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Internet Content Delivery as a Two-Sided Market

Faculty of Electronics, Communications and Automation

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The amount of content is increasing in the Internet but the current Internet's ability to scale with the growing demand for Internet capacity is unclear. To determine this, various studies on the future of the Internet have been initiated; including studies on information networking.

This work utilises value networks and the two-sided market theory in explaining the current and predicting the future market structure of Internet content delivery. The formulated value networks and SWOT analysis are used for comparing the different content delivery models; the client-server model, Content Delivery Networks (CDNs) and the Content Centric Network (CCN) model. In addition, the market potential for information networking (CCN) is investigated.

Four two-sided markets in the Internet interconnection layer are identified in this work and the two-sided analysis predicts the consolidation of CDNs and Internet service providers (ISPs). However, the number of content providers is expected to rise based on the two-sided market analysis. The value network analysis shows that the CDN and CCN models reduce off-net traffic compared to the client-server model for Internet access providers (IAPs). If the off-net cost for IAPs is reduced significantly, the CCN model may have a business case. The SWOT analysis comparison based on the formulated evaluation criteria for content distribution models concludes that most stakeholders prefer CDN and CCN models, whereas the content provider clearly favours CCN. The results are valuable in recognising the need for further research on the information networking's business model and the feasibility of implementation.

Keywords: Two-sided Markets, Future Internet, CCN, CDN, Client-server Model, Value Networks, SWOT

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Sisällön määrä kasvaa Internetissä ja nykyisen Internetin kyky skaalautua Internetin kapasiteetin kasvavaan kysyntään on epäselvä. Tämän selvittääkseen lukuisia tutkimuksia tulevaisuuden Internetistä on käynnistetty, mukaan lukien tietopohjainen verkko (information networking).

Tämä työ hyödyntää arvoverkkoja ja kaksipuolisten markkinoiden teoriaa selittämään nykyiset ja ennustamaan tulevaisuuden markkinarakenteet Internet sisällönjakelussa. Rakennettuja arvoverkkoja ja SWOT analyysia käytetään eri sisällönjakelumallien vertailemiseen; asiakas-palvelin-, CDN- ja CCN-malli. Lisäksi, tietopohjaisen verkon (CCN) markkinapotentiaalia tutkitaan.

Neljä kaksipuolista markkinaa on tunnistettu Internetin yhteyskerroksella tässä työssä ja kaksipuolinen analyysi ennustaa CDN:n ja palvelutarjoajien kasvamista. Toisaalta sisällöntarjoajien määrää odotetaan laskevan kaksipuolisen markkinan analyysin perusteella. Arvoverkkoanalyysi osoittaa, että CDN ja CCN mallit vähentävät pääsyverkon tarjoajien liikennettä muiden tarjoajien verkkoihin (off-net liikenne). Jos pääsyverkon tarjoajien off-net liikenne vähenee huomattavasti, CCN mallilla voi olla markkina-arvoa. Sisällönjakelumalleille laadittujen arviointikriteerien perusteella tehty SWOT analyysivertailu osoittaa, että useimmat sidosryhmät arvostavat CDN ja CCN malleja kun taas sisällöntarjoaja selvästi suosii CCN mallia. Tulokset ovat arvokkaita, koska ne tunnistavat tarpeen tehdä lisätutkimusta tietopohjaisen verkon liiketoimintamalleista ja toteutettavuudesta.

Avainsanat: Kaksipuoliset markkinat, Tulevaisuuden Internet, CCN, CDN, Asiakas-palvelin malli, Arvoverkot, SWOT

Preface

This Master’s Thesis has been written as a partial fulfilment for the Master of Science Degree at Aalto University, School of Science and Technology. The work was carried out in the Department of Communications and Networking as a part of the ICT cluster of the Finnish Strategic Centres for Science, Technology and Innovation (ICT SHOK) Future Internet Programme of Finland.

I wish to express my gratitude to the people who have supported me in this work. First of all, I wish to thank Professor Heikki Hämmäinen for providing the opportunity to work in his team and write this thesis under his guidance. I am especially grateful to Tapio Levä for his valuable advices and support throughout the research process. I also wish to thank the Networking Business team for their comments and discussion as well as the interview participants for their valuable insights. Furthermore, I wish to thank William Martin for proofreading the final draft of the thesis manuscript.

Last but not least, I wish to address my gratitude to my family and friends for their support during the course of my studies. Special thanks to my parents for providing me with an excellent upbringing and encouragement throughout my life.

Espoo, 26th October 2010

Nan Zhang

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Symbols and Acronyms

Symbols

p^B	Price of Buyers
p^S	Price of Sellers
π	Profit
c	Marginal Cost
D^B	Demand of Buyers
D^S	Demand of Sellers
η^B	Price Elasticity of Demand of Buyers
η^S	Price Elasticity of Demand of Sellers
p	Total Price Level
η	Total Elasticity
V^B	Net Surpluses of Buyers
V^S	Net Surpluses of Sellers
W	Social Welfare
b^S	Benefit of Seller
p_1^S	Price of Sellers of Platform 1
$\hat{b}_{12}$	Average Price of Additional Demand When Multihoming
d_1^B, d_2^B	Demand for Buyers for Platforms 1 and 2, Respectively, When the Seller Multihomes
σ_i	Singlehoming Index of Platform i
Q_i	Transaction Volumes for Platform i
m	Total Margin on the Downstream Markets
N_i^B	Transaction Volume
U_i^B, U_j^B	Net Utility for Buyers in Platforms i and j

Acronyms

3G	Third Generation
AS	Autonomous System
CCN	Content Centric Networking
CDN	Content Delivery Network
CP	Content Provider
CS	Cache Server
IaaS	Infrastructure as a Service
IAP	Internet Access Provider
IBP	Internet Backbone Provider
ICT	Information and Communication Technologies
IO	Information Object
IP	Internet Protocol
ISP	Internet Service Provider
Mbps	Megabit per Second
NetInf	Networking of Information
P2P	Peer-to-Peer
PaaS	Platform as a Service
PC	Personal Computer
PSIRP	Publish-Subscribe Internet Architecture

RP	Rendezvous Point
SaaS	Software as a Service
SLA	Service Level Agreement
SWOT	Strengths, Weaknesses, Opportunities, Threats
TV	Television
UCS	Unified Computing System
VNI	Visual Networking Index

1. Introduction

Fundamental changes are taking place in the Internet as the traffic amount keeps growing and more and more content is being provided. As a result, much research has been done in the field of Internet traffic trends. The most recent Cisco Visual Networking Index (VNI) whitepaper (Cisco, 2010a) has shown that the traffic and video amount in the Internet is growing with an alarming rate and will keep growing in the future.

The increasing traffic amount has led to the consolidation of content sources, i.e. large Content Delivery Networks (CDNs) and Internet Service Providers (ISPs) become even larger (Labovitz et al., 2009). However, with the concentration of content sources also comes scarcity of data centre and network capacity. In addition, the interconnection agreements between ISPs become more complicated and the traditional agreement types do not apply fully anymore. As a result, the focus has transferred from connectivity to contents.

Information networking is a new network concept that tries to solve the current problems in the Internet. The concept introduces routing based on content names instead of location of the content (Jacobsen et al., 2009). Three reference architectures have been developed based on the concept; Content Centric Networking (CCN) (Jacobsen et al., 2009), Publish-Subscribe Internet Architecture (PSIRP) (Fotiou, Polyzos and Trossen, 2009) and Networking of Information (NetInf) (Ahlgren and Vercellone, 2010). Each of these architectures is being researched in different research projects and the Finnish Future Internet project's work package 3's main focus is on PSIRP (ICT SHOK Future Internet, 2007).

In the content distribution market, many markets exist where one side of the market is charged while the other side is subsidised, such as the CDN (Faratin, 2007), portals and media (Rochet and Tirole, 2003) and streaming media technology (Rochet and Tirole, 2003). Thus in this work, these kinds of two-sided markets play an important role in evaluating the market feasibility of different content distribution models.

1.1 Research Question and Objectives

While two-sided markets exist in different industries, they have not been widely recognised. Managers and policy makers do not yet distinguish two-sided markets or intentionally use two-sided theory for pricing and regulations. However, because two-sided markets should be regulated and priced differently from one-sided markets, it is important to know which markets are two-sided. Drawing value network graphs is an easy and clear way to visualise the relationships between each player in a given market. Thus the main research questions are as follows:

> *What are the possible two-sided markets in Internet content delivery?*
> *What are the value networks for each technical Internet content delivery model?*

Because this work is done in the Future Internet project, the answers to the main research questions are used to analyse information networking. The following supplementary question expresses this:

> *Where is the market potential for the proposed information networking models?*

To obtain the answers for the above questions, the following objectives are set for this work:

- Identify the main stakeholders for each content delivery model: client-server, CDN and information networking.
- Identify the traffic transfer between stakeholders.
- Identify the monetary and non-monetary transfers between stakeholders.
- Identify costs and pricing faced by Internet service providers (ISPs) and content providers (CPs).
- Identify the two-sided markets of client-server, CDN and information networking.
- Compare each content delivery model with SWOT (strength, weakness, opportunity, threat) analysis.

1.2 Research Scope

The term Internet content has quite different meanings for different industries and in this work it is defined as follows:

> *Internet content is the bits and data packets that are distributed in the Internet such as video files, a piece of news or an html page.*

In addition, the terms content delivery and content distribution are considered as synonyms for each other and used interchangeably.

Most of the works on two-sided markets have focused on the two sides of consumers and service providers, because the focus has been on the services provided on the content layer. However, in this work the focus is on the Internet interconnection layer and from the CDN's perspective the ISPs represent the consumers. Thus the two sides of the market are the ISPs and the content providers. A short overview of the content layer's two-sided markets is also given. On the other hand, the consumers are significant for the content providers and thus the value network analysis will include consumers whereas the actual two-sided analysis concentrates only on ISPs and content providers as the two sides of the market.

Several architectures and models for distributing content exist in the Internet, three of which will be investigated in this work; the client-server model, CDNs and information networking. Peer-to-Peer (P2P) is also a prominent model for content distribution, but because the focus is not on consumers and the P2P model is not widely deployed by content providers (Interviews: CP1, CP2), it is not discussed in this work. Out of the three chosen model, the client-server model will only be dealt with briefly as the focus is on CDNs and information networking.

The feasibility analysis is mainly based on the cost analysis even if the investigation concludes in finding other criteria for evaluating feasibility. This is because the foundation for two-sided markets is the cost structure of a service or industry. The possible other criteria will be discussed very briefly.

1.3 Research Methods

In this work, two main research methods are adopted; a literature review and interviews. A literature review is used to give a solid background to the two-sided market theory. In addition, a literature review is used to build a foundation for the interviews regarding the different content distribution models.

Semi-structured interviews are conducted to discover the advantages and disadvantages of the current models used in content distribution. The interviewees are divided into three groups; the content providers, the Internet access providers and the data centre providers. In addition, the focus is on the costs each group faces when distributing contents. The interviews also aim at finding other criteria for evaluating the current content distribution models. A list of questions is constructed for each group as a guideline to the interviews and is shown in Appendix B.

1.4 Structure of Thesis

The structure of this work is presented in Figure 1.

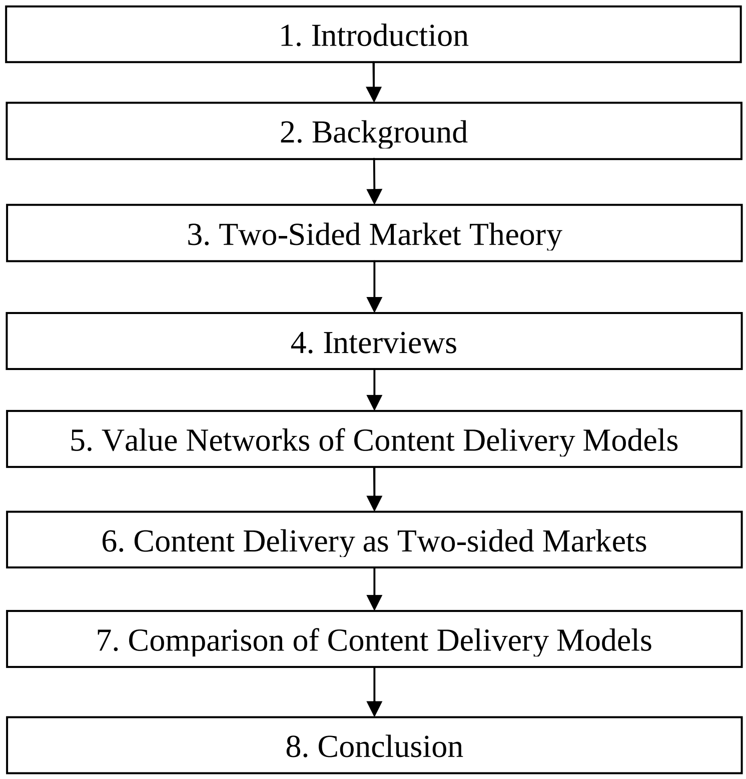

Figure 1. Structure of thesis.

The rest of this work is mainly divided into two parts. The first part consists of the background research and starts with Section 2, which describes the technical background of the work including the interconnection agreements. Section 3 introduces the two-sided market theory and presents the mathematical model to support the theory. Section 4 explains the interview procedure and summarises the results obtained from interviews. Section 5 introduces the three content delivery models and their costs as well as creates each of their value networks.

Sections 6 and 7 belong to the second part of the thesis, which provides an analysis of the different Internet content distribution models. Section 6 identifies the two-sided markets in each model and applies two-sided market theories onto them. Section 7 compares the results obtained in Section 6 and analyses them.

The final section in the thesis is Section 8 which contains the conclusion and future research proposals. In addition, this work has two Appendices; Appendix A gives the calculations to prove the two-sided market mathematics and Appendix B lists the interview questions.

2. Background

This work includes many economics and technical terms and concepts, which need some explaining. This section aims at explaining these concepts for a better understanding of the rest of the work. An overview of the Internet interconnectivity principles and agreements are first presented. The section then continues with explanations of the stakeholders considered in this work as well as discusses the different available content distribution models.

2.1 Internet Interconnection

Internet interconnection and its policies play an important role in this work. This section explains the structure of Internet interconnection along with the transit and peering agreements between Internet service providers.

The Internet (Clark et al., 2008) is a network of networks called Autonomous Systems (ASes). These ASes are administered by commercial Internet service providers, corporations and other enterprise providers, universities, government agencies as well as content providers and other specialized service providers. The ISPs offer Internet access to consumers and enterprises for a monetary compensation. In order for the ISPs to offer an end-to-end service to the consumers, interconnection between ASes must be arranged, which means cooperation between ISPs. Mainly two types of interconnection agreements exist in the Internet; the transit and the peering agreements.

Transit is when the lower level operators buy access to the upstream operator's whole network (Norton, 2010a). This means that transit agreements provide access to all the nodes in the upstream operator's routing table and it is the upstream operator's responsibility to provide connectivity to the whole Internet for the lower level operators. Peering (Norton, 2010a), on the other hand, is a bilateral agreement between two operators to access each other's customers. No monetary compensations are paid by either of the operators. Peering agreements are not transitive, which means that the operators can only access each other's customers but not the rest of the network.

A combination of the two interconnection agreements together with the ISPs form the simplified Internet hierarchy followed by traditional Internet interconnection and is shown in Figure 2. Tier 1 network operators have full-coverage of the Internet (Laffont, Marcus, Rey and Tirole, 2003) and do not buy transit services from other network providers (Norton, 2010a). Tier 2 network operators are regional and local operators that buy the transit service from Tier 1 operators and sell the connection to the consumers.

The traffic stays on-net from an operator's perspective if it stays within its own network. For example, in Figure 2, when traffic is within only one consumer group, it is on-net traffic. Off-net traffic, on the other hand, is when traffic traverses to another operator's network. From the figure, traffic between the two groups of consumers is off-net traffic. Due to the interconnection agreements, on-net and off-net traffic cause different costs for operators.

The originating network means the sender's network while the terminating network is the network where the receiver resides. When the traffic flows from the originating network to the upper level operators in the hierarchy it is called upstream traffic. On the contrary, downstream traffic is the traffic that flows from the upper level operators to the terminating network. For example, in Figure 2, when a user from consumer group 1 sends traffic to a user in consumer group 2, the traffic first goes upstream until it reaches Tier 1, then it goes downstream to consumer group 2.

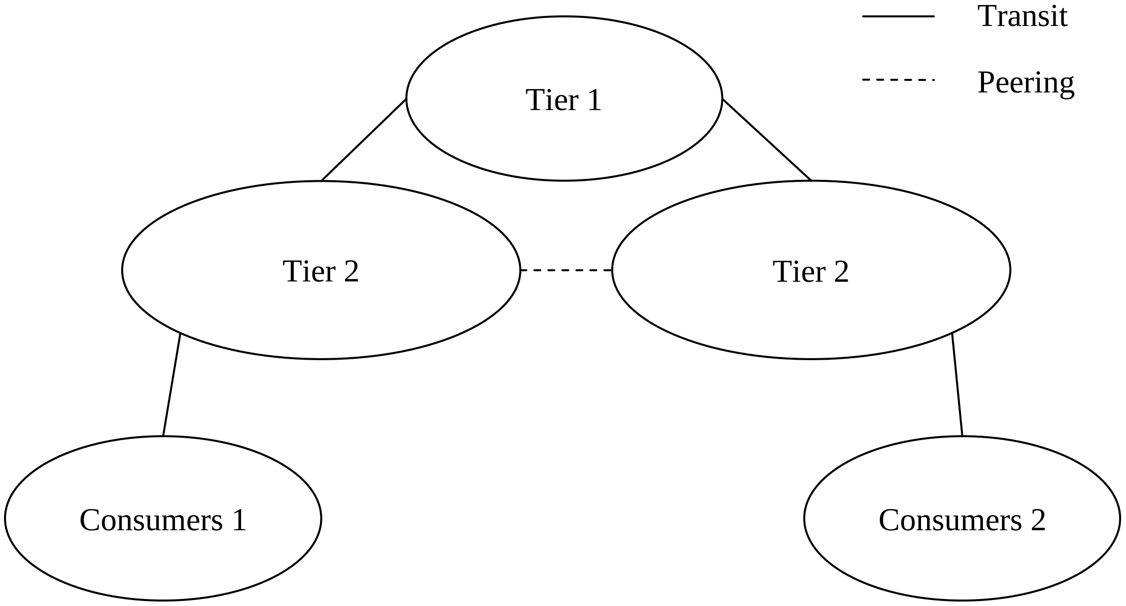

Figure 2. The simplified Internet interconnection structure. (Shakkottai and Srikant, 2006; Norton, 2003)

increase of large content sources and the increase of peering traffic, the traditional hierarchy no longer applies purely to the current Internet (Labovitz et al., 2009). The more complex interconnection relationships mainly include two new interconnection types; paid-peering and partial-transit (Clark et al., 2008).

