Where the Edges Meet, Infra Forms, Apps Land and Work Flows

*How DevOps driven optimally deployed infrastructure and software will make cloud native 5G a reality*

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Outline

- 5G and Edge

- DevOps Multi-domain Infra Orchestration
  - Public Cloud Edge Interface
  - MEC Federation use case

- Who Is Equinix?
5G and Edge
New applications drive expansion to the edge and densification of networks

<table>
<thead>
<tr>
<th>User to App Distance</th>
<th>Legacy</th>
<th>Existing</th>
<th>Forming</th>
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<tr>
<td>Distance</td>
<td>Centralized</td>
<td>Distributed</td>
<td>Edge</td>
</tr>
<tr>
<td>~ $10^3$ km</td>
<td>~ $10^0$ sec</td>
<td>~ $10^2$ km</td>
<td>~ $10^1$ km</td>
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<td>~ $10^0$ sec</td>
<td>~ $10^{-1}$ sec</td>
<td>~ $10^{-1}$ sec</td>
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Ubiquitous Edge

present, appearing, or found everywhere

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<tr>
<th>Devices</th>
<th>Fiber Aggregation</th>
<th>Traffic Aggregation</th>
<th>Interconnection Hubs / Peering</th>
<th>Cloud AZ Telco Core</th>
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<td>Tower Sites</td>
<td>Central Office</td>
<td>Edge Data Center</td>
<td>Mobile Switching Centers</td>
<td>Cloud Edge Zones</td>
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<td>Premise</td>
<td>Edge Zones</td>
<td>Multi-Tenant Data Centers</td>
<td>Cloud Local Zones</td>
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</tbody>
</table>

Latency
- **Device Edge**: 0 – 1 ms
- **Far Edge**: 1 – 5 ms
- **Micro Edge**: 5 – 10 ms
- **Macro Edge**: 10 – 50 ms
- **Core Cloud**: 50 – 100 ms

Power
- **Device Edge**: 0.5 - 1 W
- **Far Edge**: 10 – 100 KW
- **Micro Edge**: 100 – 5000 KW
- **Macro Edge**: 5000 – 20000 KW
- **Core Cloud**: 20000+ KW
5G: Major Technological Inflection Point for Digital Infrastructure

New thinking required to optimize an evolving multi-variable function

- 10 Gbps Peak Data Rate
- 10 Tbps/km² Area Traffic capacity
- 500 km/h Mobility
- 1M devices / km²
- 5 msec E2E Latency
- 99.999% Availability
- Energy efficiency
- Rapid Service Deployment
- Edge and Core Applications

### Key Metrics

- **10 Gbps Peak Data Rate**
- **10 Tbps/km² Area Traffic capacity**
- **500 km/h Mobility**
- **1M devices / km²**
- **5 msec E2E Latency**
- **99.999% Availability**
- **Energy efficiency**
- **Rapid Service Deployment**
- **Edge and Core Applications**

### Key Components

- **Open Virtual RAN**
- **5G Core**
- **Edge Compute**
- **Network Fabric**
- **5G Core**
- **Edge Compute**

### Key Areas

- **SPECTRUM**
- **FIBER**
- **TRANSPORT**
- **HARDWARE**
- **ECOSYSTEMS**
- **RAN DENSITY**
- **MICRO EDGE DC**
- **MACRO EDGE DC**
- **INTERCONNECTION**
- **APPLICATIONS**

Image: Diagram illustrating the components and metrics of 5G infrastructure, including RAN, Micro Edge DC, Macro Edge DC, Core DC, and various key metrics.
Transformation of 4G/5G infrastructure and use cases

- **2016 - 2019**
  - Virtualization and Distribution of Mobile Core
  - Network Densification (4.5G)
  - 5G Non-Stand-Alone
  - 5G Fixed Wireless Service (To home/enterprise)

- **2019 - 2022**
  - Densification Evolving
  - Cloud IoT / LPWA on Micro Edge
  - Small Cells
  - Fiber densification
  - 5G NSA Mobile Devices
  - V-RAN
  - Enhanced Mobile Broadband

- **2022 - 2025+**
  - Next Generation Long-term
  - Private 5G
  - 5G MEC
  - 5G URLL
  - Massive IoT
  - Self driving cars
  - Cloud Gaming

**Potential killer app**

**Legend**
- Infrastructure
- Service on Infrastructure
- Technology
Making 5G a Reality: Optimally-Distributed Architecture

Optimally-placed & interconnected infrastructure required to deliver on 5G performance promises

Distance spectrum dependent (0.1-5 km)

Example: Desired End-to-End Latency of 5 ms

Latencies and distances are estimates
Network Slicing for Interconnection of Core and Edge – Multi-MEC, Multi-Cloud

