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CONVEY C1-5G Core

1.CONVEY C1-5G Core overview

1.1 Design principles

The 5G core was defined in 3GPP rel.15 following the objectives that were derived from requirements coming from the ITU-2020 vision paper on the capabilities and performance needs of the 5G system both from business and technical perspectives.

Indeed, the 5G core is a fundamental pillar of the evolution of the 5G system to support URLLC and mMTC services while moving toward a digitalized era where business agility, time-to-market and automation will become de-facto industry best-practices.

Convey C1-5G Core R5.0 has been designed to fully support the 5G industry vision and up to now it implements the the following 3GPP standardized network functions:

- AMF
- SMF
- UPF
- UDR
- UDM
- AUSF
- NRF
- PCF
- CHF
- 5G-EIR

1.2. Functions and roles

The network functions of the Convey C1-5G Core are designed according to the 3GPP "*TS 23.501 System Architecture for the 5G System*" document and other specification standard listed in the "*chapter 5. Supported standards*" in this document.

Following a brief description of the key network functions and their role in the 5G core architecture.

1.2.1. Access and Mobility Management Function（AMF）

This network function is responsible for device registration, authentication and mobility. The AMF terminates the NAS (N1) interface with the device. It supports and relays authentication messages with the Authentications Server (AUSF); AMF interworks with Session Management Function (SMF) for session management. It is the single-entry point from 5G radio access to control plane functions in 5G core.

1.2.2. Session Management Function (SMF)

It establishes, modifies, and releases Packet Data Unit (PDU) sessions. It selects the right User Plane Function (UPF) to support a session. It manages and synchronizes the charging data collection at the UPF. It also handles IP address and controls session continuity aspects while the mobile moves into the network.

1.2.3. User Plane Function (UPF)

The UPF is responsible for packet forwarding, QoS enforcement and data notifications towards the SMF. It exposes capabilities that can be programmed by the SMF for the deployment of 5G user plane features. UPFs can be geographically distributed or centralized.

1.2.4. Unified Data Repository (UDR)

The UDR is the database where subscription and policy data are stored. It supports the storage and retrieval of the data respectively by the UDM and PCF.

The Unified Data Repository is located in the same PLMN as the NF service consumers storing in and retrieving data.

1.2.5. Unified Data Management (UDM)

The UDM allows subscription data management, access and service authorization and user authentication. Subscription data management includes accessing data in the UDR, delivering these data to network functions like AMF and SMF and updating UE location and serving nodes like AMF address in the UDR.

UDM also supports the generation of 3GPP AKA Authentication Credentials.

1.2.6. Authentication Server Function (AUSF)

The AUSF is responsible for the primary authentication and key agreement procedures to enable mutual authentication between device and network. It provides keying material that can be used between the device and network in subsequent security procedures.

1.2.7. Network Repository Function (NRF)

The NRF provides a service discovery function for other Network Functions. NRF capabilities include NF profile, NF instance management and NF service discovery. NF profile and NF instance management includes NRF maintaining the list of active NF instances and a profile for each instance. This profile includes e.g., the address of the instance and the supported services.

1.2.8. Policy Control Function (PCF)

The PCF supports a single policy framework to manage the network behavior. It enables the definition of policies in the network and the delivery of the policy rules to the other control plane functions. These policies might be stored in the UDR.

1.2.9. Charging Function (CHF)

In the 5G system architecture the Charging Function allows charging services to be offered to authorized network functions.

1.2.10. 5G-Equipment Identity Register (5G-EIR)

The 5G-EIR provides a mechanism to restrict malicious user terminals in a mobile network. When a subscriber or CPE connects to the network its IMEI can be queried against an EIR to determine if the device should be allowed onto the network or not. The most common use case is the stolen phones or suspected malicious IMEIs added to a forbidden list on the EIR and prohibited from connecting to the network.

1.3. Architecture

Convey C1-5G Core R5.0 is a compact and optimized implementation of the 5G core but compliant with the architectural principles and procedures defined by 3GPP in Release 16. Indeed, the Convey C1-5G Core application includes the Network Functions, protocols and signaling flows defined by 3GPP.

The 5G core Network Functions could be grouped in functional layers: Data plane, Control plane and User Plane.

