Not Paying the Truck Driver: Differentiated Pricing for the Future Internet

Dirk Trossen
University of Cambridge
dirk.trossen@cl.cam.ac.uk

Gergely Biczók
Budapest Univ. of Technology and Economics
biczok@tmit.bme.hu

ABSTRACT

We are all used to the way we pay for our Internet experience. We buy 'connectivity' from our local Internet Service Provider (ISP) and then consume a variety of Internet-based services. Some of these charge additional fees, mostly without any service guarantee. Numerous efforts have been undertaken to provide price differentiation in the Internet through introducing various control planes to be placed on top of the IP data plane. This paper is taking a fresh look at this by approaching the space more fundamentally. For that, we question the very foundation of the Internet, namely the transport of opaque data between two entities. Instead, we outline an architectural approach that focuses on information being routed, enabling differentiation at lower cost and higher scalability. We do not claim to have found the compelling evidence through evaluations that such cost and scalability benefits are indeed true. Instead, we intend to open the discussion in this area by focusing some of the new architectural approaches in the Internet on the issue of pricing regimes.

Categories and Subject Descriptors

C.2.1 [**Network Architecture and Design**]: Distributed Networks

General Terms

Design, Economics

Keywords

pricing, differentiated pricing, information networking

1. INTRODUCTION

Imagine a supermarket visit. After you have picked your groceries, you encounter two checkouts. At the first one, you pay a charge for several products, not for all of them though since quite a few are free. At the second one, you pay again but to a different person, wearing the insignia of the delivery company that supplied the supermarket. Sometimes, you might have a choice to pay different delivery companies, with all charges being monthly flat fees. A disturbing thought of our supermarket experience, is it not? But this is how we would translate the common Internet pricing model to other areas of our lives. But why paying the truck driver in the Internet? Why can we not pay for a product without worrying if I paid my basic 'delivery charge' to somebody further down the value chain?

The Internet is not all about flat fees. Content pro-viders, for instance, do pay for peering with certain transit networks. But when it comes to customer-facing pricing models, there is little beyond flat fee pricing for basic connectivity. Granted, services like IPTV or VoIP are appearing that charge for the service not its connectivity. But these examples are rare and require an extensive control plane infrastructure to make it happen. Differentiated pricing, however, is widely used in other industries for extracting consumer surplus and efficient resource utilization. Examples for this are the travel industry (market-differentiated pricing with booking classes and time-based differentiation for tickets purchased well in advance), pharmaceutical companies (geolocation differentiated pricing for various regions), or the retail industry (product-differentiated pricing with coupons, rebates and bulk prices). Furthermore, time- or locality-based discrimination allows for shifting resource provisioning towards hotspots of consumption. The Internet, on the other hand, only prices a basic resource consumption that aims for cost recovery of the original investment while services are mainly charged over the top, if at all. Only recent efforts in congestion pricing attempt to introduce some form of discrimination for the over-usage of resources at times of peak demand, similar to congestion charges in major cities, e.g., London. The question, of course, remains if the ability for product-differentiated pricing (PDP) itself would have an impact on methods for resource allocation on the (Internet) transport level. But why is price discrimination so difficult to achieve today? We shed some light on this question by focusing on the core foundation of the Internet, i.e., the transport of opaque data between endpoints and the problems that come with this approach when attempting price differentiation. In a move to support differentiated pricing, we propose a strawman architecture in which information is routed rather than opaque data. We investigate how such paradigm change could enable methods for product differentiation that go beyond today's possibilities. We also outline

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the challenges that need to be addressed to make this happen.

The paper is organized as follows. Section 2 gives an overview of pricing regimes. Section 3 provides a sketch for an information-centric architecture where individual information items are routed. Section 4 addresses a variety of challenges that we see in need to be addressed before a fully product-differentiated pricing regime will be feasible in the Internet, before we conclude in Section 5.

