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A profitable multicast business model

Sneha Kasera[a,*], Raymond E. Miller[b], Markus Hofmann[c]

[a]School of Computing, University of Utah, 50 S, Central Campus Drive, Rm 3190, Salt Lake City, UT 84112, USA
[b]Department of Computer Science, University of Maryland, College Park, MD 20742, USA
[c]Bell Laboratories, Lucent Technologies, Holmdel, NJ 07733, USA

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Abstract

One of the main impediments in wide scale deployment of multicast is lack of a good business model. Any technology needs a good business model to succeed. In this article we present a simple business model for multicast in the Internet that uses the inherent benefits of multicast to make it profitable to all the parties, including the multicast sender, multicast receivers and the network providers, that are involved.

Our model is based on the following principle. Multicast receivers should not pay any additional fee for receiving multicast over unicast but might pay for the content, the sender pays for the bandwidth used in multicast to the Internet service provider(s) (ISP) and might charge the receivers for the content. We demonstrate that the use of our model proves profitable to the sender, receivers and the ISPs. We also discuss some deployment issues.

Keywords: Unicast; Multicast; Internet service provider

1. Introduction

Multicast is an efficient paradigm for transmitting data from a sender to a group of receivers. Multicast incurs lower network bandwidth and end-system costs than broadcast to all receivers or multiple unicasts to individual receivers [6]. One of the main impediments in wide scale deployment of multicast is lack of a good business model. Any technology needs a good business model to succeed. Each of the parties involved must see some advantage in using the technology.

In this article we present a simple business model for multicast in the Internet that uses the inherent benefits of multicast to make it profitable to all the parties, including the multicast sender, multicast receivers and the network providers, that are involved. Our model is based on the following principle. Multicast receivers should not pay any extra charge for receiving multicast over unicast, the sender pays for the bandwidth used in multicast to the Internet service providers (ISP) and might charge the receivers for the content. Next, we analyze the sender, receiver and service provider profits. Using our analytical results and the results from the earlier work of Chuang and Sirbu [5], we demonstrate the benefits of our model to all the parties involved. Although we demonstrate the savings available to the sender, receivers and the ISPs using specific results on bandwidth requirements for multicast and certain assumptions about various parameters, our results clearly show that our approach is applicable to other scenarios as well. Last, we also discuss issues related to this model's implementation.

The remainder of the article is organized as follows. In Section 2 we briefly examine the existing work on the subject. In Section 3, we present our business model. In Section 4, we analyze the sender, network provider and receiver profits due to using our business model. In Section 5, we make some interesting observations that arise from our formulation. We construct numerical examples to demonstrate the profitability of our model in Section 6. In Section 7, we discuss important deployment issues. Conclusions and suggestions for future work are contained in Section 8.

2. Related work

A number of proposals to multicast pricing has been proposed by the research community [3,7]. Unfortunately, none of the ideas have been able to fully motivate all the parties involved in multicast including the sender, the network providers and the receivers. Herzog et al. [7] have

* Corresponding author. Tel.: +1-8015814541; fax: +1-8015815843.
E-mail addresses: kasera@cs.utah.edu (S. Kasera); miller@cs.umd.edu (R.E. Miller); hofmann@bell-labs.com (M. Hofmann).

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studied the problem of sharing the cost of multicast trees using axiomatic analysis. They find that the only scheme that satisfies all their basic axioms is the one that splits multicast cost among receivers. We believe that receivers should not pay any additional charge for receiving multicast. The 'split edge pricing' model presented in Ref. [3] is related to our work in that it addresses the problem of inter-domain charging. It deals with accounting and charging between different ISPs, but it does not consider the actual cost of multicasting at the intra-domain level. Instead, it proposes to decide on charges between domains in advance, which is different from our business model. Chuang and Sirbu [5], through extensive simulations of over a wide range of networks, have shown that the ratio of links in the multicast tree from a sender to n receiver sites (or POPs) to the average number of links in unicast paths from the sender to n receiver sites is $n^{0.8}$. Phillips et al. [8] have tried to provide an explanation for this result. Chalmers and Almeroth [4] show a different result for the savings of bandwidth by multicast. Based on their experiments and analysis, they claim that the exponent of n varies from 0.62 to 0.73. Our work differs from Chuang and Sirbu's work in the following significant ways. First, we propose how the sender charge could be divided among the network providers. Second our business model clearly identifies the benefits of the sender, the receivers and the network providers. In our numerical examples, we also exploit the region between $n^{0.8}$ and n to provide the benefits of multicast to all parties. Alternatively, we could use the savings claimed by Chalmers and Almeroth, or any other measure of bandwidth savings in multicast [9].

3. Business model

Multicast is inherently beneficial. A good multicast business model should be able to use the inherent benefits of multicast to provide incentives for all the parties involved. In this section we present our business model that meets this requirement. In presenting our business model we use a scenario where a sender is multicasting multimedia data to a group of N receivers, however, we believe that our approach generalizes to other scenarios, as well. The design principles of our business model are as follows:

- Receivers do not pay any extra cost for bandwidth for receiving multicast versus unicast.
- The sender pays for the multicast bandwidth.
- The sender might charge the receivers for the content.
- The network providers should receive revenue based on the proportion of their resources that are used in multicast.

Let us now see how each of the parties involved in the multicast, the sender, receivers and the ISP(s), can benefit by using multicast. As far as a receiver is concerned it does not matter whether it is receiving data through unicast or multicast. Typically a receiver pays a fixed fee to its ISP. There is no incentive for the receiver to pay or share the cost of multicast. A receiver might be interested in receiving multicast if the content is offered free or at a discounted rate when multicast. For example, when a sender sends data to a receiver by multicast, it could charge the sender less than if it were sent by unicast. A sender will be interested in multicast if it makes sure that its data reaches N receivers and by using multicast it pays less than it would for N unicast connections. It can then use a part of this profit to reduce the price of the content. It will be argued later that as the number of receivers increases the reduction in cost due to using multicast over unicast also increases. Hence the sender can afford to increase the discount of the content as the number of receivers increase. This strategy is similar to the one that was used in some online stores that reduced the price of an item depending on the amount sold. A sender could also multicast free content for an Internet radio-like service where it covers the cost of multicast as well as makes profit through commercial advertisements.