At connectivity level the system externally exposes the following 3GPP interfaces at control plane and user plane

- N1: NAS over N2 between the gNBs and the AMF
- N2: NG-AP over SCTP between the gNBs and the AMF
- N3: NG-U over UDP between the gNBs ans the UPFs
- N4: PFCP over UDP between the SMF and the UPFs
- N6: IP connectivity to external Data Networks (DN)

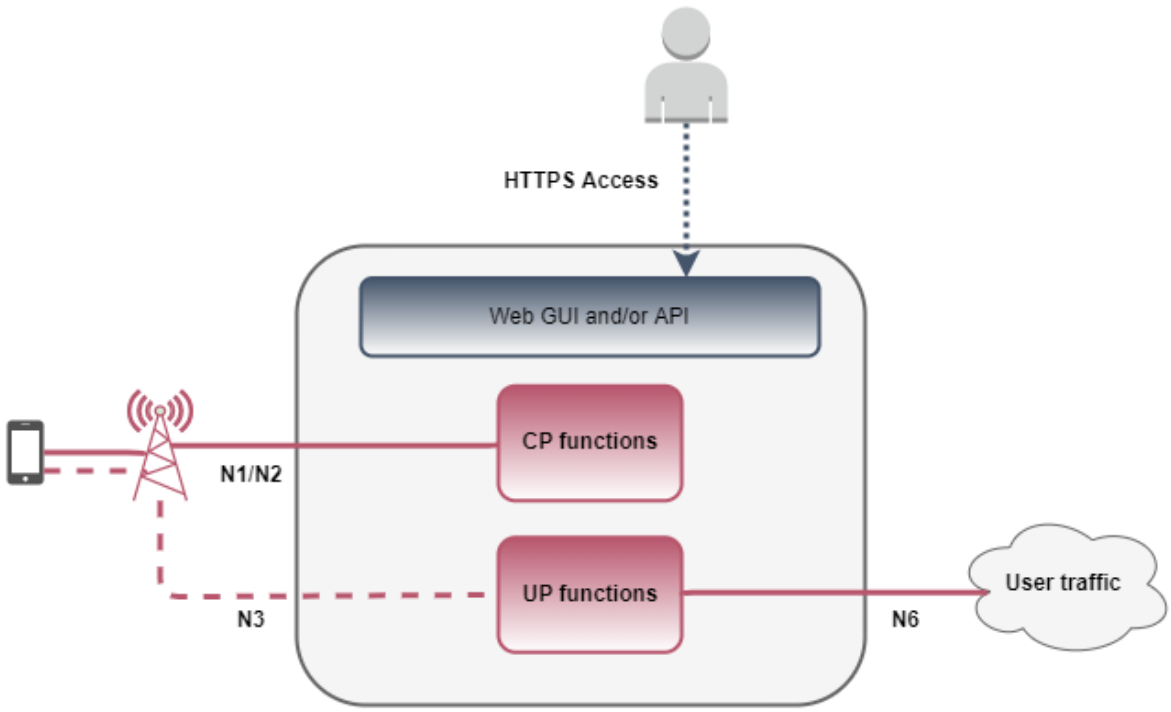

Fig. 1 Convey C1-5G core application components

Below the Figure 2 shows the 3GPP Network Functions implemented in the Control Plane and User Plane in Release 5.0, following the SBI architectural model.

- Access and Mobility Management Function (AMF)
- Session Management Function (SMF)
- Authentication Server Function (AUSF)
- Unified Data Repository (UDR)
- User Data Management (UDM)
- Policy Control Function (PCF)
- Network Repository Function (NRF)
- Charging Function (CHF)
- 5G-Equipment Identity Register (5G-EIR)

