3GPP adopted a completely new management architecture to cope with the increasing complexities of 5G management and automation. For this architecture the term Service Based Management Architecture (SBMA) was coined. The SBMA based on Release 16 provides a comprehensive toolset of RESTful Management Service components for building 5G management and orchestration solutions enabling improved operability and automation of 5G radio and core networks and services.
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The 3GPP-defined Service Based Management Architecture
Introduction

3GPP released its Rel-16 specifications for 5G management in June 2020. These specifications fully embrace the Service Based Management Architecture (SBMA) initially introduced in Rel-15. SBMA is an architectural style that defines only Management Service (MnS) components in normative fashion, and that follows strictly a model-driven approach for consumer/producer interactions. MnS components are used to build 3GPP-defined and vendor-specific Management Services and Management Functions. This approach combines the power of standardized (interoperable) interfaces for multivendor integrations with support for diverse deployment scenarios.

Rel-16 specifies a comprehensive set of different MnS components, such as powerful Create, Read, Update and Delete (CRUD) operations, rich Network Resource Models (NRM) (including the new concept of control NRM fragments) and Performance Metric definitions for diverse automation and self-organizing network (SON) functions. The wide gamut of features supported by these MnS components includes NR and 5G Core (5GC) provisioning, network slice management and orchestration (including interactions with verticals and with external management systems), data analytics, performance and SLA assurance, as well as network and service automation.

Rel-16 extends the management data reporting mechanisms available in Rel-15 with a data streaming Management Service for real-time use cases, such as real-time investigations, troubleshooting, analytics and optimization.

With SBMA, the roles of MnS producers and consumers are not limited to 3GPP Management Functions. This flexibility enables smooth integration with open source projects such as Open Network Automation Platform (ONAP) and reuse by other Standards Developing Organizations (SDOs) such as Open Radio Access Network (ORAN) for managing the ORAN Distributed Unit (O-DU) and ORAN Central Unit (O-CU). The SA5 work on slice management and orchestration is closely aligned with GSMA 5GJA.

Service Based Management Architecture

The pre-5G management architecture was a reference-point-based architecture with two monolithic Management Functions: Element Manager (EM) and Network Manager (NM). The reference point between them was the Itf-N. Management interfaces were specified for this reference point.

Just extending the two existing Management Functions for 5G was not an option. Support for features such as slice management or data analytics required the introduction of new Management Functions. However, as the number of cooperating Management Functions increases and more and more deployment scenarios need to be supported, the rigidity entailed by a reference-point-based architecture calls for a more flexible management architecture.

For this reason, SA5 moved in Rel-15 for 5G management to an architecture where only MnS components are normatively specified (with a few exceptions). These MnS components are used for building 3GPP-defined and vendor-specific Management Services and Management Functions. A Management Service is produced by a MnS producer and consumed by a MnS consumer. Any entity (even those defined outside of the management plane) can play the role of a MnS producer or MnS consumer. A Management Function produces and consumes normally multiple Management Services. This architecture is referred to as Service Based Management Architecture (SBMA).

To deploy a specific feature, multiple cooperating Management Functions are typically involved. For example, deploying closed loop service assurance may involve an Analytics Management Function and a
Service Assurance Management Function. The Analytics Management Function consumes raw performance metrics from the network nodes supporting the assured service and processes the raw data to produce enriched analytics data. The analytics data is made available using a dedicated Management Service, which is consumed by the Service Assurance Management Function. The Service Assurance Management Function compares the actual network state described by the consumed analytics data to the desired state and derives network reconfiguration actions. They are executed by consuming Provisioning Management Services exposed by the network nodes involved in the service assured.

In general, Management Functions are not normatively specified. The only exceptions in Rel-16 are the Exposure Governance Management Function and the Management Data Analytics Function.

Management Services are RESTful APIs defined using OpenAPI and published here in 3GPP Forge.

In summary, the SBMA provides a flexible toolbox that management system vendors can use for building vendor-specific products for various features with standardized interfaces. The SBMA allows for vendor differentiation without sacrificing standardized interfaces required for plug-and-play multivendor integrations.

Model-driven approach

Rel-16 follows a strictly model-driven approach relying on generic yet powerful CRUD operations and rich Network Resource Models. No task-specific operations are defined. This approach is also referred to as Representational State Transfer (REST).

Rel-16 contains Network Resource Models for the NR, 5GC and Network Slicing. Models for interactions with verticals and external management systems are available as well.

Starting from Rel-15, control NRM fragments have been introduced for different management tasks such as subscribing to receiving notifications or managing performance metric production jobs, often replacing and extending legacy approaches based on dedicated operations.

