

QoE-aware Dynamic Service Composition for Immersive Media-oriented Services

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Abstract

The immersive media is defined as an integrated representation of diverse media components that can offer presence and immersion to the participating users. In this paper, based on the understanding that current Internet is fundamentally limited in supporting upcoming demand for QoE(Quality of Experience)-aware dynamic service composition, a new type of integration framework is explored to support immersive-media-oriented services of future Internet by flexibly exploiting the virtualized high-performance networks and computing resources. In this on-going effort of designing the media-oriented service framework for Future Internet, we are attempting to take a holistic view of future Internet design by allowing users to compose service template and coordinate networking and computing resources so as to meet user's requirement.

1. Introduction

Immersive media-oriented services based on multi-modal integration of audio/video/graphic/haptic media are becoming popular by connecting the convergence-style networked-devices with Gbps high-speed networking. As an example for ultimate type of services realized by Future Internet [11], we can envision a ubiquitous and smart collaboration environment where every participant can enjoy any kind of immersive-media-based collaborative services of his/her choice [14]. For media-oriented service composition, it is very important to ensure service extensibility, service manageability, and service availability [12]. Thus, the collaboration environment should support dynamic service composition in order to reflect the dynamically-changing context of participating users and their surroundings. However, due to the diverse demands for immense amount of computing/networking resources, it is extremely difficult

to satisfy the user's QoE (Quality of Experience) over current Internet, where only tightly-coupled integration of services are possible [13]. Note that current Internet is being criticized for its fundamental limitations in many aspects including the architectural flexibility for dynamic service composition.

Thus, in our on-going effort of designing the media-oriented service framework for Future Internet, we are attempting to design a new type of service composition framework by flexibly exploiting the virtualized high-performance networks and computing resources. That is, as one of many other considerations, the targeted service framework of Future Internet is being designed to support the QoE-aware dynamic network provisioning for immersive media-oriented services. We are attempting to allow users to compose service template and coordinate networking and computing resources so as to meet user's requirement. That is, to reflect the user-centric QoE-awareness, the proposed framework attempts to identify loosely-coupled interfaces for flexible (and adaptive) yet manageable (and efficient) service compositions to realize user applications.

This paper is organized as follows. In Section 2, we introduce the QoE-aware service composition for future Internet by focusing on immersive media aspects. Preliminary framework design is discussed with open issues in Section 3, followed by conclusion in Section 4.

2. QoE-aware Dynamic Composition for Immersive Media-oriented Services

Fig. 1 shows the general approach for dynamic service composition. We locate the conceptual entity named as service broker between the services and users. Note that we prefer to use term 'service broker' rather than 'service provider', because the service consist of several components and these components are discovered, managed, and composited by the service broker before providing the complete service to users. The service broker discovers and composes dynamically generalized

service components by considering the requirements of each user when the user requests the service. A generalized service can be defined by describing: 1) the function it performs, 2) the interfaces it presents to other services, 3) any properties of the service that affects its relation with other services [5]. The composited services consist of several service components loosely coupled via generic service interface like SOA (Service Oriented Architecture) [2]. Since each service component is loosely coupled, the service broker can easily modify the whole service by changing the specific service components and reuse the service components to compose other services.

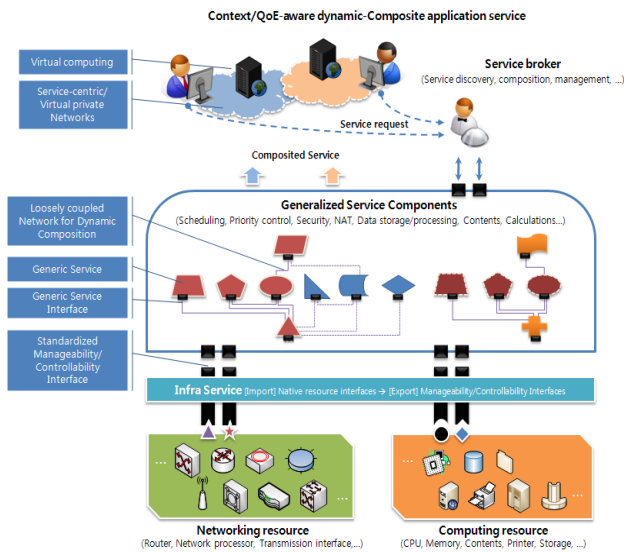


Figure 1. Dynamic service composition.

