MAVENIR

SOLUTION BRIEF

OPTIMIZING UPF PERFORMANCE USING SMARTNIC OFFLOAD

5G is bringing about a transformation in connectivity. 5G not only enhances mobile broadband experiences but also supports many different verticals like AR/VR, Automotive, Energy, and Public Safety. The 5G landscape will see enablement of services across verticals with varying performance needs. This sets very challenging and demanding requirements on latency and throughput for a better experience. Since the User Plane Function (UPF) is in the path of processing all network data, it plays a key role in the 5G network and the ability to realize the ambitious vision of supporting low latency and high throughput requirements.

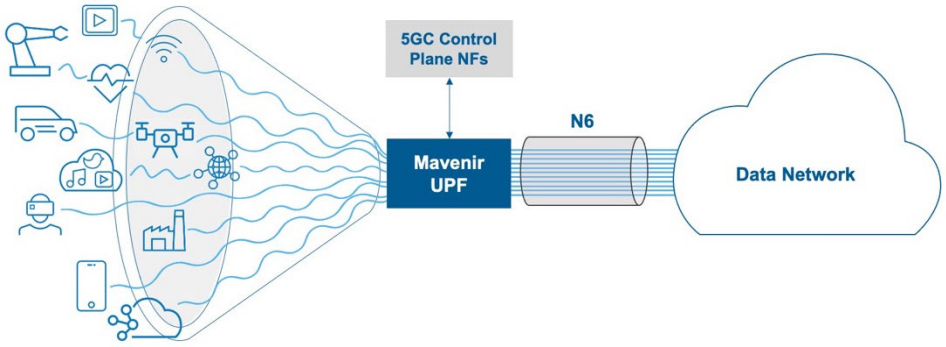

Figure 1: Mavenir's 5G UPF

Mavenir's User Plane Function

Mavenir's User Plane Function (UPF) handles the critical operation of processing subscriber traffic between the RAN (Radio Access Network) and the DN (Data Network). Mavenir's design is flexible for various deployment options that are based on operator-specific needs and use-cases. This can be either as co-located with the other Core Network functions or deployed at the edge of the network aggregation point.

Mavenir's UPF is a cloud-native, highly optimized packet processing design with configurable hardware offloading capabilities, and automation for edge deployments.

KEY FEATURES OF USER PLANE FUNCTION

- Container based Network Function
- VPP based packet processing architecture
- Optimized software for packet processing
- 3GPP Release 15 and Release 16 support
- Combo Node (UPF + PGW-U + SGW-U + GGSN-U)
- EPS Interworking
- Support IPv4, IPv4v6, and IPv6 PDUs
- Uplink Classifier and Branching Point support
- NRF based registration and de-registration
- N4/PFCP Session Management
- Lawful Intercept Support
- Transport level marking (DSCP)
- Supports N3, N6, N9 interfaces
- Supports IPv4, IPv4v6, IPv6 PDUs
- IPv6 Multi-Homing
- N6 Gi LAN services such as CGNAT and Firewall Support
- Application Awareness and Deep Packet Inspection support up to layer 7
- Session Flow Data Records and Transaction logs
- Tethering Detection and Rate Limiting support
- Hardware offloading support

While meeting very **high-performance demands** and **low hardware footprint**, Mavenir UPF also delivers on deployment automation and ease of operational maintenance through centralized management system, **reducing total cost of ownership**.

To reduce CAPEX for 5G, Mavenir UPF provides 5G UPF and PGW-U/SGW-U/GGSN-U support, delivering a unique combination of high performance and capability to support 2G/3G, 4G and 5G subscribers in a single network function.

