# Tree Construction Strategies for Survivable Overlay Multicasting in Dual Homing Networks

Wojciech Kmiecik, Krzysztof Walkowiak
Department of Systems and Computer Networks,
Wroclaw University of Technology,
Wroclaw, Poland
E-mail: wojciech.kmiecik@pwr.wroc.pl, krzysztof.walkowiak@pwr.wroc.pl

*Abstract*— **Due to the growing demand for high definition music and video content, an overlay multicasting providing live streaming services has been gaining popularity over last years. In this paper, we focus on applying the overlay multicasting for delivering of critical data that require to be transmitted safely, intact and with as little delay as possible, e.g., financial data, software security patches, antivirus signature database updates etc. To improve survivability of the overlay multicasting, we propose to use dual homing approach, i.e., each peer is connected to the overlay by two separate access links. We introduce several tree construction strategies and conduct simulation experiments to investigate problem of providing survivability to both static and dynamic types of network. Our studies demonstrate that the additional survivability requirements do not have a significant impact on the overlay multicasting system expressed as the streaming cost.**

***Keywords-overlay multicasting; survivability; dual homing; simulation; tree construction.***

## I. INTRODUCTION

Nowadays, we are observing a rapid growth in the popularity of multimedia streaming in the Internet. To emphasize the growing popularity of various video streaming services, we need to quote [1], where the authors claim that Video on Demand traffic will triple and Internet TV will increase 17 times by 2015. The total share of all forms of video (already mentioned) and P2P will grow continuously to be approximately 90 percent of all global consumer traffic in the next three years. Services such as internet radio, high definition video or audio streaming are very useful for network users, but often require a lot of bandwidth, which can be costly [1]. To reduce maintenance and investment cost, the concept of overlay multicasting is applied. An overlay multicasting technology is based on a multicast delivery tree consisting of peers (end hosts). Content transmitted by the overlay multicasting can be either streaming content with additional requirements like bit rate etc. [3], or data files. In many related works, the authors assume that users of a multicast network can leave the system. That kind of overlay network is called *dynamic* or *evolving* [4]. Among examples of such a system are popular protocols like Torrent [5], eDonkey [6] or Skype [7]. Another network type is so-called a *static* network, where hosts form static structure and are not allowed to leave the system, and which well-known examples are:

- Content delivery network (CDN), e.g., Akamai Technologies,
- Set-top box (STB) technology used in IPTV,
- Critical information streaming, e.g., hurricane warnings.

In our work, we apply the overlay multicasting in a dual homing architecture to improve network survivability, defined as the ability to provide the continuous service in the presence of failures. The dual homing approach assumes that all hosts (*nodes*) have two disjoint links (*homes*) to the network. Those links provide the network protection because of redundancy. The main contribution of the paper consists of: (i) a formulation of new strategies of creating link disjoint multicast trees in survivable overlay networks with optimization of cost and number of tree levels; (ii) a new modular simulator for testing introduced strategies in both static and dynamic networks; (iii) numerical experiments based on proposed tree construction strategies showing comparative results and other characteristics of the proposed concepts. Note that the concept of overlay multicasting protection by dual homing has been introduced in our recent papers [8],[9],[10] in the context of both streaming cost and maximum delay objective functions.

The rest of this paper is organized in the following way. In Section 2, we present previous research on overlay multicasting and dual homing multicasting with a special focus on survivability and simulation. Section 3 introduces the concept of survivable overlay P multicasting based on the dual homing method. In Section 4, we formulate tree construction strategies for the survivable (link disjoint) dual homing overlay multicast. Section 5 includes description of the overlay simulator. In Section 6, we present and discuss the results of our experiments. Finally, the last section concludes this work.

## II. RELATED WORKS

In this section, we present previous papers related to dual homing and overlay multicasting. Dual homing is a subject of several articles. Jianping *et al*. [11] created the multicast protection scheme based on a dual homing architecture where each destination host is connected to two edge routers. Under such an architecture, the two paths from the source of the multicast session to the two edge routers provide protection for the traffic from the source to the destination.

