White Paper

Mobile Network Operators, Enterprises with Private 5G

intel.

CSG Integrates 5G Monetization Solution with NiralOS 5G Core

Tests[1] show deployment, performance, integration benefits of CSG 5G Policy Management and NiralOS 5G Core on Intel® architecture processor servers

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Executive Summary

5G's second wave is underway as more mobile network operators (MNOs) build out 5G standalone networks. Policy management and monetization solutions are required to capture the value of the new services.

In this paper, CSG and Niral Networks describe the market evolution and then introduce their software: CSG Policy Control and NiralOS 5G Core. The companies then demonstrate how the CSG Policy Control product can easily integrate with the NiralOS 5G Core on hardware powered by 4th Gen Intel® Xeon® Scalable processors.

The paper further explores the vital role of 5G monetization solutions like 5G policy control function (5G PCF) and 5G charging function (5G CHF) that play in unlocking key 5G commercialization strategies for MNOs including mobile private networks (MPN) for B2B and B2B2X use cases. The paper also reviews how the deployment of a 5G PCF and 5G CHF can support operators' sustainability efforts through the efficient utilization of network resources underpinned with advanced automation leveraging artificial intelligence (AI).

Introduction

Standalone 5G networks can deliver improved and advanced wireless services including enhanced mobile broadband (eMBB) for higher speed mobile device connectivity and other long promised 5G services like fixed wireless access (FWA), ultra-reliable low latency connectivity (uRLLC), and massive machine-type communications (mMTC).

Combine these services with the flexibility of network slicing and mobile network operators (MNOs) can start a new chapter in profitable service deployment.

The key driver for deploying these innovative services? Boosting the bottom line for MNOs. 5G's initial launch promised new offerings and capabilities, but the widespread adoption has been slow. However, their potential to generate new revenue streams remains strong with the early adoption of key consumer services such as FWA showing potential and innovative private network-enabled use cases for industry, mining, ports and transport are gaining traction. By introducing software-based and cloud-native 5G SA networks, early adopters are beginning to unlock the full potential of 5G including network slicing, granular quota control, virtualization and ultra-low latency.

5G Monetization Trends and Outlook

5G SA revenue is predicted to surpass 5G non-standalone (5G NSA) revenue for the first time in 2024 and will account for more than 90%[2] of global wireless revenue by 2028. Global analysis of 5G SA deployments reveals two key drivers for 5G SA

monetization: 5G SA MPNs and FWA. To ensure profitable delivery of both these services, MNOs need agile policy and charging solutions to cater for increasingly diverse use cases, enable large-scale monetization and integrate seamlessly with existing billing support systems (BSS). The global market for charging and policy solutions is expected to grow from $1.7 billion in 2022 to $2.2bn in 2028, a CAGR of 5%. This growth is driven by the adoption of 5G SA and the need to develop new monetization use cases to deliver a return on investment.[3]

FWA is Accelerating Sustainable Monetization of 5G SA

FWA is emerging as the most actively growing consumer service based on 5G. According to a leading consulting group, 90% of CSPs that launched 5G have already offered FWA to their customers with an 88% 2020–2026 CAGR in 5G FWA connections predicted.

MPN for New B2B2Bx Revenue Streams

5G private networks are enabling cutting-edge new enterprise-focused solutions focused on previously unexplored revenue streams. As of February 2023, there were 1,077 MPNs based on LTE and 5G, deployed in 74 countries. The largest sectors for customer references are mining, education, and manufacturing.

Addressing Sustainability

With evolved policy and core network functions, 5G SA offers a more sustainable utilization of networks, since nearly every part of the network can be virtualized, componentized, and made available in real-time using standard APIs. It is possible to monetize any technological aspect of a session, network, or consumer context.

The 5G Policy Control Function (PCF) interworking, combined with other 5G core network functions (NFs), enables sustainable networks by using the right slicing capabilities at the right time, delivering efficient utilization of network resources for users and applications. This helps in streamlining network signaling and providing load balancing in complex 5G networks.

These sustainability efforts are enhanced by Intel's new software tools that enable dynamic reduction of CPU cycle times and power consumption during times of low traffic and light workloads that can deliver significant power savings.

FWA and Sustainability

Utilizing the existing spectrum for FWA improves RAN capacity, laying the foundation for profitable 5G SA deployments. This approach extends coverage to underserved areas and provides a more environmentally friendly solution compared to traditional fiber-optic infrastructure, which requires extensive excavation and potential disruption.

Specialized network slices dedicated to FWA ensure operators can meet service-level agreements (SLAs). The 5G PCF and CHF manage policies and charging rules within these slices, optimizing performance for FWA users.