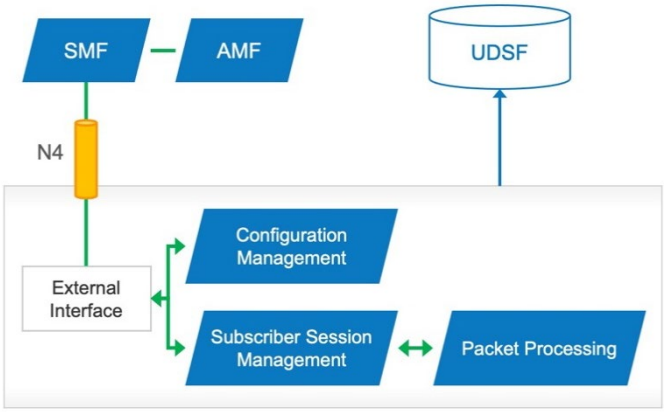

Figure 2: Mavenir's 5G UPF

Achieve 524 Gbps throughput with 50% reduction in compute costs

This is achieved with UPF Packet Processing offload using SmartNICs (Smart Network Interface Controller)

Before SmartNIC offload: No packet processing activities or features like GTPU encapsulation/decapsulation and flow tagging are offloaded.

Packet Processing Cores : 32, Avg. CPU Utilization : 78%, Throughput : 524 Gbps

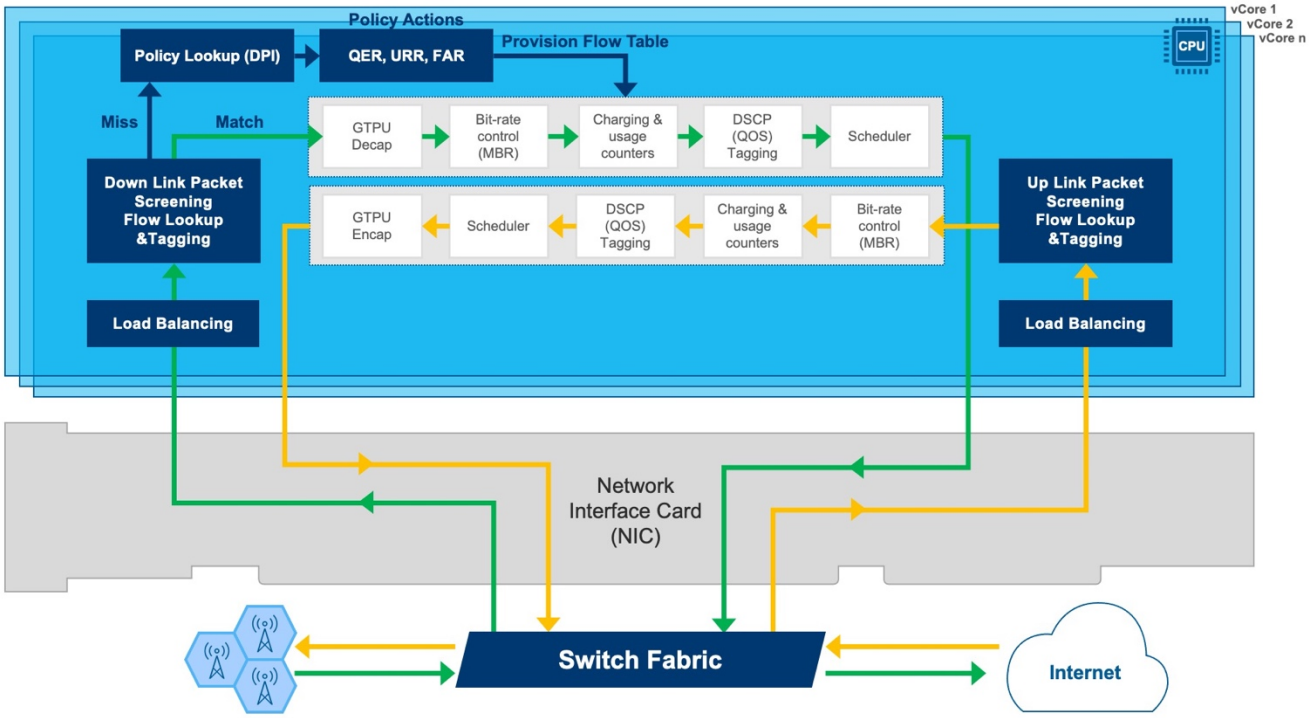

Figure 3: Before SmartNIC offload

Mavenir UPF SmartNIC offload capability offers efficient distribution of the user plane packets across multiple CPUs. Other features offloaded to SmartNIC are GTPU encapsulation and decapsulation, and flow tagging.

After SmartNIC offload: Packet processing activities or features like GTPU encapsulation/ decapsulation and flow tagging are offloaded to SmartNIC.