The main benefit of a fully model-driven approach is that the same set of basic CRUD operations can be used to generate sophisticated requests for manipulating and retrieving Network Resource Models. No task-specific operations are required.

An additional benefit of the strict separation of model and access is that the 3GPP-defined Network Resource Models can be reused easily by other management frameworks following the same separation of concerns. For example, a YANG definition of Network Resource Models required for the management 5G radio nodes is available in addition to the OpenAPI definition. This enables ORAN, which relies on NETCONF as management protocol, to fully reuse the 3GPP-defined radio models.

MnS Components

Management Services are built by combining MnS components. The following MnS components are available in Rel-16.

CRUD operations

The SBMA features CRUD operations optimized for interacting with huge hierarchical information models used for representing complex telecom networks. CRUD operations are based on the HTTP methods GET, PUT, POST, DELETE and PATCH. Query parameters provide advanced features like scoping and filtering multiple resources or attribute selection. Support for multiple patch media types enables partially updating resources and patching multiple resources.
Control NRM fragments

Control NRM fragments are defined for various management tasks. Different fragments are combined at well-defined touch points to construct an information model tailored to the needs of a specific Management Service.

Rel-16 features the following control NRM fragments:

**FM control NRM fragment:** NFs typically generate raw information about faults or malfunctions. This information is processed and analyzed and then stored in alarm records exposed by MnS producers. Alarms are stateful and contain analytics data like correlated alarms and root cause indicators, related state changes and configuration parameters of potential interest for further analysis, the perceived severity of the fault and proposed mitigations. Alarm control fragments can be chained, for example a root fragment can be located on a NF and an umbrella control fragment on a Management Function managing a subnetwork with many NFs.

**CM control NRM fragments:** These are the classical information models used for state and configuration management, for example the NR NRM or 5GC NRM.

**PM control NRM fragment:** This fragment allows MnS consumers to manage performance metric production and reporting jobs on MnS producers. Any NF or MF can play the role of a MnS producer. This allows consumers to get exactly the metrics they need from network nodes or network node groups of interest. Performance metrics can be reported with a file-based or stream-based approach in Rel-16.

**Threshold control NRM fragment:** This fragment allows MnS consumers to create threshold monitors for performance metrics on MnS producers. An alarm notification is generated when a threshold is reached or crossed. Multiple threshold levels can be specified. This is a simple but powerful data analytics technique.

**Notification subscription control NRM fragment:** This fragment allows MnS consumers to subscribe to receiving notifications. It allows specification of event types, and the subscription scope described by the set of targeted network nodes or geographical location for example.

**Heartbeat control NRM fragment:** For surveillance of the communication path between the MnS producer holding the subscription and the notification recipient, heartbeat notifications can be emitted periodically. This function is configured using the heartbeat control NRM fragment.

**Trace control NRM fragment:** This fragment allows MnS consumers to configure and activate various Trace jobs including subscriber and equipment trace, cell trace, minimization of drive tests (MDT), failure reports collection, etc. To activate a Trace job, an object instance is created on a MnS producer. When the MnS consumer wishes to deactivate a Trace job, the corresponding object instance is deleted. The control fragment allows access to all trace control and configuration parameters.

**SON control NRM fragment:** Rel-16 features diverse control NRM fragments for different SON functions like ANR management, energy saving management, RACH Optimization (Random Access Optimization), Mobility Robustness Optimization (MRO) and PCI configuration.

**Assurance control NRM fragment:** This fragment allows management of a complete service assurance control loop. Assurance goals are specified using the slice and service profiles. A status monitor provides information about the current and predicted situation regarding how well the goals are reached.

All control fragments are designed for different deployment scenarios. For example, the subscription control fragment supports a simple variant where the notification recipient only can be configured, and which can be deployed, for example, when all notifications produced by a node are forwarded to a single management system for further processing. But also sophisticated variants are supported, where
notification types, the event origin or the served area can be selected. This flavor could be deployed, for example, together with an alarm control NRM fragment holding alarm records for a complete subnetwork, and where each notification recipient is not interested in all alarms.

**Notifications**

Notifications are generated by MnS producers upon the occurrence of specific events. Events include state or configuration changes (configuration management notifications) or changes in alarm records (alarm notifications). Well defined notification formats are available for reporting different events.

**Performance metrics**

Rel-16 contains a rich set of performance metrics. Performance metrics include performance measurements and key performance indicators (KPIs) for gNB and 5GC Network Functions as well as measurements related to end-to-end 5G networks and network slicing. KPIs are available for accessibility, integrity, utilization, retainability and mobility.

