Hindawi Publishing Corporation
Journal of Sensors
Volume 2016, Article ID 8040138, 11 pages
http://dx.doi.org/10.1155/2016/8040138

Research Article

QoS and QoE Aware N-Screen Multicast Service

Ghulam Sarwar, Farman Ullah, and Sungchang Lee

Department of Electronics and Information Engineering, Korea Aerospace University, Deogyang-gu, Goyang-si, Gyeonggi-do 412-791, Republic of Korea

Correspondence should be addressed to Sungchang Lee; sclee@kau.ac.kr

Received 17 December 2015; Accepted 29 March 2016

Academic Editor: Marco Anisetti

The paper focuses on ensuring the quality-of-service (QoS) and quality-of-experience (QoE) requirements of users having heterogeneous devices in a multicast session. QoS parameters such as bit rate, delays, and packet losses are good indicators for optimizing network services but fall short in characterizing user perception (QoE). In N-Screen service, the users have different devices with heterogeneous attributes like screen size, resolution, and access network interface, and the users have different QoE on N-Screen devices with the same QoS parameters. We formulate the objective function of the N-Screen multicast grouping to ensure the minimum user's QoE with smaller bandwidth requirement. We propose a dynamic user reassignment scheme to maintain and satisfy the QoE by adapting the user's membership to the varying network conditions. The proposed schemes combine the available bandwidth and multimedia visual quality to ensure the QoS and QoE. In the network architecture, we introduce the functions of the QoS and QoE aware multicast group management and the estimation schemes for the QoS and QoE parameters. The simulation results show that the proposed multicast service ensures the network QoS and guarantees the QoE of users in the varying network conditions.

1. Introduction

Multimedia streaming is one of the fastest growing applications and the last decade alone has witnessed a rapid development in the complexity of smart devices and communication technologies. The interactive advertisement bureau report states that about 69% of users have 4-Screens [1] active and about 90% of the users' interaction is through Multi-Screen [2]. N-Screen, also termed as Multi-Screen, has different attributes such as network interfaces, media codecs, screen resolutions, computing, and storage. N-Screen service enables users to access and share the content from the same source through heterogeneous devices from any location and at any time [3, 4]. The ubiquity of communication technologies and smart devices demands that users should be able to access their subscribed services through any of the available networks such as 3G, 4G, LTE, and WiFi, as well as through any device such as smart phones, laptops, desktops, and tablets. N-Screen multimedia service demands extensive bandwidth to ensure the quality of service (QoS). A lack of bandwidth could cause higher end-to-end delay, video jitter, and packet losses. Cisco forecasts that by 2019, 80% of the global IP data will be video traffic. Moreover, the heterogeneity of N-Screen devices raises new questions about the multimedia QoS and user's experience on different terminals [4, 5]. The challenges that come with a rapid increase in mobile video traffic and ensuring multimedia QoS and user's quality of experience (QoE) on mobile devices can be addressed by either boosting the network capacity or by offloading traffic from the core and backhaul networks [6]. This paper presents a novel N-Screen multimedia multicast scheme to minimize the traffic and ensure that the QoE requirements of all group users on their N-Screen devices are met.

The huge growth rates of multimedia services utilize higher bandwidth and cause congestion in the core network. IP multicast [7] is a technique designed to conserve the network bandwidth by sending a single stream to multiple hosts simultaneously which helps in reducing the core network traffic. The multicast stream receiving nodes can have different capabilities and QoS and QoE requirements. IP multicast synchronizes the content transmission rate to the worst channel conditions among the multicast users that cause the traditional bandwidth fairness problem. To improve fairness

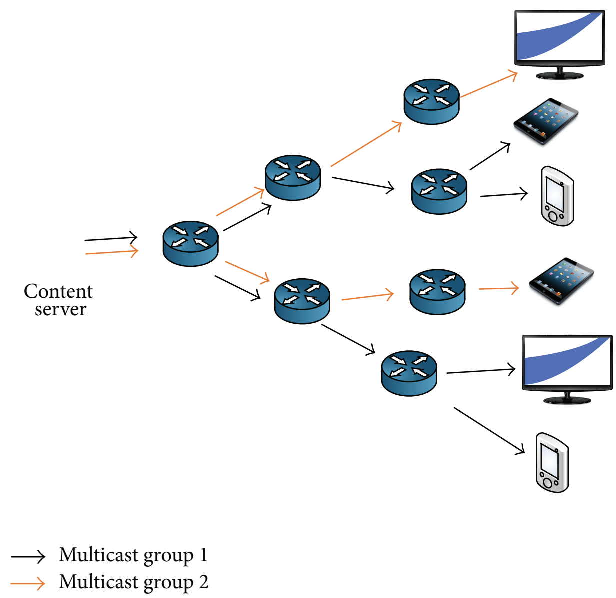

Figure 1: N-Screen aware multicast service.

among the multicast users, the destination set grouping (DSG) [8, 9] schemes proposed group users based on their available bandwidth (ABW). The existing DSG schemes do not consider the QoE requirements and different capabilities of N-Screen devices and cannot ensure the QoE requirements to all users as the QoE may be different on different devices in the same network conditions. Moreover, N-Screen devices may have the same QoE in different network conditions. The QoS requirements of N-Screen users can be ensured by defining different QoS traffic classes and serving high-quality classes with priority as in Differentiated Services [10] and IEEE802.11e [11]. Alternatively, the scalable video coding [12, 13] adapts the data transmission rate to the varying network conditions to handle the distribution of content to heterogeneous devices. These models require network transcoding to handle the different QoS classes and varying network conditions. This paper focuses on ensuring the satisfaction of QoS and QoE requirements of N-Screen multicast users without requiring in-network multimedia adaptation as that in SVC or layered video coding. We formulate the objective function of the N-Screen partitioning problem to ensure and maximize the users' QoE. The suggested scheme assigns users to the appropriate visual quality based multicast groups (MGs) at the source as shown in Figure 1.

From a network perspective, QoS is characterized by bandwidth constraints, delays, packet losses, and jitters that affect video quality. Tavakoli et al. [14] investigated the effect of the chunk/packet size and the quality switching amplitude on the QoS and QoE. Although QoS can give valuable insights about the network conditions, it alone is often inadequate for providing a reliable estimation of the video quality perceived by the end user, which is known as QoE [15]. QoS and QoE together characterize the quality of multimedia services that can be provided by the current network conditions and perceived by users of N-Screen devices. The QoS is a performance contract that can be measured either qualitatively or quantitatively between the user and service provider. The QoE is a qualitative metric which can be measured with Motion-Based Video Integrity Evaluation Index (MOVIE) [16] or mean opinion score (MOS) [17]. In this study, we adopt the MOS metric of ITU-T G.1070 [8, 18] standard which considers the N-Screen attributes and network conditions information for QoE estimation. Andrew Catellier et al. [19] stated that users have different multimedia QoS and QoE on different devices and that the perceived multimedia quality is not the same on 10′ inch tablets and 21′ inch LCD screens. Therefore, considering only the bit rate does not satisfy the QoE requirements of each user in the MG as the perceived visual quality is different for each user's N-Screen device. In this paper, we propose a bit rate and multimedia quality aware N-Screen multicast service to ensure that the QoS and QoE requirements of users in an N-Screen environment are met.