2. PRICING IN THE INTERNET

In this section, we give an overview of existing indifferent, integrated and (to some extent) differentiated Internet pricing regimes. We also argue that real differentiated pricing can be based on differentiation of pieces of information.

2.1 From Indifferent Pricing. . .

Historically, Internet-related pricing for end-users has been implemented at two tiers: most users pay for their network-level connectivity in some form of (bits and/or time based) flat fee, while some users pay for products (typically content or value-added services) at the application-level. One can argue that the latter is differentiated pricing, since users pay different prices for visibly different products. However, the Internet is only a medium in this case: we pay "on the Internet", but not "for the Internet". The key issue here is that the current TCP/IP architecture does not provide built-in hooks for differentiated pricing. IP does not expose product features without explicit higher layer signaling. Furthermore, old wisdom and empirical evidence (e.g., from the INDEX project) show that users prefer flat-rate fees to varying costs in connectivity [1].

In a number of industries, e.g., public transportation or retail, differentiation in price and quality is a frequently used tool that provides higher revenues and increases resource utilization. The pervasiveness of communication services, on the other hand, renders the above arguments secondary, while the users' desire for simplicity wins. Additionally, work such as in [2] shows that complicated pricing schemes do not result in larger profits for service providers – simplicity is what matters for end users. The main problem here is that end users perceive *connectivity* as a single product rather than an enabling service element (which might have different 'value' depending on the overall product being provided); hence they prefer a one-price-for-all (flat) pricing approach while over-the-top pricing is used for particular products.

2.2 . . . Over Integrated Pricing . . .

In an attempt to integrate 'connectivity' into a wider product range that is priced individually, *bundling services* is utilized by ISPs in so-called double, triple-, or quadruple-play service offerings. With this bundling, *integrated pricing* is used to set prices for services of each revenue producing department so that together they optimize the firm's (here the ISP) net income.

With that, bundling becomes a middle ground of some sort between indifferent and differentiated pricing. A user can get substantial discounts if subscribing for a whole suite of services instead of only a service of her choice. Cable companies use this kind of pricing regime to sell fixed line phone services and digital television, which usually comes with on-demand (pay-per-view) features potentially generating extra profit.

In a converged, all-IP world, bundling could mean a pricing plan integrated along Internet access, VoIP, and IPTV. The charging function in such system requires extensive explicit (out-of-band) signaling, implemented via complex control plane approaches, which have not been designed to offer real differentiated pricing beyond a few converged services.

2.3 . . . To Differentiated Pricing

Although they have not become widespread, a number of pricing schemes were proposed in the literature to harness the potential benefits of differentiated pricing. Due to space constraints, we do not review these proposals one-by-one, rather we point the reader to [1] [3]. The most widely used ideas in these works are *congestion pricing*, *smart markets*, and *service differentiation*; proposals either make use of single ideas, or some combination of them.

The two main goals of these proposals are to ensure efficient utilization of network resources and high revenues for the operators. Often, it is nearly impossible to satisfy both of these criteria at the same time, e.g., while congestion pricing is able to induce efficiently shared resources, it may not be feasible to use it as a charging basis for commercial network operators [3].

A smart market is another paradigm [4] to facilitate differentiated pricing in the Internet. It consists of packets having a "bid" field, and packets being processed in the order of bids. Users are then charged the capacity-clearing price. This mechanism facilitates truthful bidding, i.e., users will report their true valuation to the system. While the idea itself is genuine and interesting, it has a high transactional overhead due to its explicit bidding signaling, which leads to feasibility problems in real-world systems.

Service differentiation enables differentiated pricing by introducing *service levels*, effectively aggregating individual products into product classes that can be charged differently. DiffServ [6] is an example for a service differentiation approach that marks packets (according to their service level) as they traverse the network. Although it has not been deployed in a global scale, DiffServ is often used within operator networks (even for charging). However, since service levels are scarce, DiffServ only provides a reduced ability for differentiated pricing across several operators. Also, mechanisms are required for users and applications to mark their packets accordingly.

