NGSON: Features, State of the Art, and Realization

Seung-Ik Lee and Shin-Gak Kang, Standards Research Center, Electronics and Telecommunications Research Institute

ABSTRACT

There have been several efforts to provide service-aware technologies in the networks, such as the service-oriented architecture and service delivery platform. These technologies were integrated with service overlay network (SON) infrastructure to support control and delivery of services over multiple network domains. However, SON has limitations in handling the increasing needs of a ubiquitous and dynamic environment of users and services. To provide better quality of experience to users in this ubiquitous and dynamic environment, next-generation SON (NGSON) was introduced to support context-aware, dynamically adaptive, and self-organizing capabilities in SON. In this article, we present an overall description of the concept of NGSON, and provide a comprehensive review of the recent standardization activities related to NGSON. By visiting our experiences in designing and developing a prototype for NGSON, the challenges and opportunities of NGSON are described.

INTRODUCTION

The proliferation of the Internet has removed geographical and temporal barriers for users to access value-added applications on a global scale, and service providers have faced complicated development and costly deployment of software to support the diverse requirements and environments of users. Service-oriented architecture (SOA) [1] was introduced to address this problem by defining how to integrate the services (or functions) distributed over the Internet for the production of applications. Based on the SOA principle, the service delivery platform (SDP) [2] was introduced, which takes on creation, execution, delivery, and control of services. Within this technology, a composite service can be orchestrated and composed of one or more component services that are distributed in different network domains. This capability allows service providers to have rapid and flexible development of their composite services by utilizing existing component services. While SDP has been of great interest to network operators due to new revenue opportunities through offering their service enablers, such as billing and messaging for thirrd-party service providers, the traditional network infrastructures lack support in the delivery of such services because they manage the service delivery and its quality of service (QoS) support, but only in their own domains (called a silo approach). To tackle this problem, the service overlay network (SON) [3] was introduced, which is employed as an intermediate layer to support creation and deployment of value-added Internet services over heterogeneous networks.

In the SON approach, an overlay network is built as a common infrastructure for delivery of multiple value-added services. The overlay network is constituted by strategically deployed nodes (called SON nodes), which are dedicated to provide service-specific data forwarding and control functionalities. The SON nodes are interconnected with the logical connections provided by different underlying networks. Within this infrastructure, a composite service can be created by providing its business logic (i.e., composite service specification), which defines the interactions among component services. On a request for the composite service, SON invokes each component service in the order defined in the given composite service specification and delivers the service data for the subsequent interactions with a certain QoS guarantees regardless of the operating network domain of the component service. However, the SON approach has faced an intrinsic limitation to handling of the diverse and dynamic environments of users, services, and networks which are inherent characteristics of the recent trends in computing technology.

To address these limitations, next-generation SON (NGSON) [4] was proposed by the IEEE P1903 Working Group (WG). As an instantiation of SON, NGSON provides a framework for control and delivery of composite or component services over diverse IP-based networks (e.g., legacy IP network, P2P, and IP multimedia subsystem, IMS) with QoS support by the underlying networks. The main contribution of NGSON is to accomplish context-aware and dynamically adaptive features in the service control and

