Two-Sidedness of Internet Content Delivery

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Abstract— **The amount and importance of content is increasing in the Internet whereas the current Internet's ability to scale to the growing demand of transport capacity is unclear. Information networking featuring in-network caching has been suggested as a future networking paradigm but its market potential has not been widely studied. This paper evaluates market prospects of information networking by analyzing the current and future Internet content delivery models: the client-server model, content delivery network model, and information networking model. Value networks and two-sided markets of these content delivery models are identified in the process. The results suggest that content providers may be willing to invest in information networking due to their high willingness to pay for better than best effort content delivery. In addition, if information networking reduces off-net costs for Internet access providers significantly, they may consider investing in information networking deployment. The results are valuable in recognizing the need for further research on information networking's business models and feasibility.**

Keywords- two-sided markets, Internet, content, value network, information networking

I. INTRODUCTION

Fundamental changes are taking place in the Internet as the traffic volume keeps growing and more and more content is being provided [1]. At the same time, content sources are consolidating and most Internet inter-domain traffic flows today directly between large content providers, content delivery networks (CDNs) and consumer networks [2]. However, with the concentration of content sources also comes scarcity of data center and network capacity. As a consequence, the focus has shifted from connectivity to content.

Information networking (also content-centric networking) is a new networking paradigm that seeks to solve the scalability issues by adapting the network architecture to current network usage patterns. The concept introduces routing based on content names instead of location of the content and utilizes in-network caching of content [3][4]. In addition to Van Jacobson's Named Data Networking (NDN) project, two EU-funded research projects, SAIL and PURSUIT, are studying the concept. Even though the technical challenges are driving the research, the importance of understanding the socio-economic aspects and stakeholder incentives should not be underestimated if information networking is expected to be deployed in the real world.

Evaluating the market potential of a technology just being defined is not simple. One potential approach is to analyze similar technologies existing in the market and then draw conclusions based on the findings. From this perspective, CDNs are similar to information networking in focusing on content instead of location and doing caching in the network. Interestingly, a CDN can be considered as a two-sided platform, which aims at getting both content providers and Internet service providers (ISPs) on board, and thus contributes to the success of CDNs [5]. Therefore understanding how widely two-sided pricing is used in Internet content delivery is highly relevant.

In this paper, the market potential of information networking is investigated based on the analysis of current Internet content delivery models. Literature review and eight expert interviews covering key stakeholders (Internet service providers, content providers and data center providers) in Finland during 2010 [6] are used as an input for identifying the value networks and two-sided markets of altogether three content delivery models: client-server model, CDN model, and information networking model. The key findings are the following:

- Multiple two-sided markets are identified both in the content service and Internet interconnection layer, but they seem to be more natural in the content service layer.
- Two-sided pricing in the CDN market causes CDN providers to consolidate and may induce the content providers to grow in number.
- Content providers have higher willingness to pay for better than best effort content delivery than ISPs have. This suggests that content providers may have an incentive to pay for information networking to be deployed.
- In-network caching reduces Internet access providers' (IAP) off-net traffic costs, which can motivate IAPs to invest in information networking. Nevertheless, without a way to monetize their investment, IAPs may instead consider moving into CDN business offering similar cost savings and a revenue model that has been proven to work.
- To get accepted by content providers, information networking solutions need to solve coordination

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problems in delivering both the guaranteed service level and usage statistics to content providers.

The rest of this paper is organized as follows. Section 2 gives a brief overview into the two-sided market theory and interconnection pricing. Section 3 describes the value networks of Internet content delivery models, so that the identification and analysis of two-sided markets is possible in Section 4. Section 5 discusses the implications of the identified two-sided markets to the market potential of information networking and Section 6 concludes the paper.

II. TWO-SIDED MARKETS THEORY AND INTERCONNECTION PRICING

Two-sided markets theory belongs to the field of economics called industrial organization which studies the structure of markets and strategic interactions between firms. The theory explains the behavior of firms in markets that exhibit two-sidedness and is closely related to network externalities [7]. Rochet and Tirole [8] define two-sided markets as *markets with two distinct sides that are interlinked* (through a platform) *and where not only the overall price level matters but also the price structure between the two sides*. The demand asymmetries between interlinked markets typically lead to skewed pricing with one side charged more than the other. For example, the credit card industry is two-sided with credit card companies acting as platforms offering services below marginal costs to card holders and collecting revenue from the merchants.