The PM control NRM fragment is used to manage performance metric production and reporting jobs.

**Building a MnS from MnS components**

A MnS is built using MnS components. For example, a basic Management Service for downloading and retrieving network configuration data for NR nodes can be built with the CRUD operations and the NR NRM. In case an analytics function or some other function needs to be informed about configuration changes and wants to retrieve performance metrics, then configuration notifications, the notification subscription control NRM fragment and the PM control NRM fragment need to be supported as well. Likewise, Management Services for different management tasks can be built.

The SA5 flagship Management Service is the Provisioning MnS. This MnS features the CRUD operations, all NRM fragments and all notifications.

Another important Management Service is the Streaming Data Reporting MnS: originally introduced as part of the non-file-based Trace data reporting feature (a.k.a. Streaming Trace), the new MnS has been generalized to support multiple data types such as PM, Trace, Analytics and proprietary data. It allows near-real-time delivery (the term “near-real-time” here implies “while the data is relevant”) of large volumes of data with minimal overhead. The MnS leverages RESTful HTTP for the connection establishment and exchange of stream metadata and combines it with WebSockets carrying binary-encoded payloads serialized using ASN.1 and/or GPB. The supported streaming PM use cases focus on PM data reporting with 5-10 second intervals and streaming Trace use cases with immediate delivery of captured Trace/MDT data.

**Trace and MDT**

Trace functionality (including support of MDT) has been significantly extended in 3GPP Rel-16. The introduction of the new Trace control NRM fragment eliminates the need for dedicated Trace Management APIs and as a result enables smooth integration with non-3GPP deployment architectures (e.g. ONAP). The new data reporting mechanism supports instantaneous delivery of captured Trace and Immediate MDT data to MnS consumers such as various analytics functions, AI/ML algorithms, etc. The MDT functionality in Rel-16 remains on par with legacy LTE MDT with new measurements introduced specifically for NG-RAN.
Features

Using SBMA principles and MnS components available in Rel-16 many different management and orchestration or automation features can be implemented.

Network and service fulfillment

For network and service fulfillment, the CRUD operations and the CM control fragments are required, possibly complemented by configuration change notifications.

Lifecycle management of VNFs

A VNF is represented in the management domain like a PNF by a managed object instance. The creation of such an instance can trigger a “chain reaction” of interactions with NFV MANO and, as a result, also lifecycle operations (such as instantiation, scale out, scale in) on the instances of NS and VNF.

Alarm management

For alarm management the FM control NRM fragment is required. This fragment is typically added to a provisioning service. Stand-alone alarm management can be deployed as well.

Closed-loop network and service assurance

A closed-loop network and Service Assurance Management Function consumes on its “southbound” side services for data collection and reporting or services providing analytics as well as services for configuration management. On its “northbound” side it exposes the assurance control NRM fragment, allowing management of the closed loop and making the status regarding the target achievement available.

Slice management

For slice management the Slice NRM has been defined. This NRM features a fragment for interactions with verticals requesting a slice, and a fragment for managing slice subnets. The Slice NRM is closely aligned with GSMA 5GJA (GST/NEST).
The NRM fragment for interacting with verticals is exposed on the “northbound” side of a network slice Management Function and includes an end-to-end (E2E) service profile that allows verticals to request slices with certain service properties. The network slice Management Function decomposes the service profile into slice profiles and, in turn, requests a Management Function managing network slice subnets to allocate network slices with these profiles. This Management Function exposes the NRM fragment for managing slice subnets on its “northbound” side.

Moving on, the network slice subnet Management Function translates the received request to configuration management requests that are then sent to appropriate MnS producers, exposing for example the NR NRM or 5GC NRM. At the end of this chain the existing NFs are re-configured or new ones created.

Closed-loop automation and SON

This feature involves typically numerous Management Services and Management Functions forming a closed loop. The following figure shows an example with five Management Functions: one for data collection, one for analytics, one for intelligence, one for orchestration & control, and one implementing a central data lake.
Transitions between loop stages realized by 3GPP defined Management Services (MnS)

The data collection Management Function consumes management data collection and reporting services from MnS producers on multiple network nodes. In this example, the function acts mainly as concentrator and re-exposes the data on its “northbound” side where it is consumed by an analytics function and a central data lake. The analytics function produces analytics reports that are accessed by the intelligence function deriving reconfiguration decisions, which are then further refined and applied to the network nodes by the orchestration & control function.

