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SAND and Cloud-based Strategies for Adaptive Video Streaming

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ABSTRACT

A new architecture for defining network collaboration in DASH is called SAND. It aims to standardize communication amongst network agents participating in the streaming process. This work produces a novel taxonomy for SAND-based approaches. It places AVS solutions into four categories: (1) Management Architecture (2) Cache-based, (3) Optimization, and (4) Paradigm. Sub-categories of Management Architecture are (a) Cognitive, (b) Prioritization, and (c) Encoding and Signaling, while sub-categories of Paradigm are (a) SDN-based, (b) CDN-based, and (c) CCN-based. The approaches representing each category are presented. It is shown that using the SANDs architecture proves beneficial to approaches adopting it. In recent years Cloud-based strategies for AVS have been an important area of research and industry. This paper elaborates on Cloud-based strategies. It places current strategies into a taxonomy. The Cloud-based AVS strategies are categorized into (1) Social-Awareness, (2) Cloud-based CDN, (3) Cloud-based Gaming, (4) Cloud-based SDN, (5) File-hosting services, (6) View synthesis techniques, and (7) Error Concealment techniques. The implementations that exist for the Cloud-based strategies are discussed. Thus, the advantages of both SAND and Cloud-based approaches for use in DASH-based systems are illustrated.

Keywords - **DASH; SAND; Adaptive; video; streaming; SDN; optimization; cache; CDN; Encoding; Signaling; Cloud; Social-Awareness; Gaming.**

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I. INTRODUCTION

This work provides a body of work that builds on an AVS taxonomy presented in Section II. It provides a detailed review on current state of the art solutions in server- and network-assisted AVS. After the taxonomy is given a discussion on SAND-based AVS techniques is portrayed in Section III. This is followed by a taxonomy of SAND-based approaches to DASH in Section IV. SAND-based approaches are then illustrated in Section V. Section VI gives a discussion of Cloud-based AVS strategies. Section VII presents a taxonomy of Cloud-based approaches AVS techniques. Cloud-based strategies are shown in Section VIII. Finally, the conclusion is given in Section IX.

II. AVS TAXONOMY

This work categorizes AVS into five types: (1) Client-based, (2) Server-based, (3) Network-assisted, (4) SAND-based, and (5) Cloud-based, cf. Figure 1. However, only SAND-based and Cloud-based solutions are discussed. Another paper talks about Server-based and Network-assisted solutions.

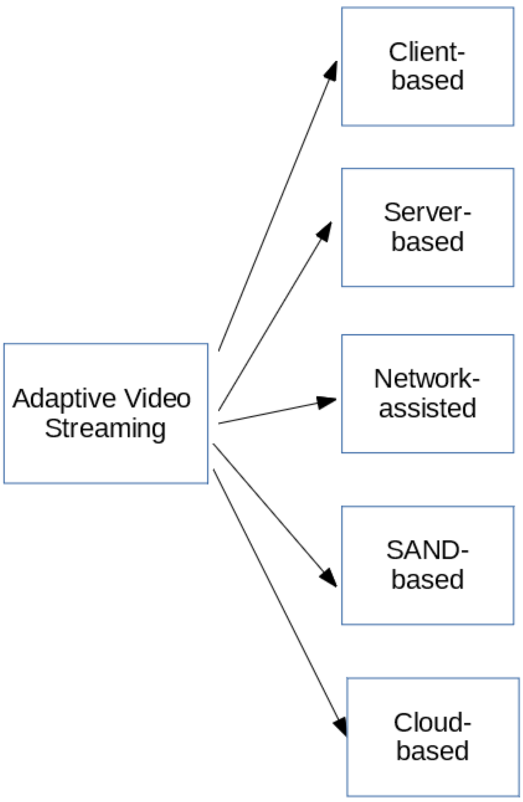

Fig. 1. AVS taxonomy

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III. DISCUSSION OF SAND-BASED AVS TECHNIQUES

Aside works which propose possible implementations of networked-assisted HAS, there are also efforts to standardize DASH-based technology [58], [9], [61]. The MPEG group is developing an extension of the Dynamic Adaptive Streaming over HTTP (DASH) standard, called Server and Network Assisted DASH (SAND) [47]. The extension provides guidelines about the communication between network nodes and the features that the network-assisted framework should possess— for example, the system should be resilient to clients that ignore the network assistance. Standardization efforts certainly motivate the development of network-assisted systems and contribute to prepare future deployments [8].

The aim of the Server and Network Assisted DASH (SAND) amendment [46] is to make DASH clients aware of networks and vice versa. This improves DASH content delivery in networks. SAND will define the signaling protocols and messages to be exchanged between DASH-aware network elements [39] [13], but the actual decision algorithms will be left out of the standard [37]. The SAND approach uses a standard signaling plane [33] [43]. This is required to enable active cooperation between network elements. Based on network state and client states in context, the SAND architecture (cf. Figure 2) allow a network element to trigger a control mechanism such as quality adaptation [30] [41], flow prioritization [5] [29] [24], or bandwidth reservation [7]. This is achieved by using asynchronous network-to-client and network-to-network communication of quality-related assisting information.

