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Architecture for delivering low latency service
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Abstract

Demand for Ultra high-Reliability and Low-latency Communication (URLLC) and Broadband Assured IP Services (BAS) will grow as new service scenarios like 5G, IoT, AR/VR, Cloud are deployed. As these new service scenarios will typically rely on shared packet infrastructure like Internet, methods to ensure URLLC and BAS performance across the underlying network resources will be required.

This document outlines the motivation and key requirements for URLLC or BAS connectivity across heterogeneous network domains. It also outlines the corresponding models and architecture required for providing orchestrated URLLC or BAS communication.

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1. Introduction

Low latency communications have been recently received much interest such as those in Ultra high-Reliability and Low-latency

Communication (URLLC) and Broadband Assured IP Services (BAS) [BAS-Architecture]. Further investigation and requirements gathering is required. Such investigation should also build on existing IETF work, including transport, security, and web technology and protocols effort [I-D.arkko-arch-low-latency]. In parallel to the IETF efforts, relevant discussion is ongoing including Time-Sensitive Networking Task Group [TSN8021] in IEEE 802.1, 5G requirements for next-generation access technology [TS38913]in 3GPP and BAS in BBF.

We may further scope the URLLC and BAS application requirements by explicitly involving end-to-end (E2E) service characteristics and capability requirements. E2E service usually traverses multiple domains and involves multiple layers. Yet, existing standards and current discussion typically focuses on a specific layer, protocol or link layer technology. This myopic view lacks a holistic approach or system view on solving the URLLC and BAS problem space.

This draft identifies common URLLC and BAS application requirements in heterogeneous networks and key challenges for delivering suitable application and user Quality of Experience (QoE). It analyses the applicability of existing technologies, and where necessary documents the gaps between URLLC/BAS requirements and network implementations.

Furthermore, the document proposes models and architecture to provide orchestrated URLLC or BAS communication.

2. Conventions used in this document

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].

3. Requirements for delivery low latency services in heterogeneous networks

Emerging URLLC and BAS applications, such as self-driving cars, industrial control, real-time gaming, AR/VR, and Cloud based applications, introduce new requirements such as high reliability and low latency on data transmission. For instance, in 5GPPP, the most stringent requirements on latency and reliability that we have identified relate to self-driving cars, where E2E latencies down to 1ms must be provided with a reliability of 1-10^-9. In other words, only one message in 10^9 data transfers may be lost or delayed by more than 1ms when the latency budget is set to 1ms.

Since these applications would force the development for high reliability and low latency networking, monitoring and storing the latency performance across the network, and latency guarantee in each network segment or even node. Unlike current packet network which is typically best-effort, making such latency guarantee is very difficult to achieve.

Multiple methods are being proposed to solve such latency guarantee issue, including cooperative hierarchical caching and routing, hardware acceleration, high-data throughput in the aggregation network, fog computing and mobile edge computing facilitating the placement of compute and applications as close to the consumer as possible.

From the Internet stack perspective, improvement for communication latency may be achieved at multiple layers. More recent technologies are being developed to reduce the communication latency, such as [L4S], [DETNET], [FlexE]. With such technologies, different network operators can build their own low latency networks. For instance, each technology can be modelled as a network service for latency improvement, but often restricted to a specific domain or layer.

Typically, heterogeneous networks are composed of a wide-range of network segments traversing multiple domains and involving multiple layers. Existing low latency technologies typically focus on specific layer, protocol or link. With such diverse networks, it becomes very challenging to deliver low latency for E2E services.

Multiple technical proposals have described similar requirements discussed in this document, such as [I-D.dunbar-e2e-latency-arch-view-and-gaps] and [I-D.arkko-arch-low-latency]. BAS has discussed performance assurance of E2E services [BAS-Architecture]. From industrial automation perspective, 3GPP specification 22.282 has also defined latency requirement for robot control applications.

4. Application requirements and network performance

Application requirements can be modeled as Quality of Experience (QoE), and qualified by various service KQIs. From users' perspective, QoE is the overall performance perception of the service.

