مجلة جامعة تشرين للبحوث والدراسات العلمية _ سلسلة العلوم الهندسية المجلد (35) العدد (2) 2013
Tishreen University Journal for Research and Scientific Studies - Engineering Sciences Series Vol. (35) No. (2) 2013

Performance Evaluation of Algorithms of Dynamic Rendezvous Point Relocation

Samer Sulaiman[*]
Jafar Al- Kheir[**]

(Received 12 / 8 / 2012. Accepted 7 / 1 / 2013)

∇ ABSTRACT ∇

Abstract. The Protocol Independent Multicast - Sparse Mode (PIM-SM) uses one center (referred here as the Rendezvous Point "RP") for all sources in a multicast group. PIM-SM distributes the multicast traffic of a source through a so-called shared distribution tree, whose root is at a predefined core called Rendezvous Point (RP). It also builds source-specific trees to the sources whose data rates exceed a defined threshold. In the literature, several investigations are done to improve and provide an efficient mechanism for the dynamic relocation of the RP depending on the sources or the members of the multicast group. In this paper, we extend the investigation of three search algorithms used to find the optimal RP position. To evaluate the performance of these algorithms, Estimated Tree Cost (ETC) and our improvement Enhanced Estimated Tree Cost (EETC), are used. The reason behind our choice these two methods is a comparative investigation of the RP-selection methods proposed in the literature. From the comparison we can see that ETC finds the most optimal position of the rendezvous point. The Hill-Climbing algorithm and the standard PIM-SM protocol with static RP-selection are used as a reference for comparison. Our algorithms result in a lower network load compared to RP-selection algorithm. However, they need additional control messages.

Keywords: Center relocation, routing protocol, multicasting, performance evaluation, protocol independent multicast, simulation**.**

[*]**Assistant Professor, of Computer and Control Engineering, University of Tishreen, Tishreen 1, Latakia, Syria**
[**]**Assistant Professor, of Computer and Control Engineering, University of Tishreen, Tishreen 1, Latakia, Syria**

مجلة جامعة تشرين للبحوث والدراسات العلمية _ سلسلة العلوم الهندسية المجلد (35) العدد (2) 2013
Tishreen University Journal for Research and Scientific Studies - Engineering Sciences Series Vol. (35) No. (2) 2013

تقييم أداء خوارزميات إعادة تموضع نقطة المركز للشبكات متعدّدة المستقبلات ديناميكياً

سامر سليمان*
جعفر الخير**

(تاريخ الإيداع 12 / 8 / 2012. قُبِل للنشر في 7/ 1 / 2013)

∇ ملخّص ∇

إن زيادة الطلب على تطبيقات المجموعات الموجهه، مثل إرسال الصوت والصورة واستقبالهما عن طريق الانترنيت، لا يمكن تحقيقه بشكل فعال وأمثل عن طريق استخدام أنظمة اتصال نقطة إلى نقطة .(Point-to-Point) ولهذا السبب تَستَخدِم معظم التطبيقات المكونة من مرسل واحد يقوم بإرسال البيانات نفسها إلى مجموعة من المستقبلات ذات عنوان انترنيت واحد متعدد الأهداف أنظمة الاتصالات المتعددة الأهداف. حيث يتم بناء ما يسمى بشجرة التوزيع لهذا الغرض وذلك من أجل وصل جميع المستقبلات بالمرسل.

يعدّ البروتوكول (PIM-SM) من بروتوكولات المسار المتعددة الأهداف، الذي يَسْتَخدِم مركزاً واحد والذي سنشير إليه لاحقاً بنقطة الالتقاء(RP)لجميع المرسلات ضمن المجموعة المتعددة الأهداف. يقوم البروتوكول (PIM-SM) بتوزيع البيانات المرسلة من قبل المرسلات بواسطة ما يسمى شجرة التوزيع المشتركة ذات مركز محدد مسبقاً والذي يدعى بنقطة الالتقاء (RP). كما يقوم هذا البروتوكول ببناء شجرة توزيع خاصة (تدعى source-specific tree) لجميع المرسلات التي يتخطى معدل إرسالها للبيانات حداً مسموحاً به.تم انجاز العديد من الأبحاث العلمية والموجودة في المراجع من أجل تحسين أداء هذا البروتوكول والوصول إلى آلية فعالة ومناسبة من أجل عملية إعادة تموضع نقطة الالتقاء (RP) ديناميكياً بالاعتماد على المرسلات، والمستقبلات ضمن المجموعة المتعددة الأهداف.في هذا المقال تم توسيع دراسةالخوارزميات الثلاثة المستخدم من أجل إيجاد الموقع الأمثل لنقطة الالتقاء (RP)، والمقترحة ضمن مقالتنا السابقة[12]، كما تم استخدام طريقتين لاختيار موقع نقطة الالتقاء (تكلفة الشجرة المقدرةETCبالإضافة إلى تكلفة الشجرة المقدرة المحسنةEETC) من أجل تقييم أداء هذه الخوارزميات. حيث قمنا بمقارنة الطرق المقترحة في المراجع العلمية واختيار الطريقة الأفضل من حيث إيجاد نقطة الالتقاء الأفضل لتقييم خوارزميات البحث بالإضافة إلى الطريقة المحسنة المقترحة في هذه المقالة. لقد قمنا باستخدام الخوارزمية (Hill-Climbing)، بالإضافة إلى البروتوكول الأساسي (PIM-SM) المُعتَمِد على الطريقة الساكنة لاختيار موقع المركز بوصفه مرجعاً أساساً من أجل المقارنة والتقييم.أظهرت نتائج الدراسة أن الخوارزميات المقترحة في هذا المقال لإعادة تموضع نقطة الالتقاء (RP) ديناميكياً أعطت نتائج أفضل من حيث تخفيض حمل الشبكة مقارنة بخوارزمية تحديد موقع نقطة الالتقاء الساكنة ولكن هذه الخوارزميات تحتاج إلى بعض رسائل التحكم الإضافية.

