Technical Paper

Performance Improvement on Chunghwa Telecom* Multi-access Edge Computing (MEC) with 2nd Gen Intel® Xeon® Scalable Processor and Intel® Ethernet 700 Series

Huge performance gain from the upgrade of Intel's technologies into Chunghwa Telecom* Multi-access Edge Computing (MEC)

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Executive Summary

The emergence of MEC is to fulfill 5G requirements: high bandwidth and ultra-low latency. It is an ETSI*-defined[1] network technology enabling cloud-computing capabilities and an IT service environment at the edge of the network[2] [3]. Telecom operators can help enterprises provide new vertical application services through this technology, especially in the field of smart manufacturing, intelligent medical, and multi-view live streaming of sports events and concerts.

Chunghwa Telecom* has developed a pioneer 5G MEC solution, called 5G Intelligent A+, which can provide a wide variety of novel services for 5G networks[5]. It is based on the bump-in-the-wire architecture, which is defined in ETSI*. Moreover, it is an inline and transparent mode and can be installed between the Base Station (BS) and the mobile core network. This deployment is very convenient[6]. Chunghwa Telecom* launched a 5G Intelligent A+ product in the 4G or 5G Non-Standalone (NSA) commercial network in Taiwan and deployed it to real enterprises' private 5G network fields.

Chunghwa Telecom* continues to enhance MEC product performance and cooperates with Intel's new technologies: Intel® Xeon® Scalable processor CPU and Intel's Ethernet adapters, in response to the growing demand for bandwidth of enterprises' private 5G networks. Intel's acceleration technology is a pioneer in the packet processing field. The objective of the Chunghwa Telecom* and Intel collaboration is to apply Intel's technologies into MEC to deliver a significant performance gain.

After the optimization activities are completed, tests are conducted to validate performance improvement and presented in the Technical Paper, and Spirent Landslide* is used to conduct simulated real-world tests based on the Landslide* available test suite. Chunghwa Telecom* uses these results to apply MEC products to assist enterprises in building private 5G networks with high-bandwidth requirements to optimize their internal operations and production efficiency.

Introduction

MEC enables a powerful cloud at the edge of the network. MEC decentralizes networks and allows any enterprise or mobile operator to place a cloud at the edge, adjacent to the end-users. MEC puts applications at just one hop from the user, reducing latency and improving user experience.

Chunghwa Telecom* 5G Intelligent A+ based on bump-in-the-wire MEC architecture is developed by Chunghwa Telecom* Research and Development (R&D) Unit, which is named Chunghwa Telecom Telecommunication Laboratories* (CHTTL*). It has a rapid deployment, transparent between the base station and core network. 5G Intelligent A+ provides local breakout with more flexible conditions (IP, MSISDN, DN, and so on), and also provides more advanced features, including autonomous, flexible, and real-time control and customized services, as shown in Figure 1. Chunghwa Telecom* 5G Intelligent A+ supports various mobile networks, such as 4G, 5G (NSA), and 5G (Standalone [SA]), and uses Commercial Off-the-Shelf (COTS) hardware including servers, Software-Defined Networks (SDN), switches, and bypass switches.

