Management, Orchestration and Charging in the New Era

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Abstract

In December 2017, 3GPP passed two major milestones for 5G by approving the first set of 5G New Radio (NR) specifications and by putting in place the 5G Phase 1 System Architecture. These achievements have brought about the need for new management standards, as 5G adds to the ever-growing size and complexity of telecom systems.

3GPP management standards from Working Group (WG) SA5 are approaching another major milestone for 5G. With our studies on the 5G management architecture, network slicing and charging completed last year,

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we are now well under way with the normative work for the first phase in 3GPP Release 15, which includes building up a new service-oriented management architecture and all the necessary functionalities for management and charging for 5G networks.

SA5's current work also includes several other work/study items such as management of Quality of Experience (QoE) measurement collection and new technologies for RESTful management protocols. However, this article will focus on the new 5G Rel-15 architecture and the main functionalities, including charging.

1 5G Networks and Network Slicing

Management and orchestration of 5G networks and network slicing is a feature that includes the following work items: management concept and architecture, provisioning, network resource model, fault supervision, assurance and performance management, trace management and virtualization management aspects. With the output of these work items, SA5 provides specified management interfaces in support of 5G networks and network slicing. An operator can configure and manage the mobile network to support various types of services enabled by 5G, for example eMBB (enhanced Mobile Broadband) and URLLC (Ultra-Reliable and Low Latency Communications), depending on the different customers' needs. The management concept, architecture and provisioning are being defined in TS (Technical Specification) 28.530 [4], 28.531 [5], 28.532 [6] and 28.533 [7].

Network slicing is seen as one of the key features for 5G, allowing vertical industries to take advantage of 5G networks and services. 3GPP SA5 adopts the network slice concept as defined in WG SA2 and addresses the management aspects. Network slicing is about transforming a Public Land Mobile Network (PLMN) from a single network to a network where logical partitions are created, with appropriate network isolation, resources, optimized topology and specific configuration to serve various service requirements.

As an example, a variety of communication service instances provided by multiple Network Slice Instances (NSIs) are illustrated in Figure 1 below. The different parts of an NSI are grouped as Network Slice Subnets (e.g. Radio Access Network (RAN), 5G Core Network (5GC) and Transport) allowing the lifecycle of a Network Slice Subnet Instance (NSSI) to be managed independently from the lifecycle of an NSI.

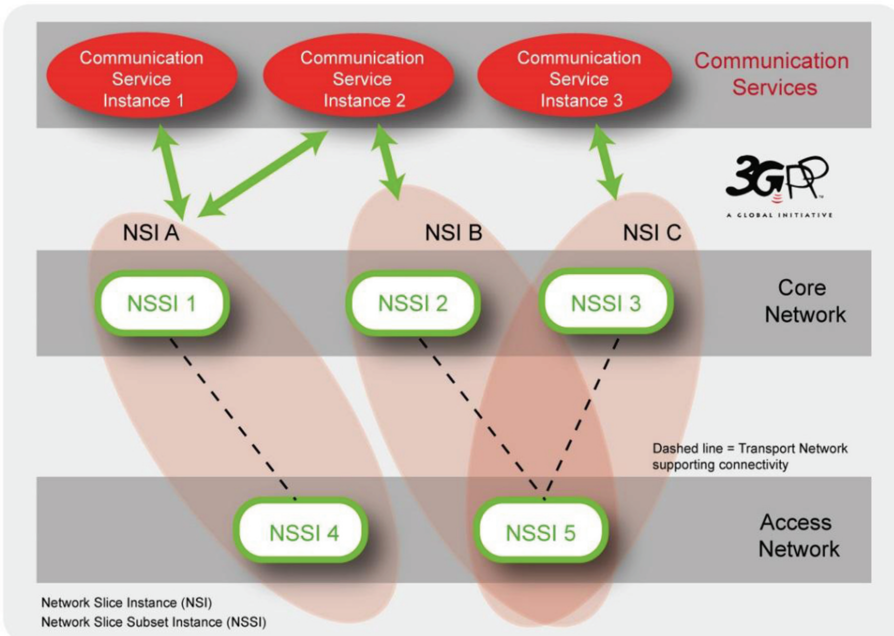

Figure 1 Communication service instances provided by multiple NSIs.

