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Mobile Applications: Delivery Technologies in Multimedia Cloud Computing

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Abstract - This paper explains the principal concepts of multimedia cloud computing and presents a novel framework. We address multimedia cloud computing from multimedia-aware cloud (media cloud) and cloud-aware multimedia (cloud media) perspectives. First, we present a multimedia-aware cloud, which addresses how a cloud can perform distributed multimedia processing and storage and provide quality of service (QoS) provisioning for multimedia services. To achieve a high QoS for multimedia services, we propose a media-edge cloud (MEC) architecture, in which storage, central processing unit (CPU), and QoS adaptation for various types of devices. Then we present a cloud aware multimedia, which addresses how multimedia services and applications, such as storage and sharing, authoring and mashup, adaptation and delivery, and rendering and retrieval, can optimally utilize cloud-computing resources to achieve better quality of experience (QoE). And also explains mobile multimedia applications discusses deployment and distribution issues, focusing on video and audio-visual services and outline future directions for advanced audio-visual and multimedia services delivery on mobile devices.

Keywords: cloud computing, mobile multimedia, QoE, QoS, delivery

I. Introduction

Cloud computing

Cloud computing is an emerging technology aimed at providing various computing and storage services over the Internet [1], [2]. It generally incorporates infrastructure, platform, and software as services. Cloud service providers rent data-center hardware and software to deliver storage and computing services through the Internet. By using cloud computing, Internet users can receive services from a cloud as if they were employing a super computer. They can store their data in the cloud instead of on their own devices, making ubiquitous data access possible. Cloud computing promotes open network infrastructures by preventing MNOs from being dump pipes for delivering cloud services from third-party cloud service providers without accruing any benefit (or revenue). Network operators would be able to offer network as a service (NaaS), enriching their network by offering highvalue network services that enhance multimedia services delivery through the cloud. A NaaS service can support enhanced service delivery, which might include localization functions, network intelligence functions, security, QoS, and QoE. As for mobile clients, they could access advanced multimedia services anytime, anywhere, and from any device without any limitations. Gaming applications could be instantiated closer to the subscriber so the games could be played from any mobile terminal.They can run their applications on much more powerful cloud computing platforms with software deployed in the cloud, mitigating the users' burden of full software installation and continual upgrade on their local devices.

Evolution of Services and Terminals

In 2008, a drastic change in service consumption occurred with mobile phones supporting different types of multimedia applications. In many countries, mobile phone use to deliver multimedia traffic outnumbered PC use—by as much as 10 to 1.[3] In 2010, e-readers resulted in the deployment of more e-reading and e-learning services on smart phones and tablet devices. Moreover, tablet owners usually consume online news and magazine content daily. Currently, the widespread adoption of smartphones and rapid increase in the number of tablet devices let users consume more mobile video and access more entertainment applications.

Changes in User Consumption

Mobile usage is also challenging mobile network operators (MNO). Half the traffic is generated by high volume/low margin (HVLM) services, such as video streaming and online gaming. This class of traffic requires the highest throughput and lowest latencies, yet generates the lowest annual revenue per user (ARPU) because of the heavy needs in terms of networking, storage, and processing capacity. In contrast, a small fraction of the traffic is composed of low volume/high margin (LVHM) services, such as e-commerce, online banking, financial services, and travel and hotel booking, many of which require short, personalized, and efficient sessions with the promise of the highest possible ARPU. Paradoxically, LVHM services could be delivered with low-cost delivery techniques, but only a few commercial solutions exist to enable MNOs to fully address this market: most vendors target HVLM services, while third-party content delivery network (CDN) providers tend to keep the MNO playing the role of "dump pipe operators." This approach isn't in the best interest of the MNO, which owns all the technical interfaces to enhance the network tools that speed up and control delivery—quality-of-service (QoS) management, traffic shaping, and so on.