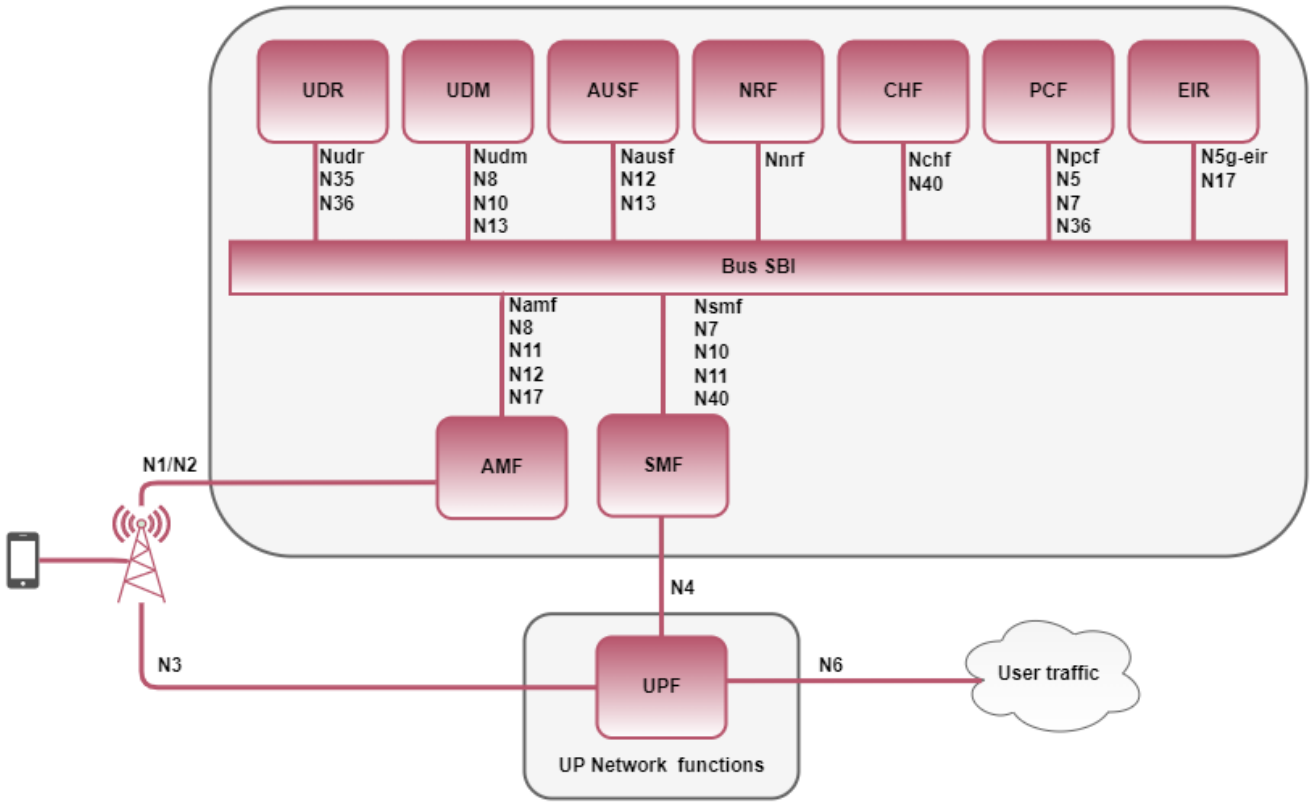

Fig. 2 Control Plane and User Plane NFs

NFs are SW implemented as OCI containers.

In addition to the 3GPP NFs Convey C1-5G Core application SW offer a set of platform services to enables management, configuration, provisioning and monitoring of the system.

Convey C1-5G Core can be managed and accessible through a Graphical User Interface console, via a browser. The GUI provides configuration, monitoring, license management and USIM provisioning functions. The same capabilities are also exposed via REST APIs and available for an integration with a 3rd party management system.

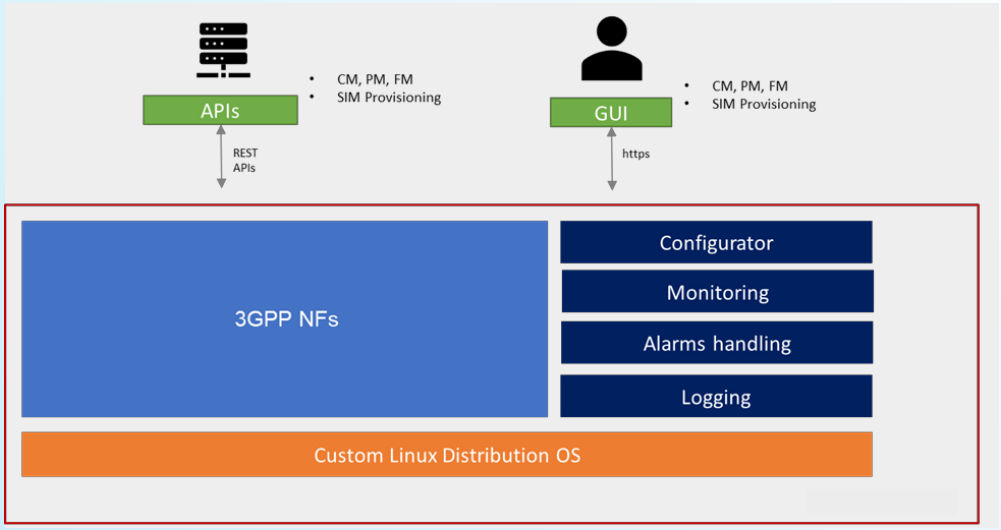

Fig. 3 Convey C1-5G Core

1.4. Deployment models

Convey C1-5G Core runs as a Linux virtual appliance installed in a VM, with VMWare as the recommended (but not limited to) hypervisor.

