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Overlay multicast tree recovery scheme using a proactive approach

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ABSTRACT

Overlay multicast scheme has been regarded as an alternative to conventional IP multicast since it can support multicast functions without infrastructural level changes. However, multicast tree reconstruction procedure is required when a non-leaf node fails or leaves. In this paper, we propose a proactive approach to solve the aforementioned defect of overlay multicast scheme by using a resource reservation of some nodes' out-degrees in the tree construction procedure. In our proposal, a proactive route maintenance approach makes it possible to shorten recovery time from parent node's abrupt failure. The simulation results show that proposed approach takes less time than the existing works to reconstruct a similar tree and that it is a more effective way to deal with more nodes that have lost their parent nodes due to failure.

1. Introduction

In overlay multicast, multicast functions are implemented at the end hosts. In other words, it emulates the conventional IP multicast by installation of application software operating at the end hosts. Application software, the overlay multicast agent, relays received data to its child nodes upon receiving data from its parent node without infrastructural level changes.

However, overlay multicast has its own drawbacks caused by dynamic characteristics. Tree reconstruction or recovery procedure which is useless in the case of IP multicast is required when a non-leaf node leaves a multicast group unintentionally or on purpose.

Most existing works related to overlay multicast have been focusing on overlay multicast protocol design to construct an efficient data delivery tree [1–10]. Whereas researches concentrated on tree recovery have been relatively rare since the relative importance between tree construction and tree recovery depends on service types in overlay multicast. For example, the first goal of overlay multicast is to transmit data through an optimal path. However, in the case of particular services such as real time broadcasting system and video conferencing, its first goal could be changed into providing Quality of Service (QoS) which requires fast tree recovery to minimize service suspension when non-leaf node fail by chance or on purpose.

In overlay multicast, tree recovery approaches could be fallen into two categories: a reactive approach and a proactive approach. Upon recognizing multicast tree failure, the former starts the tree recovery procedure based on network status and some metrics. The latter starts the tree recovery procedure using predefined backup routes or other scenarios. In this paper, we propose an overlay multicast algorithm appropriate for applications that require real time service. For this end, we use Round Trip Time (RTT) as a primary metric in a tree construction procedure and we adopt a proactive approach to minimize service suspension in tree recovery steps.

This paper is organized as follows. We briefly present related works in Section 2. In Section 3, we describe the proposed model, its approach and minute operation steps. Performance evaluations of the proposed approach and the comparison with the existing works are presented using simulation in Section 4. We conclude in Section 5.

2. Related work

In a reactive approach, once a node has abruptly lost link to its parent node, it would try to rejoin a multicast group by sending a join request to its root node or its grandparent node. However, in a proactive approach all the members, except the root node, are assigned alternative routes – back up routes – so that, in case of primary route failure, the recovery of the tree will be achieved smartly and quickly using allocated back up routes. Therefore, a proactive approach will improve the overall performance of the overlay multicast tree recovery.

In Probabilistic Resilient Multicast (PRM) [11], each node retransmits data with low probability to a specified number of nodes selected randomly in a multicast group. It could reduce

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packet loss by retransmitting data with a randomly selected route when a link of a tree was disconnected. However, it is not suitable for bandwidth sensitive services for it naturally needs additional data to other nodes.

In Okada's approach [12], a newly joined node selects a parent node which has the minimum RTT from it and then caches a backup parent node which has the second minimum RTT to offer backup route in case of a departure of parent node. It could select backup route with a minimal operation and without resource preemption. However, it could not work properly in tree recovery procedure when a backup parent node has no available out-degree.

In Yang's approach [13], for each non-leaf node, it pre-computes the recovery plan for its children in case it fails. For this end, each non-leaf node finds parents-to-be nodes of its children. Thus, a fast tree recovery is achieved. In addition, this approach could save resources because it does not preempt resources such as network bandwidth, node's computing power and so on. However, in case of a large multicast group, tree recovery time could be elongated since repetitive operations for searching nodes which have available out-degree are required.

In Kusumoto's approach [14], every node must maintain more than 1 available out-degree. By using the available out-degree, every node establishes a backup route by connecting between children and grandparent node. Compared with [13], this reduces an overhead by simplifying the backup route establishment procedure. However, maintaining at least 1 available out-degree on every node makes it difficult to construct an efficient overlay multicast tree since the tree level would be longer by the one available out-degree occupied by every node.