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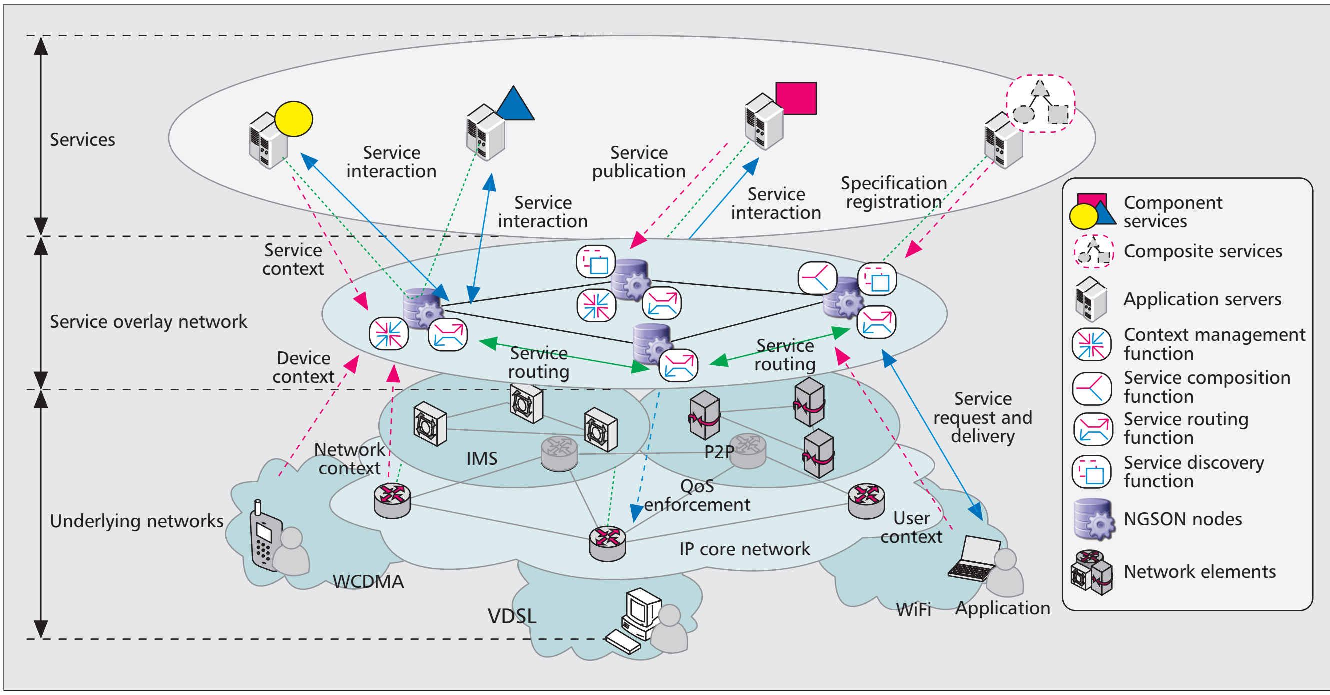

Figure 1. *A network model of NGSON.*

delivery functions of SON including autonomous management methodology for self-organization of the network. Using these advanced features of NGSON, the services can be provided to end users with better quality of experience (QoE) by customizing and adapting the service configurations to the dynamic context of users, devices, services, and networks. Due to its attractive features in dynamic and heterogeneous environments, NGSON is one of the hot topics in service-oriented networking technologies.

In this article, we present the basic concept of NGSON with its basic and advanced functionalities, and provide a comprehensive review of recent standardization activities related to NGSON. Then we present our experiences on a proof-of-concept realization of NGSON with a detailed system architecture and a prototype implementation. Finally, we conclude the article by addressing some technical challenges and a future roadmap for NGSON.

Overview of NGSON

Basic Functions

As an intermediate layer between services and transport networks, NGSON controls the interactions among distributed services with network QoS support in delivering the service data for the interactions. For this, NGSON provides

- The service control functions, which discover and execute the requested services that best satisfy the user's requirements
- The service delivery functions, which support the transport of the service data

For service control, NGSON manages the service information published by third-party service providers. When an end user requests a service, NGSON exploits the service publication information to discover an appropriate service instance that satisfies the user's requirements on the functions and properties of the target service. Based on the binding information of the selected service instance, NGSON routes the service request to the target service and invokes it for service interactions. NGSON also orchestrates a series of the service interactions among one or more component services as specified in a composite service specification. For the service delivery, NGSON extracts the requirements for service- and transport-related QoS to enforce corresponding QoS control mechanisms of the underlying networks. NGSON also provides a content delivery support with caching or storage resources especially for content-centric services. Figure 1 presents a network model of NGSON that implements the service control and delivery functions of NGSON.

Service Discovery and Negotiation — In order to ease the service requestors' burden of discovering and selecting a service instance that provides the requested function, the service discovery and negotiation function takes over the job using the service information (e.g., functional description and QoS capabilities) published by service providers. The service discovery and negotiation function first discovers the candidate services by filtering the published services with the given functional requirements. Then it further selects one of those candidate services by negotiating for better QoS or user expectations.

Service Routing — The essential function of NGSON is to route a service request received from an end-user or a service to an appropriate service instance along the overlay network. A service request contains the functional requirements of the target service and input data to be delivered to the target service for interactions. The target service can be specified with either

If an abstract component service type is specified in the service specification instead of a concrete component service, an appropriate component service instance is determined by the service discovery and negotiation function in advance.

functional description (i.e., service type) of the expected service or a concrete service instance. If only the abstract service type is given in the service request, the service discovery and negotiation function selects the best candidate service instance instead. Consequently, the service routing function binds and invokes the target service instance to forward the service request. A response to the request from the target service is forwarded back to the service requestor by the service routing function.