Common to all the above mechanisms is that they require applications to contain a certain out-of-band signaling (and therefore pricing) logic that goes hand-in-hand with the packet delivery. This may be feasible in a controlled environment or at a small scale, but not in the autonomous and complex system of today's (and more so tomorrow's) Internet. We assert that real product-differentiated pricing (PDP) across a wide range of products and across various networks *can only be achieved through implicit marking on data plane level, while reducing the need for complex out-of-band signaling.* This, however, will require some sort of architectural support from the network.

In order to justify our point, we borrow from the history of pricing in early transportation industries: it is shown that price discrimination was a significant driving force in the development of those industries [5]. In order to make differential charging effective, transportation providers reserved the right of thorough inspection of the cargo in question. This precedent might explain the will of network operators to gain greater knowledge and control over data that is transmitted over the Internet. *Deep Packet Inspection* (DPI), performed by operators to determine the nature of traffic flowing through their network, is a step in this direction. However, it breaks the current Internet architecture, while still being flawed by potential false positive results of the inspection. But it outlines the goal, namely to determine the *nature of information* (transportation: nature of goods) for differentiation in pricing. Hence, we assert:

> *If the network architecture provided explicit identification of information (with the possibility of supporting relevant additional metadata), real product differentiation could be achieved.*

We believe that an information-centric network architecture could enable flexible information-driven markets with varying pricing strategies, apart from providing many other benefits beyond implementing PDP [10].

A lot of questions arise in the context of PDP. Can it truly scale? Do end users have to abandon flat rates? Can sufficient metadata be provided? Can an effective incentive structure be designed for all players in the Internet ecosystem? We discuss these open issues in Section 4.

3. AN INFORMATION INTERNET

In the following, we outline an architectural approach to differentiated pricing through introducing a new approach to routing at the internetworking level. For that, we directly follow our assertion above by introducing information identification on routing level with the aim of capturing the long tail of the information market, i.e., the part of the market for which the usage of out-of-band signaling (see Section 2.3) is too expensive and non-scalable to perform.

3.1 Intuitive Foundation

Intuitively, we view the problem of products offered and delivered in the Internet as one of facilitating *information markets*, i.e., markets in which a set of information can be priced and traded. Such information can relate to content, services, context and even identities. We assert that facilitating such markets is achieved by basing all network operations on the notion of *information* being the primary named entity across all layers. We believe that such viewpoint aids the consistency of concepts across the layers as well as enables common cross-layer policy statements that help defining the various information markets.

Specifically for the network architecture, this intuitive view translates into the assumption that each piece of information has a statistically unique name. Applications (or services) can request from the network to deliver named information – which can be charged for individually. In order to make the vast amount of information manageable but also to allow for isolating individual pricing and market offerings, we introduce a concept called *scope* that relates individual information to some common goal (which could be associated with a particular pricing strategy). From the network's perspective however, the scope merely denotes the party being responsible for locating a copy of the data. Scopes therefore create a point of control, which enables e.g., access control and usage policies related to a set of data. An information

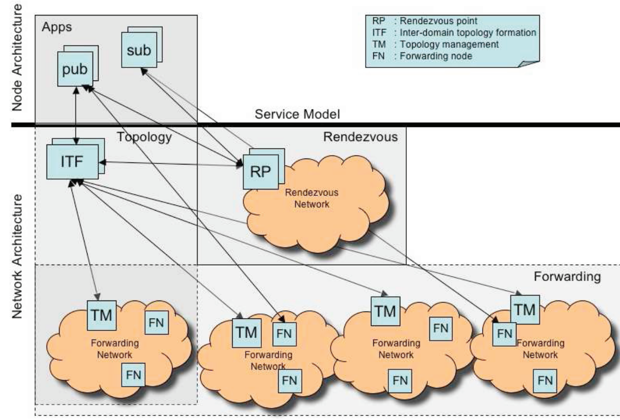

Figure 1: Conceptual architecture

item can be placed in more than one scope, e.g., when re-offering the product represented by the information item in a different context.