The final product can be delivered pre-installed on HW appliances or can be a SW installation only, directly in a cloud environment. It can run on several cloud stacks including VMware, AWS or Google Cloud.

Convey C1-5G Core can be deployed as a single or separated instances in the following logical component configurations:

- All-in-one for cloud deployments: data plane, control plane and user plane combined.
- Compact mode: data plane/control plane plane on one VM and User Plane on a separated VM
- Fully distributed: data plane/control plane and user plane might run on separated multiple VMs.

The above options offer the possibility to have a 5G core system in a compact or distributed mode offer. All Network Functions might be integrated in a single node/ *Compact Mode, with Control Plane and User Plane simple separation* or spread in multiple nodes/instances based on the network requirements.
Convey C1-5G Core supports a network design where control plane functions can be located in a centralized datacenter while several instances of the user plane could sit on the edge of the network.

1.5. Redundancy

The 5G core redundancy depends on the configuration setup.

As described in the chapter 1.4. Deployment models, Convey C1-5G Core can be deployed with great flexibility, having Network Functions which could be allocated on 1 (CP)+1 (UP) VM or more VMs depending on the

network design and the deployment requirement. The common deployments model are currently the “Compact Mode”, while for cloud deployment is “All-in-One"

The “Compact Mode” configuration implies the split of the Data Plane/Control Plane Functions (AMF, SMF, UDM, UDR, AUSF, PCF, NRF, CHF) from the User Plane Functions (UPF).

Redundancy at data and control plane level is achieved via an active-active configuration and by making use of the NG-Flex interface (between radio and core) functionalities.

Moreover, the solution could be designed to be redundant at hypervisor level while the hardware redundancy can be achieved through ensuring HW duplication.

As it has been already described, it is possible to have one control plane instance controlling one or more user plane instances. In such case the SMF can be configured to access any number of UPFs, including the UPF which is co-located.

In case of one UPF instance unavailable the traffic is redistributed across the other active UPF instances.

2. 5G System features

This section describes the 5G system features enabled by the Convey C1-5G Core.

2.1. Network Slicing

A slice is a logical 5G network that provides specific network capabilities and network characteristics.
A 5GS can provide one or more slice instances of one or more types.

A slice type is identified by a S-NSSAI, which is composed of a Slice Service Type, SST, and optionally a Slice Differentiator, SD.

Convey C1-5G core currently provides at most one slice instance of a given type.
Each slice instance is realized by assigning the network functions within each 5G core system to specific S-NSSAI through configuration.

A UE can be allowed to access any number of slices instances in the network.

The UPFs provide access to one or more external Data Networks through Data Network Names (DNNs) that are unique within each slice instance. It is possible to provide the same name to access different Data Networks in different slice instances.

To summarize the following options are available:

- Configure one or more slice per subscriber.
- The subscriber can be registered and use one or more slice at the same time.
- UPF can be selected on slice base. Different slices can be associated to different UPF.
- One UPF can be dedicated or shared among several slices.

Fig 4 shows an example deployment where UPF1 belongs to the blue slice instance, UPF2 to the blue and green slice instances, UPF3 to the yellow slice instance. UPF1 and UPF3 access two different Data Networks, but with the same name, DNN1.