Service Composition — NGSON also takes a role of aggregating the interactions among multiple component services for a single composite service. When an end user or a service requests a composite service, this service request is redirected to the service composition function, which manages the service specifications of composite services. According to the service specification of the target composite service, the service composition function orchestrates the service chains by executing and invoking every component service instance via the service routing function. If an abstract component service type is specified in the service specification instead of a concrete component service, an appropriate component service instance is determined by the service discovery and negotiation function in advance.

Transport QoS Control — To support service delivery for service interactions between an end user and a service or among services, NGSON provides the transport QoS control function to fulfill the QoS requirements of the service requestors. The transport QoS control function extracts transport-related QoS requirements from a service request and enforces the underlying networks to comply with the given QoS requirement in the transport of service interaction data.

Content Delivery Support — For content-centric services (e.g., video on demand [VoD]), NGSON provides the content delivery function to efficiently handle a large volume of content data during service delivery. The content delivery function manages storage resources for caching the content from services or end-users and provides different content distribution mechanisms (e.g., multicast and peer-to-peer) according to the service types.

Advanced Features

With the current trend of pervasive and ubiquitous computing technologies, user environments (i.e., context) are highly diverse in terms of users, devices, and networks. Since those environmental factors may vary per user, end users expect different configurations in the service control and delivery even for the same service. The user's expectation also dynamically changes as the environment does due to the changes in user location, status, and so on. The heterogeneous and dynamic characteristics are not only of the user environment but also of the service and network environments. In order to cope with these heterogeneous and dynamic environments, NGSON employs context-aware and dynamically adaptive features in the service control and delivery functions, including self-organizable features in the management of an overlay network.

Context Awareness — Basically, the service control and delivery functions perform based on the explicit user requirements specified in a service request to discover and select the component services and to execute a composite service by instantiating its service chain. In NGSON, these functions further adapt to the context of users and services. In the service discovery and negotiation functions, several candidate service instances filtered by a functional requirement are evaluated to select one of them by different criteria, such as availability or cost, which may vary with the context. The service composition functions also exploit the context to select a best-fit service instance for the requested service type during the service chain instantiation. The context is classified as four different classes according to the relevant physical entities to the service interactions: service, user, network, and device context. The context is obtained by processing and aggregating the raw context information collected from different context sources, such as user profile services, underlying networks, and terminal devices.

Dynamic Adaptation — During service control and delivery, NGSON monitors and detects changes in the user and service environments to adapt the configurations of the service control and delivery to provide seamless service interactions in terms of a session, transport QoS, and a user's QoE. Those dynamic environments include context and service status such as network location, current workload, and availability of the service. When unavailability of the target service instance is detected, for example, NGSON replaces the failed service instance with another one by rerouting the service request. If some context changes so that different user QoE is expected, NGSON can optimize the configuration of the service interactions by reselecting the target service instances with different evaluation criteria.

Self-Organization — The main objective of the self-organization feature is to minimize the administrative efforts in the management of an overlay network and its operations by providing an autonomous management capability for initial configuration, optimization, and failure recovery of the network. While this feature is another type of dynamic adaptation in NGSON, its adaptation target is not the service interactions but the configurations of the internal resources of NGSON such as the functional components (i.e., instances of NGSON functional entities) and NGSON nodes. With this feature, an NGSON node can be dynamically deployed and organized into a service overlay network without any human interaction. On top of the NGSON nodes deployed, a functional component can be autonomously activated or deactivated according to the workloads or status of the functional components and NGSON nodes.

