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Cost-Driven Multicast Communication Using Flexible Source Nodes in SDN

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Abstract

Efficient data dissemination to multiple receivers is a critical requirement in modern communication networks. Multicast routing addresses this requirement by enabling shared data transmission paths, thereby reducing redundant traffic. With the adoption of Software-Defined Networking (SDN), network operators can centrally manage routing decisions and optimize resource utilization. However, most existing multicast approaches assume a fixed source node, which is impractical in environments where content is replicated across multiple locations. This paper investigates a flexible-source multicast routing problem in SDN, where each destination can be served by any one of several potential sources. The objective is to minimize overall network cost while ensuring reliable delivery. The problem is formulated as a minimum-cost forest optimization task. Two efficient approximation algorithms are proposed and evaluated through experimental analysis and simulations. The results demonstrate significant reductions in link usage compared to traditional single-source multicast techniques.

Keywords: Software-Defined Networking, Multicast Routing, Flexible Sources, Minimum Cost Forest, Network Optimization.

Introduction

Multicast communication plays a vital role in applications such as video streaming, cloud services, and content distribution systems. By allowing data to be transmitted along shared paths, multicast reduces bandwidth consumption and alleviates source node load. Despite these advantages, large-scale multicast deployment has been limited in traditional IP networks due to complexity and lack of centralized control.

Software-Defined Networking (SDN) introduces a programmable network architecture that separates the control plane from the data plane. This separation enables centralized decision-making and global visibility of network resources, making SDN a promising platform for advanced multicast routing strategies.

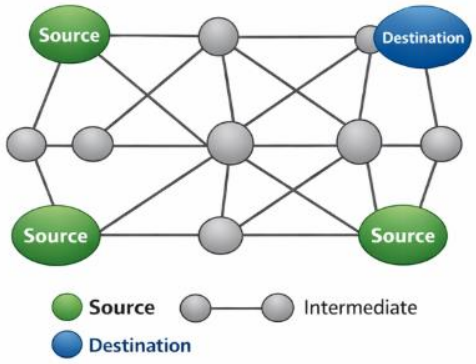

Figure 1: SDN Topology with multiple source and Destination

In many modern networks, content is replicated across multiple servers to improve availability and performance. Consequently, the source of a multicast session does not need to be fixed. Any replica can serve as the source, provided that application constraints are met. This flexibility motivates the need for a multicast routing approach that can dynamically select suitable sources while minimizing network cost.

2. Related Work

Traditional multicast routing techniques often rely on shortest-path trees or Steiner tree approximations to reduce network resource usage. While Steiner tree–based approaches provide near-optimal solutions, their high computational complexity limits practical deployment.

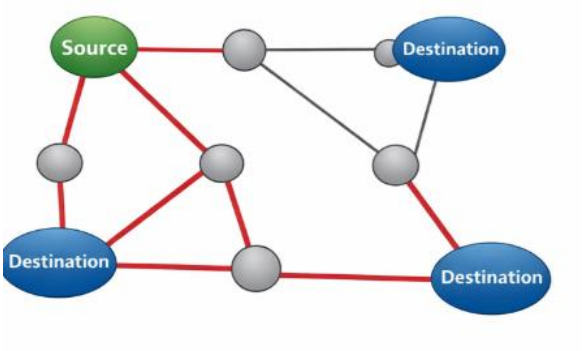

Figure 2: Minimum Cost Multicast forest

Several studies have explored multi-source multicast routing, primarily focusing on bandwidth fairness and load balancing across multiple data streams. However, these approaches are not designed to minimize link usage for a single multicast session with flexible source selection. Therefore, existing solutions are insufficient for the problem addressed in this paper.

Problem Formulation

The network is modeled as an undirected graph where nodes represent switches or servers and edges represent communication links. Each link is associated with a cost reflecting resource consumption. Let S denote the set of candidate source nodes and D denote the set of destination nodes.

The objective is to construct a routing structure such that each destination is connected to exactly one source, and the total cost of all utilized links is minimized. The resulting structure forms a forest rather than a single tree, as multiple sources may be active simultaneously. This optimization problem is computationally challenging and belongs to the class of NP-hard problems.

Proposed Routing Algorithms

To address the computational complexity of the flexible-source multicast problem, two approximation-based algorithms are proposed.

The first method constructs a reduced graph consisting only of source and destination nodes, where edge weights represent shortest-path distances in the original network. A minimum spanning structure is derived and adjusted to ensure that sources remain disconnected.

The second method enhances this approach by incorporating frequently used intermediate nodes, enabling greater path sharing and further reduction in overall network cost.

Performance Evaluation

The proposed algorithms were evaluated using both SDN-based experimental setups and large-scale simulations. Performance metrics included total link cost and data delivery completion-time.

Experimental results indicate that flexible-source multicast routing significantly reduces network cost compared to traditional single-source multicast. The enhanced algorithm consistently achieved the lowest link usage while maintaining acceptable delivery performance.

Conclusion

This paper presented a novel multicast routing framework for Software-Defined Networks that supports flexible source selection. By formulating the problem as a minimum-cost forest optimization task, two efficient approximation algorithms were developed. Experimental and simulation results confirm that the proposed methods outperform conventional multicast approaches in terms of network resource efficiency. Future work will focus on dynamic traffic conditions and fault-tolerant multicast routing in SDN environments.

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