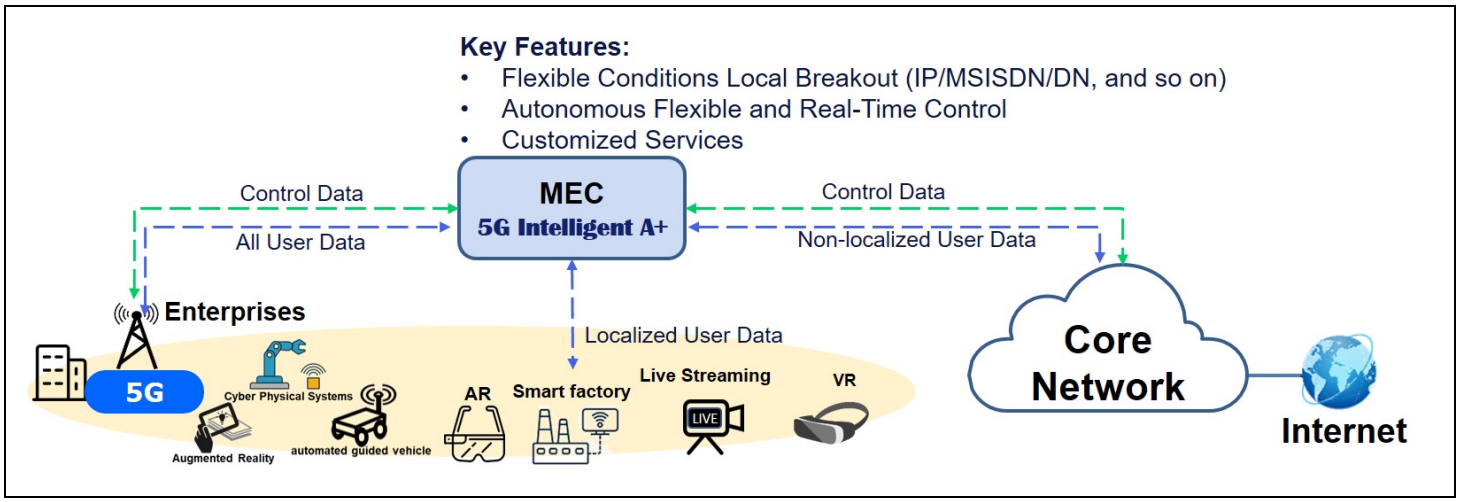

Figure 1. Chunghwa Telecom* 5G Intelligent A+ Key Features

The key features and innovations of 5G Intelligent A+ are summarized as follows[5].

- It is inline and transparent between the BS and the core network and can be easily and flexibly deployed to public and private 5G networks.
- It enables local breakout in a more versatile way, including based on destination IP address; five-tuple of packet headers; Mobile Subscriber ISDN Number (MSISDN), known as the telephone number; and domain name, unlike commercially available MEC solutions that are only based on the destination IP address.
- It supports enterprises' 5G private networks in an efficient manner. Autonomous flexible and real-time control includes enterprise on-demand service and admission control (blocklist or allowlist) functions, which are different from other currently available MEC products. Enterprise on-demand services support intelligent network access management; on-demand service; and customized bandwidth allocation based on location, time, service used, and terminal adopted by enterprises. Access control offers the enterprises flexible control for the data traffic steering.
- It supports customized services such as inter-region access and traffic statistics. Inter-region access allows employees to access the services of other sites and is suitable for use in multiple branch enterprises having independent services at each location.
- It is plug-and-play, automatically learns the configuration of the network elements, and can be connected to multiple mobile networks at the same time, so there is no Inter-operability Test (IOT) issue in this solution.
- It allows automatic addition or deletion of virtual-machine-based or container-based applications to help enterprises manage services flexibly.