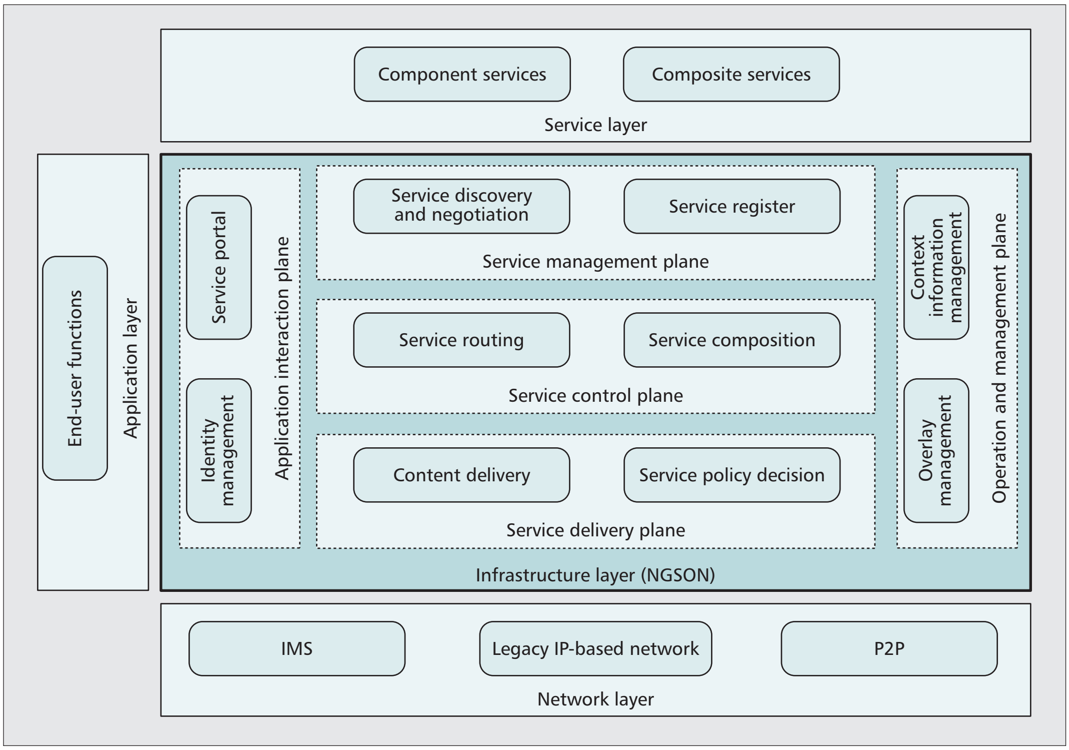

Figure 2. *A layered view of NGSON functional architecture.*

With the increasing interest in providing an infrastructure of SDP and SON, several standardization activities have been conducted to define their own frameworks and unified interfaces to interact with third-party service providers in different network domains.

FUNCTIONAL ARCHITECTURE

Figure 2 presents a layered view of the NGSON functional architecture that describes the relevant layers and NGSON functional entities (FEs) in the infrastructure layer of the framework.

In the NGSON functional architecture, there are three external entities: services, end-user functions, and underlying networks. The end user functions utilize the NGSON functions to access the base or composite services via the service portal FE. A base service handles the service requests from the end-user functions or other services via the service routing FE. The composite service, on the other hand, provides its service specification to the service composition FE for service brokering and instantiations. In order to provide QoS-controlled service delivery, NGSON exploits the underlying networks to enforce the QoS requirements via the service policy decision FE. Note that NGSON provides interoperability with other NGSON instantiations in different domains, but it is still an open issue.

To handle a service request from an end user or a service, the service routing (SR) FE discovers an appropriate target service by interacting with the service discovery and negotiation FE. The SR FE further interacts with the service register FE to retrieve the binding information of the target service including other dynamic service information such as service status and performance. Consequently, the SR FE routes the service request to the target service instance. If the requested service is determined to be a composite service, the service composition FE takes responsibility for the orchestration of the component services given in the service specification. Further invocations and executions of a chain of the component services are still handled by the SR FE. For service delivery support, the service policy and decision FE takes the role of a transport QoS control function and the content delivery FE manages the content distributed for the service interactions. The identity management FE complies the security considerations on the accesses of end-users and services.

The context information management (CIM) FE aggregates and processes the context data collected from various context sources to determine the high-level context information. This context information is provided to other FEs for the context-aware decisions in the service control and delivery operations. CIM FE also monitors the context changes to support the dynamic adaptive operations of NGSON. If the context changes are detected, CIM FE informs the relevant FEs to be able to adjust their configurations or operations. The overlay management FE is the heart of self-organizing capability of NGSON which manages NGSON nodes and FE instances in an overlay network. It autonomously assigns a role of an NGSON node by activating or deactivating an FE instance on it according to the status of the nodes and FE instances in terms of availability and performance.

