International Journal of Engineering Research and Development
e-ISSN: 2278-067X, p-ISSN: 2278-800X, www.ijerd.com
Volume 8, Issue 10 (October 2013), PP. 19-25

Multicast Routing and Bandwidth Analysis Using Relay Node for Quality Video Transmission

R.Shanthi[1], T.K.Revathi[2], Dr.J.Vellingiri[3],
[1]*M.E-Student, Department of CSE, Kongunadu College of Engineering and Technology, Tamil Nadu, India.*
[2] *Asst. Professor, Department of CSE, Kongunadu College of Engineering and Technology, Tamil Nadu, India.*
[3]*Associate Professor, Department of CSE , Kongunadu College of Engineering and Technology,Tamil Nadu, India.*

Abstract:- This paper propose a novel scalable video broadcast/multicast solution that efficiently integrates scalable video coding, broadcast and ad-hoc forwarding to achieve the optimal trade-off between the system-wide and worst-case video quality perceived by all viewers in the cell. In our solution, video is encoded into one base layer and multiple enhancement layers using Scalable Video Coding (SVC). The large number of Internet paths between popular video destinations and clients to create an empirical understanding of location, persistence, and recurrence of failures. The optimal resource allocation problem for scalable video multicast in networks. we design and implement a prototype packet forwarding module called source initiated frame restoration (SIFR). This paper deployed SIFR on PlanetLab nodes and compared the performance of SIFR to the default Internet routing. We show that SIFR outperforms IP-path selection by providing higher on-screen perceptual quality.

I. INTRODUCTION

Multimedia streaming over IP networks is poised to be the dominant Internet traffic in the coming decade. As multimedia service providers deploy services on top of packet-switched networks that compete with cable-based content providers, there is an ever-growing need to provide superior quality of experience (QoE). As a result, a video source has limited routing options when sending its packets, especially during times of an outage. However, the Internet itself comprises billions of interconnections, and the probability that there are alternate paths that can perform better is high. This paper presents a large-scale measurement-based study on the effects of Internet path selection on video-QoE and investigates ways to improve it using application-specific policies and redundant Internet paths. We seek answers to the following questions: 1) What degrades video QoE in the Internet, and where in the path do these outages frequent? 2) How does an Internet outage affect video-QoE? 3)What fraction of these outages are solvable by using redundant alternative Internet paths? 4) How can a source select the right alternative path to improve Internet video-QoE without having to perform any prior path quality measurements? To answer the first question, we probed a large number of popular Internet video destinations from 62 geographically diverse PlanetLab vantage points for seven consecutive days. To measure the perceptual degradation resulting from these outages, we reconstructed a variety of MPEG video samples using the IP-traces collected from every destination set.

Fig. 1. QoE versusQoS:While both clips experienced the same loss rate (QoS), the perceived quality can be very different depending upon what frame was impacted.

II. LITERATURE REVIEW

2.1 Performance Measurement and Analysis of H.323 Traffic

The popularity of H.323 applications has been demonstrated by the billions of minutes of audio and video traffic seen on the Internet every month. Our objective in this paper is to obtain Good, Acceptable

and Poor performance bounds for network metrics such as delay, jitter and loss for H.323 applications based on objective and subjective quality assessment of various audio and video streams H.323 is an umbrella standard that de_nes how real-time multimedia communications, such as audio and video-conferencing, can be exchanged on packetswitched networks (Internet). With the rapid increase in the number of individuals
in industry and academia using H.323 audio and video-conferencing systems extensively, the expectation levels for better audio and video performance have risen signi_cantly. Our primary focus in this paper is to understand how the various levels of network health,characterized by measuring delay, jitter and loss, can a_ect end user perception of audiovisual quality. By systematically emulating various network health scenarios and using a set of Videoconferencing 'Tasks' we determine

performance bounds for delay, jitter and loss The results of this paper could provide ISPs and Videoconferencing Operators a better understanding of their end-user's experience of audiovisual quality for any given network health diagnostics To obtain the necessary data to support the various conclusions in this paper,
we utilized the H.323 Beacon tool we have developed and a set of Videoconferencing tasks. There are two popular methods to assess audiovisual quality: Subjective quality assessment and Objective quality assessment. Subjective quality assessment involves playing a sample audiovisual clip to a number of participants. Their judgment of the quality of the clip is collected and used as a quality metric. Objective quality assessment does not rely on human judgment and involves automated procedures such as signal-to-noise ratio (SNR) measurements of original and reconstructed signals and other sophisticated algorithms such as Mean Square Error (MSE) distortion, Frequency weighted MSE, Segmented SNR, Perceptual Analysis Measurement System (PAMS) , Perceptual Evaluation of Speech Quality (PESQ) , and Emodel , to determine quality metrics.

