Topology-based Multicast Scheduling for On-Demand Multimedia Service Provisioning

Matin Bagherpour and Øivind Kure

***Abstract*—In this paper, a dynamic scheduling scheme is proposed for delivery of on-demand multimedia contents (e.g. movies) for internet service providers (ISP) that receive requests for different available contents from the customers for near future delivery. Each ISP is interested in assigning the available resources to the requests in such a way that the delivery time remains lower than a threshold, and also the profit is maximized. Regarding the diversity of customers in terms of their willingness to pay, there exists a group of budget-constrained receivers who are ready to wait longer. Therefore, since the ISP dynamically receives the requests for future delivery, postponing transmission of videos to some customers can provide the opportunity to increase the profit by reducing cost of distribution paths via multicast cost sharing. So, it can be profitable to postpone transmitting the content for some receivers (who cannot be clustered into cost saving multicast groups in the current transmission period) in hope for receiving more requests until the next transmission period, and consequently sharing the cost with a larger number of receivers. We propose a heuristic algorithm for topology-based multicast scheduling problem to find cost efficient multicast groups in each transmission period. Performance of the proposed algorithm is evaluated and compared with a popularity-based scheduling algorithm for a wide range of parameters via extensive simulation experiments.**

***Index Terms*—Scheduling, multicast communication, video on demand (vod), cost sharing.**

I. Introduction and Related Works

Internet service providers (ISP) dynamically receive requests for their available multimedia contents (e.g. movies), possibly at different rates[1], from their customers. Regarding the growth rate of potential market for on-demand multimedia products, service providers' available capacity is not sufficient for provisioning the requested service with unicast streams. Multicasting is a cost efficient option that the service provider can use to transmit the same content batched into groups of requests via multicast trees. However, cost efficiency of multicast transmissions depends on the topological structure and also the expected lost revenue (penalty) of poor quality (late deliveries).

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1 Multi-rate transmissions can be used to allow a receiver to obtain data at a rate that satisfies its requirements [1,2].

An important feature in minimizing the communication cost of a VoD system is the topological structure of the network in which it operates. According to the huge number of customers in this network, it should be carefully designed to meet certain performance measures. Many researchers have worked on VoD network design in such a way that is capable of providing the expected service to the potential customers. In [3], the authors formulated VoD design problem as locating a given number of nodes in a network to serve a given population.

Although multicasting has been suggested as a promising technique for resource efficient transmission, lack of successful business implementations has been one of the limits to its wider use [4]. A profitable multicast business model is proposed in [4]. The authors suggest that content providers could offer delivery of specific content at certain points in time. It is inspired from the fact that the longer delivery time a customer accepts, the higher the chances that more customers sign up and that the price for the movie drops.

In [5], a priority-based scheduling scheme is proposed for VoD requests to give high-priority clients a prompt service, while still providing low-priority clients with a reasonable service. Wu *et al.* [6] proposed a scheduled video delivery system which combines requests to form the multicasting groups and schedules these groups to meet the deadline. They assume the cost of video delivery to be a linear function of the number of requests that can be combined for delivery. Kreuger and Abrahamsson [7] proposed a scheduling technique for distribution of IPTV with the network links and storage facilities as resources and the objective to balance the overall load in the network. They show that scheduling and optimization techniques can be used to make the distribution of IPTV more efficient by pushing content out to caches in the network to the right place at the right time. Yu *et al.* [8] introduce a topology-based hierarchical scheduler scheme for IPTV traffic management, which controls the incoming traffic at the edge of the network based on the network topology.

In spite of importance of network topology in reservation costs of VoD transmission, in the existing multicast grouping studies which try to maximize multicast sharing advantage, merely bandwidth consumption is considered. To the best of our knowledge, only Xie *et al.* in [9] took network topology into consideration to calculate multicast group cost. They chose minimization of lower bound of volume of the actual data transmitted for a multicast group as the optimization goal while making grouping decision. They proposed a mathematical model to find optimal patching window size which minimizes transmitted data per user.