الكلمات المفتاحية: إعادة تموضع المركز – الاتصال المتعدد الأهداف، تقييم الأداء– بروتوكول المسار – البروتوكول المستقل المتعدد الأهداف– المحاكات

* مدرس– قسم هندسة الحاسبات – كلية الهندسة الميكانيكية و الكهربائية – جامعة تشرين– سورية
** مدرس– قسم هندسة الحاسبات – كلية الهندسة الميكانيكية و الكهربائية – جامعة تشرين– سورية

Introduction:

In the last several years, major developments in network topologies and their services have been presented. However, the demand of more network bandwidth and other Quality of Services (QoS) parameters has never stopped. Furthermore, new services such as Internet Protocol Television (IPTV), Video on Demand (VoD), distance learning, etc. appeared, accelerating the network traffic growth. Some of these services need a high bandwidth when they are unicasted to each customer. In this case, multicast is a promising technology for such distribution of streaming traffic. It can reduce the required bandwidth by distributing multicast traffic over so-called multicast distribution trees.

Multicast routers use a multicast routing protocol to construct and maintain distribution trees that enable the forwarding of multicast traffic. The available multicast routing protocols use different algorithms to build this distribution tree. Some of these protocols use the Source Based Tree (SBT) approach, while the others use the Shared Tree (ST) method [1], [2]. The multicast routing protocols can be subdivided into two different modes depending on the receivers' distribution in the network. The modes are the Dense Mode (DM) and the Sparse Mode (SM). The Distance Vector Multicast Routing Protocol (DVMRP) is an example of the dense mode, which has been the first multicast routing protocol specified in the year 1988 [3]. DVMRP creates for each source and its receivers group a different distribution tree (i.e. SBT), which is determined by the optimal path between the source and each of its receivers. DVMRP was developed based on the unicast protocol Routing Information Protocol (RIP).

The Protocol Independent Multicast Sparse Mode (PIM-SM) is a sparse mode protocol. In the sparse mode, the receivers are distributed over large distances in the network. The sparse mode protocols use the shared tree algorithm to build the distribution tree. PIM-SM uses the routing information of the available unicast routing protocol; therefore, it does not need to exchange any routing information [4]. PIM-SM is the only multicast routing protocol that builds both a shared and a source-based tree. Several investigations have been done to improve the switching mechanism used in this protocol [2], [5]. Furthermore, the dynamic relocation of the RP depending on the sources or the receivers of the multicast group is also an attractive solution [6]-[9]. For this solution, it is important to choose and define a suitable objective function as well as a search algorithm.

The remaining of the paper is organized as follows. An overview of the dynamic relocation algorithms is given in section II. In section III, the investigated RP-selection methods are described. In section IV, four search algorithms used to find the best RP are discussed. Results and comparisons between the investigated algorithms are shown in section V.

Related work :

Several RP search algorithms and RP-selection methods have been proposed in the literature. In this section, we present a brief overview of such algorithms. Thaler and Ravishanlar [7] classified the RP search algorithms into six classes using either a list of sources or a list of multicast members to find a good location for the RP. They compare the proposed algorithms using different RP-selection methods (evaluation criteria). They concluded that the Hill-Climbing algorithm (see section IV), which is used to find a local minimum, is the best performing if the considered RP-selection method is minimizing the tree cost. A number of methods have also been proposed for RP-selection method. Five methods (evaluation criteria), actual tree cost, maximum distance, average distance, maximum Diameter and estimated tree cost introduced in [7] are dependent on the hop-count. Other methods are presented in [6] and [11] which based on hop-count, delay, tree cost or both delay and tree cost. The classification of RP-selection methods have been presented in [6]. In this paper we use three search algorithms proposed in [12] and compare them with the Hill-Climbing algorithm using two different network topologies in order to present the effect of different topologies on the investigated algorithms. We also investigate the performance evaluation of the different RP-selection methods discussed in [7] and extend the RP-selection method (estimated tree cost) in order to use it for evaluating the investigated search algorithms.

RP-Selection Methods:

As mentioned above, different RP-selection methods have been proposed in the literature. These use only one criterion such as minimizing the tree cost, the average delay, the maximum delay and the maximum diameter [7]. In this section, we will discuss the different RP-selection methods used in our investigation. The average distance cost function ($\overline{C^{Dist}}$) refers to the mean value of multicast receiver distances to a C-RP. For a given set S and C-RP "rp", the $\overline{C^{Dist}}$ function can be defined as follows:

$$\overline{C^{Dist}} = \frac{1}{|S|} \sum_{u \in S} d(rp, u) \tag{1}$$

Similarly, we can also define the maximum distance cost function ($C_{\max}^{Dist}$) as follows:

$$C_{\max}^{Dist} = \underset{u \in S}{Max}\,(d(rp, u)) \tag{2}$$

The maximum diameter cost function ($C_{\max}^{Diam}$) is the sum of the first two longest distances to a C-RP "rp".

$$C_{\max}^{Diam} = \underset{u \in S}{Max}\,(d(rp, u) + \underset{\substack{v \in S \\ v \neq u}}{Max}\,(d(rp, v) \tag{3}$$