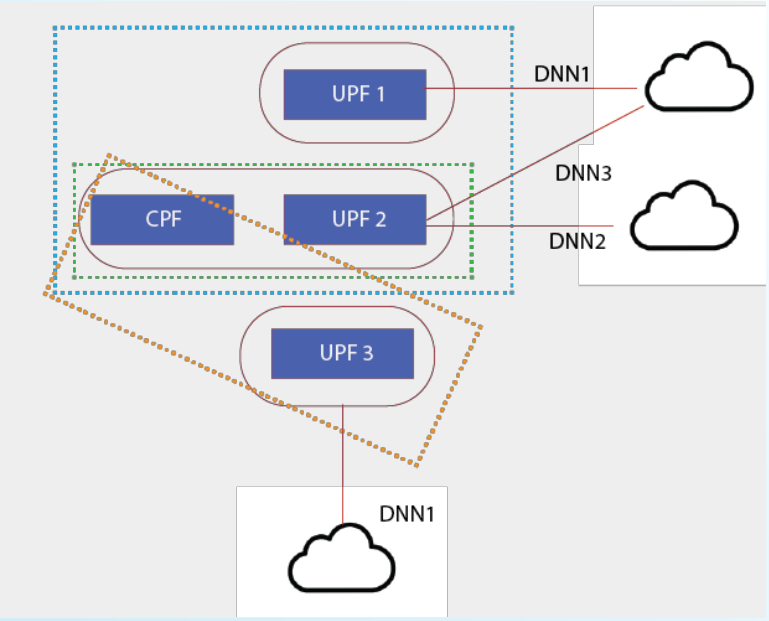

Fig 4. Example deployment of Convey C1-5G Core with three slice instances

2.2. Data Connectivity Service

UEs can subscribe to the 5G Data Connectivity service. The service authorizes the UEs to transfer data between the UE and subscribed data networks accessed by means of specific DNNs in specific slice instances.

2.3. UE Registration

To obtain the data connectivity service, UEs must first register with the 5GS. Upon successful registration, the UE is authorized to use the data connectivity service in the Tracking Area it registered from and for a set of slice instances, the allowed slice instances, determined based on the subscribed slice types and the slice types supported by the RAN.

2.4. UE Authentication

As part of the registration procedure, the UE and the 5G core, mutually authenticate each other using the 5G Authentication and Key Agreement (AKA) procedure.

2.5. UE Authorization

As part of the registration procedure, the UE is authorized for the data connectivity service using NR as the access network, based on the UE subscription data. The UE Permanent Equipment Identity (PEI) is not verified.

2.6. UE Subscriptions

The UE subscriptions define the access criteria for the UE and are defined on a per PLMN id basis. In this release, the UE subscriptions include:

- *Subscribed NSSAI*: This is a list of NSSAIs where at least one is defined as the default NSSAI. Each of the NSSAIs contain a default DNN and a list of subscribed DNNs.

- *Access and Mobility*: This includes the Multimedia Priority Service (MPS), the Mission Critical Service (MCS) priority and the UE parameter update (UPU) data.
- *SMF selection data*: This includes the list of NSSAIs and their corresponding DNNs.
- *Session management data*: This data includes the S-NSSAI and DNN configuration data, which include the QoS profile, and the session AMBR.

2.7. NAS Signaling Protection

Convey C1-5G core employs the ciphering algorithm NEA-0 for NAS signaling confidentiality protection, and the integrity protection algorithms NIA 1, NIA 2 for NAS signaling integrity protection.

2.8. PDU Sessions

UEs registered with the 5GS may request to establish one or more PDU Sessions towards subscribed external Data Networks in the allowed slice instances.

The PDU Sessions may be of the following types:

- IPv4
- IPv6
- Ethernet

In this release the PDU sessions have the bitrate limitation in the core network. It is enforced in the UPF either uplink or downlink, and the configured QoS profiles are also passed to the RAN, which could manage the enforcement in the access network too

IP addresses (or MAC address in case of Ethernet PDU type) are assigned to the UEs from IP pools configured in the SMF for each UPF per DNN per slice instance. i.e., for every UPF an SMF can access, the SMF is provided with IP pools for the Data Networks accessible through that UPF.

2.9. Service Based Interface

One of the main pillars of the 5G core system as defined by 3GPP is the introduction of the Service Based Architecture in the control plane and the related Service Based Interface among the network functions.
A key component enabling the full flexibility of the service-based architecture is the Network Repository Function.

In Convey C1-5G Core rel.5.0 the NRF supports the registration and deregistration of NFs profiles and NFs exposed services (Service Registration procedures).

NRF is configured with information for the whole PLMN.

The Service Discovery procedures are also supported. The NRF receives a service Discovery Request from a NF Consumer. Following the NRF provides the information of the discovered NF Producer to the NF Consumer.

In Convey C1-5G Core rel. 5 provides A, B communication models (direct routing, discovery via NRF services) defined by 3GPP for the service-based interface (Ref. TS 23.501).