The essential concept in SAND is a functional network entity, called DASH Aware Network Element (DANE) [1], which can understand and collect the HAS session related content and to provide HAS clients with assisting parameters to enhance the service delivery.

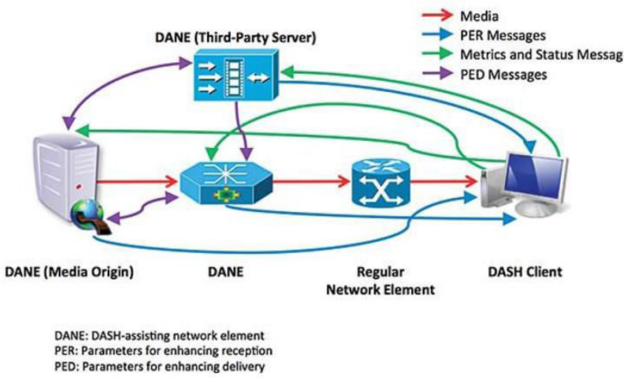

Fig. 2. SAND architecture [1].

This work consists of four sections. Section IV presents the Taxonomy of SAND-based approaches to DASH. Section V gives examples of the approaches defined in the taxonomy.

IV. TAXONOMY OF SAND-BASED APPROACHES TO DASH

The SAND-based AVS solutions are categorized into (1) Management Architecture (2) Cache-based, (3) Optimization, and (4) Paradigm. These categories are shown on Figure 3. Sub-categories of Management Architecture are (a) Cognitive, (b) Prioritization, and (c) Encoding and Signaling. Sub-categories of Paradigm are (a) SDN-based, (b) CDN-based, and (c) CCN-based.

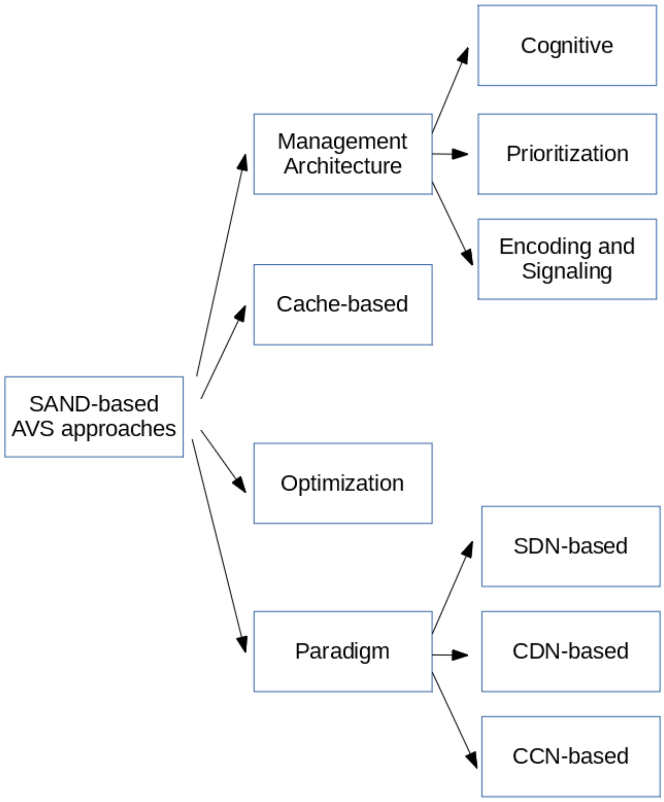

Fig. 3. SAND-based AVS taxonomy.

V. SAND- BASED APPROACHES

This review of SAND-based approaches includes those inspired by SAND and actual implementations. It should be noted that SAND is an adaptive video streaming architecture so that both inspired and direct implementations may or may not include all the features included in the architecture.

A. Management Architecture

1. Cognitive

Authors in [38] propose enhancements to the video bitrate adaptation solution of adaptive HTTP streaming by defining two network-assisted adaptation approaches (cf. Figure 4). These are based on a cognitive network management architecture. The architecture supports (1) enhanced network service awareness and (2) distributed control over video bitrate adaptation. Experiments to test the presented bandwidth management concepts are conducted in a testbed environment. This includes prototypes of the proposed algorithms, signaling framework, and video streaming service supporting MPEG-DASH. In further work the authors propose enhancements to adaptive video streaming over HTTP using a wireless bandwidth management architecture in [37] (cf. Figure 5). Additional network-side control information is provided by a distributed control architecture over video bitrate adaptation to video clients. This assists them in their decision-making. The architecture and distributed decision algorithms are network and service aware. This is enabled by a cross-layer signaling framework. Their MPEGDASH based testbed implementation is used to test the architecture. It also studies the performance in the context of two network-assisted video adaptation use cases. By analyzing the results, it was shown that the proposed solution gives benefits against a state-of-the-art client-side approach.

