NEC's UPF maximizes 5G value with high performance and flexibility in containerized, virtualized or physical deployments

NEC UPF benefits that realize the 5G potential

5G core can be decomposed into control and user planes. The control plane (C-plane) nodes provide communication control functions while User Plane Function (UPF) handle user data traffic. In 5G architecture, the C-plane and U-plane, which have traditionally been collocated, are now completely decoupled. This is known as Control and User Plane Separation (CUPS).

CUPS enables control and user planes to be independently scaled and deployed. This allows, for instance C-plane nodes to be located on a centralized cloud, so that only the UPF and Radio Access Network (RAN) are deployed closer to the edge of 5G coverage areas, reducing latency and increasing capacity.

As a result, service providers can offer C-plane functions as managed services, which will significantly reduce the load of installation and operations when deploying additional 5G coverage areas.

Having said that, UPF needs to meet several requirements to bring out the true potential of 5G. For example, 5G is expected to be several times faster than 4G LTE, with a peak speed of up to 20 Gbps downlink per device, along with high-reliability communication and ultra-low latency of less than 1 milli second. High-performance UPF is crucial to realize this promise.

In addition to this, 5G also needs to support different deployment models. It should be possible to deploy UPF on different scales and platforms to support not only commercial 5G communication services offered by mobile network operators, but also industrial solutions that use local 5G or private 5G.

The UPF developed and delivered by NEC has been designed in a cloud-native architecture to meet these requirements. NEC's strong track record and technical capabilities and expertise in both mobile networking and computing domains, enables a 5G product strategy that focuses on market needs.

Key features of NEC UPF

- 3GPP compliant
- 5G/4G/3G converged nodes (UPF+PGW-U/SGW-U+GGSN-U)
- IPv4, IPv6 and IPv4/v6 packet
- I-UPF and MEC
- Offline/online billing processing
- Rate limit
- QoS policy definition for IP traffic based on DSCP
- N+1 node redundancy (session continuity and rapid switching)
- Built-in basic DPI functions with advanced DPI plug-ins
- Multi-platform support (virtualized/containerized environments)
- Network Slicing

Market-leading performance

In June 2021, NEC successfully conducted a measurement test, which demonstrated that its UPF could handle traffic at the rate of 640 Gbps per server. NEC verified this by using 2U/2-socket servers equipped with the latest server processors and 100 GbE Network Interface Cards (NIC). The UPF capability demonstrated in this measurement test was significantly better than traditional systems.

Moreover, NEC UPF has the flexibility to support multiple platforms. It can run on virtualized or containerized environment, as well as on a COTS server. It can also be deployed on public cloud, which enables the quick launch of 5G network on a small scale with short-lived use. NEC UPF is a converged solution of 4G/3G U-plane functions

(PGW-U/SGW-U+GGSN-U) on top of 5G U-plane function, enabling investment cost reduction.
This whitepaper introduces the details of NEC's high performance UPF and the technology behind together with our extensive product lineup and the use cases.

Performance test results for containerized UPF software

Industry-leading high performance verified for NEC UPF

NEC has developed and deployed a commercial containerized UPF software and demonstrated industry-leading traffic handling at 640 Gbps per server (320 Gbps per CPU) by using that. The detailed conditions of the measurement environment and test results are described below.