2.10. VoNR

When UE is camping on NR (5G radio) in a 3GPP SA option 2 deployment model, then Voice and SMS are provided via 5G Core. Moreover, voice centric UE can successfully be registered into the 5G system and perform both voice and data traffic.

The IP Session is established with IMS DNN with Default QoS Flow, utilizing Non GBR resources to transport IMS Signaling (Default Bearer in EPS).

Then a MO/MT Voice Call triggers a PDU Session Modification request to NG-RAN to reserve GBR resources for the Call Voice media and a Dedicated QoS Flow is established (resources are released on call termination).

2.11. Charging

CDRs are generated by Convey C1-5G Core system for charging and billing purposes. They could also available to offline post-processing for monitoring and troubleshooting.

It is possible to configure the frequency of CDR Generation.

The N4 reference point supports the SMF control of the UPF collection and reporting of usage data while the

UPF supports functionality to collect and report usage data to SMF.

CHF exposes on the 5G core SBI interface the offline charging service.

The system can provide the CDRs files pull procedure via FTP.

2.12. QoS handling with bandwidth limitation

Convey C1-5G Core support the 5G QoS Handling. It's possible to configure in the system, via APIs or GUIs, the 5G QoS parameters which are sent toward the radio at the session establishment.

Moreover, the UPF enforces the bandwidth limitation, uplink and downlink, with a flow base granularity (QFI), for non-GBR flow.

QFI is identified through the signaling exchange between AF and PCF. ·A QFI has associated a specific 5QI. The QoS profile will have to include the maximum bit rate parameter (uplink/downlink) and 5QI.

To complete the QoS support at the user plane, the DSCP marking on egress UPF is also applied. The DSCP marking is done on N3 interface for downlink traffic while on the N6 is executed in uplink.

DSCP marking is done with flow base granularity (QFI).

2.13. MCPTT support with N5 interface

N5 interface is used for Application-level session information exchanges between AF and PCF. In the current Convey C1-5G Core SW release, the N5 implementation is focused on the integration of the MCPTT applications.

Reference spec for Mission Critical TS 24.379

2.14. Ethernet PDU session

The use of Ethernet PDU session is to provide UE connectivity to a Layer 2 Ethernet Data network. During the session establishment the terminal requires a session type "Ethernet".
The session is associated to a MAC address, instead of an IP address (IPv4, IPv6, IPv4/IPv6 session types). The MAC address is already owned by the UE.
Across the network the Ethernet frames are transferred at application level and not the IP packets.
Ref. spec TS 29.244 and TS 23.501

2.15. Static IP address for the UE

A static IP address could be associated to a CPE/subscriber. The IP address is configured within subscriber profile on the UDR.

2.16. Framed Routing

This feature enables the assignment of both an IP address (configured in Radius server or user profile) to CPE and the IP subnet behind the device itself.
It implies that the device could act as a router, enabling routing for private network behind a CPE.
The IP address is allocated for the UE, a specific subnet is reachable via the IP address assigned to the UE through the introduction of the subnet route in the UPF.

2.17. Radius Authentication

The SMF asks a RADIUS server for IP address allocation via Radius authentication msg.
Then Radius send back to UPF the IP address and the framed routed.
The RADIUS server could be located in the enterprise/customer network (reachable over N4-U/N6).

2.18. IMSI Whitelisting

A list of allowed IMSI to register in the private network is uploaded on the AMF.
The AMF checks the IMSI presence into the white list , prior to the standard registration and authentication procedures via UDM/AUSF ,
IMSI Whitelist with guaranteed with AMF granularity, not per TAI/cell .

3. Network Functions features

This section describes the main feature in Convey C1-5G Core R5.0 for each of the Network Functions available in the current release.

3.1. AMF

The Access and Mobility Management Function supports the following main features:

- Termination of N2 interface with 5G-RAN; NG-AP over SCTP to let gNBs connect to Convey C1-5G Core
- Termination of N1 interface with the UEs; NAS signaling with the Mobility Management functions in the AMF and the Session Management functions in the SMF
- NAS signaling confidentiality protection with ciphering algorithm NEA-0, NEA-1 and NEA-2
- NAS signaling integrity protection with integrity protection algorithm NIA-1 and NIA-2
- Registration Management, to register UEs for 3GPP access over NR
- Access Authentication and Authorization using 5G AKA
- Allocation of the temporary identifier, 5G-GUTI, to registered UEs
- Connection Management, to establish and release N1 signaling connections between the UEs and the 5G Core
- Reachability Management, through paging and periodic mobility registration update
- Mobility Management, through tracking of the user location.