In order to mimic a supply-and-demand model of markets, we assume a *publish-subscribe model* as the underlying service model. Hence, information is published by any provider, while it is subscribed to by anybody who is interested in it. In other words, data exchange only occurs when demand and supply match in the form of published (and subscribed) information item within a particular scope.

3.2 Conceptual Architecture

Following our intuitive foundation, we now formulate an architecture that places information at the centre. It enables a mapping of the information concepts onto concrete forwarding relations between endpoints, producing and consuming information. We can only provide a glimpse here; more can be found in [7] [10] [11].

Figure 1 presents the main architectural components. The application-level *pub* and *sub* components utilize the basic publish-subscribe network services. Also transactional services, operating in request-reply mode, can be supported, with the server subscribing to receive requests. The network architecture itself consists of three main functions, *rendezvous*, *topology*, and *forwarding*. The rendezvous function implements the matching between publishers and subscribers. As mentioned before, information items reside within at least one scope, which is provided by dedicated rendezvous points. There is at least one rendezvous point per scope, each of which subscribes to the scope through a global rendezvous system. Upon subscription to an information item in the scope, the request can be routed either to all or to the 'best' rendezvous point, using anycast-like functionality. Furthermore, rendezvous points implement policies associated with the matching, such as access control or accounting for pricing purposes.

After a successful match, the forwarding topology is created in negotiation with the *inter-domain topology formation* (ITF) function. Such creation is based on the publisher and subscriber "locations" at the level of forwarding networks, any applicable policies and the ITF information that includes peering and transit relationships among forwarding networks. Thus, there exists a rich set of policies attached to potentially every information item. Unlike today's inter-domain peering, this approach allows for multiple ITF functions, each offering different sets of peering and transit opportunities[1]. This establishes the potential for peering markets, with the ITF function being similar to *routing service providers* [8].

In addition to building inter-domain paths, appropriate intra-domain paths are constructed via the *topology management* function that resides in every forwarding network. This function instructs the local *forwarding nodes* (FNs) to establish paths to local publishers and/or subscribers or to serve as transfer links between networks. Publisher and subscriber locations are identified as mere *link identifiers* that only require local (network-level) uniqueness while the inter-domain path ensures delivery between forwarding networks. As in the current Internet architecture, our approach does not prescribe any particular intra-domain forwarding mechanism, with the one constraint that the local mechanisms should support the traffic policies chosen by the ITF function. An example for such intra-domain forwarding is found in [11], supporting native multicast in MAN size groups.

We recognize that the outlined architecture requires many problems to be solved that are independent from our particular view on pricing in this paper. Ongoing efforts, such as in [9] [10] however make us assume the potential future availability of such architecture in some form. We therefore omit the implementation details of the required functions and concentrate on the particular aspect as to how such (or similar) architecture could provide new methods for pricing and market creation.

3.3 Relating Pricing to Information

Two concepts are key to relate different pricing regimes to information being transferred. The first is that of *scoping*, enabling the grouping of information under a coherent concept, e.g., a communication service provided, a social network being enabled, or a collection of information sold under a common pricing regime. For instance, a group of videos (each being individually identified) could be collected under a single scope that is associated to a particular pricing structure for the video offering. The necessary accounting within the network can be achieved through the individual identification that is used for scopes and information items. Hence, pricing can (even recursively) be implemented per item or per scope. This allows for aggregation of pricing strategies with accounting functionality being possibly implemented at the appropriate points in the network (e.g., at ingress nodes within forwarding networks). The approach in [12], for instance, outlines how to relate self-created information identifiers to individual parties for accounting purposes. It also provides a mechanism to ensure the trustworthiness of scopes and items through a notion of a *scope owner*.