There are several reasons why a network provider (ISP, National service provider or NSP) might be interested in providing multicast. First, a service provider uses the same or less bandwidth for multicasting to N receivers than individually unicasting to each receiver. Hence it could offer multicast service at a cost that is less than the cost of N times the unicast cost. One might argue that this will lead to a reduction in revenues for the ISP because it is reducing its business from N unicast connections to one multicast 'connection' that is offered at a lower cost. The argument in favor of multicast is that an ISP can accommodate only a certain number of unicast connections across a bottleneck link whereas it can support an equal number of multicast connections through that link. By charging incrementally more for each multicast it can actually increase revenue since it can serve more customers. In fact, our model shows that an ISP could charge more for a certain bandwidth in multicast than in unicast and still leave room for sender profit. Also, an ISP might need to provide multicast service to stay competitive, and it could use some of its extra revenue to cover its additional costs resulting from implementing and retaining multicast service.

In Section 4 we analyze the profits of the sender, receivers and the ISP when they use our multicast business model.

4. Profit analysis

The symbols used in our analysis are given in Table 1.

4.1. Sender profit

The sender profit due to choosing multicast over unicast can be expressed as follows:

$$X = (Nx_{\mathrm{m}} - C) - (Nx_{\mathrm{u}} - Nb_{\mathrm{u}}) \tag{1}$$

The first term is the sender profit when it uses multicast and the second term is the sender profit when it uses unicast.

Table 1
Notation

x_u	Cost of content per receiver when unicast
x_m	Cost of content per receiver when multicast
b_u	Sender bandwidth charge of unicast to a single receiver
$N >$	Number of receivers
n	Number of receiver sites or POPs
X	Sender profit (or loss) due to using multicast over unicast
Y	Receiver savings due to using multicast over unicast
Z	Network provider profit
C	The multicast bandwidth usage charge

The expression for C, the multicast bandwidth usage charge, is derived in Section 4.3.

4.2. Receiver profit

The receiver savings can simply be expressed as follows:

$$Y = x_u - x_m \tag{2}$$

4.3. Network provider profit

Multicast to receivers scattered over wide area networks might involve several ISPs (as well as NSPs). A typical scenario (Fig. 1) involves the sender ISP A, an NSP X providing backbone access to several ISPs A–E. ISPs B–E are serving the receivers (R0–R8). In order to determine the ISP profits, the following two problems must be solved. First, how much do the ISPs charge the sender for multicast and second how is the charge, paid by the sender, shared among the multiple ISPs. In the remainder of this section we present solutions to both these problems.

4.3.1. Individual ISP charge

We first determine the charge of an individual ISP. In the rest of the article the acronym ISP will also include NSPs. The part of the multicast tree inside an ISP can have multiple input and output links. For example, the backbone NSP X in Fig. 1 has two input and four output links. Multiple input links to an ISP suggests that the ISP will have multiple subtrees of the multicast tree. We now derive an expression for the number of links in potentially multiple subtrees of the multicast tree inside an ISP as a function of the number of input and output links. Let I be the number of input links and J be the number of output links. Let K be the branching factor of each subtree of the multicast tree in the ISP. We start with the assumption that K is an integer greater than 1. We also assume that the subtrees are constructed in such a way that each of the internal nodes has K branches except those nodes that are parents of leaf nodes (Fig. 2). Depending on the value of J not all nodes that are parents of the leaf nodes of the subtrees will have K branches. We will find that the expression we derive holds, even when K represents the average branching factor, which is not necessarily an integer, for any general subtrees. More formally, we state and prove the following two theorems.

Theorem 1. *The total number of links, L_m, in I multicast subtrees with a branching factor of K, where K is an integer greater than 1, and with a total of J leaf nodes, is given by* $L_m = \lceil (K(J-I))/(K-1) \rceil$.

Proof: Let d_i be the depth of the ith tree. Then the total number of links in the I subtrees is given by the following

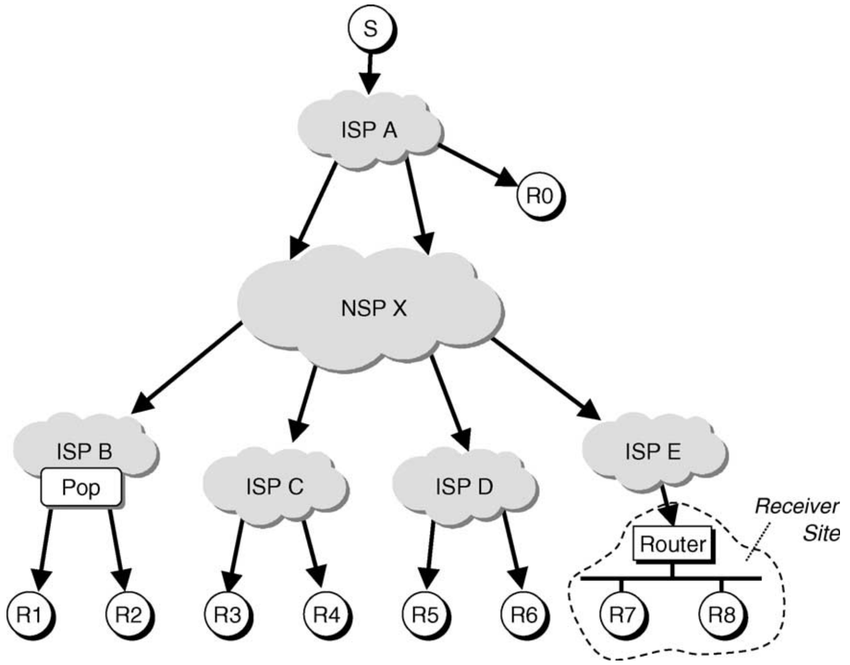

Fig. 1. Multicast involving multiple ISPs.