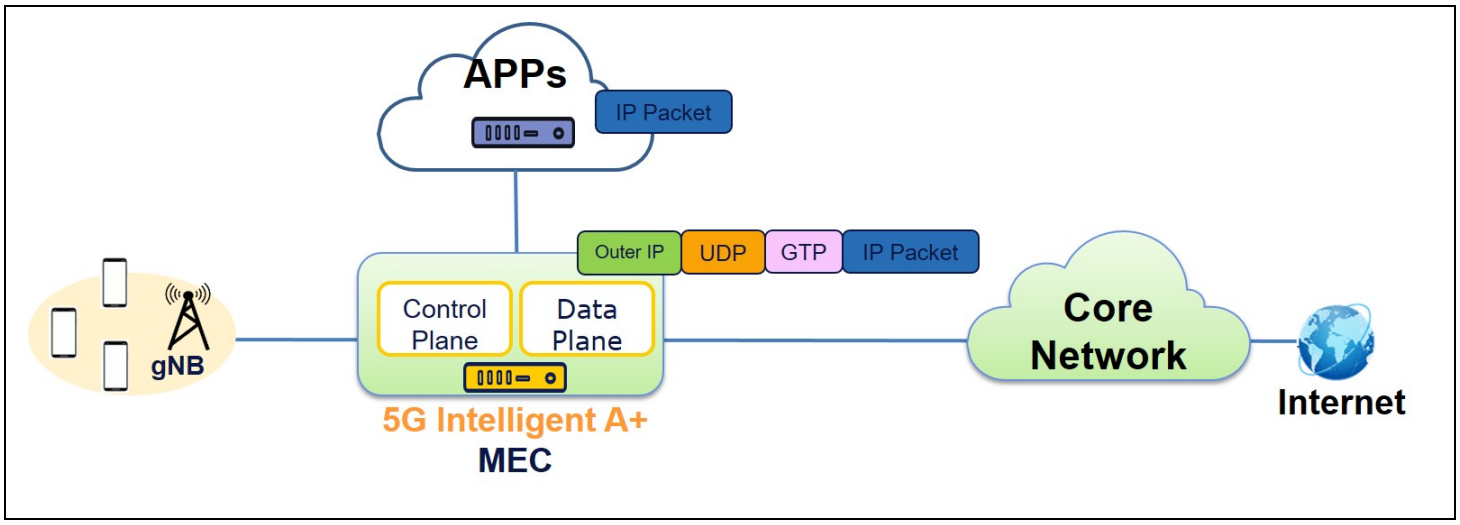

Figure 2. Components of Chunghwa Telecom* 5G Intelligent A+

The components of Chunghwa Telecom* 5G Intelligent A+ include the Control Plane (CP) and Data Plane (DP) modules, as shown in Figure 2. CP is to decode and correlate mobile signals for acquiring GPRS Tunneling Protocol (GTP) tunnel information of sessions. CP processes the S1 Application Protocol (S1AP) for 5G NSA and the NG Application Protocol (NGAP) for SA[10]. The objectives of the DP are processing the GTP-U packets and traffic steering. This interface defines the GTPv1-U protocol as the DP. In the Evolved Packet Core (EPC) or 5G core, the Mobile Management Entity (MME) and the Access and Mobility Management Function (AMF) assign hop-by-hop Tunnel Endpoint Identifiers (TEIDs) between the User Equipment (UE) and the Packet Gateway (PGW) or the User Plane Function (UPF) once UEs attach to the network. TEIDs on upstream and downstream data paths are assigned through the S1AP and NGAP protocol. TEID is intended for identification and routing of DP GTP-U tunnels. The DP of 5G encapsulates the IP packets from the Application (APP) to the UE in a DP tunnel, including an outer IPv4 header, a User Datagram Protocol (UDP) header, and the GTPv1-U header. The upstream packets are decapsulated GTP packets from MEC to APP.

Intel and Chunghwa Telecom* cooperate to gain the performance of the DP module to investigate different CPU models and Ethernet network adapters. The DP technology is based on the Data Plane Development Kit* (DPDK*), so that multi-queue can increase performance. Intel and Chunghwa Telecom* focused on using Receive Side Scaling (RSS) and Dynamic Device Personalization (DDP) technologies to direct packets to multiple CPU cores based on the packets' characteristics, thus achieving parallel packet processing and, finally, the Intel® Xeon® Gold 5218N processor, 2nd Gen Intel® Xeon® Scalable processor, and Intel® Turbo Boost Technology to increase packet processing throughput.

The Intel® Ethernet X710 family of 10-Gigabit Ethernet (GbE) server network adapters address the demanding needs of the next-generation data center. The data center network is flexible, scalable, and resilient by providing unmatched features for server and network virtualization, small packet performance, and low power. To address the ever-changing requirements for both cloud and Network Function Virtualization (NFV), the Intel® Ethernet 700 Series was designed from the ground up to provide increased flexibility and agility. DDP functionality is supported by the Intel® Ethernet Controller X710/XXV710/XL710 (X710/XXV710/XL710). DDP enables increased packet processing efficiency for NFV and cloud deployments. DDP customizable packet filtering, along with the enhanced DPDK*, support advanced packet forwarding and highly efficient packet processing for both cloud and NFV workloads.

Intel® Xeon® Gold 5218N processor is the 2nd Gen Intel® Xeon® Scalable processor. It is designed to deliver innovation and capabilities to enable rapid acceleration and growth in this data-centric era. It comes with Intel® Turbo Boost Technology; its delivery is a way to automatically run the processor core faster than the marked frequency. The processor must be working in the power, temperature, and specification limits of the Thermal Design Power (TDP). This results in increased performance of both single- and multi-threaded applications. There is no need to install any software or application to support Intel® Turbo Boost Technology.

Critical workload: MEC DP performs GTP encapsulation or decapsulation, with minimum exception traffic going through DPDK* Kernel NIC Interface (KNI) to kernel-stack-related operations.

This is a report for the activities and testing conducted with Chunghwa Telecom* MEC on Intel® Xeon® Silver 5218N processors and Intel® Ethernet X710. The document describes performance improvement by various technologies or features such as Intel® Turbo Boost Technology on Intel® Xeon® processor, RSS, and DDP on Intel® Ethernet X710.

Test Setup

Figure 3 shows the architecture of MEC on the Device Under Test (DUT). Chunghwa Telecom* MEC is connected between Landslide* and CHTTL's* 5G experimental Ericsson* Core. Landslide* simulates base stations, users, and application servers. Due to the virtualization version of Landslide*, it is to use the switch to aggregate two virtual test servers with Intel® Ethernet X710 network cards for output 40-Gbps throughput. Landslide* simulates users to attach CHTTL's* 5G experimental Ericsson* Core and generates downstream traffic from application servers to users.