2.2 Stakeholders

This section explains the different stakeholders considered in this work and their roles in the content distribution market. The stakeholders used in this work are content provider, content maker, data centre provider, Internet service provider, Internet access provider, Internet backbone provider, CDN, consumer, sponsor, and advertiser.

- **Content provider (CP)** has a central database of content and distributes it to consumers through different means of content delivery. Mainly three types of content providers exist:
    1. Makes own content and distributes it.
    2. Buys content from content makers and distributes it.
    3. Provides a platform for the content makers to distribute their content against a small fee or royalty.
- **Content maker** makes the content to be distributed. A content maker can be a separate actor or operate within the content provider.
- **Data centre provider** rents server capacity to anyone who needs it; in this case the content provider.

- **Internet service provider (ISP)** offers Internet interconnectivity services to clients and in this work an ISP can be divided into:
  1. **Internet access provider (IAP)** is the local network operator or Tier 2 operator (Norton, 2010a), which offers Internet connections to consumers and content providers.
  2. **Internet backbone provider (IBP)** is a full coverage network provider or Tier 1 provider.
- **Content Delivery Network Provider (CDN)** is the actor offering CDN services. CDN is an Internet overlay, which offers additional value to the basic Internet content delivery.
- **Consumer** in this work includes anyone who uses the content offered by the content provider.
- **Advertiser** and **sponsor** are revenue sources for the content providers and content makers. For compensation, the content providers or content makers embed adverts from these actors in their content. The main difference between an advertiser and a sponsor is that the advertiser inserts adverts only at the stage of distribution while a sponsor includes their products or brand name already in the stage of content making.

The search actors such as Google and Yahoo that match requests to content are not considered in this work for simplicity because they can exist in any of the distribution models and do not affect the traffic or monetary transfers between the discussed stakeholders.

2.3 Content Delivery Models

For a content provider trying to distribute content, several models exist. The most basic is the client-server that is employed in the basic Internet. Cloud and CDN offer a comprehensive package of services to the content providers in addition to the content delivery. In addition, the P2P model and different architectures of information networking are also means of Internet content delivery.

Client-server

Currently, the basic Internet is mainly based on one computing system model; the client-server model (Lewandowski, 1998). In the client-server model a server or a pool of servers stores information and services and waits passively for the clients to request them. The client can be any consumer that request services from the server.

The client-server model requires network components to function properly. These network components are located between the client and the server for structured communication, i.e. the basic Internet interconnectivity structure. The servers and clients connect to the Internet access providers, who in turn connect to the Internet backbone provider for connection to the whole Internet. These together with the software used in the network form the basic Internet infrastructure, which can be used for content distribution.

Cloud

Cloud computing (Vaquero, Rodero-Merino, Caceres and Lindner, 2009) is a service for better and easier hardware and software management. Clouds are pools of virtualised resources such as software, hardware and services that can be easily accessed. The idea of the cloud is to move the infrastructure to the network, which reduces the costs of resource managements and offers better scalability and flexibility.

The cloud offers mainly three services; Infrastructure as a Service (IaaS), Platform as a Service (PaaS) and Software as a Service (SaaS). In IaaS a hardware provider virtualises its resources so that they can be split and assigned dynamically to the customers. PaaS offers software platforms where systems can run on and the hardware resources required for this service are allocated in a transparent manner. SaaS offers software over the Internet as an on-demand service. All these cloud services are charged with a pay per use model and the service level agreements (SLAs) guarantee the quality of service.

Content Delivery Network

A content delivery network offers still more comprehensive services than cloud computing. The CDN was designed as an overlay on top of the basic Internet to provide better content distribution services. Internet overlays are virtual topologies that reside on top of the basic Internet and add value to the Internet by, for example, guaranteeing the data retrieval and offering load balancing (Doval and O'Mahony, 2003). The value added by a CDN are reliability of the network, reduced latencies for consumers, better throughput and origin server load balancing (Vakali and Pallis, 2003).

The CDN structure does not differ much from the basic end-to-end connection; only an additional stakeholder and network element is added into the basic network; the CDN servers and network (Vakali and Pallis, 2003). This means that the connection is no longer end-to-end, rather it is divided into two separate end-to-end connections: between the client and the CDN and between the CDN and the content server. The services CDNs offer are comprehensive – ranging from storage and distribution to hardware and software management – making content delivery easier for the content provider.

The CDNs' business model is to build or rent networks and to sell capacity. Content providers pay the CDNs for the services they offer based on the amount of traffic transferred. For the larger content providers, a direct link is connected to the CDN for transfer of content. The smaller content providers transfer data to the CDN through an ISP.

Peer-to-Peer

Another overlay to the basic Internet is the peer-to-peer network (Schollmeier, 2002), which consists of distributed resources connected by the network. It has the same network components as the client-server model. The only difference is that the clients connected to the network can also act as servers whereas in the client-server model, the roles of client and server are distinct.

Peer-to-peer networks have two architectures; the pure peer-to-peer and the hybrid peer-to-peer network. The pure peer-to-peer network does not have any central entity that controls the communication. In addition, the network service level does not suffer from a removal of one peer. The hybrid peer-to-peer network, on the other hand, has a central entity that controls the communication and offers part of the services.

Information Networking

The current Internet was originally designed as an overlay to the telephone network and has not had major architectural changes since the beginning. It is an end-to-end network that connects two hosts wishing to communicate with each other. The routing of packets is based on the destination and source addresses. (Jacobsen et al., 2009) However, with the increase of content sharing in the Internet, the current architecture has become inefficient and new solutions are being developed.

Routing in the information networking concept is based on what data is sought instead of where the data is (Jacobsen et al., 2009). This concept was first introduced by Van Jacobsen in a presentation in Google Tech Talks on August 30th 2006 (Jacobsen, 2006), where he also identified the problems faced by the old telephone network and the current packet-switched Internet.

The information networking concept aims at reaching a scalable and robust network, where security and trust are identified as the features that need to be implemented into the information networking design rather than as add-ons. The three reference architectures are the CCN, PSIRP and NetInf. CCN and NetInf can work as overlays on any kinds 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. The data moves freely in the network. No clear standards on the existence of origin servers have been defined yet. If origin servers do exist, they would need less capacity as the data requests do not have to always go by the origin server due to the caches. This means cost savings for the content provider.

CCN was proposed by Jacobsen et al (2009) and works with an Interest and Data packet pair. When Interest is expressed towards some data, the request is flooded out into the network and when it reaches someone who has the data, the Data packet is sent back. CCN can be thought of as the next step from the peer-to-peer topology. In CCN, the data is in the network and can be stored at any entity that it passes. Thus the equivalent of routers may cache the data that passes through it and next time the same Interest is received, it can reply with the data.

NetInf (Ahlgren and Vercellone, 2010) has a similar idea to the CCN concept; a peer-to-peer network with caches within the network. In NetInf, the data is stored in Information Objects (IOs) that can be located anywhere in the network. Each IO has an identifier and with that identifier the data can be found and routed to the requestor.

The PSIRP concept (Fotiou, Polyzos and Trossen, 2009) aims at building a clean-slate Internet without taking anything as given. It adopts a publish/subscribe model, where the power is within the receiver rather than at the sender. The publishers are the content providers that publish data into the network. The subscribers express interest in certain data and the network delivers this data to them when it becomes available. The network has rendezvous points (RPs), where the matching of subscriptions and published data is done and forwarded. The publication may be cached by intermediate network components and when more than one subscribes to the data, the data is multicasted to the subscribers.

3. Two-sided Market Theory

Two-sided market theory is a relatively new branch of economics theory compared to classical economics that has existed for centuries from the times of Adam Smith and David Ricardo (Glanville, 2003; p. 5, 386). The two-sided market or two-sided network effect is an economic theory that explains the behaviour of firms in markets that exhibit two-sidedness and is closely related to network externalities (Parker and Van Alstyne, 2005). Most of the literature on two-sided markets and network externalities is written in the past two decades, the findings of which will be discussed in this section.

3.1 Overview

Many markets exhibit two-sidedness, such as any market with complementary products. For example, the razor and blades market is considered to be two-sided, since the sales of one product depend on the sales of the other. Another type of two-sided network is a two-sided platform, which brings two customer sections together. For example, the credit card industry is two-sided with credit card companies acting as platforms and offering services to merchants and card holders. However, even if a market exhibits two-sidedness, it might not be a two-sided market. Rochet and Tirole (2003) defined two-sided markets as:

> *Markets with two distinct sides that are interlinked and where not only the overall price level matters but also the price structure between the two sides.*

Thus typically, the pricing in a two-sided platform is skewed with one side charged more than the other. According to Rochet and Tirole, the two-sided network effect is about getting both sides of the platform on board in the chicken-and-egg problem. Some examples of two-sided markets that comply with the above definition are listed in Table 1, where the asterisk sign (*) shows the side being charged less or even subsidised.

The basic literature on two-sided markets by, for example, Rochet and Tirole (2003), Armstrong (2006), Parker and Van Alstyne (2005) and Eisenmann et al. (2006) has been written from the platform’s perspective. Their papers concentrate on describing the behaviour of some typical two-sided platforms as well as developing a mathematical model for the pricing of a two-sided market. This section will describe the basic concepts related to two-sided markets.

A platform, in computer science, refers to the basic hardware and software of a computer’s system and defines the principles on which a computer operates (Pearsall, 1999; p. 1095). This definition is, however, only partly true in the two-sided market literature. A platform is more broadly understood as a market place for the two sides of the market to transact. For example, credit card companies provide a means of payment transactions for merchants and consumers. Evans and Schmalensee (2007) divided platforms into four types: Exchanges, Advertising-supported Media, Transaction Systems and Software Platforms.

Table 1. Examples of two-sided markets. (Eisenmann, Parker and Van Alstyne, 2006; Rochet and Tirole, 2003)

Market	**Platform**	**Side 1**	**Side 2**
PC Operating Systems	Windows, Macintosh	Consumers	Application Developers*
Online Recruitment	Monster, CareerBuilder	Job Seekers*	Employers
Yellow Pages	Telephone Companies	Consumers*	Advertisers
Web Search	Google, Yahoo	Searchers*	Advertisers
Video Games	Nintendo, PlayStation	Players*	Games' Developers
Shopping Malls	Shopping Malls	Shoppers*	Retailers
Credit Cards	Visa, MasterCard	Card Holders*	Merchants
Real Estate	Realtors	Buyers*	Sellers
Media	TV, Newspapers	Consumers*	Advertisers

Rochet and Tirole (2003) divided the fees that platform charges from its two sides into usage fees and membership fees. Usage fees refer to the per transaction fees incurred by either side of the platform when a successful transaction occurs between the two sides. For example, in the credit card business, usage fees can be understood as the royalty the merchants have to pay the credit card company each time a consumer makes a purchase with a credit card. Membership fees, on the other hand, are fees charged for belonging to a platform. Using the credit card example again, the card holders, in other words the consumers, pay a monthly or yearly fee to the credit card company for being able to use their credit cards.

The Rochet and Tirole (2003) paper mainly discusses usage fees thus it concentrates on prices charged by the platform on a per transaction basis. However, the mathematical model is extended to cover membership fees as well. Armstrong (2006), on the other hand, mainly assumes a pricing strategy of fixes prices rather than prices per transaction. Despite the differences in pricing strategies, both papers formed the same pricing structure for the two sides. Both papers conclude that the side, which is less price sensitive, should be charged more than the side with higher price sensitivity. Parker and Van Alstyne (2005) and Eisenmann et al. (2006) have reached a similar conclusion without extensive mathematical modelling. Rochet and Tirole also concluded that the skewed pricing should be practiced by two-sided markets regardless of the market structure, i.e. monopoly platform or competing platform. The next two sections explain the underlying reasoning why skewed pricing is profitable and in what kind of situations it can be used.

3.2 Externalities

An externality in classical economics exists when an activity affects a third party that was not involved in the transaction (Glanville, 2003; p. 622). Externalities can be positive or negative: positive externalities are social benefits while negative externalities are social costs. For example, when planting a flower bush in the yard brings joy to all the households in the neighbourhood, it is a positive externality. On the other hand, if one of the neighbours is allergic to flowers, the planting of flowers will be a negative externality. Positive externalities in the field of communications are very common and it is the main reason why two-sided markets exist. Several types of consumption externalities are discussed below (Katz and Shapiro, 1985).

A direct externality occurs when a consumer purchases a product based on the amount of other users using the same product. For example, consider a customer wanting to start using a peer-to-peer file sharing network. The amount of utility this consumer derives from the network depends on how many other users are on the network. The utility users derive from a network will be higher if the network is large compared to a network with less users.

The size of the service network gives rise to indirect consumption externalities. For example, a consumer buying a 3G mobile handset will be interested in knowing how many other users have 3G mobile handsets because the network coverage, service provision as well as post-purchase services to the phone itself depend on the amount of existing users.

Related to service provision is the software provision and complementary products provision. When deciding on hardware, the consumer is most likely going to choose the one with more existing software developed for it as the hardware would be useless without the software.

All the above examples relate to the size of the existing customer base, which is defined as membership externality. To determine the relevant networks of consumers, it is important to know whether the different technologies are compatible with each other. For communications networks, if a subscriber of one network provider can communicate with a subscriber from another network provider, the two networks can be thought of as one network of consumers. This is the case at present in the telephone network – telephone users from any network, be it mobile or land line, can call another user in any other network. For hardware-software markets, the integration has not gone that far yet. Usually software developed by one company can only be used on that company’s hardware (Cusumano, 2008), although open source software is becoming more common, which may lead to better compatibility of technology. In addition, the size of service networks is usually restrained to one service provider only. For example, if you have a Sonera[1] connection in Finland, your connection will only work where Sonera has coverage.

In addition, usage externalities (Rochet and Tirole, 2006) determine how much a service is used. For example, if a credit card holder benefits from using the credit card rather than cash when making a purchase, the merchant is exerting a positive usage externality by accepting the card as a payment method.

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[1] Sonera is a Finnish operator and is registered under TeliaSonera Finland Oyj in Finland. http://www.sonera.fi/.

The existence of externalities is the main reason why skewed pricing in two-sided markets exists. Usually to attract the users on one side, subsidies or discounts are offered to them. Because the platforms have this ability to attract large amounts of users on one side, they can charge the other side for the access to this side.

3.3 Mathematical Model

Both Armstrong, and Rochet and Tirole have developed independently a mathematical model for two-sided market behaviour and pricing. Because the models are very similar with minor differences in assumptions and notation, only one of them is discussed in this section: the Rochet and Tirole (2003) model.

Rochet and Tirole have attempted to prove the skewed pricing in two-sided markets with different market structures and several market governance forms. Their paper started with monopoly platforms, which is further divided into privately owned monopoly and a monopoly practicing Ramsey optimal pricing. Monopoly is a market structure with only one major player offering a service aiming at maximising profit whereas a Ramsey optimal monopolist aims at maximising social welfare. A market structure where many platforms compete for customers is discussed then. The subcategories for competing platforms are proprietary platforms and associations. In addition, some modelling with symmetric and asymmetric prices has been made. Based on the monopoly and competing platforms modelling, a business model determinant was concluded as well as some generalisation of the model into membership fees and usage costs.

Some assumptions and terminology of the paper is explained here. In the paper, interconnectivity of platform users are assumed to be the same regardless whether the market structure is monopoly or competitive. In addition, the demand for the platform of the two sides is assumed to be log concave. The two sides of the platform are called seller and buyer even if the platform’s business does not involve selling or buying. Prices mentioned below will always be the prices charged by the platform to the two sides based on a per usage basis unless otherwise stated. The below explanations will concentrate on the end results and the detailed mathematical calculations are provided in Appendix A.

3.3.1 Monopoly Platforms

Private Monopoly

A monopoly platform is shown in Figure 3. Only one platform connects the buyers and sellers on the two sides. For example, the Apple application store is a monopoly platform for the Apple product users and the application developers for Apple products.

Figure 3. Monopoly platform.

A private monopoly platform aims at maximising its own profit. It will choose a price structure for buyers p^B and sellers p^S so as to maximise the profit function:

$$\pi = (p^B + p^S - c)\, D^B(p^B)\, D^S(p^S), \tag{1}$$

where D^B and D^S are the demand of buyers and sellers, respectively and c is the marginal cost the platform endures from each transaction.

To maximise profit, the profit function has to be partially differentiated in respect to p^B and p^S separately and then the two differential equations are set to be equal.

$$\eta^B = -\frac{p^B (D^B)'}{D^B} \tag{2}$$

$$\eta^S = -\frac{p^S (D^S)'}{D^S} \tag{3}$$

Equations 2 and 3 show the price elasticities of demand of buyers and sellers, respectively, which measures the change in quantity demanded when the price is changed (Glanville, 2003, p. 627). By inserting the price elasticities of quasi-demand of buyer and seller into the differential equations and moving the terms around, Equation 4 is reached. It shows that the price structure of a monopoly platform is given by the ratio of price elasticities of buyers' and sellers' demand.

$$\frac{p^B}{\eta^B} = \frac{p^S}{\eta^S} \rightarrow \frac{p^B}{p^S} = \frac{\eta^B}{\eta^S} \tag{4}$$

In addition, the total price level charged by the monopoly platform $p = p^B + p^S$ can be given by the standard Lerner Index, Equation 5, if we let the total elasticity of the two sides to be the sum of the elasticity of the two sides, $\eta = \eta^B + \eta^S$. The Lerner index gives the degree of monopoly power a company has (Lerner, 1934).

$$\frac{p - c}{p} = \frac{1}{\eta} \tag{5}$$

Ramsey Pricing

Under monopoly, a Ramsey monopolist also exists, who aims at maximising social welfare given the budget balance. Figure 3 also shows the market structure for Ramsey pricing. Equation 6 gives the social welfare, where V^B and V^S are the net surpluses of buyer and seller, respectively, for an average transaction. The budget balance is $p^B + p^S = c$ because by definition economically efficient resource allocation is reached when the price equals marginal cost (Glanville, 2003; pp. 130-131). Thus when Equation 6 is partially differentiated under the budget balance constraint and in respect to p^B and p^S, social welfare is maximised.

$$W = V^S(p^S)D^B(p^B) + V^B(p^B)D^S(p^S) \tag{6}$$

Cost allocative efficiency, or Pareto efficiency, is reached when the social welfare changes the same amount regardless of whether the price of buyer or seller is changed; in other words when no one in the platform can be made better off without making someone else worse off (Glanville, 2003; p. 158). Thus, the partial differentials of social welfare are set to be equal and after simplification, yield the Ramsey price structure for cost allocative efficiency:

$$\frac{V^S}{D^S}\frac{\eta^B}{p^B} = \frac{V^B}{D^B}\frac{\eta^S}{p^S} \tag{7}$$

Ramsey pricing by definition means charging more from the side with relatively inelastic demand when a price is to be raised (Ramsey, 1927). From Equation 7 it can be seen, that the price structure for Ramsey pricing is also dependent on the ratio of the price elasticities of demand. Thus the mathematical modelling proves the Ramsey pricing definition and that the Ramsey prices take into consideration the average surpluses created on the other side of the platform.

