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L. Geng
China Mobile
M. Zhang
M. McBride
B. Liu
Huawei

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Problem Statement of Edge Computing on Premises for Industrial IoT

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Abstract

This document introduces the concept of Beyond Edge Computing (BEC) which brings edge computing capabilities down to the level of customers' premises for industrial IoT use cases. The purpose of the document is to discuss the general problem statement of BEC including capabilities, and use cases. Potential technical gaps in IETF problem scope that are related to BEC are also evaluated.

Status of This Memo

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1. Introduction

Edge computing is an important network architecture particularly in the support of Industrial verticals such as Energy, Manufacturing, Healthcare, Mining and Smart City/Buildings. Edge computing will provide local compute, storage and connectivity services particularly for latency and bandwidth sensitive applications. There are several organizations which are working on edge computing definition and architecture with various emphases. For instance, ETSI MEC (previously mobile edge computing and now multi-access edge computing) looks at edge computing from the perspective of the edge of the provider network. It also has an successive convention of focusing on cellular network requirements. The Industrial Internet Consortium (IIC) and Edge Computing Consortium (ECC) works on edge computing in a more general view of industrial IoT, where edge computing nodes are even closer to verticals (i.e. the very first hops where the service is connected to the network). Typically, the edge computing nodes are located at customers' premises. However, IIC and ECC are not standard organizations and they rely on communities such as IETF to provide protocols and API definitions for their architectural use especially as Operation Technology (OT), Information Technology (IT) and Communication Technology (CT) converge.

Edge computing concepts have been presented in various groups within the IETF/IRTF. The edge computing topic, similar to cloud computing, is much too broad to tackle within the IETF. There are specific protocol/interface areas, however, that can be worked on in the IETF once we identify a specific area of focus. BEC is one of the specific area which looks at edge computing from the industrial verticals such as factory, hospital, power and city/ building perspective and down to the level of local edge support for sensors, engines, pumps and machinery.

A simple example, of BEC, is factory equipment having connected sensors which are generating data and sending to the equipment within an edge computing environment. One sensor, connected to this equipment, could generate an event, such as overheating, and an connected actuator could quickly increase fan span or reduce engine speed depending upon the data within the local edge computing node. This type of event is being controlled today within closed industrial command and control protocols. But what is not generally available is the ability for open edge computing equipment to generate predictive maintenance and command and control across factories, verticals and into the cloud. This is where we see a gap in standards definitions and an opportunity for new protocols and interfaces, in which IETF could play a particularly important role.

1.1. Requirements Language

The key words "MUST", "MUST NOT", "REQUIRED", "SHALL", "SHALL NOT", "SHOULD", "SHOULD NOT", "RECOMMENDED", "MAY", and "OPTIONAL" in this document are to be interpreted as described in RFC 2119 [RFC2119].

1.2. Terminology

- o BEC - Beyond Edge Computing, a concept of on-premises edge computing where the devices deployed directly at customers' premise are worked on.

2. The Concept and Capabilities of Beyond Edge Computing

Beyond Edge Computing (BEC) looks at the on-site intelligent evolution of industrial verticals. It brings the edge computing capability down to the level of customer premises, which are typical beyond the access network of a service provider.

```
+--------------------------------+
|   Core Data Center             |
+--------------------------------+
         ***   Backbone
        *   *  Network
         ***
+--------------------------------+
|   Regional Data Center         |
+--------------------------------+
         ***   Metropolitan
        *   *  Network
         ***
+--------------------------------+
| Local Data Center/Access Point|
+--------------------------------+
      ***   Access    ***
     *   *  Network  *   *
      ***             ***
+------------+     +------------+
|  Beyond    |     |  Beyond    |
|   Edge     |     |   Edge     |
| Computing  |     | Computing  |
+------------+     +------------+
```

Figure 1: Beyond Edge Computing in the Network

Figure 1 illustrates the schematic diagram of BEC in terms of its position in a overall network. BEC takes care of the first hop where the service of a particular industrial vertical connects to the network. It can be regarded as an extended intelligent connectivity capability of a service provider’s network to industrial verticals. Meanwhile, it also expands the cloud computing ability directly to customers’ sites.

2.1. Heterogeneous IoT Device Compatibility

Vertical industries have various interfaces for on-premises LAN and WAN. This include both wireless and fixed line systems. Taking the field bus as an example, 10 different specification are defined in IEC61158, which is only a small portion of the existing field bus technologies people can actually find in real world. BEC should provide the capability of protocol translation and mapping, which enables the inter-operation between different systems.

