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From IMS Management to SOA Based NGN Management

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Abstract Although IP Multimedia Subsystem (IMS) based Next Generation Networks (NGNs) are already emerging as the common session control platform for converging fixed, mobile and cable networks, harmonized solutions for the management of these converged platforms have still got to be developed. This document describes a hands-on approach to NGN Management. Started with IMS specific management systems, succeeding research had to take into account the importance of the management of NGN SDPs as well. This work shows that the hybrid nature of an NGN, where services can be delivered at the IMS layer, by SIP signaling mechanisms, as well as at the SDP, via Web Services, requires a harmonized management approach. Taking into account Service Oriented Architecture (SOA) principles and policy based model driven architectures, this work shows that a unification of service composition and service management already at the workflow creation level, bares significant benefits in terms of automation and harmonization. Following the SOA paradigm, the approach presented here does not differentiate between business process management (BPM) and management process management. Focusing on Telemanagement Forum's enhanced Telecom Operations Map service fulfillment and service assurance operations, this document describes an New Generation Software and Services (NGOSS) based implementation of a unified Operation Support System (OSS) for NGNs that encompasses many problems of

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former stovepipe management solutions in terms of automation, flexibility and manageability.

Keywords IP Multimedia Subsystem · New Generation Operations Systems and Software · Service oriented architectures · Service fulfillment · Service assurance · Service provisioning

1 Introduction

The IP Multimedia Subsystem (IMS) emerged as the de facto standard for fixed, mobile, cable convergent next generation telecommunication networks. Together with an open Service Oriented Architecture (SOA) based Service Delivery Platform (SDP), the IMS allows for delivery of a totally new range of Web 2.0/Telco service compositions, independent from the utilized access network.

Due to its access network independence, the support for multiple end devices, multi-media, triple play services as well as the strong requirement to allow for enhanced user centric delivery of services, the complexity of a Next Generation Network (NGN), as abstractly shown in Fig. 1, is at least one order of magnitude greater than the complexity of traditional telecommunication networks. The reason for that is related to the multitude of access networks (like cable, mobile or fixed line access networks) can be supported by NGN infrastructure, most commonly by utilizing an IMS which provides access network independence. This furthermore tremendously broadens the range of end-devices that have to be managed and supported. Another key aspect that makes management of such infrastructures even more difficult is the requirement that more and more comes from third party service users and regular customers to be able to provide customizable services in a user specific way. Moreover, not only for the sake of customer satisfaction or customer retention, but also by following the trend towards "open garden" telecommunication service environments, the actual NGN service landscape is expected to expand tremendously. Apart from access and transport networks,

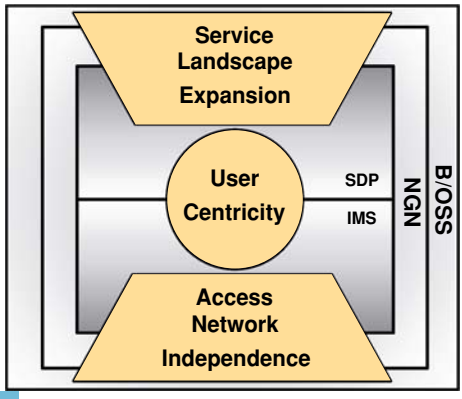

Fig. 1 NGN B/OSS challenges for managing IMS and SDP

appropriate Business and Operation Support Systems (B/OSS) for NGNs have to efficiently manage IMS based session control layers and SOA based SDPs. Irrespective of this complexity, telecommunications operator and service providers require a strong reduction of operations expenditures as well as a reduction of new service's time to market. In order to meet these requirements, several vital design principles have to be adhered.

Although during the emergence of all-IP IMS based networks, management of theses infrastructures was considered to be very similar to traditional IT infrastructure management, typically Information Technology Infrastructure Library (ITIL) based, telecommunication OSS experts more and more realize that the management of NGNs requires a total mind shift, from traditionally separated stove pipe management island towards unified, enterprise wide management systems. Telemanagement Forum's (TMF) enhance Telecom Operations Map (eTOM) provides many very useful tools and models for the development of such a unified, SOA based management infrastructure. Very much in line with current TMF approaches (the Service Delivery Framework Working Group), the central idea for the development of OSSs for NGNs, is the unification of service creation processes, business processes and management processes by utilization of workflow based service composition/brokerage mechanisms.

Based on a prototype OSS for the management of IMS based networks [1, 2, 3], this work shows the results of the continued efforts to develop an efficient, standard based framework for the management of IMS based NGNs. The approach described here makes use of late findings that are showing that service oriented interfaces like Web Services are not only providing the required capabilities to be utilized for Business Process Management (BPM), but can also be used as a unified interface for OSSs. Simultaneously, Web Service based NGN services allow for innovative service composition mechanisms, which increasingly are utilized for the development and delivery of Web 2.0/Telco converged composite applications. On the one hand these service compositions are more difficult to manage, particularly in terms of fault management, specifically root cause analysis, on the other hand these workflow based Web Service composition mechanisms can be exploited to tightly integrate service management functionalities already at service composition time.

Based on this strong trend towards SOA based service delivery strategies for telecommunication networks, this work describes a prototype architecture for converged telecommunication service composition and management.

Many standards and studies from many different standardization consortia paved the way towards this converged and unified SOA based management approach. In Sect. 2 only the strongly NGN related SOA enabled OSS efforts are being briefly described. Based on these vital standards and mechanisms in Sect. 3 FOKUS' prototype system, the Next Generation Network Business and Operations Support System (NBOSS) is being described. A SOA and workflow based NBOSS prototype system for the two mainly focused OSS domains, service fulfillment and service assurance, is described in Sect. 4. The summary in Sect. 5 concludes this work, explaining open issues and next steps.