THE STATE OF THE ART IN STANDARDIZATION ACTIVITIES

With the increasing interest in providing an infrastructure of SDP and SON, several standardization activities have been conducted to define their own frameworks and unified interfaces to interact with third-party service pro-

Capabilities	IEEE NGSON	ITU-T NGN-SIDE	ITU-T OSE	ATIS SON	TMF SDF	OMA OSE
Main focus	Context-awareness, dynamic adaptation, self-organization	Service integration within NGN	Service integration within NGN	Information and data of service enablers	Service lifecycle management	Policy enforcement, Parlay and IMS support
Context-awareness	Yes	Yes	No	No	No	No
Dynamic adaptation	Yes	No	No	No	No	No
Self-management	Yes	No	No	No	No	No
Service creation support	No	Yes	Yes	No	Yes	No
Content delivery support	Yes	No	No	No	No	No
Security support	Yes	Yes	No	No	Yes	No
Service adaptor	No	Yes	No	No	No	No
Network integration	P2P, IMS	NGN	NGN	—	—	IMS, Parlay

Table 1. *A comparison of the standardization activities for SDP and SON.*

viders in different network domains. In this section, we provide a comprehensive survey of the current standardization activities in the area of SDP and SON.

OMA Service Environment

The Open Mobile Alliance (OMA) has proposed the OMA Service Environment (OSE) [5], a logical architecture that provides a common structure and rule set for interacting with OMA enablers, services, and resources. Its main function is policy enforcement, which orchestrates the service execution by applying predefined policies on a service request. It also provides the methods to compose or delegate to OMA enabler implementations, which abstract the underlying network technologies using interface adaptors, especially with IMS and Parlay.

TMF Service Delivery Framework

The TM Forum has been working on the standardization of a service delivery framework (SDF) [6], which defines a framework that supports integration of service enablers required for a service lifecycle operation. The framework includes the service enablers and applications; service lifecycle operation support for service creation, composition, provisioning, and execution; and management of the integration infrastructure. Its featured capability compared with the other activities is the service lifecycle management capabilities, including service provisioning, monitoring, charging and billing, and trouble resolution.

ATIS Service Oriented Network

The ATIS SON Forum [7] has been working on the standardization of SON since 2009 (the work scope was adopted by the Cloud Service Forum in 2011). Its main objective is to expose the network resources and capabilities (i.e., service enablers) of a telecommunications company (telco) to web services by standardizing the methods to reuse service enablers provided by different network domains. Its target areas of standardization include service creation, common service enabler description, common policy reference model, and so on. Regarding these topics, the characteristics of service enablers and their common data models have been mainly studied to identify the common application programming interfaces (APIs) of service enablers. A service catalog function for management of the service enabler information is another issue under considerations.

Open Service Environment in NGN

In the International Telecommunication Union — Telecommunication Sector (ITU-T), there are two different approaches to SDP: NGN-Service Integration and Delivery Environment (SIDE) [8] and Open Service Environment (OSE) [9]. The main objective of both approaches is to standardize the service integration framework within the next-generation network (NGN), which provides reusable capability and resources of the NGN as a telco-operated infrastructure. NGN-SIDE covers most of the capabilities of OSE including service creation and development

