOps as a Service (DaaS). DaaS is a managed, cloud-based service that provides a unified DevOps toolchain⁶. All or most of the tools necessary for a continuous integration/continuous delivery (CI/CD) pipeline are collected in a single platform. This platform is then provided to teams with the support of dedicated DevOps professionals. The goal of DaaS is to enable organizations to focus on developing and delivering software without having to worry about managing or maintaining tools. It is designed to abstract away the intricacies of tool integration, deployment and maintenance. This enables teams to focus on higher-level tasks, and outsources significant manual effort. DaaS can provide small to medium businesses with Enterprise-level infrastructure and tooling without needing to hire more staff or build extensive expertise. Instead, these businesses can rely on the experience of DaaS providers to create, deploy and optimize a pipeline for them. These pipelines are created to be intuitive and to facilitate the smooth collaboration of all team members.

EdgeOps is a new area that will see traction in the future. Just like DevOps, EdgeOps will have a set of values, principles, methods, practices and tools related to Edge apps and services development, testing and delivery. EdgeOps will have its own set of tools and processes that will be deployed within Enterprises or it will be offered as a Service on Alef’s SD-ME platform. This is referred to EdgeOps as a Service (EOaaS).

Edge Application Environment – Mulesoft for the Edge

Mulesoft is a company that provides the Anypoint platform. Anypoint is one of the leading integration and API platforms in the industry. An Enterprise developer can use Mulesoft’s Develop, Deploy, Secure, Manage and Reuse platforms easily, and convert legacy monolithic applications that are running on-premise to entirely cloud-native applications that can run on-premise, in the cloud or in hybrid

⁵ https://theagileadmin.com/what-is-devops/
⁶ https://devops.com/devops-as-a-service-migrating-your-entire-devops-stack-to-the-cloud/
environments. Just as Mulesoft revolutionized and accelerated the development of applications and made them Cloud ready, by modeling on this vision, Alef will provide a platform with connectors, APIs, and SDKs to easily convert existing applications that are running in the Cloud or on-premise to Alef’s SD-ME platform. This will enable developers of all stripes to easily harness the power of the Edge by Edge enhancing their existing applications and being able to build a whole new class of native Edge applications. Intelligently rearchitecting applications for the Edge is one of Alef’s core competencies. We apply our knowledge of CUPS principles to keep certain microservices at the Edge and the rest in the Cloud services layer, so those microservices that are performance sensitive stay on the Edge and the rest are in the Cloud. This lowers the TCO of our deployments significantly.

Future Edge Architectures
Alef will publish Reference Designs for SD-ME deployment at the Edge in a number of areas. Some of these are listed below.

- 3GPP Security overlaid on WiFi (Passpoint)
- Edge Video Streaming for Enterprises
- Boost performance of the Internet
- SD-ME Automation
- Roaming Capabilities, (Open Roaming Initiative)
- Guest Authentication
- Video surveillance & stream processing
- Video Conferencing
- Smart Retail
- Industry 4.0
- Drone inspection from the Edge
- Management of Billing & Invoicing
- DOOH Connected Screen owner - onboarding onto the Edge

Operations Automation - AI Ops for the Edge
AIOps stands for artificial intelligence for IT operations. It refers to multi-layered technology platforms that automate and enhance IT operations through analytics and machine learning (ML). AIOps platforms leverage big data, collecting a variety of data from various IT operations tools and devices in order to automatically spot and react to issues in real-time while still providing traditional historical analytics.

This is particularly important for the Edge where workloads are dynamic, and not static as they are with the traditional hypercloud, where workloads don’t change from one server to another. In a traditional hypercloud environment, if a server goes down, redundancy ensures another server starts up, and workload dimensioning is generally predictable and static.

With the Mobile Edge, things are very different – because of mobility and the user plane moving around, servers, storage and switching capacity have to be able to dynamically sense, calibrate and adjust to continuously changing Edge compute demands. So the level of measurement, allocation and automation
needed is significant. Likewise, there is a huge premium on observation, data analysis, anomaly detection, performance analysis and knowledge management. Dashboards are very critical as well - making everything visible and actionable for network administrators.

The diagram below from Gartner shows how an AIOps platform works\(^7\). AIOps has two main components: big data and ML. It requires a move away from compartmentalized IT data in order to aggregate observational data (such as that found in monitoring systems and job logs) alongside engagement data (usually found in ticket, incident, and event recording) inside a big data platform. AIOps then implements a comprehensive analytics and ML strategy against the combined IT data. The desired outcome is automation-driven insights that yield continuous improvements and fixes. AIOps can be thought of as continuous integration and deployment (CI/CD) for core IT functions.

\[\text{Figure 4 – Gartner’s Visualization of the AIOps Platform}\]

AIOps bridges three different IT disciplines—service management (Engage), performance management (Observe), and automation (Act)—to accomplish the goal of continuous insights and improvements. AIOps creates a new approach within fast-moving and dynamic IT environments that is underpinned by advances in big data and ML.

AIOps will be a significant differentiator for a successful Software defined Mobile Edge deployment and will be an area of investment and innovation leadership for Alef.

\(^7\) Gartner’s Visualization of the AIOps platform. BMC Blogs - AIOps in 2020: A Beginner’s Guide