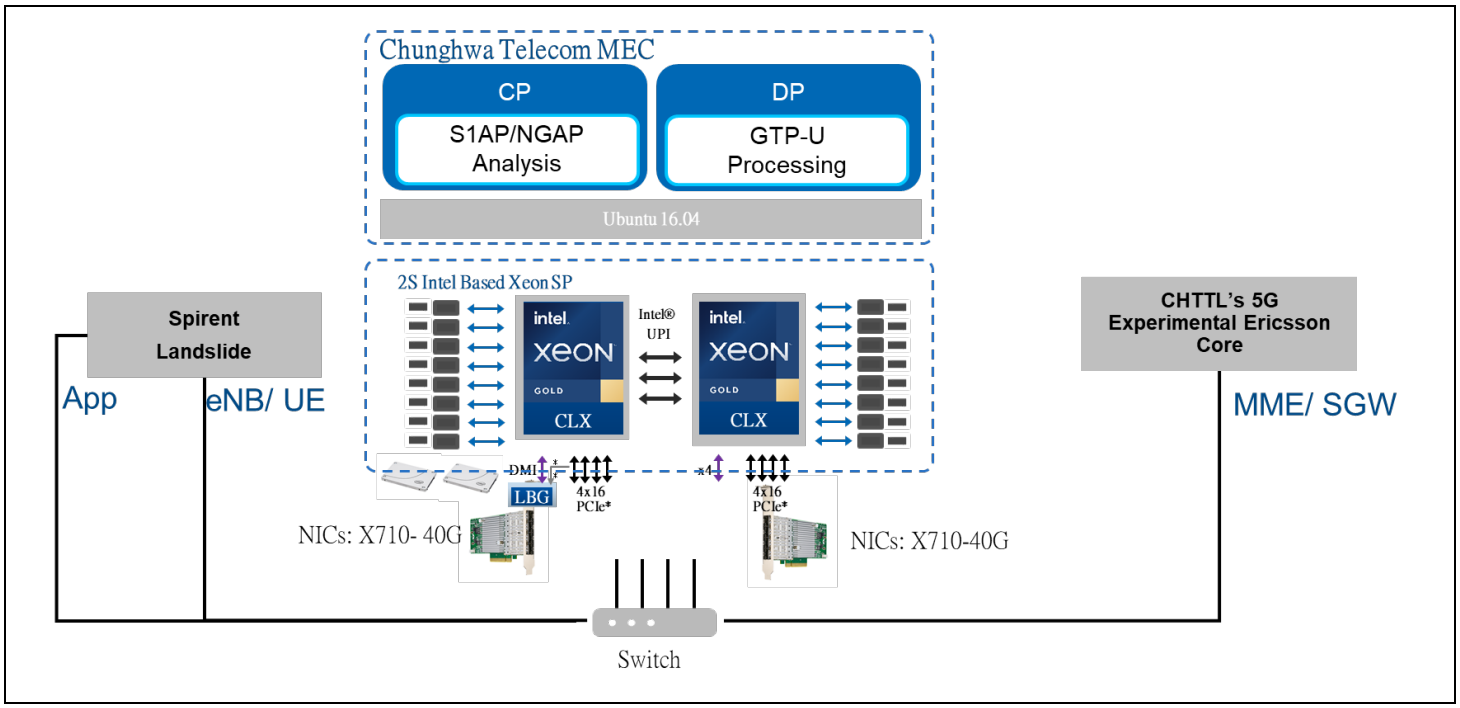

Figure 3. MEC Performance Test Architecture

The following is the Hardware configuration BOM:

Hardware Configuration	Description
Platform	Intel® Server Board S2600WFTR
Number of Nodes	1
Number of Sockets	2
CPU	Intel® Xeon® Gold 5218N processor 22M Cache, 2.30 GHz
Cores/Socket, Threads/Socket	16 Cores / 32 Threads
CPU Serial Number	56 06 05 00 FF FB EB BF
BIOS Version	SE5C620.86B.0D.01.0387.021220191105
System DDR Mem Configuration: Slots per Socket/Cap/ Speed/Rank	12 x 16G / DDR4-2667 / Rank 2
Total Memory/Node (DDR)	192G
Storage - Boot	1x Intel® SSD 240G
Network Interface Card (NIC)	None

The following is the Software configuration:

Software Configuration	Description
OS	Ubuntu* 16.04
Kernel	4.4.0-87
DPDK*	dpdk-stable-18.11
Intel® Speed Select	pwr-v0.2.1

The following is the BIOS configuration:

BIOS Configuration	Description
Hyper-Threading	ON
Intel® Turbo Boost Technology	ON
Intel SpeedStep®	Enabled. Configuration TDP Level 2. Intel® Advanced Vector Extensions 512 (Intel® AVX-512) at 2.5 GHz
Power Management	C6 enabled
Sub NUMA Clustering (SNC)	OFF
Prefetcher	ON
Intel SpeedStep® (P-states)	Enable
Hardware PM State Control - Hardware P-states	Native Mode with No Legacy Support
Intel® Speed Select Technology - Performance Profile (Intel® SST-PP)	Base
Dynamic Intel® SST-PP	Enable
Configure Intel® Speed Select Technology - Base Frequency Intel® (Intel® SST-BF)	Enable
Frequency Prioritization - RAPL Prioritization	Enable

Test Result

To demonstrate the benefit of deploying a system with Intel® Xeon® Silver 5218N and Intel® Ethernet 700 series, various test scenarios were conducted to highlight these product feature benefits to Chunghwa Telecom* MEC. These are outlined as follows:

Intel® Turbo Boost Technology

Intel® Turbo Boost Technology automatically provides opportunistic performance improvement by allowing individual cores to operate at a higher frequency. The level of turbo frequency achieved depends on several factors, including processor SKU, number of cores in C0 state, type of workload, estimated power and current, and CPU temperature. This results in higher frequency in both single- and multi-threaded applications when headroom is available.