In [12], a novel homing scheme called *dual homing with shared backup router resources (SBRR)* is introduced. The authors claim that their approach leads to savings up to 40% of the cost of traditional dual homing architecture. New ILP model for joint optimization of dedicated working and shared backup paths of anycast and unicast demands is introduced and is followed by extensive simulation research.

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Another field of application for dual homing technology is Self-healing ring networks [13][14], where new network design methods and routing algorithms are designed and developed. An integer programming formulation and the NP-completeness of the problem is presented.

In [15], Jianping *et al*. introduce a concept of partial protection for the multicast dual homing network and a new algorithm *PAS* for finding the best partial multicast protection tree is proposed. The authors claim that simulation results show that the PAS algorithm achieves performance very close to the computed lower bounds.

Wang *et al*. [16] studied IP-over-WDM network survivability with a dual homing infrastructure. The paper focuses on a problem of adding survivability to IP WDM multicasting networks for both static and dynamic traffic. The authors created and evaluated coordinated protection design.

A scalable multicast protection scheme based on the dual homing architecture was introduced in [17]. The solution proposed by Wang *et al*. can be used to choose dynamically two edge routers for a multicast host.

Thulasiraman *et al*. [18] addressed disjoint multipath routing in the dual homing network problem. An algorithm for constructing colored trees in dual-homing using colored trees is proposed.

Overlay multicast (application-layer multicast) [19], [20] is a technology, which uses the overlay network topology, that enables multicast functionality for end hosts instead of routers. The authors propose a proactive tree recovery mechanism to make the overlay multicast resilient to peer failures. Simulations are used to prove that the proactive method can recover from node failures much faster than reactive methods.

A P2P (Peer-to-Peer) simulators survey is presented in [21]. Naicken *et al*. tested the most popular P2P simulators and found that they lack some of the key functionalities and conclude that because of that the majority of P2P researchers create their own simulation environment.

## III. SURVIVABILITY FOR OVERLAY MULTICASTING

Two methods are used in order to provide the network survivability: restoration and protection. The main difference between them is that restoration applies dynamic resource allocation while protection needs preallocated network resources. This results in different overall cost and restoration time. Well-known protection methods are: automatic protection switching (1+1, 1:1, etc.), p-cycles and backup paths/links. In our previous works, we proposed to use disjoint overlay multicast trees streaming the same content [8], [22]. Peers affected by the failure of one of the trees can use another tree to receive the required data in the case of a failure. This procedure guarantees very low restoration time.

In this paper, we are studying the network survivability problem for the dual homing architecture. In Fig. 1, we present a simple example to illustrate our concept.

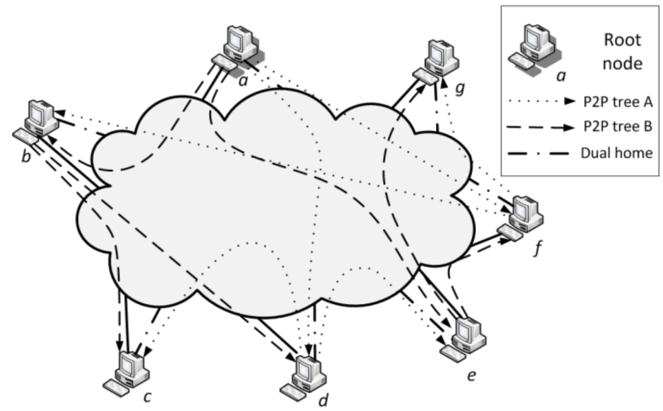


Figure 1. Simple P2P multicast scheme.

There are two disjoint multicast trees *A*, *B* that connect 7 nodes - *a*, *b*, *c*, *d*, *e*, *f*, *g*. In the case of tree *A*, nodes *a*, *d* and *f* are parents (uploading nodes), while remaining ones are leafs (nodes that are only downloading data). We use the term of *level* to describe location of nodes in the multicast tree. For example, node *a* is on level 1 of tree *B*, nodes *b* and *e* are on level 2 of tree *B* and rest of the nodes are on level 3.