In this paper, we formulate topology-based multicast scheduling problem, and propose a heuristic algorithm based on multicast cost sharing for delivery of multimedia content requests. We run extensive simulation experiments to examine the influence of parameters such as request rate, scheduling interval (transmission period), and billing method on performance of our scheduling algorithm in terms of provider's profit and customer satisfaction (measured by rejection rate).

The paper is organized as follows. In section II, problem statement and mathematical formulation for on-demand multimedia content transmission scheduling is presented. In section III, the proposed heuristic algorithm to solve the problem is explained. Numerical results of simulation experiments are presented in section IV. Conclusions and suggestions for future works are given in section V.

II. Problem Statement

A. Problem Definition

Providers of on-demand multimedia contents in IPTV are interested in assigning their available resources (bandwidth) to the requests in an efficient way, so that the delivery time remains lower than a threshold (maximum acceptable lead time for each receiver), and the profit (revenue collected from customers minus reservation costs and latency penalties) is maximized.

The ISP dynamically receives requests for the available multimedia contents for near future delivery. In these cases, people can plan in advance to request a content before it is actually viewed, which provides opportunities for the scheduled video delivery scheme [6]. It means that some receivers can wait longer (the less expensive service class customers). Therefore, postponing delivery of contents to some customers to the future transmission periods can provide an opportunity to increase the profit by reducing reservation costs of distribution paths through multicast cost sharing. As a result, we consider the request scheduling problem to be solved periodically (on transmission epochs) in a dynamic manner.

To formulate the problem, delivery time (quality requirement) can be considered either as a constraint that cannot be violated, or it can be incorporated in the objective function by considering a penalty for late delivered contents. Since the ISP expects to receive new requests in the future, if the maximum delivery time is not violated, it can be profitable for the ISP to postpone transmitting the content to some receivers (who cannot be clustered into cost efficient multicast groups in the current transmission period) to the next period in hope for receiving more requests and sharing the cost with a larger group [3,9].

In our model, the charge collected from receivers is inversely proportional to their acceptable waiting time. It means that the customers who are ready to wait longer will pay a discounted charge. These customers receive the service at a lower price because of their contribution to the possible multicast cost sharing advantage. While the ISP may earn less money by sending via multicast (in comparison with multiple unicast streams), it has more free resource which can be allocated to other requests to increase revenue.

B. Problem Formulation

The main purpose to solve this problem is to determine the requests to be delivered (streamed) together in each period, and their transmission route. At each transmission period, there are a number of requests for different multimedia objects which need to be decided whether to be delivered in the current period, or postponed to the future. The objective is to maximize the expected multi-period profit with assigning the requests for each object to multicast delivery groups and finding the optimal routes in such a way that cover the chosen receivers in each group. This is a dynamic decision making process. Requests for the same object could be combined into a group. A group is the basic unit for scheduling. Based on the requirements of the problem, the following assumptions are made:

1) Users submit requests with a specified start time. Incentives are provided so that users will specify the start times that reflect their real needs (not sooner or later). The price drops for the clients with a longer plan-ahead time;
2) All objects are assumed to have the same constant bit rate;
3) Information about the received requests (multimedia object ID and duration, arrival time, plan-ahead time, and allocated budget) are available real-time;
4) Each request has a maximum acceptable delivery time (based on the type of the customer as well as her allocated budget);
5) Number of channels (available capacity) is limited. Each group receives the requested object via a channel, and the channel becomes free again after that multimedia streaming is finished;
6) We assume a broadcast or a multicast scheme, so that a number of requests can be combined and delivered together;
7) All the multicast trees are routed in the same hub node (distribution center);
8) Total reservation cost equals to the summation of required capacity between the links of the minimum spanning tree connecting the hub node to the clients in the multicast group;
9) The clients are able to decode only one channel. Therefore, each group for each object has to be scheduled in one channel;
10) To guarantee the existence of feasible solutions for the problem, it is assumed that there is no multimedia object requiring bandwidth more than the minimum available capacity of transmission links. Sometimes, this assumption may not be true. However, those big contents can simply be partitioned into smaller objects in such a way that none of them is bigger than the minimum available capacity of the links. Each of these partitioned requests is considered as a single order in the scheduling system;
11) Violation of delivery time is only possible by paying a penalty to the client which is proportional to the delay;
12) In theory, the requests can be postponed for as many periods as possible, provided that the delay fine is paid. However, regarding that the penalty grows with delay, marginal improve in reservation cost of postponed requests will be compensated by high penalty

