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Problem Statement of Edge Computing beyond Access Network for Industrial  
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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.

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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 a 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 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 a 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 [RFC2119].

#### 1.2. Terminology

- o BEC - Beyond Edge Computing, a concept of edge computing where the edge computing devices are deployed directly at customers' premises so that beyond the access network of a service provider.

### 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 computing capability down to the level of customer premises where devices are managed by customers therefore typically beyond the reach of access network of a service provider.

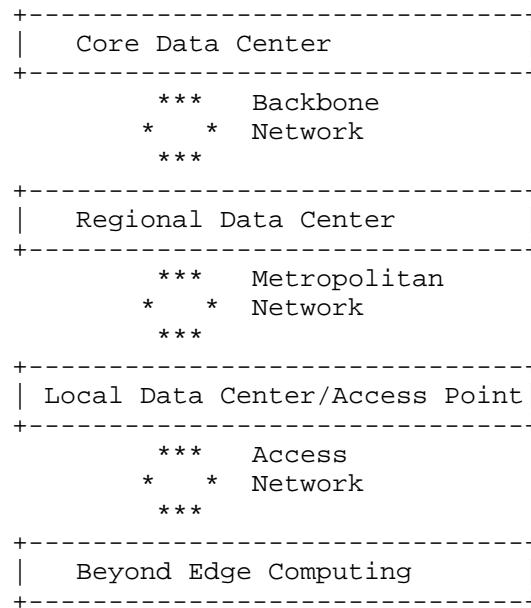


Figure 1: Beyond Edge Computing in the Network

Figure 1 illustrates the schematic diagram of BEC in terms of its position in an 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.

BEC has the following capabilities.

1. Heterogeneous IoT device compatibility
2. Extremely low and deterministic service latency
3. Local data pre-processing and offloading
4. Isolation of system resources
5. Offline process
6. End-to-end security
7. Distributed artificial intelligence

8. Real-time operation
9. Unified API for multi-ecosystem edge application
10. Service isolation for network slicing

### 2.1. Relationship between BEC and and Cloud Computing

BEC is different from Cloud Computing in the following perspectives.

- o Edge is closer to things than the Cloud, it's feasible to meet the high reliability, bounded latency or real-time requirements of verticals such AR/VR, automatic driving and smart manufacturing. For Cloud Computing, the latency is regarded as a performance index. As for Edge Computing, bounded latency is often a mandatory requirement.

- o Data can be stored at the Edge which are under the control of end users so that user's privacy can be preserved. Video surveillance, Healthcare are typical use case scenarios for this perspective.

- o Raw data can be preprocessed at the edge while only critical information is uploaded to the Cloud. In this way, Edge Computing promises lower communication cost than the traditional Cloud-only architecture.

- o The resources for Cloud Computing can be elastically allocated thanks to virtualization and resource pooling. Virtualization provides certain reliability to Cloud Computing. In comparison, the resources are normally constrained for Edge Computing. Reliability is sometimes realized through the redundant placement of physical edge devices.

- o The hardware and software of Cloud Computing are normally standardized. Devices and software being used in Edge Computing can be quite different considering various verticals are adopting Edge Computing.