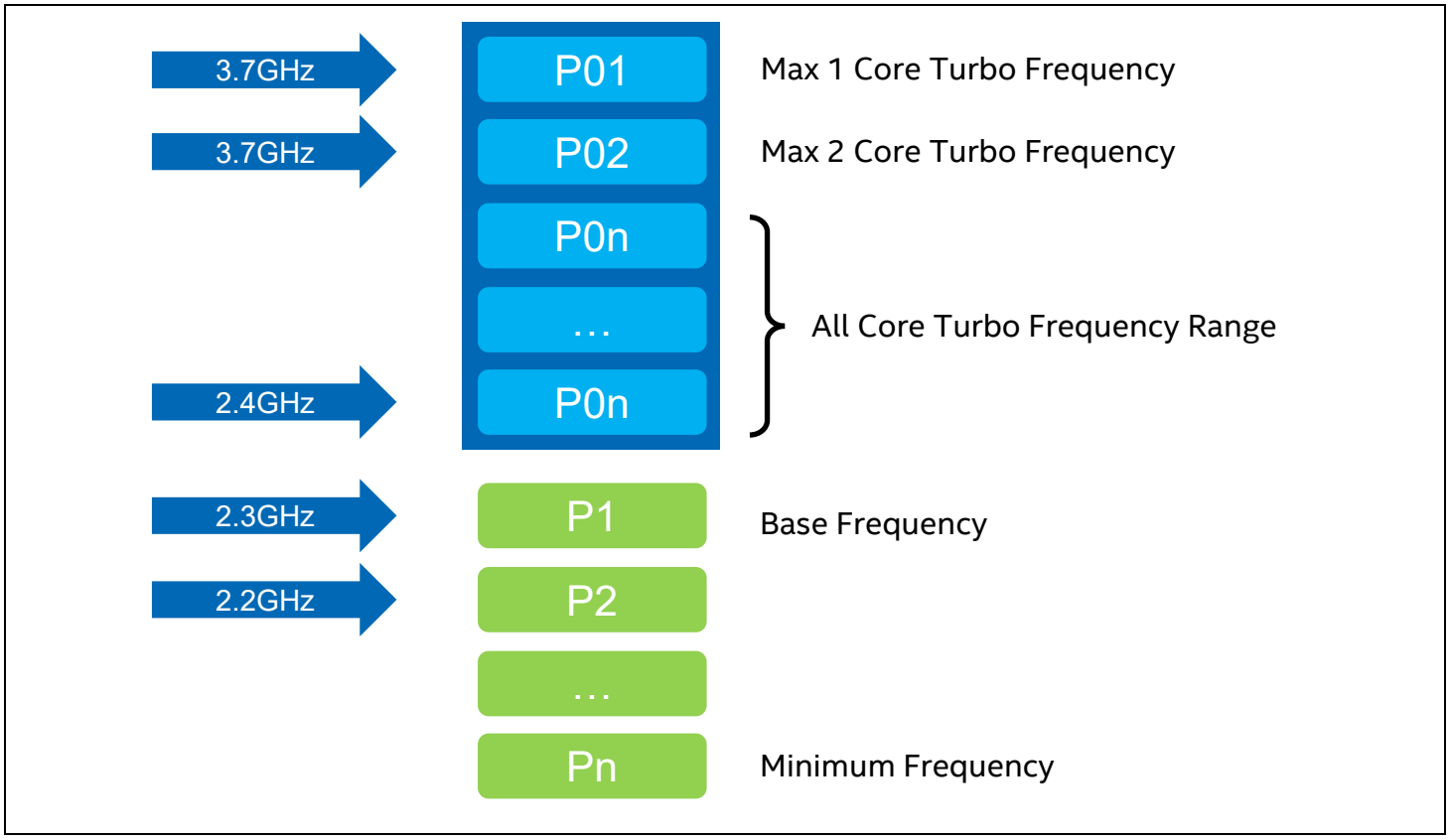

Figure 4. Intel® Xeon® Silver 5218N: Non-Intel® AVX Intel® Turbo Boost Technology 2.0 Frequency

Key takeaway Intel® Turbo Boost Technology provides opportunistic frequency improvements through higher core frequencies of select cores. The following table normalizes base performance of Chunghwa Telecom* MEC to 1:

CPU Frequency	Payload 1280 Bytes	State	Performance Gain
2.3 GHz	Core Count 1	Base Frequency	1
3.5 GHz	Core Count 1	Turbo Frequency	1.34

RSS

RSS, also known as multi-queue, receive, distributes network receive processing across several hardware-based receive queues, allowing inbound network traffic to be processed by multiple CPUs. RSS can be used to relieve bottlenecks in receive interrupt processing caused by overloading a single CPU and reduce network latency.

RSS is a hash filter; it calculates the hash signature of the input set. The calculated hash signature is then used to select the destination queue and posted to the RX descriptor to be used by software if needed. The following table normalizes base performance of Chunghwa Telecom* MEC to 1:

Number of Cores	RSS Queues	Performance Gain
1	1	1.00
1	1	1.35
4	4	1.60
5	5	1.84
6	6	2.08
7	7	1.93