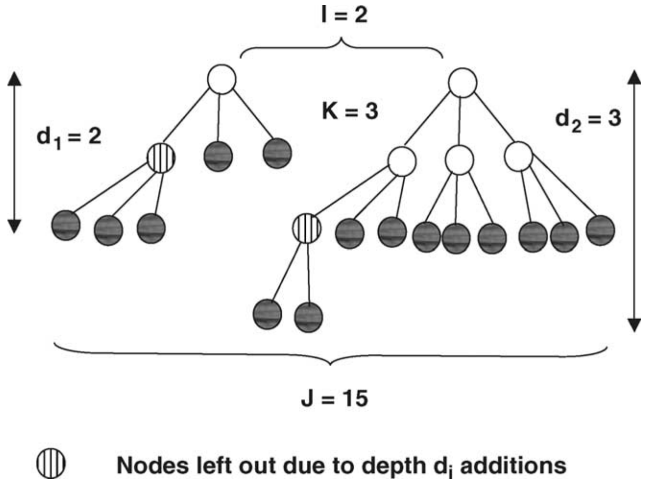

Fig. 2. Two subtrees inside an ISP.

equation.

$$L_m = \sum_{i=1}^{I}\sum_{j=1}^{d_i-1} K^j + \left(J - \sum_{i=1}^{I} K^{d_i-1}\right) + \left\lceil (J - \sum_{i=1}^{I} K^{d_i-1})/(K-1) \right\rceil \quad (3)$$

The first term in Eq. (3) is the number of links in I K-ary trees of depth $d_i - 1$ (where $i = 1, 2, 3, \ldots, I$). The second term is the sum of the additional links needed at depth d_i in all trees. The third term is the sum of the number of additional links needed in each tree i due to leaves of depth $d_i - 1$ being eliminated by depth d_i additions. By using simple algebra, Eq. (3) can be reduced to

$$L_m = \lceil (K(J - I))/(K-1) \rceil \quad (4)$$

□

Theorem 2. *Eq.* (4) *is also true for any K greater than 1.*

Proof. : We redefine K to be the average branching factor of I general trees. Now the average branching factor, K, is the ratio of L_m and the number of internal nodes (denoted N') in the I trees. Noting that $(J - I) = L_m - N'$,

$$\lceil (K(J - I))/(K-1) \rceil = \lceil ((L_m/N')(L_m - N'))/((L_m/N') - 1) \rceil = L_m.$$

□

Using Theorems 1 and 2 we can find the number of links in the portions of the multicast tree inside an ISP as a function of the number of input and output links and the average branching factor. It is important to note that Eq. (4) is true only when $K > 1$ and when $J \neq I$. When $K = 1$ or when $J = I$, we set $L_m = I$.

For a single, and balanced K-ary multicast tree of depth $d(d > 1)$, the total number of links, obtained from Eq. (4), is given by

$$L_m = \lceil (K(K^d - 1))/(K-1) \rceil. \quad (5)$$

If $\bar{d}$ is the average length of unicast paths in the subtrees of the multicast tree in the ISP p and if c_u is the cost of unicast across it[1], then an ISP p can charge C_p by using the formula

$$C_p = L_m c_u/\bar{d} \quad (6)$$

An ISP could incrementally charge more than C_p to make profit (and also to account for additional costs in constructing multicast trees and keeping multicast state at routers). Hence an ISP could potentially charge $C_p(1 + \delta)$ where $\delta > 0$. The profit of the network provider p is given by the following expression.

$$Z = C_p\delta \quad (7)$$

4.3.2. Sender charge

We propose that each receiver ISP can compute its share and pass it to the next ISP above it in the multicast tree towards the sender which adds its own share to the cost received from downtree ISPs and sends it up the tree towards the sender. Finally the sender receives the total cost that it must pay. If there are S ISPs then the sender must pay $C = (1 + \delta)\sum_{p=0}^{S} C_p$. It should be noted that this amount should be sufficiently less than Nb_u otherwise the sender will not have much incentive for using multicast.

5. Observations

Our analytical framework allows us to make several interesting observations. Some of these observations are described below. In the following description we assume that there is only one root node, i.e. $I = 1$. We do not consider multiple subtrees. Additionally, J is the number of receivers.

1. In determining the number of multicast links for a multicast tree, we find that this number depends only on the total number of leaf nodes and the average branching factor. The number of multicast links is independent of the depth of the tree. In terms of the performance benefits of multicast relative to unicast, it is the average unicast path length $\bar{d}$ that plays a decisive role. This observation could be understood with the help of the following example. In Fig. 3, two trees with the same K and J are shown. In this figure, $J = 8$ and $K = 2$. Note that the right tree has an average depth of 4.375 whereas the left tree has an average depth of 3. The relative benefit of multicast over unicast will be higher for the right tree. Therefore, the depth of the tree and not necessarily the number of multicast links, L_m, decides the performance benefit of using multicast over unicast.
2. The depth of a multicast tree is very sensitive to shared edges close to the root of the multicast tree. Adding a shared edge at the root as shown in the Fig. 4 increases the number

[1] Note that c_u is different from b_u. c_u is the cost of unicast across an ISP and b_u is the charge that the sender pays for unicast to its ISP which in turn might be paying a portion of this charge to other neighboring ISPs.