### 3. Reference Architecture

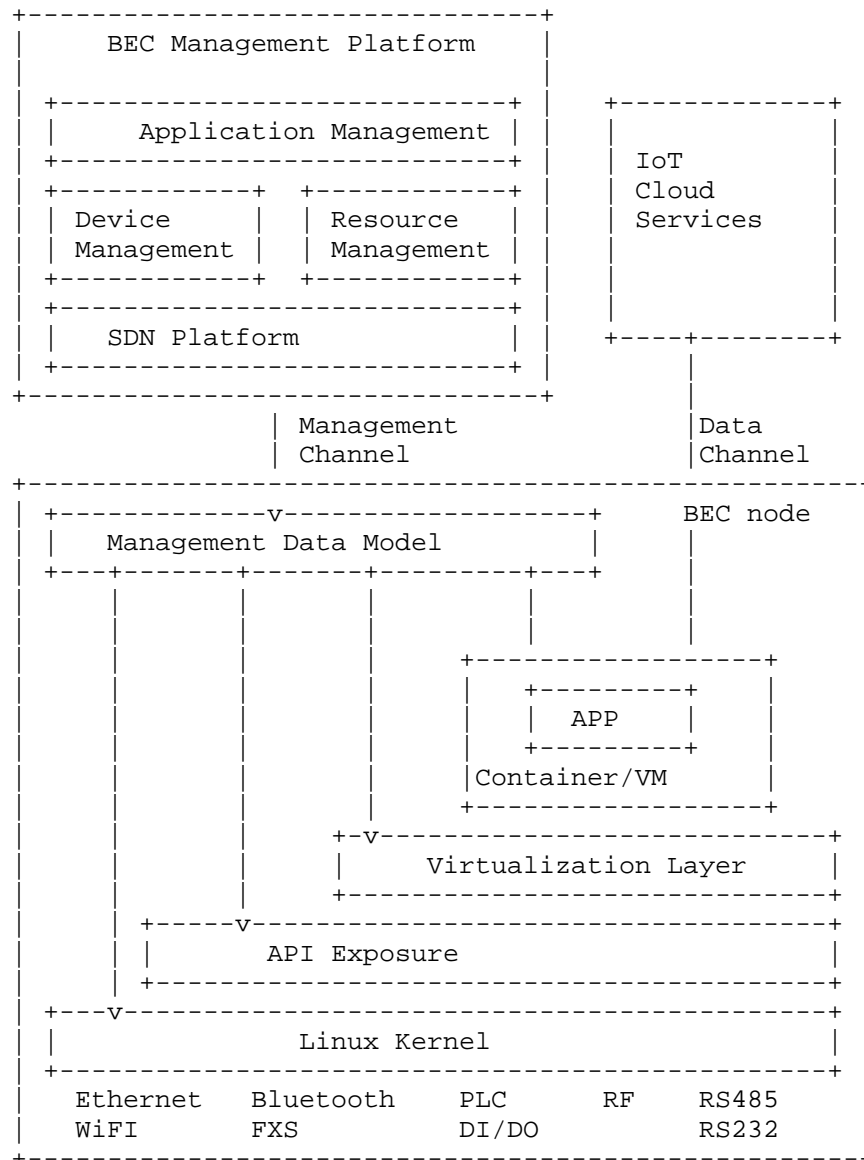


Figure 2: The Reference Architecture of Beyond Edge Computing

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 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 supervises the device, virtualization 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 preprocess 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 maintenance 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. 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, 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 industrial manufacturing network and provide the networking function. Control messages that requires deterministic latency will be carried on this network. BEC nodes need to support deterministic networking protocols such IEEE Time Sensitive Networking (TSN), Profinet, Ethernet/IP, EtherCat, etc.



The gateway can also help monitor the equipment's 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, a BEC node 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 micro grid, 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 micro grid, 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 applications providing data analysis, fault detection and automation control capabilities.

#### 5. Gap Analysis

##### 1. Multiple Virtualization Technologies Coexistence/Coordination:

Different virtualization technologies needed to meet the various vertical requirements. Coexistence and resource coordination is

needed. The focus is on the edge where different types of ASICs are found which require more input on selection.

2. Light weight Device-level management and virtual resource management:

Netconf/YANG to be considered as a baseline interface solution. Information and data modelling will need to be defined.

3. Framework and API for multi-ecosystem:

BEC framework for life cycle management. Unified API definition between framework and app including Local networking, Computing, Storage, OAM, UNI IO management and event-message management.

4. Runtime Updates

BEC nodes are commonly deployed to run for a long periods of time without downtime. Even during the update of configuration, software or firmware, the BEC nodes are required to serve the network with no interruption. For mesh-based networks, there might be some devices which are in sleeping mode. IP multicast protocols are not applicable here [draft-iab-iotsu-workshop-00]. Multicast Protocol for Low-Power and Lossy Networks (MPL) [RFC7731] should be used.

6. IANA Considerations

N/A

7. Security Considerations

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

8. Acknowledgement

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9. Normative References

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