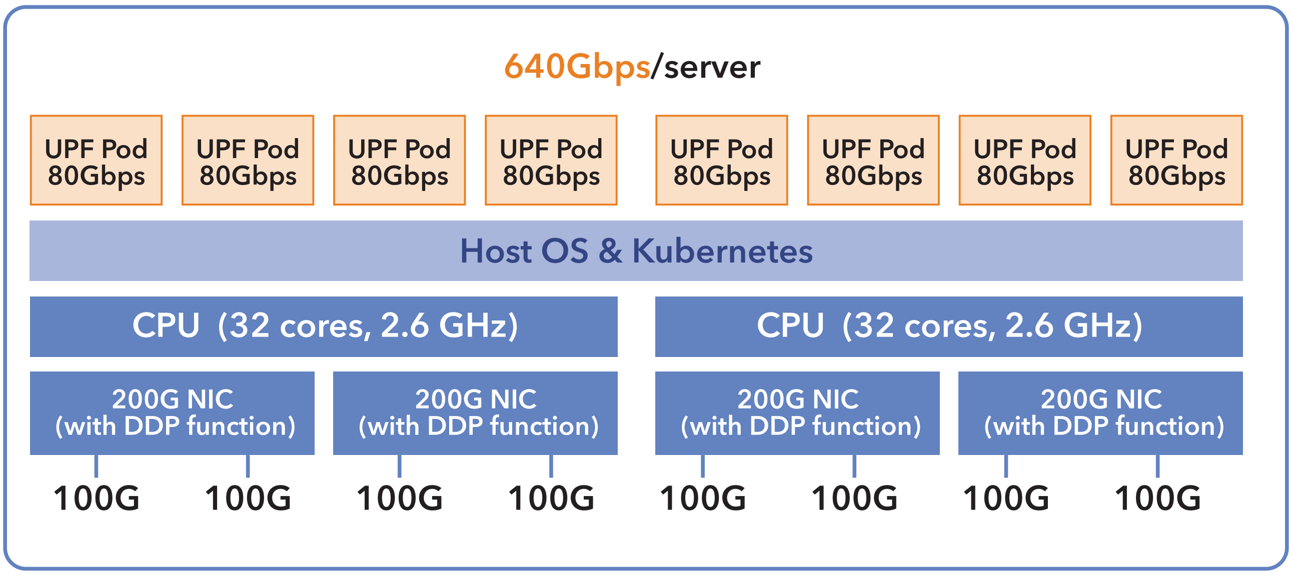
NEC's containerized UPF software (8 pods per server) runs in an environment that consists of a general-purpose x86 server with 3rd Gen Intel® Xeon® Scalable processors (32 cores x 2 sockets) and four dual-port 100 GbE NICs, along with a platform configured on Linux and Kubernetes. UPF's processing capability was measured by using test traffic that simulated the typical commercial traffic of the mobile network services.

Measurement environment

CPU	Intel® Xeon® Platinum 8358 processor 2.60 GHz, 32 cores ×2 sockets
Memory	DDR4-2933 DIMM (8ch/CPU)
NIC	Intel® Ethernet Network Adapter E810-2CQDA2 ×4
Host OS	CentOS Linux 8.2
Host OS kernel	4.18.0-193.28.1.el8_2.x86_64
Kubernetes	Ver. 1.19.3
DPDK	Ver. 20.08

Measurement conditions

Throughput (Gbps)	640 Gbps
No. of sessions	400K sessions
No. of FARs	2 FARs per session
No. of QERs	2 QERs per session
No. of URRs	2 URRs per session
Ratio of UL/DL	UL:DL = 1:3
User Packet Size	800 bytes