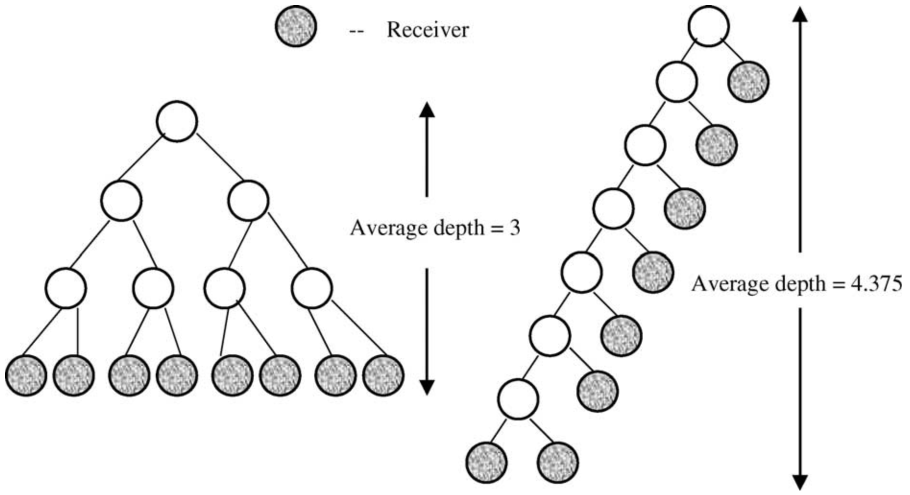

Fig. 3. Two possible trees with same average branching and number of receivers.

of multicast links and the average depth by 1. The increase in number of multicast links is negligible compared to the impact of increasing the depth. When the number of nodes is high the impact of increasing the depth will be even more pronounced.

3. Bounds on profitability in using our multicast business model can be determined by considering trees with either the highest or the lowest depths for the same number of receivers and average branching factor. In order to determine the bounds on profitability, additional constraints must be applied on the tree structure. In the discussion below, we limit the branching to a maximum value. The lowest average depth tree represents the scenario where the benefits due to multicast over unicast are minimized. Fig. 5 shows an example of the minimum average depth tree when the number of receivers is 8, the average branching factor is 2.75, and the maximum permitted branching is 3.

Although we do not provide a formal proof here, the intuition behind constructing this tree is that the maximum number of receivers should be attached to the lowest depth nodes within the permissible branching. The trees of the type shown in Fig. 5 do not represent realistic multicast routing trees and the bound obtained by using such trees are likely to be loose. Constraints other than simply limiting the maximum branching should be considered to construct more realistic trees and obtain tighter bounds. The upper bound on profitability can be obtained by constructing the deepest tree. In this case the receivers are placed at the highest depth that is permitted by the restriction on the maximum and average branching values.

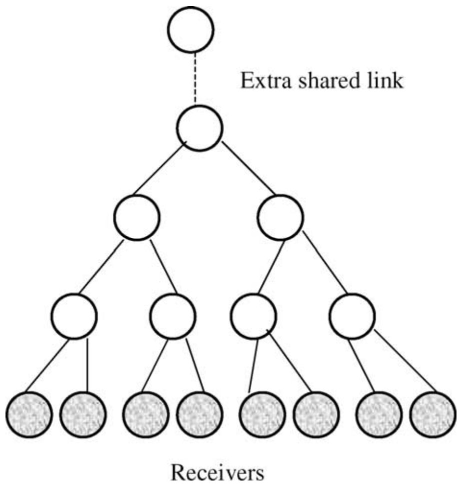

Fig. 4. Adding an extra shared edge changes the average depth.

6. Numerical examples

In this section, we present some numerical examples to demonstrate the profitability of our business model. For simplicity, we will only consider the case when the sender as well as the receivers is served by the same ISP (say ISP 1). We first use the equations derived in Section 4 to construct the examples. Later, we also use the Chuang and Sirbu law [5] to construct additional examples. In our examples, the ISP charge for unicast from a sender to a single receiver, b_u, is \$10. For a single ISP case, $c_u = b_u$. Let the amount the sender charges a receiver when it unicasts the content, x_u, be

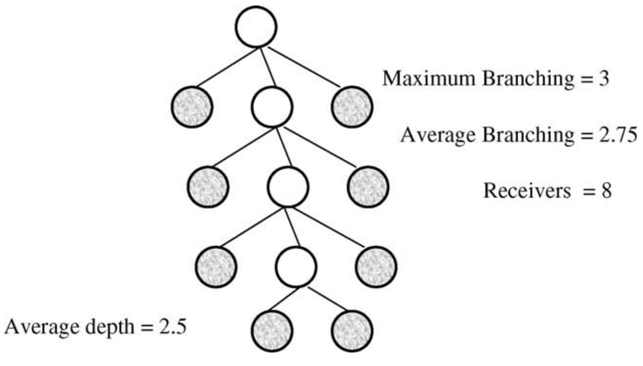

Fig. 5. Minimum average depth tree.

\$15. In a real scenario the unicast bandwidth and content charges will be paid on a monthly basis and the values chosen above seem reasonable.

6.1. K-ary tree

We now study the behavior of the sender and service provider profit, for a K-ary tree, as a function of the number of receivers, the depth of the K-ary tree, and the branching factor K. In addition to the values of x_u and b_u specified above, we also assume that the service provider makes 30% profit, i.e. $\delta = 30\%$ and the sender provides a 25% discount on the content price to users for using multicast instead of unicast to receive content. Fig. 6 shows the sender as well as service provider profit as a function of the depth of the multicast tree when the branching factor, K, is 3. In this figure, the depth also determines the number of receivers (Kd). With increase in depth and hence the number of multicast receivers, the profit due to multicast increases non-linearly. Initially for a small depth less than 4, the sender suffers a loss due to offering content at a discounted price. Beyond the depth of 4, the sender profit increases very fast.

Fig. 7 shows the sender and service provider profit as a function of the branching factor, K, when the depth of the tree is set to 10. The different values of K also determine the number of receivers. Again, with increase in the branching factor, the sender and service provider profit rises very fast.