- Transport of Session Management messages between UE and SMF
- Xn handover support
- Support of N17 interface towards 5G-EIR

3.2. SMF

The Session Management Function supports the following features:

- Establishment of PDU Sessions of type IPv4, IPv6, IPv4v6 and Ethernet.
- UE IP Address allocation performed via locally configured IP pools, UPF based allocation, or static configuration via UDM.
- Termination of NAS signaling for Session Management
- Provisioning of Access Network specific information to the N2 interface through the AMF
- PFCP session management over the N4-C interface with UPFs
- Support for PFCP Session Report from the UPF
- Allocation and Management of the GTP-U Tunnels for N4-U interface
- F-TEID allocation supported both on SMF and UPF side
- 5G QoS support, for both Non-GBR and GBR Qos Flows.
- Configurable rules for DSCP traffic marking based on Qos Flow 5QI
- Dynamic Qos Flow allocation, modification and release based on PCF provided PCC rules.
- Support for Offline Charging with N40 interface towards CHF.
- UDM controlled charging profiles charging characteristics

3.3. UPF

The User Plane Function supports the following features:

- N6 interface to connect to one or more Data Networks.
- N4-C/N4-U interface (IPv4 and IPv6), implementing the PFCP and the GTP-U protocols, to connect to the SMF
- N3 GTP-U interface (IPv4 and IPv6) towards one or more gNBs for the per-PDU Session tunnels
- non-GBR QoS flows
- Buffering of Downlink packets for deactivated PDU Sessions
- Downlink Data Notification to SMF
- PDU Sessions of type IPv4, IPv6 and IPv4v6
- Asymmetric routing with the option to send UE-UE traffic to the next hop
- Dynamic routing (BGP)
- Support for Network Address Translation (NAT)
- Error indication procedures on N3 and N4
- TCP MSS clamping
- Support for Traffic Fragmentation on N3/N4/N6 (IPv4 and IPv6)
- Support for traffic separation on all interfaces (N4, N4-U, N3, N6) via VRF and/or PBR

- Support for Usage Report procedures: Volume Threshold, Periodic and combination
- UE IP allocation both UPF side and SMF side
- F-TEID allocation both UPF and SMF side
- Support for QER rules, support setting QFI on GTP-U, support matching QFI on PDI, support for dedicated flows with SDF filters (including VoNR flows)
- Management interface via REST API
- Metrics on N3/N4/N6 interfaces
- N9 support (GTP-U to GTP-U)
- Dataplane implementation using eBPF TC/XDP
- Flow based bandwidth limitation
- DSCP marking on egress UPF
- Ethernet PDU

3.4. UDR and UDM

The UDR/UDM functions support the following main features:

- ARPF function
- SIDF function to de-conceal the SUPI from the SUCI
- 5G Authentication Vector Generation
- UE Subscriptions
- Authentication credential Repository and Processing Function (ARPF) to store the USIM long-term keys
- Transport key and OP mapping support
- UDM/UDR availability in active-active mode with subscriber profile synchronization
- Cx interface (3GPP TS 29.228, TS 29.229)

3.5. AUSF

The Authentication Server Function supports the following features:

- Authentication of 3GPP access over NR. This is an internal interface.

3.6. NRF

In release 5.0 the NRF supports the following services and procedures:

- Service Management (NFs to register, update or deregister profile in the NRF)
- Service Discovery (NFs to discover other NF Instances with the services they offer)

3.7. PCF

In the current release the PCF role is limited to support the policy control procedure related to data session, scoped for VoNR and MCPTT applications through the N5 and N7 reference points.

It also supports the Rx interface (ref. TS 29.514), to allows interactions between the PCF and the an AF , in case the AF itself does not support the N5 interface .
Moreover, the N36 interface toward the UDR for subscriber policies fetching.

3.8. CHF

In Release 5.0 Convey C1-5G core charging capabilities are limited to the session based offline charging . For this scenario CDR files are generated and CDRs can be used for offline post-processing, charging and/or analytics purposes.