Provisioning of network slice instances

The management aspects of a network slice instance can be described by the following four phases and is depicted in Figure 2:

1. Preparation: in the preparation phase the network slice instance does not exist. The preparation phase includes network slice template design, network slice capacity planning, on-boarding and evaluation of the

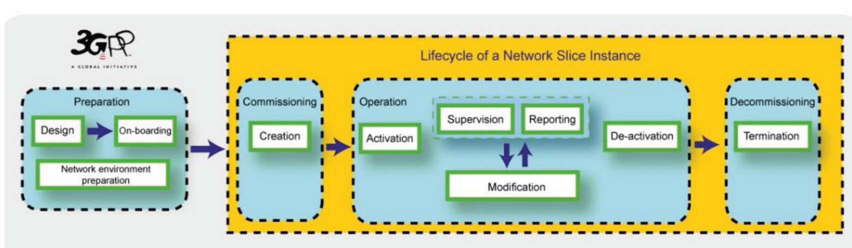

Figure 2 Lifecycle of a network slice instance.

network slice requirements, preparing the network environment and other necessary preparations required to be done before the creation of a network slice instance.
2. Commissioning: provisioning in the commissioning phase includes creation of the network slice instance. During network slice instance creation all needed resources are allocated and configured to satisfy the network slice requirements. The creation of a network slice instance can include creation and/or modification of the network slice instance constituents.
3. Operation: includes the activation, supervision, performance reporting (e.g. for Key Performance Indicator (KPI) monitoring), resource capacity planning, modification, and de-activation of a network slice instance. Provisioning in the operation phase involves activation, modification and de-activation of a network slice instance.
4. Decommissioning: network slice instance provisioning in the decommissioning phase includes decommissioning of non-shared constituents if required and removing the network slice instance specific configuration from the shared constituents. After the decommissioning phase, the network slice instance is terminated and does not exist anymore.

Similarly, provisioning for a Network Slice Subnet Instance (NSSI) includes the following operations:

- Create an NSSI;
- Activate an NSSI;
- De-active an NSSI;
- Modify an NSSI;
- Terminate an NSSI.

Roles related to 5G networks and network slicing

The roles related to 5G networks and network slicing management are depicted in Figure 3 and include: Communication Service Customer, Communication Service Provider (CSP), Network Operator (NOP), Network Equipment Provider (NEP), Virtualization Infrastructure Service Provider (VISP), Data Centre Service Provider (DCSP), NFVI (Network Functions Virtualization Infrastructure) Supplier and Hardware Supplier.

Depending on actual scenarios:

- each role can be played by one or more organizations simultaneously;
- an organization can play one or several roles simultaneously (for example, a company can play CSP and NOP roles simultaneously).

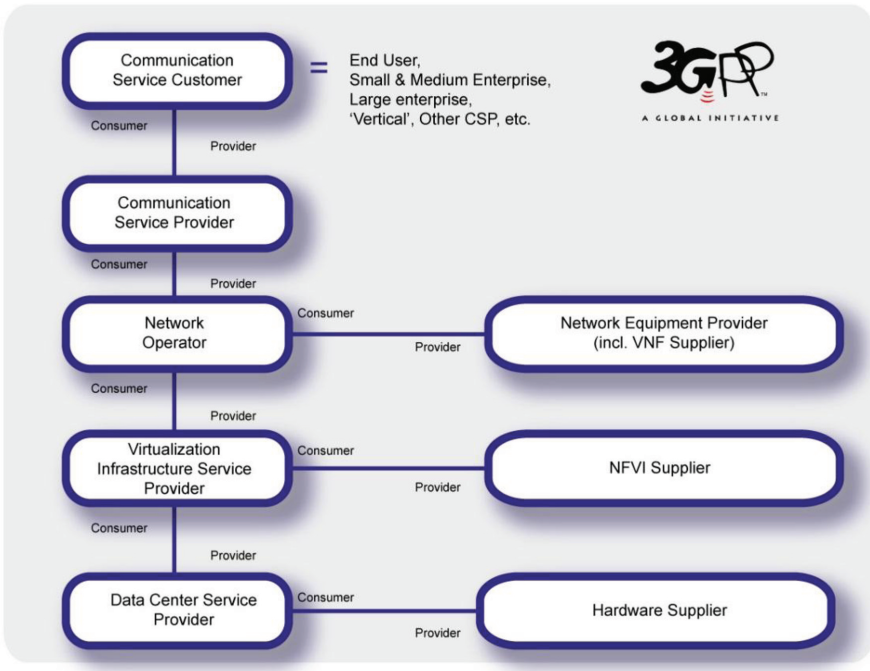

Figure 3 Roles related to 5G networks and network slicing management.