6.2. Using Chuang and Sirbu law

We now use the Chuang and Sirbu law to construct additional numerical examples. In Ref. [5], Chuang and Sirbu have shown that for multicast trees constructed from a wide range of topologies the ratio of links in the multicast tree from a sender to n receiver sites (POPs) to the average number of links in unicast paths from the sender to n receiver sites is $n^{0.8}$. This law does not depend upon the branching factor or the depth of the multicast tree. Using the Chuang and Sirbu law, $L_m/\bar{d}$ in Eq. (6) can be replaced by $n^{0.8}$. The sender charge could be expressed as $n^{0.8+\epsilon}b_u$. We add ϵ to the exponent to account for the factor δ. δ should be chosen such that ϵ lies in (0,0.2) else the sender charge for multicast to n receiver sites will be more than the charge of n unicasts. The sender and ISP profit will depend upon the choice of δ (or ϵ). The relation between ϵ and δ can be expressed as $(1+\delta) = n^{\epsilon}$.

Even though we use the Chuang and Sirbu figure of $n^{0.8}$ in our numerical calculations all our results depend on is that there is bandwidth savings using multicast over unicast. Thus, similar results could be obtained using different saving factors reported in other studies [4]. We also assume that $N = n$, i.e. there is only one receiver per receiver site. As the charge paid by the sender, to the network provider for multicast, increases only with increase in n, the sender profit determined below is the minimum sender profit.

Fig. 8 shows how the sender profit due to multicast increases with the increase in number of receiver sites for

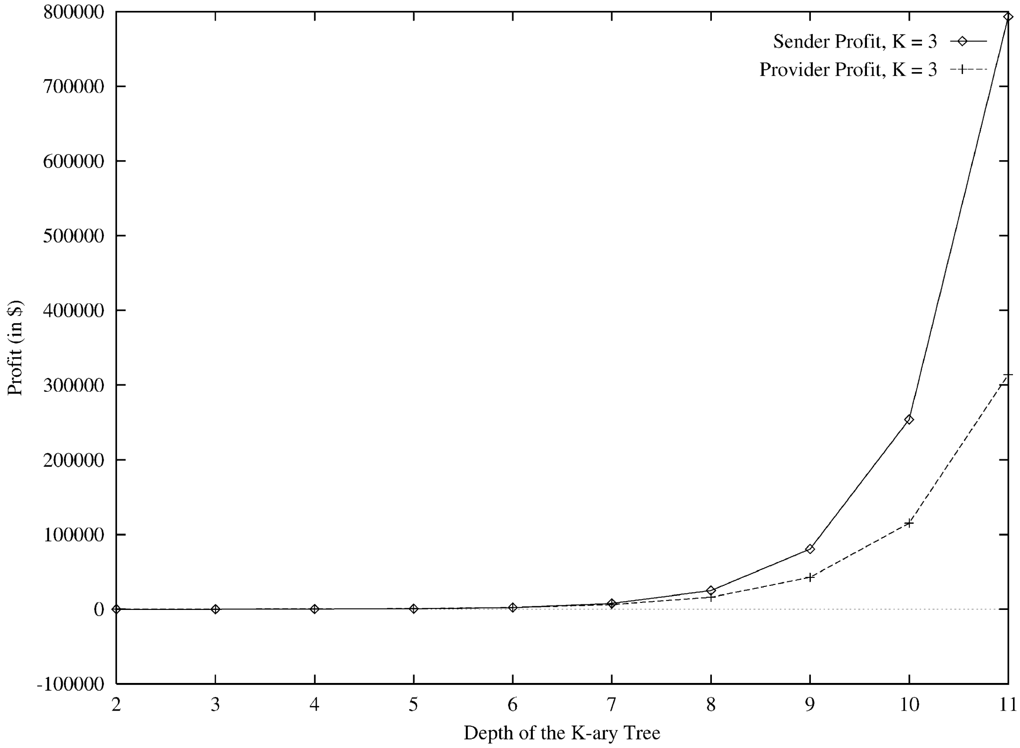

Fig. 6. Profit vs depth.

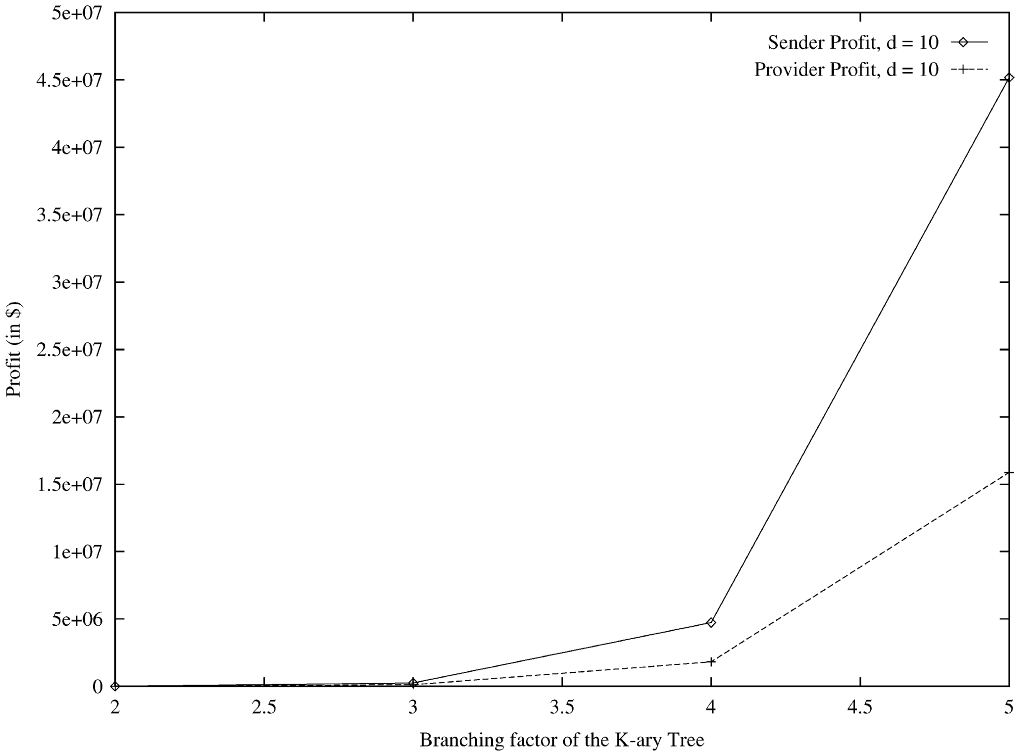

Fig. 7. Profit vs branching factor.