2.2. Deterministic Networking

One of the most important motivation of BEC is to reduce the propagation latency by the deployment of services most closer to users. However, the processing and scheduling latency cannot directly benefit from closer deployment. Especially as the end-to-end propagation latency for a edge service has been reduced to less than 1 ms, processing and scheduling latency became even more essential. At the same time, emerging services including AR/VR, Remote robot system and motion control rely on not only low but also a strictly deterministic latency. Real-time operation system will be a preferred choice for BEC. Additionally, high-precision time synchronization and packet preemption are also significant characteristics for deterministic network in BEC system.

2.3. Management of Massive Amount of Devices

It is expected the hundreds of millions of BEC nodes will be deployed in industrial internet scenario, typically in a form of gateway. Management is the key to provide reliable and flexible edge services using BEC nodes. It is preferred to have unified interface to realize both device-level and resource-level management of BEC nodes.

2.4. Support of Network Slicing

An important benefit of BEC is the capability of edge service deployment. Based on light-weight distributed NFV technologies, the resource on BEC nodes can be dedicated for particular application. At the same time, the packet of a certain edge service can be labeld and steered to the preferred network slice at the WAN side, creating a true end-to-end network slice for industrial verticals.

2.5. Multi-ecosystem Environment

It is preferred to have a unified set of APIs, which achieve a deep-level capability exposure of the BEC nodes. The functions can be exposed to the upper layer applications in terms of forwarding, address, management and physical interface functionalities.

3. Reference Architecture

```
          +--------------------------------+
          |     BEC Management Platform    |
          |                                |
          | +----------------------------+ |   +-------------+
          | |     Application Management | |   |             |
          | +----------------------------+ |   | IoT         |
          | +------------+  +------------+ |   | Cloud       |
          | | Device     |  | Resource   | |   | Services    |
          | | Management |  | Management | |   |             |
          | +------------+  +------------+ |   |             |
          | +----------------------------+ |   |             |
          | |   SDN Platform             | |   +----+--------+
          | +----------------------------+ |        |
          +--------------------------------+        |
                          | Management              |Data
                          | Channel                 |Channel
          +----------------------------------------------------+
          | +-------------v-------------------+     |          |
          | |   Management Data Model         |     |          |
          | +---+-------+-------+---------+---+     |          |
          |     |       |       |         |         |          |
          |     |       |       |         |         |          |
          |     |       |       |     +------------------+     |
          |     |       |       |     |   +---------+    |     |
          |     |       |       |     |   |  APP    |    |     |
          |     |       |       |     |   +---------+    |     |
          |     |       |       |     |Container/VM      |     |
          |     |       |       |     +------------------+     |
          |     |       |     +-v----------------------------+ |
          |     |       |     |     Virtualization Layer     | |
          |     |       |     +------------------------------+ |
          |     | +-----v------------------------------------+ |
          |     | |       API Exposure                       | |
          |     | +------------------------------------------+ |
          | +---v--------------------------------------------+ |
          | |               Linux Kernel                     | |
          | +------------------------------------------------+ |
          |   Ethernet   Bluetooth    PLC      RF    RS485     |
          |   WiFI       FXS          DI/DO          RS232     |
          +----------------------------------------------------+
```

       Figure 2: The Reference Architecture of Beyond Edge Compuring

   Figure 2 demonstrates the reference architecture of BEC system with a managed BEC node and a cloud-based management platform. An IoT gateway is the typical form of a BEC node device. Gateways always play important role in the Cloud-Edge architecture since they are the most popular devices where verticals are provided with various capabilities such as computing, storage and networking. In addition, applications for various vertical customers are developed by themselves or third-party while deployed on demand. Giving the edge computing ability of BEC, much of the data can be processed by applications running on the gateway locally as required by vertical customers. The gateways are commonly versatile protocol speakers so that devices speaking different protocols can communicate with the them. The East-West connectivity between BEC nodes might be enabled by various protocols such as OPC-UA, MQTT, TSN and other deterministic Ethernet protocols, for example EtherCat, Ethernet/IP, Profinet. To facilitate the operation of the BEC system, a central controller in the cloud is provisioned to the customer. It mainly supervise the device, virtulization resource and application life cycle of the BEC node.

The key requirements of BEC are in providing distribution service entities on the customers site (end AP, devices) to meet the growing demand for low latency, reliable, and secure vertical industries. The Computing, Storage, I/O isolation are remotely managed at the edge to provide certain dedication and quality guarantees. Agile, flexible and scalable deployment of services from operator/third party down to the edge through software entities (VM/ Containers). A light weight MANO like approach is needed to provide resource provisioning and VNF deployment. A unified API definition is needed to support the co- existence of multi-ecosystem at the BEC node. And there needs to be the ability for the edge device to map specific service requirements with an end to end network slice with certain guarantees and pass the policy identification along the path to the centralized DC.