Management models for network slicing

Different management models can be used in the context of network slicing and are depicted in Figure 4:

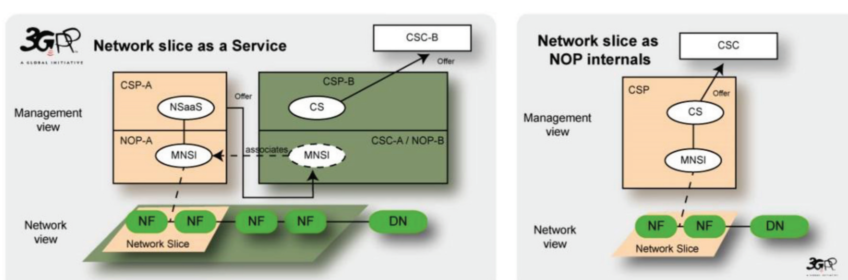

Figure 4 Management models for network slicing.

1. Network Slice as a Service (NSaaS): NSaaS can be offered by a CSP to its CSC in the form of a communication service. This service allows CSC to use the network slice instance as the end user or optionally allows CSC to manage the network slice instance as manager via management exposure interface. In turn, this CSC can play the role of CSP and offer their own services (e.g. communication services) on top of the network slice instance. The MNSI (Managed Network Slice Instance) in the figure represents a network slice instance and CS represents a communication service.
2. Network Slices as NOP internals: network slices are not part of the CSP service offering and hence are not visible to CSCs. However, the NOP, to provide support to communication services, may decide to deploy network slices, e.g. for internal network optimization purposes. This model allows CSC to use the network as the end user or optionally allows CSC to monitor the service status.

Management architecture

The 3GPP SA5 management architecture will adopt a service-oriented management architecture which is described as interaction between management service consumer and management service producer. For example, a management service consumer can request operations from management service producers on fault supervision service, performance management service, provisioning service and notification service, etc. A management service offers management capabilities. These management capabilities are accessed by management service consumers via standardized service interfaces, depicted in Figure 5, composed of individually specified management service components. The basic elements of a management service include a group of management operations and/or notifications agnostic of managed entities (Management service component type A), management information

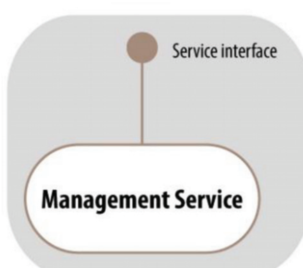

Figure 5 Management service and service interface.

represented by an information model of managed entities (Management service component type B), and performance information of the managed entity and fault information of the managed entity (Management service component type C).

Management services may reside in different management layers. For example, a network provisioning service may reside at the network and network slice management layer, and a subnetwork provisioning service may reside at the subnetwork and network slice subnet management layer.

SA5 recognizes the need for automation of management by introducing new management functions such as a Communication Service Management Function (CSMF), Network Slice Management Function (NSMF) and a Network Slice Subnet Management Function (NSSMF) to provide an appropriate abstraction level for automation.

2 Network Resource Model (NRM) for 5G Networks and Network Slicing

To support management and orchestration of 5G networks, the Network Resource Model (NRM) representing the manageable aspects of 5G networks needs to be defined, according to 5G network specifications from other 3GPP working groups as well as considering requirements from 5G management architecture and operations.

The 5G NRM specifications family includes 4 specifications: TS 28.540 [8] and TS 28.541 [9] for NRM of NR and NG-RAN (Next Generation Radio Access Network), TS 28.542 [10] and TS 28.543 [11] for NRM of 5G core network.

According to content categorization, 5G NRM specifications can be divided into 3 parts:

- Requirements, also known as stage 1,
- Information Model definitions also known as stage 2, and
- Solution Set definitions also known as stage 3.