3.3.2 Competing Platforms

Realistically no monopolies exist, thus Figure 4 shows a market structure where more than one platform competes for the consumers. The credit card industry is a good example as consumers have credits cards from more than one company and a merchant usually accepts more than one credit card company's cards.

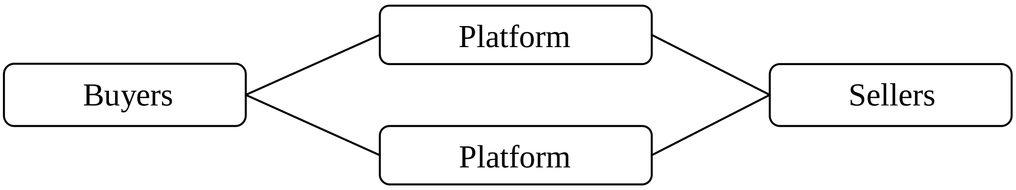

Figure 4. Competing platforms.

choose the same platform. The prices charged by the competing platforms can be symmetric or asymmetric. When prices are symmetric, the platforms charge the same prices and it can be paralleled to a monopoly platform by assuming joint ownership of the competing platforms. When prices are asymmetric, the seller has three possibilities regarding where to trade depending on its benefit, b^S, from the transacting with a certain platform.

The seller will not affiliate with any platform if its benefit is smaller than the lowest price charged by the cheapest platform. By assuming that platform 1 has a lower price than platform 2, it can be said that when $b^S \leq p_1^S$, the seller will not trade on any platform.

Sellers trade on both platforms, i.e. multihome, if their benefit is bigger than the average price of additional demand when multihoming given by Equation 8, i.e. if $b^S \geq \hat{b}_{12}$. Equation 8 is given assuming still that platform 1 has lower prices than platform 2 and where d_1^B and d_2^B are the demand for buyers for platform 1 and 2, respectively, when the seller multihomes.

$$\hat{b}_{12} = \frac{p_2^S d_2^B - p_1^S (D_1^B - d_1^B)}{d_2^B - (D_1^B - d_1^B)} \tag{8}$$

When a seller's benefit is larger than the lowest price but lower than the average price of additional demand when multihoming, the seller will only trade on the less expensive platform. Using the above assumption on platform prices, the seller with type $p_1^S < b^S < \hat{b}_{12}$ will only trade on platform 1.

It is further assumed that when sellers affiliate with multiple platforms, it is the buyer that decides where the transaction takes place. The dependence of a buyer on a certain seller is denoted by the buyer's singlehoming index of platform i, Equation 9. The singlehoming index measures a buyer's loyalty for platform i, meaning the proportion of buyers that will stop trading when platform i ceases to exist. At the same time, the singlehoming index measures the proportion of buyers who will switch to a new platform when the seller switches to another platform.

$$\sigma_i = \frac{d_1^B + d_2^B - D_j^B}{d_i^B};\ i, j = 1,2; i \neq j; \sigma_i \in [0, 1] \tag{9}$$

Proprietary Platform

Under competing platforms, two governance forms exist: proprietary and associations. Proprietary platforms are owned by companies that aim at the highest profit and the structure is shown in Figure 4. This means that proprietary platforms may have exclusive ownership over some assets (Kale, Singh and Perlmutter, 2000), from which they gain competitive advantage and thus profit. For example, the video game console makers have exclusive rights to promote and sell their own consoles.

As with the monopoly case, to maximise profit, the profit function, Equation 10, has to be differentiated partially first with respect to p_i^B and then to p_i^S.

$$\pi_i = \left(p_i^B + p_i^S - c\right)Q_i \tag{10}$$

By setting the two differentials to be equal, the following equation is obtained:

$$\frac{\partial Q_1}{p_1^S} = \frac{\partial Q_1}{p_1^B} = -\frac{Q_1}{p_1^B + p_1^S - c}, \tag{11}$$

where Q_1 is the transaction volume for platform 1:

$$Q_1 = d^B(p^B)D^S\left(\hat{b}_{12}\right) + \widehat{D}^B(p^B)\left\{D^S\left(p_1^S\right) - D^S\left(\hat{b}_{12}\right)\right\} \text{ when } p_1^S < p_2^S \tag{12}$$

$$Q_1 = d^B d^B(p^B)D^S\left(\hat{b}_{21}\right) \text{ when } p_2^S < p_1^S \tag{13}$$

To find the differentials for Q_1, both Equation 12 and 13 should be differentiated with respect to p_1^B and p_1^S and set to equal. By inserting the result into Equation 11 and solving for the prices, the price structure for a proprietary platform is found:

$$p_1^B + p_1^S - c = \frac{p^B}{\eta_0^B} = \frac{p^S}{\eta^S/\sigma} \rightarrow \frac{p^B}{p^S} = \frac{\eta_0^B}{\eta^S}\sigma \tag{14}$$

The result is otherwise the same as in the monopoly case, however, the buyer's price elasticity of demand, η^B, is replaced by the own-brand elasticity of demand η_0^B. In addition, the seller's demand elasticity, η^S, is replaced by an elasticity equivalent to the own-brand elasticity, η^S/σ, which is dependent on the singlehoming index.

Associations

Association platforms, on the other hand, are owned by members of the platform and run by the not-for-profit organisations shown in Figure 5. Prices charged to the consumers of an association are set by the members while the access charges are set by the platform. For example, the credit card company, Visa, is an association which is owned by the issuing banks and the banks decide on the usage fees (Visa, 2010).

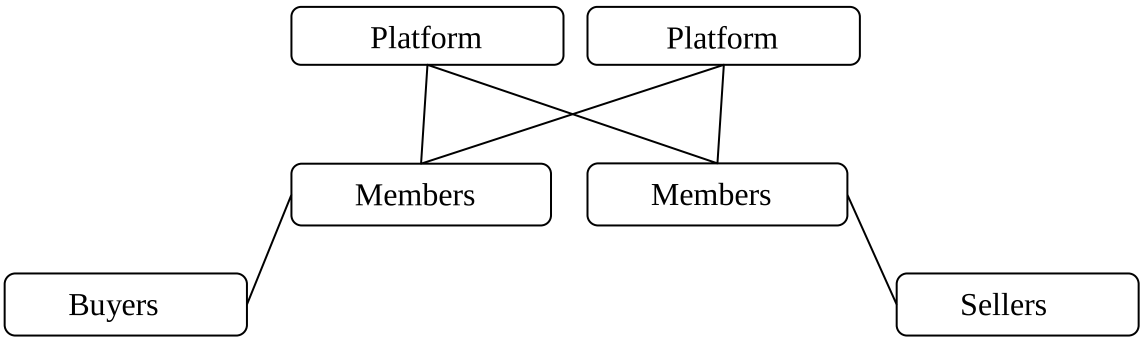

Figure 5. Competition between associations.

Because the members compete with each other within each platform and the platform is not aiming at maximising profit, the price level is set to equal the platform's total marginal cost: $p_i^B + p_i^S = c + m$, where m is the total margin on the downstream markets. This price setting will maximise the volume thus the transaction volume functions can be differentiated to gain the price structure as in the case of proprietary platforms. The resulting price structure is also the same, Equation 14.

From the above modelling, it can be seen that the private monopoly's and competing platform's pricing are not efficient. This is because, the only efficient pricing model is Ramsey pricing, which was determined through economic efficiency conditions and all the other pricing models differ in their forms from the Ramsey model.

3.3.3 Generalisations

This section explains the business model generalisation based on the above mathematical models. In addition, the membership fees are taken into consideration in this section and a generalised model for determining the price structure of a two-sided market is formulated.

Business model

A business model was concluded from the mathematical models. The prices for buyers and sellers always move in opposite directions, i.e. when buyers' prices go up, sellers' prices drop, and the amount depends on their respective demand elasticities. When a marquee buyer, i.e. a large and influential buyer, is present, the seller prices rise as the marquee buyer increases the seller's surplus from transacting on the platform. On the other hand, when captive buyers are present, the seller's price will fall because the platform can charge more from the captive buyers without losing them. Similarly, when the buyer's singlehoming index rises, the platform can charge more from the buyers.

Membership fees

So far, the discussion has assumed membership fees and fixed usage costs to be non-existent. However, the model can be extended to cover these as well. A new transaction volume function has been defined to take into consideration the fixed usage costs γ_i^B and γ_j^B for platforms i and j, respectively:

$$\begin{aligned} N_i^B &= \Pr\left(U_i^B > \max\left(0,\ U_j^B\right)\right) = d_i^B\left(p_1^B, N_1^S, p_2^B, N_2^S\right) \\ &= \Pr\left(\left(b_i^B - p_i^B\right)N_i^S - c^B - \gamma_i^B \right. \\ &\geq \max\left[0, \left(b_j^B - p_j^B\right)N_j^S - c^B - \gamma_j^B\right] \\ \rightarrow N_i^B &= (N_1^B, N_2^B) = n_i^B\left(p_1^B, p_1^S, p_2^B, p_2^S\right) \end{aligned} \tag{15}$$

U_i^B and U_j^B in Equation 15 give the net utility for buyers in platforms i and j, respectively. By using the new transaction volume function, a new profit function can be formulated:

$$\pi_i = (p_i^B + p_i^S - c)N_i^B N_i^S \tag{16}$$

By differentiating the new profit function just like in the previous governance forms, the price structure that takes into consideration fixed costs is obtained and shown in Equation 17.

$$p^B + p^S - c = \frac{p^B}{\eta_0^B\left(1 + \eta_N^S\right)} = \frac{p^S}{\eta^S + \eta_S^B\left(1 + \eta_N^S\right)} \rightarrow \frac{p^B}{p^S} = \frac{\eta_0^B}{\eta^S + \eta_S^B} \tag{17}$$

Equation 17 shows that the price structure is dependent on the ratios of elasticities. On the buyer's side, the own-brand elasticity is used. The difference from previous results is on the seller's side, where instead of demand elasticity or own-brand elasticity, a combination of own-brand elasticity and cross elasticity of buyer demand is used.

3.4 Conclusion

It can be concluded from the above discussions that skewed pricing is profitable for two-sided markets. Here it will be illustrated with two figures, Figure 6 and Figure 7. Figure 6 shows the normal pricing policies, where both sides of the market are charged a price so that the quantity demanded on one side matches the quantity demanded on the other side. The revenue in this case is maximised separately by both sides and is shown by the blue areas.

As a result of lowering side 1's price from p1 to p1', the quantity demand for side 1's services has grown. This has lead to side 2's demand growing, which is shown in Figure 7 as a shift of the demand curve to the right. Figure 7 also shows the new revenues of both sides. On side 1, the red area represents the new revenue and the chequered blue area is the revenue lost due to the lowered price. On side 2, the chequered blue area is the same as in Figure 6 and the red area represents the additional revenue gained from the rising demand and the potentially rising price.

Whether revenue is gained or lost due to skewed pricing depends on the elasticities of the two sides; in other words, the slope of the demand curves in Figure 6 and Figure 7. In addition, the decision to raise the side 2 price also depends on the elasticity of the side 2 demand curve, so that the maximum combined revenue from both sides is obtained. Given that the revenue is higher and assuming that the marginal cost of the services stays the same, the profit will be maximised.

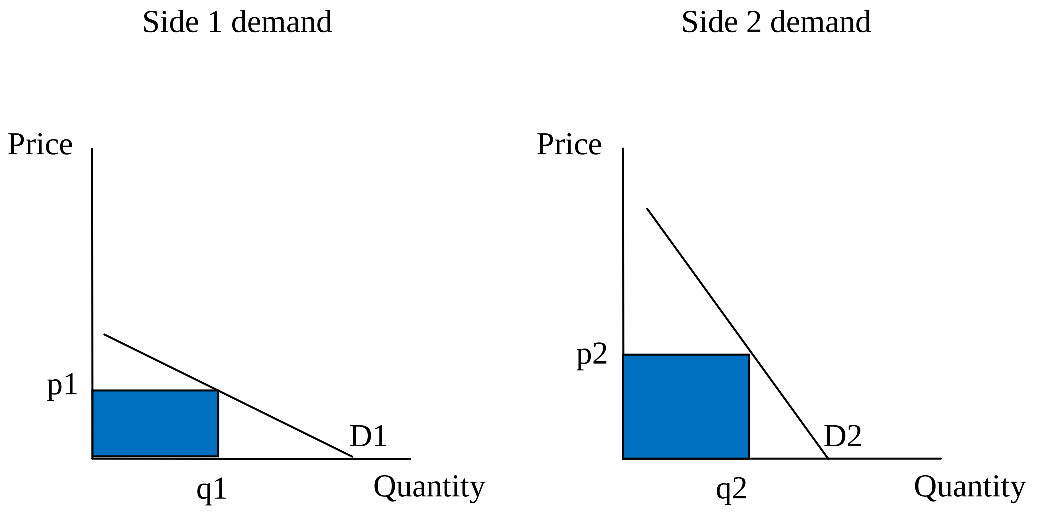

Figure 6. Normal pricing.

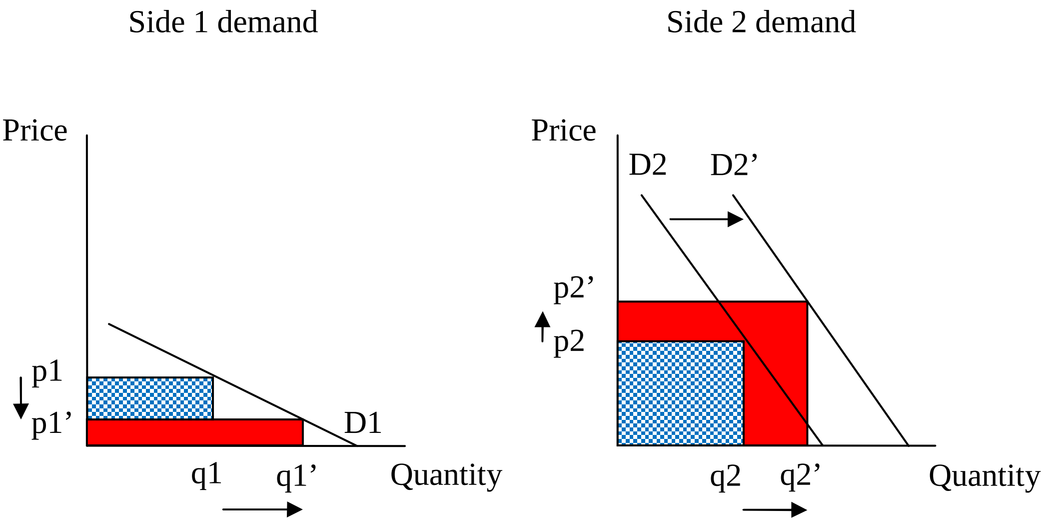

Figure 7. Skewed pricing.

The theory did not only change the pricing structure of two-sided markets but it has also affected the policy makers. Wright (2004) recognised eight fallacies about two-sided markets that come from one-sided regulations and policies. These fallacies deal with efficiency questions and anti-trust considerations as well as fairness of pricing. The most important findings that two-sided market theory offers policy makers are that charging one side of the market below marginal cost does not necessarily compromise market efficiency and that an increase in competition may not necessarily lead to a more efficient price structure.

4. Interviews

In this work, expert interviews are conducted to deepen the knowledge of the content delivery market. This section explains the interview procedure including the schedule and the number of interviewees. In addition, this section also presents the results of the interviews.

4.1 Procedure

When doing an interview, mainly three formats can be chosen: fully-structured, semi-structured and unstructured interviews (Robson, 2002). Fully-structured interviews follow a predetermined list of questions in the predetermined order. Usually the questions use specific wording that is not changed during interviews. The predetermined list of questions in semi-structured interviews acts as a guideline only, the order and the wording of the questions may be altered depending on the situation. In addition, questions may be omitted or added to better suit each interviewee. An unstructured interview can be quite informal and the conversation can develop freely within the interest area.

This work employs semi-structured interviews and a list of the interview questions is shown in Appendix B. The interview questions are divided according to three fields of expertise; the content providers, the Internet service providers and the data centre providers. From each field two interviewees are selected. In addition, two more interviewees from the education sector are interviewed for general information on the current Internet structure and the information networking functionalities. Thus altogether 8 interviewees are interviewed and they are listed in Table 2 with their current job title. Table 2 also presents the names given to each interviewee for referencing purposed in the text below.

Table 2. Table of interviewees.

Field of expertise	Position in company	Referencing
Content provider	CEO	CP1
Content provider	Head of Technology	CP2
Internet Service Provider	Technology Director	ISP1
Internet Service Provider	Ex-Vice President of Strategy and Business Development	ISP2
Data Centre Provider	CEO	DCP1
Data Centre Provider	Head of Services	DCP2
General Information on Internet	Senior Research Scientist	EDU1
Information Networking	Professor	EDU2

The chosen content providers both offer video streaming as their main content service, though CP2 also offers other Internet content on a smaller scale. CP2 is a large provider, which provides the mainstream videos while CP1 is a start-up and aims at catching niche markets. The smaller company does not only offer streaming of old videos but also live streaming of sports games.

Both Internet service providers are Internet backbone providers internationally. Nationally, they also offer Internet access services. ISP1 mainly offers services to corporations such as content providers. In addition, both ISPs offer either web hosting services or CDN services.

CDP2 in the data centre category was an actual data centre provider while DCP1 offers networking services and Internet data security solutions. However, DCP1 owns a web hosting company.

The interviews were conducted over a four-week period in the spring of 2010 with most of the interviews during one week and a few scattered interviews during other weeks. Each of the interviews was estimated to last for approximately an hour. At the beginning of each interview, a short presentation of the aims of this work was presented to the interviewees for their better understanding of the work and to obtain more relevant answers.

4.2 Results

Because a semi-structured interview was chosen, the order of the questions was changed quite freely in the interview situations to better suit the conversation flow. The estimated time for each interview was an hour. In reality, the interviews took from 45 minutes to 1.5 hours. This section presents a summary of the interview results, which are divided according to the topics discussed in the interviews: content distribution models, stakeholder cost types, future of content distribution and information networking.

