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Y. Zha
Huawei Technologies

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Deterministic Networking Use Case in Mobile Network

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Abstract

This document describes some high level use cases and scenarios with requirements on delay sensitive and deterministic networking. Not only the telecom industry but also vertical industries have been investigated. In addition to the 5G networking, industrial automation, automotive industry, media and gaming industry are typical related industries believed to be representative for the technical requirements on ultra-fast and ultra-reliability communications.

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1. Introduction

The rapid growth of the today's communication system and its access into almost all aspects of daily life has led to great dependency on services it provides. The communication network, as it is today, has applications such as multimedia and peer-to-peer file sharing distribution that require Quality of Service (QoS) guarantees in terms of delay and jitter to maintain a certain level of performance. Meanwhile, mobile wireless communications has become an important part to support modern sociality with increasing importance over the last years. A communication network

of hard real-time and high reliability is essential for the next concurrent and next generation mobile wireless networks as well as its bearer network for E-2-E performance requirements.

Conventional transport network is IP-based because of the bandwidth and cost requirements. However the delay and jitter guarantee becomes a challenge in case of contention since the service here is not deterministic but best effort. With more and more rigid demand in latency control in the future network [METIS], deterministic networking [I-D.finn-detnet-architecture] is a promising solution to meet the ultra low delay applications and use cases. There are already typical issues for delay sensitive networking requirements in midhaul and backhaul network to support LTE and future 5G network [5G]. And not only in the telecom industry but also other vertical industry has increasing demand on delay sensitive communications as the automation becomes critical recently.

More specifically, CoMP techniques, D-2-D, industrial automation and gaming/media service all have great dependency on the low delay communications as well as high reliability to guarantee the service performance. Note that the deterministic networking is not equal to low latency as it is more focused on the worst case delay bound of the duration of certain application or service. It can be argued that without high certainty and absolute delay guarantee, low delay provisioning is just relative [RFC3393], which is not sufficient to some delay critical service since delay violation in an instance cannot be tolerated. Overall, the requirements from vertical industries seem to be well aligned with the expected low latency and high determinist performance of future networks

This document describes several use cases and scenarios with requirements on deterministic delay guarantee within the scope of the deterministic network [I-D.finn-detnet-problem-statement].

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 [RFC2119]. In this document, these words will appear with that interpretation only when in ALL CAPS. Lower case uses of these words are not to be interpreted as carrying [RFC2119] significance.

3. Critical Delay Requirements

Delay and jitter requirement has been take into account as a major component in QoS provisioning since the birth of Internet. The delay sensitive networking with increasing importance become the root of mobile wireless communications as well as the applicable areas which are all greatly relied on low delay communications. Due to the best effort feature of the IP networking, mitigate contention and buffering is the main solution to serve the delay sensitive service. More bandwidth is assigned to keep the link low loaded or in another word, reduce the probability of congestion. However, not only lack of determinist but also has limitation to serve the applications in the future communication system, keeping low loaded cannot provide deterministic delay guarantee.

Take the [METIS] that documents the fundamental challenges as well as overall technical goal of the 5G mobile and wireless system as the starting point. It should supports:

-1000 times higher mobile data volume per area,

-10 times to 100 times higher typical user data rate,

-10 times to 100 times higher number of connected devices,

-10 times longer battery life for low power devices, and

-5 times reduced End-to-End (E2E) latency,

at similar cost and energy consumption levels as today's system. Taking part of these requirements related to latency, current LTE networking system has E2E latency less than 20ms [LTE-Latency] which leads to around 5ms E2E latency for 5G networks. It has been argued that fulfill such rigid latency demand with similar cost will be most challenging as the system also requires 100 times bandwidth as well as 100 times of connected devices. As a result to that, simply adding redundant bandwidth provisioning can be no longer an efficient solution due to the high bandwidth requirements more than ever before. In addition to the bandwidth provisioning, the critical flow within its reserved resource should not be affected by other flows no matter the pressure of the network. Robust defense of critical flow is also not depended on redundant bandwidth allocation.

Deterministic networking techniques in both layer-2 and layer-3 using IETF protocol solutions can be promising to serve these scenarios.

4. Coordinated multipoint processing (CoMP)

In the wireless communication system, Coordinated multipoint processing (CoMP) is considered as an effective technique to solve the inter-cell interference problem to improve the cell-edge user throughput [CoMP].

