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Abstract

Since the original design and deployment of the Internet architecture, the economical and technological requirements regarding the distribution quality of web-based information services have changed drastically. Business models have evolved that particularly address quality and cost aspects of information service distribution, e.g. content delivery networks and peer-to-peer distribution. In addition, network operators apply differentiated routing technologies in dedicated infrastructures to guarantee a superior quality of service (QoS). This article compares the value propositions of technologies for information service distribution. 103 information services were analyzed by means of discriminant analyses in order to identify the main aspects influencing delivery quality and costs. The results indicate that the value propositions differ with regard to the type of services they support rather than with regard to direct QoS criteria, such as latency and packet loss. The insights derived from this work support information service vendors in their choice of a distribution provider.

Introduction

The electronic distribution of information services has been subject to a discourse in research since the immense growth of the Internet in the late-1990s. In e-business research, a rich variety of issues concerning the application of web-based information services to support business processes have been addressed (Amit and Zott 2001, Timmers 1998).

Physical distribution is defined as the collective term for the range of activities involved in the movement of goods from the point of production to the final point of sale, such as warehousing and transportation (McKinnon 1988, 33). The objective of distribution is to meet customer desires with regard to the amount of delivered goods and the time and place of delivery. Distribution providers must thereby optimize the balance between quality and costs of delivery (Bowersox et al. 1986, pg. 19). Even though the economics of information services are fundamentally different (Demirkan et al. 2008, Shapiro and Varian 1999), the objectives for the distribution of tangible goods also hold for the distribution of information services over communication networks (electronic distribution). Despite the richness of e-business research, the economic aspects associated with technologies for electronic distribution have scarcely been addressed.

Several authors (Faratin 2007, Leighton 2009, Saroiu et al. 2002) differentiate between three major distribution methods in the Internet: centralized hosting, content delivery networks, and peer-to-peer file sharing systems. They describe technical implementations and find significant differences in traffic characteristics, but do not compare attributes related to distribution performance. In this paper, a fourth distribution method, called direct homing, is taken into account which is commonly used in practice and is based on proprietary IP networks or a modification of the public Internet architecture (Huston 2000, pp 399-406, ISO 1989, Xiao and Ni 1999): in direct homing scenarios, network operators reserve dedicated infrastructure or perform traffic differentiation in order to meet high performance requirements of specific services, such as IP TV.

Electronic distribution has evolved into a large commercial market. According to an industry report (FROST & SULLIVAN 2008), the content delivery network (CDN) market earned over \$700 million in 2007, and is predicted to increase earnings by up to 400% by 2013. A highly rated target segment for CDN providers is the delivery of Video on Demand content, i.e. the streaming of multimedia content from distributed servers. Other companies promise the same value proposition as CDN providers, i.e. high speed, reliability and efficiency, based on the peer-to-peer (P2P) distribution technology (Androutsellis-Theotokis and Spinellis 2004). P2P technology is, for example, used to distribute IP TV content in quasi real-time to global audiences.

From the perspective of an information service provider, the specific differences between the value propositions of the four mentioned distribution methods remain largely unclear. The CDN provider Akamai and the P2P distributor BitTorrent, for example, both target download and streaming delivery (BitTorrent 2009, Akamai 2009). An exemplary service level agreement of Akamai's CDN service does not quantify performance improvement guarantees (Oneclé 2009). Neither academic nor non-academic literature provides appropriate decision support for the choice of a distribution method and states which service requirements are met by which distribution method.

The objective of this paper is to compare the different technologies for IP based distribution, and to outline their distinct characteristics and their abilities to provide value in specific application contexts (value propositions). 103 information services were analyzed in order to deduce the distinctive value propositions of their associated distribution methods. We argue that information services reveal inherent characteristics of the underlying distribution methods.

This article is structured as follows: in Chapter 2, the relationship between information service quality and service distribution is described. In Chapter 3, four distinct IP based distribution methods, i.e. Centralized Hosting, Direct Homing, Content Delivery Networks and P2P Distribution are explained. In Chapter 4, a set of information service characteristics, which potentially bear a relationship to distribution performance, are identified. These relationships are verified by performing discriminate analyses in Chapter 5. The article concludes with a summary in Chapter 6.

Information service quality and distribution

Service science researchers have identified a set of constitutive characteristics of services (Demirkan et al. 2008, among others). These characteristics lead to specific requirements on service distribution and explain its importance (Figure 1).

Figure 1: Service Characteristics and Consequences for Service Distribution

Firstly, the simultaneity of service production and consumption inhibits the preproduction and storage of services and imposes high quality requirements, e.g. concerning real-time service delivery. Secondly, the wide range of potential services results in heterogeneous requirements for service distribution. This makes it difficult to find a standard solution for the distribution of a service. Thirdly, the overall evaluation of the service quality as experienced by a consumer is, to a large extent, subjective. For this reason, requirements for a satisfactory service delivery can not entirely be generalized. In addition, service delivery requires a direct customer involvement. As a consequence, the distribution quality, to a certain degree, depends on a customer's involvement (e.g. on the access capacity the customer allocates). Due to the intangibility of services the overall distribution quality can only be measured at the customer end, because this is the location at which a service is consumed. Intermediate measurements only allow predictions of overall service quality. Lastly, services are perishable. That is why technical parameters of distribution quality can only be measured at the exact time of service provisioning.