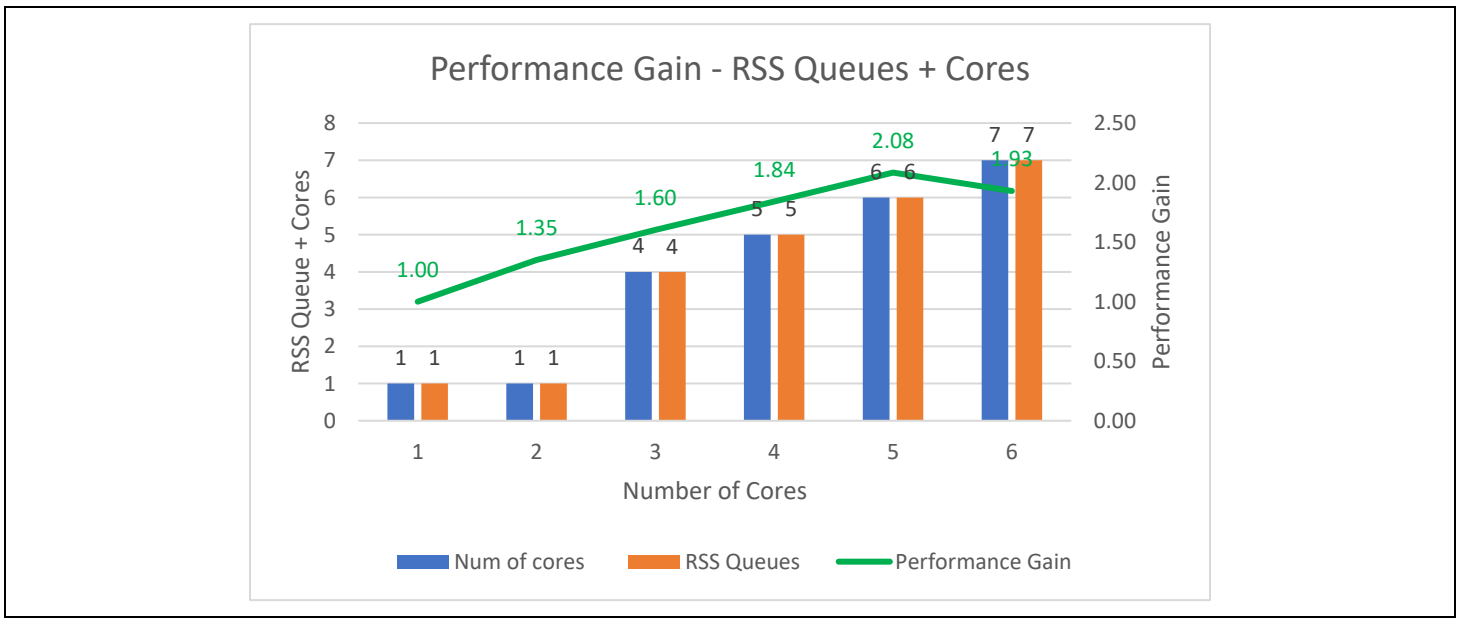

Figure 5. Performance Gain – RSS Queues + Cores

DDP

Chunghwa Telecom* MEC, utilizing the DPDK*, updated their application to utilize DDP profiles with Intel® Ethernet X710. It uses the DDP GTPv1 profile, which can be used to enhance performance and optimize core utilization for MEC use cases.

DDP allows dynamic reconfiguration of the packet processing pipeline to meet specific use case needs on-demand, adding new packet-processing pipeline configuration profiles to a network adapter at runtime, without resetting or rebooting the server. The software applies these custom profiles in a non-permanent, transaction-like mode, so the original network controller's configuration is restored after network adapter reset or by rolling back profile changes by software. Chunghwa Telecom* MEC utilizes DPDK* provided APIs to handle DDP packages. The following table normalizes base performance of Chunghwa Telecom* MEC to 1:

Payload Size (Bytes)	No DDP	DDP Enable
512	1	1.97
1280	1	2.07

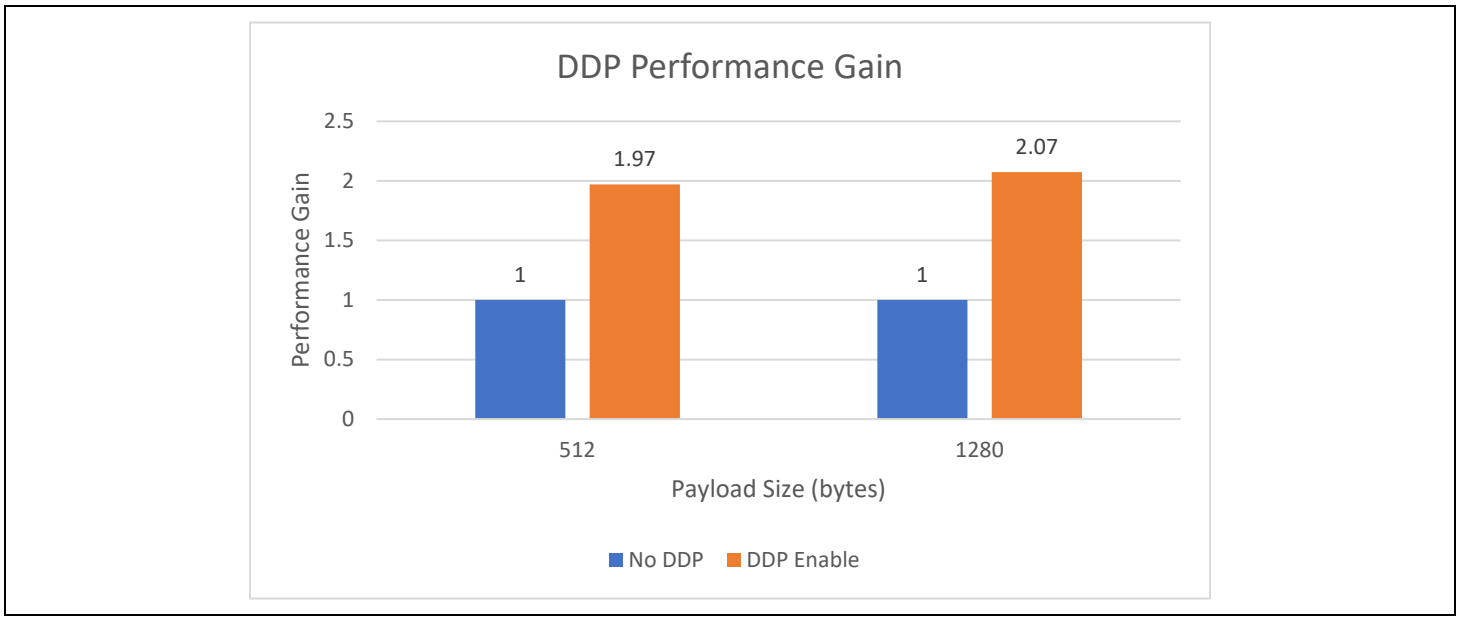

Figure 6. DDP Performance Gain

Conclusion

Summary of Chunghwa Telecom* commercial MEC's performance after incorporating Intel's technologies:

- Delivers a 34% increase in critical workload payload processing performance with a single core utilizing Intel® Turbo Boost Technology.
- Chunghwa Telecom* MEC is scaling with the increase of core count and a huge performance increase (100%) in MEC DP performance by scaling RSS queues with matching cores to six cores with six RSS queues.
- Chunghwa Telecom* MEC also enables DDP with Intel® Ethernet X710 card, and it helps MEC application increase a whopping 100% performance improvement.