MPN Offering Sustainable Industry Vertical Use Cases

MPNs can support a substantially higher density of connected devices and offer increased bandwidth and mobility with reduced latency. Using the 5G PCF and CHF to guarantee efficient and sustainable operations, 5G MPNs can drive sustainable use cases including smart port management:

1. Using a separate network slice, traffic light control is provided by the single control center. This drastically cuts back on the overuse of resources.

2. Remote management of environmental sensors that track gases and carbon dioxide concentrations and gather more insights about ship emissions.

3. Providing safety and security at the ports with fraud detection, license plate identification, face recognition, and real-time notifications on cars going above speed limits.

Value of Actionable Insights Using AI/ML in 5G: PCF and NWDAF Interworking

Mobile network management technologies allow operators to optimize their network operations through virtual network resources. These resources can be automatically deployed as needed, improving efficiency and agility. Achieving automation requires proactive management. MNOs need to continuously monitor network performance, identify potential issues, and take corrective actions quickly.

The 5G PCF and network data analytics function (NWDAF) can work together, leveraging AI and machine learning (AI/ML) to analyze network data.

- **Predictive Maintenance**: AI/ML can identify potential network problems before they occur, preventing disruptions and the need for reactive solutions.

- **Resource Optimization**: Based on real-time insights, the PCF can dynamically allocate virtual network resources, ensuring optimal performance with minimal energy consumption.

Actionable Insights from Network Data

The importance of network data extends beyond internal monitoring. B2B customers increasingly rely on service level agreement (SLA) monitoring portals to track network performance. To meet these demands and unlock further commercial value, NWDAF utilizes AI/ML algorithms and analytics on the collected data to generate real-time insights:

- **Network Conditions**: This includes monitoring network load (per slice instance and network function), predicting congestion, and anticipating changes in quality of service (QoS).

- **Abnormal Device Behavior**: AI can detect unusual device activity, enabling proactive measures to address potential security threats or network disruptions.

- **Service Experience**: Predicting and optimizing application service experience ensures consistent performance for end-users.

An integrated solution with NWDAF and service assurance can identify network slice instances and build specific performance indicators (KPIs) for each slice using AI/ML algorithms. The PCF receives real-time or periodic alerts based on these KPIs, allowing operators to dynamically manage slices. When thresholds are exceeded, the PCF leverages NWDAF insights to adjust traffic rules and allocate additional resources as needed.

This AI-powered automation empowers MNOs to achieve a self-optimizing network, reducing energy consumption, improving network efficiency, and delivering a superior service experience for B2B customers.

CSG, a member of the Intel® Network Builders ecosystem, offers a comprehensive portfolio of 5G monetization solutions backed by over 40+ years of experience serving over 900+ customers globally. CSG Network Solutions portfolio offers critical components for 5G monetization including policy management (5G PCF and policy and charging rules function (PCRF)), charging functions (CHF and Charging Gateway Function (CGF)), network messaging and convergent mediation.

 MNOs need a 5G PCF and CHF to launch the advanced B2B and B2B2X services that are critical to successful monetization of their 5G networks. This includes complete solutions for targeted verticals such as agriculture, mining, manufacturing and logistics launched using MPNs. Examples include unmanned aerial vehicles (UAVs) to monitor crop health and motion sensors that send regular alerts with high-resolution imagery (in near real-time) to farming teams or production defect monitoring and resolution with remote vision launched on dedicated network slices or mobile private networks.

These use cases require the right policy enforcement for public/private network slices and enable the right network resources availability, dynamically in real time as required by the application on top- may that be on any of uRLLC, mMTC, or eMBB streams and 2B2C UHD services that leverage cloud service platforms and 5G to give each customer a more personalized experience. The PCF-enabled quality of experience (QoE)-aware network management approach is at the heart of these services.

Customers seek domain-specialized solutions for 5G monetization. CSG has drop-in solutions that are 3GPP standards based and that minimize intrusion. Because CSG's 5G PCF works very closely with the 5G core to set and execute policies, CSG has developed low touch point integration of the PCF into any vendor's 5G core in both the user plane and the subscriber data management (SDM) function.

To demonstrate this ease of deployment, performance and seamless integration with any vendor public/private 5G core, CSG worked with Niral Networks and Intel in the Intel Network Builders demo lab.