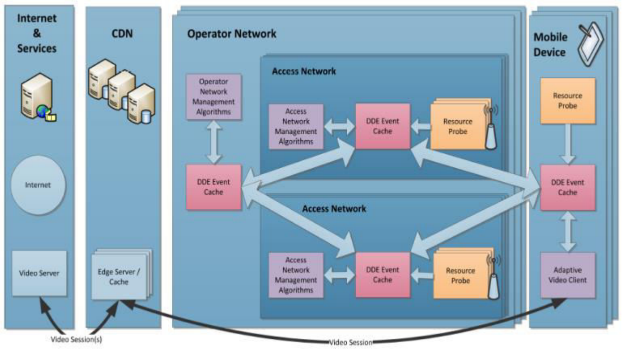

Fig. 4. Architecture for network-assisted adaptive video streaming [38].

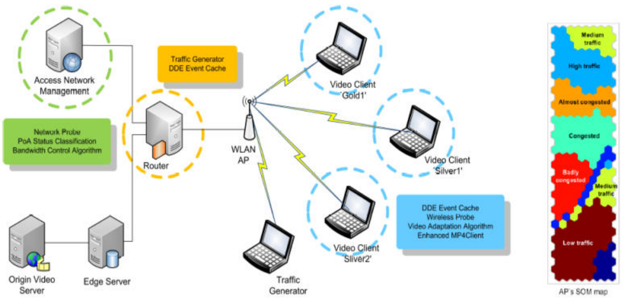

Fig. 5. The network-assisted adaptive video streaming testbed and the SOM map used in the WLAN AP's status classification [37].

2. *Prioritization*

To reduce video freezes the authors in [40] propose an Open flow based framework (cf. Figure 6). The framework's aim is to increase clients' QoE. Prioritized delivery of HAS segments is enabled by the Openflow-controller. This is based on feedback collected from both the network devices and the clients. An attempt is made to reduce the effects introduced by prioritization on the bandwidth estimation of the clients. A method is used which inform the clients about the prioritization status of the downloaded segments. This is done without any additional overhead being placed on the network. In case of prioritized delivery, the estimated bandwidth is corrected by using this information. The approach is evaluated by emulation. Evaluation is done under varying network conditions. The approach is compared to state-of-the-art heuristics. It is shown under several multi-client scenarios, that the proposed approach can reduce freezes up to 75%.

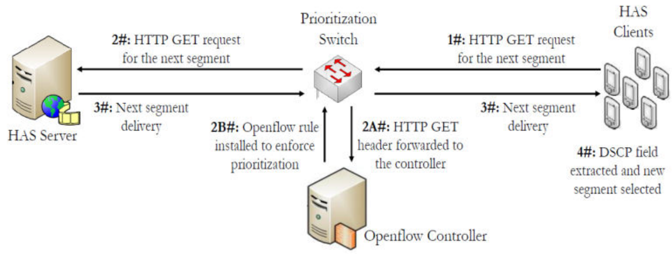

Fig. 6. Logical sequence diagram of the proposed solution [40].

3. *Encoding and Signaling*

An energy-aware dynamic encoding control for MPEG-DASH live streaming is given in [49] (cf. Figure 6). The method proves beneficial when representations are unpopular, or the network is under congestion. Messages between client and encoding server are utilized to achieve these dynamics. This is based on the MPEG standard initiative Server and Network Assisted DASH (SAND). It was shown experimentally that the dynamic encoding control signaling can reduce energy consumption in the server, and create storage savings. Thus, server costs are decreased.

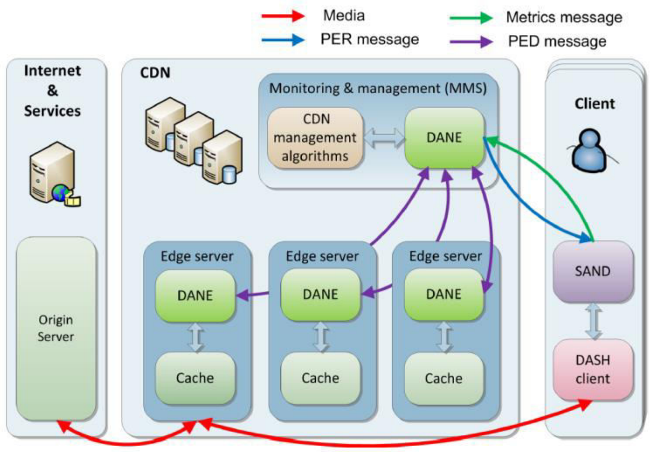

Fig. 4. Signaling in the advanced CDN architecture [49].

B. Cache-based

The benefits of a Cache Friendly HAS system (CF-DASH) is investigated in [3]. It aims to improve the caching efficiency in mobile networks. Another goal is to sustain the quality of experience (QoE) of mobile clients. A set of observations are presented to motivate the work undertaken. This is done on a large number of clients requesting HAS contents. The CF-Dash system is implemented on a developed testbed implementation. CF-dash is evaluated based on trace-driven simulations and testbed experiments. The rate adaptation logic is given in Figure 7. The validation results based on the simulations on real HAS traffic show that CF-DASH achieves a significant gain in hit-ratio within ranges of 15% up to 50%.