2.2 Symbiotic Relationships in Internet Routing Overlays

We propose to construct routing overlay networks using the following principle: that overlay edges should be based on mutual advantage between pairs of hosts. Upon
this principle, we design, implement, and evaluate Peer-Wise, a latency-reducing overlay network. We design and evaluate “virtual” network coordinates for destinations
not participating in the overlay, neighbor selection algorithms to find promising relays, and relay selection algorithms to choose the neighbor to traverse for a good detour.

Finally, we show that PeerWise is practical through a wide-area deployment and evaluation. Several distributed protocols and applications use mutual advantage as part of their design. BitTorrent peers that download the same file trade blocks the other is missing. In backup systems nodes store replicas of files for each other. Autonomous systems in the Internet negotiate peer-to-peer agreements to provide lowcost connectivity to each other’s customers. Bringing mutual advantage into the design of routing overlays has several benefits. First, mutual advantage induces better cooperation among nodes. Incentives to participate become simpler, and long-lived, fair connections appear. Building systems grounded in incentives for cooperation makes them robust to misbehavior and selfishness.

2.3 Resilient Overlay Networks

A Resilient Overlay Network (RON) is an architecture that allows distributed Internet applications to detect and recover from path outages and periods of degraded performance within several seconds, improving over today’s wide-area routing protocols that take at least several minutes to recover. A RON is an application-layer overlay on top of the existing Internet routing substrate. The RON nodes monitor the functioning and quality of the Internet paths among themselves, and use this information to decide whether to route packets directly over the Internet or by way of other RON nodes, optimizing application-specific routing metrics. The Internet is organized as independently operating autonomous systems (AS’s) that peer together. In this architecture, detailed routing information is maintained only within a single AS and its constituent networks, usually operated by some network service provider. The information shared with other providers and AS’s is heavily filtered and summarized using the Border Gateway Protocol (BGP-4) running at the border routers between AS’s, which allows the Internet to scale to millions of networks. *Resilient Overlay Networks (RONs)* are a remedy for some of these problems. Distributed applications layer a “resilient overlay network” over the underlying Internet routing substrate. The nodes comprising a RON reside in a variety of routing domains, and cooperate with each other to forward data on behalf of any pair of communicating nodes in the RON. Because AS’s are independently administrated and configured, and routing domains rarely share interior links, they generally fail independently of each other. As a result, if the underlying topology has physical path redundancy, RON can often find paths between its nodes, even when wide-area routing Internet protocols like BGP-4 cannot. The main goal of RON is to enable a group of nodes to communicate with each other in the face of problems with the underlying Internet paths.

III. INTERNET PATH SELECTION

The Internet is organized as an interconnection of thousands of ASs. Each AS is under the purview of an Internet service provider (ISP), and neighboring ASs use the Border Gateway Protocol (BGP) to exchange reachability information. Ass apply individual policies in advertising and propagating reachability information to neighboring ASs. In reality, reachability information advertised by an AS is often the result of various provider–customer relationships between the governing ISP and other ISPs. Typically, ISPs are arranged in various *tiers*,where tier-1 ISPs sell connectivity to other ISPs, while tier-3 ISPs buy connectivity from ISPs in higher tiers while charging consumers. Though the model we present here is overly simplistic,it offers a basic overview of how Internet routing works. ISP–ISP relationships are not limited to provider–consumer relationships: The emergence of Internet exchange points (IXPs) allows peer ISPs to interconnect with each other, essentially "flattening" the Internet hierarchy. Peering can also happen outside IXP, and IXPs can serve to connect provider–customer relationships. Other complex relationships are also possible. Note also that not every AS is necessarily an ISP; an AS could be owned by an enterprise, government agency, or educational institution. The end result of this process is that a typical Internet route often (not always) traverses lower-tier ISPs to reach a highertier ISP ("up" the valley), followed by a journey down to another lower-tier ISP ("down" the valley) to reach a destination.

IV. PROBING INTERNET DESTINATIONS

Streaming content on the Internet today is most commonly disseminated by VoD/IPTV service providers or by P2P streaming (e.g., Joost, BBC iPlayer, PPLive, etc.)