The tree costs can be approximately calculated using only the information from the routing table (next hop and distance to each network node). However, to calculate the exact tree cost, information about the whole topology is required. To avoid needing such detailed information, the authors in [7] have proposed another cost function called estimated tree cost using only the distance to each node. This function is calculated by taking the average of the maximum and minimum possible cost of the tree with root at each RP-candidate. The maximum possible tree cost ($C_{\max}^{Estm}$) denotes a distribution tree with a separate path for each member. Then the minimum possible tree cost ($C_{\min}^{Estm}$) refers to a linear distribution tree (chain as possible). In other words, the maximum possible tree cost is the sum of all the shortest paths between C-RP and receivers. However, the maximum number of separate paths with root at a node is equal to its degree. Therefore, if the multicast group size is larger than the C-RP degree, the difference between the group size and the C-RP degree will be subtracted from the maximum possible tree cost. On the other hand, the minimum possible tree cost considers that all multicast receivers are placed on one path (linear tree). However, if more than one receiver has the same distance to a C-RP, the linear tree (or the chain) will branch in the node before this distance. Therefore, the minimum possible tree cost is the sum of the maximum distance and the number of duplicate distance receivers.

Let S be the set of multicast group members, rp be the current RP-candidate and d(a,b) be the distance (number of hops) from node “a” to node “b”. We can then define the estimated cost for a given set S and RP-candidate rp as follows.

$$C^{Estm} = \frac{C_{min}^{Estm} + C_{max}^{Estm}}{2} \quad (4)$$

where

$$C_{min}^{Estm} = \underset{u \in S}{Max}\ d(rp,u) + dupl(S),$$

dupl(S) is the number of duplicate distance node in S, and

$$C_{max}^{Estm} = \begin{cases} \sum_{u \in S} d(rp,u) & \text{if } |S| \le \text{degree } (rp) \\ \sum_{u \in S} d(rp,u) - |S| + \text{degree } (rp) & \text{otherwise} \end{cases} \quad (5)$$

Let us give the example network topology presented in Fig. 1 with a multicast source at node “a” (TX) and a multicast group of receivers at node “k” (RX1), “m” (RX2) and “n” (RX3). By using the Eq. (4), we can calculate the estimated cost of the distribution tree with root at node “f” and d(S)={d(f,k), d(f,m), d(f,n)}= {2, 2, 2} as follows:

$$C_{min}^{Estm} = 4 \; ; C_{max}^{Estm} = 6 \quad (6)$$

Thus, the estimated cost:

$$C^{Estm} = \frac{4+6}{2} = 5 \quad (7)$$

The real shared tree with root at node “f” is shown in Fig. 2, where its real cost is equal to 4.

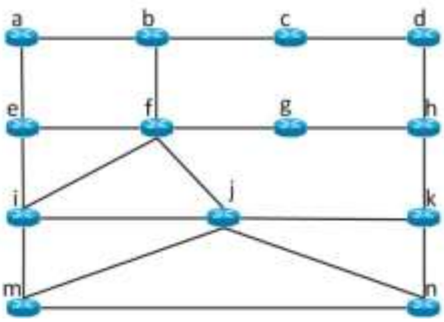

Fig. 1. Example network topology.

Our improvement consists in using the information of the distance as well as the next hop towards each receiver deducted from the routing table to calculate the minimum and maximum tree cost. The usage of the information about next hops allows us to define a set “N” to be the neighbors of rp in its distribution tree. Using Eq. (4), we can derive the minimum and maximum possible cost of the tree with root at rp. In this case, the minimum possible tree cost is the sum of the number of nodes in N which represents the set of the next hop nodes of rpplus the sum of each minimum possible tree cost of each node of N and its set S_n, where S_n is the set of multicast group receivers whose next hop towards the rp (i.e. the downstream node from rp to these receivers) is $n \in N$. In other words, we consider each neighbor as a fictive RP with its sub-set S_N of receivers’ v. In contrast to Eq. (4), the maximum possible tree cost has only one case because of using the next hop. In this case, the maximum tree cost tree can be calculated by subtracting the number of nodes in S from the sum of the number of nodes in N and the sum of the receiver distances. The minimum and maximum estimated tree cost (C_{min}^{E-Estm}, C_{max}^{E-Estm}) used the next hop can be given as follows:

$$C^{E-Estm} = \frac{C_{min}^{E-Estm} + C_{max}^{E-Estm}}{2} \quad (8)$$

where

$$C_{min}^{E-Estm} = \left[\sum_{n \in N} \underset{v \in S_n}{Max} \; d(n,v) + dupl(S_n) \right] + |N| . \quad (9)$$

Here dupl(S_n) is the number of duplicate distance node in S_n, and

$$C_{max}^{E-Estm} = \left[\sum_{u \in S} d(rp,u) \right] - |S| + |N| \quad (10)$$

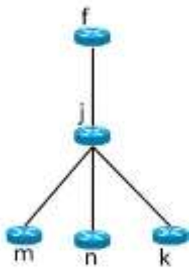

Fig. 2. Real shared tree rooted by node "f".

Similarly, we can calculate the estimated tree cost with root at node "f", N={j}and d(S_n)={d(j,k), d(j,m), d(j,n)}= {1, 1, 1} using Eq. (2).

$$C_{min}^{E-Estm} = 4 ; C_{max}^{E-Estm} = 4 \quad (11)$$

Thus, the enhanced estimated cost is

$$C^{E-Estm} = \frac{4+4}{2} = 4 \quad (12)$$

RP Position Search Algorithms:

In this paper we use three search algorithms: Longest Path (LP), All Paths (AP) and All Members (AM) proposed in [12]. We compare them with the Hill-Climbing (HC) algorithm proposed in [7]. These algorithms can be grouped into two classes according to their search method: distributed algorithms and centralized algorithms. In the case of centralized algorithms, the current RP collects information about the active multicast group (its members and their routing table) via a join/leave process. It then calculates the RP-selection function for each node in its routing table or for a set of C-RPs. That is, the current RP is responsible for the search as well as calculation process. On the other hand, each C-RP calculates its RP-selection function and informs the current RP about its own calculated tree cost in the distributed algorithms. Therefore, the current RP has to send information about the multicast group to each C-RP first. After the current RP is aware of all C-RPs tree costs, it calculates its own tree cost and selects the C-RP with the minimum tree cost to be the new RP.

