Computer Networks 54 (2010) 3388–3401

Contents lists available at ScienceDirect

Computer Networks

journal homepage: www.elsevier.com/locate/comnet

CoreCast: How core/edge separation can help improving inter-domain live streaming

Loránd Jakab [a,*], Albert Cabellos-Aparicio [a], Thomas Silverston [b], Marc Solé [a], Florin Coraş [a], Jordi Domingo-Pascual [a]

[a] Universitat Politècnica de Catalunya, Departament d'Arquitectura de Computadors, C/Jordi Girona, 1-3, Campus Nord UPC Edifici D6, 08034 Barcelona, Spain

[b] The University of Tokyo, 7-3-1 Hongo, Bunkyo-ku, Tokyo 113-8656, Japan

ARTICLE INFO

Article history:
Received 9 February 2010
Received in revised form 28 May 2010
Accepted 8 July 2010
Available online 16 July 2010
Responsible Editor: T. Melodia

Keywords:
LISP
Multicast
Live streaming

ABSTRACT

The rapid growth of broadband access has popularized multimedia services, which nowadays contribute to a large part of Internet traffic. Among this content, the broadcasting of live events requires streaming from a single source to a large set of users. For such content, network-layer multicast is the most efficient solution, but it has not found wide-spread adoption due to its high deployment cost. As a result, several application-layer solutions have been proposed based on large-scale P2P systems. These solutions however, are unable to provide a satisfactory quality of experience to all users, mainly because of the variability of the peers and their limited upload capacity. In this paper we advocate for a *network-layer* solution that circumvents the prohibitive deployment costs of previous approaches, taking advantage of the rare window of opportunity offered by the locator/identifier separation protocol (LISP). This new architecture, motivated by the alarming growth rate of the default-free zone (DFZ) routing table, is developed within the IETF, and aims to upgrade the current inter-domain routing system. We present CoreCast, an efficient inter-domain live streaming architecture operating on top of LISP. LISP involves upgrading some Internet routers and our proposal can be introduced along with these new deployments. To evaluate its feasibility in terms of processing overhead in networking equipment we have implemented CoreCast in the Linux kernel. Further, we compare the performance of CoreCast to the popular P2P streaming services both analytically and experimentally. The results show that CoreCast reduces inter-domain bandwidth consumption and that introduces negligible processing overhead in network equipment.

1. Introduction

The rapid growth of broadband access speeds has popularized multimedia services that nowadays contribute to a large part of the Internet traffic [1]. A considerable amount of multimedia content, such as popular live events commonly conveyed through IPTV, require live streaming from a source to a large set of users. For such content, network-layer multicast [2] is the most efficient solution. However, its deployment remains confined to some selected domains. Enabling inter-domain multicast requires upgrading a large subset of the existing routers and complex network management, tasks that amount to very high capital and operational expenditure [3].

As a result, during the last years, the industry along with the research community have designed several peer-to-peer (P2P) systems for streaming live events [4–8] to an ever increasing audience. These systems operate

* Corresponding author. Tel.: +34 934017182.
E-mail addresses: ljakab@ac.upc.edu (L. Jakab), acabello@ac.upc.edu (A. Cabellos-Aparicio), thomas@hongo.wide.ad.jp (T. Silverston), msole@ac.upc.edu (M. Solé), fcoras@ac.upc.edu (F. Coraş), jordid@ac.upc.edu (J. Domingo-Pascual).

1389-1286/$ - see front matter © 2010 Elsevier B.V. All rights reserved.
doi:10.1016/j.comnet.2010.07.005

at the application layer, and create complex overlay networks to distribute multimedia content. Some of the commonly used systems are PPLive [7], TVAnts [8] and UUSee [9]. These applications are very popular and are being used daily by millions of Internet users [10].

Unfortunately, it has been shown that in practice these live streaming systems are unable to provide a satisfactory quality of experience at all times. As a consequence, the research community has thoroughly analyzed the streaming quality of these large-scale P2P networks in search for explanations [10–16]. Surprisingly, one of the main findings is that the streaming quality *degrades* as the number of peers *increases* if peak hours are considered [17]. Further, server capacity still plays a key role in these systems, and its insufficient supply leads to low streaming quality [17]. The main reasons behind these inefficiencies are: (i) limited upload capacity of the peers, who usually access the Internet through asymmetric links, and (ii) churn, peers may join/leave the system at any moment. Because of these reasons, application-layer based systems cannot guarantee a reliable streaming service, and cannot be considered as the long-term solution for broadcasting live multimedia content over the Internet. In this paper we advocate for a *network-layer* approach as the long-term solution.