The paper is organized as follows: Section 2 describes the background and related works and Section 3 presents an overview of the proposed N-Screen multicast service. Section 4 explains the architecture for provisioning QoS and QoE aware N-Screen multicast service and schemes for available bandwidth estimation, as well as multimedia quality estimation. We presented the objective function of N-Screen MG management, dynamic user reassignment, and periodic MG management schemes in Section 5. Section 6 provides a discussion and a comparison of the proposed architecture simulation results with that of previously existing ones. And lastly, Section 7 concludes the paper.

2. Background and Related Works

In this section, we introduce the background knowledge and related works concerning N-Screen service, multicast service, and multimedia QoS and QoE before going into the details of the proposed N-Screen multicast service.

N-Screen service enables users to use multiple heterogeneous devices at any time and at any location. The N-Screen technology aims to provide seamless service continuity and synchronize the content over heterogeneous displays [20]. In reality, N-Screen service is the enabling of one-source multiuse (OSMU) with that of an adaptive source multidevice (ASMD). A recent work [3, 4] defined and classified the various services that can be provided on multiple devices, and also the handover mechanisms over various access networks and devices. In [21], the authors provided the implementation details of mobile DTV broadcasting for N-Screen smart devices on top of iOS and Android OS platforms. Kwon et al. [22] identified the different factors such as service quality, ease of use, and price fairness that affect the behavioral intent of using existing N-Screen service. A scalable framework is proposed in [23] to provide web-based N-Screen user interface management for different screen layouts. A seamless screen switching scheme without intervention of user is proposed considering the user's context extracted from the embedded sensors in the devices [24]. Mostly, these research works have focused on the definitions and architectures of N-Screen services. Moving forward, this paper focuses on the grouping of heterogeneous N-Screen devices for multicast-based data dissemination to alleviate the network congestion that currently exists in the mobile and fixed networks.

The multicast service provides a one-to-many or many-to-many communication to reduce the overall core network load. The multicast schemes can be application layer multicast [25, 26], IP-layer multicast [27], and link layer multicast [28]. In the multicast environment, a user may have different channel conditions that arise due to interference, fading, obstacles, and distance from the base station. The intergroup proportional fairness and multicast proportional fairness schemes are proposed in [29] to enhance the system throughput by assigning appropriate data rates to MGs according to the channel conditions. The IP Multimedia Subsystems (IMS) support in the Universal Mobile Telecommunications System (UMTS) became available in the 3rd Generation Partnership Project (3GPP) Release 5 to support service continuity in heterogeneous networks. The Release 5 of 3GPP originally only supported the unicast transmission that functions to increase the IP-core network load [30]. However, the 3GPP Release 6 and later versions [31] introduced the multimedia broadcast and multicast service (MBMS) in IMS. Converged IMS-MBMS integrated frameworks have been proposed to support multicast/broadcast services and mobility in heterogeneous networks [30–32]. Despite being superior to previous models, the MBMS service still does not consider the different capabilities and QoE requirements of N-Screen devices.

QoS is a measure of service availability and transmission quality of a network. QoS management schemes focus on application layer [33], network layer [28], and MAC layer [34] mechanisms to adapt the session to network conditions. These schemes require accurate information of the network QoS parameters such as ABW, packet loss ratio (PLR), jitters, and average packet delay. The estimation of the ABW is one of the critical factors for managing QoS and network congestion. ABW can be estimated either as hop-to-hop or end-to-end. The individual hop bandwidth estimation tools are proposed in previous studies [35, 36], and the end-to-end bandwidth estimations are *Pathload* [37] and *pathChirp* [38]. The end-to-end ABW in the network is a time-varying process and can be defined as the minimum of nonutilized capacities of all the links in between. The bandwidth estimation can be categorized as (i) *passive*, which is estimated from the packet loss, delay, and congestion without intruding into the network, and (ii) *active*, which sends probe packets to estimate the bandwidth. The active probing method is further classified as probe gap or probe rate models. The Trains of Packet Pairs [39] sends out packet pairs that are well separated in time and uses linear regression to estimate the bandwidth. The *pathChirp* uses exponential time space between the probe packets to estimate the ABW, which can accurately capture the status of network's congestion. *Pathload* uses the one-way delay of periodic packets to estimate the ABW and states that when the stream rate is larger than the ABW, the one-way delay of the periodic packets shows an increasing trend. A Bayesian-based prediction model was proposed to predict instantaneous end-to-end bandwidth change and the prediction method of one-way bandwidth estimation at the receiver [40]. Ahuja et al. [41] proposed the network such as 2G and 3G selection based on available link in the multiaccess networks environment.

In the multimedia streaming, one of the important factors is the insurance of the user's QoE requirements. The multimedia QoE estimation models can be classified as media layer models (MLMs) or packet layer models (PLMs). MLMs use the multimedia content to estimate the visual quality while the PLMs use the packet and network information to predict the visual quality [42]. In a previous research [43], the authors categorized the multimedia QoE estimation models as Full reference, Reduced reference, and No reference models. Full reference models [16] require both the original stream and the received distorted stream, Reduced reference models require some parameters description of the original stream and the received distorted stream, and No reference models use only the distorted stream. ITU-T J.144 [44] and ITU-R BT.1683 [45] are the Full reference models of the perceived visual quality estimation in the Digital TV. Kusuma et al. [46] developed the Reduced reference model for the estimation of perceptual visual quality. No reference parametric packet layer models have been proposed or studied in the past [47–49]. ITU-T G.1070 [8] is the recommendation based on the PLM of QoE estimation for videophone multimedia streaming services.

The contribution and significance of this paper compared to the existing approaches can be summarized as follows. (1) We focus on ensuring the QoS and QoE requirements of users having heterogeneous devices in a multicast session. (2) We propose the N-Screen multicast user partitioning as an optimization problem to maximize the users' QoE using smaller users' bandwidth and provide an algorithm to manage the number of MGs. (3) We propose a dynamic user reassignment scheme to maintain the QoE by adapting the user's membership according to the varying network conditions. (4) To provide N-Screen multicast service, we introduce the schemes of QoS estimation, QoE estimation, and visual quality aware MG management in the network architecture.