The overlay multicasting is done in the application layer, i.e., end-hosts are connected using the overlay network. Connections between peers are established as unicast connection over the underlying physical layer. Each peer is connected to the overlay by an access link. We propose to use the dual homing approach to protect the system against a failure of the access link. The main idea is to create two overlay multicasting trees guaranteeing that each of access links carries traffic only of one of the trees. Since each node has two access links (dual homing), it receives the streaming data from both trees on two separate links. Thus, if one of access links is broken, the node still is connected to the stream, and moreover, it can upload the stream to subsequent peers located in the tree.

A proper configuration of the overlay multicasting with dual homing protects the network from two kinds of failure:

- Uploading node failure - failure impacts all successors of the failed peer in the tree,
- Overlay link failure - overlay link failure comprises failure of both directed links between nodes.

## IV. A DISTRIBUTED APPROACH TOWARDS CREATING OVERLAY TREES

In the overlay multicasting networks we consider, hosts connect to the system by their own. A node *v* willing to join the network contacts a host with information about the network (e.g., root node) and receives a list of possible parents already connected to the multicast tree. If it successfully connects to the system, the database of feasible parents is updated. In the other case, node *v* sends a request to the root for another set of feasible parents. Another case scenario occurs when the simulated network is dynamic, meaning that nodes already connected to the system can leave the system. *CNF* message allows all the parent nodes to have updated information about their children. When node

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$v$ is disconnecting from the network, its parent informs the root node so that it can update the peers database. All the children of node $v$ are disconnected from the network and in order to reconnect have to send the *RQT* message. It uses IP-to-Location mapping prediction method and historical connections data to gain knowledge of approximate cost of all possible connections between nodes.

In [8], in the context of streaming cost objective function, we introduced novel ILP (Integer Linear Programming) formulations of survivable overlay multicasting systems using dual homing architecture. As a natural continuation, below we introduce six tree construction strategies that include ideas related to ILP models. To formulate the problem, we use the notation as in [23]. Let indices $v,w = 1,2,\ldots,V$ denote peers – nodes of the overlay network. There are $K$ peers (clients) indexed $k = 1,2,\ldots,K$ that are not root nodes in any tree and that want to receive the data stream. Index $t = 1,2,\ldots,T$ denotes streaming trees. We assume that $T = 2$, however the model is more general and values $T > 2$ may be used. In trees, nodes are located on levels $l = 1,2,\ldots,L$. That gives us possibility to set a limit on the maximum depth of the tree. The motivation behind this additional constraint is to improve the QoS (Quality of Service) parameters of the overlay multicasting, .e.g., network reliability and transmission delay. If node $v$ is root of the tree $t$, then $r_{wt} = 1$, otherwise $r_{wt} = 0$. Constant $c_{wv}$ denotes streaming cost on an overlay link $(w,v)$, that can be interpreted as a network delay or a transmission cost.

We introduce constant $\tau(v)$, which denotes a virtual node associated with the node $v$, what follows for the dual homing Nodes $v$ and $\tau(v)$ form a *primal node*.

Every primal node has in fact four capacity parameters – constants $d_v$ and $u_v$ are respectively download and upload capacity of the one access link and constants $d_{\tau(v)}$ and $u_{\tau(v)}$ are parameters of the second (dual) access link. Additionally, to be able to simulate both static and dynamic overlay multicasting networks, we introduce two constants – $ts_v$ and $te_v$, which are respectively time when a host $v$ tries to connect and to leave the network. The objective function is overall streaming cost (cost of all multicast trees). Fig. 2 depicts an example of the dual homing modeling. Dual homes are marked with a pattern of sequential lines and dots.

