

CUSTOMIZED BROADBAND CONTENT PROVISION TO LOCAL COMMUNITIES

MANOJ PARAMESWARAN, Santa Clara University

Leavey School of Business, Santa Clara CA 95053, Email: mparameswaran@scu.edu

ABSTRACT

Broadband distribution of interactive multimedia is a rapidly growing market that utilizes data networks and requires stringent resource allocations. Supporting such allocations and conserving resources require economically rational and technically feasible models. Shared distribution of products to generate customized combinations is outlined as a possible solution, augmented by a subscription-based regime that induces consumers to reveal their valuations by migrating to combinations that match their preferences. The distribution of a product involves a hierarchy of self-sustaining communities, that effectively decentralizes the informational issues. Local providers act as intermediaries procuring content from network-wide auctions and assembling it into customized bundles.

INTRODUCTION

This article develops an economic basis for shared distribution of customized bundles of multimedia products over public broadband networks to local communities of end users. The problem is addressed from the perspective of economics because production and distribution of such content necessarily constitute business models that require appropriate economic justification. In the process, the engineering framework used for distribution is accounted for, rather than abstracted away, and the distribution mechanism attempts to bridge the

technological realities and economic imperatives.

Interactive multimedia applications are rapidly emerging as a thrust area of business-to-consumer electronic commerce with telecommunications companies, media giants, and digital content providers collaborating on multiple initiatives. The worldwide market for video games and interactive entertainment is expected to grow from \$23.2 billion in 2003 to \$33.4 billion in 2008 (Research and Markets 2004). Accustream Research estimates that subscription and video streaming-based revenue will hit \$625 million this year and

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\$864 million in 2005, for a 40% increase (Stump 2004). There are several factors driving the momentum of this trend. Convergence of networking technologies, the most important factor, enhances the distribution channels in reach and capacity, and facilitates mingling of different types of traffic (data, audio and video) over same channels. The available bandwidth of the network infrastructure has been increasing sufficiently to render transmission of multimedia content a feasible prospect. Broadband usage in the United States grew by 20 percent in the second half of 2003 and 42 percent for the year as a whole, according to the semi-annual market analysis done by the Federal Communications Commission (FCC) (FCC 2004). At the end of 2003, there were over 85 million broadband subscribers worldwide, and this market is changing the map of supply and demand for visual content, as broadband video poses a threat for conventional pay television (ABI Research 2004). In one example of collaboration across industries to provide broadband multimedia content, Scripps Networks provides Comcast Corp. and MSN with 120 broadband clips each month from Food Network, Home & Garden Television, Do It Yourself and Fine Living (Stump 2004). Rapid strides are being made in multimedia encoding, compression, and distribution technologies that improve the quality of delivered multimedia content. Meanwhile, enhancement and standardization of interoperable content description formats (markup languages such as Extensible Markup Language (XML)) and protocols to aid resource discovery (Resource Description Framework (RDF), Lightweight Directory Access Protocol (LDAP)) are enabling delivery of diverse types of content in an integrated form. As a result of these factors, the Internet is emerging as a 'super media'. Interactive multimedia applications form the nucleus of this vision.

Interactivity and convergence are not the only aspects in which net-based media are seen to possess advantages over conventional media. The possibility of providing content on-demand in a dynamic fashion, allows the flexibility to customize content. Indeed, this is an important advantage as perceived by businesses producing content. In conventional

media, the efficacy of narrowcasting as compared with broadcasting has led to relative success of cable television channels and an increasing tendency among television channels to establish an identity, either of the channel, or of particular programs, as catering to individual consumer segments.

BROADBAND CONTENT PROVISION

Issues in Content Distribution

Formulation of research questions related to the business models for broadband content provision may be helped by taking a

CONTRIBUTION

The paper makes various contributions to information systems research. It examines the informational and allocation issues in a specific information economy characterized by various technological constraints. It provides a theoretical framework for scalable business models that can be used to implement distribution of broadband information product distribution, and to study the behavior of various distribution mechanisms in that context. Previous work in this regard has been confined to engineering protocols, and this work bridges the gap between engineering and business models.

Rather than focusing on a theoretical optimum, it accounts for the idiosyncratic attributes of the distribution environment, and outlines the design and properties of a technically feasible model with approximately optimal allocations. Thus, the paper makes a contribution toward development of feasible business models. In the larger context, this work helps advance the cause of interdisciplinary research among engineering and business researchers to effectively exploit the information infrastructure, which requires understanding of both.