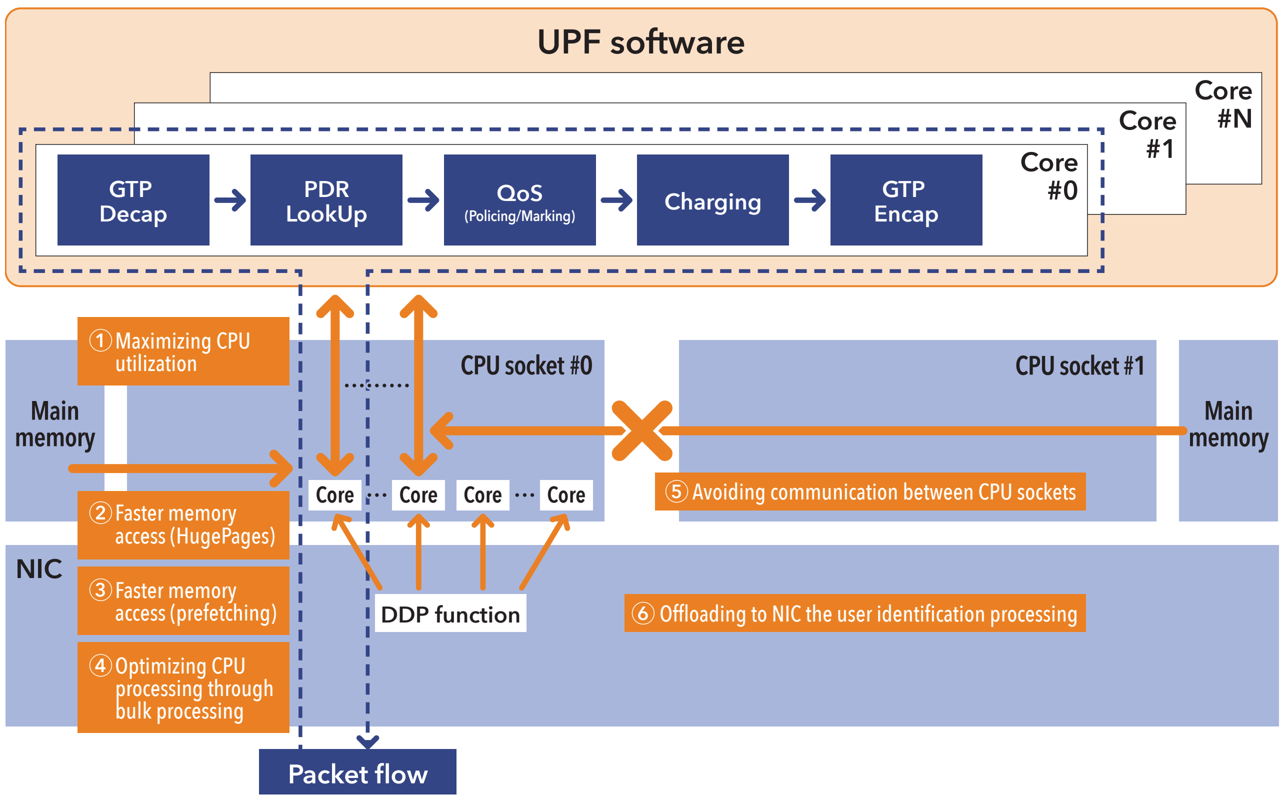
NEC's high performance UPF architecture

Industry-leading performance with NEC's expertise and technical skills

Now, let us explain how NEC has achieved such a high performance of UPF.
NEC uses Intel's technologies of Data Plane Development Kit (DPDK) and Dynamic Device Personalization (DDP). NEC performed significant optimization and improvements to be able to get the highest possible performance for the cloud native UPF. The six key aspects of our approach are described below.

① Maximizing CPU utilization with CPU Pinning and Poll Mode Driver

A normal Linux system runs multiple applications (processes and threads) on a shared CPU core. These CPU cores process instructions sequentially from multiple threads based on OS scheduling. However, if a UPF application is added here, tasks may be interrupted by other threads, which can sometimes cause packet forwarding process to wait. NEC uses Linux's CPU Pinning function in UPF packet processing threads to pin (bind) them to CPU cores. In other words, specific CPU cores are exclusively dedicated to a packet processing purpose only, in order to improve the efficiency and performance.
Moreover, NEC is using DPDK's NIC Poll Mode Driver (PMD). Usually, the OS reactively begins processing only after the NIC gets a notification about received packets. PMD improves this by proactive and constant polling to process received packets quickly, leading to stable and high-speed packet forwarding by UPF.



② Faster memory access with HugePages

Linux provides a virtual memory space that abstracts the physical memory space, making it easier for applications to handle. Virtual and physical memory spaces are divided into pages (indicating size), and each page is managed by assigning an address number to it. The default size of a page is 4 KB.
When an application needs to look up data on the memory, it specifies the data location by using the virtual memory address. Then, the processor looks up the conversion table on the kernel to translate the virtual memory address into the physical memory address and accesses the data after understanding its location on the physical memory.
When the application is handling a huge volume of data, the frequency of address translation by the kernel becomes high if the page size is small, which can degrade the application performance. UPF is one such application that consumes a huge volume of data, with gigabytes of memory to perform a large amount of packet forwarding.
To improve the situation, NEC has enabled Linux's HugePages function and configured the UPF memory's page size to 1 GB. This allows a huge memory to be looked up efficiently, reducing the processing overhead.