A. Hill-Climbing Algorithm (HC)

At first, we assume that the distribution tree is created for a given multicast source and receivers. If the multicast group has changed, the current RP will start a so-called probing process. In this process, the current RP is defined as a probing node and it calculates the tree cost with root at itself using one of the RP-selection methods explained above. Then, it sends a query message with the member list to its neighbors and waits for their reply. Each node which receives a query message calculates the tree cost with a root at itself using the same RP-selection method and replies the probing node with its own tree cost. The node with the best tree cost will start a new probing process and queries its neighbors to find the next best node. This process continues until we get a probing node with minimum tree cost compared to its neighbors.

B. Longest Path algorithm (LP)

In the longest path algorithm, all nodes of the longest path between the current RP and the group members are selected as RP-candidates. This algorithm starts when the current RP sends a query message with the member list through the longest path and ends when the current RP receives a reply message. If the current RP receives a reply message, it defines the new RP according to the tree cost received by reply message. The current distribution tree will not change, if the current RP cost is the minimum.

C. All Paths algorithm (AP)

In contrast to the Longest Path algorithm, All Paths algorithm selects all the nodes of the distribution tree as RP-candidates. Therefore, the current RP multicasts the distribution tree with a query message; and it waits for a reply from each downstream node of the distribution tree.

D. All Members algorithm (AM)

In the case of All Members algorithm, the search space (C-RP list) is composed of all network nodes in the routing table of the current RP. In contrast to the above described algorithms, this algorithm can be classified as a centralized search algorithm, where the calculation process is done by the current RP. The current RP obtains the required information through the join/prune messages used by the group receivers for joining/leaving the multicast group. The information about the distance between C-RP and group receivers as well as the next hop towards the C-RP will be obtained from each receiver's routing table. Therefore, the calculation of the RP-selection method takes into consideration the reverse path by building the distribution tree.

This capability of calculating the distribution tree cost with root at a C-RP using the reverse path from multicast receivers to the C-RP enhances the estimated process. Because of that, Eq. (2) has to be modified. In Eq. (2), the estimated tree cost is the sum of the distribution trees with root at each next hop plus the number of the next hops. However, in the centralized case, we calculate the cost of the distribution tree which consists of the C-RP as a root and the uplink hops as receivers. The estimated maximum tree cost will be then the cost of that distribution tree plus the number of the multicast receivers.

The mathematical model of the enhanced estimated tree cost can be represented for a given set of multicast receivers "S" and C-RP "rp" via Eq. (2), where

$$C_{\min}^{E-Estm} = \underset{u \in S}{Max}\,(d(n,u)) + dupl(S) + dupl(U)$$

Here U is the uplink hops set of S, and dupl(S) and dupl.(U) are the numbers of duplicate distance nodes in S and U, respectively.

$$C_{\max}^{E-Estm} = \left\lceil \sum_{u \in U} d(rp, u) \right\rceil + |S| \quad (13)$$

Performance Evaluation:

A. Comparison scenario

The four mentioned RP-selection methods (maximal distance, average distance, maximal diameter and ETC) are implemented and compared to the Real Tree Cost (RTC), which calculates the exact tree cost. The Floyd algorithm [6] is used to find the shortest path between each pair of nodes. Therefore, the routing information that results from the Floyd algorithm is used to construct the shared tree with root at each candidate RP, which in turn is used to calculate the investigated RP-selection method. Two network topologies with 50 nodes and 100 links (network A proposed in [12]) as well as 80 nodes and 160 links (network B) are used for this comparison and also used to study the proposed algorithms. The topologies are created by the network generator (BRITE) [13]. This scenario is repeated 1000 times, in which each node of the network is selected as a source for a multicast group. The receivers of every multicast group are randomly selected using a uniform random number generator. After selecting a random multicast group, each node of the network is chosen as a candidate RP, and calculates its cost in terms of the investigated RP-selection methods. The node with the minimum cost is then chosen as the optimal RP. After that the real tree cost of each optimal RP is calculated. The effect of these RP-selection methods is investigated for different multicast group sizes (NG) between 10% and 90% of the network size (N) ($NG \in [0.1, 0.9]$ N).

B. Comparison Results

Two evaluation parameters are used to investigate the effect of the above described RP-selection methods. The average tree cost for both network topologies is presented in Figs 3 and 4. From these results, we see that the average tree cost of the maximum diameter (MDM) is similar to the average tree cost of the maximum distance (MD) with a slight decrease when multicast group size is small. This is because both functions try to minimize the maximum distance of the distribution tree. The same can be seen by comparing the average distance (AD) and ETC functions. While the AD function minimizes the average of all distances to the receivers, the ETC function minimizes the number of used resources in the estimated distribution tree.