CSG Policy Control: Any 'G' Policy Solution for Network Monetization and Utilization

CSG's 5G policy management solution is a fully cloud native, microservices-based containerized application that complies to 3GPP SBIs-based standard integration to any 5G core. The software is optimized for advanced 4G/5G networks but also can bring advanced features to 2G and 3G networks. Figures 1 and 2 show the policy control features enabled by the solution.
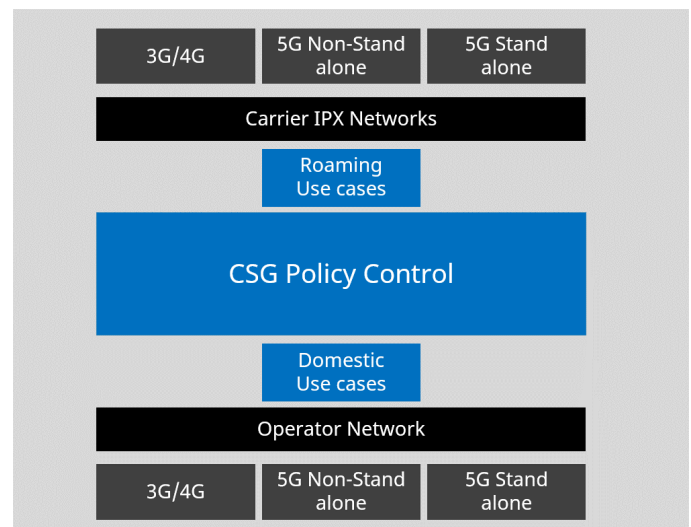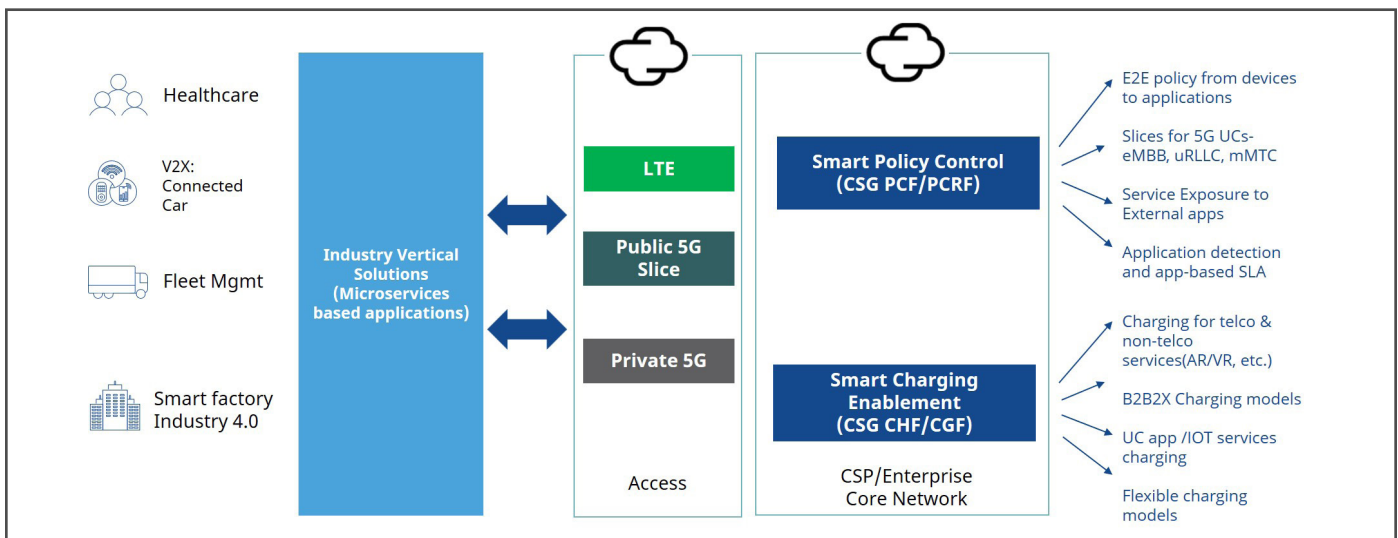

Figure 1. CSG Policy Control.

Figure 2. CSG Policy Control features.