expenditures. Hence, our mathematical model is constructed for a two-period decision making process. That is the expected profit of postponing the delivery of requests for only one period is taken into account as the optimization objective. Our simulation results also verify this assumption by observing that the average delay is less than duration of a transmission period.

The scheduling problem of on-demand requests can be formulated as a profit maximizing optimization model. In this model, the most challenging part is deriving values of expected costs of future multicast groups. Therefore, in each decision epoch, the ISP chooses the requests (multicast group) to be delivered in order to maximize its expected profit (improved by multicast cost sharing) while meeting the individual customers' needs based on:

- the available capacity (bandwidth),
- required QoS (in terms of maximum delivery time), and
- forecast of future requests.

We assume that the optimal minimum cost Steiner tree, T, spanning to each arbitrary set of receivers is known in advance. For each destination, the opportunity cost of postponing its transmission to the next period must be calculated. This opportunity cost depends on the structure of the minimum Steiner tree, especially the links that are shared between the routes to several receivers. To calculate this value, the probability of future requests and maximum delivery time of current requests must be taken into account as well. Then, the output of our topology-based scheduling scheme is to modify the current multicast tree by pruning the branches connected to the receivers whose added cost is more than the expected benefit of having them in this tree. Details of this algorithm will be explained in section III.

In this problem formulation, capacity constraints, and spanning tree constraints are considered. Having such information as receivers' topological position, link prices, and promised lead times, an integer programming model is made to determine the assignment of requests to multicast trees (groups).

TABLE I: NOTATIONS: PARAMETERS AND DECISION VARIABLES

Parameter	Description
t_0	Current time;
Δt	Transmission interval;
V	Set of available multimedia objects;
N	Set of nodes in the network;
$V(t)$	Set of objects requested at time t;
$N_i(t)$	Set of receivers (nodes) for object i at time t;
t_{ij}	Deadline of object i requested by client node j;
CL_{ij}	Penalty for delay in delivering object i requested by client node j (per time unit from the deadline);
$E(V)$	Set of network links between nodes in set V;
C_{kl}	Reservation cost of link $\{k,l\}$ from set E;
$CH(t)$	Number of available channels at time t;
s	Source node;
Decision variables	
$x_{ij}(t)$	is 1 if request for object i from client node j is in the current multicast tree (time t), otherwise 0;
$y_{ikl}(t)$	is 1 if link $\{k,l\}$ from E is in the multicast tree (time t) for object i, otherwise 0;
$z_{ij}(t)$	is 1 if node $j \in N \setminus N(t)$ is included in the Steiner tree for object i requested by client node j at time t.