The general concept of service quality has been subject to extensive research in business sciences. It can be assessed by comparing a user's expectations and perceptions of the performance level for a range of service attributes (Parasuraman et al. 1985). Accordingly, the International Organization for Standardization states: *The quality of something can be determined by comparing a set of inherent characteristics with a set of requirements [...] A quality characteristic is tied to a requirement and is an inherent feature or property of a product, process, or system* (ISO 2005). A requirement is understood as an expectation or a need of a user. Various authors discuss the types of requirements which are to be taken into account in an information service quality assessment (Liao and Cheung 2008, Liu and Arnett 2000, Zeithaml et al. 2000, Zeithaml et al. 2002). Zeithaml et al. (2002), for example, define the following attributes: information availability and content, usability, privacy/security, graphic style, and fulfilment. Such attributes represent the factors relevant to a user's perception of service quality.

In telecommunications research, the term quality of service (QoS) is used heterogeneously to describe various concepts of service quality. As discussed by Gozdecki et al. (2003), the term QoS is used, on the one hand, to describe the customer's service quality assessment (business oriented view) and, on the other hand, to define technical parameters of service and network performance (technology oriented view). Figure 2 depicts both views. Externally, i.e. in the relationship between service provider and user, service quality describes the general comparison of inherent service characteristics as expected and perceived by users. Internally, i.e. among the parties involved in service production, service performance comprises all performance related parameters of a

service described in technical terms, such as speed, accuracy, availability and reliability. These parameters are affected by the inter-working of server, distribution and client systems.

Figure 2: Quality of Service Distribution and Service Quality

The quality of service distribution represents one component of service performance, as depicted in Figure 2. It is determined by all systems involved in the delivery of content from the originating servers to the end user terminals, such as routing, forwarding and caching systems (Tanenbaum 2003, pp. 343 et sqq.). Similar to the network performance concept (Xiao et al. 1999, Zhao et al. 2000), it can be characterized by four quality parameters: bandwidth, delay, packet loss and jitter. *Bandwidth* defines the effective volume of data per time unit being transmitted between communication end points. *Delay* comprises the length of time that a data package takes from the sender to the recipient. *Packet loss* defines the number of data packets that are lost in the transmission from the sender to the receiver. *Jitter* describes the fluctuation in the delay. Since it is a function of delay, it is not separately taken into account in the following analyses. Several authors define performance levels for classes of services (CoS, Marchese 2007, pp. 5-8, Gozdecki et al. 2003). CoS concepts define bounds for the QoS parameters to precisely describe what is considered an appropriate quality for specific service classes, such as real-time conversational or near real-time interactive services.

Technologies for Information Service Distribution

Different technological approaches have evolved since the development of the Internet architecture to support information service distribution. These technologies are generally classified into four categories, summarized in Table 1. In this section, a short overview of each technology is given.

Table 1: Information Service Distribution Technologies and Case Examples

Distribution Method	Definition	Key Characteristics	References	Business Model Case Examples
Centralized Internet Hosting	Centralized Internet hosting refers to the use of “one or a small number of collocation sites to host content” (Leighton 2009).	-central server, multiple clients -Internet based	-Leighton (2009) -Tanenbaum (2003, pg. 4) -Underwood (2001)	-bluehost (Web Hosting) -Go Daddy (Web Site Hosting) -HostGator.com (Domain Hosting) -1&1 (Web Hosting)
Direct Homing	Direct homing is the distribution of services via networks, which are able to provide high QoS through technologies such as resource reservation or traffic prioritization (Xiao and Ni 1999).	-proprietary (mostly single) network -configured access lines -QoS through capacity reservation or packet differentiation	-Huston (2000, pp 399-406) -Xiao and Ni (1999) -Zhao et al. (2000)	-AT&T (U-Verse) -Swisscom (Bluewin) -BT (BT Vision) -T-Home (T-Entertain)
CDN based distribution	“CDNs act as trusted overlay networks that offer high-performance delivery of common Web objects, static data, and rich multimedia content by distributing content load among servers that are close to the clients.” (Vakali and Pallis 2003)	-multiple servers, multiple clients -Internet based	-Dilley et al. (2002) -Pallis and Vakali (2006) -Pathan and Bukay (2008) -Vakali and Pallis (2003)	-Akamai (Application Performance Solutions) -Amazon (Cloudfront) -Limelight (LimelightDELIVER) -Edgecast (Content Delivery)
Peer-to-Peer distribution	“Peer-to-peer systems are distributed systems consisting of interconnected nodes able to self-organize into network topologies with the purpose of sharing resources such as content, [...] without requiring the intermediation or support of a global centralized server or authority.” (Androutsellis-Theotokis and Spinellis 2004)	-client to client communication -Internet based	-Androutsellis-Theotokis and Spinellis (2004) -De Boever (2007) -Kwok et al. (2002)	-BitTorrent (DNA) -Sharman Networks (KaZaA) -Joost N.V. (joost) -Kontiki (Enterprise Video Delivery)

The Internet was originally designed to support highly robust communication. The first commercial World Wide Web services supported the retrieval of textual HTTP pages. Data was exchanged between centralized servers and distributed clients via the IP protocol based on the best effort principle (Centralized Internet Hosting, Leighton 2009, Tanenbaum 2003, pg. 4, Underwood 2001). Today, many information services are still hosted centrally. Tchibo.de, for example, a popular German online store, is hosted by the managed services provider Easynet (Easynet 2009). Early Internet services did not impose high QoS requirements. But since the original development of the Open Systems Interconnection (OSI) basic reference model (ISO 1989), the requirements of information services distributed via the Internet have changed radically (Faratin 2007). Services with high real-time requirements are disturbed if transported across large network distances where packets have to traverse multiple network interconnection points and packet delay exceeds tolerable bounds. Content providers in the Internet are confronted with extreme demand peaks (such as flash crowds, Pathan and Buyya 2008) because the Internet has become a mass medium. Data intensive services have emerged due to growing access capacity, which further increases the risk of transportation overloads.