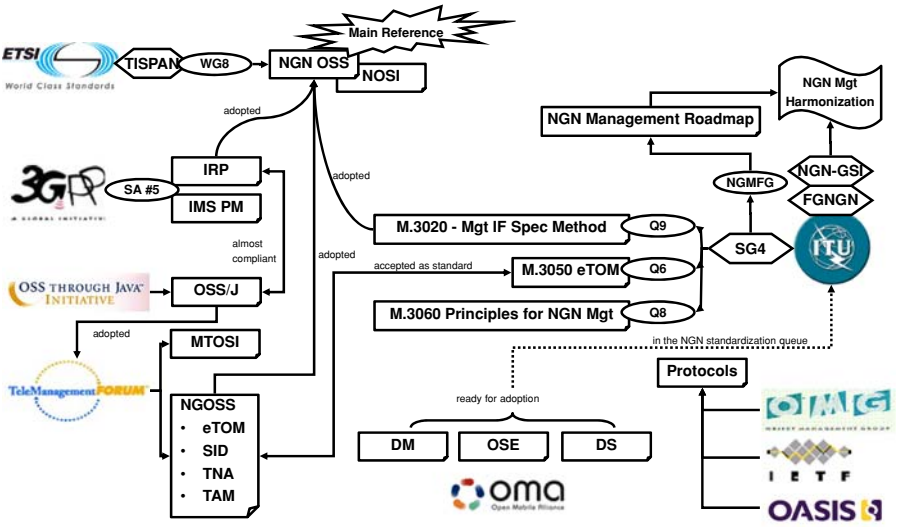

Fig. 2 NGN OSS related standardization efforts

2 State of the Art in SOA Based NGN Management

The landscape of standardization consortia responsible for the provisioning of NGN management standards and system is broad (as depicted in Fig. 2). The International Telecommunication Union Telecommunication Standardization Sector (ITU-T) as the overarching standardization consortium for telecommunication networks strives for harmonization of the different management standards and approaches [4]. The TMF eTOM [5] standard was accepted as an ITU-T standard (M.3050) and serves the European Telecommunications Standards Institute's (ETSI) Telecoms & Internet converged Services & Protocols for Advanced Networks (TISPAN) as a foundation for their NGN OSS [6] standard in the same way as its predecessor the Telecom Operations Map (TOM) serves the 3rd Generation Partnership Project (3GPP) as a fundamental reference [7]. Similarly, standards from the Open Mobile Alliance (OMA), like the OMA Service Environment (OSE), the OMA Device Management (DM) and Data Synchronization (DS) standards, as well as protocols from OMG, IETF and OASIS are currently in the OSS for NGN standardization queue of the ITU-T.

Therefore it can be stated that TMFs New Generation Operations Systems and Software (NGOSS) [8] framework (of which eTOM is one of the most important cornerstones) more and more serves the whole telecommunication OSS standardization as major reference, as depicted in Fig. 2. The cornerstones of the NGOSS framework, as depicted in Fig. 2 will be described in Sect. 2.2, whereas the depicted NGOSS compliant management interfaces and protocols are described in Sect. 2.4. Nevertheless, some terminology from the Telecom Management Network (TMN), like the differentiation between element, network, service and business management layers, is still commonly in use.

2.1 ETSI and 3GPP

Current OSS infrastructures utilize a very heterogeneous mixture of Simple Network Management Protocol (SNMP), Common Management Information Protocol (CMIP), Common Object Request Broker Architecture (CORBA) protocols and usually separated, service specific management islands with separated service and resource repositories as well as different data and information models. Therefore, at the current stage, 3GPP requires all network management systems to support a variety of management protocols, by means of adapters or mediators [9].

For a long time the performance of Web Service (Simple Object Access Protocol (SOAP)/Extensible Markup Language (XML)) based management communication modes and interfaces were considered to be insufficient due to the overhead generated by exchanging XML schemas. Therefore, 3GPP conducted a feasibility study [10] which analyzed the usability of Web Service management communication between network elements, domain and network management systems. The outcome was that Web Services can indeed be used for enterprise wide OSS tasks. Due to several advantages of Web Services based interfaces and communication, like human readability of XML schemas (in contrast to Corba binary code) or HTTP port usage, 3GPPs long term vision for a unified, plug and play OSS infrastructure specifically foresees Web Services as the common denominating communication vehicle. Based on that, 3GPP is currently standardizing Web Service solution sets for Integration Reference Points (IRPs) of OSS for telecommunication networks [11].

Now that not only business process management systems, i.e. business support systems (BSS), but also OSSs are based on Web Service communication, the idea of a converged workflow based management approach gains momentum. Since also telecommunication services, with the help of network abstraction mechanisms like Open Service Architecture (OSA)/Parlay X gateways, are nowadays exposed via Web Service interfaces, the core idea of this approach is to combine these processes following SOA principles.

2.2 The Cornerstones of Telemanagement Forum's NGOSS

The TMF NGOSS framework is comprised of the eTOM, the Shared Information and Data Model (SID), the Technology Neutral Architecture (TNA) and the Telecom Applications Map (TAM). The eTOM provides an overall blueprint of all enterprise wide processes from strategy to infrastructure and product management (SIP) to operations. Roughly specified at level 0, the eTOM model provides by each lower level a more fine grained decomposition of required management processes, which can readily be utilized to conceptualize a modular service oriented OSS. Therefore, the eTOM enables SOA based telecommunication OSSs, by allowing for decomposition and reuse of management modules throughout the entire management system.

Specified in the unified modeling language (UML), the SID provides a common information model which describes entities (from customers to resources to services) so that service oriented workflow mechanisms can deliver plug and play functionalities throughout the entire management process landscape. With the help of so-called NGOSS contracts, management processes can be composed in an automated fashion.

Step by step, from the design of a TNA to the actual, technology specific implementation, the NGOSS provides the means for the implementation of an enterprise wide management system, based on a model driven architecture (MDA) approach.

2.3 Telemangement Forum's Service Delivery Framework

Based on this new possibility to translate formerly separated management islands into one central, unified, workflow based process management engine, the TMFs Service Delivery Framework (SDF) strives for a total abstraction between workflow based OSS and BSS and NGN resources.