The problem is formulated as a mathematical programming model as follows:

$$Min\ \mathrm{EC}(\mathrm{t}_0,\Delta \mathrm{t}) = \sum_{i\in V(t_0)} \{ \sum_{j\in N_i(t_0)} \{\max\{0,(t_0-t_{ij})\}\mathrm{CL}_{\mathrm{ij}} x_{ij}(t_0)$$

$$-\max\{0,(t_0+\Delta \mathrm{t}-t_{ij})\}\mathrm{CL}_{\mathrm{ij}}(1-x_{ij}(t_0))\} + \sum_{\{k,l\}\in E(V)} C_{kl}\, y_{ikl}(t_0)\}$$

$$-\sum_{i\in V(t_0+\Delta t)} \sum_{\{k,l\}\in E(V)} C_{kl}\, y_{ikl}(t_0+\Delta t) \quad (1)$$

$$y_{ikl}(t_0) \le \max_{j\in N(t_0)}(x_{ij}(t_0)), \forall i\in V(t_0); \forall \{k,l\}\in E(V) \quad (2)$$

$$\sum_{\{s,l\}\in E(V)} y_{isl}(t_0) = \max_{j\in N(t_0)}(x_{ij}(t_0)), \forall i\in V(t_0); \quad (3)$$

$$\sum_{\{k,l\}\in E(V)} y_{ikl}(t_0) = \sum_{j\in N\setminus\{s\}} z_{ij}(t_0) + \sum_{j\in N(t_0)} x_{ij}(t_0); \forall i\in V(t_0); \quad (4)$$

$$\sum_{\{k,l\}\in E(S)} y_{ikl}(t_0) \le \sum_{j\in S\setminus\{k\}} z_{ij}(t_0) + \sum_{j\in S\setminus\{k\}} x_{ij}(t_0),$$
$$\forall S\subset N; \forall k\in S; \forall i\in V(t_0); \quad (5)$$

$$\sum_{i\in V(t_o)} \max_{j\in N(t_0)}(x_{ij}(t_0)) \le CH(t_0)\,; \quad (6)$$

$$x_{ij}(t_0) = 0,1; \forall i\in V(t_0); \forall j\in N(t_0); \quad (7)$$

$$y_{ikl}(t) = 0,1; \forall i\in V(t);$$
$$\forall \{k,l\}\in E(V); t = t_0, t_0+\Delta t; \quad (8)$$

$$z_{ij}(t_0) = 0,1; \forall i\in V\setminus V(t_0); \forall j\in N(t_0). \quad (9)$$

The model parameters and decision variables are defined in Table I.

In this model, $EC(t_0, \Delta t)$, the *expected cost* at time t_0, is approximated based on the difference between the cost of delivering the requested objects of a set of clients as multicast groups in this period (t_0) and the next period ($t_0 + \Delta t$). Since the revenue from the received requests will be achieved regardless of scheduling scheme, the objective is minimizing the cost which includes reservation cost and delay penalty. The expected cost in the current period is a function of the cost of incorporating selected client nodes in the multicast trees (reservation cost of channels), and the delay penalty (in case the deadline for delivery of an item is passed). To calculate the expected cost of the next period, set of requests in the next transmission period ($t_0 + \Delta t$) has to be predicted. Set of requests (client-object pairs) in the next period is composed of: the requests in the current period that are postponed, as well as the new requests received between t_0 and $t_0 + \Delta t$, *i.e.*:

$$if\ \exists i,j\ \ x_{ij}(t_0)=0,\ then\ i\in V(t_0+\Delta t), j\in N(t_0+\Delta t);$$

Number of requests in the next period depends on the request arrival rate for available objects from each node (client) in the network and the transmission period (Δt).

As mentioned in the assumptions, in practice a request is not supposed to be postponed for more than one period. Thus, the costs in the objective function are calculated based on a two period decision making process.

Constraints (2) guarantee that there exists a link for an object to be sent to a client only if that object is scheduled in the current transmission period. Constraints (3) satisfy that hub node s belongs to all scheduled multicast groups. Constraints (4) ensure the correct number of edges, and constraints (5) ensure that the set of chosen edges contain no cycles (generalized sub-tour elimination constraints). Constraint (6) guarantees that at each period, number of assigned channels does not exceed the available bandwidth. Amount of available bandwidth is calculated at the beginning of each period based on the status of streaming channels. Whenever delivery of an object is finished, the allocated channel for it becomes released.