Vantage Points and Destination Sets

Vantage Points: IP-based streaming services are currently popular in Germany, France, Belgium, the US, Korea, and China, among other nations. All vantage points used are PlanetLab nodes.

Destination Sets: To create our destination set, we gathered a list of the 200 most popular IPTV/VoD service providers from various Internet sources. To create a destination set for P2P video sharing hosts, we used 1200 IP addresses of broadband hosts obtained from crawls of TVU networks and PPLive. In the end, our source–destination pairs are representative of typical round-trip paths on the Internet used to disseminate streaming content. Much work has been done on performance-based and faulttolerant routing within a single routing domain, but practical mechanisms for wide-area Internet recovery from outages or badly performing paths are lacking. Although today's wide-area BGP-4 routing is based largely on AS hop-counts, early ARPANET routing was more dynamic, responding to the current delay and utilization of the network. By 1989, the ARPANET evolved to using a delay- and congestionbased distributed shortest path routing algorithm. However, the diversity and size of today's decentralized Internet necessitated the deployment of protocols that perform more aggregation and fewer updates. As a result, unlike some interior routing protocols within AS's, BGP-4 routing between AS's optimizes for scalable operation over all else. Overlay networks are an old idea; in fact, the Internet itself was developed as an overlay on the telephone network. Several Internet overlays have been designed in the past for various purposes, including providing OSI network-layer connectivity easing IP multicast deployment using the MBone , and providing IPv6 connectivity using the 6-Bone.

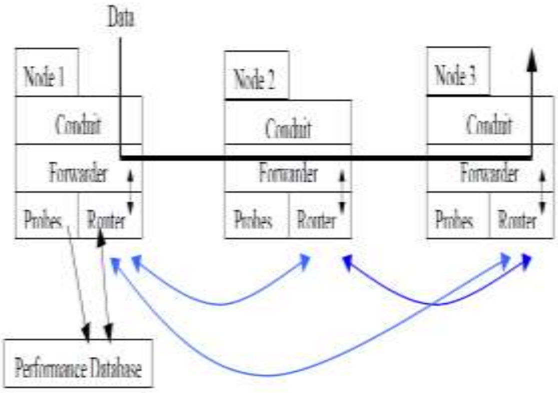

Fig 2: The RON system architecture.

4.1Design

The conceptual design of RON, shown in Figure 3, is quite simple. RON nodes, deployed at various locations on the Internet, form an application-layer overlay to cooperatively route packets for each other. Each RON node monitors the quality of the Internet paths between it and the other nodes, and uses this information to intelligently select paths for packets. Each Internet path between two nodes is called a virtual link. To discover the topology of the overlay network and obtain information about all virtual links in the topology, every RON

node participates in a routing protocol to exchange information about a variety of quality metrics. Most of RON's design supports routing through multiple intermediate nodes, but our results (Section 6) show that using at most one intermediate RON node is sufficient most of the time. Therefore, parts of our design focus on finding better paths via a single intermediate
RON node.

V. PATH EVALUATION AND SELECTION

The RON routers need an algorithm to determine if a path is still alive, and a set of algorithms with which to evaluate potential paths. The responsibility of these metric evaluators is to provide a number quantifying how "good" a path is according to that metric. These numbers are relative, and are only compared to other numbers from the same evaluator. The two important aspects of path evaluation are the mechanism by which the data for two links are combined into a single path, and the formula used to evaluate the path. Every RON router implements outage detection, which it uses to determine if the virtual link between it and another node is still working. It uses an active probing mechanism for this. On detecting the loss of a probe, the normal low-frequency probing is replaced by a sequence of consecutive probes, sent in relatively quick succession spaced by probe timeout seconds. If outage thresh probes in a row elicit no response, then the path is considered "dead." If even one of them gets a response, then the subsequent higher-frequency probes are canceled. Paths experiencing outages are rated on their packet loss rate history; a path having an outage will always lose to a path not experiencing an outage. The outage thresh and the frequency of probing permit a trade-off between outage detection time and the bandwidth consumed by the (low-frequency) probing process.

VI. IMPACT ON PERCEPTUAL QUALITY

This section analyzes the perceptual degradations caused by packet drops resulting from network anomalies in the IP-traces obtained from the previous round of study. We begin with a brief overview of the MPEG-2 encoding scheme and discuss our methodology of reconstructing MPEG-2 video clips using the IP-traces for subjective surveys.