We present CoreCast, a network-layer reliable live streaming protocol that avoids the high deployment cost of current approaches. In order to circumvent their prohibitive costs, CoreCast exploits a rare window of opportunity offered by the development and deployment of the locator/identifier separation protocol (LISP) [18], on top of which it is built. LISP is a new network architecture having an IETF working group devoted to its development and also enjoying support from Cisco. Its aim is to upgrade the current inter-domain routing system. The change is motivated by the alarming growth rate of the default-free zone (DFZ) routing table, listed as the most important problem facing the Internet [19]. In order to solve this critical issue, recent discussions within this Internet standards body suggested splitting the current IP address space into separate namespaces for identifiers and routing locators. The community generally agrees that this separation is a basic component of the future Internet, and that the current routing system must be upgraded. Among the proposals rooted in this approach [18,20,21] LISP is the most advanced one and already counts with an experimental testbed (lisp4.net and lisp6.net) in the Internet. The deployment of LISP involves incrementally upgrading the border routers of all the autonomous domains present in the Internet. CoreCast extends LISP, providing live streaming capabilities, while only requiring explicit support at these selected routers. This way, CoreCast can be deployed along with LISP, avoiding the prohibitive deployment cost of IP multicast.

CoreCast has a push-based architecture, and its operations are based on two demultiplexing points and a caching mechanism. The streaming server transmits one header per subscriber and just one copy of the content for all of them. The stream is first cached and subsequently demultiplexed towards each client ISP. Then, each client ISP's border router caches and demultiplexes again the stream towards the subscribers. The main benefit of CoreCast is that it considerably reduces inter-domain bandwidth, compared to existing P2P or unicast mechanisms. Because of its architectural principles, CoreCast can offer a guaranteed and reliable live streaming service, since ISPs and content providers may easily establish Service Level Agreements. Furthermore, it is an ISP-friendly solution, since subscribers belonging to different ISPs do not exchange traffic as in P2P systems. This is a key benefit as ISPs have recently shown their concerns because of the large amount of traffic generated by P2P applications (e.g. BitTorrent) [22].

In order to evaluate the feasibility of CoreCast we have implemented it in the Linux kernel. Our experiments show that it introduces negligible processing overhead when compared to traditional unicast forwarding. Further, the state kept in the routers is in the order of a few kilobytes, and grows linearly with the number of streamed channels, while it is independent of the amount of subscribers. Using an analytical model, we show that the inter-domain traffic generated by CoreCast is lower than that generated by P2P live streaming applications for typical traffic parameters. We support the model with an analysis of the traffic generated by some of the most popular P2P live streaming applications, PPLive and TVAnts, during two very popular events. The traffic was captured in four different countries: Japan, France, Spain and Romania.

CoreCast was first introduced in [23], and in short, the main new contributions of this paper are: (i) the CoreCast architecture, (ii) analytical and measurement-based comparison between CoreCast and P2P bandwidth requirements, (iii) an implementation for the Linux kernel and (iv) processing overhead analysis. The CoreCast implementation, along with a CoreCast packet dissector patch for the popular open source WireShark network analyzer can be found at http://www.cba.upc.edu/corecast.

2. LISP background

This section presents a basic overview of LISP [24,18]. The reader already familiar with this protocol can safely skip it. As mentioned before, the main drivers of this proposal are the scalability issues of the current Internet's routing infrastructure. The proposed solution lies in the separation of the address space of end hosts (destination space) from that of the transit network (transit space). Fig. 1 illustrates this separation. An additional plane, the Mapping System is required in order to facilitate the "glue" between the two addressing spaces.

In order to decouple the identifiers of nodes from their location, LISP introduces *Routing LOCators* (RLOCs), and *Endpoint IDentifiers* (EIDs). RLOCs are addresses used by network elements in the Transit Space, and define where a destination node is to be found in the routing topology. EIDs represent the identity of the node, regardless of its location, and are used as addresses in the Destination Space. In order to be incrementally deployable, and with no changes in end systems, RLOCs and EIDs are both using the IP address space.

When a packet is sent in the LISP-enabled Internet, it travels within the autonomous system (AS) using currently