different values of δ. Fig. 9 shows how the network provider profit increases with the increase in number of receiver sites for different values of δ. In both these figures, the discount offered by the sender to a multicast receiver, $(x_u - x_m)/x_u$, is 25%. Note that higher δ means higher network provider profit and lower sender profit. When the number of receivers is small ($n <= 10$) then the sender incurs a loss even for $\delta = 0.10$. As the number of receivers increases the benefits of multicast over unicast increases and this behavior is reflected in the increased sender and network provider profit.

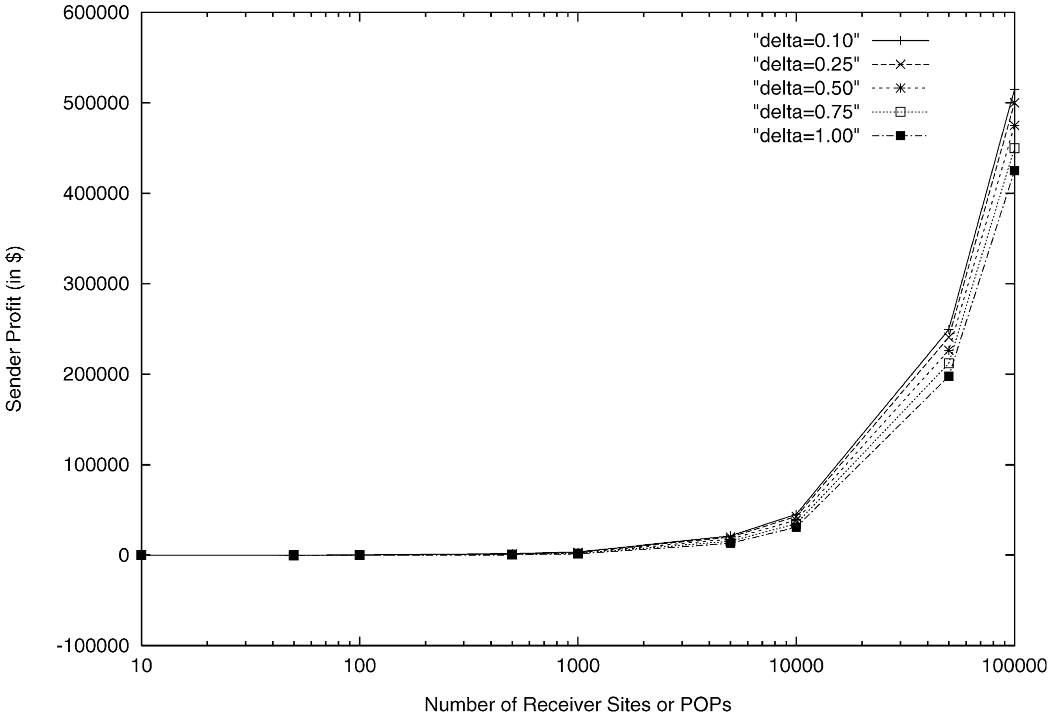

Fig. 8. Sender profit when receiver discount = 25%.

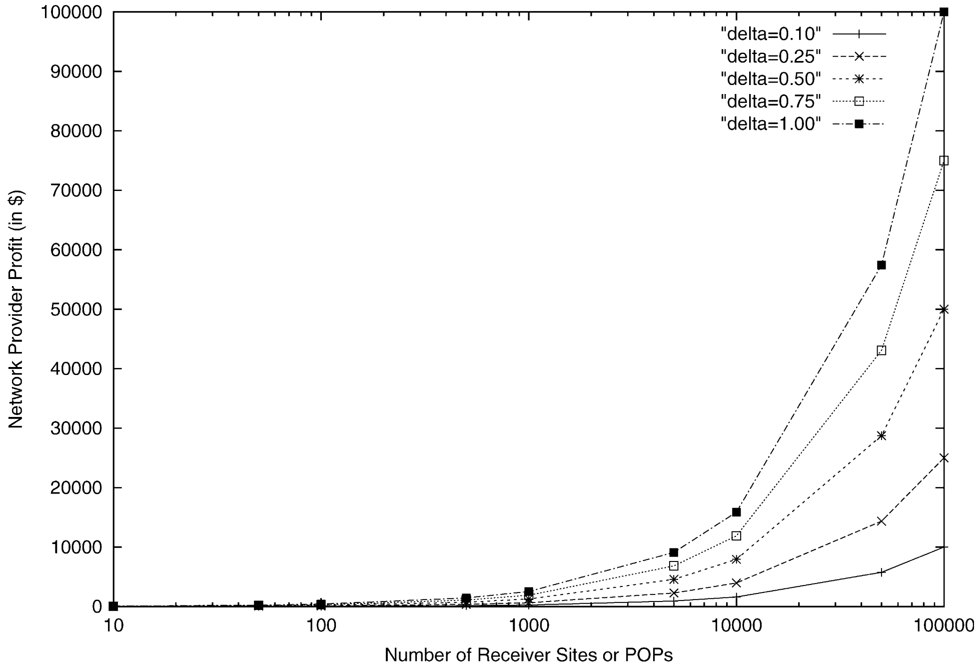

Fig. 9. Network provider profit.