3. Overview of the Proposed N-Screen Multicast Service

In the proposed N-Screen multicast service, we assume that N-Screen users specify their visual quality requirements (MOS) and the service provider side assigns the users to appropriate MGs that can meet users' requirement as shown in Figure 2. In the figure, the x-axis represents the content transmission rate of MGs at the source and y-axis represents the expected perceived visual quality on user device. In an N-Screen multicast environment, devices having different network conditions can be assigned to the same MG and vice versa. This is because the MOS depends not only on the bit rate and PLR, but also on the codec, frame rate, and screen resolution. We assume that the visual quality requirement of a user is less than or equal to the maximum visual quality that can be provided in the current network conditions on the user's device. The criteria for assigning a user to a MG and the goals of the N-Screen multicast service are briefly discussed as follows.

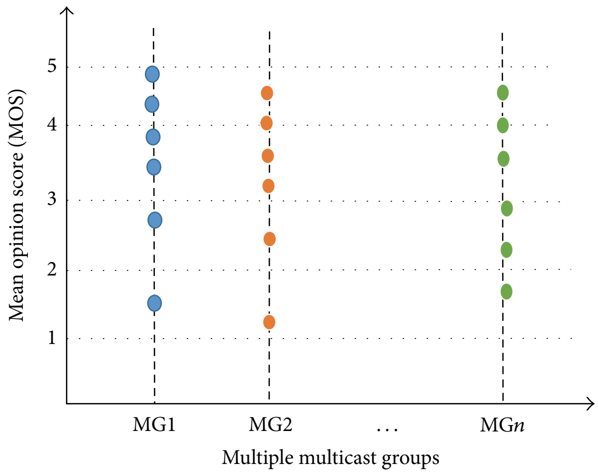

Figure 2: N-Screen, network, and visual quality aware user assignment to different multicast groups.

(i) Assign user to one of the existing MGs that can provide the required visual quality on user's device.

(ii) Assign user to the MG that provides maximum visual quality and requires smaller bandwidth as compared to other existing MGs.

(iii) Create a new MG if none of the available MGs can meet user's requirement subject to the availability of system's resources.

4. The Proposed QoS and QoE Aware N-Screen Multicast Service Architecture

Multicast disseminates the same content simultaneously to multiple receiving nodes to efficiently utilize the network resources. The main challenge of multimedia multicast service is providing the downlink data dissemination to N-Screen devices having different capabilities, QoS requirements, locations, and network conditions. Although QoS parameters such as available bandwidth, packet loss, and end-to-end delay of the underlying networks are good indicators for application service providers to optimize their services, these parameters do not reflect the perceived visual quality on the end user device. In N-Screen, users experience different visual quality on different N-Screens at the same QoS parameters due to the heterogeneous capabilities of the devices. We propose a novel N-Screen multicast service that focuses on ensuring the QoS and QoE requirements of N-Screen users at the service provider side by grouping users to appropriate MGs without requiring in-network multimedia adaptation as that in scalable video coding. In the following subsections, we introduce the proposed architecture, estimation of available bandwidth, and visual quality on N-Screen device.

4.1. Proposed N-Screen Multicast Service Architecture. To support N-Screen multicast service, we introduce the functions of N-Screen MG management, QoS and QoE estimation techniques, and N-Screen service repository in the service provider network as shown in Figure 3. We briefly discuss the functions of each node of Figure 3 as follows.

4.1.1. N-Screen Service Management System (NSMS). To efficiently support N-Screen service across heterogeneous networks and devices, there should be a node that captures the entire network information. The NSMS is the central control unit that performs the registration and authorization of user's device and provides directory service. It maintains users' device list, IP addresses, and content lists of content servers.

4.1.2. N-Screen Profile and Multicast Group Manager (PMGM). After service registration with the NSMS, the user performs device registration with the PMGM. The PMGM maintains the current network conditions information and device attributes of each N-Screen device and assigns users to appropriate MGs. It gets the user's QoS parameters from the N-Screen content server (NCS) and uses them with N-Screen attributes to estimate the perceived visual quality. If the group membership of a device is changed due to changes in the network conditions, the PMGM informs the NCS to invite the user to the appropriate MG for better service quality.

4.1.3. N-Screen Content Server (NCS). NCS performs session management and QoS parameters estimation and sends the adapted contents to MGs. It also contains a bandwidth estimation module that sends probing packet trains to N-Screen devices to estimate the end-to-end ABW and PLR and reports them to the PMGM for further actions.

4.2. QoS Parameters Estimation. The multimedia services over the best-effort networks (i.e., Internet) are confronted with many challenges, and one of the most important factors is the ABW. The unpredictable and dynamic behavior of internet traffic adversely affects the multimedia quality. ABW and PLR are critical metrics to ensure the user's QoS requirements. We adapt and extend the concept proposed in previous works [50, 51] by using probe trains to estimate the ABW. Figure 4 shows the proposed ABW estimation scheme using the Poisson distribution for the interpacket gap and an adaptive number of probing packets in the trains to accurately capture the network's congestion.

We define the maximum and minimum number of packets in a train and adapt the number of packets between the maximum and minimum limits. The bandwidth estimation module of the NCS sends back-to-back probe packets and uses one-way delay (OWD) to estimate the ABW. We linearly increase the number of probe packets in the next train if the estimated $\mathrm{OWD}_{\mathrm{train}}$ is greater than a predefined threshold. If the $\mathrm{OWD}_{\mathrm{train}}$ is less than the threshold, we reduce the number of packets in the next trains. Let t_i be the time-stamp the probe packet i starts transmission with and let t'_i be its receiving time at the receiver. The OWD of the consecutive