The ETC function shows the lowest variation from the real tree cost for small multicast group sizes. However, the effect of using ETC becomes similar to the other investigated RP-selection methods when multicast group size is large. As described previously, the estimated tree cost is calculated by taking the average of the maximum and minimum possible tree cost. The maximum possible tree cost increases with increasing the number of multicast receivers, which in turn increases the difference between the estimated and real tree costs. An optimal RP that results from the AD function is a node with a minimum average distance to the active receivers. However, the distribution tree rooted by this RP may be not the optimum tree in terms of minimum resources. This explains the difference of tree cost between the AD and RTC functions.

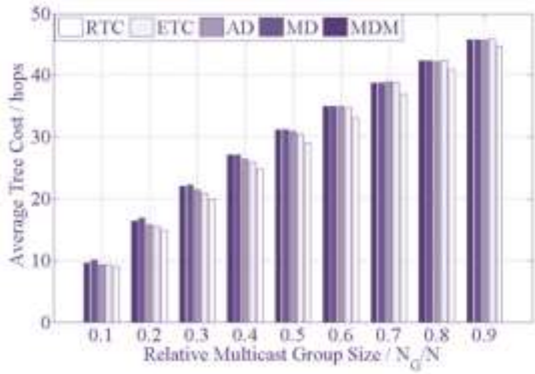

Fig. 3.Comparison of the RP-selection methods for network A in terms of average tree cost.

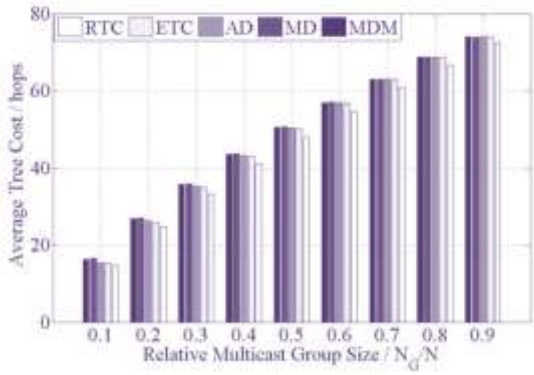

Fig. 4. Comparison of the RP-selection methods for network B in terms of average tree cost.

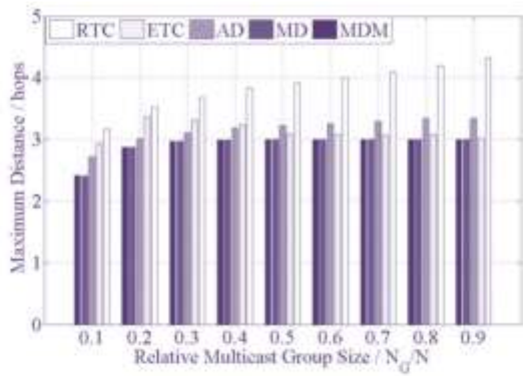

Fig. 5.Comparison of the RP-selection methods for network A in terms of maximum distance.

Figures 5 and 6 present the effect of the investigated RP-selection methods on the average value of the maximum distance gained from the calculation scenario for both network topologies. The RTC function minimizes the number of used resources in the distribution tree without taking the maximum distance into account. This may explain the high value of the average maximum distance when the RTC function is used. Because the MDM function aims to minimize the diameter of the distribution tree, it performs similar to the MD function.

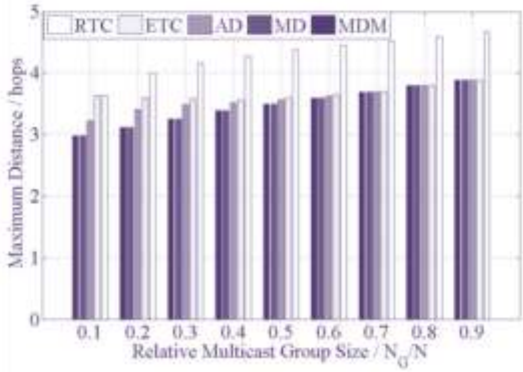

Fig. 6.Comparison of the RP-selection methods for network A in terms of maximum distance.

As mentioned above, the investigated RP-selection methods except RTC have the same effect on the average tree cost for large multicast group sizes. Therefore, they also have the same average maximum distance when multicast group size is large. The AD function minimizes the average distance to receivers. In this scenario, the first node with minimum average distance is chosen as an optimal RP without tacking the maximum distance into account. Therefore, results of the AD function depend on the first minimum average distance, which in turn depend on the network topology. This can explain the difference between the results from network A and B, presented in Fig. 5 and Fig. 6, respectively.

From this comparison, we can see that the ETC function has a small variation from the real tree cost with an acceptable maximum distance in comparison with the other RP-selection methods. Therefore, the ETC function will be used in our simulation scenarios in order to evaluate the EETC function and the search algorithms proposed in this paper.

C. Simulation Scenario

The algorithms described in this chapter are studied using NS-2 [14]. NS-2 offers a module for PIM-SM with static RP-selection and without switching mechanism. That is, the RP is selected at the beginning of the simulation and it does not change during the simulation. Furthermore, this module has the capability to construct and maintain a shared distribution tree rooted by a predefined static RP. Two network topologies (network A and B) are also used for this simulation. We simulate dynamic multicast groups with single source. Each node of this topology is chosen as a multicast source. For each source we simulate 10 runs, in which each group member will randomly join and leave the multicast group10 times. This results in 500 simulation runs (10*50) for the 50 nodes network topology, and 800 simulation runs (10x80) for the 80 node network topology for each multicast group size. We study the behavior of the investigated algorithms for different group sizes (N_G=a.N, where a=0.1, 0.2,… , 0.9).