Identified in the specifications of 5G NRM requirements (TS 28.540 [8] and TS 28.542 [10]), the NRM of 5G network comprises NRM for the 5G core network (5GC) and NRM for 5G radio access network (i.e. NR and NG-RAN). The 5GC NRM definitions support management of 5GC Network Functions, respective interfaces as well as AMF Set and AMF Region. The NR and NG-RAN NRM definitions cover various 5G radio networks connectivity options (standalone and non-standalone radio node deployment options) and architectural options (NR nodes with or without functional split).

The 5G Information Model definitions specify the semantics and behavior of information object class attributes and relations visible on the 5G management interfaces, in a protocol and technology neutral way (UML (Universal Modeling Language) as protocol-neutral language is used). The 5G Information Model is defined according to 5GC, NR and NG-RAN specifications. For example, in 3GPP TS 38.401, the NR node (gNB) is defined to support three functional split options (i.e. non-split option, two split option with CU (Central Unit) and DU (Distributed Unit), three split option with CU-CP (Control Plane), CU-UP (User Plane) and DU), so in the NR NRM Information Model, corresponding Information Object Class (IOC) is defined for each network function of gNB specified, and different UML diagrams show the relationship of each gNB split option respectively. Further, in the 5G Information Model definitions, the existing Generic NRM Information Service specification (TS 28.622 [14]) is referenced to inherit the attributes of generic information object classes, and the existing EPC (Evolved Packet Core) NRM Information Service specification (TS 28.708 [15]) is referenced for 5GS (5G System)/EPS (Evolved Packet System) interworking relationships description.

Besides 5G networks NRM definitions in the abovementioned four specifications, the information model of network slice and network slice subnet is specified in TS 28.532 [6].

Finally, NRM Solution Set definitions map the Information Model definitions to a specific protocol definition used for implementations. According to recommendation from TR (Technical Report) 32.866 [22] (Study on RESTful based Solution Set), JSON (JavaScript Object Notation) is expected to be chosen as data modelling language to describe one 5G NRM Solution Set.

3 Fault Supervision of 5G Networks and Network Slicing

Fault Supervision is one of the fundamental functions for the management of a 5G network and its communication services. For the fault supervision of 5G networks and network slicing, the following 3GPP TSs are being specified:

1. TS 28.545 [12] “Management and orchestration of networks and network slicing; Fault Supervision (FS); Stage 1”, which includes:
    - The use cases and requirements for fault supervision of 5G networks and network slicing.
    - The definitions of fault supervision related management services

2. TS 28.546 [13] "Management and orchestration of networks and network slicing; Fault Supervision (FS); Stage 2 and stage 3", which includes the definition of:
   - Operations of the fault supervision related management services (e.g. getAlarmList, subscribeAlarmNotify, unsubscribeAlarmNotify, acknowledgeAlarms, clearAlarms, unacknowledgeAlarms, etc.); (Stage 2)
   - Notifications (notifyNewAlarm, notifyClearedAlarm, notifyAlarmListRebuilt, notifyAckStateChanged, notifyChangedAlarm, etc.); (Stage 2)
   - Alarm related information models (e.g. alarmInformation, alarmList, etc.); (Stage 2)
   - Solution set(s) (e.g. RESTful HTTP-based solution set for Fault Supervison); (Stage 3)
   - New event types and probable causes if necessary.

4 Assurance Data and Performance Management for 5G Networks and Network Slicing

The 5G network is designed to accommodate continuously fast increasing data traffic demand, and in addition, to support new services such as IoT (Internet of Things), cloud-based services, industrial control, autonomous driving, mission critical communications, etc. Such services may have their own performance criteria, such as massive connectivity, extreme broadband, ultra-low latency and ultra-high reliability.

The performance data of the 5G networks and NFs (Network Functions) are fundamental for network monitoring, assessment, analysis, optimization and assurance. For the services with ultra-low latency and ultra-high reliability requirements, any faults or performance issues in the networks can cause service failure which may result in serious personal and property losses. Therefore, it is necessary to be able to collect the performance data in real-time (e.g., by performance data streaming), so that the analytic applications (e.g., network optimization, Self-Organizing Networks (SON), etc.) could use the performance data to detect any network performance problems, predict the potential issues and take appropriate actions quickly or even in advance.

For network slicing, the communication services are provided on top of the end-to-end network slice instances, so the performance needs to be monitored from end-to-end point of view.