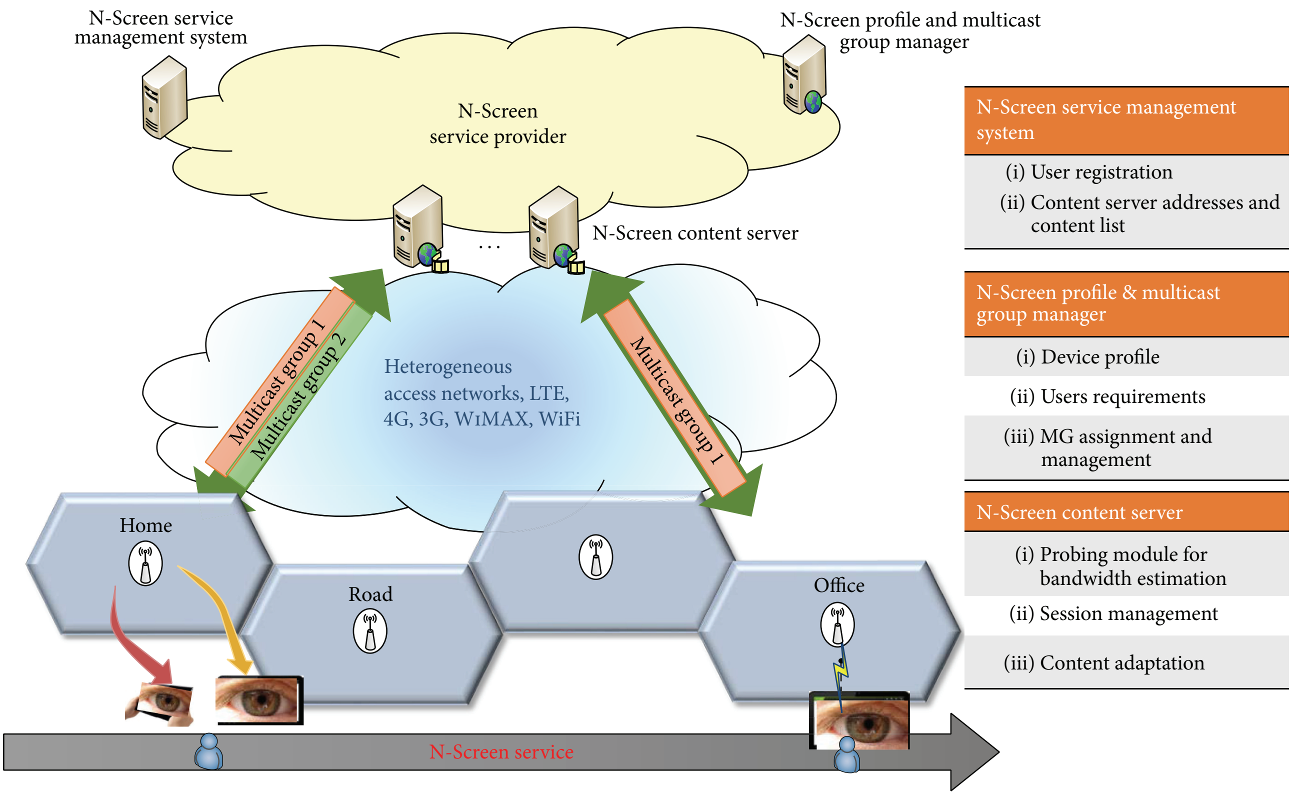

Figure 3: The proposed QoS and QoE aware N-Screen service architecture.

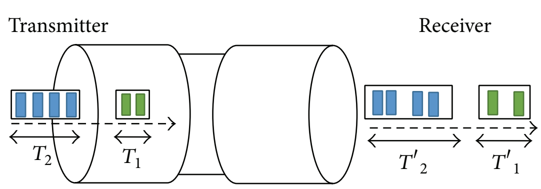

Figure 4: Available bandwidth estimation using probing train method.

probe packets in the probe train can be $(t_{i+1} - t_i) - (t'_{i+1} - t'_i)$. The $\mathrm{OWD}_{\mathrm{train}}$ can be found by the following:

$$\mathrm{OWD}_{\mathrm{train}} = \frac{\sum_{i=1}^{N-1} (t_{i+1}) - (t'_{i+1} - t'_i)}{N-1}, \quad (1)$$

where N is the number of probe packets in the train. The available bandwidth ABW for probe packet size S can be found by the following:

$$\mathrm{ABW} = \frac{\sum_{i=1}^{N-1} S_i}{\mathrm{OWD}_{\mathrm{train}}}. \quad (2)$$

Packet loss is another important QoS parameter and occurs due to many factors such as queuing, user location, and channel noise in the wireless networks. The packet losses reduce the system throughput and link reliability and increase the transmission delay due to retransmissions. The multimedia quality is highly susceptible to the packet loss as real-time multimedia services are mostly based on the unreliable User Datagram Protocol (UDP). The PLR is given by the following:

$$\mathrm{PLR} = \frac{\mathrm{ExPackets} - \mathrm{RePackets}}{\mathrm{ExPackets}}, \quad (3)$$

where ExPackets is the expected packets (transmitted packets) and RePackets is the actually received packets. Each N-Screen device reports the reception time-stamps of the packets and the ExPackets of the train to the bandwidth estimation modules to estimate the AWB and the PLR using (2) and (3).

4.3. QoE (Visual Quality) Estimation. QoS parameters give full insight about the network status but do not give any information about the multimedia quality perceived by the end user on his N-Screen device. QoE parameters estimate the perceived visual quality on user's device. The perceived visual quality depends on the capabilities of N-Screen devices and access network conditions. A user experiences different visual quality at different N-Screen devices even in the same network conditions. We adapt the concept of ITU-T G.1070 [8] to estimate the multimedia quality (MOS) on user's N-Screen device:

$$\mathrm{MOS} = 1 + \left(v_3 - \frac{v_3}{1 + [\mathrm{ABW}/v_4]^{v_5}} \right), \quad (4)$$

where MOS is the mean opinion score and its range is from 1 to 5. The variables v_3, v_4, and v_5 depend on the media code, frame rate, and screen size.

5. QoS and QoE Aware N-Screen Multicast Group Management

In this section, we introduce the QoS and QoE aware user's assignment and multicast group management. When a user requests the desired content, considering its QoS and QoE requirements and regarding the ABW, the PLR, and the expected MOS of the content on his current device, the MG management function decides whether to add the user to one of the existing MGs or a new MG. In a mobile network, the supported data rates and packet losses at the receiving nodes in a MG may be different due to different channel conditions and locations. In the paper, we approximate the PLR and ABW of a MG at the base node, that is, the node having highest losses and smallest ABW in the MG. We introduce the N-Screen group management, dynamic user reassignment, and periodic MG management schemes in the following subsections.

5.1. N-Screen Group Management. The objective of the proposed N-Screen grouping is to ensure and maximize the users' QoE using smaller bandwidth. The perceived visual quality in a MG is an increasing function of the content transmission rate (CTR) as long as the CTR is less than the ABW and is decreasing when the CTR exceeds the ABW due to the occurrence of PLR. The objective of the partitioning problem is to appropriately assign the users to MGs that ensure and maximize users' experience using smaller users' bandwidth. Let $V(U,K)$ denote the session utility "V" of partitioning users $1\cdots U$ into K groups that maximize the user's experience using smaller bandwidth. We may express V as follows:

$$V(N,K)=\sum_{u=1}^{N}\sum_{k=1}^{K}\lambda_{u,k}*\frac{((r_u-r_k)*5)/\mathrm{MaxCap}}{\mathrm{MOS}_u-\mathrm{MOS}_{u,r_k}}, \quad (5)$$