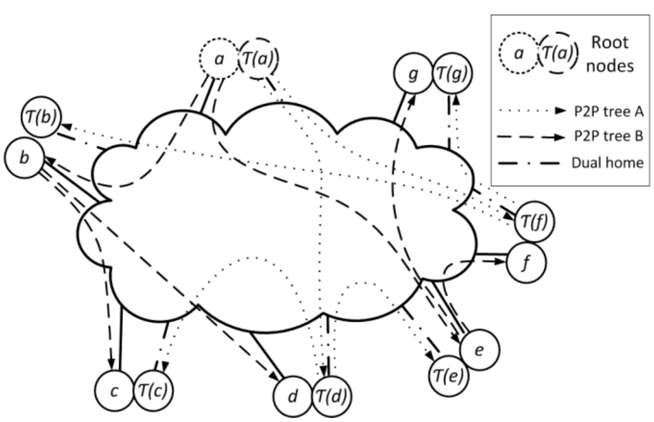


Figure 2. Modeling dual homing.

It is shown that streaming trees are using different connections to nodes.

We propose six tree construction strategies for overlay multicasting with dual homing described in details in the following section.

### *A. Tree construction strategies for overlay multicasting with Dual Homing*

In our strategies, we use specified type of messages between hosts and root node:

- RQT – message sent from a host willing to connect to the overlay network to the root node,
- LST – possible response to the RQT; list of possible parents for the requesting host (with length of 10). In the process of selecting possible parents root node is responsible of keeping multicast trees disjoint,
- DEN – possible response to the RQT message; refusal of connection when there is no feasible parent; host can try again with RQT signal,
- ATT – message sent from a host willing to connect to the network to a feasible parent with a connection request,
- PER – possible response to *ATT*; the requesting node is connected to the network,
- REF – possible response to *ATT*; the feasible parent is refusing connection, e.g., due to lack of free upload capacity,
- CON – message from a host to the root node informing about successful connection,
- DEL – message sent from the parent of a host requesting disconnection from the network to root node,
- CNF – message sent from a child to its parent every 60 seconds. If during 120 seconds the parent does not receive CNF, it sends the DEL signal.

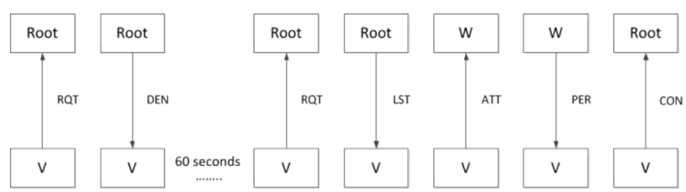


Figure 3. Example of communication process in overlay system.

In Fig. 3, we present an example of the communication in our model of the overlay system. Host $v$ is requesting a connection to the network, receives a list of possible parents, sends *ATT* message to feasible parent $w$, receives positive response *PER*, connects to parent node $w$ and sends *CON* message to the root node.

We developed the following six strategies for overlay multicasting with dual homing:

- *unprotected Cost Optimization* (*uCO*) – node $v$ willing to connect to the network sends *RQT* to the root node*,* receives a *LST* message with the sorted list of possible parents selected by minimal connection cost criterion and attempts connection to the first (the cheapest) node on the list. If the connection process is successful, node $v$

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sends a *CON* signal to the root updating information about the tree. Otherwise, the node sends *RQT* signal and receives another set of feasible parents; there is no level control; this strategy does not provide survivability because there is no requirement related to trees disjoint (nodes $v$ and $\tau(v)$ can be in the same multicast tree),

- *unprotected Cost Optimization with Levels* (*uCOL*) the aim of this strategy is to minimize the tree depth (maximum number of tree levels). For each tree, nodes requesting connection are connected to the root until free upload capacity of the root is available. When there is not enough upload capacity on the current tree level, the next level is started. Node $v$ willing to connect receives a *LST* message with the sorted (by cost) list of possible parents located only on the previous level. On each level the cheapest possible connection is selected; no survivability provided,
- *Cost Optimization* (*CO*) – analogous to *uCO*, but the root node in the process of selecting possible parents for the requesting node includes additional survivability constraints e.g., node $v$ and its *virtual node* $\tau(v)$ have to be connected to disjoint multicast trees,
- *Cost Optimization with Levels* (*COL*) – analogous to *uCOL*; survivability provided,
- *Random Selection* (*RS*) and *Random Selection with Levels* (*RSL*) – those strategies perform similar to *CO* and *COL* respectively, but parent node is picked randomly from list provided by root node (also selected by random); both strategies provide survivability through disjoint of multicast trees.