Two different approaches have emerged to support information services which cannot satisfactorily be realized through centralized hosting and best-effort transmission (Faratin 2007, Leighton 2009, Xiao 2008): the introduction of a QoS service model (as applied in direct homing), and the installation of Internet overlay structures (i.e. CDNs or P2P networks). The goal of a QoS service model is to enable a QoS which is superior to the best-effort QoS in the Internet. This is realized by a modification of the traditional Internet architecture: technologies, which allow packet differentiation or capacity reservation, must be introduced (Xiao and Ni 1999, Zhao et al. 2000, Huston 2000, pg. 399). A QoS service model can either be realized on a dedicated infrastructure, or by modifying the present architecture of the public Internet. Presently, the QoS service model is mostly realized in proprietary networks. For this reason, content distribution via the QoS service model is only realized in close cooperation between content and network providers: the content is directly homed on the QoS capable network, which provides a direct customer access to the content provider (direct homing). Well known examples in practice are the IP TV offerings of network providers, such as AT&T (U-Verse), BT (BT Vision) or Deutsche Telekom (T-Entertain).

In contrast, Internet overlay structures do not alter the traditional Internet architecture, but provide value added functionality on the application layer: *An Overlay is a set of servers deployed across the Internet that [...] in some way take responsibility for the forwarding and handling of application data in ways that are different from or in competition with what is part of the basic Internet* (Clark et al. 2005). Two overlay technologies for content

delivery have emerged which are specifically designed to optimize QoS and delivery costs of IP distribution:

CDNs and P2P networks, as pointed out by Faratin (2007) and Saroiu et al. (2002).

CDN providers operate a network of servers which are placed in multiple autonomous systems and strategically distributed across the Internet (Dilley et al. 2002, Pallis and Vakali 2006, Pathan and Bakay 2008, Vakali and Pallis 2003). In order to improve QoS performance, e.g. transmission delay and the effective bandwidth, objects such as large files or multimedia content are strategically distributed across these servers. In addition to caching, CDN providers apply technologies such as prefetching, route optimization, and sophisticated request routing mechanisms. As an example, France Televisions implements its Video on Demand offering via the content delivery network of the CDN provider Akamai (Akamai 2008).

P2P distribution systems (Androutsellis-Theotokis and Spinellis 2004, De Boever 2007, Kwok et al. 2002) are designed to make use of resources provided by end customers, such as storage space and processing power, in order to establish a distributed storage medium through which information service providers are able to distribute their content. In addition to content replication and caching, P2P systems provide functionalities, such as the distributed positioning and routing of objects, secure storage, access control, and authentication. Blizzard Entertainment, for example, partners with BitTorrent Inc. to distribute the software for the game World of Warcraft via P2P technology (Blizzard 2009). In contrast to Pathan and Bakay (2008) and in line with Leighton (2009) and Saroiu et al. (2002), CDNs are distinguished from P2P networks: whereas CDN providers centrally manage a network of surrogate servers, P2P networks are established through the contributions of independent peers.

In the following, a set of information service characteristics is presented which potentially bear a relationship to distribution performance. These relationships are then tested in the subsequent section.

Determinates of Distribution Quality

The quality of service distribution can be measured directly through the delay, error tolerance and effective bandwidth (equates to data load per second), provided by the distribution mechanism. Requirements of information services on the distribution quality are taken from the CoS conceptualizations (Marchese 2007, pp. 5-8). Information service providers are, nevertheless, unable to estimate the potential quality of a distribution technology prior to implementation. Moreover, the end-to-end measurement of distribution quality for a

representative set of customers is a very complex task due to the constitutive service characteristics, as explained above.

Information services expose heterogeneous requirements, not only on the quality of service distribution, but also on its implementation. The way information services are created and consumed, potentially has a direct impact on the performance of a specific distribution technology. The novel approach of the following analysis is the identification of dependencies of the quality provided by a service distribution technology based on the characteristics of service production and consumption (cf. Figure 3,

Table 2). These potential characteristics were identified in expert interviews and through an analysis of the literature on distribution technologies as presented above.

Figure 3: Characteristics of Information Services influencing the Quality of Service Distribution

Relevant characteristics of service production are the data load per service execution, the centrality of information origination, the interactivity of communication, the simultaneity of provisioning and demand, and the service revenues. *Data load per service execution* describes how much traffic load a single service execution generates. Traffic load, being a main cost factor, is an important aspect in content distribution and influences technological decisions such as content caching strategies and server localization. *Centrality of information origination* describes how data originates and is fed into the network. Central information origination implies that content originates at a central location and, as such, can be distributed from a central server. In contrast, distributed information origination implies that content is produced at distributed locations, e.g. the end customers' clients. Content distribution must, in this case, be carried out from distributed locations, which leads to different prerequisites, e.g. concerning the application of route optimization strategies. *Interactivity of communication* characterizes the traffic flow between communication end points: in non-interactive communication, a request by a client is typically followed by a large downstream traffic flow from a server. In interactive communication, traffic flows between end points have similar characteristics. Interactivity of

communication plays an important role in content distribution, e.g. regarding the importance of route optimization technologies and the efficiency of content prefetching. Real-time services are characterized by a *simultaneity of the provisioning and demand* for this content. As there exists no time for caching, such services rely mostly on route optimization strategies. In contrast, elastic services are characterized by a time gap between information provisioning and demand, and for this reason allow the application of buffering and caching technologies. *Service revenues*, i.e. the revenues a service provider generates per service execution, potentially provide information about the willingness of a service provider to invest in high distribution quality. Distribution technologies vary strongly with regard to the capital and operational expenses they induce. Low revenues do not allow high investments in service distribution and signal an end customer's tolerance for low distribution quality. In contrast, high revenues provide information service providers with more flexibility to invest in high distribution quality.

