Core-Based GRASP for Delay-Constrained Group Communications

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ABSTRACT

The recent development in network multimedia technology has created numerous real-time multimedia applications where the Quality-of-Service (QoS) requirements are quite rigorous. This has made multicasting under QoS constraints one of the most prominent routing problems. The authors consider the problem of the efficient delivery of data stream to receivers for multi-source communication groups. Efficiency in this context means to minimize cost while meeting bounds on the end-to-end delay of the application. The authors adopt the multi-core approach and utilize SPAN (Karaman and Hassane, 2007)—a core-based framework for multi-source group applications — as the basis to develop greedy randomized adaptive search procedures (GRASP) for the associated constrained cost minimization problem. The procedures are tested in asymmetric networks and computational results show that they consistently outperform their counterparts in the literature.

Keywords: Core-Based Approach, Greedy Randomized Adaptive Search Procedures (GRASP), Multicasting, Quality-of-Service (QoS), Routing Algorithms

INTRODUCTION

The recent proliferation of different multimedia real-time applications over the internet — such as Voice-over-IP (VoIP), videoconference, TV over the internet, radio over the internet, multipoint video streaming, distance learning, games, etc. — has created the need for scalable and efficient network support that is capable of providing the level of performance needed for these applications to function properly. The real-time transmission of multimedia information over the internet is characterized by large amount of data that have to be processed and transmitted simultaneously to multiple recipients through underlying computer networks. The transmission must be done under rigorous Quality-of-Service (QoS) constraints in order to ensure that audio and video data are delivered smoothly to the intended recipients. For instance, according to the International Telecommunication Union one-way transmission recommendations (ITU-T Recommendation G.114, 2003), data stream for video/audio conferencing with real-delivery of voice data should be delivered within 400ms. Such delay is acceptable in most situations, though users often start to become dissatisfied if the delay

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exceeds 200ms. Likewise, latency requirement for first-person shooter games is 100ms (ITU-T Recommendation G.114, 2003). Since most of the multimedia applications are delay-sensitive, the problem of establishing the group communication with minimum cost while satisfying the delay constraints has become one of the most relevant QoS problems.

Simultaneous transportation of information between one or many senders and multiple recipients is implemented through a mechanism called multicasting, which avoids sending a copy of data stream to each recipient. Multicasting protocols are implemented through either building source- or core-based trees. In both of these protocols (i.e., source-based and core-based) each sender sends only one data packet, which is then duplicated at branching points and forwarded to multiple recipients. The first multicast protocols were source-based (DVMRP – Waitzman et al., 1988; MOSPF – Moy, 1994a and 1994b; and PIM-DM – Deering et al., 1994). They establish group communication by building a separate shortest-path tree from source to all of the receivers. These protocols are suitable for small-scale applications only since they do not scale well. They tend to produce large message overhead because one piece of the state information per source and per group is kept in each router. They do not minimize the total cost of distribution and may fail if the underlying unicast routing is asymmetric. On the other hand, the core-based protocols are such that they choose one or more routers as cores and then build shortest-path trees from cores to all the multicast group members. Hereby senders transmit data to the cores, which then forward it to all the recipients. Depending on the number of cores the protocol is set to choose, they are classified as either single-core or multi-core based protocols. The first core-based protocols were single-core (CBT – Ballardie, 1997a and 1997b; and PIM - Deering et al., 1996). Unlike source-based trees, single-core trees are scalable and much easier to maintain since state information is stored one per group instead of one per source. Also, they offer better bandwidth utilization and produce lower message overhead. They are suitable for sparsely distributed receivers and are preferred to source-based trees in case of multiple sources in the multicast group (Wei and Estrin, 1994). However, single core-based trees have some serious flaws when compared to source-based trees. They produce higher delay (since data has to travel from senders to the cores first), they suffer from traffic concentration on links that converge towards the core and have poor fault tolerance in case of core failure. The introduction of several independent cores in multi-core protocols (OCBT – Shields, 1996, and Shields et al., 1997, “Sender-To-Many” - Zappala et al., 2002; “Members-To-Many” - Zappala et al., 2002) has significantly improved the performance of core-based protocols, making them a viable alternative to source-based trees. Compared to single core-based protocols, they result in less delay and incur in less total cost since nodes are more likely to locate nearby cores. They operate in a broader solution space and therefore are able to provide a solution in cases when a single-core solution does not exist. Moreover, they provide better fault tolerance in case of core failure and result in less traffic concentration around the cores. In general, for QoS-constrained applications with sparsely populated groups in a distributed routing environment the core-based approach is the preferred method providing more efficient solutions (Zappala et al., 2002). An extensive classification and comparative analysis of core-based multicast routing protocols can be found in Karaman and Hassanein (2006).

We consider the problem of cost minimization of many-to-many multicast group communication in a distributed, asymmetric environment under a hard end-to-end delay constraint. The most popular approach for this QoS-constrained many-to-many problem is GREEDY, a procedure proposed by Salama (1996), which operates in a symmetric, centralized deployment. A major improvement to GREEDY is the SPAN framework (Karaman & Hassanein, 2007a) and its extensions (Karaman & Hassanein, 2007b), which has consistently shown better performance than other approaches.
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