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Application Layer Multicast Based Services on Hierarchical Peer to Peer Architecture

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Abstract. Application Layer Multicast (ALM) is considered as an attractive approach for implementing wide area multicast services. In ALM, multicast functionality is implemented at the edge instead of the core network (*routers*). As opposed to network-layer multicast, application layer multicast requires no infrastructure support and can be easily deployed in the Internet. In this paper, we propose a new efficient and scalable model for optimizing application layer multicast using HPM architecture (*HPM: A novel hierarchical Peer-to-Peer model for lookup acceleration with provision of physical proximity*). This approach benefits from P2P properties and characteristics. In this contribution, we consider our optimized tree construction algorithm simultaneously for each ring of HPM. The global tree construction algorithm is composed of two steps. In the first step, we construct a sub-tree for each ring; the second step is to build a global tree using sub sets of adjacent rings in HPM architecture. The proposed model inherits from main P2P attributes such as: scalability, fault tolerance characterized HPM. Preliminarily performance evaluations show that results are globally satisfactory, the depth of the resulting multicast tree is optimized.

Introduction

For multimedia applications such as video on demand (VoD), media streaming or media conferencing, efficient and optimal distribution of media content to a large group of receivers constitutes a key requirement. In response to such requirement, the efficient support of multicasting by network layer components (*ie. routers*) was proposed in the form of "network" IP multicasting. However, the ubiquitous deployment of IP multicasting have been challenged by several commercial issues as well as technical challenges related to scalability, quality of service support, security access or multicast sessions management. Given the advances and performance of P2P networks, the need of multicast capability for P2P type of applications such as media conferencing is a challenge. Many problems should be adressed such as implementation feasibillity, scalability, security, optimisation in terms of several creterias such as : multicast tree depth, end to end delay. In this work, we are interesting to the optimisation problem, that leads us to propose a scalable and efficient approach that optimizes application layer multicast and accelerates the tree construction time in a specific P2P architecture called HPM.

This paper is organized as follows. First, this paper discusses about related works on Peer to Peer networks (*a special consideration is given for HPM architecture on which this contribution is based*) and application layer multicast. Next, it describes the proposed model. Then, this paper outlines and analyzes preliminary results of the performance evaluations. Finally, the paper concludes by recommending some future works.

Related Works

Peer to Peer architecture is an alternative to client/server model. The application layer multicast is also an alternative to IP multicast. Combining the two above alternative approaches for new applications (*ex. social networking*) is a new challenge. The two sub-sections bellows introduce separately the P2P and the ALM.

Peer to Peer Networks

There are several definitions of Peer to Peer systems that are being used by the P2P community. As defined in [11]. "P2P allows file sharing or computer resources and services by direct exchange between systems". Also as defined in [4]: "P2P is a class of applications that takes advantages of resources-storage, cycle, content human presence-availability at the edge of Internet". There are three main generations of P2P networks:

First generation: the main contribution of this class is the introduction of a network architecture, where machines are not categorized as client and server; but rather as machines that offer and consume resources. Napster **[6]** is an example of such system. It is composed of two services: a decentralized one for files storing with centralized directory service for lookup and retrieval. Figure 1.(a) shows Napster architecture.

Second generation: the second generation systems solved the problem of the centralized coordination. However, the problem of scalability becomes more critical due to the network traffic generated by the flooding algorithm for research or localization. Gnutella **[5]** is an example of such systems. Figure 1.(b) shows Gnutella architecture.

Third generation: the third generation of P2P networks (*eg. HPM **[1]**, Chord **[10]**, P2P based CAN **[8]** and Agregation based routing protocol **[13]***) is generally based on the DHT (*Distributed hash table*) to generate key for both nodes and data. Nodes identifier and keys value pairs are both hashed to one identifier space. The nodes are then connected to each other's in a certain predefined topology (*ring as in Chord, multi-dimensional coordinate space as in CAN and hierarchical rings as in HPM*). The figure 1 shows representative examples of each generation of P2P networks.