The relevant characteristics of service consumption are the customer segment, demand locality, level of demand, consumer mobility, consumption frequency, and security level. The *customer segment*, e.g. business or private customers, potentially has an impact on the service distribution: business-to-business services in general impose stricter requirements on distribution quality, e.g. regarding service availability and reliability, than business-to-consumer services. The *locality of demand* also has a significant impact: in order to meet a global service demand, comprehensive distribution technology implementations need to be applied, which often require higher investments than meeting a demand that is restricted to a small, well defined geographical area. The *level of demand* describes whether a service is considered a niche or a mass service. A niche service imposes different requirements for content delivery than a mass customer service. This affects the efficiency of technologies such as caching and capacity reservation. *Consumer mobility* also influences service delivery: In the case where a service is solely consumed from a single access line, such an access line can be explicitly configured prior to service distribution. In contrast, mobile services do not allow a pre-configuration of access lines, because such services must be available on multiple access lines, which cannot be determined in advance. There also exists a relationship between the *frequency of service consumption* and the efficiency of content distribution technologies: the more regularly a service is consumed, the more efficient is application of refined distribution technologies, such as the installation of local caches. The *security level* of an information service describes the requirements of a service customer regarding the security of data exchange. Sensitive customer data needs to be protected more strictly than information, which is open to the public and does not carry any security risks. This affects, for example, the employment of public infrastructure.

Value Proposition Analysis

103 IP based services were analyzed in order to identify differences in the value propositions of the four distribution technologies presented above. The services reveal insights into the value propositions of the distribution technologies they rely on.

Research Methodology

The analysis was carried out according to the directives for content analysis research (Kassarjian 1977, Kolbe and Burnett 1991).¹ Adequate sampling was ensured by pre-analyzing reference customer lists and use cases of distribution providers before making representative sample selections. The distribution methods of the samples were verified by employing various network tools such as traceroute and WHOIS.

Table 2: Criteria Categories

Criterion	Class (Number of Observations)					Mean Value	Standard Deviation
	1	2	3	4	5		
Centrality of Information Origination	decentral (37)	central (66)	/	/	/	1.64	0.48
Consumer Mobility	static (21)	distributed stationary access (59)	on the move (23)	/	/	2.02	0.66
Customer Segment	pure B2C (71)	no specific focus (20)	pure B2B (12)	/	/	1.43	0.69
Data Load per Second	< 64 kbitps (0)	[64 kbitps - 384 kbitps) (17)	[384 kbitps - 1 Mbps) (44)	[1 Mbps - 4 Mbps) (35)	>= 4 Mbps (7)	3.31	0.83
Data Load per Service Execution	< 1 MB (0)	>=1 MB (21)	>=15 MB (55)	>=500 MB (20)	>=5GB (7)	3.13	0.81
Delay Tolerance	<= 100ms (24)	(100ms – 1s] (11)	(1s – 4s] (36)	(4 s – 6s] (9)	>6s (23)	2.96	1.43
Demand Locality	regional (4)	country (36)	continent (16)	global (47)	/	3.03	0.98
Error Tolerance	0% (68)	<=0,3% (0)	<=1% (19)	>1% (16)	/	1.83	1.21
Frequency of Consumption	>= 1 per year (15)	>= 1 per month (21)	>= 1 per week (14)	>= 1 per day (36)	>= 1 per hour (17)	3.18	1.33
Interactivity of Communication	one-way communication (65)	two-way communication (control and content data flows) (13)	two-way communication (homogeneous data flows) (25)	/	/	1.61	0.85
Level of Demand	niche service (19)	regular service (37)	mass service (47)	/	/	2.27	0.76
Security Level	noncritical data (41)	data allowing end customer privacy intrusion (34)	strategic business data (20)	data critical with regard to legal and regulatory issues (8)	/	1.95	0.95
Service Revenues (in US\$)	none (2)	(0-10) (48)	[10-100) (35)	[100-1000) (10)	>=1000 (8)	2.75	0.95
Simultaneity of Provisioning and Demand	asynchronous (60)	quasi synchronous (delay tolerant) (8)	real-time (35)	/	/	1.76	0.93

¹ Refer to Table 8 in the appendix for a summary of the directives and conformance justifications.

The selected services were classified with respect to the direct distribution quality criteria and the characteristics of service production and consumption presented in the previous section. Table 2 contains a listing of the categories for each criteria.