2.4 TMF NGOSS Compliant Management Interfaces and Protocols

As a last step, in order to provide NGOSS adopters with unified, enterprise wide system communication mechanisms in a service oriented way, the TMF not only adopted the OSS through Java Initiative (OSS/J) [12], but also pushes forward the Multi Technology OSS Interface Initiative (MTOSI). Both initiatives provide implementations of Web Service based NGOSS compliant Application Programming Interfaces (APIs), ready to be implemented for harmonization of the enterprise wide management system's communication. Although the OSS/J initiative is still work in progress and since by far not all required APIs for the management of all eTOM processes have been standardized, the published APIs already serve as a vehicle to harmonize several management domains, as well as they, for the first time, enable the implementation of a workflow based management infrastructure converging both BSS and OSS.

2.5 Relation to Standards and Scope

Based on standards mentioned above, specifically TMF standards, the work described in the remainder of this document aims for a unification of the NGN management system. Moreover, based on this unified, SOA based NGN management architecture, this work shows the benefits of tightly integrating business and operations support processes into the service composition process, enabling service lifecycle management already at service deployment time. Based on a real world implementation, as part of our IMS and SOA based NGN testbeds, this work outlines the potentials and goals, but also the open issues of an automated, SOA based, business process modeled, workflow driven, unified management system for NGNs.

3 FOKUS Next Generation Network Business and Operations Support System Architecture

The FOKUS NBOSS approach started with a basic fault management and service provisioning solution for IMS [1, 2]. This initial solution monitored and controlled Session Initiation Protocol (SIP) based IMS services and IMS core [13] functions

like the Proxy, the Interrogating and the Serving Call State Control Function (CSCF) and the Home Subscriber Server (HSS). By means of active and passive SIP probing mechanisms, a fault management solution for the NGN session control layer (i.e. the IMS) was developed and implemented as a management solution for the Open IMS Playground [14]. After the deployment of an OMA [15] based SDP, the OSE [16] which gave birth to the Open SOA Telco Playground [17] as shown in Fig. 3, many formerly solely via SIP accessible services became accessible via Web Services as well. Following SOA principles the Open SOA Telco Playground comprises of a service registry, a resource inventory, a service broker (described in more detail in Sect. 3.6), a service creation environment, the OMA OSE core

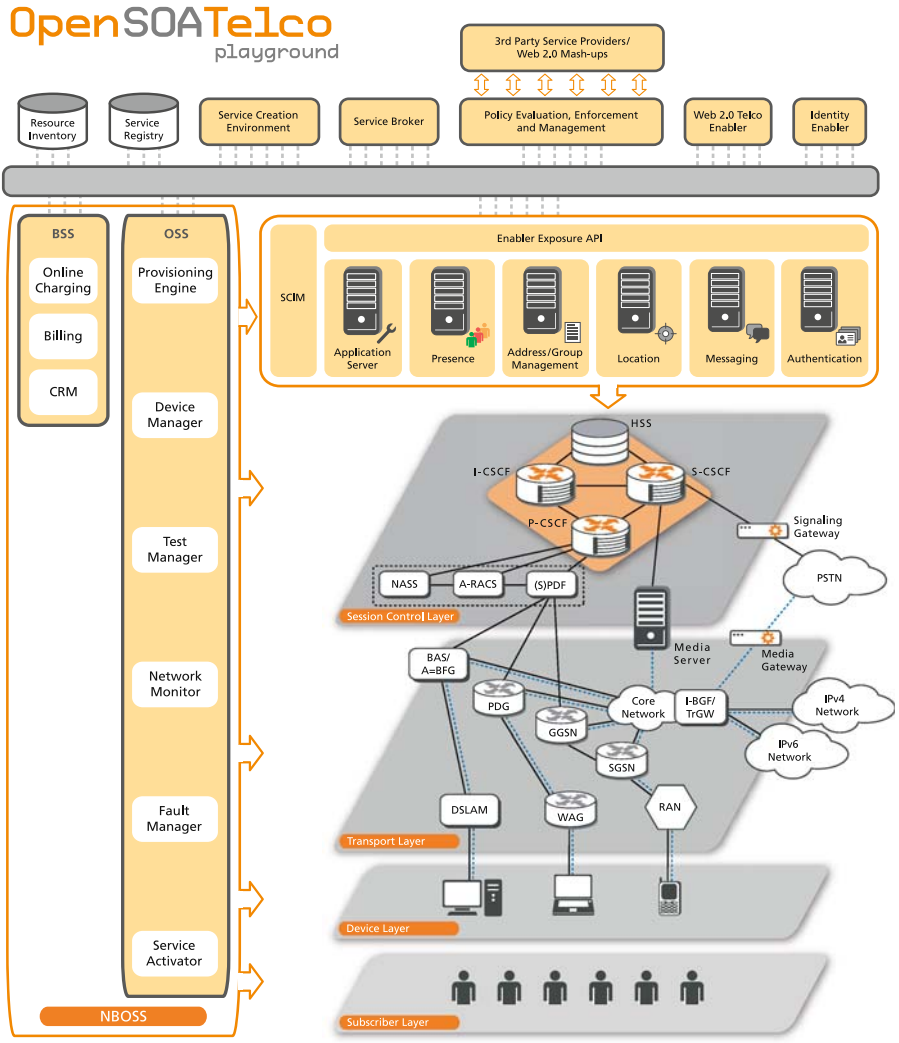

Fig. 3 NBOSS in the SOA Telco Playground

component, the Policy Evaluation and Enforcement Management (PEEM) System (described in more detail in Sect. 3.3.1), the Web 2.0 Telco enabler (as a gateway for the utilization of Web 2.0 APIs) and the Identity Enabler (for enabling single sign on mechanisms and for providing user centric mechanisms throughout the NGN). Following the "open garden" paradigm for next generation telecommunication networks, the Open SOA Telco Playground allows 3rd party service providers to securely access Telco services and network functions via policy controlled PEEM function, so that Telco/Web 2.0 mash-ups can be delivered in a secure and policy controlled manner. All these components inter-work and interconnect via a service bus. By doing so, the BSS (here in Fig. 3 for Online Charging, Billing and Customer Relationship Management) and OSS (here in Fig. 3 comprising of a Provisioning Engine, device, test and fault managers, network monitors and service activators) by itself can be plugged into the SOA environment. By utilizing mediators and adaptors (described in Sect. 3.4.1) this approach enables the unification of the management plane enabling simultaneous management of the SDP, session control (IMS functions, like P/I/S-CSCF and HSS), transport (different mobile, cable or fixed line transport functions), device and subscriber layer.

