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The Requirements for Wide-area IP Deterministic Networking draft-xiong-detnet-wide-area-ip-requirements-00

Abstract

In wide-area IP networks, more requirements need to be taken into considerations such as differentiated DetNet QoS of multiple services, high-efficiency of resources utilization and routes steering, integration of large-scale heterogeneous network and guarantees of multiple dynamic deterministic flows. This document describes the requirements in wide-area applications and proposes the solution with deterministic resources, routes and QoS.

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1. Introduction

5G network is oriented to the internet of everything. In addition to the Enhanced Mobile Broadband (eMBB) and Massive Machine Type Communications(mMTC) services, it also supports the Ultra-reliable Low Latency Communications (uRLLC) services. The uRLLC services cover the industries such as intelligent electrical network, intelligent factory, internet of vehicles, industry automation and other industrial internet scenarios, which is the key demand of digital transformation of vertical domains. These uRLLC services demand SLA guarantees such as low latency and high reliability and other deterministic and precise properties.

For the intelligent electrical network, there are deterministic requirements for communication delay, jitter and packet loss rate. For example, in the electrical current difference model, a delay of

3~10ms and a jitter variation is no more than 100us are required. The isolation requirement is also important. For example, the automatic operation, control of a process, isochronous data and low priority service need to meet the requirements of hard isolation. In addition to the requirements of delay and jitter, the differential protection (DP) service needs to be isolated from other services.

The industrial internet is the key infrastructure that coordinate various units of work over various system components, e.g. people, machines and things in the industrial environment including big data, cloud computing, Internet of Things (IOT), Augment Reality (AR), industrial robots, Artificial Intelligence (AI) and other basic technologies. For example, automation control is one of the basic application and the the core is closed-loop control system. The control process cycle is as low as millisecond level, so the system communication delay needs to reach millisecond level or even lower to ensure the realization of precise control. There are three levels of real-time requirements for industrial interconnection: factory level is about 1s, and process level is 10~100ms, and the highest real-time requirement is motion control, which requires less than 1ms.

The applications in 5G networks demand much more deterministic and precise properties. But traditional Ethernet, IP and MPLS networks which is based on statistical multiplexing provides best-effort packet service and offers no delivery and SLA guarantee. The deterministic forwarding can only apply to flows with such well-defined characteristics as periodicity and burstiness. Technologies to provide deterministic service has been proposed to provide bounded latency and jitter based on a best-effort packet network. IEEE 802.1 Time-Sensitive Networking (TSN) has been proposed to provide bounded latency and jitter in L2 LAN networks. According to [RFC8655], Deterministic Networking (DetNet) operates at the IP layer and delivers service which provides extremely low data loss rates and bounded latency within a network domain.

The deterministic networks not only need to offer the Service Level Agreements (SLA) guarantees such as low latency and jitter, low packet loss and high reliability, but also need to support the precise services such as flexible resource allocation and service isolation. However, under the existing IP network architecture with statistical multiplexing characteristics, the existing deterministic technologies are facing large scale number of nodes and long-distance transmission, traffic scheduling, dynamic flows, and other controversial issues especially in Wide Area Network (WAN) applications.

In wide-area IP networks, more requirements need to be taken into considerations such as differentiated DetNet QoS of multiple services, high-efficiency of resources utilization and routes steering, integration of large-scale heterogeneous network and guarantees of multiple dynamic deterministic flows. This document describes the requirements in wide-area applications and proposes the solution with deterministic resources, routes and QoS.

2. Conventions used in this document

2.1. Terminology

The terminology is defined as [RFC8655].

2.2. Requirements Language

The key words "MUST", "MUST NOT", "REQUIRED", "SHALL", "SHALL NOT", "SHOULD", "SHOULD NOT", "RECOMMENDED", "NOT RECOMMENDED", "MAY", and "OPTIONAL" in this document are to be interpreted as described in BCP 14 [RFC2119] [RFC8174] when, and only when, they appear in all capitals, as shown here.