All strategies are able to connect requesting hosts for both static and dynamic networks. Note that random strategies (*RS* and *RSL*) follow from real overlay systems like BitTorrent and others [5], where peers are selected by random and the transmission cost is not taken into account. For *RSL*, *uCOL* and *COL* strategies, the main goal is to limit the number of tree levels and as a result make the tree as short as possible. The motivation is to minimize the consequences of the node failure. Differently, cost optimization strategies (*uCO* and *CO*), aim in minimizing the overall streaming cost of the network, where cost can be interpreted as a network delay, transmission cost, etc.

## V. OVERLAY SIMULATOR DESCRIPTION

After doing research on some well-known P2P simulators, i.e., p2pSim and PeerSim, we decided that it would be much more time efficient to create our own overlay simulator for dual homing architecture, than implementing this architecture and all the tree construction strategies into one of those simulators. The overlay simulator we developed is rather simple and concentrates on the process of creating trees. We believe that this approach is sufficient to examine the influence of survivability constraints on the overlay multicasting network. We focus on two criteria related to overlay multicasting: overall network cost and number of levels in multicast trees.

Let constant $LT$ denote time of life in seconds for simulating the overlay network. Starting from $z = 0$ seconds, we can distinguish two phases of this process:

- Connection phase **-** all the hosts for which $ts_v = z$ attempt to connect to the network,
- Disconnection phase – all the hosts for which $te_v = z$ disconnect from the system (only for the dynamic networks). If disconnecting node $v$ was a parent in multicast tree $t$ than root is remodeling the tree by reconnecting children of node $v$ to new parents.

After executing both phases simulator increments $z$ by 1 (second) and repeats above actions. System is working until $z = LT$.

Pouwelse *et al*. [5] and Xiaojun *et al*. [24] study global characteristics of large P2P systems and provide measurements data useful in modeling P2P networks. They focus on phenomenon called *flashcrowd* effect, where peers join the network rapidly and after reaching peak number of host in network is decreasing gradually.

In our paper, we try to model this dependency in case of dynamic type of network. We set $LT = 10800$ seconds (3 hours) and during the first hour nodes are only connecting to the network. Between the first and the second hour, new nodes are still connecting, but there are also some that are disconnecting. In the last hour, nodes are only leaving the network.

For simulating the static networks, we set $LT = 7200$ seconds and nodes are only allowed to connect to the system, i.e., nodes do not leave the system during the simulation.

## VI. RESEARCH

### A. Comparing the tree construction strategies - experiment design

To compare introduced strategies, we use our overlay simulator. We randomly generated 5 different networks, where $V = 1000, 2000, 3000, 4000, 5000$ with two disjointed trees ($T = 2$). Each network consist of either symmetric nodes (100Mbps/100Mbps - 10% of all nodes) or asymmetric nodes (1Mbps/256Kbps, 2Mbps/512Kbps, 6Mbps/512Kbps, 10/1Mbps, 20/1Mbps, 50/2Mbps, 100/4Mbps). Link costs are random values from the interval [1,100]. Overall, for both static and evolving type of network, we conducted the following three experiments and each of them was executed 50 times for different sets of $ts_v$ and $te_v$:

- comparing overall network cost and number of levels for different tree construction strategies and different network size (from 1000 to 5000 nodes),
- increasing the streaming rate $q$ from 128 Kbps to 640 Kbps and verifying its impact on the overall network cost and the number of levels for different strategies,
- based on results of previous experiments, check survivability impact on overall network size.

Additional criterion of comparison for our experiments was percentage of nodes that have not been able to connect to the network, i.e., the number of rejects.