The paper will be of interest to researchers in both information systems and network engineering, as well as practitioners who seek scalable and viable allocation models.

resource allocation perspective of these models. Interactive multimedia flows require end-to-end Quality of Service (QoS)ⁱ, that is, they require dedicated resources along the entire path of the flow. However, these paths are constituted of individual segments owned by private network infrastructure providers. They will need incentives to provide dedicated resources along a connected path. Furthermore, allocations for bandwidth-intensive multimedia applications will tie up network resources, leading to opportunity cost of traffic not served. From an economic perspective, the resources required to produce the content, as well as to distribute it, are in limited supply, and should be allocated in a way that accounts for the production costs and opportunity cost of possible alternate use of the network. The design of such a resource allocation mechanism will entail the use of pricing. The question is how can a pricing mechanism be designed that will also ensure a feasible allocation of network resources and facilitate multimedia distribution as a sustainable business model, while being compatible with existing network protocols.

In the emerging multimedia distribution framework, firms that specialize in producing and distributing broadband content face a set of key business questions:

- Given an estimated cost of production, how can it be determined that it is justified to incur this cost and produce the content to make it available for distribution?
- Given estimated costs of distribution, how can it be determined as to which consumers receive the product and how much individual consumers pay?
- Given there are alternative uses of network infrastructure, and that network resources are limited in supply, how can the costs of infrastructure be recovered from the consumers?
- Given demand information, how can it be determined as to who will get true interactive content, and how do you differentiate among interactive and non-interactive distributions?

In sum, the field of broadband content distribution presents a host of interesting

questions for the business researcher. The potential benefit from tackling them would be contributions toward the evolution of business models that integrate well with network protocols. In what follows, this paper outlines distribution models for the network and for local markets along these lines.

Customized Content

In this section, we outline the conceptual basis for a business model for many-to-many, customized broadband content provision using resource sharing and bundling of content in transit.

Parameswaran, Stallaert, and Whinston (2001) analyze the infrastructure resource allocation for multimedia content from a single seller delivered to a single recipient, i.e. the unicasting case (Unicasting refers to data flows that connect a single source to a single destination, much like telephone calls). Presumably in this case the content is unique and of interest to only one individual. Based on the pattern of customized content provision today (as seen in personalized pages and portals), it is much more likely that the uniqueness is derived through customizing the content by combining multiple components from different sources. Thus the distribution model would be one of multiple providers and multiple documents that are combined during transit in the network, leading to the uniqueness. We envision numerous one-to-many distributions of individual content items combining severally in the network at the delivery points, forming products customized to match different preference types.

The unicast model (Parameswaran, Stallaert, and Whinston 2001) caters to individual suppliers using dedicated connections to deliver individual products. Such a model may be valid only when the product represents unique utility to the particular individual. However, in the world of online content, individual infotainment products are not manufactured to fit a single consumer's tastes. Rather, there are common products which are targeted at specific consumer groups, similar to local newspapers, sitcoms, cable television channels and so on. A one-to-many distribution framework allows a more flexible environment, where individual components, (say, a sports channel, a sitcom

episode, and a fashion magazine - digital versions, of course) could be combined according to customer preferences to create personalized products. Thus, products derive from multiple sources and multiple consumers may receive same components. The product becomes unique through customization. The future of content provision is captured better in this view than a single product, unicast view, and this view directly leads to the use of the shared distribution model we discuss below.

The business model for distribution comprises individual consumers, intermediate network nodes that form part of the distribution graph for a given data flow, and the firm that produces content. Together, these form a value chain. Here, the complicating factor is that the distribution channel itself affects the utility to the end user for delivered content. Moreover, the price, if any, that a group of consumers pay should be sufficient to cover the costs of production *and* distribution. However, production and distribution are controlled by different economic agents, and each has no control over the other's costs. Distribution, in particular, is determined by the routing function used in the broadband network. Thus the resource allocation mechanism is dependent on the network protocols. This entails some overlap of the economic and technological issues.

Each of the economic agents is assigned a valuation in the proposed distribution model: consumers derive a positive value from the requested content delivered at the desired level of QoS; network nodes have a negative value for every unit resource allocated for the delivery of such content; and, content providers have a negative value in producing that content. In the model, the content providers as well as the local Internet Service Providers (ISPs) become ancillary nodes in the distribution network. As discussed later, the ISP-to-consumer distribution is treated separately.

The value chain determined by the network topology of distribution may be thought of as comprising 'communities'. A community is a set of nodes that receive a particular data flow. The only common aspect to the members of the community is being part

of the distribution graph for the particular flow.

The decision to make a product available to any particular community will depend on whether the community's net value accounts for the cost of content production and of distribution to this particular community. If the net value is not sufficient, the community is removed from the distribution network. Note that 'community' here is a network-defined entity; a more general concept than that of the local communities of consumers we discuss below.