MPEG-2 Overview

Streaming content in IP networks is commonly transported as a data stream encoded using the MPEG standard and transported via the real- time protocol (RTP) over a UDP/IP stack. MPEG encodes video streams as a series of Intra (I), Predictive (P) and Bidirectional (B) frames. I-frames carry a complete video picture, and as such provide reference to the following Pand B-frames for decoding an MPEG stream. P-frames predict the frames to be coded using a preceding I or P-frame. Lastly, B-frames use the previous or next I-frame formotion compensation. Each frame is typically fragmented into multiple IP packets for transport over the Internet. The frames are packed into a GOP, where each GOP consists of an I-frame at the start and a series of B- and P-frames that use it as a reference. Depending upon the motion complexity inherent in a clip, the structure of a GOP can be very different: Low-motion clips (like a news program) have larger I-frames and a handful of P- and B-frames to complete a GOP,while highmotion (sports clip) clips have smaller I-frames and relatively larger P-frames for motion compensation.

VII. PROTOTYPE EVALUATION

Using the insights from Section VI, we now design and implement a prototype called SIFR, or source initiated frame restoration. SIFR employs frame-preserving policies coupled with a random-5 path selection strategy for improving perceptual quality of streaming content. We deploy SIFR on 32 PlanetLab nodes that were used to obtain dataset D2. We evaluate the effectiveness of SIFR over the default
IP-path in restoring and improving perceptual quality for three source–destination pairs, one each in the US, Europe, and Asia-Pacific.

7.1 Prototype Description

SIFR requires deployment at the source, the destination, and intermediate nodes. SIFR at the source applies application-specific policies to packet generation following a degradation and chooses intermediate paths based on the random-5 strategy to restore key frames. The receiver takes ingress packets and counts the number of correctly received frames in a 1-s playout buffer. When losses that manifest in perceptual degradation are observed, the destination issues an "outage" feedback to the source. Upon reception of this, the source tries to recover from the degradation by sending the next set of key frames simultaneously through five randomly chosen intermediaries. When the destination receives an intact GOP from a path after an outage, it reports of this successful reception using this path back to the source.We use a custom header to capture feedback from the destination. Finally, the intermediaries simply forward ingress packets to the announced destination. We pass the motion complexity of a clip in our custom header (essentially hard-coded) because SIFR has no way of distinguishing a video clip based on motion complexity.

7.2 Virtual Network Coordinates

Every PeerWise node must compute its own network coordinate before searching for detours. We use Vivaldi for network coordinates. Every node maintains a set of neighbors that it probes periodically. It uses the round trip time and the network coordinate of these neighbors to update its own coordinate. After each probe, the node computes the coordinate that minimizes the squared estimation error to all of its neighbors. To help the system converge quickly, nodes with uncertain coordinates can move farther with each measurement.

7.3 Neighbor Tracking

The success of our protocol depends on the ability of nodes to find other nodes to establish pairwise peerings. There are many possible relays for a node, any of which may have high embedding error with respect to the node.Recall that high embedding error for a pair of nodes indicates a higher probability that the pair is part of a detour. We use neighbor tracking to find the nodes that are more likely to offer detours. With neighbor tracking, a Peer-Wise node remembers extra neighbors and learns about good potential relays from its neighbors or from nearby (in latency) nodes. The neighbors in this section are not relays; they are only candidates for becoming so. When joining PeerWise, a node bootstraps its potential neighbor set from a known PeerWise node and uses it to compute its network coordinate. Once the network coordinate is stable, the node asks its neighbors about their own neighbors, remembering those nodes with high embedding error. For example, in Figure 8, A asks for the neighbor set of B, formed of B1, B2 and B3. Node A then computes the embedding error from itself to each of B1, B2 and B3 and adds those nodes to which the error is most positive to its neighbor list. These nodes are the most likely to form a short side of a TIV with A. For scalability, we limit the number of neighbors of each node. Neighbors with higher potential to offer the best detours replace less-efficient neighbors. We considerand evaluate different methods for ranking potential neighbors in Section 6.1. Because PeerWise allows a node to exchange information about neighbors with neighbors, we expect each node to have ample choices.

7.4 Choosing Neighbors

Each PeerWise node must be able to decide whether a new node would offer better detours than existing neighbors. A new neighbor may provide relays toward a region of coordinate space or directly to known destinations.Deciding upon future mutual advantage is a prediction of future accesses and future performance. In this section, we evaluate the ability of a PeerWise node to predict, from coordinates and measurement, whether a neighbor will contribute. If nodes were to contact only a few, known destinations,choosing neighbors would be simple: replace a neighbor if the new one provides a better path to an interesting destination. However, we do not expect access patterns to be nearly so predictable. Instead, we wish to determine, when a new neighbor arrives, whether it is likely to provide a shortcut to a useful region in coordinate space.