C. Optimization

Several network-assisted streaming approaches are investigated by [7] that rely on active cooperation between video streaming applications and the network (cf. Figure 8). A Video Control Plane (VCP) that enforces Video Quality Fairness (VQF) is built. The VCP works among concurrent video flows generated by heterogeneous client devices. A max-min fairness optimization [60] [34] problem is solved at runtime in order to achieve the VCP over VQF. The optimal solution is compared based on (1) allocating network bandwidth slices to video flows, and (2) guiding video players in the video bitrate selection. QoE-related metrics used to access the performance of VCP include (a) Video Quality Fairness [20], (b) video quality [42], and (c) switching frequency [2] [31] [48].

```
Require: Client, AdaptationSet, Representation, Limit_Profile,
if (disable_switching = TRUE) then
    return
end if
Go_Up=FALSE
DL=compute_download_rate(Client)
if (Representation.bandwidth ⩽ DL) then
    Go_Up=TRUE
end if
if (DL ⩽ AdaptationSet.Min_Representation_Bitrate) then
    DL=AdaptationSet.Min_Representation_Bitrate
end if
N=AdaptationSet.total_representations
for k = 0 → N do
    SR=Get_Representation(AdaptationSet,k)
    if (DL ≥ Selected_Representation.bandwidth) then
        if (!New_Representation) then
            New_Representation=SR
        else if (Go_Up) then
            if (SR.bandwidth ⩾
            New_Representation.bandwidth)and(k ≤
            AdaptationSet.Limit_Profile) then
                New_Representation=SR
            end if
        else
            if (SR.bandwidth ⩾
            New_Representation.bandwidth)and(k ≤
            AdaptationSet.Limit_Profile) then
                New_Representation=SR
            end if
        end if
    end if
end for
if (disable_switching =
FALSE)and(New_Representation)and(New_Representation
Representation) then
    Representation = New_Representation
end if
```

Fig. 5. CF-Dash: rate adaptation logic [3].

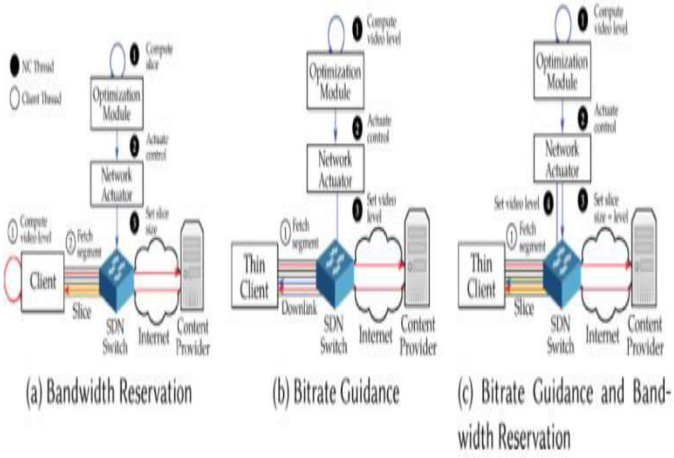

Fig. 6. The considered network-assisted SAND-based approaches [7].

D. Paradigm

1. SDN-based

An in-network QoE measurement framework (IQMF) that provides QoE monitoring for HAS streams as a service is introduced in [14] (cf. Figure 7). The framework leverages Software Defined Networking. The control plane functionality is streamlined for nonintrusive quality monitoring [36]. It offers a closed control loop for QoE-aware service management. IQMF adopts two specifically designed QoE metrics. These metrics are used to capture the user experience of HAS streams. The specific metrics are related to video fidelity [27] [11] [59] and switching impact [45] [44]. A pan-European SDN testbed is used. This testbed demonstrates how IQMF can be used as a foundation for in-network QoE measurement and service optimization.

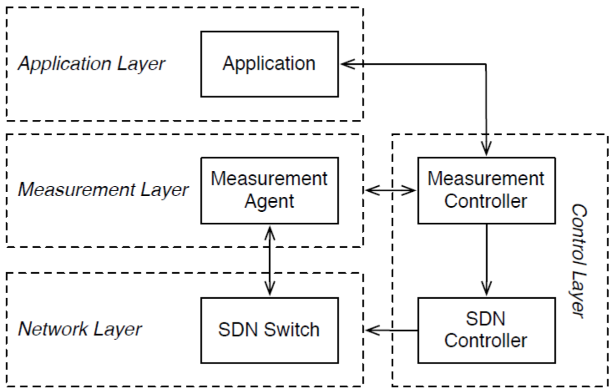

Fig. 7. SAND-based QoE Measurement Framework (IQMF) [14].

A networking architecture based on the Software Defined Networking (SDN [51]) paradigm is illustrated in [23] (cf. Figure 8). Two mechanisms for adaptation assistance is provided by controllers in the network: (a) explicitly signaling target bitrates to DASH players, and (b) dynamic traffic control in the network. This is possible as the controllers have a broad overview on the network activity. The mechanisms are evaluated based on how much each

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contribute to the delivery of a stable, high quality stream. The architecture improves the quality of experience (QoE). The video bitrate is doubled, and quality switches are reduced. This DASH-aware networking can be used at internet service providers (ISP), network administrators, and end-users to configure their networks to their desired requirements.