All interfaces (designated with “data”, “information”, “insight”, “decision” and “action”) can be implemented using different MnS components. For example, the data interface on the managed resource may exhibit a PM control NRM fragment (accessed by the CRUD operations) for managing the performance metric production jobs and a Streaming Data Reporting MnS producer for performance metric reporting. The same MnS components can be used on the northbound side of the data collection function. The analytics function can expose services that are described in a Rel-16 study, and both the “decision” and “action” interface can be deployed with CM and SON control NRM fragments, and CRUD operations to access them.

The legacy concept of automated Plug and Connect (PnC) standardized for automatic connection of eNB to the network has been adopted for inclusion in 5G SON with potential extension to other NF types.
Data analytics

Data analytics refers to diverse techniques for data analysis. Rel-16 features the performance metrics threshold monitor as a simple yet powerful data analysis technique. Also alarm records contain several attributes with analytics data.

The Management Data Analytic Function is one of the rare examples of a Management Function specified by SA5. It consumes services for data collection and configuration management. Analytics report formats have been studied in Rel-16. When leveraging network information available from NRMs, it is possible to target specific NFs, network slices or geographical areas for analytics.

It is expected that in Rel-17 an analytics control NRM fragment, allowing configuration of the analytics function and reporting of analytics data in standardized fashion, will be added.

Integration with ONAP

Increased attention of operators to various open source projects (primarily ONAP) has triggered targeted work on analysis of 3GPP and ONAP management architectures, identification and addressing of potential gaps. The adoption of SBMA made this task relatively smooth. In a scenario where 3GPP-compliant Network Functions need to be controlled by ONAP, various ONAP components play the role of 3GPP MnS consumers. Specifically, DCAE consumes 3GPP Fault Supervision MnS, Performance Assurance MnS and Trace data reporting MnS. APP-C consumes 3GPP Provisioning MnS. In order to support the AT&T VES as preferred method of notifications within ONAP architecture, SA5 developed a set of specific recommendations where 3GPP notifications are “wrapped” with VES headers and are carried as VES payloads, and certain information elements present in 3GPP notifications may be “promoted” (copied) to the fields of the VES header.

Relation to ORAN

Management in ORAN is mainly concerned with the management of the OAN defined radio nodes. ORAN reuses for that purpose the 3GPP-defined NR NRM and several control NRM fragments and extends them as required. Since ORAN does not use RESTful interfaces defined with OpenAPI but NETCONF/YANG, 3GPP introduced a YANG definition of the NR NRM and defined a subset of NETCONF protocol elements required in this context. Notifications specified in ORAN are fully based on the 3GPP OpenAPI definitions.

Relation to ZSM

3GPP SA5 collaborates closely with ETSI Industry Specification Group (ISG) zero touch network and service management (ZSM). The specific topics of collaboration include the support of E2E Network Slicing and various aspects of automation (SON, service assurance, etc.). In bi-directional collaboration ETSI ISG ZSM represents 3GPP RAN (NG-RAN) and 3GPP Core (5GC) as individual management domains. The role of the E2E management domain is to coordinate across the individual 3GPP management domains and with non-3GPP management domains such as Transport, Virtualization, etc.
Outlook

Rel-16 provides a rich toolbox of MnS components allowing the building of Management Services and Management Functions for a wide gamut of management tasks spanning from simple ones like network configuration to complex ones where multiple Management Functions are involved, such as network and service automation and closed-loop service assurance.

Rel-17 will further enrich this toolbox with new features like security management and access control, enhanced capabilities for data collection, analytics and SON; and new performance metrics. Extended support for closed-loop service assurance of E2E network slices, and assurance across radio, core and transport domains will be provided as well.

With this and going forward also in Rel-18 and beyond, 3GPP continues its journey to the ultimate goal of enabling fully autonomous networks, driven by high-level policies and rules, that are capable of self-configuration, self-monitoring, self-healing and self-optimization without further human intervention.

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The authors are Nokia 3GPP delegates. Nokia is committed to help shaping the industry’s network and service automation transformation and has been instrumental in creating 3GPP specifications for 5G management, orchestration and automation.
Abbreviations

5GC  5G Core
CM  Configuration Management
CRUD  Create, Read, Update and Delete
EM  Element Manager
FM  Fault Management
GPB  Google Protocol Buffers
KPI  key performance indicator
MDT  minimization of drive tests
MF  Management Function
MnS  Management Service
MRO  Mobility Robustness Optimization
NF  Network Function
NM  Network Manager
NRM  Network Resource Model
PM  Performance Management
PNF  Physical Network Function
REST  Representational State Transfer
SBMA  Service Based Management Architecture
SLA  service level agreement
SON  self-organizing network
VNF  Virtualized Network Function

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