In order to guarantee data validity, the classification was carried out independently by five IT service experts, who were carefully chosen with respect to three selection criteria: education, work experience in the IT services field, and expertise in IT service application, development, and management. These selection criteria ensured that the judges were familiar with the analyzed information services and their underlying technologies, and ultimately guaranteed the judges' capability to produce accurate classifications.²

Prior to coding, the judges were familiarized with the criteria and category definitions. Judges were asked to carry out the following process steps during categorization: service and business model research, service testing, and research on service usage. Service and business model research comprised the retrieval of information about the service type, service technologies, target customers and underlying business models from the service provider. This process step supplied valuable information for criteria such as the customer segment, service revenues and security level. The definition of a service type, based on CoS conceptualizations, supported the determination of delay tolerance, error tolerance, and data load per second for a specific service. In a second step, judges used and tested the services where possible. In order to track technical service parameters, such as data loads, judges were provided with network and communication monitoring tools. In combination with their personal usage experience with services of similar types, testing gave valuable insights for criteria, such as the simultaneity of provisioning and demand, centrality of information origination and consumer mobility. In a third step, judges were asked to gather information on the usage and diffusion of a service from information technology research companies and web traffic monitoring providers. This information was required for the categorization of criteria such as the level of demand and demand locality. After having followed these process steps, judges were asked to categorize an information service for all predefined criteria, and to leave blanks where a clear category distinction could not be detected. After collecting the results from all judges, abnormal value discrepancies were jointly analyzed and, in case of obvious misclassifications, eliminated in a post valuation round. The five classifications were merged in a final step by calculating mean values.

Discriminant analyses (Klecka 1980) were carried out on this data. The results indicate the relative importance of a criterion for the choice of a distribution method. For each distribution method, the group of services supported

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² For an overview of the judges' qualifications, readers are referred to Table 9 in the appendix.

by this specific method was distinguished from the rest and insights were gained into the discriminatory effect of service criteria. In each case, a univariate ANOVA and a stepwise discriminant analysis were performed. In the following section, all service criteria which were considered significant in both tests are discussed.

Centralized Hosting

Table 3: Discriminatory Service Criteria for Centralized Hosting

	Univariate Analysis			Stepwise Discriminant Analysis ^{a,b,c}			
	Group Mean 'Centralized Hosting' (n=27)	Group Mean 'others' (n=76)	F for Group Mean Equality Test	F to Remove	F to Enter	Wilks-Lambda (Removal & Entry Criterion)	Discriminant Loadings ^d
DemandLocality	2.259	3.303	28.365***	31.580***		.793	.651
DataLoadperExec	2.630	3.303	15.623***	12.237***		.676	.483
ErrorTolerance	1.148	2.079	13.314***	11.106***		.669	.446
ConsumerMobility	2.1111	1.9868	.712		3.312	.582	.169
CentralityOfInfoOrg	1.5556	1.6711	1.145		3.197	.582	-.128
SimultanProvDem	1.3704	1.8947	6.630**		3.155	.583	.051
ServiceRevenues	2.3333	2.8947	7.447***		2.540	.586	.088
LevelOfDemand	2.0370	2.3553	3.613*		2.537	.586	-.016
DelayTolerance	2.8889	2.9868	.093		1.720	.591	-.119
SecurityLevel	2.2222	1.8553	3.008*		1.335	.593	-.033
DataLoadPerSec	3.0741	3.3947	3.042*		1.071	.595	.105
FrequencyOfCons	3.1111	3.2105	.110		.434	.599	.131
CustomerSegment	1.2593	1.4868	2.163		.176	.600	.245
InteractivityOfCom	1.4074	1.6842	2.114		.029	.601	.153

***p < 0.01, **p < 0.05, *p < 0.10

^aMinimal partial F-statistic for acceptance: 3.84, Maximal partial F-statistic for exclusion: 2.71

^bWilks Lambda of Discriminant Function: 0.601, Number of Steps: 3

^cClass mean values of discriminant function: Centralized Hosting=-1.35, others=0.48

^dCorrelation between discriminating variables and the canonical discriminant function

Centralized hosting technology represents the traditional distribution method within IP networks. Content is hosted on a single server which is connected to the network. Packets are routed through interconnected networks to the requesting client. QoS in pure centralized hosting distribution varies highly, depending on the end customer's location and the specific route: thus QoS will most likely be perfectly acceptable if the end customer is connected to the same network service provider as the hosting provider or if traffic does not have to traverse large distances. QoS may exceed acceptance thresholds if traffic is exchanged over large distances through various interconnected networks. Both tests show that demand locality is the most significant criterion with respect to the choice for centralized hosting distribution: the more demand is limited to a specific region, the more effective centralized hosting becomes as a distribution mechanism. This is well in line with the argument above that interconnections and geographical distance have a significant negative impact on QoS. The tests also reveal that centralized hosting is particularly suitable for services with a low data load per service execution. Hosting providers charge per stored and accessed data volume; network service providers charge for access

capacity. Moreover, data transport becomes more expensive if more interconnections are involved. Content providers, therefore, only choose centralized hosting for services with low data volume. In addition, low error tolerance is well supported by centralized hosting. This result suggests that highly error tolerant services, such as video conferencing, telephony, and multimedia streaming, are generally not provided through centralized hosting.

Direct Homing

Table 4: Discriminatory Service Criteria for Direct Homing

	Univariate Analysis			Stepwise Discriminant Analysis ^{a,b,c}			
	Group Mean 'Direct Homing' (n=20)	Group Mean 'others' (n=83)	F for Group Mean Equality Test	F to Remove	F to Enter	Wilks-Lambda (Removal & Entry Criterion)	Discriminant Loadings ^d
ConsumerMobility	1.000	2.265	143.381***	400.532***		.385	-.336
ErrorTolerance	2.900	1.578	23.688***	104.456***		.155	.137
DataLoadPerSec	3.250	3.325	.132	33.869***		.100	-.010
InteractivityOfCom	2.600	1.373	48.757***	9.182***		.081	.196
ServiceRevenues	3.850	2.482	49.721***	7.588***		.080	.198
FrequencyOfCons	4.500	2.867	31.314***	4.915**		.078	.157
DelayTolerance	1.150	3.398	65.040***	4.061**		.077	-.227
SimultanProvDem	2.800	1.506	43.997***		1.875	.072	.266
CustomerSegment	2.100	1.265	29.887***		.095	.074	.179
CentralityOfInfoOrg	1.200	1.747	25.786***		.898	.073	-.083
DataLoadperExec	3.800	2.964	20.289***		.026	.074	.116
SecurityLevel	2.700	1.771	17.813***		.360	.074	.164
LevelOfDemand	1.900	2.361	6.307**		.371	.074	-.020
DemandLocality	2.700	3.108	2.822*		1.585	.073	.066