Since the two-sided markets are formed through asymmetric cost-allocation, the pricing models of Internet connectivity form the basis for the analysis. This paper assumes that the consumer access pricing is flat-rated. Moreover, the current Internet interconnection models, *i.e.*, transit and peering contracts, are taken as given also in the future, even though realization of information networking may require completely different cost-allocation mechanisms. Due to space constraints the reader is referred to [9] for a full treatment of the transit and peering contracts. In brief, networks having peering agreement exchange traffic reciprocally without monetary compensations whereas charging in transit agreement is based on the volume of traffic exchanged and realized using 95th percentile billing principle. On-net and off-net traffic are another important concept, because they have different marginal costs for an ISP. Traffic is said to be on-net if both end-points are located in the same ISP's network, and off-net if the end-points are located in different ISPs' networks.

III. VALUE NETWORKS OF INTERNET CONTENT DELIVERY

Value network analysis gives a solid foundation for the two-sided market analysis because it shows graphically the existing two-sided markets. This section presents the value networks of the three Internet content delivery models and gives a brief description of each model as well as the used value network notation, which is then followed by the actual value network analysis.

A. Internet Content Delivery Models

This paper focuses on content delivery between content providers and consumers. The client-server model, CDN model and information networking model are alternative end-to-end solutions for a content provider to reach their audience. In this paper, the client-server model means the basic end-to-end connection between the content provider and the consumer. The CDN model, on the other hand, divides the end-to-end connection into two separate connections: one between the content provider and the CDN provider, the other between the CDN provider and the consumer. The value added by a CDN is reliability of the network, reduced latencies for consumers, better throughput and origin server load balancing [10].

Routing in the information networking concept is based on what data is sought instead of where the data is [4]. Three recently proposed architectures are NDN [11], PSIRP [12] and NetInf [13]. NDN and NetInf can operate as overlays on any kind of network topology whereas PSIRP is a clean slate approach to replace the Internet Protocol (IP) network. The basic idea of information networking is that the network has cache servers that cache data and the data moves freely in the network. These cache servers should be placed into the access networks as close to the consumers as possible. In practice, when a piece of content traverses from the origin server to the host who has expressed interest in the content, the network elements in between caches the content. If other hosts in the same area request the same content, any one of the network elements that sees the request may reply with the content. As a consequence, the importance and load of origin servers diminish.

B. Value Network Analysis

Several stakeholders affect the formation of the value network; the ones considered in this value network analysis are defined as follows. **Content makers** produce the content, **content providers** act as portals for aggregated content and **consumers** use the content. **Data center providers** supply server space whereas **ISPs** provide Internet connectivity and include IAPs and Internet backbone providers (IBPs). **IAPs** operate access networks and **IBPs** backbone networks. In addition, **CDN providers** offer CDN services. **Advertisers** insert advertisements into final products in the distribution process and **sponsors** input their brand names during the content making process.

The value network notation used in this paper is adopted with a few modifications from Allee's [14] Three Currencies of Value and Zhao's [15] value exchanges that are used in the networking context. The currency names used are thus: traffic transfer, monetary transfer and intangible benefits. The intangible benefits are further divided into three categories based on Allee's [16] [17] definition of intangibles: brand recognition, information and loyalty. The different value exchanges in the value networks are denoted with different line styles and arrow heads.

This paper divides the Internet content delivery into two layers: the *content service layer* where the traffic is digital products like video clips or pieces of music, and *the Internet interconnection layer* where the traffic is plain bits. Fig. 1

shows the simplified value network of the content service layer, which stays the same regardless of the underlying Internet content delivery model. Fig. 1 can also be considered as the content provider's internal value network as it shows the origin of the content, the different ways the content can be stored and the different revenue sources of the content provider.

Fig. 2, Fig. 3 and Fig. 4 present the Internet interconnection layer value networks for each model. The relative traffic volume between stakeholders is presented with the difference in thickness of the arrows.

In the three Internet interconnection layer's value networks, consumers in the consumer group 1 (C1) have the same IAP as the content provider; thus they are on-net users. Consumer group 2 (C2), on the other hand, includes the rest of the users who are not on the same network. Due to this division, consumer group 2 is assumed to be bigger in size than consumer group 1. As a consequence, IAP2 is also bigger than IAP1 and the traffic between the consumers and their respective access provider is of different volumes as is shown in the value networks above. The monetary transfers from the consumers to the content provider equal the amount of traffic received by the consumers and thus are of the same thickness as the traffic between consumers and their respective IAP. However, though the monetary transfer equals the traffic volume, the source of the monetary transfer may not always be the consumers but some other revenue models may be used as is shown in Fig. 1.

The traffic into the Internet backbone provider always has the same volume as the outward traffic from the IBP because IBP presents all the Tier-1 providers through which the traffic traverses. In addition, the IBP only has inward monetary transfers as all stakeholders connected to it have to pay for the connection.