The offloading capability delivers the following benefits:

- Significantly reduces latency/jitter, avoids inter CPU handover leading to a higher throughput
- Since there is no cache miss, it consequently reduces overheads and improves latency and performance

Mavenir UPF's unique design allows efficient resource management of available CPU that further enables:

- Ability to handle varying types of user traffic with different packet sizes
- Ease of handling higher peak data rates with NSA option 3x and 5G SA peak data rates
- Higher system throughput capacity without impacting the number of subscriber sessions being handled by the UPF

Packet Processing Cores: 16 (reduced by 50%), Avg. CPU Utilization: 72% (drops by 6%), Throughput: 524 Gbps

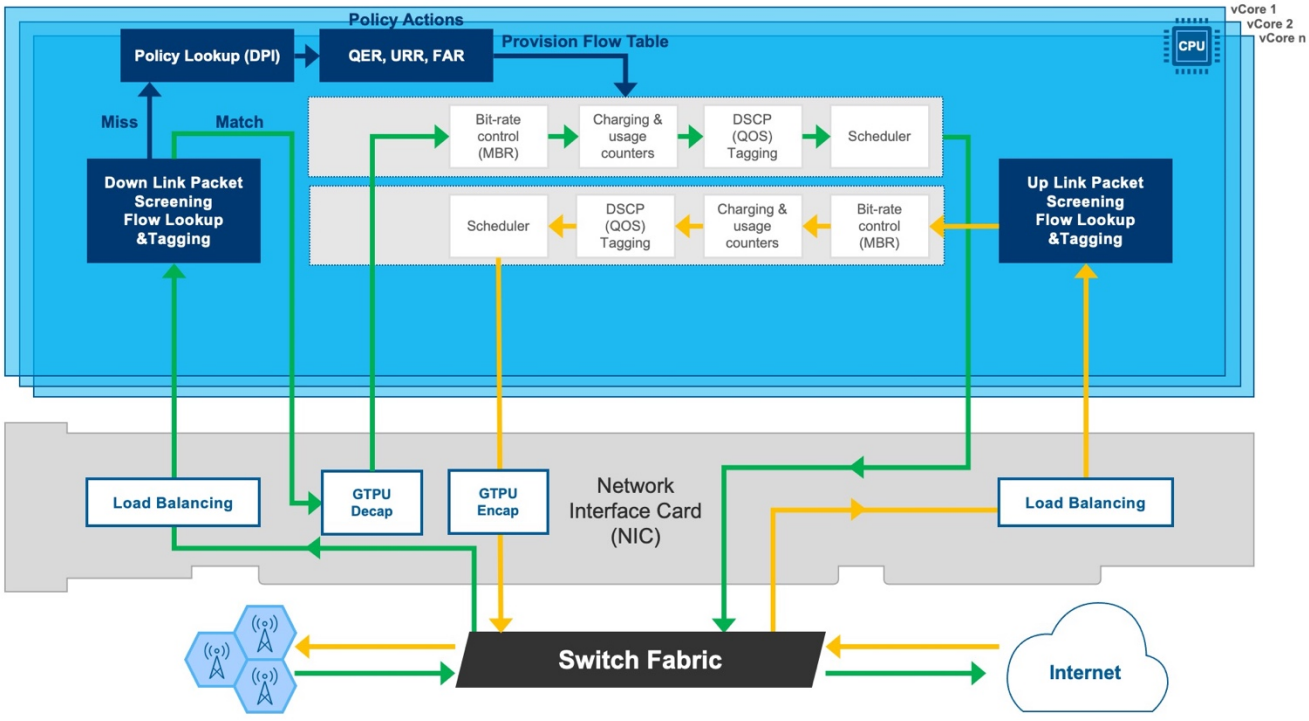

Figure 4: After SmartNIC offload

The UPF packet processing is based on FD.IO's Vector Packet Processing (VPP) technology that provides the benefits of a programmable data plane:

- Enables diverse ways of packet forwarding and supports various formats and protocols making its management easy and flexible
- Allows a programmable packet processing pipeline that further enables deployment of the porting solution on hardware platforms such as x86, standard NIC, SmartNIC

The platform supports various deployments such as edge, far edge, central, which can be scaled to support required performance needs.