The end to end performance data of 5G networks (including sub-networks), NSIs (Network Slice Instances) and NSSIs (Network Slice Subnet Instances) are vital for operators to know whether they can meet the communication service requirement.

The performance data may be used by various kinds of consumers, such as network operator, SON applications, network optimization applications, network analytics applications, performance assurance applications, etc.

To facilitate various consumers to get their required performance data, the following items are being pursued by this WI:

- performance management services for managing the measurement jobs for collecting the NF/NSSI/NSI/network performance data (the network performance data is not specific to network slicing);
- performance management services for reporting the NF/NSSI/NSI/ network performance data, including performance data file reporting and performance data streaming;
- performance measurements (including the data that can be used for performance assurance) for 3GPP NFs;
- end to end KPIs, performance measurements (including the data that can be used for performance assurance) for NSIs, NSSIs and networks (where the performance data is not specific to network slicing).

5 Management and Virtualization Aspects of 5G Networks

For 5G networks, it is expected that most of the network functions will run as software components on operators' telco-cloud systems rather than using dedicated hardware components. Besides the virtualization for Core Network (including 5GC, EPC and IMS (IP Multimedia Subsystem)), the NG-RAN architecture is being defined with functional split between central unit and distributed unit, where the central unit can also be virtualized.

SA5 conducted a study on management aspects of the NG-RAN that includes virtualized network functions, and has concluded in TR 32.864 [21] that the existing specifications (related to management of mobile networks that include virtualized network functions) need some enhancements for 5G. The enhancements are mainly on the interactions between 3GPP management system and external management systems (e.g., ETSI NFV

(Network Functions Virtualization) MANO (Management and Orchestration)) for the following aspects:

- Management requirements and architecture;
- Life Cycle Management (e.g., PNF management);
- Configuration Management;
- Performance Management;
- Fault Management.

There are gaps identified between 3GPP SA5 requirements and ETSI ISG NFV solutions to support the required enhancements, 3GPP SA5 is in cooperation with ETSI ISG NFV to solve these gaps.

Although the need for enhancements found in TR 32.864 [21] is to target 5G, SA5 generally agreed that these enhancements can be used for 4G as well. So the specifications for management of mobile networks that include virtualized network functions are being made generally applicable to both 4G and 5G networks. However, as 5G management will be based on a new service-oriented management architecture, the management and virtualization aspects of 5G networks need to be updated to adapt to the new architecture.

6 5G Charging System Architecture and Service Based Interface

Commercial deployment of the Rel-15 5G System will not be possible without capabilities for Operators to be able to monetize the various set of features and services which are specified in TS 23.501 [25], TS 23.502 [26] and TS 23.503 [27]. This is defined under the charging framework, which includes e.g. real-time control of subscriber's usage of 5G Network resources for charging purpose, or per-UE (User Equipment) data collection (e.g. for Charging Data Record (CDR) generation) which can also be used for other purposes e.g. analytics.

SA5 has investigated, during a study period in 2017, on how charging architecture should evolve, which key features should be specified as part of charging capabilities, and which alternative amongst charging solutions should be selected, to better support the first commercial 5G system deployment. Based on the study results, the charging architecture evolution and selected Rel-15 key functionalities for 5G system are under ongoing normative phase through development of a complete set of specifications (architecture, functionalities and protocols) A brief overview of the charging coverage for the Rel-15 5G system is provided in this article.

Service Based Interface

One key evolution of the charging architecture is the adoption of a service based interface integrated into the overall 5G system service based architecture, enabling deployments of charging functions in virtualized environment and use of new software techniques. The new charging function (CHF) and service based interface Nchf are introduced in the 5G system architecture, as shown in Figure 6 below, allows charging services to be offered to authorized network functions. The "converged online and offline charging" service will be defined. In addition to charging services, the CHF also exposes the "Spending Limit Control" service for the PCF (Policy Control Function) to access policy counter(s) status information.

While offering the service based interface to the 5G system, the overall converged charging system will be able to interface the billing system as for the existing system (e.g. 4G) to allow Operators to preserve their billing environment. These evolutions are incorporated in the TS 32.240 [16] umbrella architecture and principles charging specification. The services, operations and procedures of charging using Service Based Interface will be specified in a new TS 32.290 [18], and TS 32.291 [19] will be the stage 3 for this interface.