Our model proceeds by treating each product/data flow independently, and computing the routing topology for the case where all members of the hierarchy of communities receive the product. Thereafter, in a recursive traversal starting with the leaf nodes, each community's net value is examined, and the community is retained only if its net value is non-negative. Thus the tree is pruned to yield a pseudo-optimal solution.

Sharing

In a routed data network such as the Internet, packets directed at multiple individual destinations from a single source will have significant overlap in their paths. Given that broadband content distribution involves several one-to-many distribution chains, the paths for these flows will have many common arcs. The manner in which packets are routed in the Internet will amplify the extent to which paths are shared since it involves utilizing backbone connections as far downstream as possible and entering into local networks closer to destination only.

With variable rate traffic such as surfing the web, many users access the same popular website, and there is a significant amount of redundancy in packet travel. (Caching of high bandwidth content closer to locations reduces the redundancy.) However, this sort of redundancy is not a significant problem as individual bandwidth demands are low and resources are not reserved. With interactive multimedia, resources are dedicated at each intermediate node for each flow, and redundancy can be significantly wasteful.

The digital nature of the product distributed allows for easy replication at

intermediate nodes. This characteristic may be exploited to use a shared distribution model where content originates as a single flow, and gets replicated at intermediate nodes when multiple downstream paths need to be supported. Such a shared distribution model will determine the terminal nodes that are to receive content, and construct a distribution tree that eliminates redundant segments in the path with the help of replication. The terminal nodes and intermediate transit nodes will be members of this tree.

From the viewpoint of technology, IP multicast protocol allows for shared distribution to members of a controlled group. Further, QoS-based variants of multicast may be used to support capacity commitments along the path to provide end-to-end QoS required for multimedia flows. The following discussion is characterized in terms of a general shared distribution business model that allows for any technically feasible protocol that supports sharing; though QoS-based multicast is the most likely candidate to be used for that. The significance of multicasting is that it portends a scalable business model for distribution of interactive multimedia contents to target groups, to be built around multicast. However, the realization of a model along these lines still faces several obstacles. Accordingly, considerable ongoing work in the internet design community is focused on improving and extending the specifications for multicast to support QoS and facilitate inter-domain multicasting, due to great expectations about broadband content distribution over both data networks and wireless networks.

Local Markets

The markets where the products reach end users via local ISPs, are characterized by specific issues that may need different treatment from the rest of the network. It was stated earlier that valuations from consumers form part of the input to the resource allocation process; however, extracting these valuations is a particularly difficult problem in the local markets. This is due to the fact that provision of a product at an ISP node is dependent only on the net valuation from all local users defraying the cost of availability at that node. Once the product arrives at the local ISP node, it can be replicated and distributed

to members of the community without significant additional costs and this process is limited only by network capacity.

This essentially means that it is difficult to exclude members of the community from consuming the product. Thus the content exhibits characteristics of a public good in the local market (Samuelson 1954). Consumers have an incentive to underreport their valuations and ‘free ride’, in the presence of valuations that add up. Since the sellers are private enterprises, they need to capture demand information and be able to charge prices in order to make the production decision (the decision to deliver the product at the ISP node with the requisite QoS).

Due to this problem, the consumers are not made part of the shared distribution allocation, and the local markets are treated differently. The intuition is to convert the public goods into a few private goods by creating customized bundles that match specific demand types. The general distribution model may be used to assemble multiple products into different combinations during transit, thus providing individual local markets with different customized bundles.

Economic Models in an Engineering Environment

The distribution environment is made up of an engineered network, and therefore, constrained by its idiosyncrasies. Distribution over this network is implemented by communication protocols that emphasize engineering efficiency. However, viewed in the context of the economic activity of broadband provision, this is a market characterized by scarce resources, market imperfections, and asymmetry of information. Also, the network infrastructure is owned by self-interested private providers even though it is open for public usage. Any resource allocation mechanism over this network should then be justified by economic rationale, and not just by engineering efficiency. These mechanisms will need to be incentive-compatible to participating economic agents and will need to extract private information and induce efficient allocations.

Engineering solutions that seek to implement allocations typically have different

objectives compared to economic models; however, they can both co-exist, provided the economic model is designed around the engineering protocols. Engineering solutions typically ignore economic costs, incentive issues, as well as decisions about how to choose from among contending requests for network resources based on willingness to pay. Further, the end-to-end allocations are typically built by allocating resources incrementally using reservation requests, which ignores the node-level allocation problem, and is not efficient from an economic point of view (Parameswaran, Stallaert, and Whinston 2001).

