

Implementation of Application Layer Multicast in OverSim

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(*Extended Abstract*)

Abstract—This paper presents an overview of the implementation of Application Layer Multicast (ALM) in OverSim, a simulation framework designed specifically for simulating overlay networks. OverSim builds upon the OMNeT++ discrete event simulator.

In addition, the paper presents guidelines for further research work based on reliable and Quality of Service (QoS)-aware multicast overlay networks. This research work is part of a bigger research project, called "Routing in Overlay Networks (ROVER)" which is focused on unicast and multicast routing in overlay networks with QoS guarantees and congestion control facilities on top of existing and future Peer-to-Peer (P2P) networks.

I. INTRODUCTION

In recent years, the Internet has experienced an unprecedented growth, which, in turn, has led to an increase in the demand of real-time and multimedia applications with high QoS demands. Moreover, the Internet has evolved into the main platform of global communications infrastructure and Internet Protocol (IP) networks are practically the primary transport medium for both telephony and other various multimedia applications.

This evolution poses important challenges to Internet Service Providers (ISPs) to provide good QoS for their customers as well as the ability to offer differentiated service subscriptions for customers willing to pay more for higher grade services. Thus, an increased number of ISPs are rapidly extending their network infrastructures and resources to handle emerging applications and a growing number of users.

However, in order to enhance the performance of an operational network, Traffic Engineering (TE) must be employed at the traffic and the resource level. Performance optimization of an IP network is accomplished by routing the network traffic in an optimal way. To achieve this, TE mechanisms may use several strategies for optimizing network performance, such as load-balancing, fast re-routing, constraint-based routing and multipath routing.

Several solutions are already implemented by ISPs and backbone operators for attaining QoS-enabled networks, e.g., Virtual Circuits (VCs) and Multi Protocol Label Switching

(MPLS). The provisioning of the QoS guarantees are mainly accommodated through the exploitation of the *connection-oriented* paradigm.

In this context, IP multicast has not yet experienced a large-scale deployment although it is able to provide (conceptually) efficient group communication and at the same time maintain an efficient utilization of the available bandwidth [4]. Besides difficulties related to security issues [6], need for special support from network devices and management problems faced by IP multicast, one problem that still needs to be addressed is related to the need for an efficient multicast Congestion Control (CC) scheme. Consequently, multicast overlay services have become a feasible solution for applications and services that need multicast-based functionality [3].

Consequently, a tremendous development of *overlay networks* have emerged in the Internet. In essence, an overlay network is any network running on top of another network, such as IP over Asynchronous Transfer Mode (ATM) or IP over Frame Relay. In the context of this paper however, the term refers to application networks running on top of the IP-based Internet.

Overlay networks can be viewed as networks operating at the inter-domain level. The overlay nodes learn of each other and form loosely-coupled peer relationships. Routing algorithms operating at the overlay layer may take advantage of the underlying physical network and try to accommodate the performance to different asymmetries that are inherent in IP networks, e.g., variable link bandwidth, link connectivity and variable resources at a network node (e.g., processing capability, buffer space and long-term storage capabilities).

New efforts to provide QoS have therefore been focused on the use of overlay networks. The major advantage of overlay networks is their ability to establish subsidiary topologies on top of the underlying network infrastructure and to act as brokers between an application and the required network connectivity. Another key advantage is the ability to offer some form of QoS routing on top of the shortest-path routing provided by IP. This implies choosing a path in the overlay network with specific constraints, e.g., packet loss ratio, delay, average bitrate.

Nevertheless, overlay networks also need to address similar issues related to efficient and scalable multicast CC schemes in order to attain a widespread deployment and acceptance

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from both end-users and various service providers.

II. MULTICAST OVERLAY NETWORKS

Although IP multicast was introduced more than a decade ago, it has not yet achieved its desired deployment [4]. In recent years a new approach to multicast has therefore emerged, namely to provide multicast communication at the application layer (so-called Application Layer Multicast (ALM)) by using the unicast transport facilities offered by Transport Control Protocol (TCP) and User Datagram Protocol (UDP). Operations related to group membership, addressing and multicast routing are implemented in this case at the application layer on the end hosts of a network. Application specific intelligence can be used to develop efficient multicast services.