III. Heuristic Scheduling Algorithm

We propose a dynamic scheduling algorithm to find the multicast groups in each period for the problem formulated in section II. That is, the algorithm is called periodically upon the event of transmission epoch. Regarding that many requests are received by the provider, the algorithm must be called frequently. So, runtime of the algorithm, as well as the quality of solutions are of great importance. To find cost efficient schedules fast enough, we use a pre-structured set of multicast trees. Hence, the algorithm has two phases: (1) Static phase: routing of arbitrary multicast groups; (2) Dynamic phase: scheduling of requests through fixed multicast trees. The steps of the algorithm are as follows:

Phase 0: Find the minimum spanning tree on the graph of all potential receivers, T_0. Each of the main paths, branched from the source node s, is considered as a *main branch*. Main branches of this tree, originating from the source node, are denoted by (B_1, …, B_m). Also, (NB_1,…, NB_m) denotes the partitioning of network nodes by the main branches, *i.e.* set NB_i contains the nodes in branch B_i of T_0.

Phase 1 (at each transmission period t, for each video object i): Find the minimum Steiner tree (T_i) spanning to all the client nodes who have requested object i. Then, specify the branches of T_i (BT_{i1},…, $BT_{im'}$). For each branch BT_{ij} of T_i characterize the node (receiver) right after the source node in the branch as $S(BT_{ij})$. Find the partition NB_k from branches of T, to which $S(BT_{ij})$ belongs.

Phase 2 (for each branch BT_{ij} of T_i): Find the opportunity profit of postponing delivery of object i to the receivers on this branch to the next period by taking into account the probability of receiving requests from receivers in NB_k during one period (Δt):

$$\begin{aligned}&Opportunity(BT_{ij},t) = Cost(BT_{ij},t+\Delta t) - Cost(BT_{ij},t)\\&= (Penalty(BT_{ij},t+\Delta t) + MST(BT_{ij},t))\\&- (Penalty(BT_{ij},t) + MST(BT_{ij}^{\Delta t},\Delta t))\end{aligned}$$

where $Opportunity(BT_{ij},t)$ is the opportunity profit of postponing delivery of branch BT_{ij} at time t, $Cost(BT_{ij},t)$ is the cost of delivery of requests in branch BT_{ij} at time t, $Penalty(BT_{ij},t)$ is the delay penalty for receivers in branch BT_{ij} at time t:

$$\sum\nolimits_{k\in BT_{ij}} \max\{0,(t-t_{ik})\}CL_{ik} ,$$

and $MST(BT_{ij},t)$ is the cost of minimum Steiner tree spanning to the clients in the branch BT_{ij} at time t. $BT_{ij}^{\Delta t}$ is the expected set of receivers in branch BT_{ij} after Δt time units. This set is found by taking into account the arrival rate of requests from clients in NB_k.

If, even with considering the penalty for delayed requests, expected profit of postponing the transmission to the receivers in BT_{ij} is still positive, prune this branch from T_i, and postpone their delivery to the next transmission period. *Assumption*: In order to calculate the opportunity cost of delivery postponement of the nodes in BT_{ij}, it is assumed that the impact of the nodes in branches other than NB_k is negligible. Effect of this assumption on the accuracy of solutions depends on the network topology and degree of nodes. Our simulation results confirm this assumption that influence of the other branches on the opportunity cost of postponement of a baranch is not significant.

Fig. 1 shows an illustrative example. The minimum spanning tree (Fig. 1.a) has two branches originated from the source: B_1 and B_2. The network is partitioned by these two branches into two groups of nodes: NB_1 = {2,4,5,8,9,10,13,14}, and NB_2 = {3,6,7,11,12}. Assuming that the service provider has received requests for object i from users located at nodes {7,8,9,13,14} at transmission epoch t_1, the minimum Steiner tree spanning to these nodes is shown in Fig. 1.b. This tree has two branches BT_{i1} and BT_{i2}, where $S(BT_{i1})$ = 2 and $S(BT_{i2})$ = 7. $S(BT_{i1})$ belongs to NB_1, and $S(BT_{i2})$ belongs to NB_2. All nodes in NB_1 are currently in BT_{i1}. Since all the potential receivers of branch B_1 are already in branch BT_{i1}, there is no benefit in postponing transmission of receivers in this branch to the next period. So, in this stage, the algorithm needs to decide about postponing delivery of object i to the receivers in BT_{i2}.