D. Simulation Results

In the following, the simulation results of both network topologies will be presented and discussed. We compare the RP position search algorithms proposed for the PIM-SM protocol. We use the same performance criteria proposed in [12] for our comparison: network load (ρ) and reaction time (TRT), are evaluated. The network load is consists of the load from the data packets (ρ_d) as well as control packets (ρ_c). Two RP-selection methods (estimated tree cost and enhanced estimated tree cost) are used for this comparison.

Confidence intervals for a 95% confidence level are used throughout to show the accuracy of the mean values. Note that the confidence intervals of some results are too small to be visible.

2. Network Load Ratio (RNL)

The RNL is the relative difference of the network load (ρ) between the PIM-SM model without and with relocation algorithm. Eq. (14) describes this parameter:

$$R_{NL} = \frac{\rho_d^{Orig_{wsw}} - \{\rho_d^{AM} \mid \rho_d^{AP} \mid \rho_d^{LP} \mid \rho_d^{HC}\}}{\rho_d^{Orig_{wsw}}} \quad (14)$$

where $\rho_d^{Orig_{wsw}}$, ρ_d^{AM}, ρ_d^{AP}, ρ_d^{LP}, and ρ_d^{HC} are the data traffic loads caused by using the investigated algorithms for the reference PIM-SM model and the PIM-SM model using the All Members, All Paths, Longest Path and Hill-Climbing algorithms, respectively. So RNL is positive in case of a reduction.

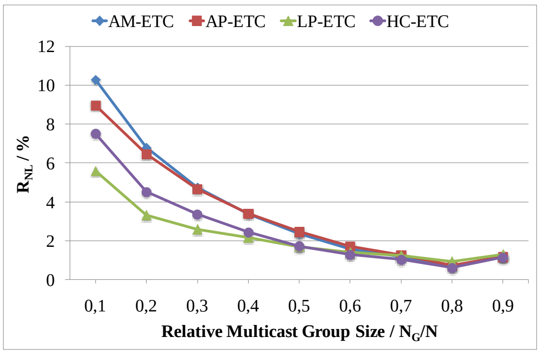

Fig. 7. Network load ratio of network A using estimated tree cost function.

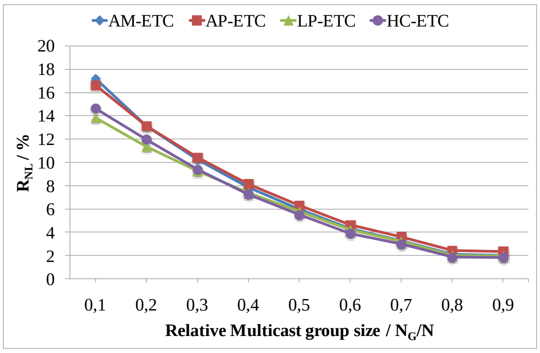

Fig. 8. Network load ratio of network B using estimated tree cost function.

Figure 7 shows the network load ratio as a function of the multicast group size by using the Estimated Tree Cost (ETC) as an RP-selection method, whereas Fig. 9 presents the data load ratio using the Enhanced Estimated Tree Cost (EETC). These results are gained for network A. The results of network B are presented in Fig. 8 and Fig. 10.

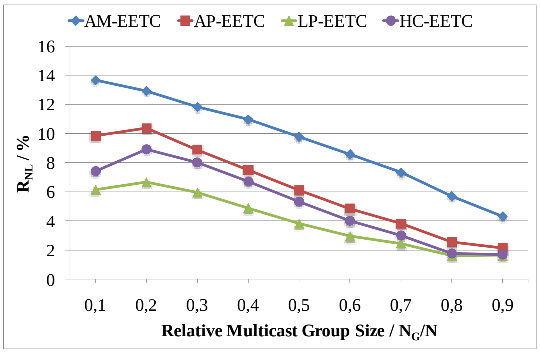

Fig. 9. Network load ratio of network A using enhanced estimated tree cost function.

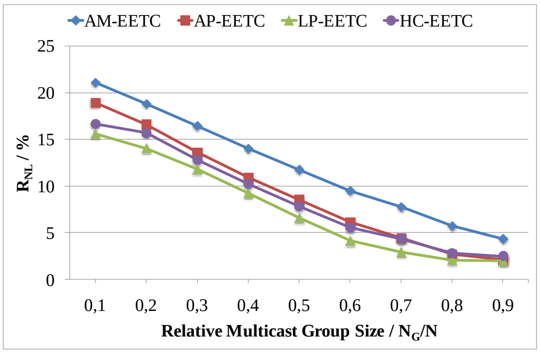

Fig. 10. Network load ratio of network B using enhanced estimated tree cost function.

We see that the enhanced estimated tree cost performs better than the estimated tree cost especially in the case of the All Members (AM) algorithm. This is because the estimated tree cost method uses only the distance to the receivers, which results in a larger deviation from the real tree cost than when we use the enhanced estimated tree cost. Figures 8 and 9 show that if the relative multicast group size (NG) is larger than 30% for network A and 20% for network B the AP algorithm performs similar to the AM algorithm. This is because the search space of the AP algorithm depends on the multicast distribution tree size. In other words, each node of the current distribution tree is used as a candidate RP in the AP algorithm. Therefore, the probability of finding the optimal RP in the current distribution tree by using the estimated tree cost function is very high when the number of receivers in the multicast group increases. Furthermore, a C-RP with an optimal estimated tree cost can be found, but it may be not the optimum RP because of the deviation from the real tree cost when the estimated method is used.

The longest path (LP) algorithm has the lowest improvement because of its small search space (it contains only the nodes of the longest path). The HC algorithm stops the searching process when it finds a local optimum RP position. Therefore, the improvement of the network load of the HC algorithm falls between AP's and LP's network load improvements.