3. Requirements for Wide-area IP Deterministic Networking

3.1. Differentiated DetNet QoS of Multiple Services

As defined in [RFC8655], the DetNet QoS can be expressed in terms of : Minimum and maximum end-to-end latency, bounded jitter (packet delay variation), packet loss ratio and an upper bound on out-of-order packet delivery. As described in [RFC8578], DetNet applications differ in their network topologies and specific desired behavior and different services requires differentiated DetNet QoS. In the WAN scenarios, multiple services with differentiated DetNet QoS is co-existed in the same DetNet network. The classification of the deterministic flows is should be taken into considerations. It is required to provide Latency, bounded jitter and packet loss dynamically and flexibly in all scenarios for each characterizd flow.

As the Figure 1 shown, the services is divided into 4 levels and level 1~3 is the DetNet flows and level-4 is non-DetNet flow. DetNet applications and DetNet QoS is differentiated within each level.

Item	Level-1	Level-2	Level-3	Level-4
Applications Examples	Industrial	VR/AR	Audio and Video	Broadcast
DetNet QoS	Ultra-low latency and jitter	Low latency and jitter	Low latency	Best Effort

Figure 1: Figure 1: The classification of multiple services

Moreover, different DetNet services is required to tolerate different percentage of packet loss ratio such as 99.9%, 99.99%, 99.999%, and so on. It is also required to provide service isolation. In some scenarios, such as intelligent electrical network, the isolation requirements are very important. For example, the automatic operation or control of a process or isochronous data and service with different priorities need to meet the requirements of hard isolation. In addition to the requirements of delay and jitter, the differential protection (DP) service needs to be isolated from other services and hard isolated tunnel is required.

3.2. Integration of Large-scale Heterogeneous Network

In WAN application, large-scale number of nodes and long-distance transmission in the network will lead to latency and jitter, such as increasing transmission latency, jitter and packet loss. It is to required reduce the scale of the network topology by establishing cutthrough channels. The existing technologies such as FlexE and SR tunnels should be taken into consideration. And multiple capabilities is also provided by the nodes and links within the network topology such as FlexE tunnels, TSN sub-network and IP/MPLS/ SRv6 tunnels. It is required to integrate the multi-capability resources to achieve the optimal DetNet QoS.

Another option is to divide the network into several domains and segments. And the deadline of latency and jitter of each domain and segment should be determined and controlled. It is required to control the DetNet QoS at the inter-domain boundary nodes and achieve the end-to-end latency, bounded jitter and packet loss ratio across.

3.3. Efficiency of Resources Utilization and Routes Steering

Traditional Ethernet, IP and MPLS networks which is based on statistical multiplexing provides best-effort packet service and offers no delivery and SLA guarantee. As described in [RFC8655], the primary technique by which DetNet achieves its QoS is to allocate sufficient resources. But it can not be achieved by not sufficient resource which can be allocated due to practical and cost reason. So it is required to achieve the high-efficiency of resources utilization when provide the DetNet service.

Network resources include nodes, links, ports, bandwidth, queues, etc. The congestion control, shaping and queue scheduling and other traffic mechanisms which have been proposed in IEEE 802.1 TSN such as IEEE802.1Qbv, IEEE802.1Qch, IEEE802.1Qav, IEEE802.1Qcr and so on. Heterogeneous resource should be used and unified and simplified resources mechanism under the selection of existing multiple technical methods to realize the elastic of deterministic capability.

Resource classification and modeling is required along with the explicit path with more SLA guarantee parameters like bandwidth, latency, jitter, packet loss and so on. On the basic of the resources, the steering path and routes for deterministic flows should be programmed before the flows coming and able to provide SLA capability. And the routes should be considered to be established in distributed and centralized control Plane.

3.4. Guarantees of Multiple Dynamic Deterministic Flows

As described in [RFC8557], deterministic forwarding can only apply to flows with such well-defined characteristics as periodicity and burstiness. As defined in DetNet architecture [RFC8655], the traffic characteristics of an App-flow can be CBR (constant bit rate) or VBR (variable bit rate) of L1, L2 and L3 layers (VBR takes the maximum value when reserving resources). But the current scenarios and technical solutions only consider CBR flow, without considering the coexistence of VBR and CBR, the burst and aperiodicity of flows. The operations such as shaping or scheduling have not been specified. Even TSN mechanisms are based on a constant and forecastable traffic characteristics.