For calculating opportunity profit of postponing delivery of the current users in BT_{i2} to the next period, the probability of receiving a request from each member of NB_2 must be considered. If the provider decides to deliver the requested object i to the receivers in branch BT_{i2} in the current transmission epoch, then the expected cost of this branch is:

Cost to transmit to the receivers in BT_{i2}

+

Expected cost of transmission to the receivers in $BT_{i2}^{\Delta t}$

=

$$\begin{aligned}&MST(BT_{i2},t)) + MST(BT_{i2}^{\Delta t},\Delta t))\\&= 10 + \sum\nolimits_{b(\Delta t)\subset NB_2} P\{b(\Delta t)\}MST(b(\Delta t))\end{aligned}$$

where $P\{b(\Delta t)\}$ is the probability of receiving requests from nodes in set $b(\Delta t)$ (subset of main branch NB_2) during a transmission interval Δt (and no request from $NB_2 \setminus b(\Delta t)$). The expected reservation cost of postponing transmission of BT_{i2} can be calculated as follows:

$$MST(BT_{i2}^{\Delta t}, \Delta t))$$
$$= \sum_{b(\Delta t) \subset NB_2 \setminus BT_{i2}} P\{b(\Delta t)\} MST(BT_{i2} \cup b(\Delta t))$$

In order to decide about postponement of delivery to clients in BT_{i2}, delay costs should also be calculated for two consecutive transmission epochs. It should be noted that if in a transmission period there exists no cost effective receiver to be clustered with a client whose transmission deadline has reached, the service provider may transmit the content via a unicast stream to that receiver.

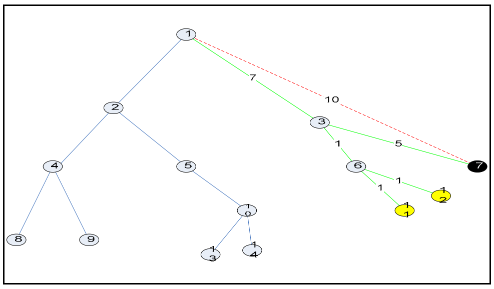

Fig. 1. a. Minimum spanning tree to all potential clients

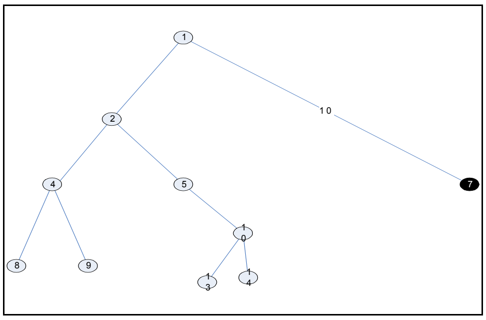

Fig. 1. b. Actual minimum Steiner tree to available clients

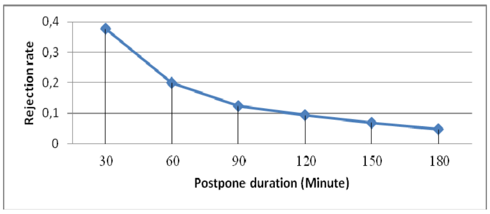

Fig. 2. Rejection rate vs. transmission interval (Number of channels = 30, Arrival rate = 5/min)