Traffic Growth and Trends

The mobile media population grew 19 percent in the first half of 2011 to more than 116 million people.4 Mobile usage for multimedia services can take three forms: fixed, nomadic, and mobile. 6 Mobile data traffic is expected to roughly double each year, increasing 66 times between 2008 and 2013, and the world's mobile data traffic will be almost 61 percent video in 2013.6 According to the global mobile data forecast, there will be 788 million mobile-only Internet users by 2015, increasing global mobile data traffic by a factor of 26 by 2015.[6] Figure 1 illustrates global mobile data traffic, which is expected to grow at a compound annual growth rate of 92 percent between 2010 and 2015.[7]

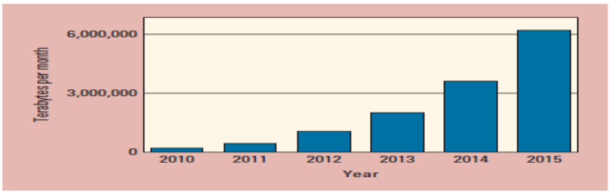

Figure 1. Overall mobile data traffic (2010–2015). Global mobile traffic is expected to be around 1,500 terabytes per month in 2015.[7]

Mobile video content has a much higher bit rate than other content types and is expected to generate much of the mobile traffic growth through 2015, when 4.2 Exabyte's of the 6.3 exabytes global mobile traffic will be due to video traffic. Figure 2 shows a forecast for the evolution of the mobile video traffic to 2015, which is expected to generate 66 percent of the world's mobile data traffic. Figure 3 shows results from an analysis carried out in August 2011 for the largest mobile content categories by audience. It shows that people use mobile media to connect with others, to consume information, and for entertainment. Among the categories analyzed, personal emails attracted the largest audience with more than 81 million mobile users.

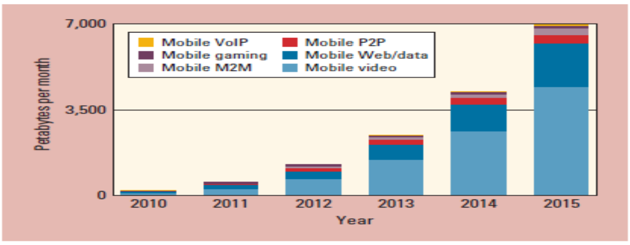

Figure 2. Video mobile data traffic (2010–2015). In 2015, mobile video traffic is expected to generate 66 percent of the world's mobile data traffic.[7]

Support and Delivery

The General Packet Radio System emerged to support data packet transport in 2G mobile networks with a throughput reaching 21 Kbps,8 followed by Enhanced Data Rate for Global System for Mobile Communications Evolution as 2.5G mobile networks, allowing a throughput increase of up to 236 kilobits per second. Universal Mobile Telecommunication System (UMTS) was developed for 3G mobile networks to support a throughput of up to 384 Kbps. High Speed Downlink Packet Access (HSDPA) came as an improvement over UMTS's limitations and is considered a 3.5G mobile network.9 It offers significantly higher data capacity and throughput on the downlink supporting 1.8, 3.6, 7.2, and 14 Mbps on the downlink. Long Term Evolution (LTE) has become the successor of HSDPA and is considered the 4G mobile network. 10 LTE emerged from market needs for an all-IP mobile broadband technology allowing a considerably high network throughput. Table 1 illustrates mobile network technologies that support different applications. To compare 2G, 3G, and 4G mobile networking support for multimedia services, we use mobile TV as an example. Table 2 compares throughput and cell capacity support for high-definition TV (HDTV).

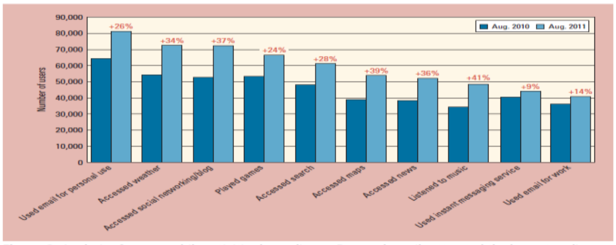

Figure 3. Analysis of some mobile activities by audience. Personal emails attracted the largest audience.

Table 1. Mobile networking support for multimedia applications.

	2.5G	3G/UMTS*	3.5G/HSDPA†	LTE‡
Voice-over-IP service	Poor quality	Supported	Supported (richer QoS)	Supported
TV	Supported with limited throughput	Supported	Supported (richer QoS)	Supported
Video streaming	Not supported	Supported	Supported (richer QoS)	Supported
Interactive applications (as multiuser gaming)	Not supported	Not supported	Supported	Supported

**Universal Mobile Telecommunication System*
†High Speed Downlink Packet Access
‡Long Term Evolution

Table 2. Mobile TV support for various mobile networks.