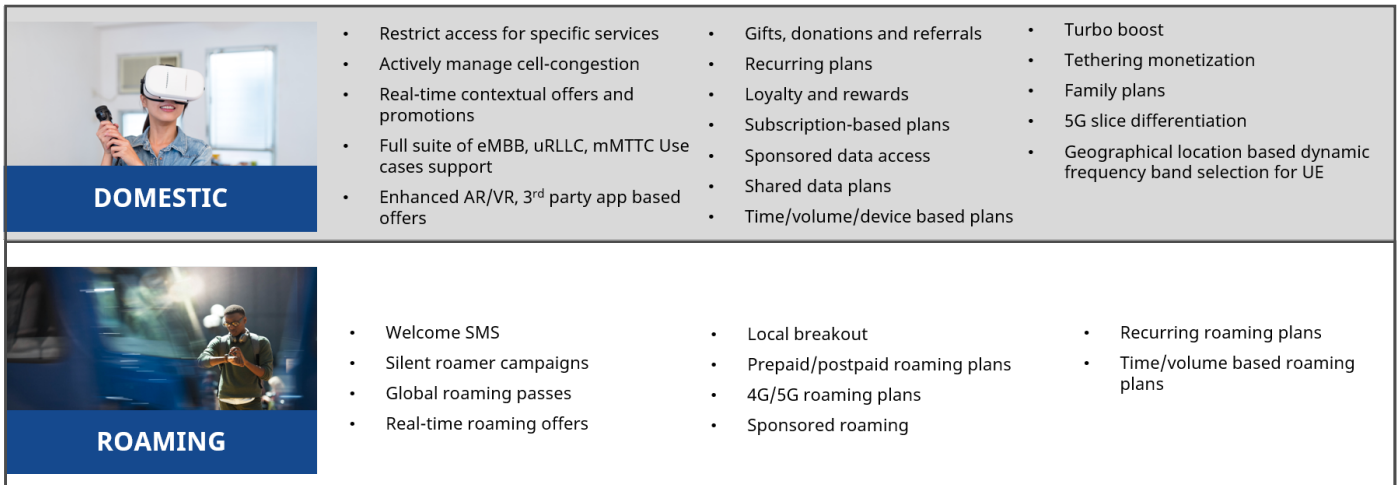| DOMESTIC | • Restrict access for specific services
• Actively manage cell-congestion
• Real-time contextual offers and promotions
• Full suite of eMBB, uRLLC, mMTTC Use cases support
• Enhanced AR/VR, 3rd party app based offers | • Gifts, donations and referrals
• Recurring plans
• Loyalty and rewards
• Subscription-based plans
• Sponsored data access
• Shared data plans
• Time/volume/device based plans | • Turbo boost
• Tethering monetization
• Family plans
• 5G slice differentiation
• Geographical location based dynamic frequency band selection for UE |
| ROAMING | • Welcome SMS
• Silent roamer campaigns
• Global roaming passes
• Real-time roaming offers | • Local breakout
• Prepaid/postpaid roaming plans
• 4G/5G roaming plans
• Sponsored roaming | • Recurring roaming plans
• Time/volume based roaming plans |

Figure 3. CSG Policy Control use cases.

The software can be used for both connectivity services and advanced use cases including network slicing, edge network applications, or over the top (OTT) services such as VoLTE / VoNR, AR/VR, gaming, massive IoT and critical IoT. The vendor-agnostic and standards-based solution is designed to handle the complexity of multi-vendor, multi-service environments.

CSG Policy Control complies with 3GPP service-based interface (SBI) that enables standard integration with any 5G core CNFs. CSG Policy Control can be deployed alongside the existing charging and revenue management systems of any 3G/4G/5G network to enable gradual migration of legacy plans and services to new 5G services. In 5G, a clear architectural separation remains between the CCS and the PCF. This provides flexibility and independence in deploying, scaling, and updating network functions.

CSG 5G PCF is deployed in various 5G use cases (see Figure 3) to address the needs of uRLLC, eMBB, mMTC, etc.:

- Use cases are centered around both CSPs and enterprises. Some examples: advanced FWA, entitlements, perimeter centric monetization (events), various MPN use cases around Industry 4.0, etc.

- As such, the system needs to scale up and down dynamically and, at the same time, be performant to the needs of the use case / deployment.

The deployment options at the edge versus those available in a centralized cloud differ when it comes to handling policies for B2C users (FWA) and a large number of IOT devices (mMTC). Therefore, the CSG 5G PCF must demonstrate scalability and performance along with ease of deployment on Intel® architecture servers.

NiralOS 5G Core Designed for Private 5G

Niral Networks offers a comprehensive suite of industry specific solutions designed for enterprises to seamlessly deploy high-performance private 5G networks and harness the full potential of digital technologies for maximizing an enterprise's operational effectiveness.

Niral Networks has created a modular operating system called NiralOS* based on software-defined networking capabilities to simplify the provisioning of multi-site, multi-application networks. It can operate efficiently on commodity hardware while seamlessly integrating with third-party radio systems, backhaul systems and edge applications.

The NiralOS 5G Core is designed specifically for private stand-alone 5G deployments within enterprises including manufacturing, mining (see Figure 4), oil and gas, shipping ports, warehouses and other industrial applications. The software (see Table 1 for features) is 3GPP Release 16 compliant and contains the complete set of 5G network core functions such as mobility management, authentication, session, policy management and others.

The software is hosted on Intel architecture commercial off-the-shelf (COTS) servers. NiralOS seamlessly integrates with third-party radio area network (RAN) systems and other edge applications, simplifying multi-site network and edge infrastructure provisioning and management through a unified dashboard.