such that

$$0\le\sum_{g=1}^{G}\mathrm{BW}_g\le\alpha T\le T, \quad (6)$$

$$\mathrm{MOS}_{u,k}\le\mathrm{RQ}_u, \quad (7)$$

$$\mathrm{BW}_k\le\min\{\mathrm{ABW}_i\}_{i=1}^{U_k}, \quad (8)$$

$$\forall Ki,Kj,i\ne j: Ki\cap Kj=0, \quad (9)$$

$$1\le U_k\le U_T, \quad (10)$$

$$1\le K\le U_T, \quad (11)$$

$$\sum_{i=1}^{K}U_k=U_T, \quad (12)$$

where $\lambda_{u,k}\in\{0,1\}$ is the assignment of user u to MG k, r_u is the available bandwidth of user u, is the CTR of MG k, and MaxCap is the maximum link's capacity. We scale the bit rate in (5) from 0 to 5 to make it comparable to the MOS parameter in the equation. The constraint in (6) states that bandwidth assigned to MGs should not overwhelm the system threshold bandwidths which is 60% in the standard eMBMS specification. Equation (7) states that the visual quality provided by the MG "k" should satisfy the user's requirements. The constraint of (8) shows that the CTR of a MG "k" should be less than minimum ABW among all the users of the group. Notations section shows the symbols and notation descriptions used in these equations and this paper. The system performs user's assignment to the groups using Dynamic Programming Algorithm as in [52]. The group membership of a user is decided by using the following decision equation:

$$\lambda u,k=\begin{cases}1; & \text{if } \dfrac{((r_u-r_k)*5)/\mathrm{MaxCap}}{\mathrm{MOS}_u-\mathrm{MOS}_{u,r_k}}\ge\dfrac{((r_u-r_j)*5)/\mathrm{MaxCap}}{\mathrm{MOS}_u-\mathrm{MOS}_{u,r_j}} \\ & \text{for } j=1,2,\ldots K,\ j\ne k,\ \text{subject to MOS contraints} \\ 0; & \text{otherwise.}\end{cases} \quad (13)$$

5.2. Dynamic User Reassignment. The perceived visual quality by N-Screen users from multicast groups varies due to the varying network conditions, and fixing a user's assignment to multicast groups cannot ensure the visual quality requirements of of the user during the lifetime of the session. We suggest dynamic user reassignment to maintain the perceived visual quality and ensure the user's requirements. The dynamic user reassignment algorithm is shown in Figure 5. Considering the current network conditions, user's requirements, and N-Screen attributes, the proposed scheme monitors the visual quality deterioration. If the visual quality deterioration condition is satisfied, the suggested scheme searches for another existing MG that can provide better visual quality and may ensure user's requirement. The system invites the user to the appropriate MG to maintain the QoE requirements.

6. Evaluation Results

The section provides the comprehensive simulation results and comparison with other schemes. The results show that the proposed multicast service efficiently utilizes the network resources and provides the QoS and QoE endurance. We use the OMNET++ based simulation environment [53]. Figure 6 shows the simulation model to estimate the available bandwidth and multimedia visual quality. In the figure, S are the sources that generate the background traffic, R are the routers, AP are the wireless network base stations, and the N-Screen devices are four heterogeneous devices with each AP. Table 1 shows the simulation parameters used in the simulation and evaluation of the scheme.

Figure 7 shows the comparison of the bandwidth estimation schemes using the probe gap model, the linear increment in the number of probes, and the proposed Poisson distribution based interpacket gap model with an adaptive number of packets in the trains. The proposed scheme predicts fast bandwidth fluctuation as compared to the other schemes. The result clearly demonstrates that traditional methods

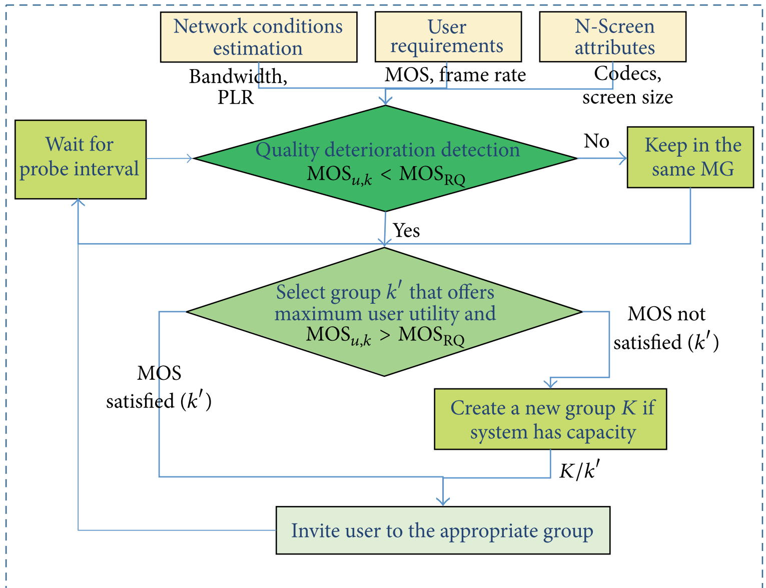

Figure 5: Algorithm of dynamic user reassignment.

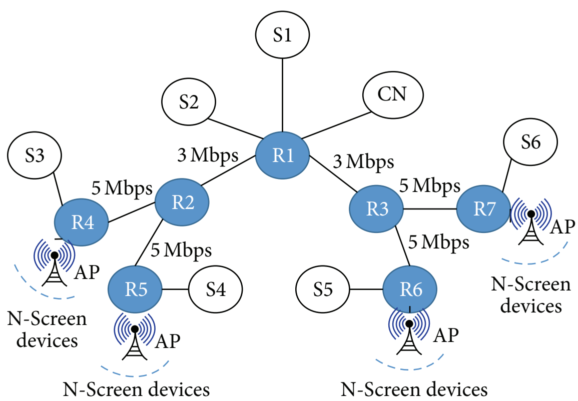

Figure 6: Simulation environment.

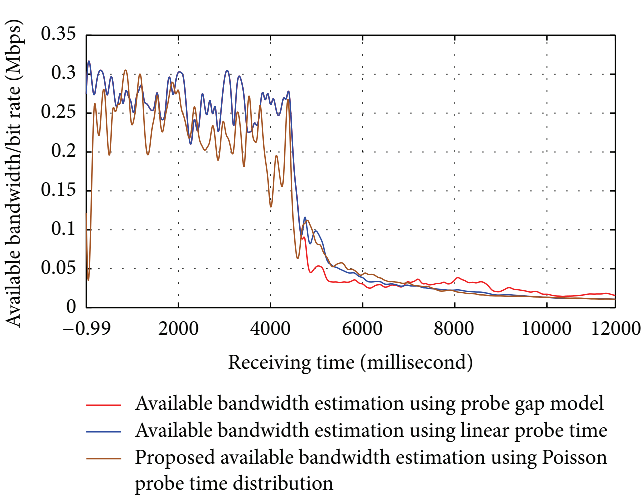

Figure 7: Comparison of the available bandwidth estimation schemes.

Table 1: Simulation setup parameters.

Parameter	Value
Probe packet size	1000 bytes
Bottleneck links capacity	3 Mbps
Other links	5 Mbps
Frame rate	30 fps
Minimum probe packets in train	2
Maximum probe packets in train	5

do not have the caliber to abruptly detect the changes in the available bandwidth. Figure 7 shows the scenario of normal background traffic and at 44960 ms, we increase the background traffic to detect the change in the bandwidth. The proposed scheme detects the change about 97 ms earlier than the other schemes. Since the proposed scheme can detect the changes in the available bandwidth earlier than schemes so the source can adjust its bit rate in advance. This helps to decrease the congestion, reduce the packet losses, and improve the user's QoE.