Consequently, the network itself is relieved of these responsibilities, and only needs to provide the basic stateless, unicast, best-effort delivery. The architecture therefore decouples multicasting from the unicast routing infrastructure, which gives important advantages in terms of ease of deployment and flexibility. However, ALM faces a number of challenges related to routing, efficiency, reliability and scalability, which must be solved in order to gain acceptance. Three categories of ALM are distinguished, namely P2P multicast, Overlay Multicast (OM) and Waypoint Multicast (WM) [12].

III. CHALLENGES

Several attributes are required from an overlay multicast so as to provide a feasible solution over traditional IP multicast. At the same time, each attribute generates itself several challenges that must be addressed.

An overlay multicast must be *scalable* since this is one of the major drawbacks of conventional IP multicasting and one of the main reasons behind the overlay multicast solution. In addition, an overlay multicast solution should provide a *performance* comparable or at least not much worse than conventional IP multicast.

Another challenge that researchers and multicast service providers must solve is that an overlay multicast is required to quickly *adapt* to changes affecting the underlying network and to *react* in an appropriate manner so as to provide the expected performance. Moreover, the overlay multicast must be *robust* with regard to multicast group dynamics and multicast topology changes created for instance by node failures or churn behavior of the overlay nodes.

Further, the overlay multicast should also supply extra services or features that traditional IP multicasting does not provide such as for instance *security* of data transmission. Finally, in order to get a widespread acceptance by both end-users and diverse service providers, the overlay multicast must provide *reliable* communication regardless of the application that employs it.

IV. PERFORMANCE METRICS

Several performance metrics have been defined to characterize the multicast communication service and impacts on the network. The most important metrics are [5], [12]:

- **Link stress** defined in terms of number of identical packets a physical link carries.
- **Link stretch** also called relative delay penalty. This is the ratio of delay between two nodes along the overlay distribution topology to delay of the direct unicast path.
- **Resource usage** in terms of the sum of the delay-stress product over all participating links.
- **Time to first packet** is the time required for a new member to start receiving data after joining a group.
- **Losses**, which is the average number of packet losses after an ungraceful failure of a single participating node.
- **Robustness** to changing network conditions.
- **Control overhead** related to number of messages exchanged and bandwidth utilization required for maintaining the topology.
- **Efficiency**, to evaluate the overlay efficiency in real networks.

Since overlay multicast is operating at the application level, there are two main disadvantages, i.e., a higher delay and less efficient utilization of the available bandwidth. This is mainly because a packet in an overlay network may cross the same physical link several times before reaching the intended recipient.

In this context, two parameters (metrics) are widely employed in order to assess the quality of data delivery for an overlay path. These are the *stress* of a link belonging to the data plane (i.e., the physical underlying network), and the *stretch* of an overlay path between the source and a given destination.

The stretch of a path is defined as the ratio between the delay of the path in the overlay network and the minimum delay achievable at the network layer for the same path. The stress of a link is defined as the total number of identical packets transmitted over the same link due to the overlay network. The *efficiency* of an overlay multicast tree, based on the stress metric, is often used in order to evaluate its efficiency in real networks [1]:

$$\delta = 1 - \frac{L_m}{L_u} \quad (1)$$

where L_m is the defined as the total number of links traversed in the overlay multicast distribution tree and L_u is the total number of all unicast links traversed to reach all multicast group members. Consequently, δ represents the percentage gain of using multicast instead of unicast transmission. Thus, a value of δ close to 0 means that employing multicast instead of unicast provides little advantage (i.e., bandwidth efficiency) as is the case of widely distributed multicast groups. In a similar manner, a value of δ approaching 1 means that all receivers are sharing a single multicast overlay path resulting thus in maximum bandwidth efficiency in the overlay distribution tree [1].

As a general comment, it is observed that many solutions existent today implement the multicast overlay by using application-level performance measures, e.g., delay, throughput. The goal in this case, is to reduce the overall delay and construct a minimum-diameter tree with constrained degrees [13].