Mobile network type	2G	3G/UMTS	3.5G/HSDPA	LTE
Cell throughput	236 Kbps	258–260 Kbps	0.5–4.2 Mbps downlink and 0.6–1.7 Mbps uplink	100 Mbps downlink and 50 Mbps uplink
TV throughput	Initially 50 Kbps then increased to 80 Kbps	250 Kbps	250 Kbps	300 Kbps, 650 Kbps, 1.5 Mbps
Streaming capacity per cell	2 users max (not adapted to live streaming)	Limited for HDTV	Depends on user location in the radio cell (users at cell borders are impacted)	More cell capacity for the streaming (> 200 users per cell)
HDTV	No support	Supported at 384 Kbps	Supported	1.5 Mbps

II. Technologies

Streaming Technologies

The following adaptive streaming techniques are used to transport mobile multimedia services:

• *HTTP adaptive streaming* downloads and stores all content in the virtual memory before reading it, applies to VoD applications, and supports live TV services when the delay isn't critical.

• *HTTP progressive download* starts reading the file after a short download interval and before the entire file is received and used with Internet VoD applications (such as video streaming from YouTube or DailyMotion), storing the content in the physical memory.

• *Real-time streaming* reads the file in real time while downloading it and supports VoD and live TV services but is more adapted to live TV services and broadcast distribution solutions, such as MBMS.

III. FEATURES & CHALLENGES

Delivery and Distribution Challenges

With mobile multimedia applications, users have more interest in on-demand services, and telecommunication companies are looking to provide more content to maintain their revenues. These requirements lead to several delivery and distribution issues—namely, QoS, quality of experience (QoE), content adaptation, and security. Addressing these issues will make the multimedia experience more cost-effective for mobile users and will improve the quality.

Mobile Access

Delivering mobile multimedia services for mobile access is more challenging than for fixed broadband access. The main technical issues are

• the diversity of terminal characteristics, such as screen widths and hardware accelerators for network/video processing of specific protocols;

• the strong variations of channel capacity during a session—changes of radio access type (2G, 3G, Wi-Fi) and fading and shadowing factors; and

• the effect of “hyperconnectivity” on networks, including IP network support for more tasks and functions simultaneously occurring on networked devices.

Core Network Congestion and QoE

Although LTE seemingly presents a great opportunity for mobile multimedia applications delivery, MNOs must address some challenges to fully exploit this technology’s power. In 3G and 3.5G mobile networks, congestion occurs more frequently at the physical layer because of the high mobile multimedia applications consumption, which in turn causes more delays on cellular networks and has a direct impact on the users’ QoE.15 To address the increased delays in application delivery and enhance the QoE, content must be adapted or optimized on the basis of metadata related to the network, terminals, service, and user.

Device Features

Other technical issues related to mobile device designs include

• *power consumption*: battery technology for mobile phones and for portable and tablet devices must support mobile content and enhanced functions;

• *memory*: memory capabilities must support the high buffer requirements of most mobile services (such as TV and video P2P) and enable long hours of mobile TV viewing;

• *processing power*: processing power must support processor-intensive applications, such as mobile TV;

• *software defined radio (SDR)*: mobile devices must support several types of wireless technologies to match the applications’ needs. SDR technology helps mobile devices reap several benefits, including smaller sizes, lower costs, faster development cycles, and easier upgrades and interoperability.

IV. ARCHITECTURES

Cloud Computing and Mobile Multimedia

To provide good media services, multimedia computing has grown as a eminent technology for generating edit, process and search media contents, such as images, video, audio, graphics, and so on. Now a days for multimedia applications and services over the Internet and mobile wireless networks, there are strong demands for cloud computing because of the huge amount of calculations required for serving millions of Internet or mobile users at the same time. In this new cloud-based multimedia-computing model, users store and process their multimedia application data in the cloud in a distributed manner, eliminating full installation of the media application software on the users’ computer or device and thus reducing the burden of multimedia software maintenance and upgrade as well as sparing the computation of user devices and saving the battery of mobile phones.

For multimedia computing in a cloud, continuous bursts of multimedia data access, huge processing, and transmission in the cloud would create a threshold in a general-purpose cloud because of tough multimedia QoS requirements and large amounts of users’ simultaneous accesses at the Internet scale. However, for multimedia applications, in addition to the CPU and storage requirements, another very important factor is the QoS requirement for bandwidth, delay, and jitter. Therefore, using a general-purpose cloud in the Internet to deal with multimedia services may suffer from unacceptable media QoS or QoE [3]. Mobile devices have limitations in memory, computing power, and battery life; thus, they have even more prominent needs to use a cloud to address the tradeoff between computation and communication.