Fig. 10 shows how the sender profit due to multicast increases with the increase in the number of receiver sites for different values of the discount offered by the sender to receiver for using multicast. In this figure $\delta = 0.30$. We see that as the number of receiver sites increases the sender is able to afford higher discounts.

In summary, both for the formula for K-ary tree and the Chuang and Sirbu law, the sender and the service provider make profit using multicast instead of unicast even for a moderate number of receivers. The sender is also able to provide discounts on the price of content.

We end this section by comparing $L_{\mathrm{m}}/\bar{d}$ obtained from the K-ary expression and from the Chuang and Sirbu law. Fig. 11 shows how $L_{\mathrm{m}}/\bar{d}$ varies with changing depth, d (which is same as $\bar{d}$). In this figure, the branching factor is set to 3 and the number of receivers is determined by computing 3^d. As seen in Fig. 11, the two graphs are very close for smaller number of receivers but diverge when

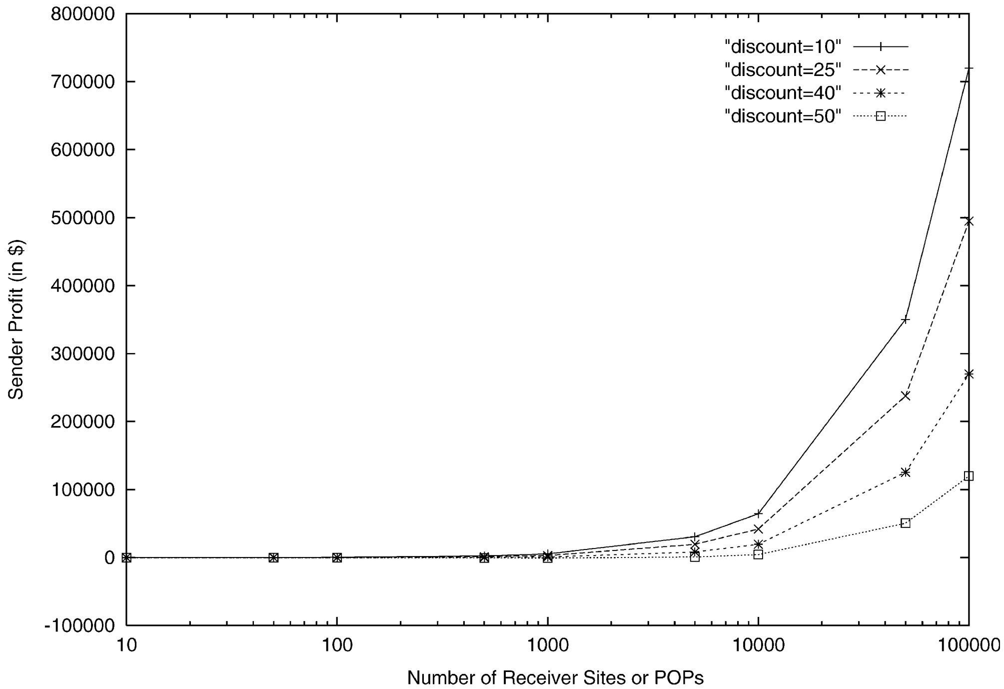

Fig. 10. Sender profit when $\delta = 0.30$.

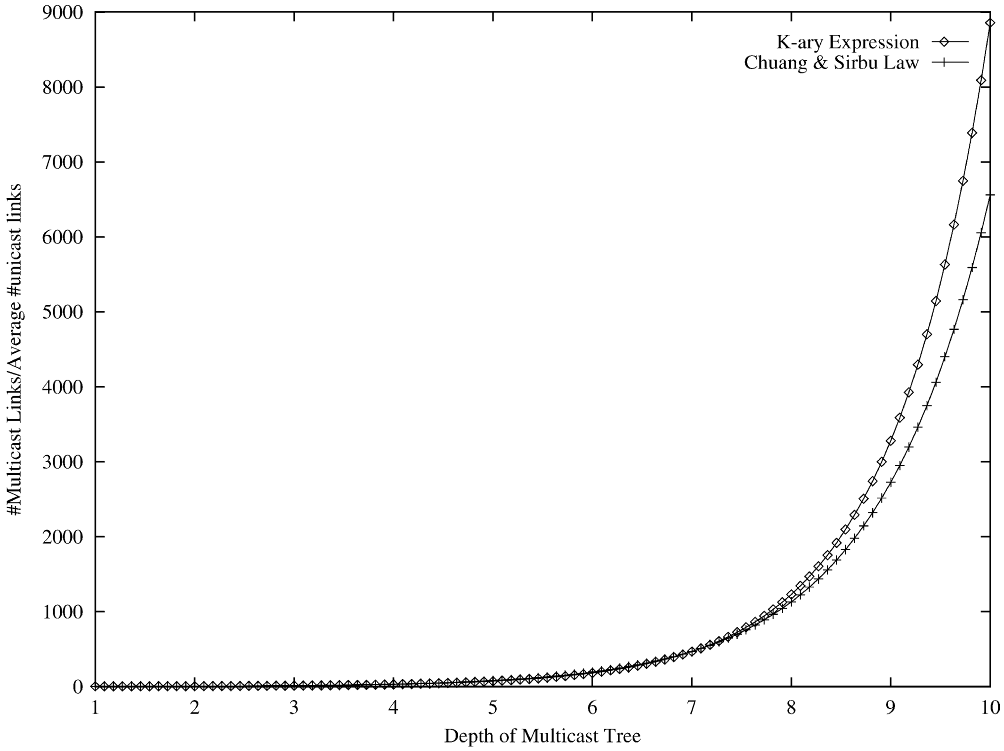

Fig. 11. Comparison of K-ary expression with Chuang and Sirbu Law.

the number of receivers becomes large. Therefore, it is not surprising that the profitability results obtained using the K-ary expression appear similar to those obtained using the Chuang and Sirbu law when the number of receivers is not very large.