The traffic transfers from the content provider to the IBP, IAP and CDN show the alternative ways for a content provider to distribute content to off-net users and the three routes can replace each other or be used simultaneously. The transfer arrows in Fig. 2 and Fig. 3 are, however, of different sizes as the on-net traffic also traverses the route between the content provider and its IAP, whereas the other routes are only used by off-net users. In Fig. 4, the content is cached at the IAP1, thus the traffic volumes from the CP to the IAP1 and IBP are of the same size.

In Fig. 2 and Fig. 4, the monetary transfers always equal the corresponding traffic transfers. In the CDN case, however, the content provider pays the CDN provider for the amount of

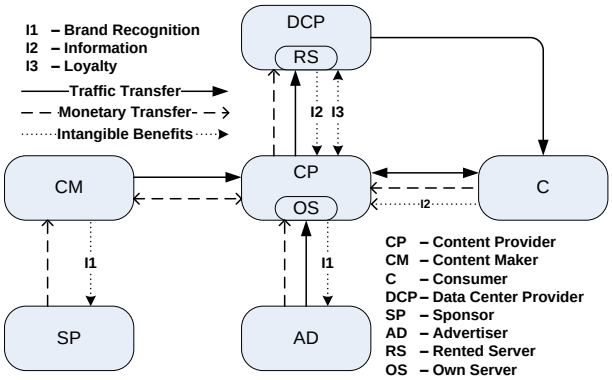

Figure 1. Simplified value network of the content service layer.

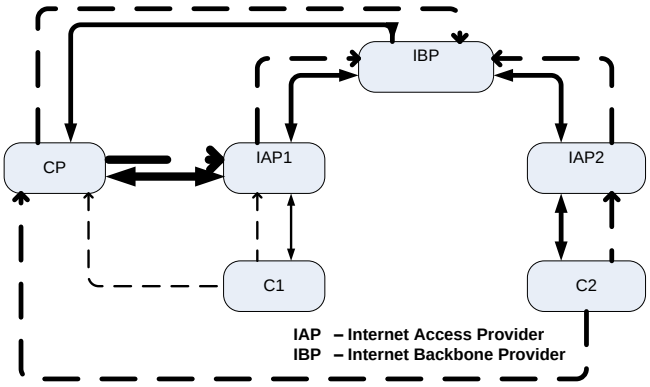

Figure 2. Value network of the client-server model with weighted arrows.

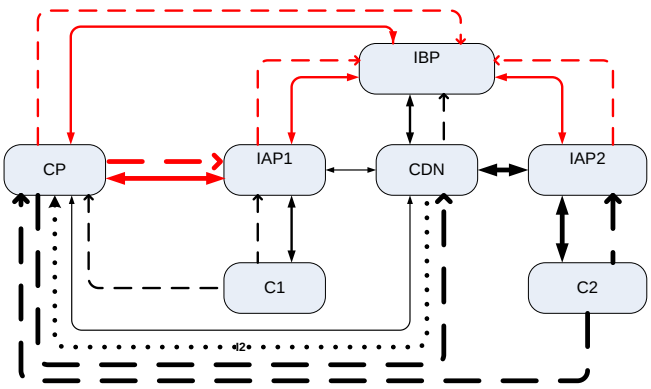

Figure 3. Value network of the CDN model with weighted arrows.

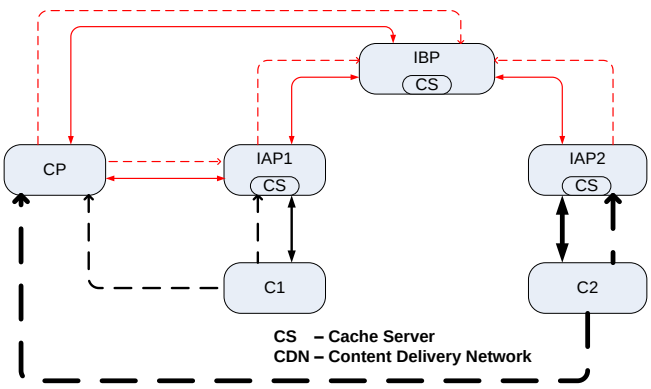

Figure 4. Value network of information networking with weighted arrows.

traffic delivered and thus the monetary transfer from the content provider to the CDN equals the traffic transfer between the CDN and IAPs rather than the traffic transfer between the content provider and CDN. Despite of heavy traffic, no money is exchanged between the CDN and IAPs.