The Slicing Must Go On

- MNO Common Control Plane Functions (Auth, Billing, Policy, Mobility)
- Equinix Network Slicing Controller/Orchestrator
- Cloud Control Plane

- **Device Segment**
  - Ultra Reliable / Low Latency Slice
  - Programmable Network Fabric

- **RAN Segment**
  - Virtual Network

- **Transport Segment**
  - L2/L3
  - 3rd Party Compute

- **Core Segment**
  - Equinix Metal
  - MEC
  - UPF
  - L2/L3

- **Software Defined Interconnection Segment**
  - Equinix Fabric
  - Enhanced Mobile Broadband Slice
  - Machine Type Communications Slice

- **Cloud Control Plane**
  - AWS
  - Equinix Data Center
  - Cloud Provider

- Mobile Network Operator

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Equinix Metal

Programmable Network Fabric

L2/L3

3rd Party Compute

Equinix Fabric

Enhanced Mobile Broadband Slice

Machine Type Communications Slice

Mobile Network Operator

Equinix Data Center

Cloud Provider
DevOps Multi-domain INfra Orchestration
The purpose of Public Cloud Edge Interface (PCEI) Blueprint is to develop a set of open APIs, orchestration functionalities and edge capabilities for enabling Multi-Domain Interworking across the Operator Network Edge, the Public Cloud Core and Edge, the 3rd-Party Edge as well as the underlying infrastructure such as Data Centers, Compute Hardware and Networks.
Public Cloud Driven Edge Computing: PCC-PCE Interactions

- **Orchestration (O):** Automation and sequencing of deployment and/or provisioning steps. Orchestration may take place between the PCC service and PCE components and/or between an Orchestrator such as the PCEI Enabler and PCC or PCE.
- **Control (C):** Control Plane messaging and/or management interactions between the PCC service and PCE components.
- **Data (D):** Data Plane messaging/traffic between the PCC service and the PCE application.
High-Level PCEI Architecture

UE1

MNO RAN Functions

MNO Control Plane and Orchestration Functions

3rd-Party Edge App (3PE)

Public Cloud Edge App (PCE)

Public Cloud Core (PCC)

Public Clouds

Infrastructure

EWBI Interconnect

Bare Metal Orchestration

Virtualization

Distributed User Plane Function (UPF/SPGW-U)

Far/Micro/Macro Edge DCs

Cloud DCs

MNO Compute HW

MNO Core Network

MNO DCs

SGi/N6

L1-L3 Interconnect / Networking

IP

P2'

P3

P5

P4

P7

P8

Fronthaul/ Midhaul

Bare Metal HW / Orchestrator

Apps and Functions

Network Function Deployment

Edge App Deployment

UE2
Orchestration with Infra-as-Code

- **Uniform** - use of the same infrastructure orchestration methods across public clouds, edge clouds and interconnection domains.

- **Model-free** – the orchestrator does not need to understand the details of the individual infrastructure domains (i.e., implement their models). It only needs to know where to retrieve the Terraform plans for the domain in question and execute the plans using the specified provider.

- **External state** – the state of infrastructure resources created by the orchestrator is stored outside of the orchestrator itself, making it stateless with respect to the infrastructure.

- **DevOps driven** – the Terraform plans can be developed and evolved using DevOps tools and processes.
- NBI APIs
  - GIT Integration
  - Dynamic Edge Cluster Registration
  - Dynamic App Helm Chart Onboarding
  - Automatic creation of Service Instance in EMCO and deployment of Apps
  - Automatic Terraform Plan Execution
- Workflow Engine
  - Camunda
- Integrated Terraform Plan Executor
  - Azure (PCC)
  - AWS (PCC)
  - Equinix Fabric (Interconnect)
  - Equinix Metal (Bare Metal Cloud)
  - Openstack (3PE)
- Equinix Fabric Interconnect
- Multi-Public Cloud Core (PCC) Orchestration
  - Kubernetes Edge
  - Openstack Edge
  - Cloud Native 5GC and UPF Deployment
MEC Federation with PCEI?

(Solution submitted for the ETSI – LF Edge Hackathon 2022)
MEC Service Federation for Location-aware IoT with DevOps MEC Infra Orchestration

ETSI – LF Edge Hackathon 2022

Team DOMINO solution submission
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Vivekanandan Muthukrishnan, Aarna Networks,
vmuthukrishnan@aarnanetworks.com
In our solution we use Akraino Public Cloud Edge Interface (PCEI) blueprint and MEC Location API service to demonstrate orchestration of federated MEC infrastructure and services, including:

- Bare metal, interconnection, virtual routing for MEC and Public Cloud IaaS/SaaS, across two operators/providers (a 5G operator and a MEC provider)
- 5G Control and User Plane Functions
- Deployment and operation of end-to-end cloud native IoT application making use of 5G access and distributed both across geographic locations and across hybrid MEC (edge cloud) and Public Cloud (SaaS) infrastructure