4.2.1 Features of Content Distribution Models

In the interviews, the different content distribution models used and considered are discussed. In addition, the features of each model appreciated or disliked by each stakeholder are explained.

The content providers have considered CDN, the client-server model and cloud as the alternatives for content distribution. In the end, both companies have chosen to use a combination of CDNs and client-server with their own or leased servers. The CDNs play a small part and is only used for live streaming or where large traffic amounts are expected. The CDN companies that are in use or have been used are Level 3, TeliaSonera and Akamai. Leased and private servers are the main method for content storage and local ISPs are used for content distribution.

The most important feature of any content provider's current distribution setup is cost efficiency. The next most important features are scalability and reliability. Flexibility and fast distribution of content are at the bottom of the list. In addition, a very important feature for the smaller provider [CP1] with regard to CDNs or leasing servers is the lack of investment upfront.

As the content provider's decision of distribution model was based on the costs of each model and the client-server model with either the content provider's own, rented or leased servers is the first choice of content providers, it can be concluded that the client-server model is the most cost efficient choice from the considered models. From Norton's (2008) calculations, it can also be seen that excluding peer-to-peer, the hybrid transit/peering, i.e. client-server, model is the most cost effective for mid to large scale content providers. In addition, reliability and geographical coverage are considered as criteria for choosing the content distribution model. The client-server model is quite reliable as the content provider has total control over one's own servers and maintenance, which guarantees the service availability. Because in the client-server model the content distribution can be handled by local Internet service providers, the delay and inefficiency due to geographical distances may not a problem as ISPs are everywhere.

When the content provider gains more users, scalability becomes a problem for the client-server model. This is why the content providers when they grow bigger also buy services from the CDN for the most popular content. Scalability thus is the main selling point for CDNs.

A drawback for the CDN service is its high price. However, the prices of CDNs are falling and the content providers seem to be happy with the current price vs. quality ratio of CDNs. Another disadvantage of CDNs is geographical coverage as CDNs do not have service offerings everywhere in the world. For example, in Asia, CDNs do not have proper coverage [CP1].

Some other features that are missing from the CDNs' service include mobile device enabled protocols, storage of different mobile device file extensions and user identification, which directly relate to copyright protection [CP1]. For example, now copyright is protected by geographical regions; some content can only be accessed within Finland. If every user can be identified, copyright can be better protected. The copyright protection is now left to the responsibility of content makers and if the content makers do not obey copyright laws, their IPs can be banned from using the content providers' service.

From an ISP's perspective, it does matter which content distribution model is used. The client-server traffic does not strain the backbone network as much as the access network because according to ISP1, the growth of off-net traffic has slowed to 10% in 2009 due to the increase of video traffic while on-net traffic has grown by 300%. On the other hand, CDNs and large server hotels cause a lot of traffic load around them, which means they should be placed close to consumers. ISPs receive cloud traffic as transit traffic, or over peering networks, and pass this traffic along so it is just like any other type of traffic.

4.2.2 Stakeholder Costs

An important topic of the interviews is the cost types the different groups of interviewees face regarding content distribution. This section summarises these costs for each group.

The main costs the content providers face arise from the traffic amount, i.e. Internet connectivity costs and streaming. In addition, CDN fees and server rents also comprise a large part of the costs. Encoding and other software costs, human expertise and infrastructure are also a significant part of the cost structure.

An ISP incurs most of its costs by offering network capacity. The costs of building the physical backbone network are quite significant for an ISP. In addition, ISPs bare costs from transit and peering agreements. Power consumption is also a large expense for ISPs, especially those that offer CDN or web hosting services. Some minor costs arise from customer billing and marketing, etc.

The data centres incur the largest costs from infrastructure building and maintenance. These include office and server hall space, air conditioning for servers and Internet connectivity. Some other costs include information and communication technologies (ICT) such as firewalls and operating systems as well as human capital. In addition, 18% of ICT sector's power consumption in the world is caused by data centres (European Commission, 2010) thus energy is a major source of costs. Hardware costs are no longer a major cost source because the storage capacity costs are falling.

4.2.3 Content Distribution Market Prospects

The interviewees also talked about the current content distribution market situation and based on it discussed the future of the market. These findings are presented in this section.

ISP1 offers web hosting services, which solely concentrate on renting servers and server maintenance. The web hosting sector of the company grows twice as fast as the rest of the company thus they have also considered becoming a CDN. At the moment, they also rent servers and sell Internet capacity to CDNs. CDNs mainly pay ISP1 a fixed monthly rate but they can also be charged for the traffic amount transferred.

The current network keeps growing as the amount of information grows and the capacity needs are also growing [EDU1], requiring faster Internet connections and cables. From the current cables only a small percentage can be used to transport traffic at the speed of 100 gigabytes/s. Thus when the physical bottleneck is reached, the old cables have to be replaced with new ones that can accommodate the higher speed traffic. Due to this reason, the network capacity cannot keep growing endlessly, and other solutions have to be implemented.

According to the ISPs, the Internet is developing into a video or media network. CDN is now a major player in the content distribution business and the interviewees believe that without CDN the current Internet would have died already due to lack of capacity. However, the current CDN is not enough to satisfy the needs with the current development trend. The current capacity is not enough to watch unicast Internet TV and because multicast is not available to all the consumers, the current CDN model has to change to accommodate the demand growth. Alternatively a proper P2P system with supernodes could be developed or common anycast standards could be agreed on [ISP1].

In addition, ISP1 believes that Google Net will break away from the current Internet within this decade because the Internet limits it and filters its services. It already has the infrastructure available for being a separate network; i.e. mail servers, domain name servers, etc.

4.2.4 Information Networking

Following the future of the market discussion are the questions relating to caching and information networking. The following findings are made.

ISPs do not do caching; however, the option of caching is under consideration. In addition, ISPs are interested in investing in network supernodes for caching data because it would reduce capacity requirements on the backbone. Caching used to be more popular with ISPs before but because the content is dynamic and becomes stale quickly, caching soon became less popular. In addition, advertising now tends to be personalised, thus ads cached with the traffic for one user is not valid for another user. Dynamic content is also a challenge for information networking.

It will take time before the majority of routers have caching capabilities. However, the development is going in the direction of a complete semantic network. Take, for example, the Cisco UCS (Cisco, 2010b) that installs blade servers into its routers. The blade servers cache content closer to the consumers; it is more efficient and feasible and is a step in the right direction.

On an abstract level, information networking is basically a network with CDN servers everywhere. This gives rise to the question whether it is enough for Akamai or another large CDN to locate its servers within each IAP or is having caching capability on every router really needed [EDU2]. Information networking can also be compared to a data cloud network, which covers the whole Internet.

The content providers think that information networking is a good idea if it leads to cost savings. In addition, they think that the capacity requirements at the origin server of the content can be lowered if information networking is really in use. However, they raised a few challenges that have to be addressed before the network is viable. Live video streaming with P2P is challenging because the source may stop seeding at any time. Because information networking is similar to P2P, the same problems can arise. In addition, because the content is cached within the network, anyone who has access to the network can view the content. This may cause control issues to arise, such as copyright infringements.

On the other hand, the information networking system would be more self-controlling thus requiring less network management. The concept sounds like a smart idea and it has already been used by AppleTalk where each network component is accessed by its name and not address (Kosiur, 2003).

Despite all the talk about the Internet growing and the need for new solutions, DCP1 has not received any signs from the market on the need for a system like information networking even though they are in the networking business. Thus it may take ten years for the concept to be widely deployed. It would seem that the network is going in the general direction of information networking but it will be slow. Some issues have been raised: how will the routers communicate with each other? In addition, the possibility that no common standard is provided and manufacturers have their own standards exists, which leads to routers not being able to communicate with each other. This was a problem when the current Internet was implemented.

DCP2 believes that information networking can be both a threat and an opportunity depending on how the company reacts to the change. Technology itself is neither bad nor good; it is only a tool for making business. Companies also follow the Darwinian law of evolution. If a company can adapt to the environmental and technical changes and make use of the new ideas, it will prosper, otherwise it will die away.

5. Value Networks of Content Delivery Models

A major part of the Internet is content sharing and many architectural solutions for content delivery exist. From the five content distribution models discussed in Section 2.3, the client-server model, Content Delivery Networks and information networking are examined in this section by analysing their costs and modelling their value networks. Peer-to-peer and cloud are also alternatives for content distribution but they are not widely used by content providers based on the interview, therefore they are not discussed in this section. The information on value networks and costs are based on public information as well as interviews. The next sections will follow the general structure of first explaining the value network's traffic, monetary and intangible flows and then explain the weighted arrows separately. Lastly, the cost a content provider faces in each content distribution model is discussed.

5.1 Value Network Notation

The value network notation used in this work is derived from Allee's (2000a) Three Currencies of Value. Allee's value network configuration defines three key value exchanges or currencies:

1. Goods, Services and Revenue (Actual goods or services and the monetary payments).
2. Knowledge (Strategic information, planning and process knowledge, technical know-how, etc).
3. Intangible Benefits (Customer loyalty, sense of community, image enhancement, co-branding opportunity).

In addition, Zhao (2008) has adopted a modified categorisation of value exchanges to better fit the networking context in his work on mobile Internet:

1. Services and Goods
2. Monetary Benefit
3. Intangible Benefits (Attention, loyalty, information)

This work adopts the basic idea of Allee's configuration but with a few modifications based on Zhao's configuration to better suit the context of this study. The currency names used in this work are listed and explained below.

1. Traffic Transfer
2. Monetary Transfer
3. Intangible Benefits
    i. I1: Brand recognition
    ii. I2: Loyalty
    iii. I3: Information

The biggest difference from the previous configurations is the first value exchange. The goods and services offered in Internet content distribution is Internet content, which is transferred as Internet traffic. Consumers, on the other hand, produce Internet traffic when requesting Internet content. Thus the first value exchange is named traffic transfer and each traffic transfer shows the physical link between two stakeholders.

Because the value network in this work shows the technical connectivity between stakeholders, process knowledge transfers do not exist. In addition, the revenue received by each stakeholder does not fit into traffic transfer, thus the second currency is called monetary transfer similarly to Zhao's monetary benefit.

The last currency in this work is also called intangible benefits. Allee (2000b) divides intangible benefits into six subcategories: business relationships, human competence, internal structures, social citizenship, environmental health and corporate identity. Trust between stakeholders is part of business relationships and thus one of the intangibles in this work is loyalty. Zhao includes brand recognition within loyalty while attention is used to describe the benefit received from advertising. However, in this work brand recognition replaces attention because brand recognition is the consequence of increased attention. According to Allee's (2008) definition of intangibles, an intangible benefit can arise from converting a tangible value input into non-financial assets. Thus gathered information is the third intangible benefit because usage information may, for example, increase the level of marketing competence of a company.

5.2 Client-Server Model

To use the client-server model for content distribution, content providers rent or purchase servers for storing the content and consumers access the contents by requesting them from the servers. The complete value network with weighted traffic and monetary transfer arrows for the client-server model is shown in Figure 8. The possible peering agreements between IAPs are not shown in the value network because they are not considered in this work.

Content provider resides on the server side. The content provider's internal value network is shown within the dotted box in Figure 8. It shows that the content makers may not be the content providers. When content maker do not distribute content themselves, a one-way traffic flow from the content maker to the content provider is shown. A two-way monetary transfer between the CP and the content maker exists because the content maker may pay the content provider for the distribution service while the content provider forwards the consumers' content fees to the content makers.

For data storage, the content provider can either purchase own servers or rent server capacity from the data centre provider, thus a monetary transfer from the content provider to the data centre provider is drawn. If data centres are used, a traffic transfer is drawn from the content provider to the server. In addition, the data centre provider can also provide some usage information and other services to the content provider, which is shown as a transfer of I2 in Figure 8. Other intangible benefits between the content provider and the data centre provider are trust and reliability related benefits in the relationship or partnership, i.e. loyalty shown as I3.

For distribution when using own server, the CP's own servers are connected to the Internet through the Internet access provider and the Internet backbone provider, thus a monetary transfer from the content provider box to the IAP is shown. The IAP then pays the IBP for the backbone connectivity, which is shown as a monetary transfer from the IAP to IBP in Figure 8. The data centres have backbone access in their premises and part of this capacity is allocated to the servers rented to a CP. The data centres pay the Internet backbone provider for the backbone access as shown in Figure 8 by the monetary and traffic transfers directly from the CP box to the IBP.

On the client side, the consumer connects to the Internet through an IAP, which is connected to the IBP. Thus the consumer pays the IAP, which in turn pays the IBP for the Internet access. In the own server's case, when the consumer requests content from the content provider, it first sends the request to its own IAP. If the consumer's IAP is the same as the content provider's IAP, the request can be directly forwarded to the content servers. If the consumer's IAP does not have direct connection to the servers, the request is forwarded through the IBP to the content provider's IAP. In the case of rented servers, the request traffic from consumer group 2 goes through the backbone directly to the data centre provider. After the servers receive the content request, a reply with the content is sent back to the consumer. This is shown as the traffic transfers between the consumer and IAP, the IAP and IBP, the IAP and the server, and the IBP and the server in Figure 8. In addition, a possible money transfer from the consumer to the content provider for the content exists.

In addition, the content provider may have other revenue sources than content fees such as the advertising revenue model and sponsorships. In the advertising case, the advertisers pay the CP for putting adverts on the content, which is shown as a monetary transfer from the advertiser to the CP. The transfer of the adverts to the CP is shown as the traffic transfer. In addition, advertisers receive an intangible benefit I1, which stems from the increased publicity when consumers see the adverts. The sponsors usually deal with the content makers instead of directly with the content providers. The content makers get sponsorships from companies and the content provider may either get its revenue from sharing the sponsorship or through content distribution fees. The benefit for the sponsors is the same as for the advertisers; the publicity and brand recognition. Though publicity arises from consumers, for simplicity of the value networks, this intangible benefit originates from the content provider and content makers.

Weighted Value Network

In Figure 8, the thickness of the transfer lines represents the amount of traffic or money transfers thus lines with the same thickness represent the same amount of traffic. The money transferred for the service always has the same thickness as the corresponding traffic transfer's arrow. The monetary transfer between the content provider and the content maker is not weighted because the amount depends on the charging principles used between the two and not on network architectures. In addition, the traffic amount from the advertiser to the content provider is not weighted because the adverts are transferred to the content provider and stored in their servers thus the traffic amount from the advertiser does not depend on the amount of content users.

When using the data centre service, the traffic between the content maker and content provider and between the content provider and the data centre has the same thickness, which means that all the content the content maker sends to the content provider is forwarded to the rented servers in the data centre's premises. In addition, the traffic between the CP box and the Internet backbone provider, the IBP and the Internet access provider 2 and between the IAP2 and the Consumers group 2 are equally large.

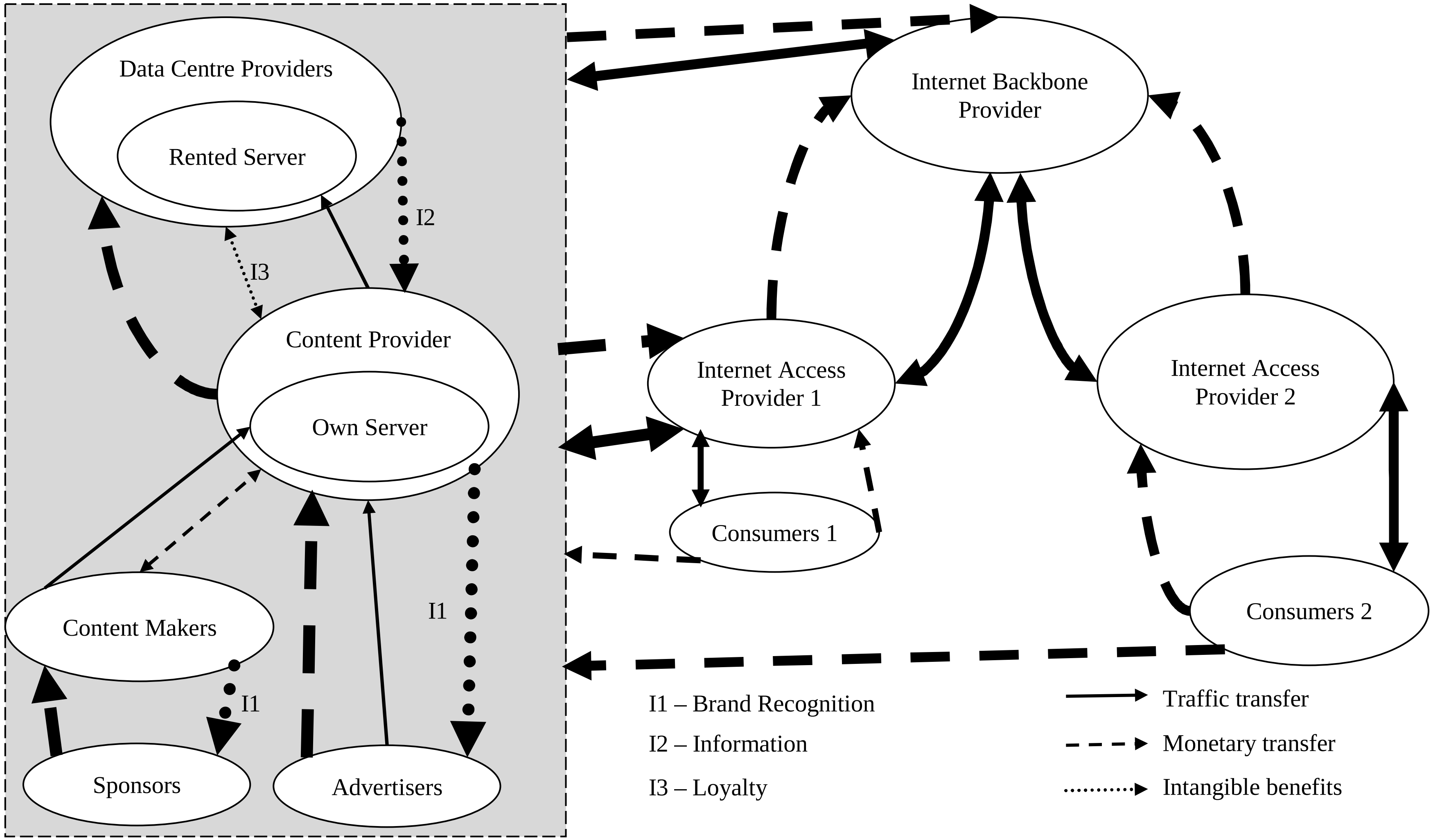

Figure 8. Value network of the client-server model.