Dynamic Allocation and Auctions

Many users and products contend for scarce bandwidth resources in the distribution network, and the valuations (of capacity by each node and for delivered products by users) are difficult to ascertain by a central market maker. With externalities in distribution as well as public good characteristics in delivered products, it is difficult to provide participating agents with incentives to reveal their true valuations. Furthermore, the networks considered in the discussion below (IP multicast networks), constitute a real time stochastic environment. The stochastic nature of the environment leads to variations in agent valuations. This implies that allocations have to be determined based on the current state of the network, over short time periods, i.e. allocations have to be dynamic. On the other hand, engineering approaches to resource allocation in IP networks frequently use static allocations. In addition to the above factors, the type of content that will be distributed in our model, interactive multimedia, is itself dynamic in nature, and usage will vary. All these factors necessitate dynamic allocation of resources. However, under a dynamic allocation scenario with asymmetric information, posted prices and contracts will be difficult and inefficient to administer.

A more efficient and feasible solution would be requiring all participants to submit bids indicating their valuation of resources (or willingness to pay). A clearing process can use this along with network connectivity information to arrive at approximately optimal allocations. Such a process may be

characterized as an auction from an economic point of view. Where the environment displays asymmetry of information and a difficulty in determining individual valuations, auctions serve as a practical and efficient means for resource allocation (McAfee and McMillan 1987). In the shared distribution environment, use of bidding would differ from a classic auction in many ways: there is no simple buyer-seller pairing where goods are traded; the delivered product is assembled as a result of content creation and transmission, and may be viewed as a bundling of value by several players. Moreover, the market clearing problem will be non-trivial, and may require pseudo-optimal solutions to achieve computational feasibility. In a complex stochastic environment that requires co-existence with the engineering architecture, such approximations are justifiable (Gupta, Jukic, Parameswaran, Stahl, and Whinston 1997). Feasibility and the dynamic nature of allocations will also require that auctions be periodic.

THE ALLOCATION MODEL FOR BROADBAND CONTENT

The allocation model consists of two parts: the first determines shared distribution of content to ISP nodes by implementing capacity allocations in connected paths from source to destination as multicast trees for individual content items, and the second determines how ISPs group consumers into homogeneous communities that receive combinations of content. Note that we use QoS-based multicast as a feasible example for implementing shared distribution; the description of the distribution model is not specific to multicast.

Shared Distribution

Sharing is achieved by using QoS-based Multicast over IP networks. IP networks provide connectionless service with no QoS guarantees; however, the broadband content requires connection-oriented service with a consistent rate throughout the path for the duration of the flow. In general, high quality multimedia streams require performance similar to dedicated channels. In order to achieve this, some capacity needs to be

reserved at each node that forms part of the connected path for distribution of a product.

The capacity for each product will equal its bandwidth requirement. In practice, this may be effected as a peak rate specification similar to what is used the premium service model in Diffserv (Clark and Wroclawski 1997; Nichols, Jacobson and Zhang 1997). The contracted parameter in such a model would be a specified peak-rate for each flow. At the source, packet shaping will ensure conformance to this rate. At intermediate nodes, the appropriately tagged flows will be serviced by premium queues. Each intermediate node will support multiple tagged flows, limited by the size of the queue at the node. The engineering design of such models to support differentiated service is capable of ensuring the progress of flows with insignificant queuing delay. Over-subscription is not allowed, and allocations to support a contracted rate are deterministic. This has the added advantage of avoiding complex queuing policies.

A set of these allocations along a connected path for a given flow constitute a virtual connection. Thus the broadband content is treated as premium flows that get connection-oriented service over a connectionless environment.

Since the available queue capacity at each node is limited, the premium flows contend for a share of this capacity, and any allocated capacity incurs an opportunity cost that must be defrayed. For each flow, at each node, capacity is allocated in the full requested amount, or not at all. The multimedia flow derives no value from getting a fraction of the bandwidth requirement.

Use of the multicast distribution implies that each flow may be replicated as many times as necessary for downstream distribution once it arrives at a node. A single flow originates at the content provider node, and at each subsequent node, the flow replicates as many times as is necessary to support downstream nodes connected through multiple arcs. This replication exploits the overlap in distribution paths and the costless replication of digital content to conserve network resources. This means that there is no conservation of the flow at an intermediate

node. Furthermore, the requirements of fill or kill allocations for flows and the need for an incoming flow to be present to sustain downstream flows lead to the inclusion of integer and non-linear constraints in the allocation model.

Bidding Process. The content provider node and the local internet service provider nodes are combined with the IP network to form the distribution network. The allocation process determines distribution graphs for each product over this augmented network as multicast trees. At the beginning of the auction process, the content provider advertises(bids) availability of a particular product at a source node, along with its bandwidth requirements and cost. Each network node advertises the cost for reserving resources at the node, and the amount of resources available. Each ISP node specifies the products required and their valuation for them.