## *B. Comparing the tree construction strategies– results*

For the purpose of the first experiment, we set streaming rate *q* to 256 Kbps and *L* value to 100. In Figs 4 and 5, we show results of tree construction strategies for different size of the network. For all strategies, the overall network cost is increasing with size of the network. In terms of the overall network cost, strategies *uCO* and *CO* prove to be most efficient.

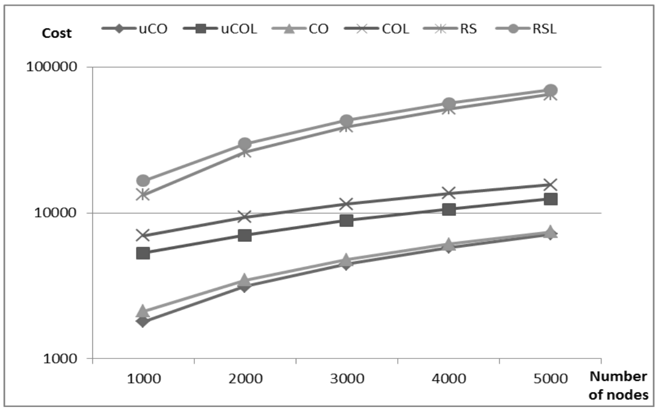


Figure 4. Streaming cost as a function of number of nodes (static).

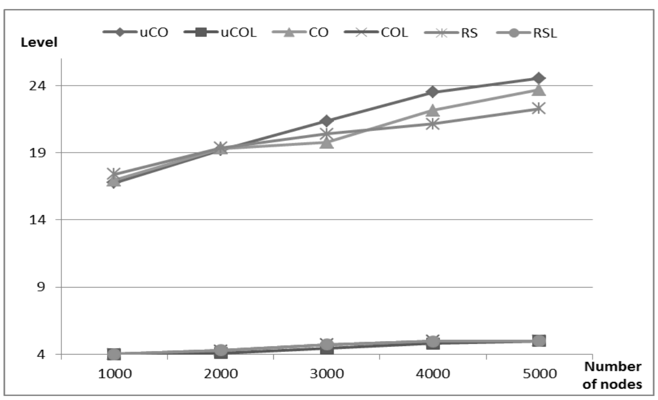


Figure 5. Number of levels as a function of size of the network (static).

*uCOL* strategy achieved lowest average number of levels in the multicast trees – 4,5. Results of strategies with survivability constraints (*COL* and *RSL*) were worse only by 2,2%. Results of the first experiment are in line with our expectations, since *uCO* and *CO* are minimizing the overall streaming cost, while *uCOL* and *COL* number of tree levels.

TABLE I. COMPARISION OF TREE CONSTRUCTION STRATEGIES FOR DYNAMIC TYPE OF NETWORK – SIZE OF THE NETWORK

| Strategy | uCO | | uCOL | | CO | | COL | | RS | | RSL | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Number of nodes | cost | level | cost | level | cost | level | cost | level | cost | level | cost | level |
| 1000 | 1361.6 | 42.9 | 11643.5 | 4.0 | 1529.9 | 41.8 | 13607.3 | 4.1 | 10934.7 | 20.0 | 19819.7 | 4.0 |
| 2000 | 2472.4 | 56.4 | 14889.3 | 4.1 | 2630.5 | 47.9 | 18678.1 | 4.5 | 21692.2 | 22.8 | 33628.7 | 4.4 |
| 3000 | 3587.7 | 68.8 | 17856.0 | 4.5 | 3760.0 | 52.0 | 23568.8 | 4.8 | 32341.2 | 23.6 | 46290.6 | 4.8 |
| 4000 | 4692.3 | 74.8 | 22861.5 | 4.8 | 4859.6 | 57.5 | 28530.8 | 5.0 | 42982.9 | 24.7 | 60022.1 | 5.0 |
| 5000 | 5814.2 | 79.0 | 29218.9 | 5.0 | 5956.6 | 62.3 | 36156.5 | 5.1 | 53602.5 | 25.3 | 74523.9 | 5.0 |