The degree constrains are therefore used for controlling diverse metrics, e.g., stress on the physical links.

In order to manage the overlay network, the participating overlay nodes must exchange *refresh* messages with the neighboring overlay peers, resulting in overhead control traffic experienced by an overlay network. This aspect must be also taken into consideration to attain a scalable overlay.

V. SIMULATION ENVIRONMENT

For the ALM simulation purposes, OMNeT++ [9] together with OverSim [10] have been chosen as simulation platform. The main reasons include the ease of use, a highly flexible and modular architecture as well as an open-source code base. Both OMNeT++ and OverSim are built as hierarchical architectures. Thus, at the lowest level of the hierarchy simpler modules encapsulate the desired behavior. These modules are implemented as C++ classes.

More complex modules (compound modules) may be composed of several simpler modules as well as other compound modules. The communication among modules is attained through *message-passing*. As a result, a simulation event is said to have occurred when a module sends or receives a message. A module may need certain initialization parameters in order to run and in this case external initialization files are used. If needed, the parameters can be varied among different simulation runs.

Further, the OverSim framework provides several important advantages [10]:

- Allows for simulating both structured and unstructured overlay networks. In similarity with OMNeT++, its modular design allows for extensions of new features and/or protocols.
- Provides exchangeable underlying network models with both a patched INET framework version available for OMNeT++ and a simpler alternative for high simulation performance. The patched INET allows for highly configurable network topologies having realistic bandwidths, packet delays and packet losses.
- Allows for various statistics collection through the provision of sent/received/forwarded network traffic per node, hop count per packet, successful/unsuccessful packet delivery, etc.

VI. SIMULATION EXPERIMENTS

In the context of the ALM middleware simulation, the initialization files are used for analyzing different ALM configurations allowing thus for a comparative study of several implemented protocols. Regarding the topology of an ALM overlay, several strategies to construct ALM overlays may be used [12]:

- Mesh-based overlays
- Tree-based overlays
- Multiple tree/mesh overlays
- Ring and multi-ring overlays
- Distributed Hash Tables (DHTs)

In our case, the ALM modules implement topologies created according to several strategies such as distributed-mesh

approach, centralized-tree approach and DHTs approach. The ALM modules also implement several support functions such as:

- Topology management functions – provide module topology information.
- Basic communication functions – provide establishment or removing of overlay links between the participating nodes as well as message passing (i.e., send, receive and forward).
- Performance monitoring functions – provide support maintenance for ALM applications with information such as node connectivity, available bandwidth, packet delay, packet loss and jitter.
- ALM protocol design support functions – provide high level support, for instance a basic tree topology construction satisfying a given condition (e.g., minimum delay).

Based on this, we will conduct an intensive comparative simulation study of different ALM approaches. These models will be further developed to integrate protocols providing *reliable* overlay multicast communication [3]. Consequently, several proposed solutions (e.g. Overcast [7], Reliable Multicast proXy (RMX) [2], Overlay Multicast Congestion Control (MCC) [15]) will be implemented in OverSim. These solutions will be compared to the new protocols and algorithms developed by the research team at the Dept. of Telecommunication Systems at Blekinge Institute of Technology (BTH).

The planned future work is to conduct the simulation study and to implement a virtual testbed (middleware) to be used as a research framework to study several important issues of overlay networks:

- Identify traffic invariants in overlay networks via traffic measurements and simulation studies to establish adequate and credible traffic models that capture and characterize traffic burstiness and correlation.
- Design algorithms that maximize the end-to-end (e2e) throughput of the sessions in the multicast overlay with main focus on streaming media distribution.
- Design algorithms that minimize the delay observed by receiving hosts in a multicast session.
- Design algorithms that maximize the resource utilization of the available resources in the overlay.
- Design algorithms that are robust with regard to adverse overlay dynamics, e.g., the presence of high churn rates with the consequence of highly dynamic topology and difficulties to provide QoS guarantees.

In addition, we plan to join PlanetLab [11] to test our solutions in a real network environment allowing thus for the validation under real conditions of our algorithms and QoS-aware overlay routing mechanisms.

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