In this paper, we propose an ALM based HPM. The HPM protocol **[1]** is based on structured and hierarchical rings. Each ring has 256 nodes (*maximum*). The first level ring contains nodes for which IP addresses are different in the first part, with no restriction in the other parts. Each node in HPM is identified by a unique identifier *n* which is the i^{th} part of its IP address ($1 \leq i \leq 4$), with *i*: the level on which the node belongs to. The resources are also identified by a unique identifier generated by the distributed hash tables. Each resource key is composed of four parts (a.b.c.d) too. Each node maintains a routing table containing the IP address and port numbers of the "neighboring" nodes. In each ring, nodes are ordered increasingly based on their identifiers.
Let *m* be the number of bits in the space of node identifiers on one level ($m = 8$ *for 256 nodes*). Each node *n* maintains a routing table of at most *m* entries called the finger table. The i^{th} entry in the finger table of node *n* contains the identifier of the first node *p* that succeeds *n* by at least 2^{i-1} on the identifiers circle, where $1 \leq i \leq m$. We call node *p* the i^{th} finger of node *n*. A finger table entry includes both the HPM" identifier and the IP address and port number of the relevant node. In HPM there are one ring in the first level, 256 nodes in the second level, 256^2 in the third level and 256^3 in the fourth level (255^{i-1} *in the* i^{th} *level*). Figure 2 shows the HPM architecture and the finger table of one node belonging to two levels, and then has two identifiers, for example: N50 on level 1 and N52 on level 2. The keys of resources are used in the context of resources discovery and localization of P2P networks, but in ALM, they are not important elements as opposed to key nodes.

Application Layer Multicast

Several different and independent mechanisms are defined. The main existing protocols for implementing multicast are: Any Source Multicast (ASM), Single Source Multicast (SSM) and Application Layer Multicast (ALM). ALM aims to address scalability issues of unicast by distributing data replication process among the different group members, in an adaptative and efficient way. However ALM is not as efficient as IP multicast in terms of data duplication. In ALM the nodes are self-organized based on mesh or tree structures.