TABLE II. COMPARISION OF TREE CONSTRUCTION STRATEGIES FOR STATIC TYPE OF NETWORK – STREAMING RATE *Q*

| Strategy | uCO | | uCOL | | CO | | COL | | RS | | RSL | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| q [Kbps] | cost | level | cost | level | cost | level | cost | level | cost | level | cost | level |
| 128 | 4377.4 | 19.0 | 8508.9 | 3.0 | 4648.8 | 18.6 | 11153.1 | 3.1 | 38843.5 | 18.1 | 43005.8 | 3.1 |
| 256 | 4449.4 | 21.4 | 8898.5 | 4.4 | 4780.7 | 19.8 | 11478.5 | 4.7 | 38884.9 | 20.4 | 43061.9 | 4.7 |
| 384 | 4799.7 | 21.8 | 9226.0 | 6.2 | 5335.1 | 21.1 | 12384.6 | 6.6 | 39469.4 | 20.0 | 43542.5 | 6.6 |
| 512 | 4839.1 | 23.9 | 9259.7 | 7.5 | 5430.1 | 21.8 | 12470.4 | 7.8 | 39388.4 | 20.1 | 43710.7 | 7.9 |

In Table I, we show results of analogous experiment, but for dynamic type of the network. For each strategy and network size, we report the average cost and the average number of levels obtained in the final configuration. We can observe, that results for the dynamic case are similar to those for the static approach. Random tree construction strategies (*RS* and *RSL*) are much less efficient than *CO* and *COL* in terms of overall network cost. Surprisingly, *CO* strategy is creating trees with lower number of levels than strategy with no survivability (*uCO*). This is implied by the fact that the survivability constraints cause both multicast trees to connect the same number of nodes. For the strategies with no survivability constraints there is no such requirement, so one of the multicast trees can have more nodes than the other one and in effect have more levels.

The next goal of experiments was to verify how the overall streaming cost and number of levels are influenced by the streaming rate *q*. For this experiment, we set the level limit *L* to 100 and chose network with 3000 nodes. Table II presents results related to comparison of the introduced strategies in terms of the overall streaming cost and maximum depth (level) of the multicast trees in the static environment. In line with our expectations, both the overall streaming cost and the number of levels are increasing with streaming rate *q* for all tree constructing strategies.

For the streaming rate *q* equal to 640 Kbps, strategies with the survivability constraints were unable to connect all the requesting nodes, as shown on Fig. 6:

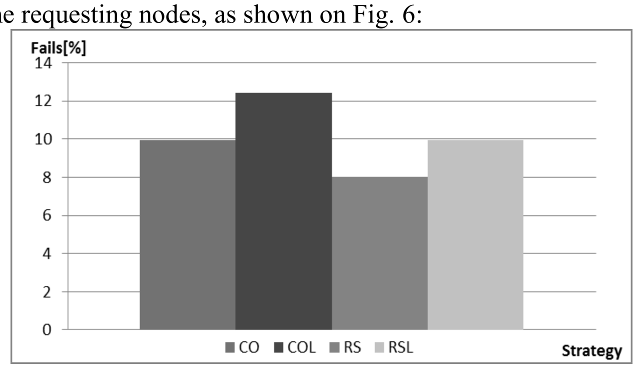


Figure 6. Percentage of not connected nodes for *q* = 640 Kbps – static network.

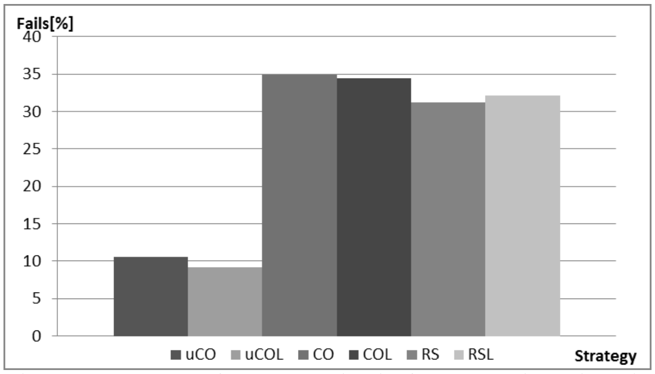


Figure 7. Percentage of not connected nodes for $q$ = 640 Kbps – dynamic network.