③ Faster memory access by prefetching data

Prefetching is a process in which the data that a program references or uses is fetched from the main memory (DRAM) to the CPU's cache memory (D-Cache) ahead of time. If the program fetches data by accessing the main memory after a process starts, that process will be delayed by the time taken to access DRAM. Prefetching can reduce this delay. NEC's UPF proactively uses prefetching to reduce processing overhead, which boosts the processing speed.

④ Optimizing CPU processing through bulk processing

The CPU has a mechanism to cache application instructions (I-Cache) just like data cache. If a process needs to be executed multiple times, instructions are cached the second time onwards for faster processing. Processing instructions multiple times simultaneously with this mechanism is called bulk processing.
Packet forwarding in UPF essentially repeats the same processing steps for each packet. NEC decided to aggregate multiple packets at the same time in each processing step so that they are processed in bulk. This boosts the efficient use of instruction caching and improves the throughput accordingly.

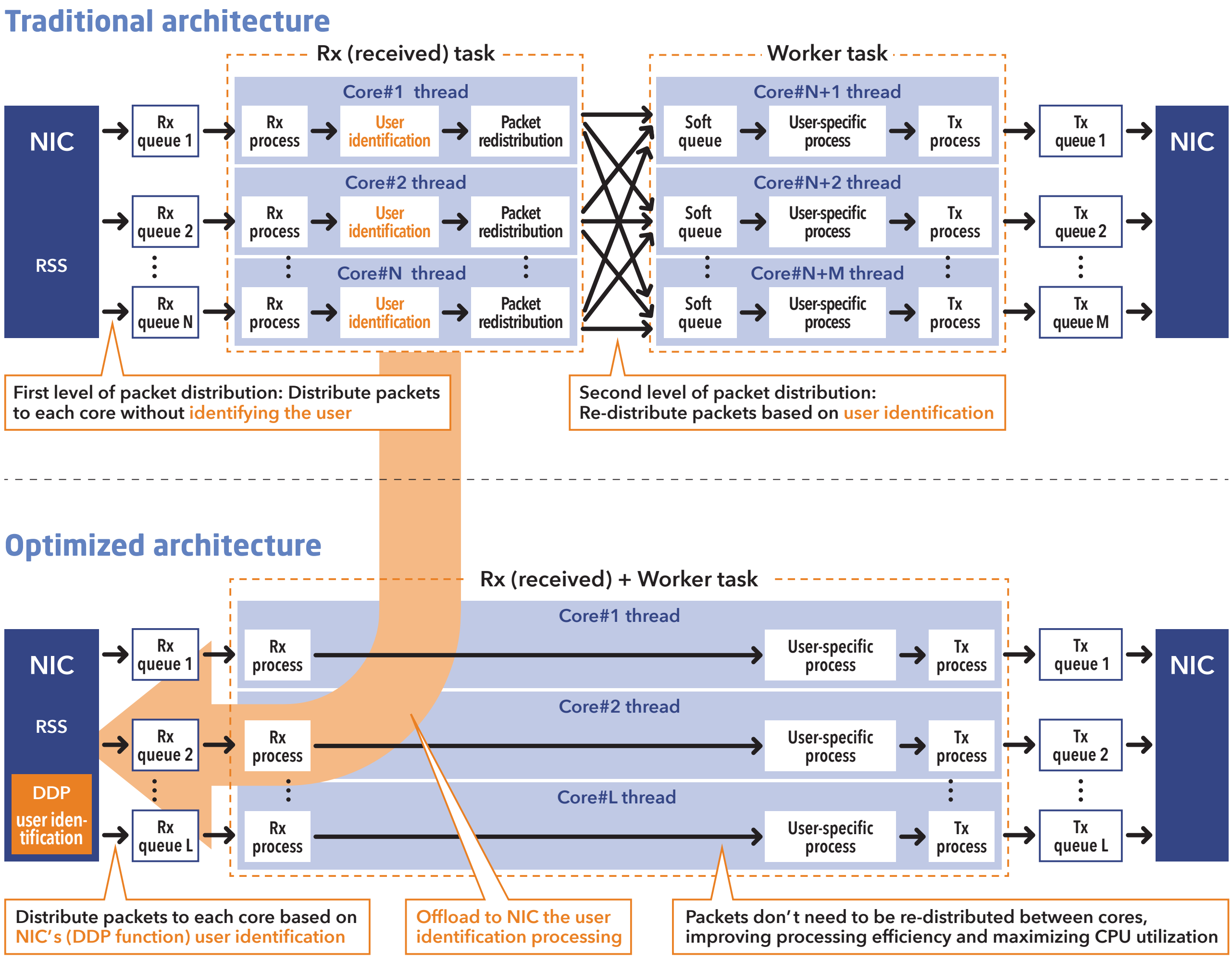
⑤ Avoiding communication between CPU sockets