Software optimization done by Mavenir using VPP implementation includes benefits such as:

- Optimized use of CPU's instruction cache, memory footprint reduction to fit L2/L3 cache for best performance
- Use of software pre fetch to hide memory access latency

UPF Benchmarking

Mavenir conducted a benchmarking test to quantify the UPF performance improvements by offloading the following UPF functions to the SmartNIC: GTP RSS, GTP Encapsulation, GTP Decapsulation and Flow Tagging. We conducted a test with 3 configurations:

Test Configuration 1: There is no offload in this scenario

Test Configuration 2: Only RSS is offloaded, Flow Tagging and GTP Encapsulation/Decapsulation are not

Test Configuration 3: RSS, Flow Tagging and GTP Encapsulation/Decapsulation are offloaded

	Test Configuration 1	Test Configuration 2	Test Configuration 3
RSS Offload	No	Yes	Yes
Flow Tagging	No	No	Yes
GTP Encapsulation/Decapsulation	No	No	Yes
Packet Processing Cores	32	22	16
Total Throughput (Gbps)	524	524	524
Average CPU Utilization (%)	78%	76%	72%
Downlink PPS (in millions)	57.5	57.5	57.5
Uplink PPS (in millions)	28.9	28.9	28.9
Average Packet Size (bytes)	743	743	743

Test Lab Configuration

1. *Dell R740 server with two Intel® Xeon® Gold 6248R processors, 384 GB RAM and a 1.6 TB SSD Drive.*
   - *R740 Dell Server*
     Intel® Xeon® Gold 6248R 3.0G, 24C/48T, 10.4GT/s, 35.75M Cache, Turbo, HT (205W) DDR4-2933 5-PCIe3x16, 384GB RAM, TB 7.2K RPM NLSAS 12Gbps 512n 3.5in Hot-plug Hard Drive RAID
     4x900 GB SSD (total 3.6TB)
2. *The server featured Dual-Port 100G NVIDIA Mellanox ConnectX-6 NICs.*
   - *A total of 6 NICs of these were installed on the server*
3. *Software included Containerd v1.2.10, Kubernetes v1.17.3, DPDK 19.11, and VPP 19.01*
4. *The testing environment was set up with 50,000 emulated subscribers*
5. *2PDR, 2URR, and 2QER per session were enabled; L7 DPI were not enabled*
6. *Total of 6 UPF PODs where deployed on the same Dell server. Per the picture below UPF1, UPF2, UPF3, and UPF6 were assigned 16 PCIe slots each. UPF4 and UPF6 were assigned 8 PCIe slots each.*

Figure 5: UPF performance results

KEY FINDING:

50% reduced compute cost for the same throughput of 524 Gbps.

Mavenir was able to demonstrate 524 Gbps of throughput on a single server using 16 packet processing cores. As per the figure below, Mavenir was able to reduce the UPF footprint from 32 FastPath (FP) pCores when no offload was used to 16 FastPath (FP) pCores when GTP RSS, GTP Encapsulation, GTP Decapsulation and Flow Tagging was offloaded to the SmartNIC. That is a 50% of FastPath (FP) pCore savings in order to achieve the same 524 Gbps throughput

Mavenir's UPF Architecture

Mavenir's solution is modular, extensible, scalable, service-based, and highly optimized to meet the higher performance requirements for 5G systems.

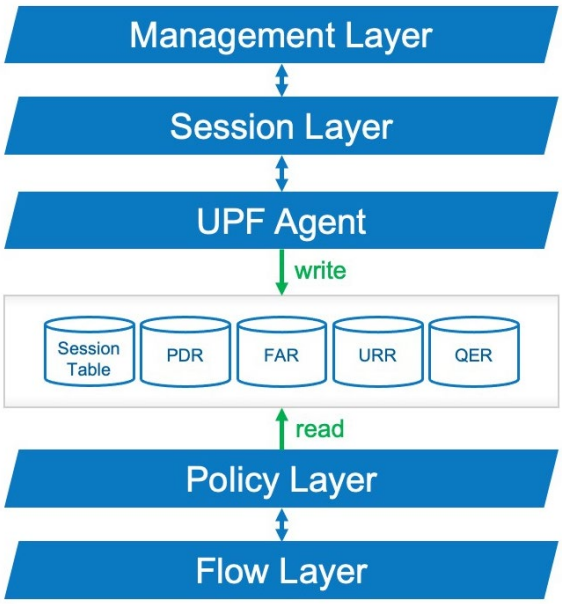

Figure 6: Mavenir's UPF Architecture

KEY ARCHITECTURE COMPONENTS

The Vector Packet Processing framework implements plug and play graph nodes thus enabling programmability and faster time to market