The IP network is assumed to span a single administrative domain, so that negotiations among multiple domains to form interconnection agreements are left out. Interconnection agreements among internet providers in backbone networks remain a difficult problem; and the contracts used today are frequently arbitrary, the process neither regulated, nor transparent (Srinagesh 1997). Parameswaran, Stallaert, and Whinston (2001) discuss how path allocations may be extended across multiple private domains using incentive compatible contracts that trade capacity in the aggregate.

The bids are collected by a central market process that computes allocations. This process is also provided with the connectivity information for the network. The allocation process maximizes the net surplus in the system, defined as valuations by terminal nodes net of the costs of capacity and content. This surplus is shared among the ISP nodes in proportion to their bids.

Due to the integer and non-linear constraints, the allocation problem turns out to be a version of the prize-collecting Steiner arborescence, which is NP-hard (Parameswaran, Stallaert and Whinston, 2004). The need for computational feasibility dictates the use of heuristics that approximate

optimal solutions. One such heuristic is briefly described below.

The heuristic sorts the products in a greedy manner, picking those with highest net valuations per unit capacity first. For each product, a minimum cost graph is constructed, as a Steiner arborescence. At this stage, all bidders are expected to receive the products subject to node capacities.

Self-sustaining communities. The distribution graph for a data flow turns out to be an arborescence rooted at the source node. Any sub-arborescence of this graph may be construed as a community. Thus, a hierarchy of communities is induced. Once the product is available at the root node of the sub-arborescence, it may be shared among the community. It follows that the product is made available at the root node only if the cumulative surplus of the community is positive. We can think of these communities as self-sustaining. The objective is to construct a hierarchy of such communities.

Using this principle, the heuristic will do a depth-first traversal of the tree for each

product, computing the net surplus at each node (net surplus being defined as net surplus of the community rooted at that node), and eliminating the community at that node if surplus is not positive. Each time a sub-tree is pruned, the net surplus in the entire network moves closer to optimum. Repeating this process for all products yields the final distribution graph. Parameswaran, Stallaert, and Whinston (2004) present a detailed description of an allocation model and the heuristic used to solve it.

A MODEL OF LOCAL COMMUNITIES

Terminal Nodes with Public Goods Problem

The terminal nodes in the above model correspond to the ISPs in local markets. They in turn distribute the products to end users. While it is possible to consider the end users as part of the distribution graphs and have them bid for the products, that can introduce inefficiencies into the model. At any given ISP node, an available product will display a public good characteristic. We can think of the end users as a community rooted at the ISP

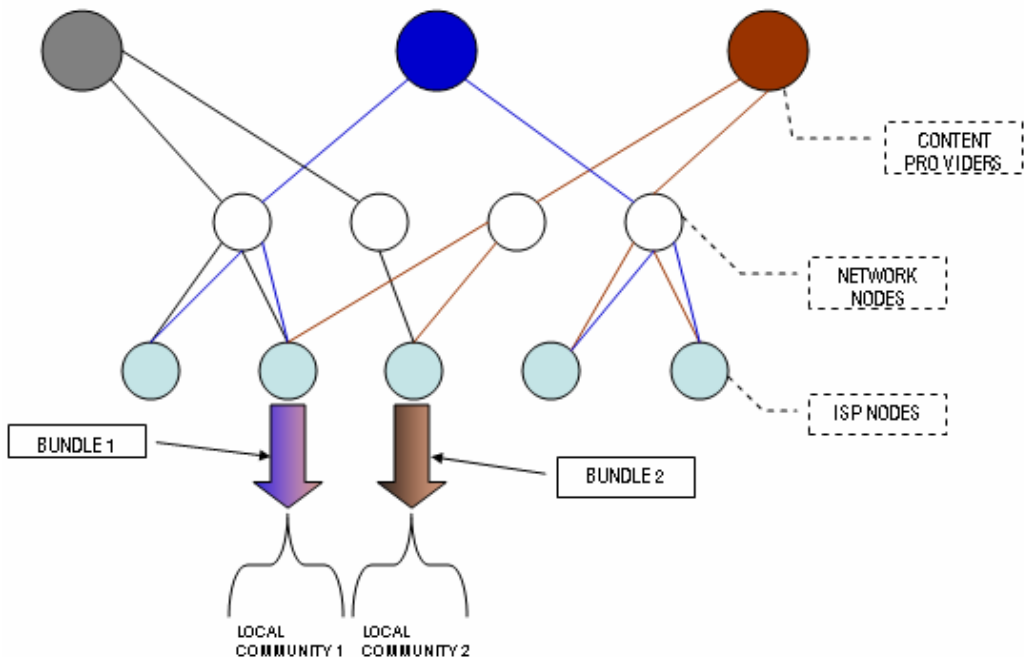


Figure 1. Simplified Schematic of the Distribution Model. In a real hierarchy, the network notes will include multiple levels.

node, and the demands for the community members are vertically additive. If the net valuation of the community is sufficient to obtain the product at the ISP node, this community can be part of the distribution graph. Since consumers know this, they have the incentive to under-represent their valuations, expecting others to bid sufficiently high to yield the required net surplus. This attempt to free ride can spread among the community and break the system down.