OSA/Parlay Gateways (in Fig. 3 termed enabler exposure API), responsible for the IMS network abstraction, provide the capabilities to expose SIP Services not only to third parties, but also for the modular, SOA based composition of Web 2.0/IMS service mash-ups. Rapidly created, utilizing internal as well as spatially separated external service enablers (service building blocks), usually via Web Service APIs, this new generation of telecommunication services requires new OSS mechanisms.

The current NBOSS approach is based on a business process management system, which, apart from service composition, simultaneously initiates service assurance and service fulfillment mechanisms for these newly created composite services, i.e. service mash-ups.

3.1 From IMS Management to SOA Based NGN Management

Management systems, especially for assuring basic, "Class A" IMS services require a range of active and passive SIP (partially also Diameter) based monitoring mechanisms in order to detect IMS traffic anomalies as well as for root cause analysis. With the help of SIP based user end-point emulators, the IMS core functionalities, i.e. IMS registration, IMS session setup as well as IMS messaging can proactively be tested for, faulty components located and self-healing mechanisms conducted.

However, by integrating an IMS based SDP, the service landscape dramatically expands towards composite service mash-ups. Therefore, a solution had to be developed that was not only capable of managing SIP based IMS services, but also Web Service based composite services. Following SOA principles, it was found that the most efficient approach for the management of a rapidly changing service portfolio was to tightly integrate BSS and OSS processes already into the service creation/service composition process. Since not only BSS processes, but also service composition processes predominately are Web Service based, the

implementation of workflow based management mechanisms was becoming more and more obvious.

3.2 SOA Principles

In order to represent management processes in terms of workflow choreographies, SOA based principles have to be introduced throughout the management system. On the one hand, management resources, from active to passive traffic monitor, local agents, provisioning systems as well as network elements have to be equipped with common service oriented interfaces. On the other hand, the workflow itself has to be designed following a service oriented process schema.

For harmonizing the management communication, NGOSS based OSS/J interfaces were selected. In order to decompose and choreograph the workflow in a service oriented manner, TMFs eTOM, together with the SID was used as a reference.

3.3 Fundamental Guidelines

Utilizing SOA principles alone does not provide the abilities to flexibly and dynamically react on network changes. In order to realize a higher degree of automation as well as a plug and play integration of new resources and services, several more vital principles had to be adhered.

3.3.1 Policy Based Network Management

Policies as a means to separate programming logic from system run-time behavior, as well as to provide subscriber centric service delivery had to be integrated not only at the service level but also at the resource level. Therefore policies simplify network administration (like shown in [18]), but also enable enhanced customer centric service delivery. Open Mobile Alliance's core component, the PEEM system initially only served as a means to authenticate third parties for IMS/NGN service enabler utilization. Step by step the spectrum of PEEM policies not only covered more subscriber related policies (e.g. age verification, subscriber preferences, Service Level Agreements (SLAs) etc.) but also OSS related policies (e.g. whether a service enabler already is monitored, provisioned, for which subscriber, etc.). Based on this enhanced PEEM [19], not only policy repositories were unified, but also the management of newly composed services was automated.

3.3.2 Model Driven Architectures/Services

Utilizing models already at service design time allows rapid development and deployment into the existing infrastructure, already knowing about the impact of the new service on the existing service enablers and OSS infrastructure. Utilizing TMFs NGOSS contracts to specify input (preconditions), output (post-conditions), parameters and arguments of a service, enables plug and play service composition as well as automated service and resource management. As will be described later on, the workflow service composition and management system has to dynamically

be able to lookup (discover) already existing services as well as appropriate services to manage newly created services. Therefore, a service repository, not only for service enablers but also for OSS services, was utilized, which exposed applicable services via semantically enriched Web Service Description Language (WSDL-S) schemas. Based on that, not only services can be composed out of an existing set of service enablers (presence, location, group-lists, etc.), but also simultaneously appropriate composition of service specific management workflows can be conducted in a plug and play, automated fashion.

3.3.3 Autonomic Control Loops

In order to reduce operation expenditures, i.e. efforts to usually manually operate, configure and resolve faults, autonomic "self-*" principles have to be adhered wherever applicable. Now that the infrastructure already is equipped with policy based management mechanisms, more self-regulating, i.e. self-healing, self-monitoring mechanisms can readily be incorporated into the overall management system. Closed control loops enable mechanisms to self-monitor, self-analyze and self-react already at the network element layer. The current state of the NBOSS infrastructure already integrates macro closed control loops for the overall network fault management architecture, where the overall management system is capable of conducting self-healing mechanisms (currently predominantly start, stop and restart mechanisms, in the future more and more load-balancing, hot swapping, as well as real-time service component replacement functionalities). Especially for managing service compositions, where spatially separated service components (e.g. Web 2.0 service enablers) have to interwork tightly and efficiently, closed control loops enable the real-time replacement of malicious service components. Inside of the Autonomic Communication Forum's (ACF) [20] Service Composability Management Working Group, autonomic mechanisms for the management of NGN service composition are being developed, as shown in [21].

3.4 Towards a Unified Management Infrastructure

In contrast to an ideal, from the scratch designed management network, where unified network element interfaces can be deployed from the very beginning, already existing networks have to be unified in terms of interfaces, communication protocols and service, resource and policy repositories. The NBOSS strives for a unified approach for NGN service and policy repositories as well as for unified service orchestration mechanisms. In terms of unified management protocols, NBOSS follows the OSS/J Web Service harmonization approach encouraging mediators or adaptors (SNMP to MTOSI to OSS/J) in order to integrate other protocols and OSS interfaces.