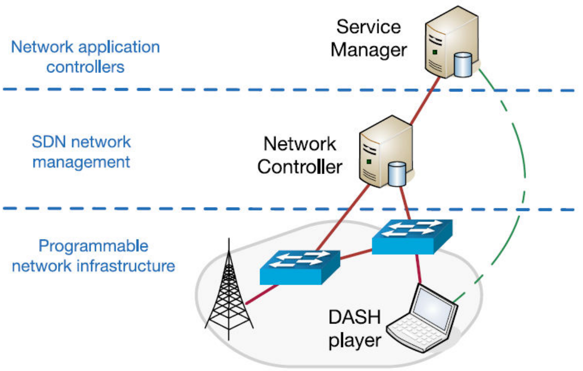

Fig. 8. DASH aware SDN architecture that separates data plane (network infrastructure) from control plane (network management and application controllers). The mixed-dashed line indicates a communication channel between DASH player and Service Manager [23].

2. CDN-based

An advanced Content Delivery Network (CDN [35]) solution for enhancing the delivery and caching of adaptive HTTP-based video streaming is proposed in [19] (cf. Figure 9). A testbed implementation of the proposed system is also illustrated. It utilizes (1) open source components, and (2) a standardized MPEG-DASH based video streaming solution. The proposed CDN management features and the associated signaling are inspired by the upcoming MPEG standard for Server and Network assisted DASH (SAND) [19]. The experimental evaluation results attest the benefits of the proposed solution. It enhances MPEGDASH delivery in CDNs for the selected test cases.

An advanced Content Delivery Network (CDN) solution for enhancing the delivery of adaptive HTTP-based video streaming is introduced in [18]. The implementations showcase intelligent and scalable CDN testbeds. These are based on intelligent CDN management functionalities and scalable CDN architecture. The upcoming MPEG standard for Server and Network assisted DASH (SAND) gives inspiration for the intelligent CDN management functionalities and the associated signaling. Lightweight service virtualization allows dynamic scaling and balancing of available resources according to the current needs make the scalable CDN architecture possible. A scenario where end-users are streaming MPEG-DASH video from the advanced CDN is illustrated. It features (a) intelligent CDN management, and (2) monitoring functionalities. These dynamically (1) add or remove virtualized edge servers, and (2) reroute end-users based on the resource needs and the location of end-users. A more balanced traffic load within the network and better Quality of Experience (QoE) for end-users is achieved.

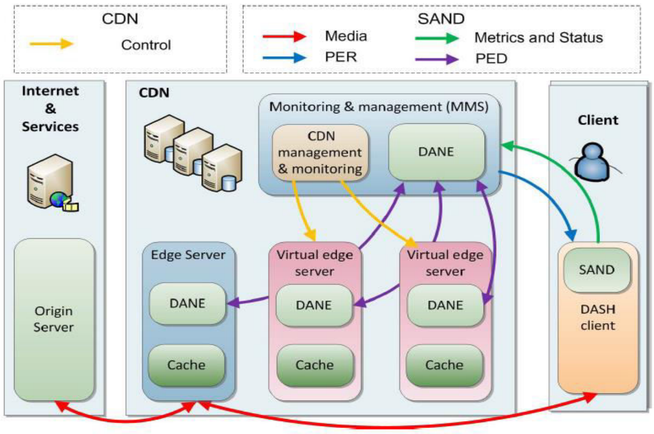

Fig. 9. Signaling in the advanced CDN architecture. [19].

3. CCN-based

A new internet architecture such as Content Centric Network (CCN [28]) is proposed to enhance DASH streaming in [22] (cf. Figure 10). With its in-network caching salient feature, this architecture, improves Quality of Experience (QoE) from consumer side. Advantages of the proposed approach are (1) it reduces delays [56], and (2) increases throughput [32] by providing the requested video segment from a near point to the end user. However, the main disadvantage is that there are oscillations issues induced by caching with DASH. The newly proposed Network-Assisted Strategy (NAS) is based-on traffic shaping and request prediction. It aims to improve DASH flows by investigating the new internet architecture CCN.

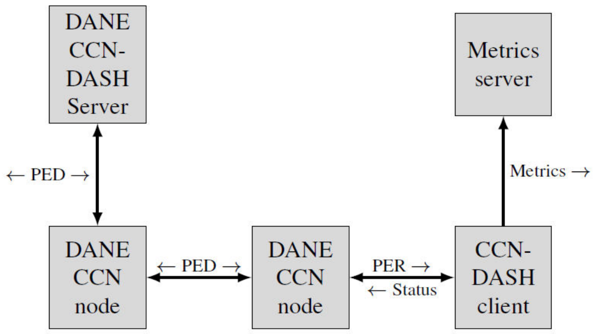

Fig. 10. SAND-CCN architecture [22].

VI. DISCUSSION OF CLOUD-BASED AVS TECHNIQUES

Over the last few years, there has been an increased number of applications that have "migrated to the cloud", and new cloud-based applications that have become popular [52]. The most famous cloud-based media services include Youtube, Daily motion, Microsoft Azure and Putlocker [62]. Cloud computing provides not only high computation power but also huge amount of storage space, so that it enables end users to utilize best services without having an expensive and complex architecture at their side. However, cloud architecture suffers from transmission degradations, especially transmission errors and security threats in cloud networks [62].