4.1. CoMP Architecture

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             +---------------------------+
             |           CoMP            |
             +--+--------------------+---+
                |                    |
          +-----------+             +------------+
          |  Uplink   |             |  Downlink  |
          +-----+-----+             +--------+---+
                |                            |
     --------------------              ------------------------
     |         |        |              |          |          |
+---------+ +----+  +------+       +------------+ +------+ +------+
|  Joint  | | CS |  | DPS  |       |    Joint   | | CS/  | | DPS  |
|Reception| |    |  |      |       |Transmission| | CB   | |      |
+---------+ +----+  +------+       +------------+ +------+ +------+
     |                                      |
     |-----------                           |-------------
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      |          |                        |           |
+-------------+  +----------+      +-----------+  +-------------+
|    Joint    |  |   Soft   |      | Coherent  |  |     Non-    |
|Equalization|  |Combining|      |    JT     |  | Coherent JT|
+-------------+  +----------+      +-----------+  +-------------+
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Figure 1: Framework of CoMP Technology

As shown in figure 1, CoMP reception and transmission is a framework that multiple geographically distributed antenna nodes cooperate to improve the performance of the users served in the common cooperation area. The design principal of CoMP is to extend the current single-cell to multi-UEs transmission to a multi-cell-to-multi-UEs transmission by base station cooperation. In contrast

to single-cell scenario, CoMP has critical issues such as: Backhaul latency, CSI (Channel State Information) reporting and accuracy and Network complexity. Clearly the first two requirements are very much delay sensitive and will be discussed in next section.

4.2. Delay Sensitivity in CoMP

As the essential feature of CoMP, signaling is exchanged between eNBs, the backhaul latency is the dominating limitation of the CoMP performance. Generally, JT and JP may benefit from coordinating the scheduling (distributed or centralized) of different cells in case that the signaling exchanging between eNBs is limited to 4-10ms. For C-RAN the backhaul latency requirement is 250us while for D-RAN it is 4-15ms. And this delay requirement is not only rigid but also absolute since any uncertainty in delay will down the performance significantly. Note that, some operator's transport network is not build to support Layer-3 transfer in aggregation layer. In such case, the signaling is exchanged through EPC which means delay is supposed to be larger.

CoMP has high requirement on delay and reliability which is lack by current mobile network systems and may impact the architecture of the mobile network.

5. Industrial Automation

Traditional "industrial automation" terminology usually refers to automation of manufacturing, quality control and material processing. "Industrial internet" and "industrial 4.0" [EA12] is becoming a hot topic based on the Internet of Things. This high flexible and dynamic engineering and manufacturing will result in a lot of so-called smart approaches such as Smart Factory, Smart Products, Smart Mobility, and Smart Home/Buildings. No doubt that ultra high reliability and robustness is a must in data transmission, especially in the closed loop automation control application where delay requirement is below 1ms and packet loss less than 10E-9. All these critical requirements on both latency and loss cannot be fulfilled by current 4G communication networks. Moreover, the collaboration of the industrial automation from remote campus with cellular and fixed network has to be built on an integrated, cloud-based platform. In this way, the deterministic flows should be guaranteed regardless of the amount of other flows in the network. The lack of this mechanism becomes the main obstacle in deployment on of industrial automation.

6. Vehicle to Vehicle

V2V communication has gained more and more attention in the last few years and will be increasingly growth in the future. Not only equipped with direct communication system which is short ranged, V2V communication also requires wireless cellular networks to cover wide range and more sophisticated services. V2V application in the area autonomous driving has very stringent requirements of latency and reliability. It is critical that the timely arrival of information for safety issues. In addition, due to the limitation of processing of individual vehicle, passing information to the cloud can provide more functions such as video processing, audio recognition or navigation systems. All of those requirements lead to a highly reliable connectivity to the cloud. On the other hand, it is natural that the provisioning of low latency communication is one of the main challenges to be overcome as a result of the high mobility, the high penetration losses caused by the vehicle itself. As result of that, the data transmission with latency below 5ms and a high reliability of PER below 10E-6 are demanded. It can benefit from the deployment of deterministic networking with high reliability.

7. Gaming, Media and Virtual Reality

Online gaming and cloud gaming is dominating the gaming market since it allow multiple players to play together with more challenging and competing. Connected via current internet, the latency can be a big issue to degrade the end users' experience. There different types of games and FPS (First Person Shooting) gaming has been considered to be the most latency sensitive online gaming due to the high requirements of timing precision and computing of moving target. Virtual reality is also receiving more interests than ever before as a novel gaming experience. The delay here can be very critical to the interacting in the virtual world. Disagreement between what is seeing and what is feeling can cause motion sickness and affect what happens in the game. Supporting fast, real-time and reliable communications in both PHY/MAC layer, network layer and application layer is main bottleneck for such use case.

The media content delivery has been and will become even more important use of Internet. Not only high bandwidth demand but also critical delay and jitter requirements have to be taken into

account to meet the user demand. To make the smoothness of the video and audio, delay and jitter has to be guaranteed to avoid possible interruption which is the killer of all online media on demand service. Now with 4K and 8K video in the near future, the delay guarantee become one of the most challenging issue than ever before. 4K/8K UHD video service requires 6Gbps-100Gbps for uncompressed video and compressed video starting from 60Mbps. The delay requirement is 100ms while some specific interactive applications may require 10ms delay [UHD-video].

8. Security Considerations

TBD

9. IANA Considerations

This document has no actions for IANA.

10. Acknowledgments

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Authors' Addresses

Yiyong Zha
Huawei Technologies
Email: zhayiyong@huawei.com