By orchestrating, bare metal servers and their software stack, 5G control plane and user plane functions, interconnection between the 5G provider and MEC provider, connectivity to a public cloud as well as the IoT application and the MEC Location API service, we show how it is possible for providers to enable sharing of their services in a MEC Federation environment.
Summary of contributions and innovations

• A practical use case showing a realization of ETSI MEC Federation architecture
• An introduction and a functioning demonstration of MEC Federation Data Plane
• Implementation of the GSMA OPG Edge Node sharing scenario using MEC Federation
• Implementation of ETSI MEC Location API Service and its integration with a MEC application
• Implementation of a combined MEC Federation Broker and MEC Orchestrator with unique capabilities for infrastructure orchestration in multiple domains such as public cloud, edge/MEC cloud, network operator, 5G control plane and user plane cloud native function deployment as well as cloud native service and application deployment
• Implementation of integrated Terraform Infrastructure-as-Code module into the orchestrator enabling DevOps infrastructure orchestration
• Implementation of integrated Ansible Infrastructure Configuration and Installation module into the orchestrator
• Cloud native 5G Control Plane and Distributed UPF deployment design and the correspondent Helm Charts
• Use of production services (by Equinix) such as bare metal cloud, virtual network functions, public cloud access and a global interconnection fabric as dynamically orchestratable infrastructure components for the realization of the MEC Federation use case
• Implementation of a reference IoT client
• Implementation of a custom software module for Azure IoT Edge that enables its integration with ETSI MEC Location API service
• An end-to-end demonstration of the infrastructure orchestration, 5G control plane and user plane functions deployment, ETSI MEC Location API service deployment and the location aware, distributed IoT application operation
Use Case Description
What does the use case do?

**Infrastructure Orchestration Stage**
- **5G Operator**
  - Orchestrate Bare Metal
  - Orchestrate K8s Install
- **MEC Fed Interconnect Provider**
  - Create Private
  - MEC Federation Data Plane Connection
- **MEC Provider**
  - Orchestrate Bare Metal
  - Orchestrate K8s Install
  - Orchestrate virtual router
  - Orchestrate ExpressRoute to Azure

**5G Network Functions and MEC Services/Applications Deployment Stage**
- **5G Operator**
  - Create 5G network slice for IoT customer
  - Orchestrate 5G Control Plane Functions
  - Orchestrate 5G User Plane Functions
  - Orchestrate MEC Location API Server
- **MEC Provider**
  - Orchestrate hybrid MEC IoT Application
  - Orchestrate Azure IoT Edge GW on MEC Server
  - Orchestrate Azure IaaS and IoT SaaS (IoT Hub)

**End-to-end Application Operation Stage**
- **5G UE**
  - Register with 5G Network
  - Establish PDN Connection
- **IoT Client**
  - Send Encoded
  - IoT Sensor data
    (Temp, Humid, Pressure)
- **IoT Edge Gateway**
  - Receive encoded data
  - Decode sensor data
  - Obtain location data
  - Send sensor and loc data to cloud
- **Cloud IoT Hub**
  - Receive IoT data
    (Temp, Humid, Pressure, Lat, Lon, Alt)
MEC Service Federation Call Flow: Location aware Low Power IoT

**IoT Client/UE**
- Send sensor data in Low Power Encoding: Temp, Humidity, Pressure, UE ID
- Obtain UE Location
  - Respond with UE Location Info Lon, Lat

**5G Operator UPF**
- Decode sensor data and Convert to JSON
- GET UE Location, UE ID

**MEC Location API Server**
- Add UE Location Info to decoded IoT message

**MEC Fed Data Plane**
- Post decoded and enriched IoT message to IoT Hub
  - Temp, Humidity, Pressure, Coordinates

**MEC App IoT Edge**
- Display location aware IoT Data on map

**Virtual Router VNF**

**Cloud Interconnect ExpressRoute**

**Public Cloud IoT Hub SaaS**
Architecture of the Orchestrator
Orchestration with Infra-as-Code

- **Uniform** - use of the same infrastructure orchestration methods across public clouds, edge clouds and interconnection domains.

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- **DevOps driven** – the Terraform plans can be developed and evolved using DevOps tools and processes.

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**Orchestrator**

**Workflow Engine**

**Terraform Microservice**

**Git**

**Terraform Plan (templates)**

**NBI APIs**

**Attributes**

**Terraform Provider**

- **Service** (bare metal)
- **Component** (compute server)
- **Feature** (os, lacp...)