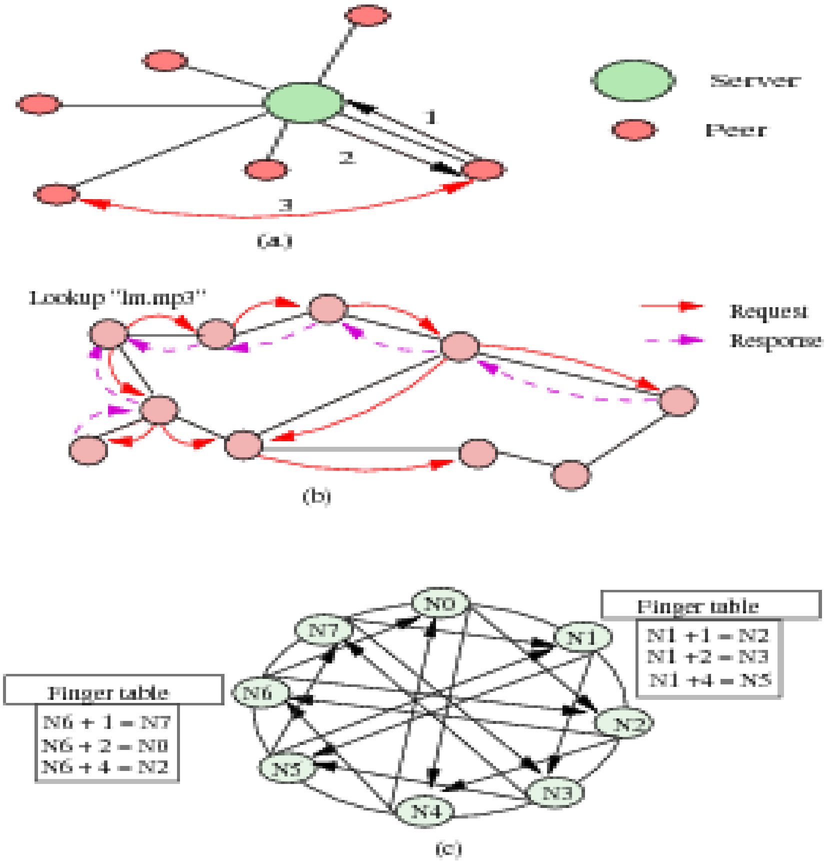

Figure 1. Examples of P2P architectures: (a) Napster, (b) Gnutella and (c) Chord

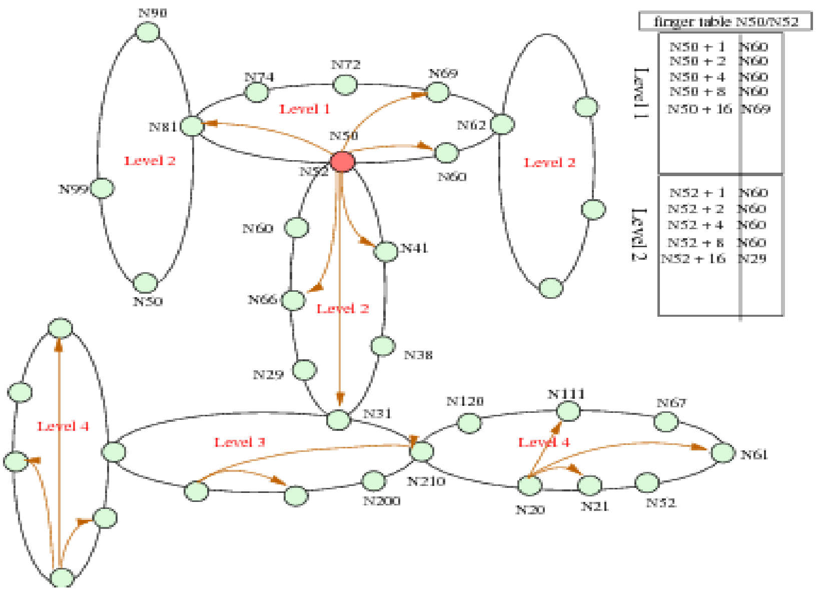

Figure 2. HPM Architecture

In Narada [12], the overlay network is built according two steps process. The first step is for establishing an optimized well-connected and controlled mesh topology. The Second one is for building a source tree from each potential sender to every receiver, using a subset of existing mesh links. As opposed to Narada, ALMI [7] relies on a central session controller node to calculate a bi-directional and minimal spanning tree data distribution overlay between the registered nodes. The session controller can be implemented on one of the participant nodes or on a well-known external node. NICE [9] uses hierarchical clustering techniques to build overlay tree, whereby group members arrange themselves into clusters with the neighboring nodes. Recent type of ALM based applications have been emerged the P2P networking such as streaming [14], telemedecine [15] and social networking [16]. The main objective of our proposed model is to build an efficient and optimized multicast tree from any node (*root or sender*) to all other nodes (*receivers*) using HPM as underlying architecture. The next section describes our architecture.

Proposed Approach

In this paper, we propose a new efficient and optimized application layer multicast. We use HPM as architecture for our model. Our proposed ALM model is a sevice that should be impleted on the top of HPM architecure, in order to give media streaming based applications or conferencing applications.

Motivation. In a large scale Peer-to-Peer system, any node can be the source of a data flow (*eg. real time applications*) that potentially concerns a large number of receiving nodes. Also collaboration oriented applications such as media-conferencing need somehow multicast mechanisms **[2]**. The media flow (*audio, video or data*) should be distributed between multiple and independent participants and conference groups, with efficiency and optimization. Our contribution based HPM architecture, aims to contribute to this efficiency and optimization by minimizing the overhead and network traffic, and the depth of the constructed multicast tree, which has an impact on delay, one of the most important impairment of QoS.

Functional Principal. Our proposed model uses HPM architecture for global tree construction. The algorithm is composed of two steps. The first step is to build a sub-tree in each ring of HPM, and the second step is for relaying adjacent sub-trees corresponding to two neighboring rings.