Network performance can be evaluated by network KPIs such as delay, jitter, and packet loss. As mentioned, URLLC and BAS applications require the capabilities of high reliability and low latency networking, which is unlike the current best-effort packet network. Hence, it is important to identify and manage network KPIs to quantify and achieve the corresponding service KQI, as shown in Figure 1. The KQI for a given service can be expressed as a function of a set of KPIs, expressed as KQI=f(KPI1, KPI2, …, KPIn).

```
                            +-------------+
                            |Requirements |
                     +-------------+------+---------+
                     |             |                |
                     |             |                |
                +-----+-----+  +----+---+     +-----+----+
Service KQI     |   KQI1    |  |  KQI2  |     |   KQI3   |
                +-----+-----+  +--------+     +----------+
                      |
           +-----------------------+--------------+-----------+
           |          |              |              |           |
Network+---v-+   +---v--+   +--------v--------+   +-v---+   +----v------+
KPI    |KPI1 |   | KPI2 |   |     KPI3        |   | ... |   |    ...    |
       +-----+   +------+   +-----------------+   +-----+   +-----------+
```

Figure 1: KQI-KPI Correlation

However, how to map URLLC and BAS application KQI to the corresponding set of network KPIs could be challenging. Furthermore, there could be potential need of defining new network KPI (e.g. latency down to 1ms must be provided with a reliability of 1-10^-9) to reflect some new application requirements.

5. Low latency delivery models

5.1. Application service and network service model

Application service model has information about application level policies and requirements, such as end user information, application service attributes. Such model is constructed based on service KQIs. Figure 2 shows an example of application service model.

Service Name	KQI Value
4K/8K Video	quality/zap time/response time
Bank Transaction	transaction Rate/Locking/Idle Time
Driving assistant	map updated time/map accuracy

VR/AR	data rate/delay
Factory Automation	real-time control/automation

Figure 2: Application Service Model Example

Network service model is used to describe the configuration, state data, operations and notifications of abstract representations of services. Take L2VPN service model as example [L2SM], it provides an abstracted view of the L2VPN service configuration components, which contains L2VPN domain relevant information, as well as network QoS or KPI information in the L2VPN domain.

As mentioned in previous section, the latency sensitive applications might traverse multiple domains and need E2E latency guarantee across multiple domains. Assuming the maximum latency is guaranteed and cannot exceed a predefined value called MAX-LATENCY, the MAX-LATENCY should be divided into multiple latency values and mapped to multiple domains. In each domain, the transmission latency must be guaranteed less than the latency value allocated to it.

Some network KPI metrics of the network service model are listed in the Figure 3. Note that the KPIs of latency bound and reliability could be new element, compared to existing network service model, in order to support the aforementioned new URLLC and BAS applications.

KPI Name	KPI Value
Service type	4K/8K/VR etc
User Information	Triple-5/User ID
Service Profile	Platinum/Gold/
Latency bound	MAX-LATENCY
Reliability	MAX-RELIABILITY
throughput	MAX-THROUGHPUT
packet loss rate	MAX-PKTLOSSRATE
jitter	MAX-JITTER

bandwidth	MAX-BANDWIDTH

Figure 3: Network Service Model

The network service model shown in Figure 3 can be generic in the sense that it has no assumption on the underlying network technologies. It is up to the network provider to translate this network service model to specific network service models based on the underlying network implementation, such as L2/L3VNF service model, Detnet service model, FlexE/MPLS configurations, etc.

5.2. OAM model

During each latency performance measurement period, latency metric is sent to the OAM model ready to be analyzed. Periodically, OAM model retrieves aggregated monitored data and applies data classification techniques to filter the data. OAM model is responsible for monitoring the reliability of the filtered data, and performs trouble shooting based on the preconfigured reliability requirement. If the analyzed reliability of traffic data is lower than the preconfigured reliability, OAM model issues a problem report. Some parameters in OAM model are listed in Figure 4.