**Edge Providers**

**Terraform Provider**

- **Service** (L2)
- **Component** (E-LINE)
- **Feature** (802.1q, Q-in-Q)

**Interconnect Providers**

**Terraform Provider**

- **Service** (Networking)
- **Component** (VPC)
- **Feature** (subnet)

**Public Cloud Providers**

**Uniform**

**Terraform resource and data definitions**

**DevOps driven**

**External state**
Orchestration Workflow Design
ETSI MEC Location API server implementation

- Use ETSI MEC spec – MEC013 Location API
- Generate and containerize MEC013 Location API server code
- Generate Helm charts for the code to make it deployable on Kubernetes
- Use Akraino PCEI Orchestrator as a MEO/MEPM to:
  - Onboard MEC013 Location API server as a Service/App
  - Deploy Equinix Metal server (MEP/MEC Host)
  - Install Kubernetes on Metal server
  - Onboard Kubernetes cluster to PCEI Orchestrator
  - Deploy MEC013 Location API Service (as MEC App)

API Requests

MEC013 Location API Client
Inside IoT Edge PCE App

API Responses
End-to-end traffic flow

PCEI Enabler (MEC Federation Broker/Orchestrator)

Operator A Resources (Silicon Valley, CA)  MEC Federation Interconnection Provider Resources  Operator/Provider B Resources (Dallas, TX)

5G Core Control Plane  IP/Network  Bare Metal/K8s

BGP  MEC Fed Data Plane (Fabric)  L2

IP/Network  Bare Metal/K8s  Bare Metal/K8s

5G Network Slice and Location Service  gNB  UE

MEC Federation Data Plane  Location request/response

MEC/LoT Edge (Azure)  Bare Metal/K8s  Fabric

Decoded IoT and Location data

Public Cloud Core (PCC)  IaaS/SaaS IoT Hub (Azure)

MEC Federation Interconnection Provider Resources

Equinix  Aarna  ETSI MEC  free5GC  IoT App (Azure IoT Edge and Azure Cloud)
Thank you

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vmuthukrishnan@aarnanetworks.com

For more details, please follow the links:

Detailed solution document
Demonstration video
Solution presentation
Who Is Equinix?
Who Is Equinix
Equal access, neutrality and interconnection
History of Equinix
At the center of digital transformation for over 20 years
Equinix by the Numbers

Global infrastructure and exchange platform for digital business

- **248+** Data Centers
- **71** Metros
- **31** Countries
- **6** Continents
- **10,000+** Companies
- **435,000+** Interconnections
- **99.9999%** IBX Uptime

**Ecosystems**
- 1,800+ Networks
- 650+ Media & Entertainment
- 1,250+ Financial Services
- 3,000+ Cloud & IT

**Edge Services**
- Network Edge (NFV)
- Bare Metal (BMaaS)

**Interconnection**
- Equinix Fabric (SDN-enabled)
- Internet Exchange (12.6+ Tbps)

**Strategic Locations**

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*Provides connectivity to local clouds within the UAE.*
# Building Ubiquitous Edge with Platform Equinix

## Infra Orchestration
- APIs
- Terraform
- Portals

## Edge Services
- Network Edge
- Bare Metal
- Precision Time

## Interconnection Services
- Cross Connects
- Equinix Internet Exchange™
- Equinix Connect
- Equinix Fabric™

## Data Center Services
- Edge Data Centers
- IBX® Data Centers
- xScale™ Data Centers
We Can Start Making 5G Real Now

80% of U.S. urban/metropolitan population is within 10 ms RTT from Equinix data centers
Call for Collaboration (Better Together)

Industry engagements – 5G and edge

**Equinix 5G and Edge Technology Development Center**

- Develop 5G and edge architectures leveraging ecosystems already in place at Equinix
- Explore hybrid multicloud interconnectivity scenarios between MNOs, public clouds and private infrastructures
- Develop multiparty business models, partnering strategies and go-to-market motions for 5G and edge market

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<th>Multi-Domain Orchestration</th>
<th>Network Slicing Orchestration</th>
<th>5G Core Orchestration</th>
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<th>Simulation And Testing</th>
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<td>Edge Compute Apps</td>
<td>Cloud Native 5G Core</td>
<td>Equinix Metal</td>
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<td>Micro Edge DC</td>
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<td>Macro Edge DC</td>
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Call for Collaboration (Better Together)

Industry engagements – open-source & developer community

- **LF Edge** – The Linux Foundation
  - Premier member (top-level membership)
  - Governing Board member
  - Technical Steering Committee Co-Chair of Akraino project
  - Technical lead for Public Cloud Edge Interface blueprint

- **LF Networking** – The Linux Foundation
  - Silver member (standard membership)

- **CNCF** (Cloud Native Computing Foundation) – The Linux Foundation
  - Gold member (2nd-top-level membership)
  - Governing Board member