The AM algorithm calculates the estimated tree cost reversely using the routing information received from each receiver through the joining process. Therefore, its deviation from the real tree cost resulting from using the enhanced estimated tree cost method is smaller than the other investigated algorithms. This increases the probability of finding the optimum position of the RP. The improvement of the network load resulting from network B is better than this of network A (14% from network A and 21% from network B). This is because network B contains more nodes with high degree (large number of neighbors), which are distributed over the network.

3. Control Load

The Control Load (ρc) gives the network load introduced by the multicast control messages. It is defined as a total number of control packets flowing in the network divided by the simulation time. The control throughput of the $Orig_{WSW}$ is nearly constant for all group sizes, whereas the control throughput of AM, AP, LP and HC algorithms depends strongly on the receiver life time as well as on the frequent changing the multicast group [12]. In our simulation, the average of receiver life time is about 225 seconds. Furthermore, 500 group changes for network A and 800 group changes for network B are simulated in approximately 22500 seconds in the case of NG = 0.1N and approximately 2500 seconds for NG = 0.9N. Obviously, the effect of the load of the new control messages, which are resulting from the investigated algorithms, decreases with the increase of the average lifetime of the receivers and the decrease of the group changing frequency. The results from Figs 11 and 13 present the control load using estimated tree cost and enhanced estimated tree cost for network A. The same results are presented in Figs 12 and 14 for network B.

We see that the control load caused by using the AP algorithm is the highest in both topologies because of flooding the distribution tree with request and reply messages which are needed to calculate the tree cost for each node of the distribution tree. Because the LP algorithm uses only the nodes of the longest path as candidate RPs, the increase of the control load is fairly low.

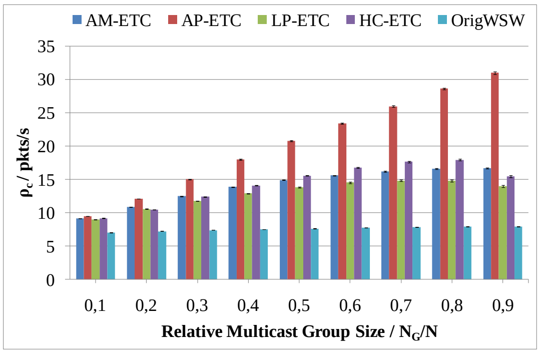

Fig. 11. Control load of network A using estimated tree cost function.

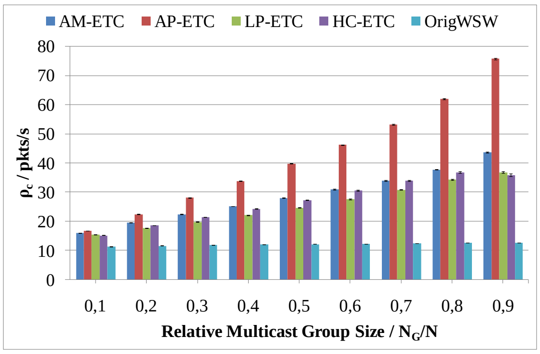

Fig. 12. Control load of network B using estimated tree cost function.

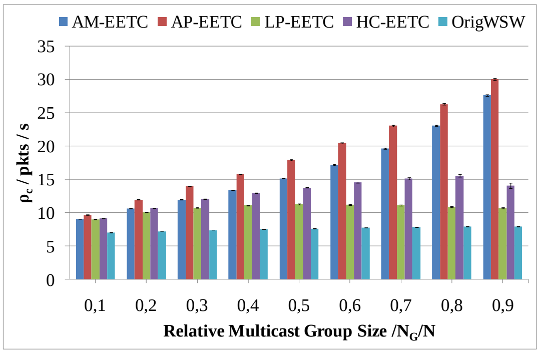

Fig. 13. Control load of network A using enhanced estimated tree cost function.

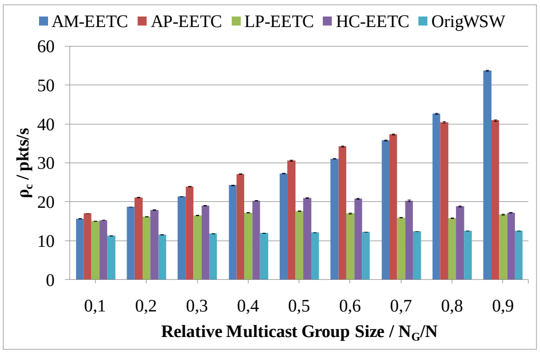

Fig. 14. Control load of network B using enhanced estimated tree cost function.

The average control load of the AP algorithm presented in Fig. 14 is smaller than the result of the AM algorithm when the multicast group sizes are larger than NG = 0.8N. The AP algorithm rarely finds a new RP when the enhanced estimated tree cost method is used. Therefore, the control load resulting from the advertisement of a new RP to all network nodes is very small in this case. Furthermore, the number of query and reply messages resulting from the searching process is smaller than the number of the control packets used in the advertisement process. This is because each node broadcasts the address of the new RP to all its neighbors when it receives this address for the first time. This leads that the address of a new RP will be received several times by each node. Thus, the load resulting from the RP advertisement process increases with increasing the network size. On the other hand, query and reply messages are sent over the current distribution tree. This means that each node of the current distribution tree receives only one query and reply message.

4. Reaction Time

The reaction time (TRT) can be subdivided into two main parts: searching time and new RP advertisement time. The searching time ends as soon as the found new RP receives a control message from the old RP. The advertisement time is the time that is needed to deliver the new RP address to each node.