A related issue is that of *metadata*, which is information about information, such as individual items or entire scopes. It could include, among others, pricing information pertaining to the information the metadata is 'linking' to. Such linking is easily enabled at the network level through the individual identification of information that traverses it, including the identification of the metadata itself.

3.4 Differentiated Resource Allocation

Relating pricing regimes to the information traversing the networks is only one side of enabling differentiated pricing. Another one is that of differentiated resource usage based on the exchanged information. Grouping information along pricing structures (and providing an efficient way of referencing to these pricing structures through metadata) allows for more fine-grained control of resources like interdomain paths, caches, or even radio spectrum. For instance, Section 3.2 outlined the possible selection of different ITF functions based on the information being transferred.

Hence, the direct identification of the information (utilizing the resources) and the efficient provisioning of metadata (outlining the underlying pricing regimes) enables an inband signaling that promises to be significantly more efficient than current out-of-band approaches. Hence, the data plane could subsume many of the functions of today's control plane approaches while providing a higher granularity of product differentiation through the individual identification of the information (and hence, the product). Such possibilities for more fine-grained control let us even envision methods for dynamically switching off unused resources based on popularity of information (groups)[2].

4. CHALLENGES TO BE ADDRESSED

There are many challenges to be addressed in order to move from the conceptual architecture in Figure 1 to an Internet with a wide support for differentiated pricing. This section outlines a few crucial ones, defining a possible agenda for the wider research community.

4.1 Accounting for Resource Usage

While the architecture in Section 3.2 provides identification of individual information items with the ability to group them through its scoping mechanism, the issue of resource accounting is not specifically addressed. Hence, *solutions are required that utilize the explicit information labeling to account for resource usage throughout the network.* This could be done through resource monitoring at ingress/egress points of network domains. As mentioned in Section 3.2, also the formation of the inter-domain topology provides hooks for price differentiation based on individual information items or groups of products. Given the explicit labeling of information, we can expect a more efficient implementation of such resource monitoring, probably in hardware, than current DPI technologies.

4.2 Handling Payments

The ability to monitor resource usage on a fine-grained level, see Section 4.1, potentially enables to efficiently solve the problem of handling payments throughout the system. The foundation of this is the development of a set of (organizational) pricing structures that efficiently utilizes the concepts of scoping that the underlying architecture supports, e.g., in the form of various (pricing) scopes for different industries or various scopes for different pricing regimes across industries. *This effectively requires research into pricing ontologies that could be reflected with the concepts provided by the architecture, similar to [13].*

In addition to the information structures, mechanisms are required for large-scale provisioning of the accounting in-

[1]The selection of appropriate ITF functions can be based on pricing strategies that are associated with the information item or the scope it resides in.

[2]However, this might require collaboration with the rendezvous functionality of the architecture, i.e., the function that matches supply and demand of information.

formation that has been gathered within the defined pricing structures that underlie the product-differentiated pricing regimes. In essence, *a clearinghouse plane is required that consolidates the accounting information with the pricing structures into a 'price label' that can be associated with a particular information item (or group of items).* Certain industries, like the mobile Internet one, have been investigating solutions in this space for limited offerings. We believe that the underlying information provisioning architecture of Section 3 enables the large scale realization of this plane beyond a single industry.

4.3 Structure of Metadata

Section 3.3 points to the concept of metadata as being crucial in relating information to pricing regimes. While it is understood that, generally, individual information items can be 'linked' to pricing regimes as a form of metadata, it is an open question as to *what information this metadata needs to entail, what its structure could be and how it could be (effectively) structured in itself?*

In this, a key role will fall to standard bodies as to define the framework in which this metadata will be described.