3. Proposed scheme

3.1. Overview

In our proposal, every node, except the root node, has service out-degree and backup out-degree. The out-degree of a given node represents the number of the child nodes that can be served by a given node. The back up out-degree of a given node is used for reserving the back up or alternative routes. The service out-degree of a given node implies the number of the child nodes that can be served by a given node for service purpose or transmitting a data. Let m be the maximum out-degree of one node. Let n be the backup out-degree of that node, then, the service out-degrees would be $m - n$. The reason why we reserve backup out-degrees is that this reserved out-degree would be switched into service purpose during a tree recovery procedure. Our proposal is based on a proactive approach to recover tree failure. Thus it could achieve a fast tree recovery. However, a constructed tree using the proposed scheme would be a tree that has a large value in its depth and its average transmission delay compared with an optimal tree. The results are caused by the reserved backup out-degrees. To alleviate the overhead incurred by the backup out-degree, we do not allocate any backup out-degree on root node.

During the multicast tree construction process, a join requesting node first contacts the root node operating as a rendezvous point to get the information of a multicast tree. Then, the root node sends the information called Potential Parent List (PPL) to the join requesting node. PPL consists of nodes' IP addresses and corresponding RTT values from the root node. A detailed structure of PPL on the root node is shown in Fig. 1. Generally, a PPL contains only the information for service purpose, but in our proposal, the PPL includes additional information related to backup purpose used to select a backup node. Next, upon receiving the PPL from the root node, the join requesting node determines its parent node and backup node. The PPL information related to both service and backup purposes would be updated whenever a multicast tree changes.

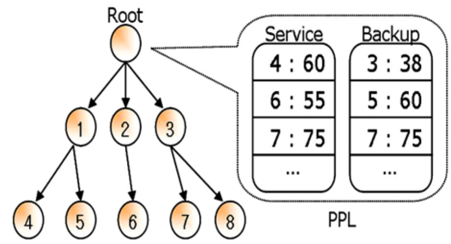

Fig. 1. Structure of Potential Parent List on root node.

3.2. New node join

An example of new node join procedure is shown in Fig. 2. A detailed procedure of a new node join is presented as follows.

(i) A join requesting node N sends join request to the root node.
(ii) The root node checks its available out-degree to determine whether it has enough out-degree to provide service to node N or not.
(iii) If the root node has enough out-degree then it sends Ack message to node N and begins to offer service to node N.
(iv) Else, the root node sends a PPL collected from group members to node N. Node N measures RTT between itself and the nodes in the service fields of PPL and calculates a route RTT, respectively, by adding measured RTT to RTT in PPL.
(v) The route RTTs are sorted and node N selects a node that offers the shortest route RTT value as its Potential Parent Node (PPN). And then, if a PPN has enough available service out-degree, it sends Ack message to node N and begins to offer service to node N.

If two or more join requesting nodes select one specific node as their PPN simultaneously in Step (v), then, PPN would selects its child node sequentially according to the join requesting time. However, if there are no available service out-degrees at the PPN, then it sends a Nack message to a newly joined node. Next, the join requesting node selects a new node which has the second shortest route from the PPL as its PPN. The aforementioned process would be repeated until all the join requesting nodes join a multicast group.

An example of a PPL update procedure is shown in Fig. 3. After node N joins a multicast group, node N and node 4 send messages to the root node. The message sent by node N includes its route RTT, service and backup available out-degrees. The message sent by node 4 also contains its out-degree changes. If node 4 has no service available out-degree then the root node deletes node 4 from the PPL. Thus the root node could always maintain the newest information about a multicast group.

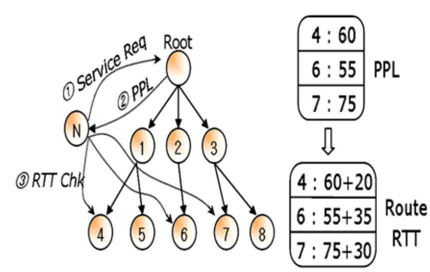

Fig. 2. Example of join procedure.