Chunghwa Telecom* is committed to increasing the performance capacity of MEC (5G Intelligent A+) products by cooperating with Intel technology to meet the high-bandwidth requirements of 5G applications and assist enterprises with building private 5G networks to bring new business opportunities.

References and Resources

1. Multi-access Edge Computing (MEC). ETSI. Retrieved 25 April 2021. https://www.etsi.org/technologies/multi-access-edge-computing
2. Garvelink, Bart (14 July 2015). "Mobile Edge Computing: a building block for 5G". Telecompaper. https://www.telecompaper.com/background/mobile-edge-computing-a-building-block-for-5g--1092281
3. Ahmed, Arif; Ahmed, Ejaz. "A Survey on Mobile Edge Computing". India: 10th IEEE International Conference on Intelligent Systems and Control (ISCO'16). doi: 10.1109/ISCO.2016.7727082
4. Multi-access Edge Computing (MEC). https://www.etsi.org/technologies/multi-access-edge-computing
5. Ling-Chih Kao and Wanjiun Liao, "5G Intelligent A+: A Pioneer Multi-Access Edge Computing Solution for 5G Private Networks," IEEE Communications Standards Magazine, vol. 5, no. 1, pp. 78-84, March 2021.
6. MEC Deployments in 4G and Evolution Towards 5G. https://www.etsi.org/images/files/etsiwhitepapers/etsi_wp24_mec_deployment_in_4g_5g_final.pdf
7. Taiwan Operators Taking 5G to the Tech Sector. https://lightreading.com/asia/taiwan-operators-taking-5g-to-tech-sector/d/d-id/768422
8. Spirent Landslide™ LTE Test Application Data Sheet. https://assets.ctfassets.net/wcxs9ap8i19s/6Y5NQxoPzc4M1ENbypqePx/08083d9d7095fdd6806e24ac70ca2b1e/Landslide_LTE_Test_Application_datasheet.pdf

9. 3GPP. Technical Specification 29.281: General Packet Radio System (GPRS) Tunneling Protocol User Plane (GTPv1-U). Release 15, 2018. https://www.3gpp.org/ftp//Specs/archive/29_series/29.281/29281-f50.zip
10. Ashkan Aghdai et al., "Enabling Mobility in LTE-Compatible Mobile-edge Computing with Programmable Switches" arXiv: 1905.05258v1 [cs.NI], 2019. https://arxiv.org/pdf/1905.05258.pdf

Glossary of Terms

Term	Description
App	Application
Intel® AVX	Intel® Advanced Vector Extensions
BKC	Best Known Configuration
BOM	Bill of Material
BS	Base Station
CHTTL*	Chunghwa Telecom Telecommunication Laboratories*
CP	Control Plane
COTS	Commercial Off-The-Shelf
CPU	Central Processing Unit
DDP	Dynamic Device Personalization
DN	Domain Name
DP	Data Plane
DUT	Device Under Test
DPDK*	Data Plane Development Kit*
eNB	evolved NodeB
EPC	Evolved Packet Core
ETSI*	European Telecommunications Standards Institute*
GTP	GPRS Tunneling Protocol
IOT	Interoperability Test
IT	Information Technology
Landslide*	The Spirent* 5G mobility infrastructure test platform incorporates device emulation and network testing capabilities that expand through various 3GPP* releases (release 13 and onward).
MEC	Multi-access Edge Computing
MME	Mobility Management Entity
MSISDN	Mobile Subscriber Integrated Service Digital Network (ISDN) Number
NFV	Network Function Virtualization
NGAP	NG Application Protocol
NIC	Network Interface Card
NSA	Non-Standalone
PGW	Packet Gateway
RSS	Receive Side Scaling

Term	Description
RX	Receive
S1AP	S1 Application Protocol
SA	Standalone
SDN	Software Defined Network
SP	Scalable Processor
TDP	Thermal Design Power
TEID	Tunnel Endpoint Identifier
UDP	User Datagram Protocol
UE	User Equipment
UPF	User Plane Function

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