Multicast Tree Construction. To build an optimized multicast tree, we define a specific data structure (*adjacency matrix*), and propose an algorithm for multicast tree construction (*calculation*). The algorithm is applied by the same manner in each ring of HPM based on this adjacency matrix. Based on each neighbor node of HPM architecture, we define the adjacency matrix in our model (denoted Adj_Mat) as: Adj_Mat[i,j] = 1 : if there is a link between node N_i and N_j (*not bijective link*), else it is equal to zero. Table 1 represents the adjacency matrix of node N50 in ring R1 of level 1 for the network topology as illustrated figure 2.

Table 1. Adjacency matrix

	N0	N1	N2	N3	N4	N5	N6	N7
N0	-	1	1	0	1	0	0	0
N1	0	-	1	1	0	1	0	0
N2	0	0	-	1	1	0	1	0
N3	0	0	0	-	1	1	0	1
N4	1	0	0	0	-	1	1	0
N5	0	1	0	0	0	-	1	1
N6	1	0	1	0	0	0	-	1
N7	1	1	0	1	0	0	0	-

Based on the adjacency matrix defined above, we give an efficient and scalable ALM (*algorithm 1*) for multicast tree construction. The algorithm is applied with the same manner in each ring of HPM.

Algorithm 1: Multicast tree construction algorithm

1: Begin
2: If (N_i is a source node) **then**
3: Send message Child (N_i) to all nodes in its finger table
4: else //N_i is not a source
5: At the reception of the messages Child (N_i)
  5.1 If N_i belongs to another ring **then**
  N_i become a source and executes the multicast tree construction algorithm
  5.2 Else forwards this message to all nodes in its finger table except those in set A, B or C,
Where:

A: the sets of nodes which precede N_i (*Parent*)
B: the sets of nodes at the same level as N_i (*Brothers*)
C: the set of nodes which is child of its brothers and those last have an identifier numerically lower than that of N_i
6: End.

Algorithm 1. Multicast tree construction algorithm

Shared Adjacency Matrix. The Adjacency matrix represents a global knowledge of nodes in each ring of HPM, and then it must be shared between them. Algorithm 2 shows how to share the adjacency in our model,

Algorithm 2: Shared Adjacency Matrix Algorithm

1: Begin
2: For any change in finger table or at reception of a new entry of adjacency matrix **do**
3: Update this entry.
4: Send this entry to all successors in the finger table
5. End.

Algorithm 2. Shared Adjacency Matrix Algorithm

Nodes Join and Leave Processes. In a dynamic environment, nodes can join or leave the network at any time. Given this, a "Bootstrapping mechanism" constitutes a required key functionality, and is required for P2P networks. Nodes intending to participate in such overlay network, initially have to find at least one node already member of this network. Four types of bootstrapping mechanism exist: Static Overlay Nodes Bootstrapping Servers, Out-of-band Address caches, Random Address Probing and Employing Network Layer Mechanism. For simplification, we choose the static overlay nodes bootstrapping. When a new node joins the system, it takes place in the HPM architecture. When its parent p discovers this node, it sends the message *Child (p)* to the new comer. This last accepts and forwards the message to all its children (*successors*). Consequently, just a portion of the multicast sub-tree is updated (*in one ring*). When a node leaves the system, a stabilization algorithm of HPM is invoked. This process should be executed following a node join or leave (*or failure*), and then a portion of the multicast sub-tree is updated. Fig. 3 shows the static overlay nodes bootstrapping Servers mechanism, generally used in peer to peer networks.