More specifically, in mobile media applications and services, because of the power requirement for multimedia [5] and the time-varying features of the wireless channels, QoS requirements in cloud computing for mobile multimedia applications and services become more stringent than those for the Internet cases. To meet multimedia’s QoS requirements in cloud computing for multimedia services over the internet and mobile wireless networks, we tell the main concepts of multimedia cloud computing for multimedia computing and communications, shown in Figure 4.

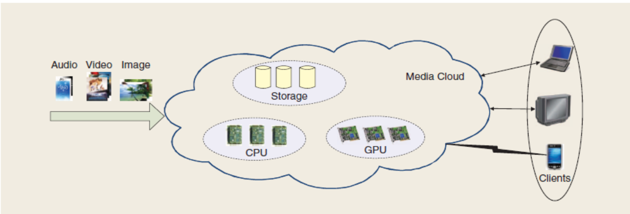

Fig 4 : Fundamental Concept of Multimedia Cloud Computing.

We explain multimedia cloud computing from multimedia-aware cloud (media cloud) and cloud-aware multimedia (cloud media) models. A multimedia-aware cloud focuses on how the cloud can provide QoS facilities for multimedia applications and services. Cloud-aware multimedia focuses on how multimedia can perform its content storage, processing, adaptation, rendering, and so on, in the cloud to best utilize cloud-computing resources, resulting in high QoE for multimedia services. Figure 5 depicts the relationship of the media cloud and cloud media services.

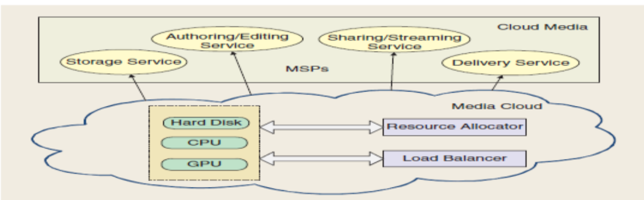

Fig 5: The relationship of the media cloud & cloud media services.

MULTIMEDIA-AWARE CLOUD

The media cloud needs to have the following functions: 1) QoS facilities and support for various types of multimedia services with different QoS requirements, 2) distributed parallel multimedia processing, and 3) multimedia QoS adaptation to fit various types of devices and network bandwidth.

MEDIA-CLOUD-COMPUTING ARCHITECTURE

In this architecture, an MEC is a cloudlet with data centers physically located at the edge. The MEC stores, processes, and transmits media data at the edge, thus with a shorter delay. The media cloud consists of MECs, which can be managed in a centralized or peer-to-peer (P2P) manner. First, to better handle various types of media services in an MEC, we propose to place similar types of media services into a cluster of servers based on the properties of media services. Specifically, we propose to use the distributed hash table (DHT [6]) for data storage while using CPU or GPU clusters for multimedia computing. Second, for calculating efficiency in the MEC, we will try a distributed parallel processing model for multimedia applications and services in GPU or CPU clusters. Third, at the proxy/edge server of the MEC, we propose media adaptation/transcoding for media services to different types of devices to get high QoE.

Finally, it can be seen that multimedia computing in an MEC can produce less multimedia traffic and reduce latency when compared to all multimedia contents that are located at the central cloud. As shown in Figure 6(a) and (b), respectively, an MEC has two types of architectures: one is where all users' media data are stored in MECs depending on their user profile or context, while all the information of the related users and content locations is communicated by its head through P2P; the other one is where the central administrator (master) contains all the information of the related users and content locations, while the MEC distributedly holds all the content data. Within an MEC, we use P2P technology for distributed media data storage and computing. With the P2P architecture, every node is equally important and, thus, the MEC is of high scalability, availability, and powerfully built for media data storage and media computing. To support mobile users, we propose a cloud proxy that resides at the edge of an MEC or in the gateway, as shown in Figure 6(a) and (b), to perform multimedia processing and caching to compensate for mobile devices' limitations on calculational ability and battery life.