With built-in open application programming interfaces (APIs), the NiralOS 5G Core can be integrated with third-party applications and features built-in multi-tenant controller functionality.

To accelerate data packet throughput, the fast path user plane uses open source Data Plane Development Kit (DPDK) and Vector Packet Processor (VPP). The NiralOS 5G Core features a web-based dashboard for subscriber provisioning and management.

The processor footprint of the 5G core is small so that its server can also host additional third-party networking or service creation applications. The software is designed to work with all popular cloud services.

4th Gen Intel® Xeon® Scalable CPU is Optimized for Private Cellular

The server platform for the PCF and 5G core integration tests is based on 4th Gen Intel® Xeon® Scalable processors. This
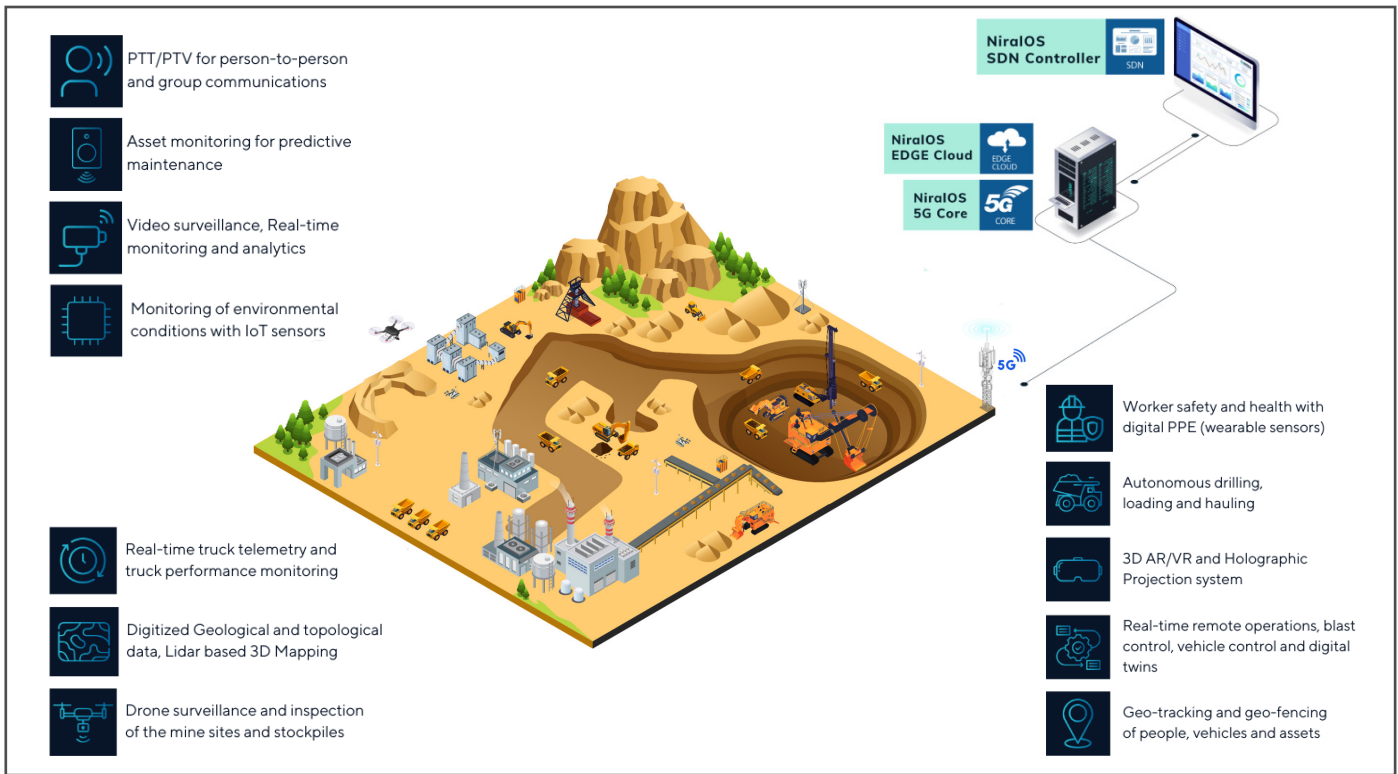
Figure 4. Integrated solution for Mining 4.0 using Niral Networks 5G core.

processor family delivers compute agility and scalability, benefiting from decades of innovation for the most in-demand workload requirements. Intel® Xeon® Scalable processor family features a balanced architecture that supports Open RAN, 5G core and other workloads with built-in acceleration and hardware-based security features.

Other CPU features for private 5G network workloads target low latency, high throughput, and deterministic performance. In addition, the processors also have a range of features for managing power to further optimize performance per watt. The Open RAN-optimized 4th Gen Intel Xeon Scalable processors support up to 52 high-performance compute cores and six on-chip accelerators that improve performance a wide range of workloads.