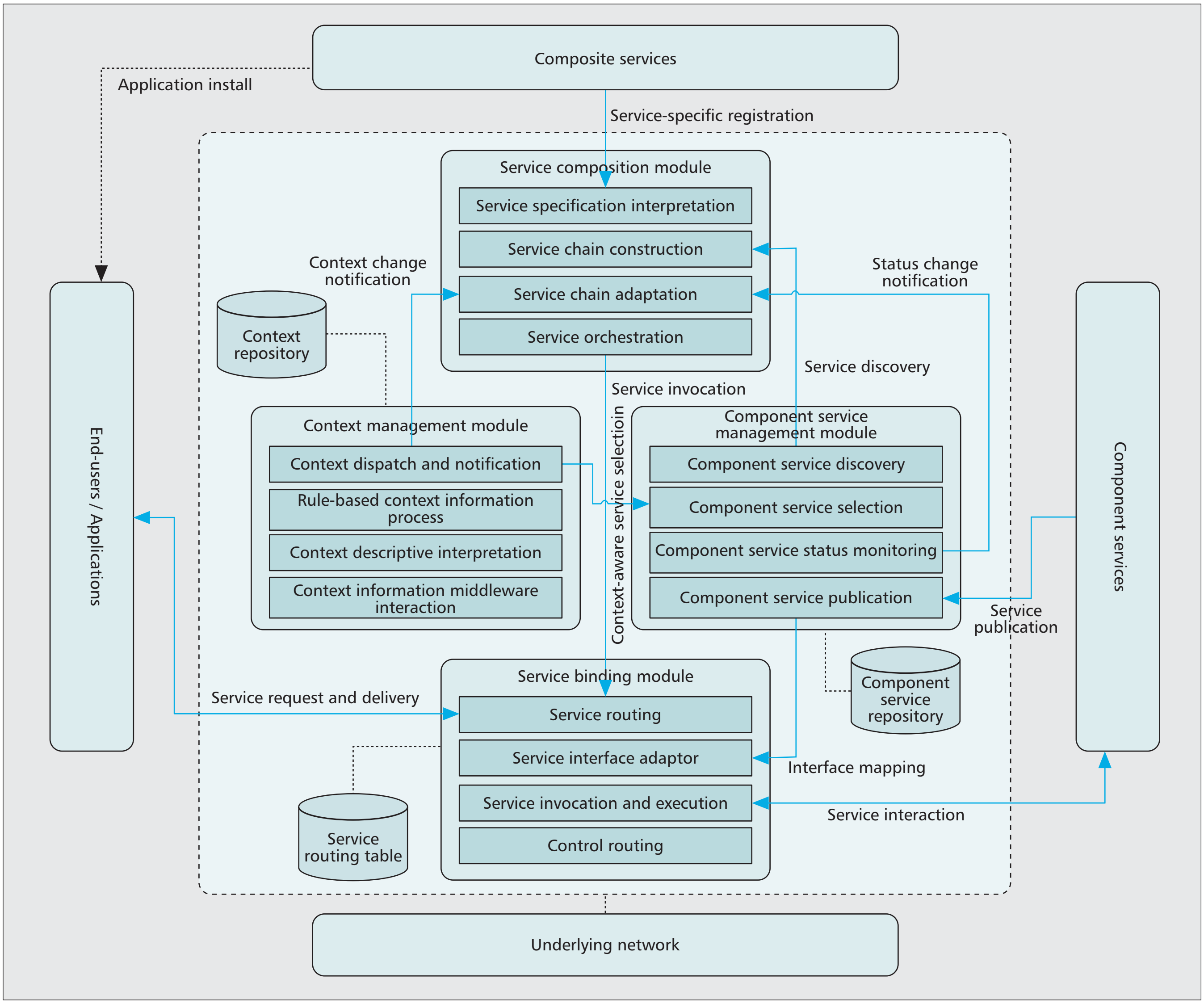

Figure 3. *System architecture of the implementation.*

support, service execution, and service delivery management capabilities. Additionally, NGN-SIDE incorporates an adaptation layer for resource brokering. Using this capability, the interactions among different types of resources offered by NGN or non-NGN can be adapted to be seamlessly integrated by applications. Compared to the traditional standardization activities, the featured capabilities of NGN-SIDE are context management to support heterogeneous user environment and content management to support content-centric services.

Table 1 presents a brief comparison of the standardization activities aforementioned including NGSON.

Realization of NGSON

In this section, we describe our realization of NGSON to give a proof-of-concept of its aforementioned functionalities. Within this realization, we have designed a system architecture with basic functions compliant with those of NGSON's functional architecture. A prototype implementation is also given as a demonstration, simplifying the details of the functions.

System Architecture and Design Considerations

This system architecture focuses on the composition and execution of composite services by aggregating the interactions among component services, management of component service information, and context management. Figure 3 presents the system architecture of our implementation.

The basic operations of the implementation are almost the same as those of NGSON described earlier. To build a service chain based on the given composite service specification, the service composition module requests the component service management module to discover and select the appropriate component service instances based on context. According to the built service chain, the service binding module invokes and executes the component services. We also advocate the advanced features of