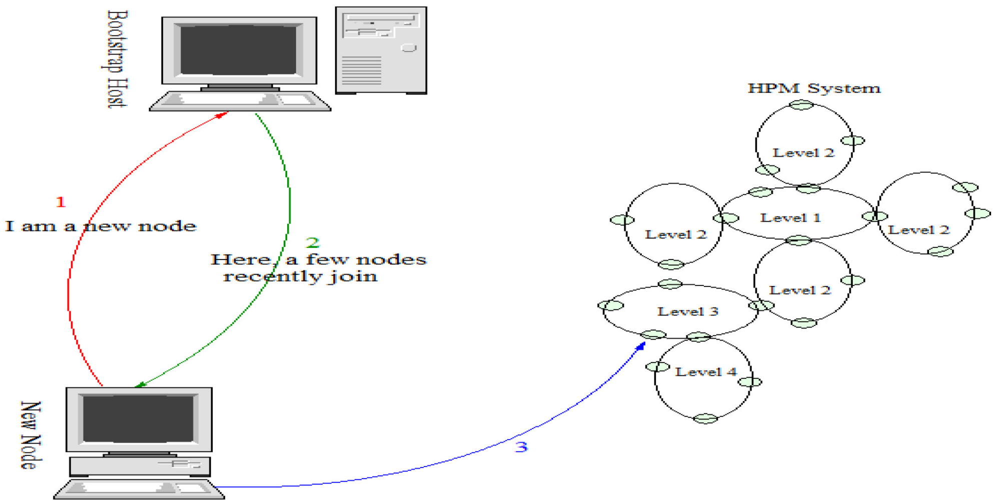

Figure 3. The bootstrapping mechanism

Performance Evaluation

In order to evaluate the performance, we consider the following metrics for evaluating our proposed solution:

- **Data Structure Size**: it mesures the size od adjacency matrix used by the multisat tree construction algorithm and stored at each participating node,
- **Overhead**: it mesures the number of exchanged messages between nodes in order to construct the multicast tree,
- **Tree depth**: it mesures the depth of the generated multicast tree in term of number of gops.

The simulations are down on machine carried out in a personal computer with the following characteristics: 2.16 GHz and 1GB of RAM. The figure 4 shows that the cost of adjacency matrix is $O(Log_2(n_i))$, $n_i \leq 256$, where each cell contains one bit, which means that this data structure does not affect the scalability of our approach.

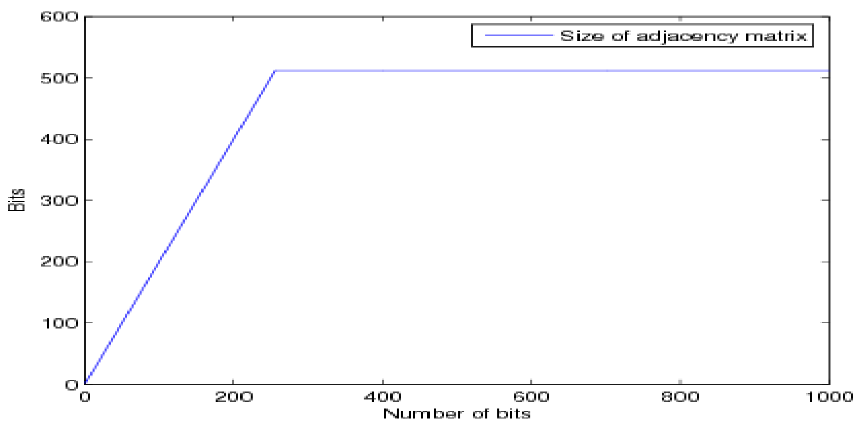

Figure 4. Adjacency matrix size

Figure 5 shows the average of overhead messages generated when applying the multicast tree construction algorithm simultaneously/sequentially in each ring. The figure shows that the overhead messages are reduced when using sequentially multicast tree construction algorithm, but evidently the simultaneously method reduces the time taken by the algorithm. Figure 6 shows the average depth of resulting multicast tree, which increments in logarithmic way in the beginning (*when HPM is composed of one ring*) but also, it is maximized by the value 16. This is has an impact on delay, one of the most important parameter for real time applications, like video/audio conferencing based multicast.