The framework is optimized to process high data rates and support a large number of flows with varying packet sizes

It supports receiver side scaling to load balance traffic based on a various set of criterial elements such as source and destination address based load balancing

The UPF framework allows the offloading of packet processing components to SmartNICs

UPF Architecture Layers

- **Management Layer**: Performs application configuration management and OAM procedures
- **Session Layer**: Performs UPF session handling and interfaces with other control plane elements
- **UPF Agent**: Provides fast path services to slow path applications
- **Policy Layer**: Provides fast path application logic of policy lookup, execution, and flow offloading
- **Flow Layer**: Terminates N3, N6/N9, S1/S5/S8/Gn/Gp and SGi Interfaces. Runs Graph nodes for IPv4/v6, GTPU, UPF Session Lookup, PDR rule match & Action handling, QoS Enforcement, DPI, CGNAT

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Mavenir UPF Packet Processing Evolution

Mavenir's UPF is evolving over multiple phases to deliver a high performance and cost optimized UPF. Over these phases, Mavenir is developing and enhancing its UPF leveraging the benefits of Software acceleration techniques like DPDK and VPP, as well as Hardware optimization techniques like SmartNIC and Switch Fabric Offload.

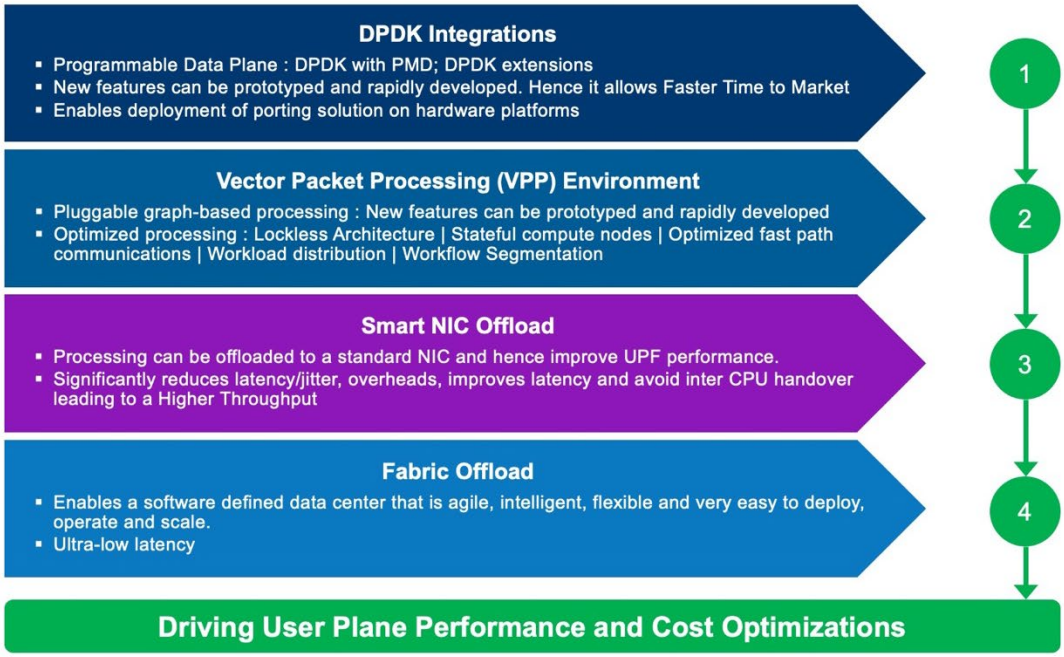

Figure 7: Mavenir's UPF evolution

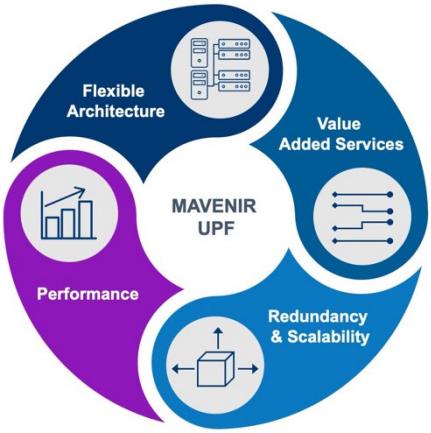

Figure 8: UPF Differentiators

UPF Differentiators

Flexible Architecture

- Flexible hardware offload
- 2G/3G/4G/5G combo node support
- UPF internetworking with any vendor's SMF via N4
- Integrated UPF and CU-UP

Value-add Services

- VPP plug-ins for GLAN services (i.e. DPI, Tethering, CGNAT, FW)
- Policy Rules and Enforcement

Performance

- Containerized UPF running on bare metal
- 524Gps on 16 packet processing pCores
- No east-west traffic, single hop

Redundancy & Scalability

- M : N redundancy
- Fast Switchover during HA
- K8s and Application KPI based Scaling

CONCLUSION

Achieve Lower TCO using Mavenir's UPF

TCO is a crucial element in the transition to 5G. While multiple aspects influence the TCO towards 5G, there are specific factors of Mavenir UPF implementation that optimize the cost as noted below:

a. Mavenir UPF's cloud-native design renders a **smaller hardware footprint**. The containerization of the UPF software offers increased flexibility, efficient resource utilization and elimination of dependency on hardware.
b. Cloud-native applications are managed dynamically on a proven Kubernetes based container-orchestration platforms that offer hardware decoupling that is essential for **deployment automation.**