***p < 0.01, **p < 0.05, *p < 0.10

^aMinimal partial F-statistic for acceptance: 3.84, Maximal partial F-statistic for exclusion: 2.71

^bWilks Lambda of Discriminant Function: 0.074, Number of Steps: 7

^cClass mean values of discriminant function: DH=7.14, others=-1.72

^dCorrelation between discriminating variables and the canonical discriminant function

Within direct homing, IP traffic is not routed as part of the best effort Internet class, but instead as a privileged class or through reserved capacities. Consumer mobility is the dominant selection criterion for direct homing. This is caused by the fact that direct homing only supports service consumption with guaranteed end-to-end QoS from pre-configured access lines. Thus, end customers can not make use of reserved capacities from arbitrary access points, but only from dedicated access points. Hence, this technology is not adequate for mobile end customer services. IP TV with guaranteed QoS, for example, is installed with a configured router on a single access line. A highly reliable and configurable QoS with low latency is aspired through the privileged treatment of direct homing traffic. This is especially valuable for services with a high degree of interactivity, such as Voice over IP (VoIP). The tests affirm that directly homed services are indeed characterized by a high level of

interactivity and error tolerance. As data transport is carried out on predetermined routes, interactive services can be supported more effectively than by other distribution technologies. The high error tolerance of directly homed services suggests that direct homing is often used for error tolerant services such as voice and streaming services. Traffic differentiation or routing through dedicated networks does not necessarily imply the need to install separate hardware, but requires at least additional investments in the installation and operation of routing systems. As direct homing is often more cost intensive than other distribution methods, direct homing is only adequate for services with a high frequency of consumption and for services which generate high revenues. Otherwise, the high investments are not justifiable. In contrast to intuition, direct homing does not primarily address a B2B service context. Direct homing represents the only distribution technology, where delay tolerance is a significant criterion. In contrast to the other distribution methods, where the direct discriminatory effect of delay tolerance is insignificant, this aspect is directly taken into account for direct homing.

Content Delivery Networks

Table 5: Discriminatory Service Criteria for CDNs

	Univariate Analysis			Stepwise Discriminant Analysis ^{a,b,c}			
	Group Mean 'CDN' (n=30)	Group Mean 'others' (n=73)	F for Group Mean Equality Test	F to Remove	F to Enter	Wilks-Lambda (Removal & Entry Criterion)	Discriminant Loadings ^d
ConsumerMobility	2.400	1.861	16.264***	24.990***		0.796	0.530
ServiceRevenues	2.900	2.694	0.994	23.533***		0.787	0.131
CentralityOfInfoOrg	1.900	1.528	14.212***	12.356***		0.714	0.495
LevelOfDemand	2.467	2.181	3.089*	5.241**		0.667	0.231
DataLoadperExec	3.133	3.139	0.001		3.211	0.613	0.257
DataLoadPerSec	3.467	3.250	1.441		2.712	0.616	0.382
InteractivityOfCom	1.267	1.764	7.604***		1.517	0.623	-0.255
ErrorTolerance	1.733	1.889	0.349		1.146	0.626	0.077
DelayTolerance	3.500	2.722	6.605**		1.050	0.626	0.209
DemandLocality	3.367	2.875	5.514**		0.949	0.627	0.149
FrequencyOfCons	2.800	3.347	3.621*		0.491	0.630	-0.154
SimultanProvDem	1.633	1.819	0.837		0.338	0.631	-0.177
CustomerSegment	1.300	1.486	1.519		0.254	0.631	-0.103
SecurityLevel	1.833	2.014	0.757		0.017	0.633	-0.097

***p < 0.01, **p < 0.05, *p < 0.10

^aMinimal partial F-statistic for acceptance: 3.84, Maximal partial F-statistic for exclusion: 2.71

^bWilks Lambda of Discriminant Function: 0.633, Number of Steps: 4

^cClass mean values of discriminant function: CDN=1.17, others=-0.49

^dCorrelation between discriminating variables and the canonical discriminant function

CDN providers operate a complex network of edge servers. Content is distributed from and cached on these servers based on strategies which take into account the location of end customers, as well as network and server characteristics. CDNs, in contrast to direct homing, support a high customer mobility during service consumption. CDN service coverage is not limited to configured access lines and networks. CDNs support

mobile services and are well suited to deliver services such as video streaming, which are consumed en-route. CDN technology relies on a single central origin server, that contains core service information and that directs content or requests to the edge servers. On the other hand, CDN is not well suited for services without a central origination of information, such as communication services in which each end customer feeds data into the network. For such services, content caching on the edge servers can not be carried out efficiently. Content caching becomes more efficient with higher cache hit ratios, i.e. the ratio of cached versus total documents requested. For this reason, CDNs particularly address services with a mass customer focus. For niche services, cache hit ratios tend to be low, which decreases the efficiency of cache networks. As the content needs to be transported to the edge servers prior to its distribution to end customers, this distribution method does not seem adequate for services where the origination of information coincides with the demand for this information. However, this hypothesis can not be confirmed. CDN providers constantly improve their capabilities to support real-time services, e.g. through the development of route optimization technologies. For quasi real-time services such as live streaming, CDN technology is widely applied (Pathan and Bukay 2008).