One of those accelerators is the Intel® vRAN Boost, which offloads computationally heavy layer 1 tasks such as low-density parity check (LDPC) decoding and forward error correction (FEC). The integrated accelerator replaces a discrete accelerator card for a solution that reduces system complexity and consumes less power creating more sustainable RANs.

In fact, 4th Gen Intel Xeon Scalable processors with Intel vRAN Boost delivers up to twice the capacity and an additional ~20% compute power savings versus the previous generation Intel architecture processor.[4]

CSG And Niral Networks Proof of Concept

The interoperability and functionality validation were managed by CSG and Niral Networks using Intel's Network Builder Ecosystem test lab. Once the CSG PCF was successfully loaded on to the 4th Gen Intel Xeon Scalable servers, the tests were run in two phases:

- **Phase 1**: Demonstrate IOT for basic 5G use cases around policy with Niral Networks.

- **Phase 2**: Perform load/performance test for sm-policy session over N7 interface.

| |
|---|
| 3GPP Rel 16 compliant control plane functions: AMF, SMF, NRF, NSSF, PCF, AUSF, UDR, UDM |
| 3GPP Rel 16 compliant 5G user plane function (UPF) with local breakout |
| 3GPP Rel 16 compliant N1, N2, N3, N4, N6 interface and PCFP with CUPS architecture |
| Integrated with gNB and O-RAN-based radios of more than 10 manufacturers |
| Supports network slicing, Kubernetes, MEC and SDN integration |
| Supports disaggregated deployment using containers, VNFs or bare metal |
| Provides a simplified, multi-site private 5G management web dashboard |

Table 1. Key features of NiralOS 5G Core.
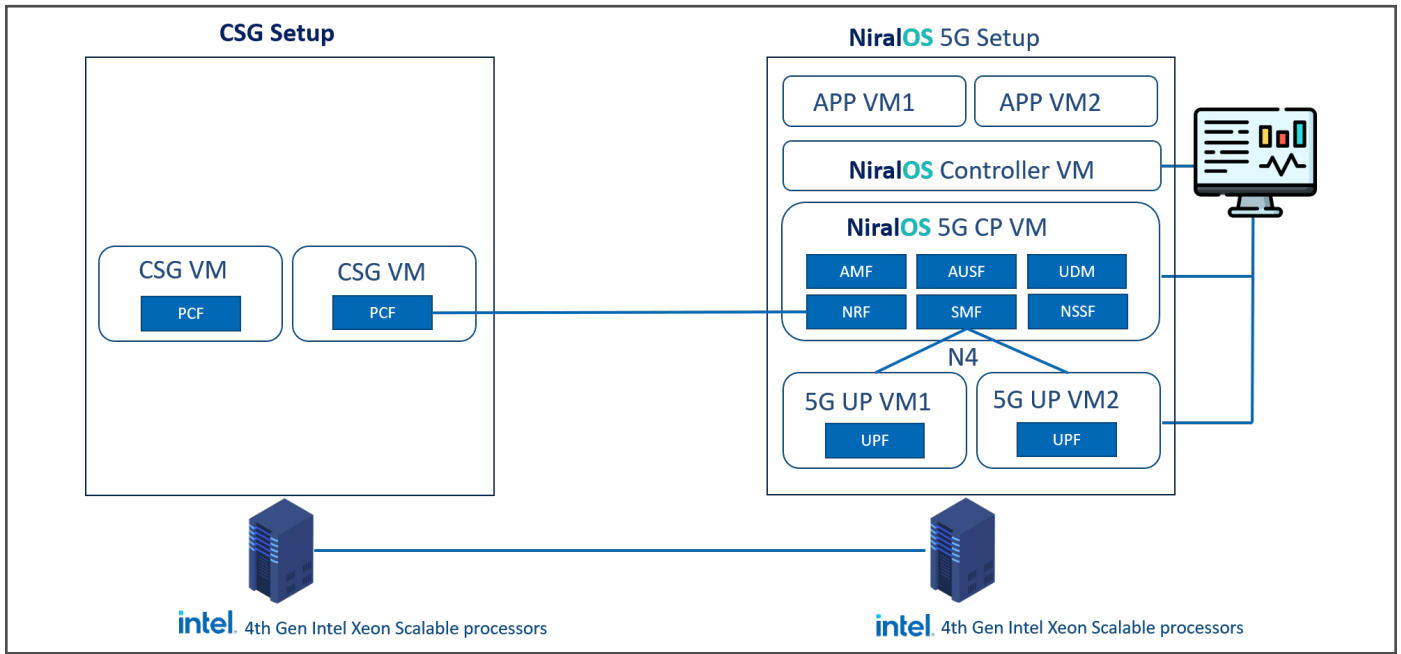
Figure 5. Test set up for CSG Policy Control and NiralOS 5G Core.