Also, the immersive media is defined as an integrated representation of diverse media information that can offer presence and immersion to participants. The immersive media-based services can be implemented as the diverse composition of media creation, processing, storing, and transmission, especially in multi-dimensional media format including the sense of sight, hearing, and touch feeling (i.e., haptic). Let us present a simple scenario showcasing some of the capability of the proposed service composition. We envision a ubiquitous and smart collaboration environment where every participant can enjoy any kind of collaborative services of his/her choice in high quality [3]. The collaboration environment should be able to represent the context of user (as well as environment) and satisfy the required QoE. For that, the service broker first discovers available service components that match the user's service function requirements (e.g., media capture, compression/transport, and display service). For example, we can implement a decentralized service discovery using the distributed hash table (DHT) system. Second, it checks statistical QoS/QoE condition, networking and computing resource availability (e.g., CPU, memory, available bandwidth, and delay), and inter-service dependency/commutative

relations to select qualified service components. In order to guarantee the user's QoS, the service components are needed to maintain the consistency of QoS between the current and next-hop-candidate service components. The immersive media node provides various type of media services, which makes it essential to check the QoS consistency between connected service components[4,5]. Then, the service broker selects the adequate service based on network and computing resources and composes selected service using service composition algorithms [4, 6-8]. For example, the media transport service is implemented by a various type of method such as 'DV (~30Mbps)/HDV (~25Mbps)' and uncompressed HD (~1.5Gbps)' transport system. Therefore, we have to choose adequate services based on the availability of networking and computing resources, since the requirements of each service are different. In addition, if user wants to check the condition of underlying network and transport system, the monitoring service can be added dynamically. Finally, the service broker needs to manage the service. In SON (Service Overlay Network), a highly dynamic service system is required compared to the IP network infrastructure because, unlike routers, hosts can dynamically join or leave SON over long timescales. Therefore, the service composer provides: 1) initial service composition, which can compose a service node in the discovered service template using qualified service link and 2) dynamic service composition, which can dynamically re-compose the service path or use alternative backup service path to recover from service outages and QoE violation.

Several existing works address the multimedia service composition problem. The SAHARA project [8] addressed the fault-resilience problem in wide-area service composition and the adaptability problem in service composition is addressed in the CANS project [9]. The SPY-Net [10] framework addresses the problem of resource contention while finding a multimedia service path. In the Gaia project [2], the QoS consistency and load partition issues for composing service path are addressed for ubiquitous computing environments. In particular, QoS-aware service composition based on overlay network mostly concentrates on the area of multimedia. In [5, 11], a QoS-assured infrastructure of service composition was brought forward to map service composition requirement into the routing in SON and to provide the end-to-end QoS assurance and load balancing. These service composition schemes can be used to compose SON for immersive media-oriented services. However, prior works are not enough to support immersive media since they only consider QoS parameters like delay and bandwidth. Service composition for immersive media-oriented services has to reflect the parameters of space, human feeling, and media itself.

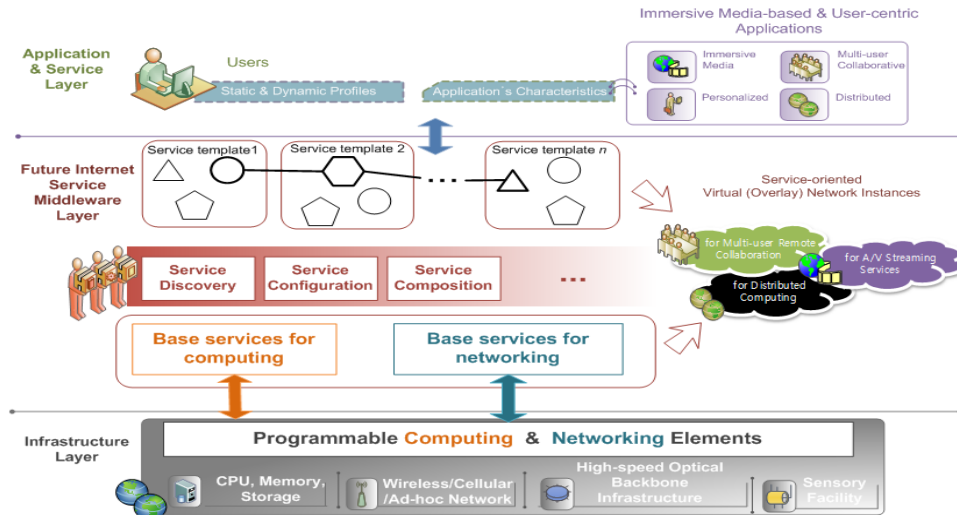


Figure 2. QoE-aware dynamic composition framework for immersive media-oriented services.

The infra services play an important role in making the standardized manageability and controllability interfaces to access the heterogeneous resources. The infra service has to understand and maintain the whole type of native interfaces as in the computer OS (operating system) that has to keep all of drivers of installed devices to maintain the system. The infra services import the native resource interface and export these in the standardized form. For standardized manageability and controllability, the infra service have to solve the issues such as extensibility, adaptability, fault-tolerance, responsiveness, resource heterogeneity, virtualization (or isolation), scalability, and security concerns that are caused by heterogeneous resources, varying resource conditions, and multiple administrative domains.