Name	Elements
traffic data	
minimum latency	
maximum latency	
average latency	
percentile latency	
queue length/size	

Figure 4: OAM Model

6. Low latency delivery architecture

6.1. Architecture Overview

Figure 5 shows an architecture for low latency service delivery (LLD). It could be beneficial to define low latency delivery architecture (or cook book) to coordinate and orchestrate multiple low latency tools, in order to support low latency requirements from user’s perspective. Note that LLD architecture has referred to ABNO architecture [ABNO] especially the layer design, components definition, etc.

```
 +-------------------------------------------------------------------+
 |                 OSS/NMS/Application Service Coordinator           |
 +--+--------+-------------------------+-------------------------+---+
    |        |                         |                         |
    |        |                         |                         |
    |        |                         |                         |
    |     +--+---+    +----------------+----------------+     +--+----+
    |     |Policy+----+         LLD Orchestrator        +-----+  OAM  |
    |     |Agent |    +---+------------+-------------+--+     |Handler|
    |     ++-----+        |            |             |        +-----+-+
    |      |              |            |             |              |
    |      |              |            |             |              |
 +--+------++      +------+---+   +----+-----+   +---+------+       |
 |          |      |   L4S    |   |  DETNET  |   |   FlexE  |       |
 |  LLD-DB  | +----+Controller|   |Controller|   |Controller|       |
 +--+------++ |    +-----+----+   +----+-----+   +---+------+       |
    |      |  |          |             |             |              |
    |   +--+--+--+       |             |             |              |
    |   |        |       |             |             |              |
    |   | LLD-PC |       |             |             |              |
    |   +---+----+       |             |             |              |
    |       |            |             |             |              |
    |       |            |             |             |              |
+---+-------+------------+-------------+-------------+--------------+--+
|                      Network elements                                |
+----------------------------------------------------------------------+
```

Figure 5: LLD Architecture

6.2. Components

6.2.1. LLD orchestrator

The LLD orchestrator is responsible to translate the generic network service model into the specific network service models, such as data model for L2VPN service delivery [L2SM], data model for L3VPN service delivery [RFC8049], and data model for EVPN [draft-ietf-bess-evpn-yang], in corresponding domains.

Each domain has a separate controller that is responsible for receiving the network configuration from LLD orchestrator. Based on the network configuration, the controller learns how to control the network elements. One representative example of controller is PCE controller.

6.2.2. OAM handler

Latency measurement is also very crucial to make sure the latency bound is not violated and useful for E2E latency aware OAM mechanism. There is a need to support the measurement of latency inside of a network device.

Existing technologies such as OWAMP [RFC4656] and TWAMP [RFC5357] is focused on providing one way and two-way IP performance metrics. Latency is one of metrics that can be used for E2E deterministic latency provisioning. Use OWAMP/TWAMP protocols or extension on that to support measurement of flow latency performance is feasible.

The OAM Handler is responsible for monitoring the network elements, collecting the measurement results and receiving notifications from the network elements. The OAM Handler also reports network performance and problems to NMS/OSS/application service coordinator.

6.2.3. Policy agent

Policy agent is configured by the NMS/OSS, and it is connected to some components where the corresponding policy can be applied to.

6.3. Functional interfaces

6.3.1. Low latency path computation

Low latency path computation is a critical and fundamental feature because individual controller in each domain is only able to share abstracted information that is local to their domain.

Via the interface between LLD orchestrator and controller, the controller gets the network service configuration and learns the latency upper bound value in its domain. After that, the controller computes the optimized path to cover the latency upper bound, and reserves and activate corresponding network resource for the path.

6.3.2. OAM and report

OAM Handler interacts with the network to perform several actions:

- Enabling OAM function within the network.
- Performing proactive OAM operations in the network.
- Receiving notifications of network events.

For low latency service, OAM handler correlates events reported from network and reports them onward to the LLD orchestrator and to the NMS/OSS/Application service coordinator.

7. Use cases

7.1. Network slicing

TBD

7.2. Provisioning E2E low latency path

TBD

8. Security considerations

TBD

9. Conclusions

TBD

10. References

10.1. Normative References

10.2. Informative References

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11. Acknowledgments

TBD

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