With the addition of the CDN and cache servers, the traffic volume between the content provider and its IAP lessens. In addition, the traffic volume through the Internet backbone also decreases in the CDN and information networking models. These changes are highlighted in Fig. 3 and Fig. 4 by using red arrows. CDN also adds an intangible benefit to the network in the form of collected usage information, as is shown in Fig. 3.

IV. TWO-SIDED MARKETS IN INTERNET CONTENT DELIVERY

This section identifies and analyses the most important two-sided markets in both the content service and Internet interconnection layers. However, because the focus of this paper is on the different content delivery models and not on the services provided, the content service layer's two-sided markets will be discussed only briefly.

A. Identified Two-Sided Markets

The identified two-sided markets are shown in Table 1, where the asterisk (*) sign shows the side that is being subsidized. The advertising, sponsorship and content sharing markets shown in white background are located in the content service layer whereas the two-sided markets in grey are located in the Internet interconnection layer.

The content service layer's two-sided markets have already been discussed in detail in previous studies. For example, Hagiu [18] discusses the advertising market's two-sidedness with a Googlecase, and Rochet and Tirole [19] explain the sponsorship and content sharing markets through Portals and media, and PC operating systems cases.

From the Internet interconnection layer's two-sided markets, the IAP and IBP markets are common to all three content delivery models. From the CDN model, a unique two-sided market is present – the CDN market, of which a similar analysis has been done in earlier works by Faratin [5]. However, in the information networking model, no unique two-sided markets are found, the consequences of which are discussed in the challenges of information networking section. The Internet interconnection layer's two-sided markets are discussed in more detail in the following subsections.

B. IAP Market

The IAP market has Internet access provider as the platform with the two sides being on-net consumers and off-net consumers of the same IAP. On-net consumers are assumed to be the users who generate mostly on-net traffic while off-net users generate mostly off-net traffic. In this setup, the off-net users are being subsidized because presumably off-net traffic is more costly for the IAP to deliver than on-net traffic but both consumer groups are being charged the same price for the same level of service.

Looking purely from an economics theory point of view,

TABLE I. TWO-SIDED MARKETS IN INTERNET CONTENT DELIVERY.

Platform	**Side 1**	**Side 2**	**Market**
Content Provider	Consumers*	Advertisers	Advertising Market
Content Maker	Consumers*	Sponsors	Sponsorship Market
Content Provider	Consumers*	Content Makers	Content Sharing Market
Internet Access Provider	On-net Consumers	Off-net Consumers*	IAP Market
Internet Backbone Provider	Eyeball heavy IAPs*	Content heavy IAPs	IBP Market
CDN Provider	ISPs*	Content Providers	CDN Market

the main consequence of subsidizing off-net traffic producers is that they will produce even more off-net traffic and that on-net producers will also start to produce off-net traffic. This will lead to more off-net traffic and less on-net traffic, which causes higher costs and lower profit to the Internet access providers. If the costs of IAPs rise too high, they might want to limit the amount of off-net traffic or establish more peering agreements with other IAPs. In addition, IAPs may also raise prices for all consumers to cover the increasing costs and declining profit. Alternatively, if the IAPs are not able to pass on the higher costs onto consumers, the revenue may not cover costs and they may go out of business.

In addition, with the decrease of on-net traffic, the market may lose its two-sidedness and become a one-sided market. Together with the rising prices, the IAPs with the highest costs may lose consumers and eventually some IAPs may go out of business. However, the two sides in the IAP market do not benefit from each other directly and consumers usually do not know where the other end-point is located, which may suggest that the IAP market is not two-sided after all.

C. IBP Market

The Internet backbone provider is the platform in the IBP market, with "eyeball" heavy IAPs (IAP1) and "content" heavy IAPs (IAP2) on the two sides. Eyeball heavy IAPs, such as Verizon or AT&T, connect consumers to the Internet, whereas content heavy IAPs, such as Abovenet or Cogent, host a lot of content servers [20]. The two-sidedness of the market is based on the traffic and cost asymmetries of the upstream and downstream traffic, where the IBP incurs more costs from the receiving IAP [21]. In the Internet content delivery context, eyeball heavy IAPs are expected to have mainly downstream traffic while content heavy IAPs produce upstream traffic. Assuming that both sides are using the 95th percentile billing algorithm, upstream and downstream traffic are not differentiated in billing [9], thus the eyeball heavy IAP is being subsidized in the IBP market.

The subsidy to eyeball heavy IAPs is passed on to the consumers, who perceive more value from the connection and thus may generate more traffic for both the eyeball heavy IAP and IBP. As a consequence, the content providers connected to the content heavy IAP may gain more clients or more advertising revenue, which may lead to more profit. However,

when the Internet access providers' off-net traffic increases, it follows the same analysis as in the IAP market.