This means that when the consumers in group 2 requests data, it is all forwarded through the Internet access provider 2 to the Internet backbone provider, who then requests the data from the data centre. The requested data is returned through the same path. It is not important and cannot be known whether the traffic from the content provider to the data centre or the traffic between the CP box and the Internet backbone provider are the same, thus the traffic between the CP box and the IBP is assumed to be thicker in Figure 8 for easier comparison between content distribution models.

In the value network, the consumer group 1 represent the consumers who are on the same access network as the content provider while the consumer group 2 consists of all the consumers on a different access network than the content provider and thus needs backbone connections to reach the content. Due to this reason, the consumer group 2 is assumed to be larger than consumer group 1. Because of the size difference in the consumer groups, the traffic amount also is different. From the weighted value network, it can be seen that the consumer group 1 has less traffic than the consumer group 2. This also means that the consumers in group 1 as a group pay less than the consumer group 2. However, it is presumed that individually each consumer pays approximately the same amount.

When the content provider uses its own server, all the content is delivered through the content provider's own Internet access provider. As can be seen from Figure 8, most traffic traverses between the content provider box and its Internet access provider. This is because both the consumers 1's and 2's requests and content transfers go through the Internet access provider 1.

Because the monetary transfer between the actors depends on the corresponding traffic amount between each actor, the greatest monetary transfer is from the content provider to its own Internet access provider (IAP1). The smallest monetary transfers are the fees consumers 1 pay IAP1 and the content provider due to its small size of population. Consumers 2's payment transfer to the IAP2 and the content provider are the same thickness as the amount of traffic it generates and content it uses. Because the IAP2 forwards all the traffic consumers 2 generate, the monetary transfer between the IAP2 and the Internet backbone provider is the same size as the consumers 2's fee to IAP2. Depending on whether rented or the CP's own servers are use, the monetary transfer from the data centre and the IAP1 to the Internet backbone provider has the same volume compared with each other and with the consumers 2's fee to IAP2. The monetary transfer from the content provider to the data centre for the rented server capacity and Internet backbone access corresponds to the content amount stored and transferred and thus is thicker than the traffic transfer from the content provider to the data centre.

The size of the intangible benefits I1 and I2 depends on the consumer's population size. I2 is only affected by the size of consumers group 2 whereas I1 is affected by both the consumers 1 and the consumers 2. Therefore, I1's thickness is the same as the traffic between the content provider and the Internet access provider 1. I2's thickness is then equal to the traffic amount going through the Internet backbone provider from the consumers 2 to the data centre. The monetary transfers from the sponsors and advertisers correspond to the size of their intangible benefits and hence the arrows have equal thickness. I3's size, however, cannot be determined because the reliability, quality and other guarantees depends on the two companies and their mutual relations.

Costs

The types of costs a content provider faces when using the client-server model are discussed in this section. The list is comprised based on the interviews, the summary of which is shown in the previous section. The cost types vary depending on whether the content provider's operation is large scale or a smaller business.

For large content providers, the main costs arise from the large amount of traffic. The amount of traffic requires fast Internet connections and large capacity, which is costly. Besides a large amount of traffic, the content data amount stored is also great. This requires vast server capacity and because a large content provider may have the benefit of economies of scale, they tend to build their own server systems. In addition, the larger the content amount, the more encoding of the contents into a compatible format is required. For reliability and better after sales service, larger content providers tend to use proprietary software or program their own software rather than use open source firmware. The server maintenance, license fees and programming costs contribute to the overall expenses.

A smaller content provider often leases servers and thus the renting cost forms a big part of their cost structure. In addition, the Internet connection and other infrastructure investments may become a major expense. However, the server leasers also tend to offer network connectivity, which lessens the CP's need for a high speed Internet connection. In addition, smaller content providers may not have much capital and they tend to use open source software, which cuts costs. Encoding costs are also faced by the smaller content provider; however, because the amount of data and traffic is smaller, the proportion of encoding costs with respect to the total costs is smaller.

When the content provider is also the content maker, some costs arise from producing the content. On the other hand, if the content provider does not make its own content and distributes content with copyright protection, the right for distribution has to be bought from the owner. Marketing costs may rise if content providers advertise their services. In addition, all content providers have employees, to whom a salary has to be paid, which incurs human capital expenses.

5.3 Content Delivery Networks

The CDN market currently has over twenty pure-play CDN providers in addition to the telecommunications operators and carriers that operate their own CDNs (Rayburn, 2010). The value network for a content provider using the CDN service is shown in Figure 9. Similarly to the client-server model, the content makers may not be the same as the content providers. The revenue models for CPs are also the same as in the client-server model with advertising, sponsorships and from the content and its distribution.

When the content provider uses a CDN, the same two possible ways to store data exist as in the client-server model, i.e. using servers the CP owns or rented servers from the data centre provider. A CP may choose to use both CDN and the basic Internet for content distribution, where the less delay sensitive content is distributed through the IBP. This is also shown in Figure 9. However, here only the traffic caused by the CDN is discussed as the rest of the value network is the same as in the client-server model.

To connect to the CDN, the CP can connect via an IAP or have a direct link to the CDN's servers. The content provider pays the CDN for content caching and distribution thus a monetary transfer is drawn from the content provider box to the CDN in either case. If an IAP is used, the content provider pays the IAP for the Internet access, thus both a monetary and data transfer are drawn from the content provider to the IAP. The IAP then forwards the content to the CDN. If the CDN has a direct link to the content provider, an actual data transfer directly from the content provider to the CDN exists. Only one traffic line is drawn from the CP box to the CDN because it is insignificant to know whether the content is stored within the data centre or the CP's own servers.

For consumers, the CDN does not change the flow of traffic and payments. The consumer still sends content requests to its own IAP and pays both the IAP for Internet access and the content provider for the content. The difference is with the consumer's IAP, which forwards the request directly to the CDN instead of the IBP. The CDN replies to the IAP without asking the content provider for the content if the requested content is cached at the CDN. If no cache for the content is found, the CDN will request it from the CP as in the client-server model. If the consumer uses the same IAP as the content provider, the IAP can directly request the data from the content provider without going through the CDN.

For the whole Internet interconnectivity, a monetary transfer from the IAP's is received by the IBP. Lastly, intangible benefits may be flowing between the content provider and the CDN, for example, in the form of usage information.

Weighted Value Network

Similarly to the client-server model, the thickness of the arrows represents the volume of each transfer. The volumes of the monetary transfers are also equal to the corresponding traffic transfer's volume. The monetary transfer between the content maker and the content provider, the traffic from the advertiser to the content provider and the intangible benefit I3 are not considered in this analysis for the same reasons as in the client-server model.

Because all of the content that the content provider is sharing is sent to the CDN for distribution, the arrows from the content maker to the content provider, from the content provider to the CDN or data centre and from the IAP1 to the CDN have the same thickness. The monetary transfer from the content provider to the CDN depends on the amount of data transferred through the CDN thus the monetary transfer is thicker than the traffic transfer between CP and CDN. In addition, the usage information transfer from the CDN or data centre to the CP depends on the amount of traffic requested from the CDN or data centre and thus the I2 transfer arrows have the same thickness as the content request traffic transfers.

The traffic flow through the Internet backbone is quite similar to the client-server case. However, because the Internet backbone is used only by consumers with high tolerance of latency, the traffic volume is smaller than the traffic volume through the CDN. This also leads to the volumes of monetary transfers into the Internet backbone provider to be smaller than into the CDN from both of the Internet access provider and the CP box. As a consequence, the monetary transfer from the content provider to the data centre provider is thinner than in the client-server case. In addition, usage information transfer from the data centre to the CP is smaller. The red lines in Figure 9 shows the lines that have become thinner compared to the client-server model due to the usage of a CDN. However, whether CDN is a feasible model for CPs depends on the difference between the amount paid to the CDN and the decrease in payments to ISPs.

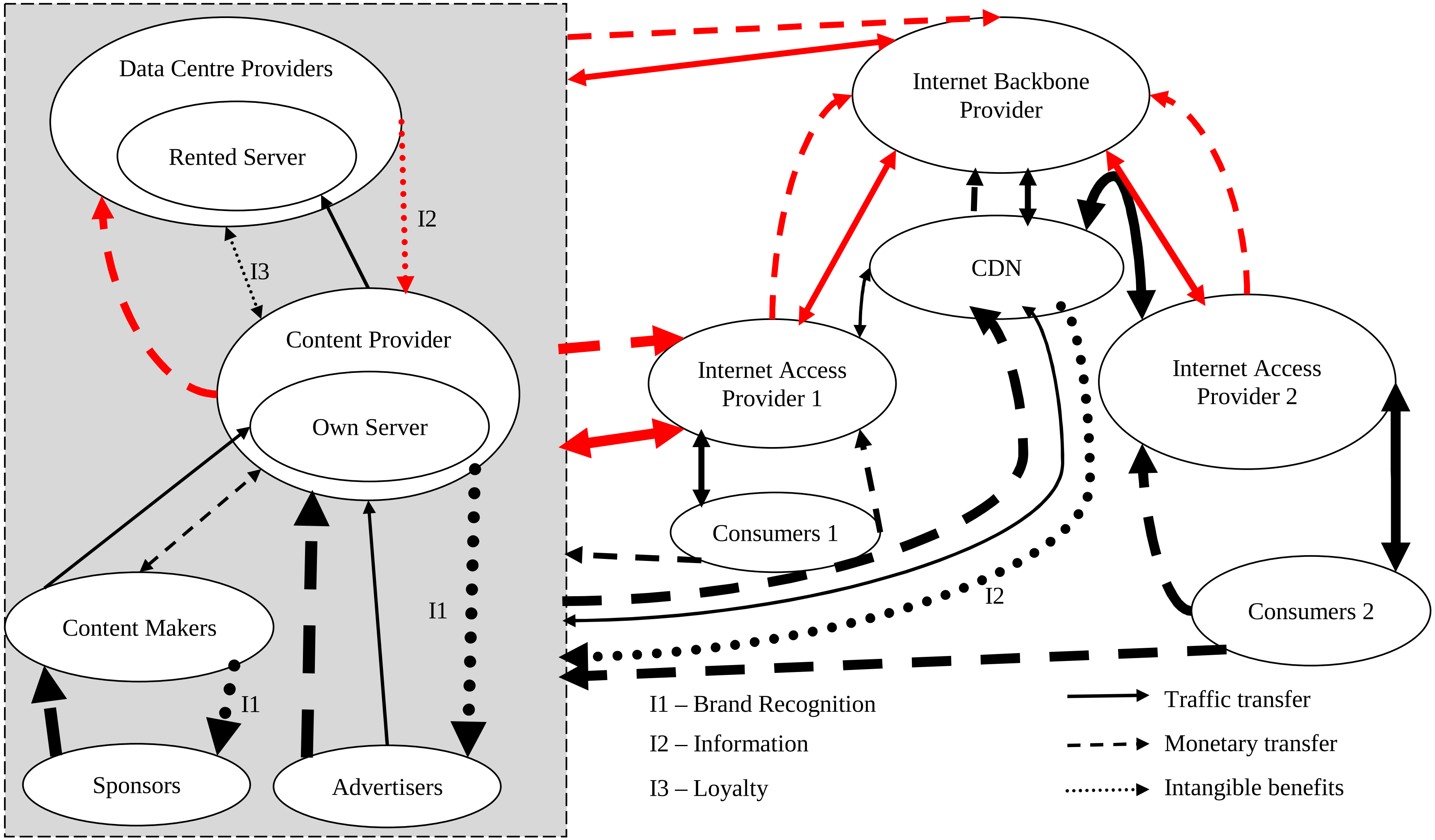

Figure 9. Value network of a Content Delivery Network.

If the payments to CDN exceed the decrease in payments to ISPs, CPs incur more costs with CDN and thus it is not a feasible model financially.

The traffic transfer from the content provider to IAP1 is thinner than in the client-server case because the traffic transferred through the Internet backbone provider is smaller. However, the traffic between CP and IAP1 is thicker than the combined traffic between IAP1 and IBP, and IAP1 and consumer group 1 because traffic to the CDN may also be transferred through IAP1. The monetary transfer between CP and IAP1 has the same thickness as the corresponding traffic transfer.

The traffic and monetary transfers between the two consumer groups and their Internet access providers are the same as in the client-server model because the access operators' network size does not depend on the content distribution model.

Costs

The costs faced by content providers that use CDNs are discussed in this section. Just as for the client-server model, the references for the costs are the interview results in the previous section. When CDN is used, it does not really matter if the content provider is large or small: the cost structure is the same.

As distribution costs are the greatest expenses for content providers, the fees paid to CDNs are the main contributor to the overall costs. Because the CDNs handle the content distribution, content providers do not have to take care of encoding, which cuts expenses. In addition, the content provider's Internet capacity does not have to be considerable because the traffic amount between the IAP and CP is smaller due to the CDN. All these cost savings are reflected then in the CDN service prices.

The rest of the costs are the same as in the client-server model. Infrastructure is needed, to a lesser extent, even if the actual content distribution is not handled by the content provider. Content still has to be produced and managed thus the same software, human capital and hardware costs exist. The developed content has to be marketed and the distribution right has to be bought from the copyright owners.

5.4 Information Networking

Out of the three information networking architectures, the CCN architecture is designed as an overlay to the basic IP network and can be best compared with CDNs. Thus the CCN's value network is produced in this section and shown in Figure 10.

The value network of the CCN is practically the same as for the client-server model. The traffic and monetary transfers all stay the same as well apart from changes in thickness. The only difference is the addition of cache servers located within the Internet access providers, the Internet backbone provider and the network. Due to these cache servers, not all requests go all the way to the origin server of the content but may be answered already by one of the caches.

When the content is first requested, the IAP and IBP forward the request to the content provider and the content is replied from either the content provider's own servers or rented servers. When the content flows through the Internet access provider, the Internet access provider's cache server stores this content for the predetermined time period, after which it is deleted. The same caching process is done by all the caching servers that the content passes en route to the consumer. The next time the same content

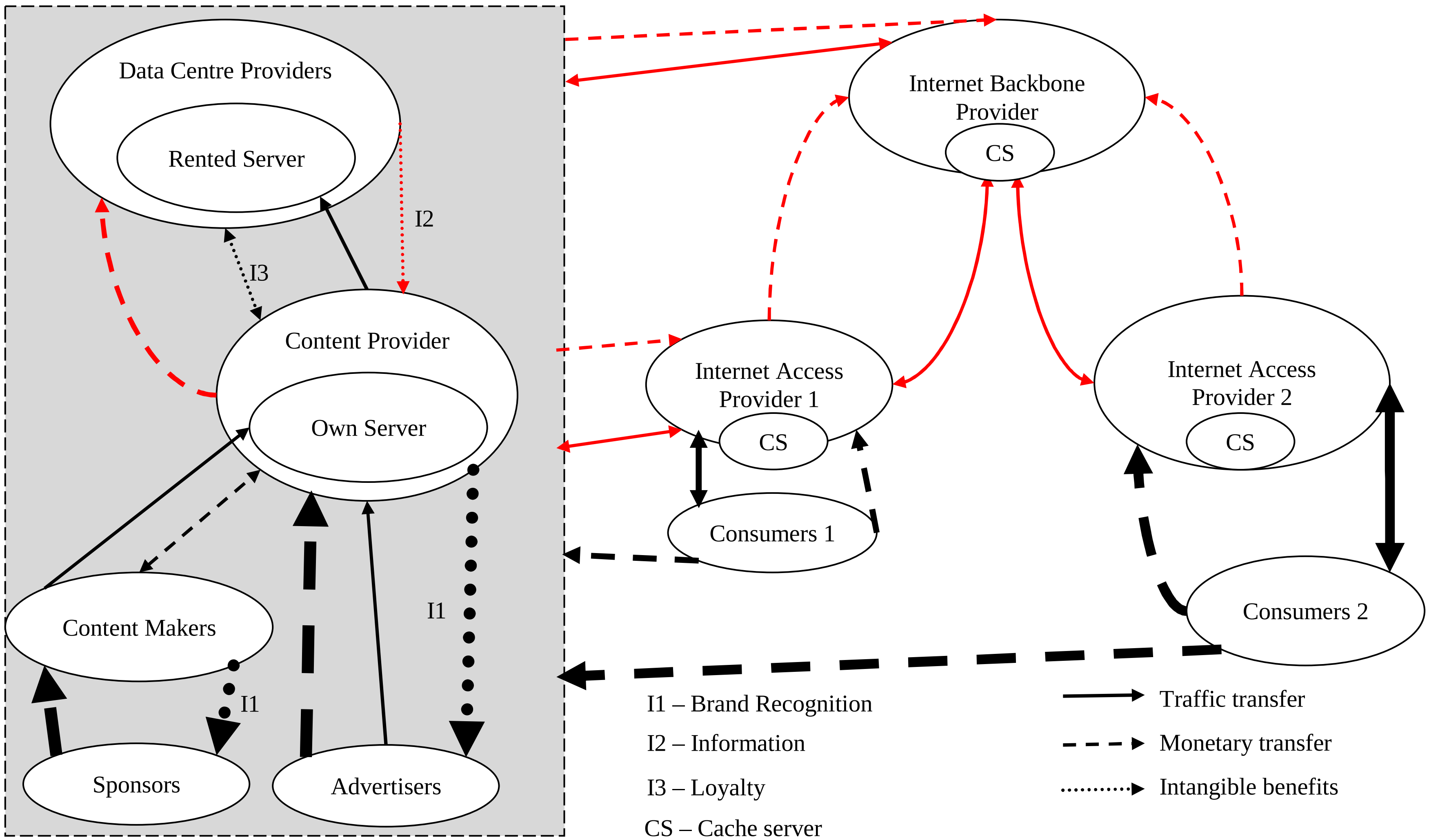

Figure 10. Value network of a Content Centric Network.

is requested, one of the cache servers may directly reply to the consumers if the validity period has not expired.

In addition, in CCN, the consumers may act as servers and send each other the content requested. However, this is not shown in Figure 10 as all this traffic would still go through the Internet access provider and maybe even through the backbone network.

Weighted Value Network

The weighted traffic is mainly the same as with the client-server model with only a few differences shown as red lines in Figure 10. The first difference is the traffic transfer between the content provider and IAP1, which has the same thickness as the amount of content produced in the CCN model and not the sum of the two traffic transfers between consumers and IAPs. This is because once all the content has gone through IAP1 once, the content are stored in the cache server and replies to the rest of the requests directly from the cache.

As a result of lower traffic between the IAP1 and content provider, the content provider also pays less to IAP1 for Internet access. In Figure 10 this can be seen from the thickness of the monetary transfer, which is as thick as the traffic transfer between IAP1 and the content provider.