Thus, using an auction process among end users is not viable due to the public goods problems. So we propose a different allocation scheme for the local markets that will induce consumers to reveal their valuations for the products.

Local Communities

In this model, different ISP nodes run different types of communities, with each community characterized by a combination of products and homogeneity. Consumers can switch to communities that offer products matching their preference profile. Instead of asking consumers to reveal their valuations through bidding, the ISP charges a membership fee for each community. The choice of community by a consumer reveals preferences, and the fee acts like a tax on the public good. Figure 1 shows a schematic representation of how the ISPs may obtain products through shared distribution and in turn distribute bundled products to different local communities.

This type of allocation allows consumers to obtain all their goods at a single source rather than maintain multiple connections, a more feasible solution compared to consumers connecting to multiple providers for individual items of content. So also it allows a price regime that is easier to administer, and reduces co-ordination costs.

This shifting of responsibility for consumer prices to local markets from the central allocation process can ameliorate the public goods problem by making them (at least partially) private in nature. The bundling of multiple products to customize delivered products further enhances the private nature of the goods. Unlike the classic public good scenario, the provider is not a central

government seeking benefit for its citizens, but a private provider that faces a public good problem in trying to sell goods that were produced at cost. The public government's role is more passive in that it responds to the demand of the people and tries to accommodate it in a feasible manner; the private ISPs in the model play a role more similar to intermediaries in a market system. The division into local communities, and the consequent reduction of the public goods aspect, are similar to what happens with local (city or town) governments administering public goods. Local governments can also customize different suburbs to match different types of consumers, and identify valuations by consumer choice of where to live; taxation follows. (Tiebout 1956; Stiglitz 1977).

The problem here is much more amenable to a solution using multiple communities compared to the local governments' problem due to various reasons. In case of local governments, consumer choice is limited, as sufficiently large number or diversity of suburbs may not exist. In the case of digital content, adequate number of combinations can be provided based on consumer demand types. In the local government problem, choosing suburbs involves costly physical moves, and may be subject to exogenous restrictions due to career and other factors. In the case of broadband content, choosing communities is a simple matter of switching the package the consumer subscribes to. The private ISP can engage in profit seeking behavior much more explicitly and directly compared to a local government administering taxes. That is, the providers are entrepreneurs rather than democracies. In an online economy, consumers are far better informed about the choices available as well. Finally, the public good nature of the products considered here is partial; they are not pure public goods, reducing the severity of the problem to be addressed. All these factors make the choice of segregation into communities an even more attractive option in the case of online users as compared to residential communities.

Assumptions

The assumptions underlying the distribution model for local markets are stated below:

1. The consumers can switch among communities costlessly and without significant delay.
2. Consumers belong to different types according to which set of products they prefer. The distribution of these types is common knowledge, though it is not known to the ISP as to which type each consumer belongs to. Consumers will switch to the community that matches their preference type.
3. There are at least as many communities as there are types of consumers.
4. Communities are autarkic and cannot trade among each other.
5. Each community has a fixed factor of production, (bandwidth) that sets an upper limit on its size. Beyond the limit, congestion will degrade the value of the products being sold. Changing this factor (as by expanding infrastructure) will entail significant costs.
6. Consumption in any community doesn't produce any external economies in relation to other communities.

Analysis

Assumption 1 is necessary to enable users to keep moving till they find the community that best matches their valuations, and thus allow the provider to capture the demand information. In the setting of content distribution networks, this is a realistic assumption, as the move from one community to another entails only switching a provider node, and not a physical move. Such a switch is relatively costless, and fast.

Assumption 2 states that customers' preference type is private information. But providers do know which types exist. This helps organize consumers into communities homogeneous in type, and by virtue of assumption 1, consumers effortlessly migrate to their matching community, revealing the private information by their choice. For example, providers may organize products into

family packages, news and finance packages, sports and action packages etc.

Assumption 3 ensures that there is a sufficiently large number of communities to support consumer choice and an efficient allocation. If not, many consumers may be left out, and communities may not all be homogeneous. How realistic this assumption is will depend on how many types there are: in one extreme case, each consumer may belong to a different type, leading to communities of one consumer each. In the other extreme, all consumers may belong to the same community that provides all the goods. Given the nature of the products offered, it is reasonable to assume that neither extreme is likely, and that a moderate number of preference types may be identified. This implies that types are identified based on common characteristics, and minor variations may be ignored. This is reasonable, and is employed in various real world pricing scenarios for simplicity of administration, as well as due to the low marginal gain obtained by seeking finer granularity of types.