3. Preliminary QoE-aware Dynamic Service Composition Framework

To guarantee the QoE for immersive media-oriented services (or applications) to the participants, we are tentatively building a QoE-aware dynamic service composition framework illustrated in Fig. 2. In this framework, we try to take a holistic view of future Internet design by allowing users to compose service template and coordinate networking and computing resources so as to meet user's requirement. The proposed framework was guided by following goals.

- 1) **Flexibility and scalability:** Unlike the strict layering and tight integration, the proposed framework has to support the interworking flexibility and scalability by loosely coupling via generic service interface. The major feature of immersive media is combination of diverse service components. Therefore, to support immersive

media, the proposed framework has to easily combine the service components and extend new services.

- 2) **QoE-aware service composition:** The proposed framework has to be QoE-aware that can understand and respect other's policies, performance levels, security requirements, service-level agreement (SLA) stipulations, and so on. These features can be achieved by decoupling application services and network services. It reduces the complexity of network services management and control, especially in terms of QoE management and control.
- 3) **Exploiting network and computing resource:** As explained before, the networking and computing resources are exported through standardized interface as the services. Thus, service composition has to reflect this for QoE-aware service composition since the resource status can affect the service composition quality. Moreover, the exported services should be monitored and managed for stable and efficient service offers.

For this, one of the candidates is *virtualized* service overlay network (vSON). Note that vSON is regarded as one of promising approaches to meet the various user requirements. In vSON, each node provides not only application-level data routing but also a set of value-added services. Service composition in vSON has emerged as a cost-effective approach to quickly creating new services. However, existing SONS only consider simple QoS parameters like CPU, bandwidth, and latency. These are not enough for immersive media-oriented services that depend more on environmental parameters. For immersive media-oriented services, vSON has to

reflect more parameters related to space, time, human feeling, and media itself.

As a related SON-based service composition, in SILO[5], they propose a networking framework that consists of building blocks of fine-grain functionality, explicit support for combing elemental blocks to accomplish highly-configurable complex communication tasks, and control elements to facilitate cross-layer interactions. Regarding the service composition, SILO and proposed framework share similar goals. SILO however only considers functional blocks as service components unlike proposed approach.

Another example, SpoVNet[10] enables flexible, adaptive, and spontaneous provisioning of application-oriented and network-oriented services on top of heterogeneous networks. SpoVNet supplies new and uniform communication abstractions for future Internet applications. The SpoVNet approach is different from existing pure peer-to-peer overlay approaches in two aspects. First, it allows using cross-layer information for performance optimizations. Second, they consider the user of optional SpoVNet-supporting nodes in the infrastructure to increase the efficiency and performance of the communication. Like SILO, SpoVNet also considers executable applications as service components. However, it is expected that the core algorithms of these service compositions can be recycled for proposed service composition.

In this paper, we provide a simple description of interfaces required in the QoE-aware dynamic composition framework. The descriptions focus on composing the services and managing the resources. In Fig. 2, at the infrastructure layer, the resource elements are managed directly through their native manageability interfaces (for discrete resources, these are usually CIM/WBEM, SNMP). To hide the heterogeneity, the base services for the computing and networking resources at the service middleware layer, expose standardized manageability interfaces for the service to use, while communicating with its associated resource through the resource's native interfaces. For this, the base services have to interpret whole types of native resource interfaces by maintaining the device drivers to handle each of devices installed. This manageability interface has functionality such as configuring, controlling (i.e., setting the resource state), monitoring (i.e., obtaining the resource state including events) of resources associated with the services. Finally, the composited services at the service layer should be irrelevantly composed w.r.t. the lower layer. The generic service interfaces provide the common way to access the services as in SOA. Each of services exposes his capabilities including data format and protocols used for service access. The service provider then seeks and interconnects the services through the generic service interfaces.

We consider two major approaches in integrating the notion of SON and the virtualization to accomplish the QoE-aware dynamic service composition via the vSON.

First approach is radical in which all of computing and networking infrastructure are rebuilt so that they could be divided and provided to the users in a fine-granular form. Each resource is treated like a service and the composited service provided to the specific user is absolutely isolated with others. Second approach is moderate, where current SON only provides the data-centric routing between the services. We can start from isolating each of data flows as in that the PlanetLab utilizes the 'netfilter' to isolate data flows from different slices. We then extend the scope of the isolation in stages by utilizing the middleware (ex., Globus, UCLP) and providing the relatively fine-grained resources (ex., storage, memory, network bandwidth) to the users. We will discuss about which approach is the best to accomplish the QoE-aware dynamic service composition framework later.

4. Conclusion

To ensure service extensibility, service manageability, and service availability, we explore a new type of media-oriented service composition framework for Fugure Internet. The proposed service composition framework can setup common interfaces to export computing and networking resources and to manage exported services. In addition, we plan to study the dynamic service composition of vSON with services that are exported through standardized interface.

Acknowledgements

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