It will be more complicated in WAN applications where much more flows coexist and the traffic characteristics is more dynamic. It is required to offer reliable delivery and SLA guarantee for dynamic flows. For example, periodic flow and aperiodic flow (including micro burst flow, etc.), CBR and VBR flow, flow with different periods or phases, etc. When the network needs to forward these deterministic flows at the same time, it must solve the problems of

time window selection, queue processing and aggregation of multiple flows. It is required to classify the dynamic deterministic flows and map them into different virtual topologies to limit the number of the concurrent flows and reduce the micro bursts.

4. Solutions Considerations of Wide-area IP Deterministic Networking

4.1. The Deterministic Resources

As defined in RFC8655, the resource allocation is one of the techniques to achieve the DetNet QoS. Network resources include nodes, links, ports, bandwidth, queues, etc. The deterministic resources require planning and arrangement of network resources, resources modeling, resource allocation and reservation, resource isolation and resource scheduling, etc. In order to meet the requirements of deterministic service, resources need to be classified, including ultra-low delay resources, low delay resources, low jitter resources, etc.

Deterministic resources guarantee the delay, jitter and other requirements of deterministic services by reserving resources for flows. If the network resources are sufficient, congestion and packet loss can be eliminated to meet the requirements of low delay jitter. If the network resources are insufficient, congestion control, queue mechanisms of deterministic flows need to be carried out. The nodes with different queue mechanisms provide different latency and bounded jitter. Moreover, network resources could to be reconstructed to provide ultra-low latency, for example, L1 layer resources could be used to provide cutthrough channels, FlexE pipes, etc.

4.2. The Deterministic Routes

The deterministic routes is based on the provision of deterministic resources. The deterministic routes refers to the requirements to select the network routes for the deterministic flows to guarantee the stability of the routing at least during the packets transmission, and the path will not change within the real-time change of network topology. Moreover, the deterministic routes should provide the capability including the latency, jitter and packet loss ratio.

Routes generally perform forwarding function including receiving the incoming packets and forwarding the packets to a Router based on the header information and a forwarding information base. It is necessary to provide pre-routes with SLA capability and generate endogenous deterministic routing with deterministic capability. The deterministic routes perform the functions of forwarding and QoS

guarantee at the same time. The types of deterministic routes can be classified into ultra-low delay routes, low delay routes, low jitter routes, and so on. There can also has replication routes and aggregation routes.

The mechanisms of path establishment include traffic engineering technology (MPLS-TE, SR-TE, static configuration, etc.), IGP technology, etc. Explicit strict routing can guarantee the delay jitter and other requirements of services. Loose routing only generates some endogenous deterministic routes, and other routes still need forwarding and scheduling, such as dynamic resource-aware routing and queue scheduling.

4.3. The Deterministic QoS

The deterministic QoS is to arrange and schedule the deterministic flows on the basis of providing deterministic resources and routes, so as to control of each flow and meet the DetNet QoS goals.

The scheduling and control include the classification of the deterministic flows, queue scheduling mechanism for each class of deterministic flow, deterministic shaping at boundary nodes, limiting the number of concurrent flows and reducing micro bursts, mapping the dynamic concurrent flows into different virtual topologies. Moreover, flow aggregation is performed at the aggregation node to reduce flow state maintenance and replication or elimination is performed at the relay node to achieve reliability.

If the deterministic flows crosses multiple domains, the end-to-end latency is the sum of delay from all domains. It is required to control the deadline delay of each domain. Moreover, bounded jitter (packet delay variation) should be adjusted and scheduled at the inter-domain boundary nodes.

5. Security Considerations

TBA

6. Acknowledgements

TBA

7. IANA Considerations

TBA

8. Normative References

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