Similar motivations that have driven mobile enterprise cloud services are also driving adoption of mobile consumer cloud services: the ability to access media from anywhere: any device, platform, and network [52]. Cloud computing, with its elasticity, offers a way to match the users demand by dynamically scaling the allocated resources and by using a pay-as-you-go charging model without the need of large upfront capital investments [10]. Despite the desperate efforts of network operators to enhance the wireless link bandwidth (e.g., 3G/4G), the soaring video traffic demands from mobile users are rapidly overwhelming the wireless link capacity [54].
It is crucial to improve the Quality of Service (QoS) of mobile video streaming while utilizing the networking and computing resources efficiently [54]. It is desirable that the network infrastructure supports some means to provide Quality of Service (QoS) for multimedia traffic. To this effect, the Internet Engineering Task Force (IETF) has explored several QoS architectures, but none has been truly successful and globally implemented [12]. There is a guaranteed need for tools and techniques for modelling, simulating, analyzing, planning, provisioning and monitoring real-time service oriented applications deployed within clouds of virtualized computing, storage and video networking environments.
Media delivery is predominately accomplished via a content distribution network (CDN), which is a large distributed system of servers deployed in multiple data centers, serving contents to end users with high availability and high performance (e.g., fast response, high throughput) [55]. Content Delivery Networks (CDNs) are employed to provide a scalable and reliable video streaming services [10].
In the mobile cloud gaming scenarios, the resource-demanding game logics (e.g., state update and graphics rendering) are performed on cloud servers and the players receive the encoded streaming video via mobile devices (e.g., smart phone and iPad) [57]. Delivering high-quality cloud gaming experience is challenging, mainly because: 1) modern computer games are mostly resource hungry; 2) the real-time nature of games imposes stringent deadline; and 3) gamers have high expectations on different aspects of gaming experience. More specifically, gamers ask for both high-quality game scenes and low response delay, where: 1) the quality of game scenes is measured by metrics like resolutions, frame rates, fidelities, and 3-D effect levels and 2) the response delay refers to the time difference between the time when a gamer triggers an input and the time when the client renders the corresponding effect. Concurrently achieving both high-quality scenes and fast responses consumes a huge amount of computation and network resources [21]. File streaming allows gamers to start playing games after a small subset of files has been downloaded, while the remaining files are streamed in the background [21].
Crowd sourcing was first introduced in 2005 by Merriam-Webster as a way to obtain resources by collecting contributions from crowds of people, instead of employees or suppliers, particularly in the online community. Since then, crowdsourcing has been attempted as the method for various tasks and applications. Over the past three years, crowd sourced live streaming have emerged too, with a series of real world platforms being available in the market, such as Youtube Live, Azubu.tv, Hitbox.tv, Daily motion Games, and Ustream, to name but a few [50].
This work consists of four sections. Section VII presents the Taxonomy of Cloud-based strategies to DASH. Section VIII gives examples of the approaches defined in the taxonomy.

VII. TAXONOMY OF CLOUD-BASED APPROACHES

The Cloud-based AVS strategies are categorized into (1) Social-Awareness, (2) Cloud-based CDN, (3) Cloud-based Gaming, (4) Cloud-based SDN, (5) File-hosting services, (6) View synthesis techniques, and (7) Error Concealment techniques. These categories are shown on Figure 11.

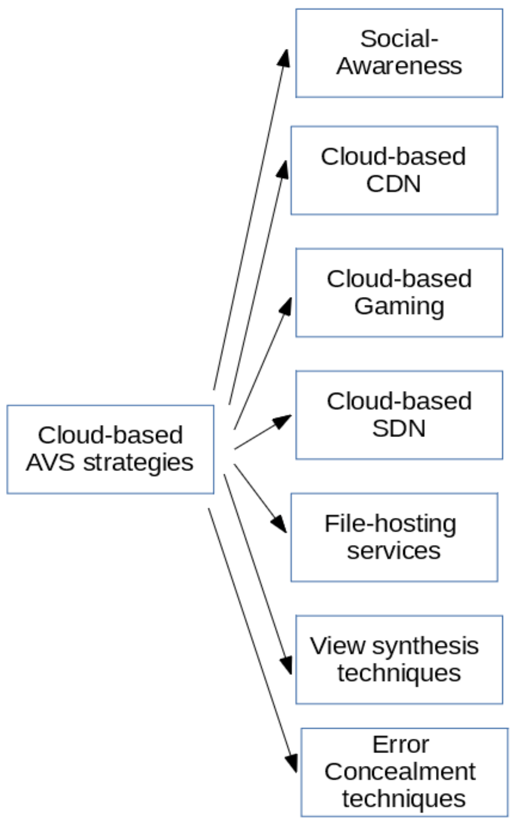

Fig. 11. Cloud-based AVS taxonomy

VIII. CLOUD- BASED STRATEGIES

A. Social-Awareness

Authors in [49] propose AMES-Cloud. This is a new mobile video streaming framework. It has two main parts: (1) adaptive mobile video streaming (AMoV), and (2) efficient social video sharing (ESoV). A private agent is afforded to each mobile user to provide efficient video streaming services. AMoV lets her private agent adaptively adjust her streaming flow with a scalable video coding technique for a given user. This is based on the feedback of link quality. ESoV monitors the social network interactions among mobile users. This is similar to AMoV. It then uses private agents to prefetch video content in advance. The performance of the AMES-Cloud framework is demonstrated. It is shown experimentally that the private agents in the clouds can effectively provide the adaptive streaming, and perform video sharing (i.e., prefetching) based on the social network analysis.