P2P Distribution

Table 6: Discriminatory Service Criteria for P2P Distribution

	Univariate Analysis			Stepwise Discriminant Analysis ^{a,b,c}			
	Group Mean 'P2P' (n=26)	Group Mean 'others' (n=77)	F for Group Mean Equality Test	F to Remove	F to Enter	Wilks-Lambda (Removal & Entry Criterion)	Discriminant Loadings ^d
DemandLocality	3.692	2.805	18.476***	20.026***		0.782	-0.584
ServiceRevenues	2.154	2.948	15.639***	8.677***		0.708	0.537
SecurityLevel	1.231	2.195	24.426***	4.224**		0.678	0.671
InteractivityOfCom	1.462	1.662	1.074		2.401	0.635	0.366
SimultanProvDem	1.500	1.844	2.684		1.557	0.640	0.400
DataLoadperExec	3.115	3.130	0.006		1.255	0.642	0.190
CustomerSegment	1.231	1.494	2.831*		1.081	0.643	0.350
ConsumerMobility	2.269	1.935	5.246**		1.053	0.644	-0.462
DelayTolerance	3.808	2.675	13.761***		0.609	0.647	-0.381
DataLoadPerSec	3.423	3.273	0.637		0.596	0.647	0.019
ErrorTolerance	1.846	1.831	0.003		0.071	0.650	-0.052
CentralityOfInfoOrg	1.769	1.597	2.505		0.028	0.650	-0.187
FrequencyOfCons	2.692	3.351	4.916**		0.006	0.651	0.289
LevelOfDemand	2.577	2.169	5.928**		0.004	0.651	-0.322

***p < 0.01, **p < 0.05, *p < 0.10

^aMinimal partial F-statistic for acceptance: 3.84, Maximal partial F-statistic for exclusion: 2.71

^bWilks Lambda of Discriminant Function: 0.651, Number of Steps: 3

^cClass mean values of discriminant function: P2P=-1.25, others=0.42

^dCorrelation between discriminating variables and the canonical discriminant function

P2P distribution does not require large capital expenses. The main resource is P2P software running on end customers' clients with established network connections. Content providers do not need to constantly feed

content into the network from central servers and therefore save transit costs. As overall distribution costs increase with the global nature of demand, P2P especially addresses services with a global demand. This is the most important criterion for choosing P2P distribution. In the case of a strictly local service demand, services could be distributed via centralized hosting without significant distribution costs. In case of a global demand, content distribution via P2P incurs significantly less transit costs. As content providers do not have to feed content into the network for each customer request, this distribution method is particularly attractive for services which generate low revenues and do not justify investments in a costly distribution technology with high QoS guarantees. Hence, cost savings in distribution are a dominant decision factor. More than in other distribution methods, content is exposed to the risk of manipulation. Since content is cached by third party clients prior to its distribution, the risk of unauthorized service access or service modification is high compared to other distribution methods. For services with high security requirements (e.g. file storage and exchange services for businesses), this risk is generally not tolerable.

Summary

In this article, the quality provided by different technologies for information service distribution is discussed. An analysis of 103 information services was carried out in order to identify the main characteristics influencing an information service providers choice of a specific distribution method. An underlying assumption of this approach is that the information services analyzed are best supported by their associated distribution methods and, as such, allow deductions on the value proposition of the distribution technologies. This assumption is justified by the rationale that firms seek an optimal distribution choice. The results of our analysis reveal that distribution technologies vary strongly with respect to the information services they support. A set of characteristics concerning service production and consumption was identified which have a strong influence on the quality provided by distribution technologies. Distribution technologies and their significant service characteristics are summarized in Table 7.

From the set of hypotheses, i.e. the set of characteristics which were taken into account, several were proven irrelevant: most notably, criteria directly describing the quality of service distribution, namely packet delay and data load per second, have an insignificant influence on the choice of a distribution technology. This means that there is no distribution technology which generally provides a superior distribution quality. Instead, information service providers need to match their individual service characteristics to the technological capabilities of distribution methods for an optimal choice. Moreover, the simultaneity of provisioning and demand and the

customer segment are irrelevant service criteria. From this it follows that the analyzed distribution technologies all have real-time capabilities and that none is specifically tailored for a business or an end consumer service scenario.

Table 7: Distribution Technologies and their significant service characteristics

Distribution Technology	Significant Service Characteristics
Centralized Hosting	Local demand, low data load per service execution, low error tolerance
Direct Homing	Low consumer mobility, high error tolerance, high interactivity of communication, high service revenues, high frequency of consumption, low delay tolerance
Content Delivery Networks	High consumer mobility, high centrality of information origination, high level of demand
P2P Distribution	Global demand, low service revenues, low security level

This work represents an initial analysis comparing the capabilities of service distribution technologies. The results provide information service providers with practical guidance in their choice of a distribution provider. They allow the selection of a distribution method based on a matching of service characteristics and capabilities of distribution technologies.