Assumption 4 ensures there is no resale among communities. If a consumer wishes to obtain a combination i of goods, she must choose the community that provides i . In a multimedia distribution network with interactive content, we believe this is a justifiable assumption.

Assumption 5 sets a reasonable limit on the size of a community served. With a bounded resource, a maximum size is determined by the minimum average cost of producing the services. This cost to the ISP is incurred in terms of the infrastructure to distribute content from ISP node to local consumers; since that infrastructure will have a bandwidth and server limit beyond which QoS will degrade, this is a reasonable assumption. Otherwise, the ISP could infinitely expand the size, especially given that the product may be replicated at will. Essentially, the maximum size will be the optimal level the ISP seeks to operate at. Below it, the profit seeking ISP will (ideally) seek to attract more customers, and above it, it will not, as congestion will result.

Assumption 6 essentially states that consumers in one community are affected by what transpires in other communities only

through the subscription fees and migration, and no external effects occur.

Given these assumptions, consumers will switch among communities till their preference type is matched. Such moves will typically bring the destination communities closer to their maximum size. It is always possible that a subset of consumers will not be satisfied; but as the supply improves through increased broadband penetration and content availability, the market will move closer to equilibrium. At equilibrium, no given consumer will be better off by choosing another community, and no provider will be better off by increasing or decreasing the size of its community. The requirement for choosing a community forces the consumer to reveal her preference type by the act of choice, and once preference is revealed, the provider can charge a subscription fee based on it.

A key aspect of the model is the relation of cost of product to the size of a community. The notion of existence of an optimal size is dependent on this relation. If the cost of product is independent of the size, (for instance if cost of content rather than cost of bandwidth determines the cost of the product and no per capita royalty payments are required) the model can lead to inefficiencies. However, it is reasonable to assume that cost of the delivered product does depend on the size of community, since both bandwidth and royalty can be constraining factors.

The ISP nodes procure the products through the shared distribution market. The aggregate amount they get in that market may be thought of as reflecting total demand across all the consumers. Thus the role of the ISP is similar to an intermediary. The larger and more diverse the set of communities, the closer this market approximates a general equilibrium scenario. Note that so long as ISPs obtain the product through a common market, any upstream allocation system can co-exist with this model. The multicast-based shared distribution fits as an example due to its own rationale of eliminating redundant use of capacity as well as its ability to combine products in transit into combinations.

We can add another assumption stating that the number of communities is finite and significantly less than the number of

consumers to preclude the possibility of the model converging to a market where each consumer is served with a combination that exactly matches her preferences. However, marginal costs of providing additional combinations will be sufficient to limit the number of communities from exploding.

What this division into communities does is to convert the economy into a spatial economy, albeit it is the cyberspace rather than physical separation. The great advantage in using cyberspace to separate consumers is that you obtain separation at minimal transport costs, which makes more efficient allocations possible. This is indeed a general principle that may be extended to other realms of the digital economy.

DISCUSSION

As mentioned earlier, it is possible that some customers may not find a community that meets their preferences with room for new members even if they are willing to pay the fee. This is essentially an issue of insufficient supply.

This model has profit seeking providers maximizing the population of their communities subject to constraints. If they were in perfect competition, the equilibria would be Pareto optimal. If not, monopoly rent may be extracted from customers, or oligopolistic games could result.

If the shared distribution model is used, the products are bid on individually, whereas community memberships are based on preferences for combined products. Some of the products in any given combination may not be procured due to failing bids: that raises the issue of whether to provide a partial bundle or none at all. One solution would be to conduct *bundled* or *combinational* auctions upstream where products are delivered only in bundles as bid by ISP nodes. The local providers would submit bids for a bundle of goods, and would win full bundles or none at all. That would increase the computational complexity and may need more heuristic solutions. A more pragmatic solution would be to only advertise bundles that have already been procured through bidding; using historic downstream demand information in each

period to tender bids for subsequent procurement from upstream.

While discussing the shared distribution model, it was stated that the surplus is shared among the ISPs in proportion to their bids; this is not strictly necessary. (This strategy can act as an incentive against under-bidding by ISPs.) Alternate strategies may be used to distribute surplus. Their significance would be that the prices upstream would be determined based on them.

CONCLUSIONS

The conceptual model outlined allows an economically rational way of providing broadband content that is consistent with the engineering environment, and feasible. It induces a feasible allocation that approximates the optimum, and addresses the public goods problem effectively in the local markets. In the context of the phenomenal growth in the market for broadband content, viable and scalable business models are essential, and this discussion sets out the framework for such models.