When content providers gain more clients and possibly profit, more content is made to be distributed and more content providers may enter the market, which in turn may attract more consumers. This cycle will continue until the market is saturated. The increase in both content supply and consumers leads to more demand for ISP services. As a conclusion, it can be said that the two-sided pricing in this two-sided market is beneficial for the Internet backbone providers as the higher Internet penetration likely increases their revenue. For the Internet access providers, the situation may be the opposite due to the increase of off-net traffic and the potential threat of going out of business.

D. CDN Market

The CDN model presents its own two-sided market with the CDN provider as the platform. The two sides are content providers and Internet service providers. When CDNs first emerged into the market, two business models were tested by two big CDN providers: Akamai charged the content providers for the service and Inktomi charged ISPs [22]. Seeing that Akamai's revenue model now dominates the CDN market, charging the content providers for the service rather than ISPs seems to be more feasible. Thus as can be seen from Fig. 3, no money flows between the IAP and CDN provider; *i.e.*, ISPs are being subsidized in the CDN market.

When a CDN provider subsidizes IAPs, it will be connected to more IAPs, and thereby has a better reach to the consumers. All content providers want to be connected to the CDN with the largest reach of consumers. As a consequence, both more content providers and more IAPs connect to this CDN, which then may grow into a natural monopoly or at least a few large CDNs will dominate the market; *i.e.*, an oligopoly situation. All stakeholders benefit from this situation, including the consumers who reach more content providers and experience better quality.

V. CHALLENGES OF INFORMATION NETWORKING

Several challenges for the deployment of information networking have been identified based on the key findings of this paper and are discussed in this section. First is the two-sided pricing in the CDN market, which causes CDN providers to consolidate and become network wide CDNs. As information networking can be seen as a CDN with caching done at access network level, a network wide CDN can be a direct competitor to information networking.

The CDN model, being a two-sided market, has a central platform that coordinates the service provisioning and offers service level guarantees. In addition, the CDN provider provides usage statistics to the content providers as a service. Information networking does not have a unique two-sided market with a central platform that can offer guaranteed service levels and value added services. As content providers value both service level guarantees and usage statistics, information networking needs to solve these issues to gain acceptance from content providers. In addition, content caching makes identifying each individual user more difficult, which is important for the advertisers that are a revenue source for the content providers. To solve this problem, IAPs could collect usage and user information for the content providers. However, information networking's ability and IAP's willingness to provide such services is not known.

The content provider's control of its content is another issue in information networking, especially with dynamic contents such as targeted marketing. This means that conflicts may arise between the content providers and IAPs: the IAPs may not have the incentive to update content caches very frequently while content providers may wish the content to be up to date. Legal measures and monetary incentives may help solve this conflict but it, nevertheless, has to be solved before information networking can prosper.

The central platform also makes charging of the service simpler. In information networking, it is unclear who can monetize the service offering and who should be charged for the service. The CDN market's analysis suggests that content providers have higher willingness to pay for better than best effort content delivery than the ISPs. Despite this, ISPs' willingness to deploy information networking is more crucial as they control the network locations, where cache servers should be located. One potential platform could thus be the ISPs, if they can pass the extra costs to the consumers or content providers.

IAPs' willingness to invest in information networking can be determined by summing up the net benefit of reduced off-net traffic, extra investments and other costs. IBP's willingness to add cache servers to its network may be stimulated by the significant falling of Internet transit prices [23]. Since transit revenue has traditionally been the major income for IBPs, IBPs are now shifting to other revenue sources such as providing CDN services [2]. Thus IBPs may be open to the possibility of finding viable revenue models from information networking.

VI. CONCLUSION

Information networking is a prominent concept for solving the problems of the current Internet but it still faces both technical and especially business challenges. Content delivery networks, a kind of early information networking approach, prosper because they have solved the coordination problem of end-to-end quality of service and have utilized the demand asymmetry between Internet access providers and content providers. Successful deployment of two-sided pricing has made CDNs attractive to both IAPs and CPs. Current information networking proposals are missing a similar kind of platform solving coordination challenges related to the cost-allocation, contracting and content usage statistics.

The deployment of information networking requires that the incentives of all stakeholders are aligned. Even though content providers make the final decision how to deliver their content to consumers, ISPs' willingness to deploy information networking is crucial as they control the network locations, where cache servers should be located. However, their willingness to invest is not clear because no business model for ISPs to pass investment costs to content providers exists. Therefore possible business models and value network configurations of information networking need to be studied in

the future. Another interesting future research topic is whether a platform, two-sided or not, can and need to be devised to enable the success of information networking.

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