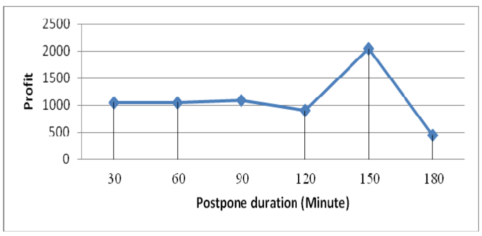

Fig. 3. Expected profit vs. transmission interval (Number of channels = 30, Arrival rate = 5/min)

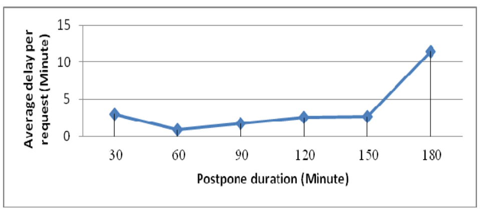

Fig. 4. Average delay per request vs. transmission interval (Number of channels = 30, Arrival rate = 5/min)

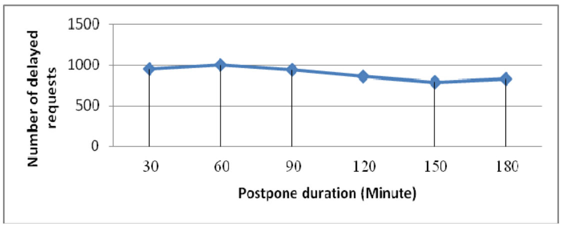

Fig. 5. Number of delayed requests vs. transmission interval (Number of channels = 30, Arrival rate = 5/min)

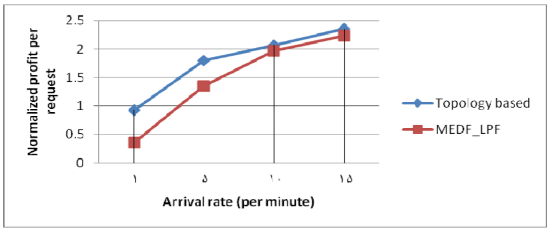

Fig. 6. Normalized profit per request vs. arrival rate (Fixed budget; Number of channels = 30, Transmission interval = 150 min)

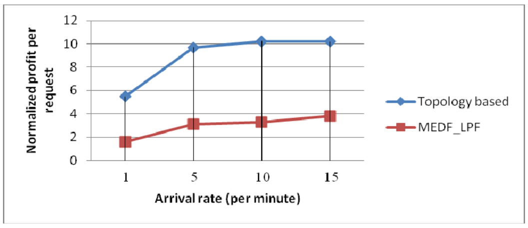

Fig. 7. Normalized profit per request vs. arrival rate (Thrift model; Number of channels = 30, Transmission interval = 150 min)

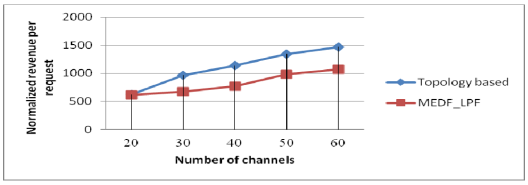

Fig. 8. Normalized profit per request vs. number of channels Thrift model; Arrival rate = 5/min, Transmission interval = 150 min)

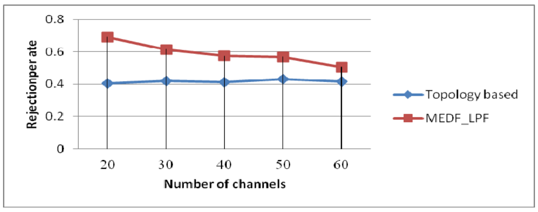

Fig. 9. Rejection rate vs. number of channels (Thrift model; Arrival rate = 5/min, Transmission interval = 150 min)

IV. Simulation Results

In this section, results of simulation experiments executed to evaluate the performance of our topology-based scheduling algorithm is presented. First, the simulation environment is described. In our study, we use *intention-driven* and *budget-driven* (fixed budget and thrift model) user behavior models as explained in [5]. In intention driven model, a user may have the freedom to choose a plan-ahead time that reflects her intention, without concerning budget. However, a user is considered budget-driven, if she has a maximum budget allowed for an object (*fixed budget*), or selection of the plan-ahead time is influenced by cost (*thrift model*). The request with a higher budget will have a shorter plan-ahead time.