In a server with two Intel® Xeon® Scalable processors, the memory is split and connected under each CPU socket. So when the memory connected under processor B is accessed from processor A, communication takes place via Intel® Ultra Path Interconnect (UPI), which is a communication path that connects processors. However, UPI capacity can be a bottleneck in processes that handle large volumes of data, slowing down the processing speed. To overcome this bottleneck, NEC's UPF software is designed to prevent memory access across UPI.

⑥ Offloading to NIC the user identification processing

To increase the efficiency of packet forwarding in UPF, the same user's packets must be sent to the same CPU core for user-specific processing.
To achieve this, until now the user identification for received packets was performed in the UPF software, which was then distributed to the same CPU core that is assigned to handle a specific user's traffic. But in this case, a switch would occur between the core that performs first-level of processes for the user identification, and the core that performs subsequent user-specific processes of the packet forwarding. The core was poorly utilized, and the process itself was complicated.
Now, NEC has offloaded the user-identification process to NIC by using the Dynamic Device Personalization (DDP) function provided by Intel NIC (E810). The DDP function performs user identification for a packet on the NIC, and forwards the packet to a specific core assigned to that user.
The DDP function improves the utilization of CPU cores because the UPF software doesn't need to perform the user identification process anymore. In addition, packets no longer need to be redistributed (switched) between cores, reducing the time lost in the switching process. The overall software

processing has become simpler, with significant improvements in processing efficiency and speed.