c. Less hardware and efficient network management systems **improve operational resiliency** and reduce complexity, thus lowering costs.

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An Open, Highly Flexible Solution using Cloud-native Principles

Mavenir is a leader in accelerating and redefining network transformation for Service Providers, by offering a comprehensive product portfolio across every layer of the network infrastructure stack. From 4G and 5G application/service layers to 5G core and EPC and open RAN – Mavenir leads the way in evolved, cloud-native networking solutions enabling innovative and secure experiences for end users.

Mavenir's solutions are deployed at 250+ CSPs who cover about 4B subscribers. Mavenir's platform enables these CSPs to successfully deliver next generation vision today and realize new revenue streams and operational efficiencies

Mavenir's containerized packet core solution leverages proven industry tools, software, and best practices to provide an open and highly flexible solution. Using general purpose servers and standard operating systems (Linux), Mavenir packet core solution including UPF is designed for maximum interoperability, allowing seamless integration with third-party tools for extended functionality. Fully automated Life Cycle Management (LCM) and scalability based on Kubernetes integration. Continuous Integration and Continuous Delivery (CI/CD) software pipeline. The system can scale down to meet far edge deployment use case requirement. The UPF should be dynamically deployable and granularly scalable. This can only be achieved through cloud-native web scale deployment methodologies, UPF as a container can be remotely instantiated and maintained further reducing the edge deployment time and operation costs.

Maximizing Investments

To help optimize technology investments, Mavenir and its partners offer complete solutions that include professional services, technical support, and education.

For more on Mavenir Solutions please visit our website at www.mavenir.com

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LIST OF ACRONYMS

Acronym	Explanation
3GPP	3rd Generation Partnership Project
5G	5th Generation
AR/VR	Augmented Reality/Virtual Reality
CGNAT	Carrier Grade NAT (Network Address Translation)
DN	Data Network
DPDK	Data Plane Development Kit
DPI	Deep Packet Inspection
EPS	Evolved Packet System
GGSN	Gateway GPRS Support Node
GTP	GPRS Tunneling Protocol
LAN	Local Area Network
NRF	Network Repository Function
NSA	Non-Standalone
OAM	Operation and Maintenance
PDU	Packet Data Unit
PFCP	Packet Forwarding Control Protocol
PGW	Packet Gateway
PPS	Packets Per Second
QoS	Quality of Service
RAN	Radio Access Network
RSS	Rich Site Summary
SGW	Serving Gateway
UPF	User Plane Function
VPP	Vector Packet Processing