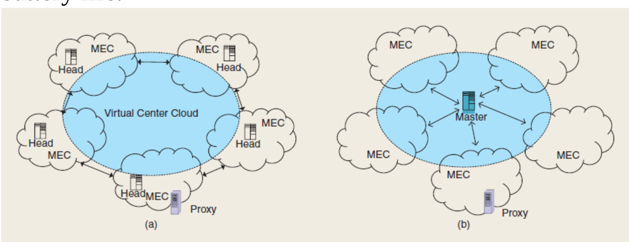

Fig 6 : Architecture of (a) P2P-based MEC computing & (b) central-controlled MEC computing.

MEDIA CLOUD QOS

Another key challenge in the media cloud/MEC is QoS. There are two ways of providing QoS facilities for multimedia: one is to add QoS to the current cloud-computing infrastructure within the cloud and the other is to add QoS middleware between the cloud infrastructure and multimedia applications. In the former case, it focuses on the cloud infrastructure QoS, providing QoS facilities in the cloud infrastructure to support multimedia applications and services with different media QoS requirements. In the latter case, it focuses on improving cloud QoS in the middle layers, such as QoS in the transport layer and QoS mapping between the cloud infrastructure and media applications.

In the result, an MEC can provide QoS support for different types of media with different QoS requirements. To improve multimedia QoS performance in a media cloud, in addition to moving media content and computation to the MEC to reduce latency and to perform content adaptation to different devices, a media cloud proxy is proposed in our architecture to further reduce latency and best serve different types of devices with adaptation especially for mobile devices. The media cloud proxy is designed to deal with mobile multimedia computing and caching for mobile phones. As a mobile phone has a less battery life and computation power, the media cloud proxy is used to perform mobile multimedia computing in full or part to compensate for the mobile phone's demerits mentioned above, including QoS adjusting to various types of terminals.

V. APPLICATIONS

CLOUD-AWARE MULTIMEDIA APPLICATIONS

As shown in Figure 7, a typical media life cycle consisits of acquisition, storage, processing, dissemination, and presentation. For a long time, high-quality media contents could only be acquired by professional organizations with efficient devices, and the distribution of media contents relied on hard copies, such as film, video compact disc (VCD), and DVD.

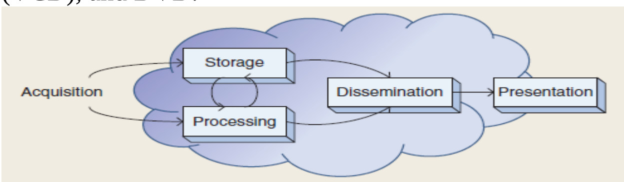

Fig 7: A typical media life cycle.

STORAGE AND SHARING

Cloud storage has the advantage of being "always-on" so that users can access their files from any device and can share their files with anyone who may access the content at an any time. It is also an important feature that cloud storage provides a much higher level of reliability than local storage. Cloud storage service can be classified into consumer- and developer-oriented services. Within the category of consumer-oriented cloud storage services, some cloud providers use their own server farm, while some others operate based on user-contributed physical storage.

The request of easy sharing is the main reason the multimedia contents occupy a huge portion of cloud storage space. The person who shares simply uploads the contents to the cloud storage at his or her convenience and then sends a hyperlink to the persons being shared with. The latter can then access the contents whenever they like, since the cloud is always avialable. Sharing through a cloud also increases media QoS. Online music and video sharing can be achieved through streaming.

AUTHORING AND MASHUP

Multimedia authoring is the process of editing segments of multimedia contents, while mashup deals with combining multiple segments from different multimedia sources. To date, authoring and mashup tools are roughly classified into two categories: one is offline tools, such as Adobe Premiere and Windows Movie Maker, and the other is online services, such as Jaycut. The former provides more editing functions, but the client usually needs editing software maintenance. The latter provides fewer functions, but the client need not bother about its software maintenance.

Authoring and mixing are generally time consuming and multimedia contents occupy large amount of storages. A cloud can make online authoring and mixing up very effective, providing more functions to clients, since it has powerful computation and storage resources that are widely distributed geographically. Moreover, cloudbased multimedia authoring and mashup can avoid pre installation of editing software in clients. In this framework, users will conduct editing and mashup in the media cloud. One of the main challenges in cloud-based authoring and mashup is the computing and communication costs in processing multiple segments from single source or multiple sources.