The second difference is the amount of traffic going through the Internet backbone provider. Due to the cache servers, the traffic going through the IBP has the same thickness as the amount of content produced instead of the traffic generated by consumers 2 as is the case in the client-server model. As a consequence of reduced traffic through the IBP, the content provider also pay less to the data centre. In addition, the amount of usage information gathered by the data centre is also smaller; only the first requests of contents is recorded as the rest of the requests do not go all the way to the data centre.

The difference between the CCN and CDN models is in the thickness of the red lines shown in Figure 10. In CCN, the red lines will have the same thickness regardless of how much more content is requested by consumers 2 while in CDN the traffic going through the IBP increases with the amount of consumer requests. In addition, the traffic between the CP and IAP1 is thinner in CCN compared to CDN’s case.

Costs

The cost types faced by the content provider in the CCN model are most likely the same ones as in the client-server model. The difference may be in the volume of the costs. From the above value network analysis, it can be seen that at least the Internet access costs are lower in the CCN model than in the client-server model.

However, if the IAPs have adopted the cache server, the installation costs and the extra maintenance costs may be reflected on the Internet access prices charged to the content provider. On the other hand, it is also possible that the lowered traffic between the IBP and the IAP lowers the costs for the IAPs, which compensates for the cache server costs. In this case, the Internet access price for the content provider may not rise.

The content providers may also be willing to invest in the cache servers to be placed in the network, which will add to the hardware costs that the content provider faces. In addition, maintenance costs will arise from having the cache servers.

Because content is cached locally and may be found anywhere in the network, the network requires a mechanism to map requests to the data. It may be a third party that offers this service and it is possible that the service provider charges the content provider for the service. In addition, usage statistics on each piece of content, now provided by the CDN, are required by the content providers and advertisers also in the case of information networking. It also may be a third party that provides this service and the content providers may be charged for the service. This third party, however, is not shown in the value network and in information networking, collecting usage information may be impossible.

6. Content Delivery as Two-sided Markets

The different ways of distributing content have been identified in the previous sections along with the two-sided market theory. This section combines the distribution models with the economic theory by first identifying the different two-sided markets in each content distribution model. The identified two-sided markets are then categorised into content and Internet interconnection layers. Lastly, for each distribution model a cost analysis is performed on the two-sided markets of the Internet interconnection layer.

6.1 Identification

This section tries to identify the most significant two-sided markets of the client-server model, CDN and information networking regardless of whether they belong to the content layer or to the Internet interconnection layer. The identification is based on the value networks presented in Section 5. Because the whole value network is complex, the identified two-sided markets only take into consideration a limited piece of the value network.

6.1.1 Client-Server

The client-server model has mainly two two-sided market platforms; the content provider and the Internet service providers. The content provider has two two-sided markets and the ISPs have three two-sided markets. Each of them will be discussed here briefly, starting from the content provider's two-sided markets. Table 3 shows all the two-sided markets found in the client-server model, where the loss leader is shown with the asterisk (*) sign. Table 3 also shows the platform of each two-sided market and presents a name to each for easier referencing.

Table 3. Two-sided markets found in the client-server model

Platform	Side 1	Side 2	Name
Content Provider	Consumers*	Advertisers	Advertising market
Content Provider	Consumers*	Content Makers	Content Provision Market
Internet Access Provider	On-net Consumers	Off-net Consumers*	On-net vs. Off-net
Internet Backbone Provider	Consumers*	Content Providers	ISP Market 1
Internet Backbone Provider	Content Providers*	Content Makers	ISP Market 2
Content Maker	Consumers*	Sponsors	Sponsorship market

Advertising Market

The first two-sided market of content providers is between the consumers and advertisers. It is assumed here that the content providers bear some costs from producing or distributing the content. The interviews have showed that content is mainly distributed free of charge to the consumers. Thus the advertising revenue model is used, which forms a two-sided market. The advertisers pay for the advertising space or time offered by the content providers while the consumers use the content for free. The only cost that consumers face is the time lost due to the advertising.

Content Provision Market

The second two-sided market of content providers is between the consumers and content makers. Here, it is assumed that the content makers are not the same actors as the content providers. In addition, the assumption that distribution of content incurs costs to the content provider is still valid. In this two-sided market, the content providers do not get any payments from the consumers, because the potential content fees all go to the content makers. The content providers' revenue is raised through the content distribution fees charged from the content makers. This fee can be a royalty based payment from each content piece distributed or it can be a fixed fee for using the service. For example, application stores for mobile handsets offer a platform for consumers and application makers to meet. The consumers pay the application makers for the applications and the application store receives a cut from this payment.

On-net vs. Off-net

Based on the interview, it can be seen that traffic within one operator (on-net) and traffic between several operators (off-net) have different costs. This is due to the transit and peering agreements. Because the marginal cost of on-net and off-net are different for an Internet access provider, it should charge the consumers differently based on whether the traffic stays within the operator or needs connection to another operator. However, consumers pay the same flat rate fee to the Internet access provider. Assuming that off-net traffic exists, this means that consumers are paying a price between the on-net price and off-net price for all their traffic, be it on-net or off-net. The two-sided market following this assumption has Internet access providers as the platform. The two-sides are the on-net and off-net traffic; this basically means that the consumers mainly having on-net traffic is subsidising the consumers who have a lot of off-net traffic.

ISP Markets

Laffont et al. (2003) argue that the marginal cost of the originating traffic Internet backbone operator is different from that of the receiving backbone operator. Specifically, Laffont et al. (2003) write that it is cheaper to send traffic than to receive traffic from an Internet backbone provider's perspective. This is because the operators have the incentive of passing on off-net traffic as soon as possible due to hot potato routing (Ben-Dor, Halevi and Schuster, 1998) and the transportation costs are mainly borne by the receiving Internet backbone operator. Due to this asymmetry in marginal costs, the Internet backbone providers should charge the Internet access providers, who in turn should charge the consumers more for receiving traffic compared to sending traffic. However, the consumers pay the same amount regardless of the traffic type; i.e. upstream or downstream. This is another reason why two-sided markets exist.

The first two-sided market having the Internet backbone operator as the platform is between the content providers and consumers. Both the content provider and the consumers pay a flat rate fee to the Internet access providers for a certain level of service regardless of the traffic type. In reality, the traffic is mainly upstream on the content providers' side and downstream for the user. This would suggest that the consumer should pay more for the connection. However, this is not the case, which means that the marginal costs of transportation is indirectly borne by the content provider and the consumer benefits from this flat rate pricing.

A second two-sided market also follows Laffont et al.'s reasoning: the Internet backbone provider is the platform and the two sides are the content makers and content providers. The Internet connection between them is mainly upstream at the content maker's side and downstream at the content provider's side, though they pay the same amount for the Internet connection between them. This two-sided market cannot be seen from the value networks because for simplicity, a direct link from the content maker to the content provider is drawn. However, it is highly probable that the traffic actually goes through at least an Internet access provider if not also through an Internet backbone provider.

Sponsorship market

In addition, the content maker can also be a platform when content makers do not handle content distribution themselves but rather use a content provider's services. In this case, the two sides of the market are sponsors and consumers. The costs from making the content and paying the content provider are covered with sponsorships. The sponsors pay the content makers for brand visibility for their products. The consumers are assumed to have access to most of the content for free, thus becoming a loss leader.

6.1.2 Content Delivery Network

Because the Content Delivery Network is an overlay of the basic Internet, it also has all the same two-sided markets as the client-server model shown in Table 3. In addition, Faratin (2007) has recognised one more two-sided market in the CDN model between the content provider and the Internet access provider. Table 4 shows all the two-sided markets found in the CDN model, where the asterisk (*) sign marks the loss leader of each market and the cells with grey background marks the two-sided markets specific or the CDN model. The platform and the naming of each two-sided market are also shown in Table 4. However, only the CDN market is discussed in this section to avoid repetition.

CDN Market

In this two-sided network, the CDN provider is the platform. The Akamai versus Inktomi (Faratin and Wilkening, 2006) fight over the CDN business dominance has proved that it is more feasible to charge the content providers for the service rather than the Internet service providers. In the Akamai versus Inktomi case, Akamai charged the content providers while Inktomi charged the ISPs and in the end, Akamai won the competition. Thus, the loss leader in the CDN two-sided market is the Internet service provider and the revenue side is the content provider.

6.1.3 Information Networking

Because the Content Centric Networking architecture has the same stakeholders and traffics as the client-server model, the two-sided markets in information networking are also the same. These two-sided markets are shown in Table 3 of the client-server section. However, information networking exists only on a prototype level and not all functionalities are developed yet thus it is possible that new two-sided markets in information networking may still emerge.

Table 4. Two-sided markets found in the CDN model.

Platform	Side 1	Side 2	Name
Content Provider	Consumer*	Advertisers	Advertising Market
Content Provider	Consumer*	Content Makers	Content Provision Market
Internet Access Provider	On-net Consumer	Off-net Consumers*	On-net vs. Off-net
Internet Backbone Provider	Consumer*	Content Providers	ISP Market 1
Internet Backbone Provider	Content Providers*	Content Makers	ISP Market 2
Content Maker	Consumers*	Sponsors	Sponsorship Market
CDN Provider	Internet Access Provider*	Content Provider	CDN Market

6.2 Categorisation

The two-sided markets found in the previous sections can be categorised into the content layer and the Internet interconnection layer. The categorisation of the two-sided markets is made in this section. Before the two-sided markets are categorised, the two layers needs to be explained.

Figure 11 shows the two layers with examples from each layer. The figure is positioned in an end-to-end manner; at the two ends are the consumers and content providers. The drawings between the two ends represent the network with its services and stakeholders. The content layer consists of the application and service providers, such as online content stores and video streaming applications. The Internet interconnection layer includes the basic Internet and all overlay networks used for content distribution. Some examples of overlay networks are the CDN and peer-to-peer networks.

The categorisation of the two-sided markets is shown in Table 5. The content layer consists of content providers and content makers as platforms. The Internet interconnection layer includes the Internet access and Internet backbone providers as platforms. The CDN platform is categorised into the Internet interconnection layer as well.

Table 5. Categorisation of the two-sided markets in the content distribution market.

Layer	Name
Content	Advertising Market
Content	Content Provision Market
Internet	On-net vs. Off-net
Internet	ISP Market 1
Internet	ISP Market 2
Content	Sponsorship Market
Internet	CDN Market

6.3 Analysis

The previous sections identified and categorised the two-sided markets found in the three content distribution models. In this section, a two-sided market analysis will be made. The main focus of this work has been on the Internet interconnection layer and the analysis made in this section has the same scope. However, though the two-sided markets in the content layer are not discussed, they may affect the future market structure of content delivery. This section is divided into the different two-sided markets of the Internet interconnection layer because most of the two-sided markets are common in all of the content distribution models. The two-sided analysis will first explain the reasons why the two-sided markets have emerged and continue onto finding the impact that they have on the content distribution market.

The following two-sided market analysis considers only the costs and traffic between the players in question and is not taking into consideration the whole value network. For example, the content provider most likely pays the Internet access provider for its Internet connection to the whole network. However, in each two-sided market, only the cost of a certain link is taken into consideration, so the overall Internet connection cost of the content provider is divided into the cost for connecting with the consumers, the data centre and the content maker.

6.3.1 On-net vs. Off-net

From the four two-sided markets, the Internet access provider platform with on-net and off-net traffic users on the two sides can be argued to not be a proper two-sided market. This is because the consumers producing the on-net and off-net traffic can be the same ones. However, in this work, consumers who produce more off-net traffic than on-net traffic are assumed to be the off-net consumers while the ones producing more on-net than off-net traffic are on-net consumers. Following this assumption, a valid two-sided analysis on this market can be made.

The platform in this market is recognised as the Internet access provider. Tier 1's are not included because they do not pay for their off-net traffic since all traffic is handled with peering agreements with other Tier 1's.

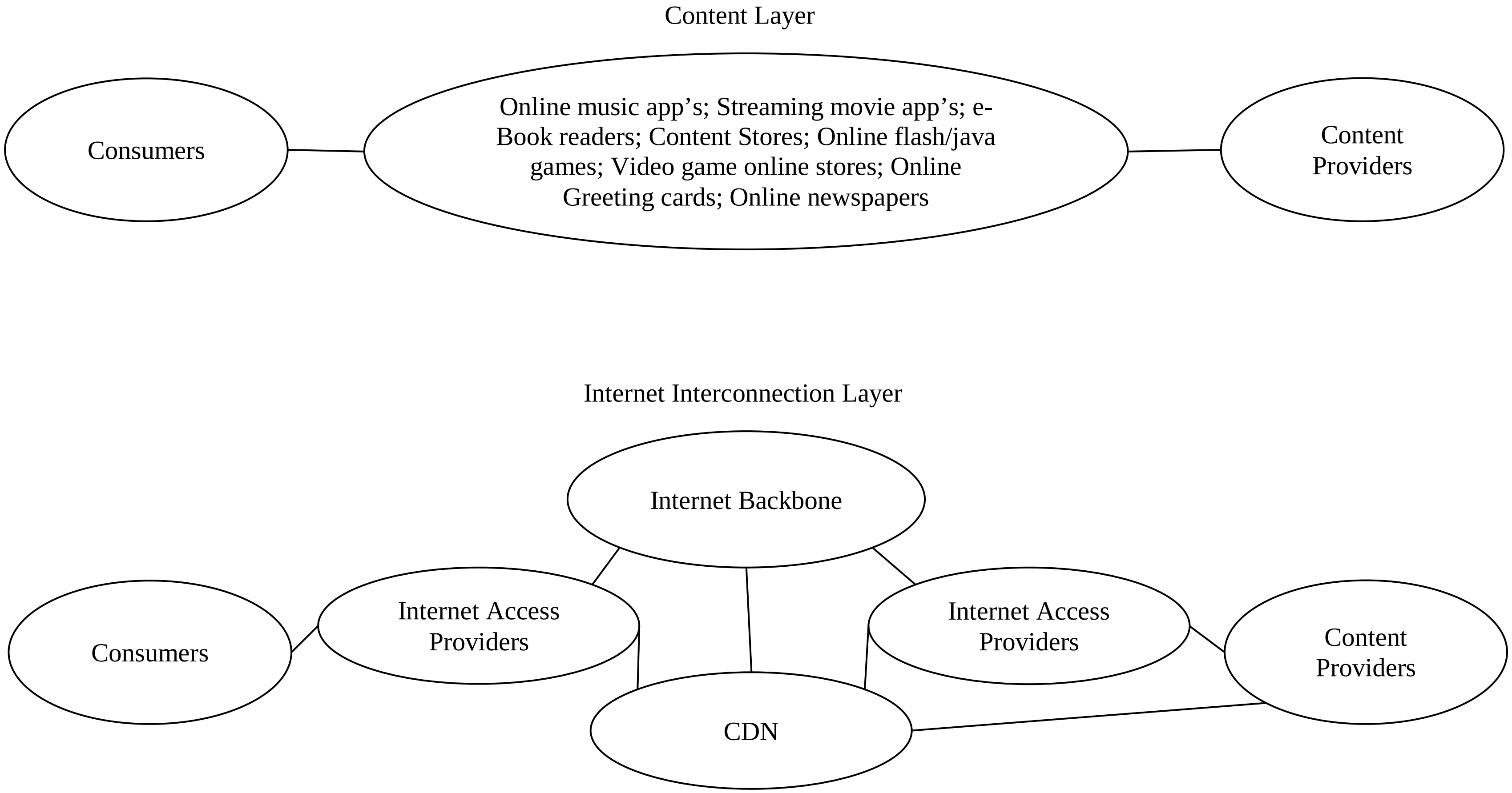

Figure 11. Content and Internet interconnection layers with examples from each.

Causes of On-net vs. Off-net

In this market, the same price is charged from both the on-net and off-net traffic producers. However, the on-net traffic has zero marginal cost while off-net traffic is costly for the Internet access provider to deliver because the Internet access provider has to pay the Internet backbone provider for the interconnection to another operator's network. It is because of this asymmetry in marginal costs that the two-sided market arises.

The asymmetry in marginal costs means that the on-net traffic producers pay a higher price than the price determined by the marginal costs. On the other hand, the off-net traffic producers may have a price lower than the price based on marginal costs of delivering off-net traffic. This means that the off-net traffic producers are being subsidised while the Internet access providers gain revenue from the on-net traffic consumers.

The pricing decision according to classical economics theories should be based on the elasticities of the two sides. Given that the off-net traffic consumers are being subsidised, they are likely to have more price elastic demand compared to the on-net traffic consumers. However, it is more likely that the pricing is the same for both sides because consumers prefer flat rate pricing and have no interest in knowing where the other endpoint is located.

Impact of On-net vs. Off-net

The main reason why two-sided pricing is practiced is to increase the willingness of the unsubsidised side to pay. This is because the subsidised side's demand increases with the subsidy, which should be perceived as value added to the other side. However, this is not the case with the on-net vs. off-net market as the value on-net traffic producers perceive will not increase if more off-net traffic consumers joined the network. Some consequences do follow from the two-sided pricing and are discussed next.

Looking purely from an economics theory point of view, the main consequence of subsidising 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 rising costs and declining profit.

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. Alternatively, the IAPs may not be able to pass on the higher costs onto consumers so the revenue does not cover costs and thus go out of business.

Thus from an Internet access provider's point of view, the increasing of off-net traffic has a negative effect and they should change the current pricing policies. However, consumers prefer flat rate pricing with Internet as the size of each bill is predictable (Herweg, 2010). This could mean that the traditional Internet hierarchy and the transit and peering agreements may not be the best system for Internet interconnectivity. Some alternatives may have to be designed to replace the transit/peering connections.

However, looking at the Internet growth statistics, on-net traffic has grown with a much higher rate than off-net traffic, which may suggest that the on-net vs. off-net market is not two-sided after all.

6.3.2 ISP Markets

The platform in this two-sided market is the Internet backbone provider. The two-sidedness is based on the assumption (Laffont et al., 2003) that the traffic originating (upstream) and terminating (downstream) backbone operators face different costs. A thorough explanation is provided next.

Causes of ISP Markets

According to Laffont et al. (2003), the receiving operator bears most of the costs of delivering the traffic. In the case of content sharing, the content provider mainly has upstream traffic while the consumers have downstream traffic. Because the platform is the Internet backbone provider and the consumer group 1 has only on-net traffic, only the consumer group 2 is considered. The assumption that each customer pays the same amount for the same level of service still holds in this market, though the consumers 2 should pay more than the content providers according to Laffont et al. This means that the consumers 2 are being subsidised while the content providers generate revenue to the Internet backbone provider.

The two-sided pricing practice seems to be reasonable as consumers are most likely more sensitive to price changes than the content providers are because consumers have less disposable income. In addition, the increase in consumer volume leads to higher value for the content providers as will be explained in the next section.