The number of video objects is 200 by default. For each generated request, a video is selected using the Zipf distribution. The video length is chosen from a uniform distribution between 100 and 140 minutes. The request arrival rate is set between 1 and 15 requests per minute. The request arrival pattern has Poisson distribution. We compare performance of our topology-based scheduling algorithm with MEDF[1]-LPF[2] (scheduled video delivery) proposed in [5] against two metrics: 1) service provider's expected profit, and 2) customer satisfaction (rejection rate for a fixed number of channels).

A. Effect of System Parameters on Profitability and Customer Satisfaction

Performance of our video delivery scheme depends on the customer arrival rate, number of available channels, and transmission interval. Fig. 2 to Fig. 5 show the rejection rate, provider's profit, average delay per request, and number of delayed requests respectively, obtained from implementation of our topology-based scheduling scheme for budget-driven users with arrival rate of 5 requests per minute, and 30 channels for various durations of transmission period.

Fig. 2 illustrates that rejection rate is exponentially improved (decreased) with transmission period duration. This result is consistent with the fact that the longer we wait (postpone) the transmission, the more requests are received during the transmission period, and hence the possibility of constructing a cost efficient multicast tree increases. In Fig. 3, it can be observed that for shorter transmission periods, postponing delivery of requests has no significant influence on profit of service provides, until the postponement duration is at least two and half hours (150 minutes). It is interesting that increasing this duration after this value is not profitable. The reason is that for longer periods, the compensation in cost, achieved by constructing cost efficient trees, is offset by the penalty paid for delayed requests. Moreover, Fig. 4 and Fig. 5 illustrate that for this parameter setting a 150 minute transmission period has an acceptable performance in terms of average delay and number of delayed request respectively.

B. Effect of Arrival Rate on Profitability

We implemented the algorithm for two budget models, and observed the profit obtained by the provider for different request rates. Fig. 6 and Fig. 7 illustrate the simulation results for normalized total profit using two algorithms: topology-based, and MEDF_LPF for a netwrok with budget-driven customers (fixed and thrift model) respectively. While performance of both scheduling schemes in terms of profit per request improves in higher arrival rates, popularty-based schemes generate a significantly lower profit. The reason is that our scheduling scheme allows the requests to be delivered after the deadline (by incorporating a penalty proportional to the delay), if this cost can be compensated by lower reservation cost in the next transmission epoch.

C. Effect of Available Bandwidth (Number of Channels) on Profitability and Customer Satisfaction

In this section, effect of provider's resource (available channels) on performance of scheduling algorithms is studied. Fig. 8 shows how collected revenue per request grows by number of channles. Again, it is observed that our topology-based scheme outpeformes the other approach. Fig. 9 illustrates the influence of available bandwidth on request rejection rate. While MEDF_LPF shows better performance (customer satisfaction) when the provider increases the number of channels, our topology-based scheduling scheme is less sensitive to it, and always has a significantly lower rejection rate. In other words, our scheme provides higher customer satisfaction with lower resource expenditure requirement.

V. Conclusion

The work presented in this paper proposes a framework for topology-based video delivery scheduling. The preliminary results show that this method outperforms the previous scheduled video delivery scheme in terms of profitability and request admission rate. As a future study, we are working on investigating the effect of graph topology related parameters such as average node degree and graph height on performance of multimedia scheduling scheme. Moreover, integrating the topology-based scheduling with revenue maximizing call admission control policies for media on demand [11] can further improve profitability of service provider.

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[1] Modified Earliest Deadline First
[2] Least Popularity First

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