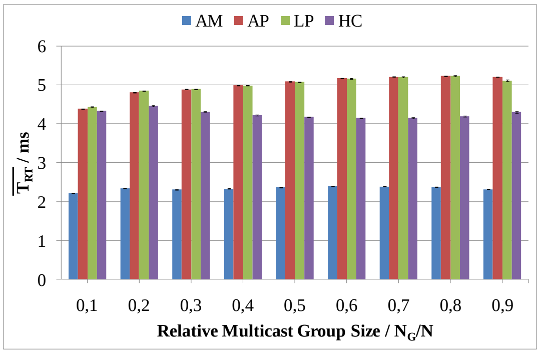

Fig. 15. Average reaction time of network A

.

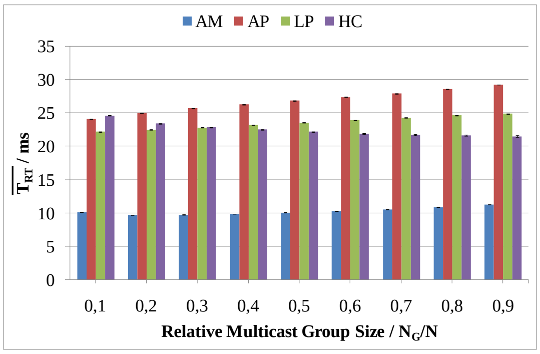

Fig. 16. Average reaction time of network B.

Results in Figs 15 and 16 show that the multicast group size does not have a large effect on the reaction time. This is because the advertisement time is independent of the multicast group size. Furthermore, the longest path of the current distribution tree and its RP position play a major role in the search time calculation. The longest path of the current multicast distribution tree, resulted from small multicast group sizes, is often shorter than in the case of large multicast group sizes. Therefore, the reaction time of AP and LP algorithms is shorter in the case of small group sizes ($NG \in [0.1, 0.3]$ N) than in the large group sizes case. On the contrary, the search space of HC algorithm is variable and depends on current RP as well as on new RP position. In the case of small group sizes, the new RP position will be strongly changed depending on the current position of multicast receivers. It results in an increasing distance between current and new RP compared to the large multicast group sizes. Because of that, the reaction time of HC algorithm in small group sizes is longer than in large group sizes.

Conclusions:

This work describes the effects of using different RP-selection methods as well as RP relocation algorithms on the network load in different multicast network topologies. The data throughput ratio shows clearly that the RP-selection method plays a major role; especially for the AM algorithm. However, the control load depends on the receiver life time and the frequencies of group changes. In the results of the network load, we can see that the improvement descends with increasing number of multicast members. On the other hand, the improvement increases with the increase of the size of the network topology. While the position of the best RP in small multicast groups can be heavily changed, the improvement resulted from the dynamic RP relocation is nearly low in the case of larger members. This is because the static RP of the $Orig_{WSW}$ is chosen as the best RP when all the network nodes are members. The problem of the increasing control load by using the dynamic relocation algorithms can be neglected in the case of long member life time, which results in reducing the group changing frequency.

References:

1. Wei, L., Estrin, D. A Comparison Of Multicast Trees And Algorithms. Technical Report Usc-Cs-93-560, 1994.
2. Williamson, B. Developing Ip Multicast Networks, Volume I. Cisco Press, 1999.
3. Waitzman, D., Partridge, C., Deering, S. Distance Vector Multicast Routing Protocol. Rfc1075, 1988.
4. Fenner, B., Handley, M., Holbrook, H., Kouvelas, I. Protocol Independent Multicast - Sparse Mode (Pim-Sm): Protocol Specification. Rfc4601, 2006.
5. Filali, F., Dabbous, W. A Qos-Aware Switching Mechanism Between The Two Modes Of Pim-Sm Multicast Routing Protocol. In Proceedings Of Itc15 Specialist Seminar, Wuerzburg (Germany), 2002.
6. Grama, A., Gupta, A., Karypis, G., Kumar, V. Introduction To Parallel Computing. Addison Wesley, 2003.
7. Thaler, D. G., Ravishankar, C. V. Distributed Center-Location Algorithms. Ieee Journal On Selected Areas In Communications, 1997, Vol. 15, No. 3, P. 291-303.
8. Lin, Y. D., Hsu, N. B., Pan, C. J. Extension Of Rp Relocation To Pim-Sm Multicast Routing. In Proceedings Of Icc 2001, Vol. 1, 2001, P. 234-238.
9. Mukherjee, R., Atwood, W. Rendezvous Point Relocation In Protocol Independent Multicast-Sparse Mode. Telecommunication Systems, 2003, Vol. 24, No. 2-4, P. 207–220.
10. Grama, A., Gupta, A., Karypis, G., Kumar, V. Introduction To Parallel Computing. Addison Wesley, 2003.
11. Calvert, K. L., Zegura, E. W., Donahoo, M. L. Core Selection Methods For Multicast Routing. In Proceedings Of Icccn’95, 1995, P. 638-642.
12. Sulaiman, S., Haidine, A., Lehnert, R. Performance Evaluation Of Center Search Algorithms Used For Dynamic Rendezvous Point Relocation. In Proceedings Of Icumt 2009, St.-Petersburg (Russia), 2009, P. 1-8.
13. Medina, A., Lakhina, A., Matta, I., Byers, J. Brite: Universal Topology Generation From A User’s Perspective. Boston University, 2001.

Url Http://Www.Cs.Bu.Edu/Brite/Publications/Usermanual.Pdf.

14. Fall, K., Varadhan, K. The Ns Manual. The Vint Project, 2011.

Url Http://Www.Isi.Edu/Nsnam/Ns/Doc/Ns_Doc.Pdf.