Authors in [54] propose and discuss a framework to improve the quality of video services. They target mobile users. The framework includes two parts: (1) cloud-assisted adaptive video streaming, and (2) social-aware video prefetching. A scalable video coding technique based on the feedback of link condition is used for each active mobile user. The video quality (bit rate) is adaptively adjusted by a private agent. The private agent is constructed in the cloud center. The online social network interactions among mobile users are monitored by the cloud-based agents. This ensures that videos shared among users will be effectively prefetched in advance. A prototype implementation of the framework is used to test the adaptability of the video streaming and the effectiveness of the social-aware prefetching supported by cloud computing.

Authors in [21] study the problem of optimally adapting ongoing cloud gaming sessions. Their goal is to maximize the gamer experience in dynamic environments. The considered problem is quite challenging because: 1) gamer experience is subjective and hard to quantify; 2) the existing open-source cloud gaming platform does not support dynamic reconfigurations of video codecs; and 3) the resource allocation among concurrent gamers leaves a huge room to optimize. The authors rigorously address these three challenges by: 1) conducting a crowdsourced user study over the live Internet for an empirical gaming experience model; 2) enhancing the cloud gaming platform to support frame rate and bitrate adaptation on-the-fly; and 3) proposed optimal yet efficient algorithms to maximize the overall gaming experience or ensure the fairness among gamers. Extensive trace-driven simulations were conducted. It demonstrates the merits of the proposed algorithms and implementation. Simulation results show that the proposed efficient algorithms: 1) outperform the baseline algorithms by up to 46% and 30%; 2) run fast and scale to large (≥8000 gamers) problems; and 3) achieve the user-specified optimization criteria, such as maximizing average gamer experience or maximizing the minimum gamer experience. The resulting cloud gaming platform can be leveraged by many researchers, developers, and gamers.

Authors in [17] present a generic AVS cloud-based framework. It utilizes powerful and elastic cloud computing services. These services are used for crowdsourced live streaming. However, the framework works with heterogeneous broadcasters and viewers. It jointly considers the viewer satisfaction and the service availability/pricing. These metrics are based on the geo-distributed cloud resources for transcoding. We develop an optimal scheduler for allocating cloud instances with no regional constraints. The framework is then extended to accommodate regional constraints. In addition, a series of practical enhancements is discussed. These include: (a) popularity forecasting, (b) initialization latency, and (c) viewer feedbacks. These solutions have been evaluated under diverse networks and cloud system configurations. Parameter settings were also given. The superiority of the design was confirmed with trace-driven simulations. Planetlab-based experiments were offered as giving further practical hints toward real-world migration.

B. Cloud-based CDN

Authors in [10] focus on the design of a control plane for cloud-based adaptive video streaming delivery networks. It employs feedback control techniques. A dynamical Resource Allocation Controller is designed. The controller throttles the number of virtual machines in a Cloud-based CDN. The goal is to minimize the distribution costs, and provide the highest video quality to the user. Results are obtained via experiments. These indicate that the resource allocation controller is able to significantly decrease distribution costs. In addition, it provides a high video quality to the user.

Authors in [26] study a QoE-driven mobile edge caching placement optimization problem. It is targeted for dynamic adaptive video streaming environments that properly takes into account (1) the different rate distortion (R-D) characteristics of videos, and (2) the coordination among distributed edge servers. Then, the aggregate average video distortion reduction of all users is maximized. This is done by the optimal caching placement of representations for multiple videos. At the same time the additional cost of representation downloading from the base station is minimized. This maximization and minimization is subject not only to the storage capacity constraints of the edge servers, but also to the transmission and initial startup delay constraints of the users. The proposed optimization problem is formulated as an integer linear program (ILP). It provides the performance upper bound. In addition, a practically feasible cost benefit greedy algorithm is developed. This is taken as a submodular maximization problem with a set of knapsack constraints. The proposed algorithm has polynomial computational complexity and a theoretical lower bound on its performance. Simulation results were collected. The proposed algorithm can achieve a near-optimal performance with very low time complexity. Thus, the proposed optimization framework reveals the caching performance upper bound for general adaptive video streaming systems. The proposed algorithm provides some design guidelines for the edge servers to select the cached representations in practice. This is based on both the video popularity and content information.

Authors in [4] present an integer linear program (ILP) for cloud-based CDN AVS. It maximizes the average user quality of experience (QoE). A heuristic algorithm is proposed that can scale to large number of videos and users. Two new datasets are introduced: (a) one characterizing a popular live streaming provider (Twitch), and (2) another characterizing the computing resources needed to transcode a video. Realistic test scenarios are set up. The performance of the optimal ILP solution is compared with current industry standards. It shows that the latter are sub-optimal. The importance of the type of video on the optimal streaming preparation is shown by the solution of the ILP. The proposed heuristic can efficiently satisfy a time varying demand with an almost constant amount of computing resources by taking advantage of this.