3.4.1 NGN Management Mediators, Adaptors and Harmonizers

In contrast to OSS/J, the also Web Service based MTOSI is more powerful in terms of integration capabilities for legacy management protocols (e.g. SNMP). However,

OSS/J and MTOSI can interoperate. Therefore, the NBOSS approach unifies the management protocol landscape by utilization of OSS/J interfaces and encourages integration of legacy protocols by MTOSI mediation.

3.4.2 NGN Service Orchestration

Typically for the hybrid (SIP-/Web Service-domain) nature of IMS based NGNs, there currently are two standardized components for service orchestration, one called the Service Capability Interaction Manager (SCIM) for the SIP layer, and the PEEM for the SDP, i.e. the Web Service domain. The NBOSS approach developed a converged SCIM/PEEM system, capable of orchestrating SIP as well as Web Services in a user centric fashion. Policies govern the orchestration mechanisms, preventing service dead-locks.

3.4.3 Unification of Repositories

NBOSS publishes WSDLs of new services, existing Parlay X service enablers as well as OSS/J management services by means of an open source Universal Description, Discovery and Integration (UDDI) service repository. Service discovery mechanisms during service creation/composition time dynamically lookup existing service components as well as appropriate management services. Typical WSDLs do not provide sufficient information about service component specific preconditions, post-conditions, or input parameters. Therefore semantically enriched WSDLs (WSDL-S), where supplementary information about the specific features of a service is specified, allow for automated service composition and management.

3.5 Unified Business Process and Management Process Management

While formally there was a clear separation of BSS and OSS, where workflow systems were predominantly used for enterprise wide business transactions (Billing, Customer Relationship Management, Content Management Systems, etc.), with the help of service oriented, unified management infrastructures, an elegant convergence of these two domains can be delivered. After it was found out (as described in Sect. 3.1) that Web Service can indeed be used for a huge range of management tasks, not only subscriber and order management, but even time-critical performance, and fault management tasks, the utilization of workflow based management systems gained momentum.

eTOM together with TMFs SID can now be used to design an enterprise wide BSS and OSS workflow system, where complex processes can dynamically be concatenated in a plug and play manner, based on a clear definition of NGOSS contracts.

3.6 Converged Service Composition and Management Framework

The core component of the Open SOA Telco Playground [17], a state of the art implementation of the OSE, in terms of service composition and management is

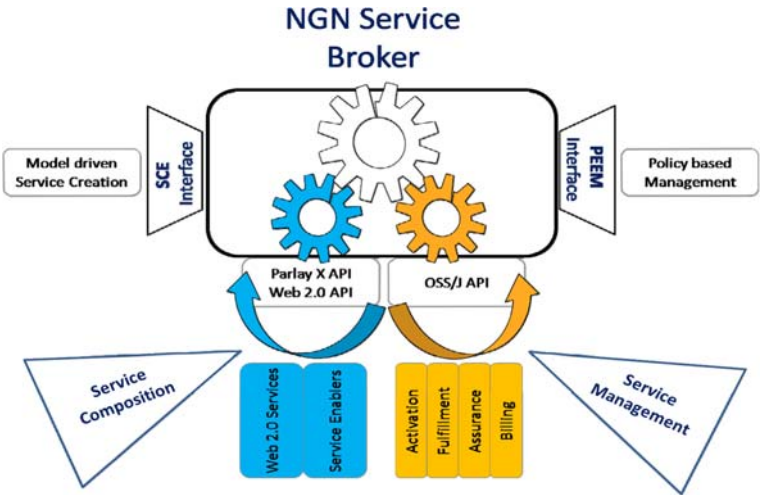

Fig. 4 Converged service composition and service management

termed NGN Service Broker. Based on Business Process Execution Language (BPEL) based workflow engine (Active BPEL [22]), the service broker receives service composition and service execution requests and interfaces with the PEEM, the Service Creation Environment (SCE), service enablers, service repositories as well as OSS and BSS via an Enterprise Service Bus (ESB). This solution, as shown in Fig. 4 not only allows for dynamic composition of composite NGN services, via Parlay X Web Service APIs, but also, via OSS/J Web Service APIs, initiates a range of OSS processes in order to provision network elements (at the IMS core layer, e.g. the HSS, as well as at the application layer, e.g. the XML Document Management Server (XDMS) [23] or SIP Application-Servers) for the new service to be activated as well as for assuring proper service delivery by means of active and passive monitoring of the composed service performances as well as of its service building blocks.

3.6.1 NGN Service Composition and Service Management

NGNs that follow the so-called "Open Garden" paradigm by means of service exposure mechanisms, allow third parties to utilize and integrate telecommunication services into their service offerings. Vice versa, telecommunication service providers with the help of a SOA based SDPs are able to compose value added services utilizing external service building blocks, e.g. Google-maps APIs to provide a map feature to the location based services delivered to their customers. The OMA standardized several service enablers, i.e. service building blocks for IMS based NGNs. These reusable service components can readily be utilized to compose a huge variety of innovative composite services. Basic telecommunication functionalities like call control or conferencing, as well as presence, location or address-book functionalities can easily be integrated into so-called service mash-ups. This innovative, SOA based capability of composing complex service composition out of reusable service building blocks tremendously speeded up service's time to market,

since only new service features have to be implemented. Many OSS workflows, particularly when offered in a service oriented fashion can similarly be composed. The initial solution of NBOSS focuses on the TMF eTOM operations domains, service fulfillment and service assurance. The goal was to automate service fulfillment and assurance processes already at service composition time.