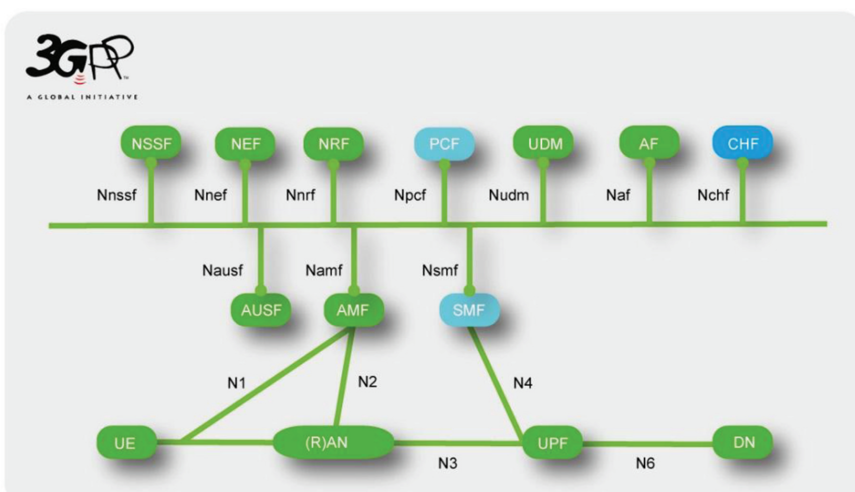

Figure 6 New charging function (CHF) and service based interface Nchf.

5G Data connectivity charging

The "5G Data connectivity charging", achieved by the Session Management Function (SMF) invocation of charging service(s) exposed by the charging function (CHF), will be specified in a new TS 32.255 [17], encompassing the various configurations and functionalities supported via the SMF, which are highlighted below.

For 3GPP network deployments using network slicing, by indicating to the charging system which network slice instance is serving the UE during the data connectivity, the Operator will be able to apply business case charging differentiation. Further improvements on flexibility in charging systems deployments for 5G network slicing will be explored in future releases.

The new 5G QoS (Quality of Service) model introduced to support requirements from various applications in data connectivity, is considered to support QoS based charging for subscriber's usage. 5G QoS-based charging is also defined to address inter-Operator's settlements (i.e. between VPLMN (visited PLMN (Public Land Mobile Network)) and HPLMN (Home PLMN)) in roaming Home-routed scenario.

All charging aspects for data services in Local breakout roaming scenarios will be further considered.

In continuation with existing principles on Access type traffic charging differentiation, the two Access Networks (i.e. NG-RAN and untrusted WLAN access) supported in Rel-15 are covered.

Charging capabilities encompass the various functionalities introduced in the 5G system to support flexible deployment of application functions (e.g. edge computing), such as the three different Session and Service Continuity (SSC) modes and the Uplink Classifiers and Branching Points.

Charging continuity for interworking and handover between 5G and existing EPC is addressed.

In 5G Multi-Operator Core Network sharing architecture (i.e. shared RAN), identification of the PLMN that the 5G-RAN resources were used to convey the traffic, allows settlements between Operators.

The stage 3 for "5G data connectivity charging" will be available in TS 32.298 [20] for the CDRs' ASN.1 (Abstract Syntax Notation 1) definition and in TS 32.291 [19] for the data type definition in the protocol used for the service based interface.

7 5G Trace Management

Subscriber and Equipment Trace can provide detailed information at session level on one or more specific users or devices. The collected information is useful in various use cases: e.g. troubleshooting triggered by an end user complain, or network performance monitoring and optimization.

SA5 is mandated to take the lead on Trace related normative work in cooperation with RAN and CT WGs, and SA5 is now specifying management and signalling trace activation mechanisms for 5GC and NG-RAN ensuring that subscriber and equipment trace capabilities are supported in 5G on par with UMTS (Universal Mobile Telecommunications System) and LTE (Long Term Evolution) systems.

The 5G Trace activation mechanisms specified by SA5 have been communicated to the RAN and CT WGs ensuring that 5G signaling specifications will support this important feature.