The perceived visual quality strongly depends on the network conditions and N-Screen attributes as shown in Figure 8(a). The codecs with high compression ratio such as H.264 and higher transmission rate can provide better visual quality in good channel conditions, but as the PLR increase less, a codec with less compression ratio such as MPEG-4 and less transmission rate offers better visual quality than H.264. The system assigns a user to the MG that offers better visual quality on an N-Screen device in the current network conditions. Due to the unpredictable nature of background internet traffic, we suggest dynamic MG reassignment to maintain and ensure the required QoE as depicted in Figure 8(b).

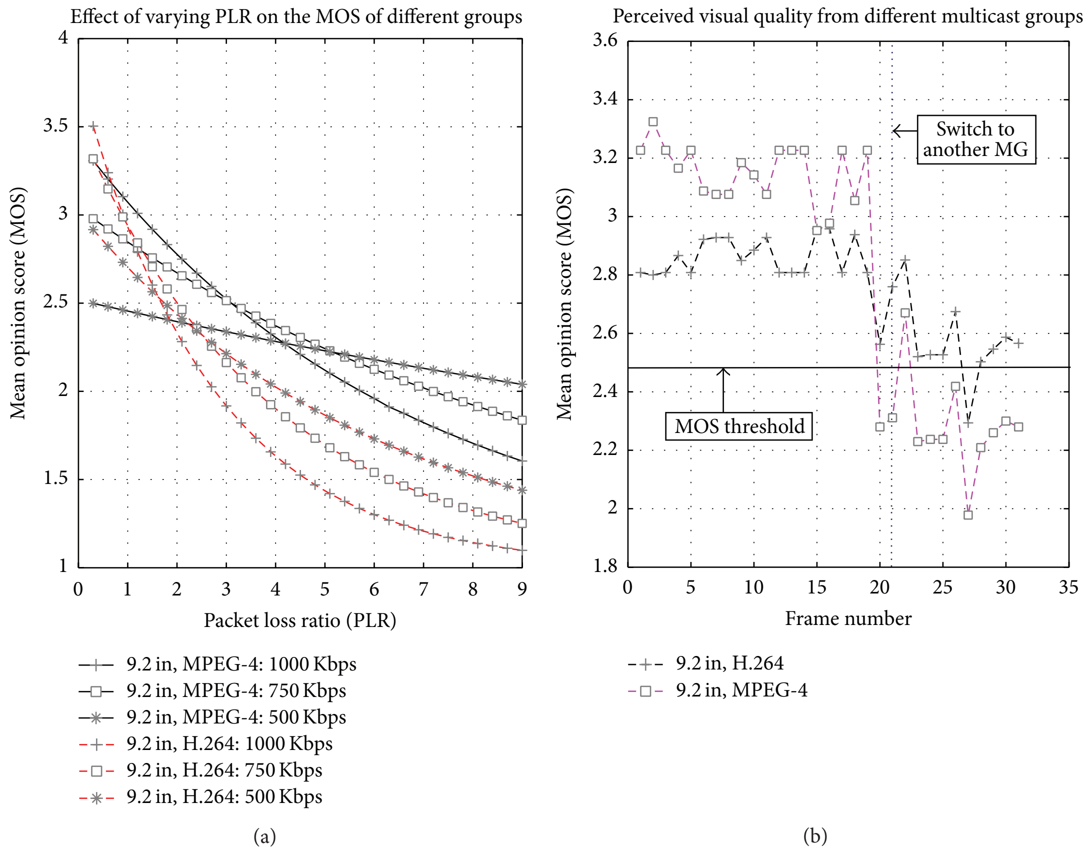

FIGURE 8: Effect of dynamic group assignment on visual quality.

TABLE 2: Comparison of N-Screen multicast with unicast and multicast schemes.

Device ID	Screen size	QoE requirements	ABW (Kbps)	PLR	Unicast	Bit rate based multicast scheme		Proposed N-Screen multicast	
					MOS	MOS	Grouping	MOS	Grouping
D-1	2.1″	MOS > 2.5	300	0.6	3.48	3	Transmit at base rate (200) to all users but cannot ensure the visual quality requirements of all users	3	MG1: base rate (200)
D-2	4.2″	MOS > 2	500	0	3.48	2.11		2.11	
D-3	2.1″	MOS > 2.5	200	0	3.18	3.18		3.18	
D-4	9.2″	MOS > 2	500	0	2.25	1.73		2.18	MG2: base rate (450)
D-5	4.2″	MOS > 2	450	2	2.46	1.77		2.46	

Table 2 shows a comparison of the proposed QoS and QoE aware N-Screen multicast service with the traditional bit rate based multicast and unicast schemes. The bit rate based multicast scheme groups devices in a single multicast session although the QoE requirements of D-4 and D-5 are not fulfilled. Unicast based transmission offers high visual quality to N-Screen users by utilizing the user's ABW at the cost of network resources. The proposed scheme divides the users into MGs to ensure that visual quality requirements of all N-Screen users are met. Figure 9 compares the efficiency of the proposed N-Screen multicast service in terms of perceived visual quality with that of traditional unicast and multicast schemes. In the experiment, we vary the number of users in the session.

7. Conclusion

In the paper, we proposed QoS and QoE aware adaptive mapping of N-Screen devices to multicast groups (MGs) at the application layer to ensure the visual quality requirements of N-Screen devices in varying network conditions without requiring network transcoding. In N-Screen service, users have heterogeneous devices that have different attributes, and the users have different QoE on different devices with the same QoS. We proposed the architecture, management functions, and the parameters estimation schemes for providing N-Screen multicast service. The proposed multicast service ensures the minimum QoS and QoE requirements of users in the varying network conditions. Furthermore, the proposed

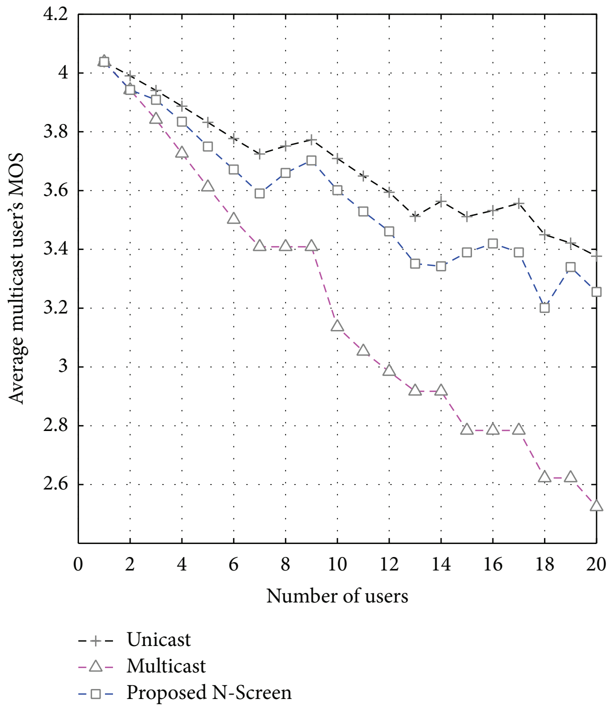

Figure 9: Comparison of the proposed N-Screen multicast with unicast and multicast schemes.

available bandwidth estimation scheme can abruptly detect the changes in the network conditions. The proposed N-Screen multicast scheme can efficiently utilize the network resources and offers comparable visual quality as that by a unicast session.