4.4 Impact on the End User

Does a product-differentiated pricing regime mean an end to those flat fees that we all became accustomed to? Music streaming services, for instance, already charge flat fees, although they apply to the entire product, not to a single service element (connectivity). Differentiation leads to a pricing regime, where the cost for a particular product is exposed to the end user, not the distribution along the value chain for the particular product. And this applies for the end user herself when turning into a, e.g., content, provider. What arises is the problem of price setting strategies in which the end user needs to participate (or not). Because of this, we see a potential role for *brokers* that trade content or information on behalf of end users that do not want to directly participate in a price setting exercise. In conclusion, such fundamental change away from a well known flat fee connectivity price to a supermarket-like product pricing *requires research into the impact on user behavior and acceptance of various pricing regimes, the role of price setting strategies (and the end user's understanding of these) and other end user related issues.*

4.5 Creating the Ecosystem

Such rather radical shift in pricing structures that we propose in this paper requires an understanding of how to create an ecosystem that makes the proposed differentiated pricing feasible. Incentives need to be understood and, if necessary, created for all major players, namely ISPs, service and content providers and end users.

A major step is that of recognizing that current over-the-top pricing with flat rate connectivity fees creates an imbalance that threatens the viability of the current ecosystem. There is growing evidence that major parts of the industry do recognize this issue. The line of arguments presented in [14] is still valid in the current industry structure, compiled and presented by major players of the industry. And the continuing debate on network neutrality in various parts of the world, with attempts to prioritize the delivery of particular content, also shows that product differentiation is seen as a way forward. One major driver in this debate is the need for the right incentives for continuous infrastructure investment [14].

Once recognizing the current imbalance, *creating a set of incentives for change and sustainable investment is crucial.* One such incentive, for ISPs, could lie in the potential for caching. The ability to 'relate' information on routing level opens the potential for pre-filling caches based on experienced or expected demand. Coupled with the envisioned accounting and payment methods of Sections 4.1 and 4.2, payment would flow to the ISP who can best provide the requested and most relevant information.

A main incentive for content providers could lie in the ability for fine-grained price differentiation. Only a thorough economic evaluation, however, will shed light on the expected revenue optimization by better accounting for resource usage in such differentiation schemes. This has to be aligned with the preference of end users for calculable bills, a major driver for flat fee connectivity charges.

Generally, a deep understanding is required of the various markets that are being created with such product-differentiated approach. The work in [15] outlines early results for the problem of information rendezvous markets.

4.6 Impact on the Pricing Strategies

Authors of [2] introduce the "price of simplicity" as the ratio of revenues from flat rate pricing and the theoretical maximum revenue. They also show how differentiated service classes produce around the same revenue as a single class and a flat fee. While being an interesting result, it is unclear how to translate this onto an information-centric Internet, where the potential for price differentiation spans many service, including connectivity, level. *Hence, we need to revisit this issue with similar work that compares (connectivity) flat rate, PDP and maximum revenue.*

The economic impact of architectural content-awareness is analyzed in [16]. While it points to possibly qualitatively relevant results, the results are ambivalent regarding welfare and revenue optimization impact. Furthermore, it compares two architectural choices, while our proposal is a transitional one, i.e., migration strategies can counter some of the effects outlined in [16], such as the clutter effect. *Hence, we have to evaluate a transition from a traditional IP towards an information-centric network with regards to welfare, revenues, and consumer surplus.*

5. CONCLUSION

Price differentiation is commonplace in our society – but hardly in the Internet. We are still fixed into a behavior where we buy connectivity separately from the product we are actually interested in (information, services, content). We believe that the root for this is a deeper architectural one, which is why this paper has outlined an architectural approach to overcoming it. For that, we have sketched an internetworking architecture that places information as individually identifiable elements in the centre of its operations. We strongly believe that this paves the way for product-specific differentiation, utilizing the architecture's support for structuring information along the resulting pricing regimes. This approach, however, does not come without its challenges. These form a research agenda for the wider community to focus their efforts to finally enable differentiated pricing in the Future Internet.

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