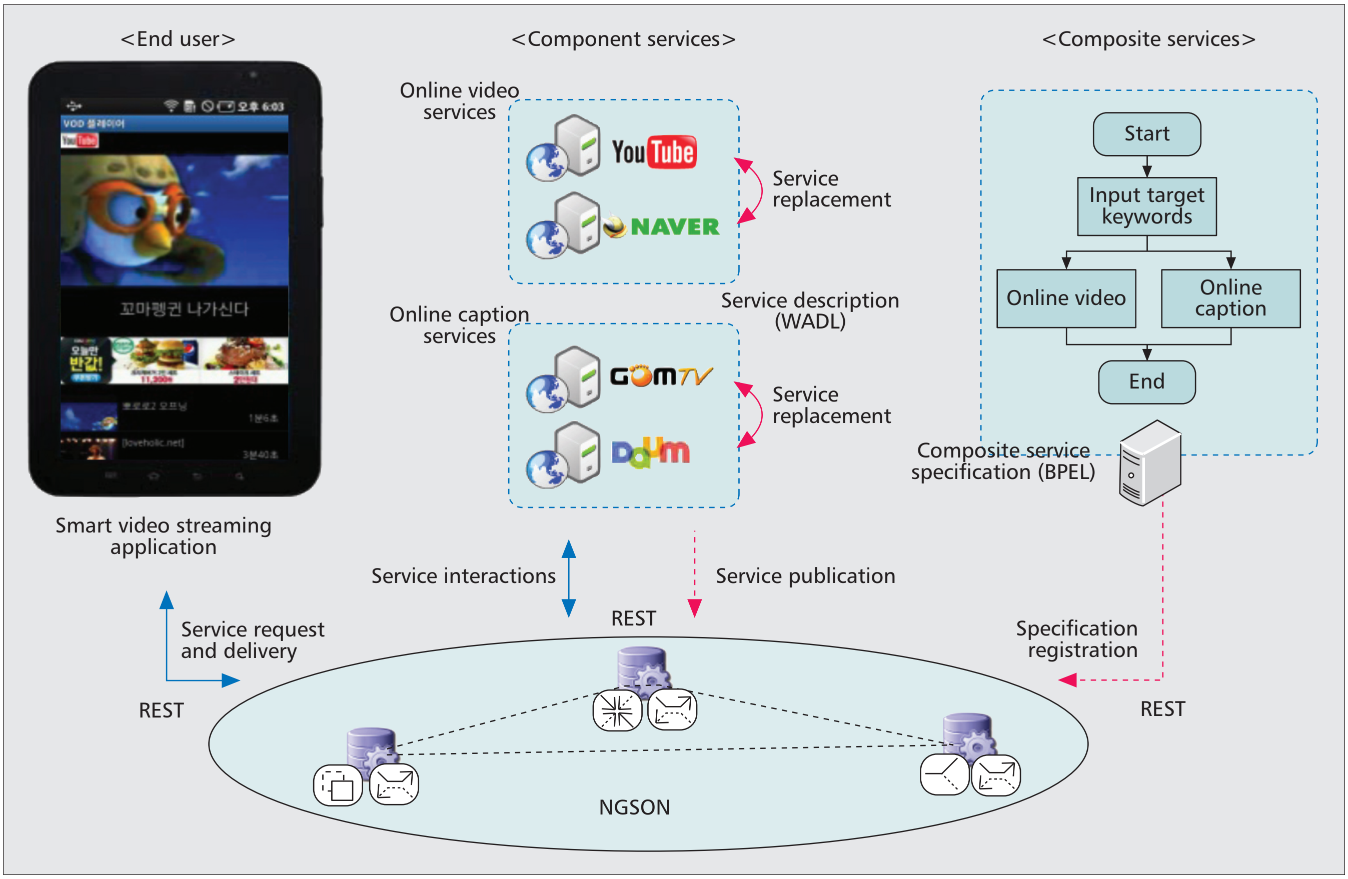

Figure 4. *A prototype implementation and demonstration.*

NGSON. In order to make the notion of the features practical, however, we have devised specific mechanisms to deal with the heterogeneous and dynamic environments of users and services.

The system supports context-aware service selection by evaluating the candidate component services on different evaluation metrics per context. We use six evaluation metrics: availability, reliability, throughput, cost, security, and proximity. Based on the user and service context, one or more evaluation metrics are selectively used for the component service evaluations. The selected metrics are then further measured per component service instance by the context management module. For example, if an end user in a secured office requests a composite service, the corresponding component service with the highest security level is selected according to the user context. In order to implement the dynamic adaptation feature of NGSON, the system supports the simplified adaptation scheme, which replaces a failed component service with another one in an active state. The status of the component services are monitored by the service management module, and a failure is reported to the service composition module to make it adapt the service chain by replacing the failed component service. Seamless adaptation of the service chain in the middle of a session is currently an open issue. This system does not fully implement the self-organization feature of NGSON defined in [4] but provides the control routing function, which manages the interaction messages among the distributed functional modules. For this operation, the control routing function manages the IP addresses of all NGSON nodes and deployed functional modules in the nodes. When an NGSON node or a functional module is newly added and deployed, the control routing modules are informed of the location or capabilities of the new nodes, including the deployed functional modules. If some of the nodes or functional modules are in failure or overloaded, the control routing is also informed of new target modules in different locations.

Prototype Implementation

As depicted in Fig. 4, we have developed a prototype implementation that includes the functional modules on NGSON nodes and a sample application on the end user's device.