CHF offer the following procedures:

- Charging create services operation for opening a CDR based on the info provided by the SMF.
- Charging update for reporting usage which may cause update of the CDR or production of an interim CDR in the CHF. Charging update service is consumed by the SMF.
- The charging delete request is used to report usage and close the CDR in the CHF if it has been opened. It is used by SMF to release the resource of charging session information.

4. OAM Functions

The Convey C1-5G Core system supports a set of OAM functions including Fault Management, Performance Management, Configuration Management, and Provisioning. Moreover, the O&M functionalities gives the possibility to configure permission, roles and users which could access the 5G core system.

A GUI is provided to configure the Control Plane functions and the UPF. The GUI also permits the configuration of networking in the Linux host.

All the management can be handled via GUI and most of the capabilities are available via RESTful APIs too. For details on the APIs, please refer to the “Swagger.JSON v1.0” and “API Guide v1.0” documents

4.1. USIM Data Provisioning

Authentication data, including the long-term key, K, for the UEs’ USIMs is provisioned in the UDR function through the GUI or the provisioning APIs. In addition, the GUI allows the operator to assign a friendly name to each USIM.

4.2. UE Subscription Provisioning

UE Subscriptions can be provisioned through the GUI or via API. The details of the supported subscriptions are described in the section “3.6 UE subscription of this document”.

4.3. Network Name Configuration

It is possible to configure network names. The operator can configure the network name through the GUI or via API.

4.4. Backup and Restore Functions

Through the GUI and APIs, the operator can back up the configuration of the entire system. This configuration can be restored in a new VM that is required to have identical configuration to that of the original VM. This is typically used during SW upgrades that are done through creating a new VM that restores the configuration and provisioning data of the old VM.

Subscriber data can also be backed up and restored into a new UDR/UDM.

The data of the Users and Roles can be backed-up and restored into a new 5G system via GUI or API.

4.5. Performance and System monitoring

Convey C1-5G Core has a pre-installed instance of the third-party product Prometheus.

The Prometheus instance provides statistics on the CPU, memory, disk usage, IO, system processes, as well as statistics on the usage of the Control Plane functions and the UPF.

The metrics can be accessed by any tool that is able to fetch Prometheus data. Grafana is the recommended tool.

A Prometheus data source can be added to Grafana.

Performance and system monitoring data are visible via GUI and can be accessed via API.

Performance and system monitoring data can be exported to an external data storage using APIs.

4.6. License Control

The solution is licensed, and the licensing controlled through a Licensing Service.

A license is required to be installed for each NF in the system. It is provided by Athonet personnel, and the GUI or APIs can be used to install it.

4.7. Alarm Handling

A set of alarms is available for NVFs and system level performances. The alarms can be viewed in the GUI or accessed via API.

5. Supported standards

Convey C1-5G Core solutions are based on and support the following protocols, interfaces, and standards:

- TS 23.501 - System Architecture for the 5G System
- TS 23.502 - Procedures for the 5G System
- TS 24.008 - Mobile Radio Interface Layer 3 Specification; Core Network Protocols
- TS 24.501 - NAS Protocol for 5G System
- TS 28.552 - Management and orchestration; 5G performance measurements
- TS 29.244 - Interface between the Control Plane and the User Plane nodes
- TS 29.502 - Session Management Services

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- TS 29.503 - Unified Data Management Services
- TS 29.509 - Authentication Server Services
- TS 29.518 - Access and Mobility Management Services
- TS 33.501 - Security Architecture and Procedures for 5G System
- TS 38.413 - NG Application Protocol
- TS 29.514 - Policy Authorization Services
- TS 32.297 - Charging management; Charging Data Record (CDR) file format and transfer
- TS 32.295 - Charging management; Charging Data Record (CDR) transfer
- TS 29.500 - 5G System; Technical Realization of Service Based Architecture
- TS 32.240 - Charging Architecture and Principles
- TS 32.290 - Operation and Procedures of charging using SBI
- TS 32.255 - Charging management
- TS 32.256 - Connection and mobility management charging
- TS 29.281 - (GTP-U) Tunneling Protocol User Plane
- RFC 768 - User Datagram Protocol
- RFC 791 - Internet Protocol
- RFC 793 - Transmission Control Protocol
- RFC 2460 - Internet Protocol version 6 (IPv6)
- RFC 4960 - Stream Control Transmission Protocol (SCTP)
- RFC 6733 – DIAMETER Protocol
- RFC 2865 – RADIUS Protocol

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