The test architecture (see Figure 5) shows the PCF configuration on the left hand side and the 5G core on the right hand side.

Figure 6 shows the feature integration more closely with the PCF functions in blue and the 5G core functions in orange. The result of the test is complete integration of PCF into the 5G core.

Test Results

The test results show the seamless integration between CSG Policy Control and the Niral Networks NiralOS 5G Core as shown by the following test achievements.

- Successfully deployed VNF PCF 2.1.0 on 4th Gen Intel Xeon Scalable servers and integrated with the following Niral Networks 5G Core network functions: AMF, SMF, SCP, NRF, UDR, NSSF, UPF.

- Network function (NF) management and NF discovery service operations tested successfully with CSG Policy Control and NiralOS NRF/SCP.

- Successfully installed am-policies over N15 with NiralOS AMF and CSG Policy control like service area restrictions, RFSP index, UE max bit rate at the time of UE registration.

- Successfully executed data session and installed relevant PCC rules, QoS attributes, revalidation time over N7.
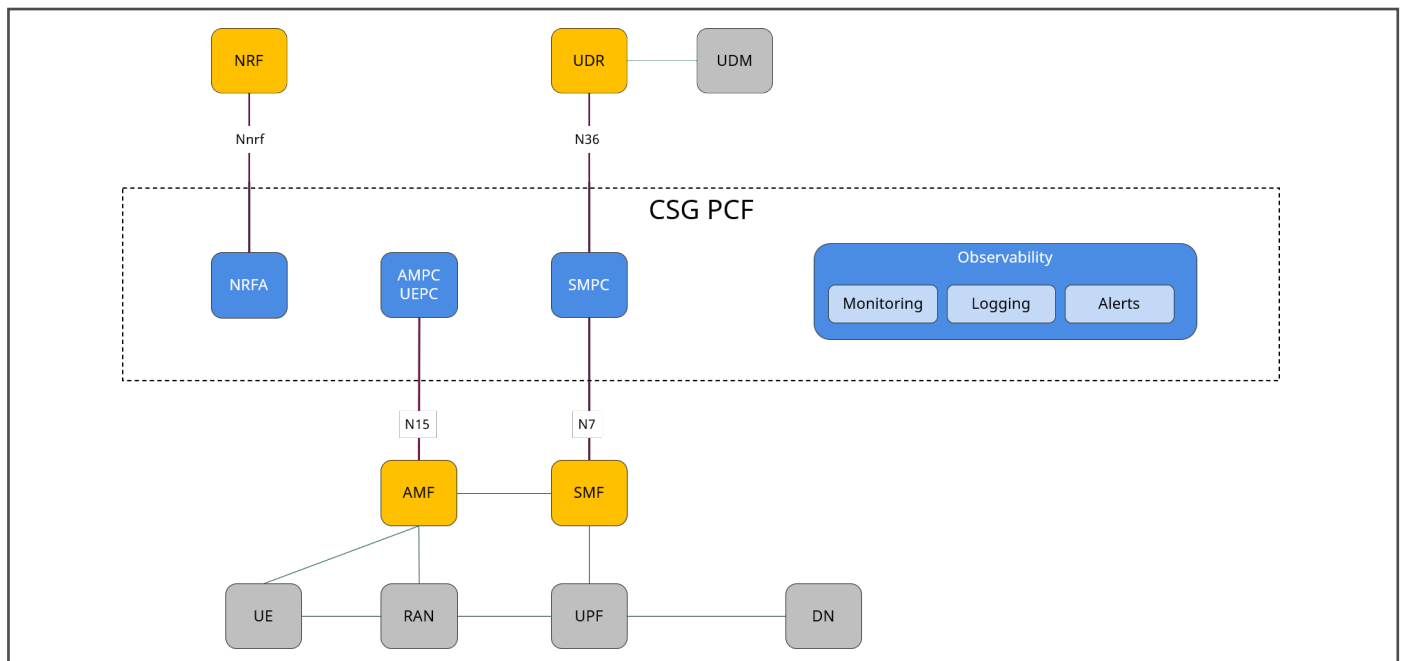

Figure 6. Complete feature integration between CSG Policy Control and NiralOS 5G Core.

▪ Successfully utilized Niral Networks UDR to retrieve policy subscription data for both N7 and N15 sessions using Nudr Query operation over N36 interface.