3.6.2 Service Discovery/Service Repositories

Composite services require several service enablers to exchange information. A very simple, purely IMS service enabler based composed service could be: "Send an Instant Message to all my online Buddies". Although this appears to be a straightforward command, several service enabling components have to inter-work to fulfill this request. At first, the complete buddy list has to be downloaded from the XDMS, via Parlay X Address List Management Web Service API. Second, the presence state of all buddies has to be checked via the Presence server by initiating a Web Service request towards the Parlay X Presence API. Finally, an Instant Message is sent via the Parlay X Send Multimedia Message API. In order to compose such a service, as shown in Fig. 5, after authentication took place at the PEEM (Step 1 in Fig. 5) and the request had been delegated to the Service Broker (Step 2 in Fig. 5), the workflow engine has initially to query the OSS/J Inventory API in order to check for the availability of the required service enablers (products in TMF eTOM Taxonomy). The Inventory API triggers a service discovery request, via OSS/J Discovery API (Step 3 in Fig. 5) which looks up available service enablers by querying the UDDI. The workflow engine receives a list of semantically enriched WSDL-s from the UDDI and after input, output, parameters and arguments (the service specification) have been matched, composes the entire service workflow (Step 4 in Fig. 5). Finally and importantly, the workflow engine composes a new WSDL-s for the newly created services, which via the same mechanism as

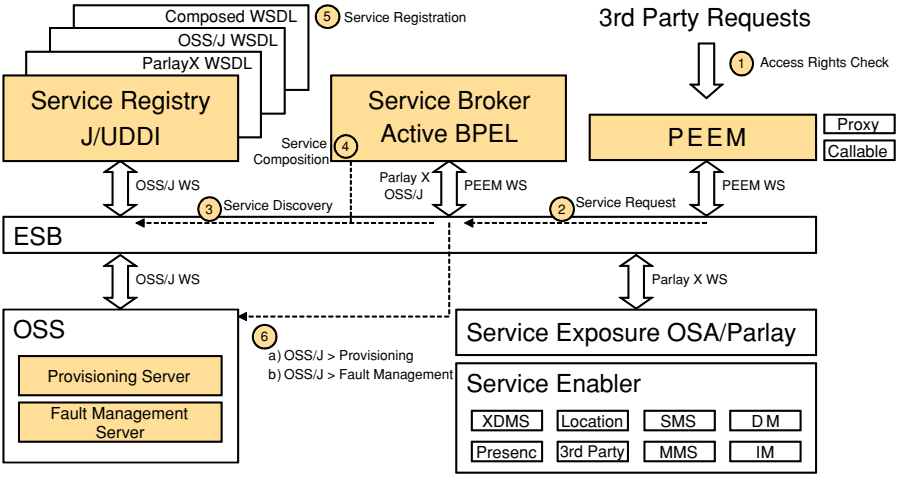

Fig. 5 Automated workflow based service discovery, composition and management

described above is being fed into the UDDI for later usage (Step 5 in Fig. 5). Following these mechanisms, iteratively more and more complex services can be created out of already existing composed services.

The same applies to the management of newly generated service compositions. At the current stage, with the help of a Provisioning Server and a Fault Management System as shown in Fig. 5, the network (i.e. the IMS core as well as the Service Enabling layer) can automatically be provisioned by triggering the OSS/J Order Management API. Furthermore, for service assurance, via the OSS/J Fault Management API, the process of active and passive service monitoring mechanism is being triggered. Therefore, the workflow engine after the discovery of the relevant management services (Order Management for Fulfillment and Fault Management for Assurance) initiates the operation support processes (Step 6 in Fig. 5) as part of one and the same service composition choreography.

3.6.3 Converged Policy Management

At the current stage, the specification of the OMA PEEM policies primarily focuses on subscriber specific access right policies. In order to unify and harmonize the SOA based SDP policy strategy the NBOSS approach greatly extends the policy landscape of the PEEM. The PEEM is invoked by the central workflow engine as soon as a service composition has either got to be provisioned for, or fault management for the specific composed service as well as for its components should be triggered. Policies govern whether the network was either already provisioned for a new service composition or for its enabling parts. Likewise, policies tell whether a service composition, as a whole, or its service enabling components already are managed by the fault management process.

4 NBOSS Prototypes

Based on already existing prototypes for the provisioning and fault management of IMS core elements and IMS service enablers, SOA based *service assurance* and *service fulfillment* mechanisms were developed also for the NGN Service Delivery Platform, depicted in Fig. 6. By utilization of session control layer management functionalities together with application layer management mechanisms, as will be shown, not only services, but also resources can comprehensively be monitored.

4.1 NBOSS—Converged Service Fulfillment

Service fulfillment requires several processes either to be conducted in case a customer initially registers for NGN usage, a customer subscribes for a new service or a service is being deployed. Different network elements have to be provisioned in each case.

As soon as a customer registers the first time for NGN utilization, several components at the session control layer, as well as at the application layer have to be provisioned. Amongst others, the IMS HSS has to be equipped with a new User

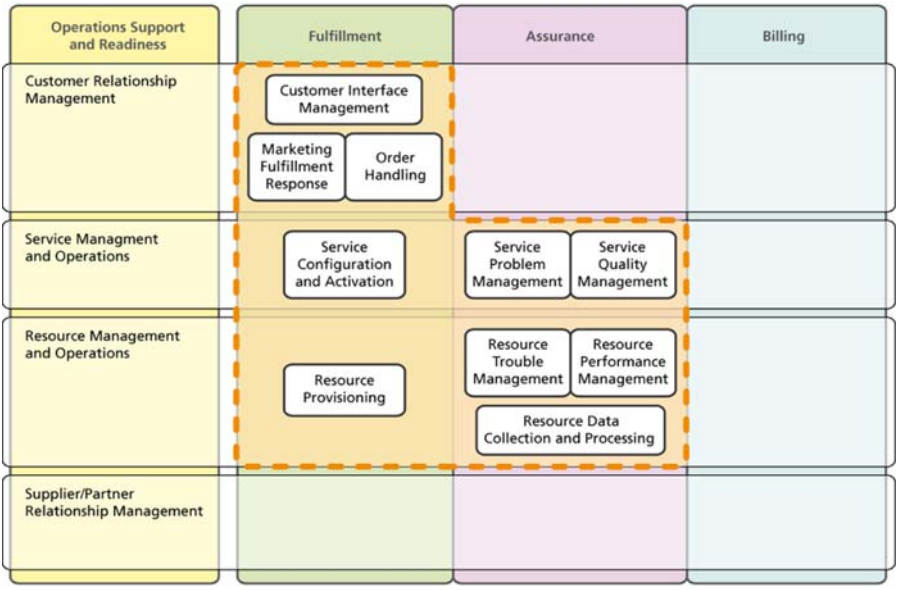

Fig. 6 Focused NBOSS operations: service fulfillment and assurance (eTOM [5] context)

Profile where for each subscriber authorization specific values, private and public Uniform Resource Identifiers (URIs), as well as an initial service profile are being stored. At the application layer, several components have to be provisioned upon registration of a new user. Subscriber specific charging rules and Service Level Agreements, address books as well as policies for the PEEM have to be set up.