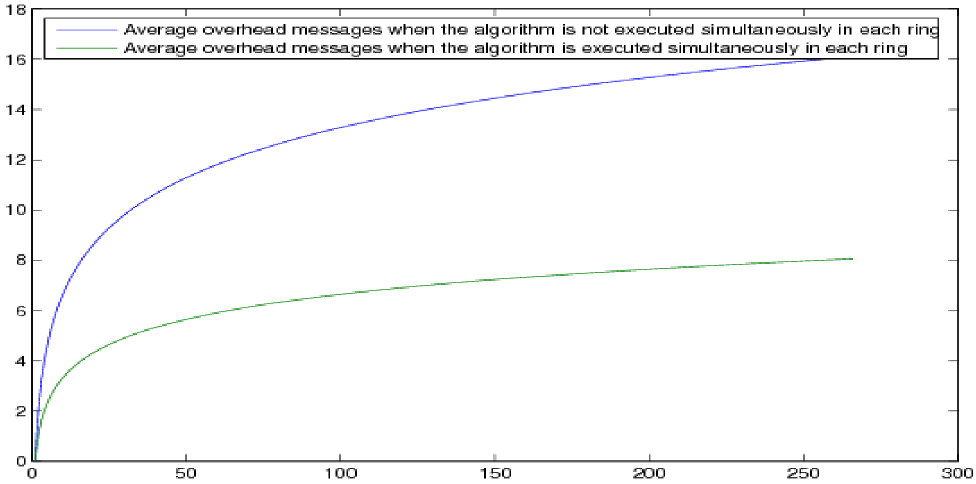

Figure 5. The average of overhead messages

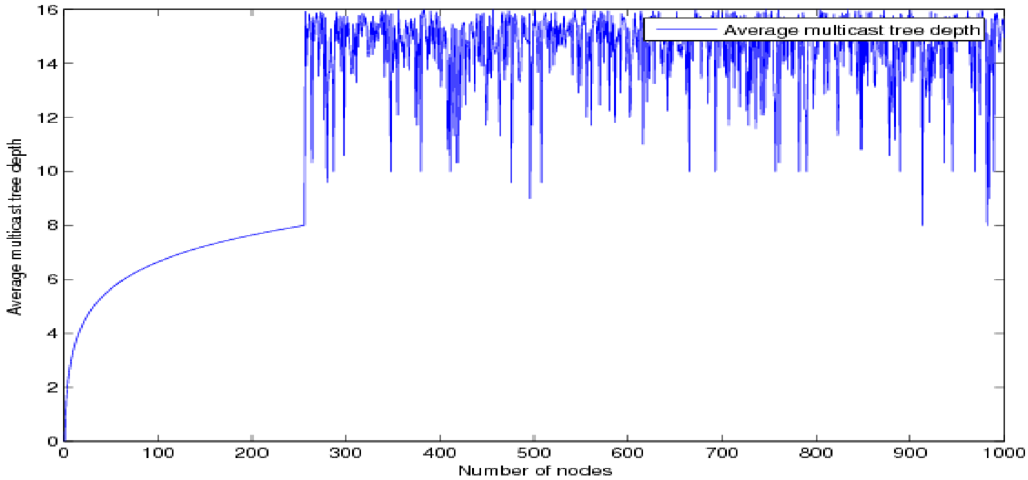

Figure 6. The average depth of multicast tree

Conclusion

Heterogeneity is one of the main characteristics of Internet. It is necessary to create efficient, fault-tolerant, efficient and scalable solution for data delivery especially for group communications. Application layer multicast is based on different, independent mechanisms. Building multicast on top of decentralized, scalable, and reliable peer-to-peer overlay networks offers a promising approach. In this paper, we have proposed a novel efficient and scalable model for optimizing application layer multicast using HPM architecture. We provide an efficient algorithm for multicast tree construction. It is based on a particular shared data structure called Adjacency matrix. Performance evaluation shows that our proposed approach is globally satisfactory. The average depth of resulting multicast tree is $O(\log_2(n))$, which has an important impact on delay, one of the most important parameters of QoS for real time application like video/audio conferencing. In term of perspectives, in one hand we envision extending our proposed model in the context of social networking in order to make an optimized media streaming over existing social networking architectures such as Routil [3]. In other hand, we studying the generic aspect of the proposed multicast tree algorithm in order to implement it on the top of other P2P architectures.

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