Another two-sided market following the Laffont et al.'s assumption is between the content makers and content providers and also has IBP as the platform. In this two-sided market, the content makers develop content and send it to the content provider. No traffic moves from the content provider to the content makers and because no other links are considered, the content provider is the receiving party in this two-sided market. Following this reasoning, the content providers are being subsidised in this market.

In this two-sided market, it is not clear which side has higher price elasticity of demand and which one is less elastic. Thus the two-sided pricing in this market may be purely because the same price should be charged for the same level of access service regardless of the marginal costs.

Impact of ISP Markets

By subsidising the consumers, the consumers perceive more value from the connection thus the Internet backbone provider may have more traffic in its network. If more consumers want to use the backbone access, IAPs may gain more subscriptions or the existing consumers may generate more traffic. As a consequence, the content providers may gain more clients or more advertising revenue, which may lead to more profit. However, when the Internet access providers' off-net traffic increase, it follows the same analysis as in the on-net vs. off-net two-sided market.

If content providers only gain more clients without more profit, the content makers may wish to produce more content to meet the higher demand. More content in turn might attract more content users and thus more consumers for both the Internet service providers and the content providers. With more consumers, the cycle begins again, which may continue until the market is saturated.

If content providers also gain more profit, the content distribution market may be perceived to be more attractive and thus new entrants may enter the market. In the second case, new content providers will continue to enter the market until the profit level has dropped back to the previous level. The larger amount of content providers will have mainly two effects. The first one involves content makers, who will have more choices on who can distribute their content, which may lead to the service fees declining with the increasing competition. When the service fees are lower, more content may be produced by the content makers and the same cycle as above is reached. The second effect concerns the consumers as will they have more choices on where to get the content.

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 they will reach higher Internet penetration. In addition, decreased load on single links is also positive for the Internet backbone providers. 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.

When the content provider is subsidised in ISP market 2, more content providers may enter the market because the new entrants may perceive more value in the content provision market. As more content providers enter the market, the effect it has on the market is the same as in ISP market 1. The content makers and consumers will have more choices of content providers. The same conclusion is reached as in ISP market 1.

6.3.4 CDN Market

This two-sided market has the CDN as the platform. The two sides of the market are the content providers and the Internet access providers, who represent the consumers. The use of CDNs is beneficial for both the content providers and the Internet access providers. The content providers do not need to worry about content distribution or scalability. The Internet access providers pay less transit fees to the Internet backbone providers because part of the traffic is distributed by the CDN rather than through the Internet backbone.

Causes of CDN Market

This two-sided market is so far the clearest as different prices are charged from the two sides. The skewed pricing can be seen clearly in Figure 9, where the content provider pays the CDN for the service while no money is flowing between the Internet access providers and the CDN. In addition, the CDN may even offer free peering points into its backbone network to IAPs. Keeping in mind that both the content provider and the IAPs benefit from the CDN's services, the pricing can be described as two-sided. In this two-sided market, the content providers generate revenue for the CDNs while IAPs are being subsidised.

From the Akamai vs. Inktomi case it can be deduced that charging the content providers is more profitable than charging the Internet access providers as Akamai succeeded in capturing market share while Inktomi did not. This may mean that the content provider has relatively lower price elasticity of demand than the Internet access providers.

Impact of CDN Market

The lack of monetary transfer between the CDN and the IAPs are compensated by the intangible network effects between the two. This means that if the IAPs have large networks, the CDN will indirectly gain more value from being connected to the IAP. Vice versa, if the CDN is large and has lots of content, the IAP would gain more value from connecting to it. This is due to the existence of positive externalities. Externalities are the basis for network effect and the positive network effect between the CDN and the IAP will cause the CDN to grow until only one CDN is dominant in the market.

In addition, when a CDN subsidises IAPs, it will be connected to more IAPs, so it 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. The CDN may then grow into a natural monopoly or at least a few large CDNs will dominate the market.

When a monopoly exists in a market, mainly two outcomes can occur; one positive, the other negative. The positive outcome involves the monopoly gaining economies of scale and thus having lower marginal costs. When marginal costs are lowered, the monopoly CDN may lower its prices to reach economic efficiency. On the other hand, a monopoly has the power to set prices as it has no competition; thus a monopoly CDN may raise prices. However, the more likely outcome is an oligopoly situation with a few large CDNs dominating the market because the government policies tend to prevent monopolies from forming. The large CDNs may also gain economies of scale and due to the existence of competition, no one can raise prices.

7. Comparison of Content Delivery Models

The previous sections identified the content distribution models as well as analysed them with two-sided market theory. This section will make a comparison of the three models; client-server, CDN and CCN. In addition, the feasibility of the models is examined. Lastly, the future of the content distribution market is discussed.

7.1 SWOT Analysis

This section compares the three content distribution models using the SWOT analysis method. SWOT (Strengths, Weaknesses, Opportunities, Threats) (Johnson, Scholes and Whittington, 2005) analysis summarises the key capabilities of a company or organisation and key issues from the market environment to determine the organisation's competitiveness. This work attempts to identify the strengths, weaknesses, opportunities and threats of content distribution models. Because no single company or organisation exists for Internet content delivery models, the analysis is done from each model's perspective.

7.1.1 Client-Server

Table 6 shows the SWOT analysis of the client-server model. Some of the strengths of client-server include reliability of hardware, relatively low deployment prices for the content providers compared to the CDN, for example, and availability to everyone connected to the Internet. However, the weaknesses are lack of service quality guarantees due to the best-effort nature of the IP Internet, which include delays and packet losses. In addition, large and popular content may cause a lot of traffic load around the origin server.

Table 6. SWOT analysis of client-server.

Strength	**Weakness**
- Basic infrastructure, available for everyone - Content providers have better control over where and who has access to the data - Relatively cheap - Reliable	- End-to-end delay - Packet losses - Best-effort provides no QoS guarantee - Big and popular files cause large network load, especially on access networks
Opportunity	**Threat**
- May offer more services on top of the basic network	- May be replaced by overlays running on top of the basic network, such as CDN and P2P

Being a basic Internet architecture has its opportunities and threats, depending on how the situation is managed. The opportunity of client-server arises from network components offering additional services on top of the basic network. However, third parties, who wish to offer overlays such as CDNs or P2P networks presents a threat to the client-server model.

7.1.2 Content Delivery Network

The SWOT analysis made for CDN is shown in Table 7. Scalability and offering of a comprehensive service are some of the key capabilities a CDN has to successfully compete in the content distribution market. In addition, CDNs may offer service level guarantees in the form of service level agreements and the content provider's access network is not strained because the traffic goes directly through the CDNs' servers. The main weakness of a CDN is the high prices that it charges content providers for the service. Some other weaknesses include high traffic loads on links around the CDN server and the loss of perfect control of a content provider.

The existence of network effects in the CDN market can be both an opportunity and a threat, depending on the size of the CDN. For a large scale CDN, the size may get even larger due to the network effect and this means gaining market share at the expense of smaller CDNs. As a consequence, one or a few major CDNs may see the opportunity to dominate the market while the smaller CDNs face a threat of going out of business. CDN as an architecture has the advantage of being an overlay, which functions on top of any network, may it be an IP network, Ethernet network or even PSIRP.

Table 7. SWOT analysis of CDN.

Strength - Scalable - Service level guarantees - Comprehensive service package - CP's network not strained	**Weakness** - Relatively expensive - CDN servers concentrate traffic around them, which strains the links connected to the servers - CPs cannot control where and who has access to the data
Opportunity - Network effect may produce dominant CDN - As an overlay, works on any network; IP or something else	**Threat** - Network effect may cause smaller CDNs to go out of business - Consolidation of CDN market may raise prices

7.1.3 Content Centric Network

Table 8 shows the SWOT analysis of the Content Centric Network. Scalability is also a key capability for CCN in additional to being cheap and content centric instead of location centric. Content centric means also user friendly as the data chunks have meaningful names instead of addresses. In addition, the caches may lessen delay and congestion in the network. The only weakness of CCN is the lack of a mechanism to find data if no nearby caches are found. Flooding is used in CCN to find content but for finding a data piece that is located far away in the network, flooding may not be the most efficient method to find data and the network may become congested.

Table 8. SWOT analysis of CCN.

Strength	Weakness
- Scalable - Content centric - User friendly - Networks not strained - Less delay - Cheap	- Flooding to find content may cause problems if no caches are found nearby - Less control - No simple means to collect usage data or other statistics
Opportunity	**Threat**
- CCN can work as an overlay, thus functions on any network - Reduced off-net traffic for IAPs, thus IAPs may be interested in investing	- No deploying incentive - PSIRP and other information networking architectures - Large enough CDN may offer the same level of service as CCN - Copyright protection; may or may not be managed well - Value not in transferring bits anymore, where is it then?

CCN can also be understood as an overlay, which means it can function on any network. Like in the case of CDNs, this is an opportunity. However, if some content centric basic network architecture such as PSIRP is widely deployed, an overlay that functions with a similar concept may not be needed. Another threat includes a CDN becoming so widely connected that it offers the same level of services as a CCN would, thus making CCN obsolete. When the data is cached at the local ISPs and other cache servers, it is hard to manage the copyright protection unless each individual file is protected. This may be a big threat for the CCN. The threat of a new invention not being competitive enough for someone to invest in it always exists; this is also the case with CCN. However, as CCN reduces off-net traffic for IAPs and does not change the basic IP architecture, IAPs may be interested in deploying caches. Lastly, the content centric concept may change the network so that the value does not come from moving the bits anymore thus it may take the revenue source from ISPs if they cannot think of other ways to charge the clients. This may lead to ISPs resisting the change into content centric.

7.1.4 SWOT Comparison

The results of the SWOT analysis are collected and the three models compared here. Some important criteria gathered from the SWOT analysis are presented in Table 9 together with each distribution model's standing with the criteria. In addition, an explanation of each criterion is given in this section.

- Cost for CP – The price the content provider has to pay for the service. Low means less costs while high is for higher costs.
- Cost for ISP – The price the ISPs have to pay for the service.
- Scalability – How scalable the model is when more consumers use the service. Low means bad scalability while high stands for scalable.
- Delay – The network delay that the packet faces when traversing in the network. Low delay mean small roundtrip time and high is large roundtrip time.
- Network congestion – Network congestion criterion tells where if at all congestion exists in the network when many consumers are connected to the service and requesting for content.
- Accessibility of service – Measures how accessible the data is. This includes the hardware and software operability as well as downtime guarantees and backup systems.
- QoS levels available – Measures how much control does the content provider have on the quality of service level in each content distribution model.
- CP's Control over content – Measures how well the content provider can remove, update or modify content as well as get usage statistics.
- Copyright protection – Measures how well the content providers can manage copyright issues.

Table 9. Comparison of the content distribution models based on the SWOT analysis.

Criteria	Client-Server	CDN	CCN
Cost for CP	Low	High	Low
Cost for ISP	Medium	Low	Medium/High
Scalability	Low	High	High
Delay	High/Medium	Medium	Low/Medium
Network Congestion	Around the central server	Around CDN servers	When flooding for non-cached item
QoS Levels Available	Low	High	Low
Accessibility of Service	High	High	High/Medium/Low
CP's Control over Content	High	Medium	Low
Copyright Protection	High	Medium	Low

From the SWOT analysis and the above comparison of results, a few conclusions can be drawn about the content distribution models:

- The highest service fees that the content providers face is with the CDN, while in client-server and CCN no third party charges service fees from the content provider. CPs pay service fees to the Internet access provider in all three cases.
- A content provider using the client-server model has lower degrees of scalability than a content provider using the CDN or CCN models due to server capacity constraints of servers owned by the content provider. A CDN may allocate dynamically more server capacity to the content provider when more clients use the service and for CCN, the content is cached nearer the consumers thus the origin server load is much smaller.
- Delay in the client-server model may become high during the peak traffic hours for popular content. In CDNs the delay may also become a problem if the links to the CDN servers become crowded, but the CDN can have several CDN servers dedicated for certain high traffic areas. In a CCN, because the content is cached near the consumers and several sources may exist, the delay is of less a significant problem. However, for new content, some delay may arise when the network is flooded to find the data. Thus delay is the highest in the client-server model and lowest in CCN.
- In the client-server model, usually a central origin server is used, from where all content the delivered. This is a source for congestion, especially

during peak hours. CDNs may have congestions near the servers as well but by locating servers containing the same content at different places, the risk of congestion can be reduced. With CCN, the content is cached anywhere in the network that it passes, thus the next requesters in the area may get the content from a local source. This reduces congestion considerably. However, during the content discovery face, the flooding may congest the network. Thus the client-server model has the highest congestion risks while the CCN has the smallest congestion risks.

- When using the client-server model, the content providers have better control over the hardware and software of their distribution system thus the service is more reliable. CDNs offer service level guarantees thus they have backup servers to handle the distribution if the main servers fail. This means that the service should be quite reliable. The CCN uses cache servers for content distribution, which causes one significant problem; the content provider cannot control the cache servers. However, several sources of the same data should mean that the accessibility of the data is good. As a conclusion, the reliability of service for the client-server and CDNs are good while accessibility to data cannot be guaranteed with the CCN.
- Due to the control over the data servers in the client-server model, the content provider also has control over who can access the content and from where. In the CDN, the content provider cannot control who has access to the data servers but a protection mechanism on each data file can be implemented. How well the file protection works depends on the algorithms. In addition, the CDN has contracts with CPs that can guarantee copyright protection. CCN relies solely on protection algorithms and copyright protection cannot be guaranteed. Thus copyright protection is best in the client-server model and CDN comes as a good second while in CCN, it may or may not be good.

7.2 Comparison Summary

So far the content distribution models have been analysed with the two-sided market theory and SWOT analysis. This section combines the interview results from Section 4 and the SWOT analysis done in this section to form some conclusions on the prospects of information networking in the content distribution market. The conclusions are done from different stakeholder's perspectives, starting from the content provider.

Content Provider

As the interviews have revealed, the most important feature of a content distribution system from a content provider's perspective is the cost efficiency. This suggests that the CCN or the client-server is the best option for the content providers based on the service fees faced by them in each model.

The next important features for the content providers are scalability and reliability. From the two relatively low cost distribution models, CCN offers better scalability while in the client-server model better control over the service provision is achieved, which may result in better reliability. In terms of guaranteed QoS, CDN offers the highest QoS through Service Level Agreements (SLAs).

For the smaller content providers, it is very important that no major upfront investments are made as their funding may be limited. Thus the CDN business model of monthly payments is ideal for the smaller content providers. In the CCN, the origin servers' capacity and processing power may not need to be very significant as the content is cached into the network and only some traffic goes all the way to the origin servers. This means that the upfront investment in hardware and software may not need to be very high in CCN.

The last feature on the importance list is the fast distribution of content. As can be seen from Table 9, the client-server model has the highest delay whereas the CDN and CCN have lower delays. However, the content providers regard low delay as the least important, thus it is only used if the other features are not enough to determine which distribution model is best suited for content distribution.

From the above discussions it can be seen that the client-server model and the CCN are in a tie situation after considering the most important features. Taking into consideration fast distribution and low upfront investments for smaller providers, CCN ranks better than the client-server model. Thus it can be concluded that from the content providers' perspective, CCN is the best alternative for content distribution. However, the low control of content and service level as well as unguaranteed reliability may limit the success of CCNs. In addition, for a content provider offering delay sensitive data, CDN should perform better in the comparison.

Internet Access Provider

In the interviews, it is mentioned that the client-server model may strain the access network. Assuming that the Internet access provider does not wish to have congestion in its network, it may be suggested that the client-server model is not the most ideal for the IAP.

In addition, the Internet interconnection agreement principles have pointed out that the Internet access providers prefer on-net traffic rather than off-net traffic. The interviews have showed that the growth of off-net traffic has slowed while the growth of on-net traffic is high. This may suggest that the IAPs have intentionally avoided off-net traffic by maybe switching to architectures with less off-net traffic.

From the three content distribution models, the CDN and CCN produce less off-net traffic than the client-server model. CDNs quite often have local CDN servers in highly populated areas, thus the traffic does not need to go to other operators' network. In addition, a large CDN may have its own backbone network for content distribution and offer free peering points for IAPs thus no transit fees are paid, which is equivalent to not having off-net traffic. CCN produces some off-net traffic but for each piece of data, after the first request, the data will be stored in cache servers within the operator's network and thus later requests do not generate off-net traffic.

However, the interviews have also revealed that the main cost source is the energy consumption from server halls. In CCN, the IAPs would need to install and maintain cache servers, which consume more energy and thus add to the energy costs. It may then be argued that a cost saving IAP may not want to deploy CCN and from the IAP's perspective, the CDN is a better choice. On the other hand, if the extra energy consumption is compensated by savings in the off-net traffic costs, IAPs may want to invest in cache servers of the CCN model.

Internet Backbone Provider

An Internet backbone provider's revenue arises from selling transit services thus if a model lowers IBP's transit sales, the model may not be preferred by IBPs. Since a CDN with its own backbone network does not require the Internet backbone providers' services, the IBP may not want CDNs to be used. In addition, in the interviews, it was mentioned that the CDNs may cause congestions in the network around the servers. Thus IBPs may not prefer CDNs to be used by the content providers. However, IBPs may enter the CDN market if revenue from selling transit lowers significantly.

Similarly to IAPs, the major cost source the IBP faces is also from energy consumption. Thus IBPs may not want to increase this cost by installing and managing cache servers. However, from the interviews, it can be seen that the IBPs have considered caching and would be interested in deploying it if some challenges can be solved.

Another large cost for IBPs arises from building the network thus IBPs may not want to create more infrastructure to meet the growing demands of network capacity. A solution could be to deploy CCN. However, if a network wide CCN is deployed, less transit services may be needed and thus the IBPs may suffer from it.

For an Internet backbone provider, no clear preference for one content distribution model is formed. The best alternative depends on the respective cost savings and additional costs of deploying each model.

Consumers

For a consumer the content distribution model mainly has no effect. In each model, the consumer has to pay for Internet access to the Internet access provider and a possible content fee to the content provider. When the content is time sensitive, the consumer may want to have the least possible delay in the service. In this case, the CDN and the CCN can provide the best service for the consumer. However, during non-peak hours or for not so popular content, the client-server model may also provide delay free service. On the other hand, the IAP's costs are more or less directly reflected on the consumers' prices, thus it would suggest that the consumers prefer the same model as the IAP.

Data Centre Provider

A data centre provider rents out data servers to anyone who requires server capacity. The server can be rented to practically anyone: the content provider in the client-server model, the CDN service provider in the CDN model or as cache servers in the CCN model. Thus, for a data centre provider, it also does not matter which content distribution model is in use.