We have used commercial web services as the component services to show the simplicity and viability of the proposed architecture. The prototype implementation uses Business Process Execution Language (BPEL) to describe the composite service specifications; Web Application Description Language (WADL) to specify the service functional descriptions [10]; and Representational State Transfer (REST) to deliver the service interaction data. The NGSON functional modules also provide the REST interfaces for reusability, and were implemented in Java 1.6 on the Apache and Tomcat platforms in the Windows XP environment. The sample application was also implemented in Java 1.6 and runs on Android 2.2 on the Samsung Galaxy S and Galaxy Tab.

We have tested the prototype with an example scenario of a smart video streaming composite service that provides a streaming video of the requested content with online captioning. When the end user starts the corresponding application, a service request for the composite service is delivered to the service binding module, and then the service composition procedures are initiated. To instantiate the online video component service, one of the component service instances published to the component service management module needs to be selected by evaluating the candidate ones. In this example scenario, throughput is selected as the evaluation metric according to the composite service context, which is sensitive to the performance of the video streaming component. By emulating a failure of the selected component service instance during the session, the service chain successfully adapts by replacing the failed one with another component service instance selected. A pause in video playback of a few seconds during the service chain adaptation was encountered in the test, but it is still an open issue to support seamless adaptation in NGSON.

Concluding Remarks

In this article, we have investigated the motivation of NGSON by revisiting the history of SOA, SDP, and SON. We have briefly reviewed the main features of NGSON and compared them with the other approaches by surveying the state-of-the-art standardization activities. Through comprehensive study of the standardization activities, we found that their service-aware capabilities offer many attractive benefits to end users and service providers, resulting in high demand in the market. With a demonstration of the prototype implementation of the NGSON features, we also found that the NGSON functionalities are practical and efficient to handle the future trends of dynamic and heterogeneous environments of users and networks. The featured capability of NGSON will obviously encourage the network operators (or telcos) to deploy such infrastructure so that they can create a new business area to increase revenue [11]. As well as network operators, application developers can also get lower development cost because NGSON orchestrates the service chain given by the service specification in a manner that is context-aware and adaptive to dynamic environments of services and users.

While the conventional SON approaches including NGSON have focused on service control and delivery, content delivery support needs to be further considered since multimedia services are being used more and more. A few content-aware approaches using peer-to-peer (P2P) overlay were introduced to address the content delivery issues, but have failed because they cannot exploit the underlying network information that actually bears the data flows. As proposed in NGSON, the infrastructure can provide intermediate cache and storage resources. But this approach just helps ease the burden of content providers and their access networks without providing the essential resolution of the traffic optimization problems.

Within NGSON, services can easily be created by composing other component services, and the newly created component services can also be easily exposed by service publication. Thus, user-created services will be the next promising notion after the paradigm of user-created content. For this new paradigm, NGSON can take the role of a service store, which distributes the component services on sale. Another opportunity to the success of NGSON is the future network researches. NGSON capabilities are currently laid at the intermediate layer over the transport networks. Within the effort of developing future networks, there have been some expectations to include service-aware capabilities into the network elements. With a rationale of the clean-slate design of the future network, this approach is reasonable and attractive for making the network service-oriented.

Within the effort of developing future networks, there have been some expectations to include service-aware capabilities into the network elements. With a rationale of the clean-slate design of the future network, this approach is reasonable and attractive for making the network service-oriented.

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Biographies

SEUNG-IK LEE (seungiklee@etri.re.kr) received his B.S. degree in computer science and engineering from Handong University, Korea, in 2000, and his M.S. and Ph.D. degrees in computer science from Korea Advanced Institute of Science and Technology (KAIST) in 2002 and 2009, respectively. He joined the Standards Research Center of the Electronics and Telecommunications Research Institute (ETRI), Korea, in May 2009, and has participated in the standardizations of IPTV, multicast, and NGSON in ITU-T SG13, JTC1/SC6, and IEEE P1903. His research interests include IPTV, mobile multimedia transport, and future networks.

SHIN-GAK KANG (sgkang@etri.re.kr) received B.S., M.S., and Ph.D. degrees in electronics engineering from Chungnam National University, Daejeon, Korea in 1984, 1987, and 1998, respectively. He joined ETRI in 1984 and is currently director of the Smart Communication Standards Research Team in the Standards Research Center. He has actively participated in many international standards bodies such as ITU-T SG11, SG13, SG16, JTC1/SC6, and IEEE NGSON as Rapporteur, Convenor, and Editor. His current research interests include multicast, IPTV/smart TV, and service overlay and content networking.