4. Use Cases of BEC

1. Elevator Networks

Description: There are more than 15 million elevators around the world and the daily maintenance of these elevators costs elevator operators a large amount of revenue. An elevator usually carries hundreds of sensors which are generating a large amount of data to be uploaded to the cloud. The BEC nodes can preprosess the data gathered from elevator sensors so that the volume to be uploaded to the Cloud is greatly reduced. Based on the input from elevator sensors, AI programs installed on BEC nodes may locally make decisions without the intervention of the Cloud. For example, when the noise or vibration of an elevator exceeds a certain level, the

BEC node may notify elevator maintainers to reach this elevator and perform maintanence or repair.

Goal: BEC nodes are deployed into elevators to gather/preprocess/ compress the data to save the communication cost. Based on the data gathered from elevator sensors, BEC nodes can assist operators to do predictive maintenance.

Requirements: Customized gateways operated by elevator providers. An open platform with VMs/containers which can hold customized Apps. These Apps are managed by elevator operators while developed by gateway vendors or any other third parties. Various connectivities are supported (2G/3G/LTE/eMTC/Ethernet) by BEC nodes. A central controller to perform configuration and management of the network. AI models are trained on the Cloud while the reasoning of these AI models are performed at the Edge.

2. Intelligent Street Lights

Description: BEC nodes are placed on street lights to act as board routers of LLNs. BEC nodes may act as RSUs of vehicle networks. With AI programs installed on the BEC nodes, reasoning and decisions might be made locally at the edge. For example, For example, BEC nodes can adjust the lights’ brightness and operating hours according to environment parameters, providing illumination when needed while reducing power consumption. With sensors on trash cans, BEC nodes are aware whether a trash can is full. Trash collecting cars can communicate with the BEC nodes to determine whether to reach a trash can to collect the trash.

Goal: BEC nodes gather data from sensors which are used to monitor various information (e.g., brightness, temperature, humidity) of a district.

Requirements: BEC nodes SHOULD support ROLL [RFC] in order to join the LLN as a board router. Various wired/wireless communication protocols such as Radio Frequency (RF) protocols (e.g., Zigbee, WI-SUN) and Power Line Communication (PLC) should be supported. The BEC nodes can use 2G/3G/LTE/Ethernet to communicate with the Cloud.

3. Smart Manufacturing

Description: BEC nodes join the industiral manufacturing network and provide the networking function. Control messages that requires deterministic latency will be carried on this network. BEC nodes need to support deteministic networking protocols such IEEE Time Sensitive Networking (TSN), Profinet, Ethernet/IP, EtherCat, etc.

The gateway can also help monitor the equipments' status, and send out alarms or warnings when malfunction is detected or predicted.

Goal: Edge computing enables interconnection of deterministic networks.

Requirements: BEC nodes should support industrial machine-to-machine message bus connectivity protocols such as OPC-UA, DDS, MQTT. The network may be configured by a central controller using Netconf/YANG. BEC nodes should support the interconnection of heterogeneous deterministic Ethernet protocols.

4. Smart grid

Description: BEC nodes can be deployed in three scenarios of the smart grid. In advanced metering infrastructure (AMI), besides the routing function, it can also act as a concentrator to collect and aggregate the meters' data. It can also provide primary analysis to detect theft and outage. Firewall function can be deployed at the gateway to deal with attacks from the edge. In distribution automation (DA), BEC nodes provide bounded latency connection between controller and actuators such as switches and transformers. Edge computing applications can be implemented on these devices to monitor the status and react rapidly to faults. In terms of microgrid, the BEC node monitors the local power generation and storage, and helps smoothly integrate the energy generated by photovoltaic panels and wind turbines, whose power is very unstable, into the macro grid.

Goal: In AMI, the BEC node works as a router, firewall and concentrator, providing data preprocess services. In DA, BEC node enables the deterministic connection between controllers and actuators. In microgrid, BEC node is the coordinator between distributed and centralized generation.

Requirements: The gateway should support various wired/wireless communication protocols, such as Power Line Communication (PLC), Radio Frequency (RF), NB-IOT and 2G/3G/LTE. Bounded latency is required in automation use cases. Open platforms are needed to accommodate various applicaitons providing data analysis, fault detection and automation control capabilities.

5. IANA Considerations

N/A

6. Security Considerations

Security considerations will be a critical component of IIoT edge computing particularly as intelligence is moved to the extreme edge.

7. Acknowledgement

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8. Normative References

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Authors' Addresses

Liang Geng
China Mobile

Email: gengliang@chinamobile.com

Mingui (Martin) Zhang
Huawei

Email: zhangmingui@huawei.com

Mike McBride
Huawei

Email: michael.mcbride@huawei.com

Bing Liu
Huawei

Email: remy.liubing@huawei.com