7.5 Choosing Relays

Neighbor selection determines the set of neighbors that may provide a detour path. With relay selection, a node attempts to discover quickly the neighbor that offers the best detour to a specific destination. Like serverselection problems solved by network coordinates, relay selection seeks the shortest combination of the direct path to the relay and the predicted path between relay and destination. Over time, this performance can be measured, but to minimize latency, detour performance should be predicted. At the very least, we hope to reduce the number of relays that we need to simultaneously contact to find a good detour when contacting a destination for the first time. We consider the following policies for choosing relays for a destination. Direct prediction adds the measured source-to-relay latency to the estimated relay-todestination distance in coordinate space, then chooses the relay with the lowest sum. Because latency measurements may be more reliable than coordinates, we evaluated a conservative prediction, which adds the source-torelay latency measurement again to increase its influence in the prediction. This is based on the expectation that coordinates are inaccurate and seeks greater likelihood of a good detour in preference to the best detour at the top of the list. A high-risk scheme chooses the neighbor with the highest embedding error. Finally, random provides a baseline. We select 32 neighbors for each node using the proximity-based algorithm and evaluate the four relayselection algorithms. The conservative approach performs best: approximately 80% of the detours chosen are only 20% longer than the best detour between the same pair of nodes.

7.6 Deciding Whether to Relay

Deciding whether to use a detour depends on a prediction of whether it will improve application performance This has two components: whether the traffic is sensitive to latency and whether a known neighbor is likely to provide a detour path. We evaluate the latter. Whether traffic is latency sensitive can be crudely inferred by ports, by commercial packet scheduling products, or by application-based proxies that can differentiate classes of traffic. In this section, we assume that the traffic is latency sensitive and attempt to predict whether to relay.

VIII. RELATED RESEARCH

Internet pathologies have been well investigated in the past. Researchers have consistently found that Internet outages are unpredictable and, worse, can go undetected for a whil. BGP convergence times and IP-rerouting following a path outage can take the order of minutes, while streaming services demand path switching in the order of milliseconds. Overlay networks have been proposed as a solution to many of Internet's problems: from resilience in recovering from outages using RON to multicasting to providing higher QoS . Improving Web-browsing experience using randomized load allocation to choose alternate paths was studied in. However, the ensuing perceptual benefits for Web browsing were determined to be negligible. RON creates the possibility of misuse or violation of AUPs and BGP transit policies. RON provides a flexible policy mechanism that allows users to implement *better* network policies than those permitted by BGP. Because RONs are deployed between small groups of cooperating entities, they cannot be used to find "backdoors" into networks without the permission of an authorized user of that network. Users who violate network policy today are dealt with at a human level, and that should remain unchanged with RON deployment. On the positive side, if an Overlay ISP buys bandwidth from traditional ISPs and routes data using a RON, it can express and enforce sophisticated policy routes.

IX. CONCLUSIONS

This paper presented large-scale Internet measurements to understand the effects of Internet path selection on perceptual quality of MPEG-2 video and investigated ways to improve it. We began by performing repeated video "fetching" acts from top IPTV/VoD providers, PPLive hosts, and random

Internet destinations for one week from geographically diverse PlanetLab nodes.We mapped the probe responses to perceptual quality by reconstructing numerous representative low- and high-motion video sequences and conducted subjective surveys. PeerWise is based on building overlay networks from mutually advantageous peerings; we show that such a simple, locally enforced mechanism is sufficient to provide detour routes in the Internet using them. Resilient Overlay Network (RON) can greatly improve the reliability of Internet packet delivery by detecting and recovering from outages and path failures more quickly than current inter-domain routing protocols. A RON works by deploying nodes in different Internet routing domains, which cooperatively route packets for each other. Each RON is an applicationlayer overlay network; nodes in a RON monitor the quality of the underlying Internet between themselves and use this information to route packets according to application-specified routing metrics either via a direct Internet path or by way of other RON nodes. The performance bounds for network metrics such as delay, jitter and loss. We use these bounds to determine the impact of network health on end-user perception of audiovisual quality of H.323 applications. By emulating various network health scenarios both in the LAN and on the Internet and by using realistic Videoconferencing tasks, we show that end-user perception of audiovisual quality is more sensitive to the variations in end-to-end jitter than to variations in delay or loss. In the Internet tests, by considering almost every possible last-mile connection, we demonstrated that the results we obtained in the LAN tests scaled consistently to the Internet. The results of our studies could serve as trouble-shooting information during periods of suspected network trouble affecting H.323 audio and video conferences. They can also foster broader understanding of the behavior of audio and video traffic over the Internet which can then lead to better designed networks in the future.