As soon as a service is being deployed, similar distributed provisioning tasks have to be carried out. At the IMS level, the HSS has to be updated with a new service profile, where the initial Filter Criteria (iFC) for the specific services are stored. Many applications require service enabler inter-working, specific charging rules as well as service specific policies. Therefore, a complex workflow has to be processed again in order to activate a new NGN service.

Last but not least upon subscriber's subscription to a service, a similar row of processes has to care for the appropriate configuration of network elements in order to activate a specific service for a specific user.

Learned from the internet, the NBOSS offers subscribers a Web Portal for customer self order, where the customer can either register for initial usage of NGN services or can subscribe for further services. Similarly, the central NGN service broker upon generation of a new service composition triggers the NBOSS provisioning engine via OSS/J service order and OSS/J inventory APIs.

The NBOSS provisioning Engine, as shown in Fig. 7, utilizes the Service Provisioning Markup Language (SPML) [24] to administer required provisioning tasks on various session control layer and application layer network elements.

By doing so, the NBOSS approach for service fulfillment automates the process from customer self order to service configuration to resource provisioning to service activation.

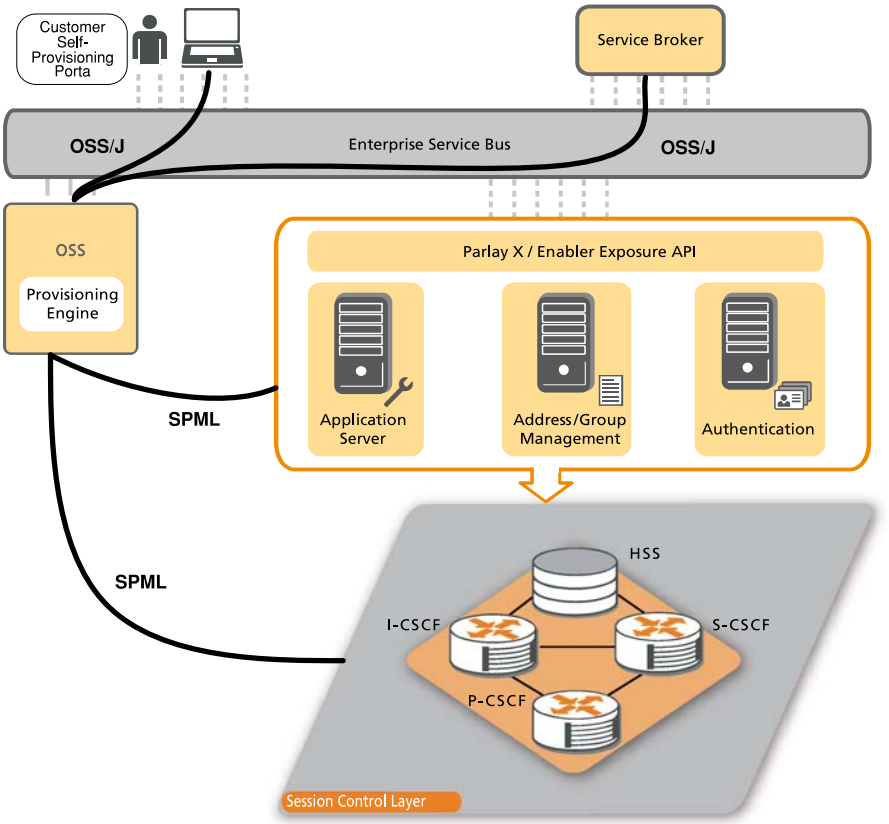

Fig. 7 NBOSS provisioning engine

4.2 NBOSS—Converged Service Assurance

While the NBOSS service fulfillment mechanisms could be unified by a single provisioning protocol and interface (i.e. SPML), adequate service assurance mechanisms require several more components to inter-work. Particularly it requires the monitoring of both session control layer (the SIP and Diameter plane of the IMS) and application layer (the SOA/Web Service domain for the SDP). IMS Clients, mobile end-devices as well as desktop user endpoints can trigger IMS services via SIP requests as well as via Web Service requests. The proper functioning of a service can frequently not be tested by conducting single SIP or single Web Service tests alone. A service as well as a service enabler like the XDMS [23] as shown in Fig. 8 exposes its services directly through SIP interfaces and often indirectly (via OSA/Parlay Gateways) through Web Services.

Only if both functionalities are simultaneously, periodically, proactively and passively being tested for, proper service functioning can be assured. Therefore, the NBOSS service assurance system, as shown in Fig. 9 utilizes network taps (for traffic sniffing), user endpoint emulators as well as traffic analyzers in a hybrid way.