To show this challenge, we present an extensible markup language (XML)-based representation file format for cloud-based media authoring and mashup. As shown in Figure 8, this is not a multimedia data stream but a description file, indicating the organization of different multimedia contents. The file can be logically considered as a multilayer container. The layers can be entity layers, such as video, audio, graphic, and transition and effect layers. Each segment of a layer is represented as a link to the original one, which maintains associated data in the case of being deleted or moved, as well as some more descriptions. The transmission and effects are either a link with parameters or a description considering personalized requests. Thus, the process of authoring or mixing up is to edit the presentation file, by which the computing work on the cloud side will be significantly reduced. In our approach, we will select an MEC to serve authoring or mashup service to all varities of clients including mobile phone users.

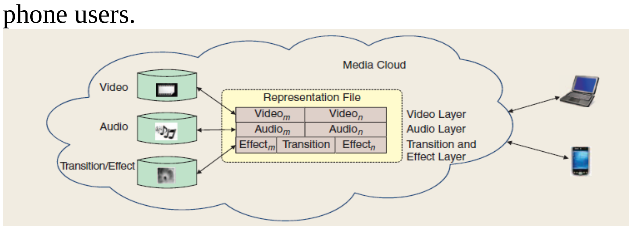

Fig 8: cloud-based multimedia authoring & mashup.

ADAPTATION AND DELIVERY

Video adaptation [17], [18] plays an important role in multimedia delivery. It changes input video(s) into an output video in a form that is required by the user's needs. In general, video adaptation needs a large amount of computing and is difficult to do especially when there are a many number of consumers requesting service simultaneously. Because of the strong computing and storage power of the cloud, both offline and online media adaptation to different types of terminals can be conducted in a cloud.

We present a framework of cloud-based video adaptation for delivery, as illustrated in Figure 9. Video adaption in a media cloud shall take charge of collecting customized parameters, such as screen size, bandwidth, and generating various versions according to their parameters either offline or on the fly. In the presented framework, adaptation for single-layer and multilayer video will be performed differently. If the video is of a single layer, video adaptation needs to adjust bit rate, frame rate, and resolution to meet different types of terminals. For scalable video coding, a cloud can produce various forms of videos by deleting its changeble layers based on the clients' network bandwidth.

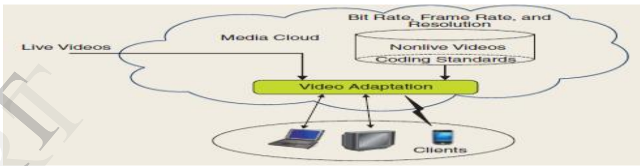

Fig 9: cloud-based video adaptation & transcoding.

MEDIA RENDERING

The cloud consists of GPU can perform rendering due to its strong computing capability. Considering the tradeoff between computing and communication, there are two types of cloud-based rendering. One is to conduct all the rendering in the cloud, and the other is to conduct only computational intensive part of the rendering in the cloud, while the rest will be done on the client. In this article, we present cloud-based media rendering. As illustrated in Figure 10, the media cloud can do full or partial rendering, generating an intermediate stream for further client rendering, according to the client's rendering capability. More specifically, an MEC with a proxy can help mobile clients with good QoE since rending can be done in an MEC proxy. Multimedia accessl, such as content-based image retrieval (CBIR), is a good application example of cloud computing as well.

Fig 10: cloud-based multimedia rendering.

Here, we show an overview of mobile multimedia applications, focusing on video and audiovisual services and their deployment issues. Mobile multimedia applications cover a different range of services, added by several factors including the evolution of powerful mobile

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end points, which led to mobile multimedia applications, starting with the Wireless Application Protocol standard.

VI. CONCLUSIONS

This article presented the fundamental concept and a framework of multimedia cloud computing. We addressed multimedia cloud computing from multimedia-aware cloud and cloud-aware multimedia perspectives. On the multimedia-aware cloud, we presented how a cloud can provide QoS support, distributed parallel processing, storage, and load balancing for various multimedia applications and services. Specifically, we proposed an MEC-computing architecture that can achieve high cloud QoS support for various multimedia services. On cloud aware multimedia, we addressed how multimedia services and applications, such as storage and sharing, authoring and mashup, adaptation and delivery, and rendering and retrieval, can optimally utilize cloud-computing resources. In this article, we presented some thoughts on multimedia cloud computing and our preliminary research in this area.

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