This 5G system Trace specifications comprise the following aspects:

- 5G Trace use case and requirements
- 5G Trace session activation and deactivation mechanism (including both management based and signalling based Trace activation and deactivation).
- 5G Trace control and configuration parameter definitions
- 5G Trace record data definitions and trace data collection mechanism
- 5G Trace management requirements and interface specifications in alignment with the Management and Orchestration of 5G networks and network slicing work items

8 Study on Energy Efficiency of 5G Networks

Following the conclusions of the study on Energy Efficiency (EE) aspects in 3GPP Standards, TSG SA#75 recommended initiating further follow-up studies on a range of energy efficiency control related issues for 5G networks including the following aspects:

- Definition and calculation of EE KPIs in 3GPP Systems
- Energy Efficiency control in 3GPP Systems
- Coordinated energy saving in RAN and other subsystem in 3GPP Systems
- Power consumption reduction at the site level
- Energy Efficiency in 3GPP systems with NFV
- Energy Efficiency in Self-Organizing Networks (SON).

TR 32.972 [23] (Study on system and functional aspects of energy efficiency in 5G networks) aims to:

- Identify EE KPI definitions made by ETSI TC (Technical Committee) EE, ITU-T SG5, ETSI NFV ISG (Industry Specification Group), etc., which are relevant for 5G networks, in addition to definitions made in SA TR 21.866 [24]. Such EE KPIs can be defined at various levels, incl. network and equipment levels (potentially, at virtualized network function and virtualized resource level), and per deployment scenario (dense urban, rural, etc.). With 5G, potentially, EE KPIs can be defined at network slice level;
- Identify metrics to be defined by 3GPP so as to be able to calculate the above EE KPIs for 5G networks. Such metrics might relate to data volumes, coverage area or energy consumption;
- Assess whether existing OA&M (Operation, Administration and Maintenance) mechanisms enable to control and monitor the identified metrics. In particular, check if the Integration Reference Point (IRP) for the control and monitoring of Power, Energy and Environmental (PEE) parameters for Radio Access Networks (RAN) (TS 28.304 [1], 28.305 [2], 28.306 [3]) can be applied to 5G networks. If not, identify potential new OA&M mechanisms;
- Elaborate further on the EE control framework defined in TR 21.866 [24] and identify potential gaps with respect to existing management architectures, incl. SON and NFV based architectures;
- Examine whether new energy saving functionalities might enable the 3GPP management system to manage energy more efficiently. In particular, the applicability of ETSI ES 203–237 [28] (Green Abstraction Layer; Power management capabilities of the future energy telecommunication fixed network nodes) to the management of 5G networks is to be evaluated;
- Identify potential enhancements in existing standards which could lead to achieving improved 3GPP system-wide energy efficiency.

This study requires interactions with other 3GPP working groups and SDOs (Standards Development Organisations) working on related topics, including ITU-T SG5, ETSI TC EE, ETSI NFV ISG.

9 Conclusion

The road to 5G lies ahead of us and we are moving along it swiftly, towards the next milestone for SA5; the approval of the first phase of standard service-oriented 5G management specifications in 3GPP Release 15.

The journey will not end there. Release 16 will build on the achievements of phase 1 with more services, extended information models and new measurements that will specify the management and charging of the evolving 3GPP 5G eco-system.

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Biographies

Thomas Tovinger received a Master of Science degree in Engineering Physics with Computer Science specialization at Chalmers University of Technology, Gothenburg, Sweden, 1980. He joined Ericsson the same year and since 1993 he has been a standardization delegate representing Ericsson as an OSS expert in ETSI and 3GPP. He has held numerous rapporteurship and leadership positions in 3GPP SA5 since 1999, particularly Vice Chair from 2007 to 2015 and Chair from 2015 until present date. He has also co-authored a number of articles in 3GPP News and IEEE Communications Magazine.

J-M. Cornily received his Ph.D. degree in Computer Science from the University of Rennes, France, in 1988. As an Operations, Administration & Maintenance (OA&M) architect and standards expert, he actively participated in ITU-T SG15, ETSI TM and OMG. He co-authored 'Achieving Global Information Networking' (Artech House). As an Orange representative to 3GPP since 2008 and Vice-Chairman of 3GPP/SA5 since 2013, he has been rapporteur for topics such as e.g. 3GPP networks energy efficiency, and integration of ONAP for the management of 5G networks.

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