UPF product lineup for a variety of deployment scenarios and use cases

Support for container, virtual, and physical platforms

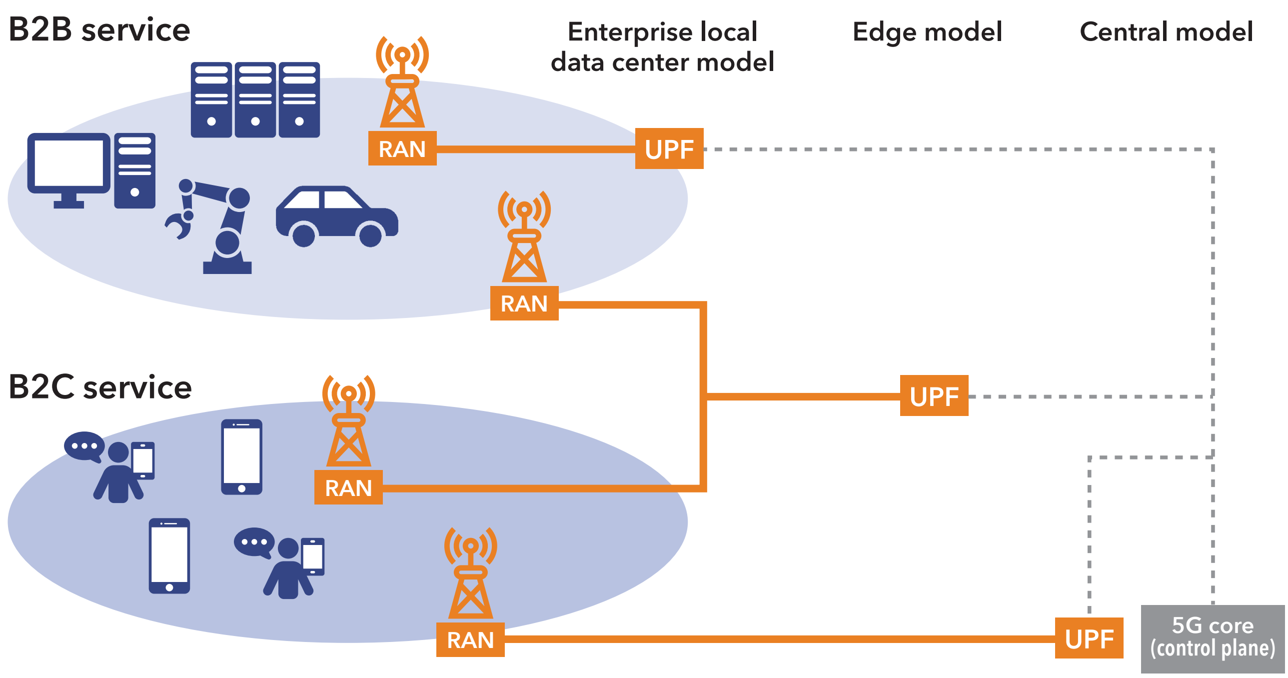
NEC's UPF is designed to be cloud native and hardware agnostic. It can be deployed on a wide range of platforms.
Either containerized or in virtualized environments (i.e. NFV: Network Functions Virtualization), the UPF software can be deployed in CSPs data centers, either centrally or at the edge, but also in enterprise data centers as well as in the public cloud. Leveraging the benefits of cloud native UPF allows flexible and rapid deployment scenarios based on traffic and network characteristics, including deployment on the same infrastructure as CU/DU/MEC. Moreover, its high performance enables extremely efficient use of power and server-installation space in data centers, helping CSPs to reduce their costs.

1BOX-UPF, a COTS server consisting of UPF software installed on an x86 server, uses custom tuning to extract the best hardware performance, delivering high throughput and session-processing capabilities in a 2U server. Our product lineup also includes a small UPF, a compact server that is less than half the size of 1BOX-UPF. The small UPF can be easily installed in environments such as local 5G or temporary setups for one-time events.

5G/4G/3G Integrated U-plane

The converged UPF integrates 4G/3G U-plane processing functions (PGW-U/SGW-U+GGSN-U), in addition to 5G UPF functions. For example, while migrating to a 5G network from a 4G/3G network, processing of the mixed user traffic (i.e. 5G/4G/3G traffic) can be easily handled by this converged UPF alone, preventing the duplication of investment and operating costs.

Multi-deployment model in NEC UPF



Realizing B2B2X business models

NEC UPF easily supports a wide range of use cases because it can be deployed on a variety of platforms. In addition to the commercial networks of mobile network operations and local 5G of enterprises, it is also expected to make business development easier for the B2B2X model in which CSPs collaborate with industry partners to deliver solutions for various industries.

For example, if a 5G solution for smart factories is to be delivered through a B2X model, C-plane can be offered as a managed service by deploying the 5G core on a central data center, while the UPF and RAN equipment are deployed in the user environment (factory).

In this case, U-plane traffic stays within the local network, so that you can securely handle data that you don't want to share externally. This can be used in various scenarios – for example, to perform consolidated analysis of a factory's operation and management by connecting to the company's data network via UPF.

Further, the U-plane can be flexibly deployed wherever needed in the network, so cost-effective and optimal U-plane deployment is possible in usage scenarios with different requirements like high bandwidth and ultra-low latency.

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In addition to UPF, NEC's 5G core network consists of containerized cloud-native components, and uses 3GPP-compliant open architecture. 5G is a technology that is likely to be deployed in diverse businesses. In this context, NEC's 5G products facilitate rapid, flexible, and powerful 5G deployments for users in all scenarios.

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