Notations

OWD:	One-way delay for a packet
BW_{av}:	End-to-end available bandwidth
S:	Probe packet size
PLR:	Packet loss ratio
MOS:	Mean opinion score (multimedia quality range: 1–5)
G:	Number of multicast groups
U:	Number of unicast users in the system
$\|U_g\|$:	Number of multicast users in the multicast group
α:	Total bandwidth of the system
BW_g:	Fraction of bandwidth assigned to multicast services
BW_i:	Bandwidth assigned to multicast group i
$U_g - U_k = 0$:	Users will belong to one multicast group for the same service.

Competing Interests

The authors declare that there is no conflict of interests regarding the publications of this paper.

References

[1] "The Multi-Screen Marketer: Interactive Advertising Bureau Report," 2012, http://www.iab.net/media/file/The_Multiscreen_Marketer.pdf.

[2] Australian Multi-Screen Report, 2014, http://www.nielsen.com/content/dam/nielsenglobal/au/docs/reports/australian-multi-screen-report-q32014.pdf.

[3] C. Yoon, T. Urn, and H. Lee, "Classification of N-screen services and its standardization," in *Proceedings of the 14th International Conference on Advanced Communication Technology (ICACT '12)*, February 2012.

[4] F. Ullah, G. Sarwar, H. Lee, W. Ryu, and S. Lee, "Control framework and services scenarios of provisioning n-screen services in interactive digital signage," *Tehnicki Vjesnik*, vol. 21, no. 6, pp. 1321–1328, 2014.

[5] J. Kim, T.-W. Um, W. Ryu, B. S. Lee, and M. Hahn, "IPTV systems, standards and architectures: part II—heterogeneous networks and terminal-aware QoS/QoE-guaranteed mobile IPTV service," *IEEE Communications Magazine*, vol. 46, no. 5, pp. 110–117, 2008.

[6] S. Spagna, M. Liebsch, R. Baldessari et al., "Design principles of an operator-owned highly distributed content delivery network," *IEEE Communications Magazine*, vol. 51, no. 4, pp. 132–140, 2013.

[7] S. Deering, "Host extensions for IP multicasting," RFC 1112, 1989, http://www.ietf.org/rfc/rfc1112.txt.

[8] ITU-T G, "Opinion model for video-telephoney applications," Recommendations 1070, 2007.

[9] S. Y. Cheung, M. H. Ammar, and X. Li, "On the use of destination set grouping to improve fairness in multicast video distribution," in *Proceedings of the 15th Annual Joint Conference of the IEEE Computer Societies, Networking the Next Generation (INFOCOM '96)*, vol. 2, pp. 553–560, San Francisco, Calif, USA, March 1996.

[10] K. Nichols, S. Blake, F. Baker, and D. Black, "Definition of the differentiated services field (DS Field) in the IPv4 and IPv6 headers," RFC RFC2474, 1998.

[11] D. Kaur, K. Kaur, and V. Arora, "QoS in WLAN using IEEE802.11e (Survey of QoS in MAC layer protocols)," in *Proceedings of the 2nd International Conference on Advanced Computing and Communication Technologies (ACCT '12)*, pp. 468–473, Rohtak, India, January 2012.

[12] H. Schwarz, D. Marpe, and T. Wiegand, "Overview of the scalable video coding extension of the H.264/AVC standard," *IEEE Transactions on Circuits and Systems for Video Technology*, vol. 17, no. 9, pp. 1103–1120, 2007.

[13] L. Wang, Z. Yang, L. Xu, and Y. Yang, "NCVCS: network-coding-based video conference system for mobile devices in multicast networks," *Ad Hoc Networks*, 2016.

[14] S. Tavakoli, K. Brunnström, J. Gutiérrez, and N. García, "Quality of experience of adaptive video streaming: investigation in service parameters and subjective quality assessment methodology," *Signal Processing: Image Communication*, vol. 39, pp. 432–443, 2015.

[15] F. Tommasi, V. De Luca, and C. Melle, "Packet losses and objective video quality metrics in H.264 video streaming," *Journal of Visual Communication and Image Representation*, vol. 27, pp. 7–27, 2015.

[16] K. Seshadrinathan and A. C. Bovik, "Motion tuned spatio-temporal quality assessment of natural videos," *IEEE Transactions on Image Processing*, vol. 19, no. 2, pp. 335–350, 2010.

[17] K. Seshadrinathan, R. Soundararajan, A. C. Bovik, and L. K. Cormack, "Study of subjective and objective quality assessment of video," *IEEE Transactions on Image Processing*, vol. 19, no. 6, pp. 1427–1441, 2010.

[18] Excel, "Video Quality Analysis Software G. 1070 Revision 2007 + G.107 Revision 2006," ITU-T G 1070, Excel, 2007, http://www.e-model.org/.

[19] A. Catellier, M. Pinson, W. Ingram, and A. Webster, "Impact of mobile devices and usage location on perceived multimedia quality," in *Proceedings of the 4th International Workshop on Quality of Multimedia Experience (QoMEX '12)*, pp. 39–44, Victoria, Australia, July 2012.

[20] K. Ha, K. Kang, and J. Lee, "N-screen service using I/O virtualization technology," in *Proceedings of the International Conference on Information and Communication Technology Convergence (ICTC '10)*, pp. 525–526, IEEE, Jeju, South Korea, November 2010.

[21] S.-H. Park, Y.-S. Park, S.-B. Yu, and J.-R. Choi, "Implementation of ATSC mobile DTV broadcasting for N-screen smart devices," in *Proceedings of the IEEE International Conference on Consumer Electronics (ICCE '12)*, pp. 331–332, Las Vegas, Nev, USA, January 2012.

[22] B.-R. Kwon, S.-H. Ryu, and Y.-G. Kim, "Identifying factors affecting behavioral intent of potential and existing N-screen service users," *ETRI Journal*, vol. 37, no. 2, pp. 417–427, 2015.