Results obtained for the dynamic type of network are similar to those in Table II. Figure 7 shows percentage of nodes that failed to connect to the network for streaming rate $q$ = 640 Kbps.

We can easily notice that all the strategies were unable to connect all of requesting nodes. Strategies with no survivability (*uCO* and *uCOL*) had average number of rejects of 9-10%. Adding the survivability constraint increases this parameter by 20-25%. The main conclusion is that for highly constrained networks (e.g. low $L$ limit or high $q$ value) survivability strategies may more often not be able to find any feasible solution than strategies with no survivability constraints. Those findings are in harmony with our previous conclusions [10].

In the last experiment, we tested the impact of the survivability constraints on the overall streaming cost, i.e., we compare results of *CO* against *uCO* and *COL* against *uCOL*. Results are presented in Tables III and IV. Our observations are as follows:

- The average cost (considering all experiments) of providing additional survivability was 8% for the *CO* strategy and 28% for the *COL* strategy.
- As the number of nodes grows, the gap between strategies with additional survivability requirements and normal strategies decreases. This can be explained by rapid increase in size of the solution space. As a result, it is possible to find a cost efficient solution with the survivability constraints.
- With the increase of the streaming rate $q$, the additional cost of providing survivability grows. Again, this is caused by the fact, that with increase of $q$, the solution space shrinks.

TABLE III. DIFFERENCE IN COST BETWEEN STRATEGIES WITH AND WITHOUT SURVIVABILITY [%] – SIZE OF THE NETWORK

| | Static networks | | Dynamic networks | |
|---|---|---|---|---|
| **Number of nodes** | **CO** | **COL** | **CO** | **COL** |
| **1000** | 17.8% | 31.8% | 12.4% | 16.9% |
| **2000** | 10.3% | 33.3% | 6.4% | 25.4% |
| **3000** | 7.4% | 29.0% | 4.8% | 32.0% |
| **4000** | 5.5% | 28.9% | 3.6% | 24.8% |
| **5000** | 4.1% | 25.3% | 2.4% | 23.7% |

TABLE IV. DIFFERENCE IN COST BETWEEN STRATEGIES WITH AND WITHOUT SURVIVABILITY [%] – STREAMING RATE $Q$

| | Static networks | | Dynamic networks | |
|---|---|---|---|---|
| **Streaming rate [Kbps]** | **CO** | **COL** | **CO** | **COL** |
| **128** | 6.2% | 31.1% | 4.0% | 25.9% |
| **256** | 7.4% | 29.0% | 4.8% | 32.0% |
| **384** | 11.2% | 34.2% | 7.8% | 22.9% |
| **512** | 12.2% | 34.7% | 8.9% | 22.3% |

## VII. CONCLUSION AND FUTURE WORK

In this paper, we focused on the survivable overlay multicasting systems with the dual homing architecture in both static and dynamic networks. We introduced six different tree construction strategies (of which four provide survivability constraints), along with the overlay simulator, and compare their results for different types of networks in terms of the overall streaming cost and the number of levels in the multicast trees. According to the obtained results, we can conclude that cost optimization strategies obtain results from 4 to 8 times better than random optimization strategies in respect of the streaming cost in all multicast trees. We observe that the average cost of providing survivability in all of our experiments was 8% and 28% for *CO* and *COL* strategies, respectively. Moreover, the additional cost is decreasing with the increase of the network size. We can derive that the additional constraints that allow constructing failure-disjoint trees do not influence significantly the performance of the overlay multicasting system in terms of the streaming cost.

In future work, we plan to develop additional strategies that will provide even more survivability, like node and ISP disjoint trees, and conduct more experiments evaluating these solutions.

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