REFERENCES

[1]. D. G. Andersen,H.Balakrishnan, M. F. Kaashoek, and R.Morris, "Resilient overlay networks," in *Proc. 18th ACM SOSP*, Banff, Canada, Oct. 2001, pp. 131–145.

[2]. S. Blake, D. Black, M. Carlson, E. Davies, Z. Wang, and W. Weiss, "An architecture for differentiated services," IETF RFC# 2475, Dec. 1998.

[3]. P. Calyam, M. Sridharan, W. Mandrawa, and P. Schopis, "Performance measurement and analysis of H.323 traffic," in *Proc. PAM*, Apr. 2004, pp. 137–146.

[4]. K. Chen, C.Wu, Y. Chang, and C. Lei, "A crowdsourceable QoE evaluation framework for multimedia content," in *Proc. ACM Multimedia*, Beijing, China, Oct. 2009, pp. 491–500.

[5]. A. Czumaj and V. Stemann, "Randomized allocation processes," in *Proc. Symp. Found. Comput. Sci.*, Miami, FL,USA,Oct. 1997, p. 194.

[6]. D. Eager, E. Lazowska, and J. Zahorjan, "Adaptive load sharing in homogeneous distributed systems," *IEEE Trans. Softw. Eng.*, vol. SE-12, no. 5, pp. 747–760, May 1986.

[7]. ANDERSEN, D. G. Resilient Overlay Networks. Master's thesis, Massachusetts Institute of Technology, May 2001.

[8]. BALAKRISHNAN, H., SESHAN, S., STEMM, M., AND KATZ, R. Analyzing Stability in Wide-Area Network Performance. In *Proc.* ACM SIGMETRICS (Seattle, WA, June 1997), pp. 2–12.

[9]. CHANDRA, B., DAHLIN, M., GAO, L., AND NAYATE, A. End-to-end WAN Service Availability. In *Proc. 3rd USITS* (San

[10]. Francisco, CA, 2001), pp. 97–108.

[11]. CLARK, D. Policy Routing in Internet Protocols. Internet Engineering Task Force, May 1989. RFC 1102.

[12]. COLLINS, A. The Detour Framework for Packet Rerouting. Master's thesis, University of Washington, Oct. 1998 ERIKSSON, H. Mbone: The Multicast Backbone. Communications of the ACM 37, 8 (1994), 54–60.

[13]. J. Greengrass, J. Evans, and A. C. Begen, "Not all packets are equal, Part I: Streaming video coding and SLA requirements," *IEEE Internet Comput.*, vol. 13, no. 1, pp. 70–75, Mar. 2009.

[14]. J. Greengrass, J. Evans, and A. C. Begen, "Not all packets are equal, Part II: The impact of network packet loss on video quality," *IEEE Internet Comput.*, vol. 13, no. 2, pp. 74–82, Mar. 2009.

[15]. K. Gummadi, H. Madhyastha, S. Gribble, H. Levy, and D. Wetherall, "Improving the reliability of Internet paths with one-hop source routing," in *Proc. OSDI*, San Fransico, CA, USA, Dec. 2004, p. 13.

[16]. International Telecommunication Union, "Subjective video quality assessment methods for multimedia applications," Rec. ITU-T, Sep.1999, pp. 910–910.

[17]. R. Jain, "Quality of experience," *IEEE Multimedia*, vol. 11, no. 1, pp. 95–96, Mar. 2004.

[18]. J. Jannotti, D. Gifford, K. Johnson, M. F. Kaashoek, and J. O'Toole, "Overcast: Reliable multicasting with an overlay network," in *Proc. OSDI*, San Diego, CA, USA, Oct. 2000, p. 14.

[19]. C. Labovitz, R. Malan, and F. Jahanian, "Internet routing instability," *IEEE/ACM Trans. Netw.*, vol. 6, no. 5, pp. 515–528, Oct. 1998.

[20]. M. Lu, J. Wu, K. Peng, P. Huang, J. Yao, and H. Chen, "Design and evaluation of a P2P IPTV system for heterogeneous networks," *IEEE Trans. Multimedia*, vol. 9, no. 8, pp. 1568–1579, Dec. 2007.