[23] Y. Bae, B. Oh, and J. Park, "Adaptive transformation for a scalable user interface framework supporting multi-screen services," in *Ubiquitous Information Technologies and Applications*, vol. 280 of *Lecture Notes in Electrical Engineering*, pp. 425–432, Springer, Berlin, Germany, 2014.

[24] Y. T. Hong, Y. S. Hwang, S. H. Nam et al., "A seamless screen switching scheme for N-screen services based on context awareness," *Wireless Personal Communications*, 2016.

[25] S. Banarjee, B. Bhattacharjee, and C. Kommareddy, "Scalable application layer multicast," in *Proceedings of the Conference on Applications, Technologies, Architectures, and Protocols for Computer Communications (SIGCOMM '02)*, pp. 205–217, Pittsburgh, Pa, USA, August 2002.

[26] J. H. Wang, J. Cai, J. Lu, K. Yin, and J. Yang, "Solving multicast problem in cloud networks using overlay routing," *Computer Communications*, vol. 70, pp. 1–14, 2015.

[27] S. E. Deering, "Host extensions for IP multicasting," 1988.

[28] E. Cerqueira, L. Veloso, A. Neto, M. Curado, E. Monteiro, and P. Mendes, "Mobility management for multi-user sessions in next generation wireless systems," *Computer Communications*, vol. 31, no. 5, pp. 915–934, 2008.

[29] H. Won, H. Cai, K. Guo et al., "Multicast scheduling in cellular data networks," *IEEE Transactions on Wireless Communications*, vol. 8, no. 9, pp. 4540–4549, 2009.

[30] A. Ikram, M. Zafar, N. Baker, and R. Chiang, "IMS-MBMS convergence for next generation mobile networks," in *Proceedings of the IEEE International Conference on Next Generation Mobile Applications, Services and Technologies (NGMAST '07)*, pp. 49–56, Cardiff, Wales, September 2007.

[31] 3GPP TS 23.246 v7.2.0, Multimedia Broadcast/Multicast Service (MBMS), 2004.

[32] M. Knappmeyer, B. Ricks, R. Tönjes, and A. Al-Hezmi, "Advanced multicast and broadcast content distribution in mobile cellular networks," in *Proceedings of the 50th Annual IEEE Global Telecommunications Conference (GLOBECOM '07)*, pp. 2097–2101, Washington, DC, USA, November 2007.

[33] Y. C. Yee, K. N. Choong, A. L. Y. Low, and S. W. Tan, "SIP-based proactive and adaptive mobility management framework for heterogeneous networks," *Journal of Network and Computer Applications*, vol. 31, no. 4, pp. 771–792, 2008.

[34] M. Oche, R. M. Noor, and J. I. Aghinya, "Network centric QoS performance evaluation of IPTV transmission quality over VANETs," *Computer Communications*, vol. 61, pp. 34–47, 2015.

[35] V. Jacobson, *Pathchar: A Tool to Infer Characteristics of Internet Paths*, 1997.

[36] B. A. Mah, pchar: a tool for measuring internet path characteristics, 2001, http://www.kitchenlab.org/www/bmah/Software/pchar/.

[37] M. Jain and C. Dovrolis, "Pathload: a measurement tool for end-to-end available bandwidth," in *Proceedings of the Passive and Active Measurements (PAM '02)*, pp. 14–25, March 2002.

[38] V. Ribeiro, R. Riedi, R. G. Baraniuk, J. Navratil, and L. Cottrell, "Pathchirp: efficient available bandwidth estimation for network paths," in *Proceedings of the Passive and Active Measurement Workshop (PAM '03)*, April 2003.

[39] P. Selin, K. Hasegawa, and H. Obara, "Available bandwidth measurement technique using impulsive packet probing for monitoring end-to-end service quality on the Internet," in *Proceedings of the 17th Asia Pacific Conference on Communications (APCC '11)*, pp. 518–523, Sabah, Malaysia, October 2011.

[40] A. Javadtalab, M. Semsarzadeh, A. Khanchi, S. Shirmohammadi, and A. Yassine, "Continuous one-way detection of available bandwidth changes for video streaming over best-effort networks," *IEEE Transactions on Instrumentation and Measurement*, vol. 64, no. 1, pp. 190–203, 2015.

[41] K. Ahuja, B. Singh, and R. Khanna, "Network selection based on available link bandwidth in multi-access networks," *Communications and Networks*, vol. 2, no. 1, pp. 15–23, 2016.

[42] A. Takahashi, D. Hands, and V. Barriac, "Standardization activities in the ITU for a QoE assessment of IPTV," *IEEE Communications Magazine*, vol. 46, no. 2, pp. 78–84, 2008.

[43] M. Carnec, P. Le Callet, and D. Barba, "Full reference and reduced reference metrics for image quality assessment," in *Proceedings of the 7th International Symposium on Signal Processing and Its Applications (ISSPA '03)*, pp. 477–480, July 2003.

[44] ITU-T, "Objective perceptual video quality measurement techniques for digital cable television in the presence of a full reference," Recommendation J.144, 2004.

[45] ITU, "Objective perceptual video quality measurement techniques for standard definition digital broadcast television in the presence of a full reference," ITU-R BT.1683, 2004.

[46] T. M. Kusuma, H. Zepernick, and M. Caldera, "On the development of a reduced-reference perceptual image quality metric," in *Proceedings of the Systems Communications*, pp. 178–184, Montreal, Canada, August 2005.

[47] A. R. Reibman, V. A. Vaishampayan, and Y. Sermadevi, "Quality monitoring of video over a packet network," *IEEE Transactions on Multimedia*, vol. 6, no. 2, pp. 327–334, 2004.

[48] J. Joskowicz and J. C. L. Ardao, "A parametric model for perceptual video quality estimation," *Telecommunication Systems*, vol. 49, no. 1, pp. 49–62, 2012.

[49] M. Cheon, S.-J. Kim, C.-B. Chae, and J.-S. Lee, "Quality assessment of mobile videos," in *Visual Signal Quality Assessment*, C. Deng, L. Ma, W. Lin, and K. N. Ngan, Eds., pp. 99–127, Springer, 2015.

[50] F. Ullah, G. Sarwar, and S. Lee, "A network and visual quality aware N-screen content recommender system using joint

matrix factorization," *The Scientific World Journal*, vol. 2014, Article ID 806517, 13 pages, 2014.

[51] D. Kim and K. Chung, "A network-aware quality adaptation scheme for device collaboration service in home networks," *IEEE Transactions on Consumer Electronics*, vol. 58, no. 2, pp. 374–381, 2012.

[52] Y. R. Yang, M. S. Kim, and S. S. Lam, "Optimal partitioning of multicast receivers," in *Proceedings of the International Conference on Network Protocols*, pp. 129–140, Osaka, Japan, November 2000.

[53] OMNET++ based Simulator for Wireless and Mobile Networks, http://mixim.sourceforge.net/.