C. Cloud-based Gaming

Authors in [52] propose a rendering adaptation technique. It can dynamically vary the richness and complexity of graphic rendering depending on the network and cloud computing constraints. Thus, it impacts both the bit rate of the rendered video (this needs to be streamed back from the cloud server to the mobile device), and the computation load on the Cloud Mobile Gaming (CMG) servers. Experiments were conducted on a cellular network. These demonstrate that the proposed technique can significantly improve user experience. It also ensures scalability of the CMG approach in terms of both network bandwidth and server computational need.

Authors in [57] propose an online video frame selection algorithm. It minimizes the total distortion. This is based on: (1) the network status, (2) input video data, and (3) delay constraint. In addition, researchers introduce an unequal FEC coding scheme. It provides differentiated protection for Intra (I) and Predicted (P) frames with low-latency cost. The proposed APHIS framework can appropriately filter video frames. It adjusts data protection levels to optimize the quality of High-frame-rate (HFR) video streaming. Extensive emulations in Exata involving HFR video encoded with H.264 codec was conduct. Experimental results were obtained via simulation. It was shown that APHIS outperforms the reference transmission schemes in terms of (a) video peak signal-to-noise ratio, (b) end-to-end delay, and (c) goodput. APHIS was recommended for delivering HFR video streaming in mobile cloud gaming systems.

Authors in [16] focus on how to automatically tune the video quality to meet with the available network resources. In doing so it increases the user's video quality. The server stores several streams at different quality and resolution then switches among them during the play back to match user bandwidth and CPU. The proposed approach is compared to traditional streaming techniques. It shows better performance in term of Frame Rate (FR) switching. The FR remains unchanged. In addition, the resolution of the video matches the available bandwidth at the terminal.

D. Cloud-based SDN

An adaptive Software Defined Networking (SDN)-based architecture running on Cloud Mobile Media (CMM) is proposed in [15]. It estimates MOS using a statistical method. This method is based on Factor Analysis (FA). Consequently, the SDN controller will be able to schedule different actions. The MOS estimation is based on different measured variables throughout the CMM infrastructure. The accuracy of the estimated MOS is tested experimentally against well-known publicly available video quality algorithms.

E. File-hosting services

Vsync is a framework for cloud based video synchronization, which is introduced in [6]. It is targeted for mobile devices. A video content is streamed using (1) a cloud-based real-time transcoding, and (2) a transmission framework to provide smooth video quality. It is built over prediction models for video transcoding sessions. In addition, it uses a QoE based adaptive video streaming protocol. Vsync is able to obtain the improvements of 37 to 80% when compared to other schemes. Experimental evaluations were done using a dataset on a pool of 220K video clips.

F. View synthesis techniques

An improved DASH-based IMVS scheme over wireless networks is proposed in [62]. The main contributions are twofold: (1) the scheme allows virtual views to be generated at either the cloud-based server or the client, which adaptively selects the optimal approach based on the network condition together with the cost of the cloud, and (2) scalable video coding is used in our system. NS3 are used to run simulations. It demonstrates the advantage of the proposed scheme over the existing approach with client based view synthesis and single-layer video coding.

G. Error Concealment techniques

Authors in [50] proposes a time-efficient and quality oriented Error Concealment (EC) method. The proposed method considers H.265/HEVC based intra-encoded videos. This is then used for the estimation of whole intra-frame loss. The recovery of Motion Vectors (MVs) of a lost frame in real-time is the main emphasis in the proposed approach. A bigger block size and searching in parallel are both considered to boost up the search process for the lost MVs. Simulation results are carried out. It clearly shows that the proposed method outperforms the traditional Block Matching Algorithm (BMA). This is by approximately 2.5 dB. The Frame Copy (FC) outperforms the BMB by up to 12 dB at a packet loss rate of 1%, 3%, and 5% with different Quantization Parameters (QPs). The BMA is outperformed by the proposed approach by approximately 1788 seconds.

IX. CONCLUSION

SAND-based approaches to DASH have certain advantages over traditional client- or proxy-based approaches. It is proposed that the sharing of information among client and network devices enhances the streaming process. This work produces a novel taxonomy for SAND-based approaches. It places AVS solutions into four categories: (1) Management Architecture (2) Cache-based, (3) Optimization, and (4) Paradigm. Sub-categories of Management Architecture are (a) Cognitive, (b) Prioritization, and (c) Encoding and Signaling, while sub-categories of Paradigm are (a) SDN-based, (b) CDN-based, and (c) CCN-based. The approaches representing each category are presented. It is shown that using the SANDs architecture proves beneficial to approaches adopting it.

Cloud-based strategies for AVS have been an important area of research and industry. This paper elaborates on Cloud-based strategies. It places current strategies into a taxonomy. The Cloud-based AVS strategies are categorized into (1) Social-Awareness, (2) Cloud-based CDN, (3) Cloud-based Gaming, (4) Cloud-based SDN, (5) File-hosting services, (6) View synthesis techniques, and (7) Error Concealment techniques. The implementations that exist for the Cloud-based strategies are discussed. Thus, the advantages of both SAND and Cloud-based approaches for use in DASH-based systems are illustrated.

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