8. Conclusion

This section presents the key findings of the thesis and discusses the limitations of the study and applications of the results. In addition, topics of future research are proposed.

8.1 Key Findings

On the general level, one of the key findings is that the current Internet cannot efficiently meet the increasing content volume and demand for network capacity. Thus modifications to the current Internet or entirely new Internet architectures must be designed and implemented. This work has discovered three future Internet suggestions that adopts the information networking concept – CCN (Jacobsen, 2009), PSIRP (Fotiou, Polyzos and Trossen, 2009), NetInf (Ahlgren and Vercellone, 2010) – and one modification to the current Internet (network wide CDN).

The interviews indicate that CCN and NetInf are designed as overlays for the current Internet while PSIRP is the only clean-slate Internet architecture suggestion. A closer look on CCN was taken in this work by comparing CCN and CDN as the two models can substitute each other on the conceptual level.

The two-sidedness of the content distribution market may increase off-net traffic, which is unfavourable for the Internet access providers (IAP), who wish to reduce the amount of off-net traffic. The performed value network analysis indicates that the CCN model reduces off-net traffic, especially for the Internet access providers. This finding may be the only business case for information networking as IAPs may be willing to invest in cache servers if they benefit from the investment. However, the exact amount of benefit from reduced off-net traffic can only be determined after taking into consideration the initial investment and the relative increase in energy consumption costs. In addition, a network wide CDN with servers within each IAP's network should have the same effect on off-net traffic as the CCN.

The two-sided market analysis suggests that as a result of the two-sided pricing in the Internet interconnection, more content providers may emerge in the market and the Internet backbone providers' network may reach wider connectivity. In addition, the two-sided pricing in the CDN market may cause one CDN to become a monopoly or oligopoly, which may lead to a network wide CDN coverage. Following these conclusions, the qualitative two-sided analysis can be said to explain the current market structure. In addition, it may predict future market structure, the accuracy of which cannot be determined. However, two-sided analysis' ability to compare different models in the qualitative level is not optimal.

The SWOT analysis identifies the criteria to measure each content distribution model. Based on the criteria, each stakeholder's preference of distribution models is derived. For the consumers and data centre providers, the content distribution model does not affect their market behaviour. IAPs prefer either the CDN or CCN whereas the IBPs' preference could not be concluded with the available information. Lastly, the content provider prefers the CCN model. This finding means that the content provider may be willing to invest in the cache servers to be placed in the network.

8.2 Discussion

This work analyses the two-sided market and value networks of content distribution models. In addition, the market demand for information networking is explored. In the process, many assumptions and simplifications are made to ease the analysis. However, in real life cases, these assumptions may not hold entirely since the real world relationships are much more complex.

This work assumes that the content maker bears some costs for producing the content. However, with most digital products, the marginal cost of producing one more product is practically zero. In addition, content providers are assumed to bear costs from distributing content to consumers. This is only partly true as content providers do pay for having access to the Internet but they do not pay specifically for delivering the content to the consumer. These assumptions have enabled the two-sided market identification involving the content provider as a two-sided platform.

The simplification that the consumers who produce mostly off-net traffic are off-net consumers is made. The same simplification applies for on-net consumers as well. Without these simplifications, the on-net and off-net consumers cannot be identified and thus the on-net vs. off-net two-sided market analysis would not be possible. Without separating on-net and off-net consumers, the two sides would have the same price elasticity of demand and intentional two-sided pricing cannot be practiced.

This work has ignored the link asymmetry in access networks. In reality, the downstream link between the consumer and the Internet access provider has higher capacity than the upstream link. This asymmetry may in fact be the reason why the marginal costs of upstream and downstream traffic are also asymmetric apart from the hot-potato routing. However, taking into account the link capacity asymmetry does not necessarily change the two-sided pricing in access networks.

The two-sided analysis in this work is limited only to the qualitative analysis due to the lack of quantitative data. For this reason, the two-sided analysis on the Internet interconnection layer is limited. In addition, limiting the two-sided analysis on the Internet interconnection layer and only the link between the players in question may have an impact on the results. For example, content providers act as platforms in the advertising and content provision markets and according to the two-sided market theory should predict consolidation of content providers. This opposes the conclusion of content providers increasing in number based on the Internet interconnection layer's two-sided analysis. The comparison of the distribution models and their feasibility thus is mostly based on the SWOT analysis and value network analysis instead of the two-sided analysis.

This work has not aimed at finding or formulating business models for the CCN model. However, CDN's two-sided market analysis has showed that content providers pay more willingly than ISPs for the service. This may also apply in the CCN case because it is basically a network full of local CDNs. On the other hand, no clear two-sided market like the CDN market is found from the CCN model, which means that the CCN model does not have a platform that charges content providers or ISPs. In addition, the CDN provider provides intangible benefits to content providers in the form of usage information, which may be the reason why content providers are willing to pay for the service. The CCN model provides no such intangible benefits. This may mean that the

CCN model does not have business prospects and ISPs should consider getting into CDN business.

Despite content providers' preference for CCN, ISPs' willingness to deploy CCN 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 are willing to invest in the CCN deployment. ISPs then could either pass the extra costs onto consumers or content providers. Since ISPs include both IAP and IBP, their separate willingness for extra investments is next discussed.

IAPs' willingness to deploy CCN 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, on the other hand, is not straightforward but the following reasoning provides some stimulus for IBPs to consider CCN. Due to the changes in network hierarchy and other reasons, the Internet transit prices have dropped significantly and is converging towards zero pricing for each Megabit per second (Mbps) (Norton, 2010b). Since transit revenue has traditionally been the major income for IBPs, now IBPs are shifting to other revenue sources such as providing CDN services (Labovitz et al., 2009). Thus IBPs may be open to the possibility of finding viable revenue models from CCN services.

8.3 Future Research

This work has presented a qualitative analysis of the two-sided markets as well as a comparison of content distribution models. The next step would be to apply mathematical formulation to each model and to find quantitative data on each stakeholder's costs, prices and willingness to pay for the cache servers. However, companies may be reluctant to share detailed information on their costs and pricing. Thus methods to estimate quantitative data need to be formulated.

The profitability of two-sided pricing depends largely on the existence of network externalities and thus network effect. The size of the network effect cannot be easily quantified although this information would be beneficial for the price setters. In addition, the extent of the price discrimination and whether the two-sided pricing in a two-sided market is stable depends on the respective price elasticity of each side. Thus it would also be interesting to estimate the price elasticity of different stakeholders.

The CCN model is concluded to be preferred by content providers; however, whether it is deployed depends on ISPs' willingness to invest in cache servers. Thus different business models for ISPs to profit from the extra investment are important and research on this subject should be conducted.

The scope of this work is limited to include only the client-server, CDN and CCN models because content providers prefer client-server and CDN. Other content delivery models such as the cloud and peer-to-peer are also interesting research topics thus the research scope can be expanded to include them. In addition, a feasibility analysis can be performed on PSIRP and NetInf once more technical details are known of the architectures.

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Appendix A – Mathematics of 2SM

A.1 Monopoly platforms

Private Monopoly

Total profit is price times the quantity demanded, thus the profit function in a private monopoly is:

$$\pi = (p^B + p^S - c)\, D^B(p^B)\, D^S(p^S), \tag{A1}$$

where (p^B + p^S - c) is the total price of both sides minus the marginal cost of producing one extra product. D^B and D^S are the demand of the two-sides; buyers and sellers.

To find the maximum of a function, it is first differentiated and then set to equal zero. Eq. (A1) has two variables and thus to maximise profit, Eq. (A1) is partially differentiated with respect to both of the variables; p^B and p^S, separately:

$$\frac{\partial \pi}{\partial p^B} = \frac{1}{p^B + p^S - c} + \frac{(D^B)'(p^B)}{D^B(p^B)} = 0 \tag{A2}$$

$$\frac{\partial \pi}{\partial p^S} = \frac{1}{p^B + p^S - c} + \frac{(D^S)'(p^S)}{D^S(p^S)} = 0 \tag{A3}$$

Because both Eq. (A2) and Eq. (A3) are equal to zero, they can be set to be equal and by moving the terms around Eq. (A4) is formed.

$$(D^B)' D^S = (D^S)' D^B \tag{A4}$$

Elasticity is the percentage change in quantity demand divided by the percentage change in price as shown below in equation form:

$$\text{Elasticity} = \frac{\Delta Q}{Q} \Big/ \frac{\Delta P}{P} = \frac{dQ}{dP}\frac{P}{Q}$$

By substituting the demand and price terms of a monopoly platform, the elasticities of demand of buyers and seller, respectively, are formed and shown in Eq. (A5) and Eq. (A6).

$$\eta^B = -\frac{p^B (D^B)'}{D^B} \tag{A5}$$

$$\eta^S = -\frac{p^S (D^S)'}{D^S} \tag{A6}$$

By inserting Eq. (A5) and Eq. (A6) into Eq. (A4) and moving the terms around, the price structure of a monopoly platform in terms of price elasticity of buyer’s and seller’s demand is reached and shown in Eq. (A7).

$$\frac{p^B}{\eta^B} = \frac{p^S}{\eta^S} \rightarrow \frac{p^B}{p^S} = \frac{\eta^B}{\eta^S} \quad \text{(A7)}$$

Ramsey Pricing

Social welfare of a monopoly platform is the net surplus of all transactions on both sides, represented by $V^S(p^S)D^B(p^B)$ and $V^B(p^B)D^S(p^S)$.

$$W = V^S(p^S)D^B(p^B) + V^B(p^B)D^S(p^S) \quad \text{(A8)}$$

Social welfare is maximised by partially differentiating Eq. (A8) with respect to p^B and p^S, separately:

$$\frac{\partial W}{\partial p^B} = V^S(D^B)' - D^B D^S = 0 \quad \text{(A9)}$$

$$\frac{\partial W}{\partial p^S} = -D^S D^B + V^B(D^S)' = 0 \quad \text{(A10)}$$

Setting the two equations to be equal gives Eq. (A11).

$$V^S(D^B)' - D^B D^S = -D^S D^B + V^B(D^S)' \quad \text{(A11)}$$

After simplification of Eq. (A11), the Ramsey price structure for cost allocative efficiency is found and shown in Eq. (A12):

$$\frac{V^S}{D^S}\frac{\eta^B}{p^B} = \frac{V^B}{D^B}\frac{\eta^S}{p^S} \quad \text{(A12)}$$

A.2 Competing Platforms

The profit function of a platform i competing with other platforms is given by Eq. (A13).

$$\pi_i = \left(p_i^B + p_i^S - c\right)Q_i \quad \text{(A13)}$$

Partially differentiating Eq. (A13) with respect to p_i^B and p_i^S and setting the two differential equations to be equal maximises profit. The differential equations are shown in Eq. (A14) and Eq. (A15).

$$\frac{\partial \pi_1}{\partial p_1^B} = Q_1 + \left(p_1^B + p_1^S - c\right)\frac{\partial Q_1}{p_1^B} = 0 \quad \text{(A14)}$$

$$\frac{\partial \pi_1}{\partial p_1^S} = Q_1 + \left(p_1^B + p_1^S - c\right)\frac{\partial Q_1}{p_1^S} = 0 \quad \text{(A15)}$$

Setting the two equations to be equal gives Eq. (A16).

$$\frac{\partial Q_1}{p_1^S} = \frac{\partial Q_1}{p_1^B} = -\frac{Q_1}{p_1^B + p_1^S - c}, \tag{A16}$$

where Q_1 is the transaction volume for platform 1:

$$Q_1 = d^B(p^B)D^S(\hat{b}_{12}) + \widehat{D}^B(p^B)\{D^S(p_1^S) - D^S(\hat{b}_{12})\} \text{ when } p_1^S < p_2^S \tag{A17}$$

$$Q_1 = d^B d^B(p^B)D^S(\hat{b}_{21}) \text{ when } p_2^S < p_1^S \tag{A18}$$

To prove that Q_1 is differentiable at $p_1^S = p_2^S$, both Eq. (A17) and Eq. (A18) is partially differentiated with respect to p_1^S and the resulting differentials are compared:

Eq. (A17): $$\frac{\partial Q_1}{\partial p_1^S} = (D^S)' \frac{(d^B)^2}{2d^B - \widehat{D}^B} \tag{A19}$$

Eq. (A18): $$\frac{\partial Q_1}{\partial p_1^S} = (D^S)' \frac{(d^B)^2}{2d^B - \widehat{D}^B}$$

Because the differentials are the same, Q_1 is differentiable at $p_1^S = p_2^S$.

By partially differentiating Q_1 at $p_1^S = p_2^S \equiv p^S$ and $p_1^B = p_2^B \equiv p^B$ with respect to p_1^B gives:

$$\frac{\partial Q_1}{\partial p_1^B} = \frac{\partial d_i^B(p^B, p^B)D^S(p^S)}{\partial p_1^B} \tag{A20}$$

Setting Eq. (A19) and Eq. (A20) to be equal with Eq. (A16) and substituting the terms with the singlehoming index σ, the own brand elasticity of demand η_0^B and the elasticity of the seller's demand η^S gives the price structure of competing platforms shown in Eq. (A21):

$$p_1^B + p_1^S - c = \frac{p^B}{\eta_0^B} = \frac{p^S}{\eta^S/\sigma} \rightarrow \frac{p^B}{p^S} = \frac{\eta_0^B}{\eta^S}\sigma \tag{A21}$$

A.3 Membership fees

The net utility of a competing platform is given with Eq. (A22)

$$U_i^B = (b_i^B - p_i^B)N_i^S - c^B - \gamma_i^B, \tag{A22}$$

where b_i^B is the buyer average benefit of receiving the service, p_i^B is the per transaction mark-up for the buyer, c^B is the platform's fixed cost per buyer and γ_i^B is the buyer's fixed usage cost.

For consumers to singlehome to platform i, the utility consumers gain from associating with platform i must be positive and greater than the utility from platform j. Thus the new transaction volume function is shown with Eq. (A23).

$$\begin{aligned} N_i^B &= \Pr\left(U_i^B > \max\left(0,\ U_j^B\right)\right) = d_i^B\left(p_1^B, N_1^S, p_2^B, N_2^S\right) \\ &= \Pr\left(\left(b_i^B - p_i^B\right)N_i^S - c^B - \gamma_i^B \right. \\ &\left. \geq \max\left[0, \left(b_j^B - p_j^B\right)N_j^S - c^B - \gamma_j^B\right]\right) \end{aligned} \tag{A23}$$

Substituting N_1^S and N_2^S with $N_i^S = D^S\left(p_i^S, N_i^B\right) = \Pr\left(\left(b^S - p_i^S\right)N_i^B > \gamma^S\right)$ gives Eq. (A24).

$$N_i^B = (N_1^B, N_2^B) = n_i^B\left(p_1^B, p_1^S, p_2^B, p_2^S\right) \tag{A24}$$

The profit function now becomes:

$$\pi_i = (p_i^B + p_i^S - c)N_i^B N_i^S \tag{A25}$$

Partial differentiation of Eq. (A25) with respect to p_i^B and p_i^S maximises profit. By setting the two equations to be equal and substituting the own elasticity for buyer demand η_0^B, cross elasticity for buyer demand η_S^B, own price elasticity for seller demand η^S and network elasticity for seller demand η_N^S into the differential, the price structure that takes into consideration fixed costs is obtained and shown in Eq. (A26).

$$p^B + p^S - c = \frac{p^B}{\eta_0^B\left(1 + \eta_N^S\right)} = \frac{p^S}{\eta^S + \eta_S^B\left(1 + \eta_N^S\right)} \rightarrow \frac{p^B}{p^S} = \frac{\eta_0^B}{\eta^S + \eta_S^B} \tag{A26}$$

Appendix B – Interview questions

B.1 Questions for Content Providers

- Which content distribution models have you considered and which one(s) do you use? (e.g. CDN, own server system, rented server system, cloud)
- What was the decision based on? (e.g. cost, reliability, scalability, other reasons)
- If you used CDN, which company did you use?
  - Is there a server within your premises or are you connected to the CDN via IAP?
  - When did you start to use CDN?
- What business model do you use regarding CDNs?
  - Do you pay something to the CDN company?
    - Are you happy with the price level?
  - Are there non-monetary benefits moving either way?
- What is the concrete technical and business interface between you and the CDN?
- What do you think is the CDN's business model?
- What features of CDN are important? List the following in the order of most important first.
  - Scalability
  - Reliability
  - Fast distribution of content
  - No upfront investments
  - Flexibility
  - Other feature?
- Is there anything missing from the CDN service?
- Have you faced any problems with your current setup? (e.g. scalability, security issues, leak of important information, QoS, revenues not covering costs)
- Are you happy with the service in terms of price vs. quality of service?
- What kind of relationship do you have with advertisers?
- What kind of costs do you face? Does it depend on which model you use? (e.g. software, hardware, servers/CDN fees, Internet connectivity, human resources, others)
- How do you manage copyright issues?
- Interviewees were asked to give comments on value networks drafts.

Caching/Information Networking

- Do you see it as an alternative or complement to the current services?
- Would it change your content distribution model?

B.2 Questions for Internet Service Providers

- From an ISP's perspective, does it matter, which content distribution model the content provider uses, i.e. CDN, own server system, rented servers, and cloud?
  - Cost wise?
  - Otherwise?

- Do you consider CDNs as competitors?
- Do you have agreements with CDNs?
  - Is there monetary compensation moving in either direction?
  - Are there non-monetary benefits moving either way?
- What is the concrete technical and business interface between you and the CDN?
- From an ISP's perspective, do you think CDN will continue to prosper? Or will some other model take over (e.g. P2P)?
- What kind of costs do you face? (e.g. backbone connectivity costs, peering or transit agreements with other ISPs)
- Interviewees were asked to give comments on value networks drafts.

Caching/Information Networking

- Do you currently do some form of caching?
  - Have you done it earlier?
- Would you be interested to deploy content centric networking?
- From an ISP's perspective, what are the possible advantages and disadvantages of information networking?

B.3 Questions for Content Hosting Companies/Data Centre Providers

- How do you differ from CDN's?
  - Technically?
  - From a business perspective?
- What costs do you incur? (e.g. hardware, software, distribution costs)
- What kind of agreements do you have with CP's?
  - What is the concrete technical and business interface between you and the CP?
  - Do you charge by bit stored or with a flat rate?
- Do you collaborate with the ISP's?
- Do content users get content directly from your servers or through the CP?
  - What kind of traffic network is there?
- Have you considered becoming a CDN?
- Interviewees were asked to give comments on value networks drafts.

Information Networking

- Would you consider content centric networking as competition or opportunity?
  - Would you switch to it?