7. Deployment issues

Although the proposed business model and pricing scheme is independent of actual implementation techniques, there are a few implications for its deployment in real networks. This section will discuss how various parameters in our business model can be determined in practice, how ISPs will interact with each other, what their relationship will be, and opportunities for new services driven by our multicast business model.

Our scheme allows ISPs to calculate their fair share of the sender charge based on their local view and knowledge of the multicast transmission. It is not necessary for the ISPs to know the shape of the entire multicast tree, but just the section in their own domain. In particular, it is sufficient for an ISP to consider the number of links coming into its domain (I) and the number of outgoing links (J) per multicast session. This information can easily be obtained at the border routers of the ISP. It is not necessary to do any monitoring or to maintain any state in the core of the network, nor is it necessary to introduce additional signaling or control protocols. This improves scalability and allows for easy deployment without additional complexity. Besides these two session-specific parameters, each ISP must determines the average branching factor (K) and the average depth (d) of the multicast subtree in its domain. We envision that ISPs will start monitoring these parameters on a per-session basis during an initial deployment phase, but will gain enough experience to determine flat values based on the characteristics of their network. The average depth (d) of the multicast subtree, for example, could be set to the average length of a unicast path through the ISP's network. Similarly, the ISP might use the average fan-out of multicast routers in its network as the average branching factor (K). Network specific simulations and real-life experience will provide more insights on how to dimension these parameters. Practical experience will also provide feedback on meaningful values for the profit factor δ from a business and a technical perspective.

Using the local parameters mentioned above, each ISP calculates its fair share in the sender's charge. Shares from different ISPs will then be accumulated in a bottom up manner, i.e. they will be accumulated from receiver ISPs (leaf ISPs) up to the sender ISP (root ISP). In Fig. 1, for example, each leaf ISP (B–E) calculates its individual multicast charge and gets paid for it by the parent NSP X. NSP X accumulates the amount paid to its child ISPs (B–E), adds its own multicast charge and gets paid for the accumulated amount by its parent ISP A. Finally, ISP A charges the sender for the entire amount, including the individual cost of ISP A. It is up to the sender to charge receivers for delivered content, thus covering part of the transmission cost. The sender also decides whether parts of its savings will be passed on to receivers in form of a discount.

The proposed pricing scheme requires interaction only between neighbor ISPs, there is no need for information exchange between non-neighbor ISPs. This reflects existing (bilateral) business relationships and avoids the need for additional partnerships. However, our model presupposes a trust relationship between the ISPs, because it implicitly assumes that each ISP is using reasonable values for K and d. This might not be taken for granted, because manipulating these values allows ISPs to gain more profit. While actual verification and security mechanisms are out of the scope of this article, our approach does include hooks for integration of such features. For example, ISPs could include flat values for K and d into bilateral service level agreements with neighbor ISPs. This allows them to verify the multicast charge of their neighbors, assuming that ISPs will report the number of output links for a multicast session to their parents. Together with signed charge reports that are passed along the ISP tree towards the root ISP, this feature allows the sender to verify the correctness of a multicast charge. Other mechanisms may exist and details need to be worked out. The point is, however, that our business model provides a reasonable and simple mechanism for verification purposes.

One potential concern with our business model is that it does not use flat rate pricing between ISPs.[2] Flat rate pricing allows for management simplicity. In our model, although the ISPs could negotiate the average branching factor and the average depth of the multicast subtrees, as noted above, each ISP must keep track of the number of links coming into its domain (I) and the number of outgoing links (J) per multicast session. Depending on the number of the incoming and outgoing links, an ISP will charge different amounts. However, for popular content providers, it is possible for an ISP (e.g. ISP C in Fig. 1) to charge a flat rate price to a neighboring upper-level ISP (ISP X in Fig. 1) as long as the number of outgoing links in its network remains higher than a certain threshold. In such situations, an ISP might only occasionally observe the number of incoming and outgoing links for a better understanding of its network usage and renegotiate contracts if necessary.

In some cases, peering ISPs forward each other's traffic for free. An ISP involved in such a contract (e.g. ISP X in Fig. 1) might not pay the peering ISP (e.g. ISP C in Fig. 1) any money for multicast traffic but could continue to charge its upper-level peer (e.g. ISP A in Fig. 1) in the same way as if this agreement did not exist.[3]

As we have shown in Section 6, our business model allows a sender to give higher discounts as the number of receiver sites increases. This opens an opportunity for a new breed of content delivery services. Content providers could offer delivery of specific content at certain points in time. Interested customers would sign up for a specific delivery time and would see the price decrease as more and more customers sign up. For example, a movie could be offered for delivery in 1 hour, 2 hours, 3 hours, etc. The longer delivery time a customer accepts, the higher the chances that more customers sign up and that the price for the movie drops. This model is similar to the purchasing service offered by some online stores where the price of a product drops as the number of buyers increase. Our business model enables a variety of similar services in the context of content delivery.

[2] Interestingly, Bailey et al. [1,2] make the case for charging models that are not flat rate.

[3] Assuming that ISPs X and A do not have an agreement for forwarding each other's traffic for free.

8. Conclusions

One of the main reasons for multicast technology not being deployed on a wide scale is the lack of a good business model. We have proposed a simple business model that uses the inherent benefits of multicasting to make it attractive and profitable to all parties, including the sender, the receivers, and the network providers. In our scheme, the responsibility for paying the multicast transmission lies with the sender. Each ISP will calculate its 'fair' share of the sender charge based on its local view and knowledge. Receivers will not be charged any additional fee for receiving multicast data. While this principle makes sense from a business point of view, it opens technical challenges that need to be solved outside the scope of this article. Mechanisms need to be in place disabling receivers from joining an arbitrary multicast session, thus increasing the sender's cost. Also, receivers should be prevented from joining non-existent multicast sessions to avoid unnecessary ISP cost. Other issues for future work include verification and security issues, as well as the trust model between ISPs.

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