CSG's PCF Performance Benchmarks Achieved

For the performance benchmarks, CSG's PCF was hosted on Intel 4th Gen Intel Xeon Scalable processors and the PCF workload (PCF 2.1.0 (SMPC application)) was tested. Table 2 shows the configuration and setup of the PCF workload performance test with Intel technology:

Item	Configuration
Workload	CSG PCF 2.1.0 (SMPC application)
OS	RHEL 8.8
Platform	Sapphire Rapids
CPU	Intel® Xeon® Platinum 8470N
Cores/Socket	1, 1
Intel® Hyper-Threading Technology (Intel® HT Technology)	2.0
Intel® Turbo Boost Technology	Yes

Table 2. PCF workload performance test configuration and set up.

CSG was able to demonstrate incremental TPS achieved of 10,400 TPS using 16 CPU cores.

Figures 7 and 8 below show the TPS growth with the efficiency of 4th Gen Intel Xeon Scalable processors which powered the PCF's high TPS growth almost linearly. Intel® Hyper-Threading Technology (Intel® HT Technology) and Intel® Turbo Boost Technology was enabled.

Niral Networks UPF Performance

The NiralOS UPF throughput measured for various deployment configurations included:

The test validated that enabling DPDK, VPP and SR-IOV can significantly improve the performance on an Intel architecture-based server, and the solution can reserve more CPU threads to scale the UPF performance to meet the customer requirements for private 5G.

Max UPF throughput per thread	Throughput
Using Linux kernel	1.05 Gbps
Using VPP, DPDK without SR-IOV	5.96 Gbps
Using VPP, DPDK and SR-IOV	6.9 Gbps

Furthermore, multiple instances of the 5G UE and gNB simulators were created on another Intel server and could register 10,000 active subscribers and transfer data simultaneously using the UPF for the 10,000 subscribers.

The Intel® Xeon® Platinum 8470N Processor used in the lab has total of 52 cores, 104 threads, 256 GB of RAM and 800GB SSD. So, a single server can meet a typical private 5G customer requirement of 10,000 active subscribers and 40 Gbps aggregated throughput and still have CPU threads available for running the edge compute and application use cases.

Conclusion

5G SA deployments are rapidly surpassing NSA, enabling MNOs to unleash the true potential of 5G, opening the door to key revenue streams across B2C and B2B2X markets. Sophisticated 5G monetization solutions are essential to support these new business models, based on APIs, access, MEC scenarios, etc.

Figures 7 and 8. CPU (left image) and memory (right image) utilizations of CSG PCF.

CSG Policy Control enables MNOs globally to increase revenues and enhance customer experience through personalized services and the sustainable and optimized utilization of network resources. Niral Networks offers a comprehensive 5G private core with open integration to monetization solutions like CSG Policy Control.

Niral Networks offers a comprehensive private 5G core with open integration ability to monetization solutions like external PCF or CHF. Niral Networks provides a multi-site web dashboard to simplify the private 5G deployment and management at scale. Early adopters of private 5G along-with monetization solutions are stadiums, airports, or seaports.

Ease of deployment and seamless integration with 5G core is critical for domain specialized monetization solutions, such as CSG Policy Control. CSG's PCF interworks seamlessly with any vendor's 5G core with rapid integration capabilities and use case enablement. CSG works closely with many 5G core vendors to ensure full functionality and high performance.

Policy control and charging are the bridge between evolved network capabilities and business operations in the 5G era.

They empower MNOs to optimize resource allocation and drive revenue growth. MNOs need expert partners who know how to deploy a product into a multi-vendor environment and enable charging and policy in these new ways to fully monetize 5G.

Learn More

CSG Network Solutions

CSG Policy Control

Niral Networks Website

NiralOS 5G Core

4th Gen Intel Xeon Scalable processors

Intel Network Builders

[1] Device Under Test: 4-node, 1x Intel Xeon Platinum 8470N processors with 252 GB (16 slots/ 32GB/ 3200) total DDR4 memory, microcode 0x280, HT and Turbo on. OS: Red Hat Enterprise Linux rel. 8.8. Workload: PCF 2.1.0, NiralOS 5G Core 2.1, NiralOS Controller 1.2. Tested by CSG International in Jan. 2023.

[2] 5G charging standards: contributors and implications for service providers: https://www.analysysmason.com/contentassets/0150978e8a534bf896a388be3acb5e28/analysys_mason_5g_charging_standards_perspective_march2023.pdf

[3] 5G Charging and Policy Vendor Survey: Solution Functionality, Standards Compliance, and Customer Adoption," Omdia Dec. 11, 2023: https://omdia.tech.informa.com/om033664/5g-charging-and-policy-vendor-survey-solution-functionality-standards-compliance-and-customer-adoption

[4] For workloads and configurations visit www.Intel.com/PerformanceIndex. Results may vary.

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