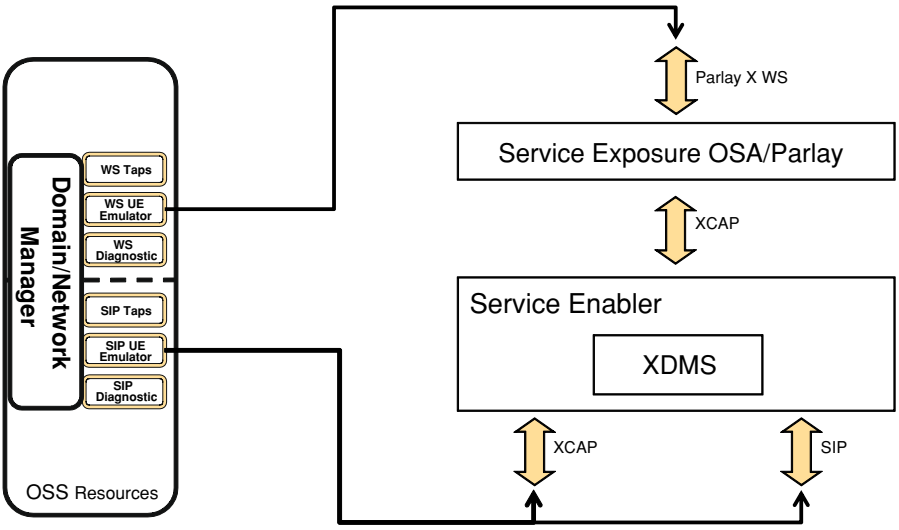

Fig. 8 Service assurance with proactive Web Service and SIP testing

The workflow of the Service Broker, here depicted as the OSS Central Processing Unit (CPU), spawns management processes for both domains. Via active and passive probing mechanisms the SDP components (service enablers as well as the central intelligences for service orchestration, the PEEM and the Service Broker), as well as the session control layer components (IMS core as well as the central intelligence for orchestration, the iFC based S-CSCF routing as well as the SCIM) are monitored. By doing so, the proper communication between these two domains, at the IMS Service Control Interface (ISC) can be assured.

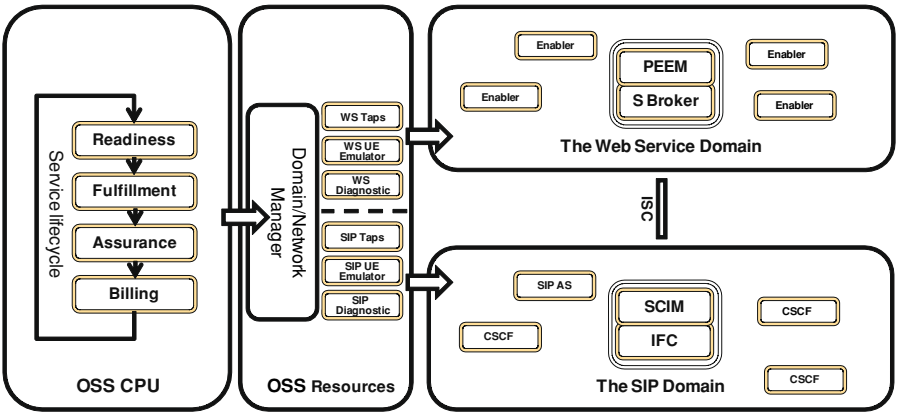

Fig. 9 NGN service assurance mechanisms for IMS and SDP

4.2.1 Active and Passive IMS Monitoring

For the session control layer, SIP user endpoint emulators periodically test IMS core functionalities and performance as well as SIP application-server functionalities and performance. Different emulated test users (with different service profiles) invoke different services by sending a variety of SIP test sequences (for example SIP INVITES, SIP MESSAGES, SIP SUBSCRIBE, SIP PUBLISH, etc). By doing so, the entire spectrum of SIP related network functionalities and services is periodically and proactively being tested for.

For passive monitoring of the session control plane, network taps are integrated at important interfaces, for example the Gm interface between User Endpoints and the P-CSCF as well as the IMS Service Control Interface (IFC) between the S-CSCF and the application plane. These network taps monitor the SIP traffic and, upon error detection, send alarm messages to the network management system.

4.2.2 Active and Passive Service Delivery Platform Monitoring

Similar to the monitoring mechanisms for the session control layer, the SOA based SDP with all its service enablers is being monitored in a proactive and passive fashion.

Active Web Service probing systems are periodically invoking Web Service transactions in order to check the availability and execution performance of service enablers as well as of composed services.

Passive monitoring of the SOA based SDP is being carried out at the ESB level, where all Web Services are being routed through. Via filtering and correlation mechanisms, each specific Web Service transaction can be supervised. Upon detection of malfunctioning or failures, the analyzer sends alarm messages towards the central fault management system.

4.2.3 Managing Service Enablers and Composite Services

Upon composition of a new service, the fault management process for service quality assurance is triggered as part of the workflow processes of the NBOSS Service Broker. Fault management is being conducted for the service as a whole as well as for its service components. Depending on the specification of the service (as specified in the WSDL-s), either SIP monitoring or Web Service monitoring or both monitoring mechanisms are being triggered. Via the OSS/J Service Activation API the fault management system receives either a SIP-URI and/or a WSDL for integration into the monitoring process. By doing so fault management processes are automatically triggered simultaneously to the actual service composition process.

5 Summary and Outlook

Managing NGNs is a complex task and requires a total mind-shift from stove pipe management systems to horizontal layered, unified architectures. In order to

decrease operation expenditures and to allow for rapid service creation and deployment, SOA principles, policy based network management principles, semantic service descriptions, information and data models, MDA principles as well as autonomic communication/computing mechanisms have to be utilized.

As it was shown in this document, Web Services not only emerge as the common vehicle of the internet, but also drive the convergence of telecommunication service exposure/composition, business processes and management processes. A SOA based workflow engine, which triggers service compositions, business processes as well as management (OSS) processes simultaneously was found to be a highly efficient mechanism not only to roll out NGOSS for NGNs, but also for the automation of the overall management processes.

In order to enable full plug and play capabilities of the described NBOSS system, generic information models for IMS/NGN services and resources are currently investigated. Not only will the process of service composition heavily benefit in terms of automation, but also the management of NGN service compositions can then be carried out more efficiently.

In the pursuit of improving the overall autonomy of NBOSS, there are currently several investigations being conducted that strive for enhanced closed control loops at the element management layer, as well as for the whole service delivery and management lifecycle. Inside the Autonomic Communication Forum's (ACF) Service Composability Management Working Group [20, 21], a new generation of self-healing, self-monitoring of NGOSS based OSSs for NGNs is currently being developed, allowing for the provisioning of more autonomous management infrastructures in the near future.

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