The paper implies that it is desirable to extend the multicast protocols so as to form the technological substrate for broadband content provision in a shared manner, and to develop associated business protocols. It suggests that it is more efficient to aggregate content into customized bundles in local markets rather than at source. In the local markets, diversity of content and of providers should be encouraged to improve customer choice and social welfare.

REFERENCES

- ABI Research, "Broadband Video Is Set to Threaten the Prevailing Video Distribution Models", *Business Wire*, July 12, 2004.
- Clark, D. and J.Wroclawski, "An Approach to Service Allocation in the Internet", 1997. Available at: www.watersprings.org, last accessed 30 Oct 2004.
- Federal Communications Commission, "Report on High Speed and Advanced Telecommunications Capability in the United States", Available at: www.fcc.gov , last accessed September 2004.
- Gupta, A., B. Jukic, M. Parameswaran, D.O. Stahl and A.B. Whinston, "Streamlining the Digital Economy: How to Avert a Tragedy of the Commons", *IEEE Internet Computing*, Nov-Dec 1997, 1:6, pp.38-46.

In terms of regulatory policy, it is essential to promote consumer mobility by reducing switching costs, and lowering barriers to entry. It should be mentioned that in the growth phase, significant investments are required to build the infrastructure needed to extend market penetration, and the regulators may choose to protect the first mover in markets with limited coverage. They may open up the market later for alternative providers as well, and allow for easy switching. Once the infrastructure is in place, it will be desirable in the consumers' interest to have it opened up for competitors. This will allow consumers to choose on available product bundles rather than on who owns the infrastructure. These are somewhat controversial issues in telecommunications policy today; as such policies are seen to not protect the investments made by broadband providers.

It would be useful to empirically verify some of the conclusions of the model. Whether profit maximizing local providers trying to maximize their community size can lead to Pareto optimality under the assumptions made could be the subject of such an inquiry.

ⁱ QoS: a general term that may refer to various attributes of a data flow that characterize the quality of the connection, depending on the manner in which the flow provides value; attributes may include peak and burst rates, latency, jitter, packet drop probabilities etc. For our purpose, QoS may refer to a consistent peak rate that should be maintained, which can be interpreted as a token bucket rate in a premium service model. We use the term capacity to refer to this peak rate.

- Herzog, S., S. Shenker, and D. Estrin, "Sharing Multicast Costs", in L.W. McKnight and J.P. Bailey(Eds.), *Internet Economics*, The MIT Press, Cambridge, Massachusetts, 1997.
- McAfee, P. and J. McMillan, "Auctions and Bidding", *Journal of Economic Literature*, June 1987, 25, pp.699-738.
- Nichols, K., V.Jacobson and L. Zhang, "A Two-Bit Differentiated Services Architecture for the Internet", 1997. Available at: www-nrg.ee.lbl.gov , last accessed 30 Oct 2004.
- Parameswaran, M., J. Stallaert, and A.B. Whinston, "A Market Based Allocation Mechanism for the Diffserv Framework", *Decision Support Systems*, 2001, 31:3, pp. 351-361.
- Parameswaran, M., J. Stallaert, and A. B. Whinston, "Shared Distribution of Digital Products using Multicast", Under review, 2004.
- Research and Markets, "Worldwide Market for the Video Game and Interactive Entertainment Industry to reach \$33.4 billion by 2008", *Business Wire*, July 29, 2004.
- Samuelson, P.A., "The Pure Theory of Public Expenditures", *Review of Economics and Statistics*, Nov.1954, 36:4, pp. 387-89.
- Striganesh, P., "Internet Cost Structures and Interconnection Agreements", in , McKnight, L.W and J.P. Bailey(Eds.), *Internet Economics*, MIT Press, Cambridge, 1997, pp. 269-286.
- Stiglitz, J., "Theory of Local Public Goods", in Feldstein, M., and R. Inman (Eds.), *The Economics of Public Services*, , Macmillan, London, 1977.
- Stump, M, "Streaming Becomes a Revenue Stream", *Multichannel News*, July 19, 2004.
- Tiebout, C., "A Pure Theory of Local Expenditures", *Journal of Political Economy*, 1956, 64, pp. 416-424.
- Tirole, J., *The Theory of Industrial Organization*, Cambridge,MA:The MIT Press, 1988.

AUTHOR



Dr. **Manoj Parameswaran** is an Assistant Professor of Operations & Management Information Systems at Santa Clara University. His research interests include resource allocation in networks, content distribution, and peer-to-peer networks. He holds a PhD in Information Systems from The University of Texas, Austin. mparameswaran@scu.edu