Distribution technologies are constantly being enhanced. CDN and P2P technologies, for example, are most recently being applied jointly to reach a more efficient service distribution. Blizzard Entertainment uses AKAMAI's CDN and BitTorrent's P2P technology to distribute its World of Warcraft Software (Blizzard 2009). The future evolution of information service distribution is dependent on deeper insights into the quality of information services and the influence of distribution performance. Zeithaml et al. (2000) state that a negative perception of information service quality result from several gaps, two of which are critical for service distribution: the information gap represents differences between customer requirements and a service provider's beliefs about requirements. The design gap describes discrepancies between the identified requirements and the implemented service. By filling the information gap, service providers gain a more profound understanding of the constitutive characteristics of service quality. This knowledge is a prerequisite for service implementation. The design gap is closed by correctly matching requirements with service specifications and by achieving these specifications during service operation. In this phase, the required quality of service distribution for specific information services is identified. This work represents an approach to close these gaps by establishing a relationship between service requirements and distribution methods which are currently in operation. A clear

understanding of both gaps is a prerequisite for the further development and effective application of distribution technologies.

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Appendix

Table 8: Conformance with content-analysis research directives (based on Kolbe and Burnett 1991)

Objectivity	Definition of rules and procedures	Reporting of categories and definitions
	Judge training	Presentation of category definition prior to coding
	Unit measure pretesting	Pretesting conducted by authors
	Judge independence	Engagement of four non-authoring judges
	Multiple judges	
Systematization	Prohibition of bias between category selection and thesis	Avoidance of result predetermination by definition of categories in cooperation with independent experts and based on literature
	Hypothesis testing	Hypothesis formulation and foundation
Sampling Methods	Generalizability of sample	Selection of representative published use cases
	Manageability of sample size	Sample size of 103 applications
Reliability	Categorical reliability	Clear definition of categories
	Interjudge reliability	Introduction of feedback cycle to avoid interjudge disagreements

Table 9: Information on Judge Qualifications

Judge	Education	Work Experience in the IT services field	Expertise in IT Service Application, Development, and Management
1	Information Engineering and Management (MSc)	6 years	Application Programming, Software Engineering, Network Technologies, IT Service Management
2	Industrial Engineering and Management (MSc)	3 years	Web Design, IT Service Quality Management, Internet Technologies
3	Information Systems Management (MSc)	8 years	Application Programming, Software Engineering, IT Service Management
4	Industrial Engineering and Management (BSc)	1 ½ years	Web Design, IT Service Management, Internet Technologies
5	Computer Sciences (BSc)	3 years	Application Programming, Network Technologies, Server Configuration

Table 10: List of Analyzed Information Services

<u>Name of Information Service</u>	<u>Information Service Provider</u>	<u>Type Description</u>	<u>Distribution Technology</u>	<u>Distribution Provider</u>
ICQ / AOL Instant Messenger	AOL	Instant Messenger, Internet Telephony	P2P	AOL
20th Century Fox Films	20th Century Fox	Video Streaming	P2P	Vuze
301 Records Music Album	301 Records	Music Download	P2P	Kazaa
ABS-CBN TV	ABS-CBN Global	TV Streaming	CDN	EdgeStream
Aeria Game Patches	Aeria Games	Game Distribution	P2P	BitTorrent
Altnet Musical Download Service	Altnet	Music Download	P2P	Kazaa
amazon.de Web Shop	Amazon	Online Shop	IP Transit	Level3
AMD Drivers	AMD	Driver Download	CDN	Akamai
Audi Website	Audi AG	Business Internet Representation	CDN	Akamai
B2B-trade.net	B2B-Trade Ltd. & Co. KG	B2B Marketplace	IP Transit	Hosteurope
morgenpost.de	Berliner Morgenpost	News Portal	IP Transit	Arcor
bild.de	BILD digital GmbH & Co. KG	News Portal	IP Transit	Colt Telecommunications
billiger.de	billiger.de	Information Aggregator	IP Transit	IP Exchange GmbH
Bluewin TV	Swisscom	TV, Video Streaming	Direct Homing	Swisscom
Bollywood Movies	IndiaFM.com	Movie Download	P2P	Kazaa
Music Video Streaming	Sony BMG	TV, Video Streaming	Direct Homing	BT
Business Connect Professional	Swisscom	VoIP	Direct Homing	Swisscom
Business Video 1000MXP	T-Systems	Video Conferencing	Direct Homing	T-Systems
Cathay Pacific Airways Website	Cathay Pacific Airways	Website	CDN	Akamai
CNBC Homepage	CNBC	News Portal	CDN	Akamai
Comedy Central Series	Comedy Central	Video Streaming	P2P	BitTorrent
tagesspiegel.de	Der Tagesspiegel	News Portal	IP Transit	IP Exchange GmbH
DirecTV VoD	DirecTV	TV Streaming	CDN	Technicolor EDS
DreamWorks Video Clips	DreamWorks	Clip Stream	CDN	Limelight Networks
Ebay.de Transaction Platform	eBay	Online Auction House	IP Transit	Level3
Electronic Arts Games Software	Electronic Arts	Software Download	CDN	Limelight Networks
End Customer VoIP	Private End Customers	VoIP	Direct Homing	Telefonica Deutschland GmbH
End Customer VoIP	Private End Customers	VoIP	Direct Homing	o2
End Customer VoIP	Private End Customers	VoIP	Direct Homing	Arcor
End Customer VoIP	Private End Customers	VoIP	Direct Homing	HanseNet
End Customer VoIP	Private End Customers	VoIP	Direct Homing	1&1
Equant Managed IP-VPN	Equant	IP VPN	Direct Homing	Equant
ESA Portal	ESA	Clip Stream	CDN	Akamai
FAZ.net	F.A.Z. Electronic Media GmbH	News Portal	IP Transit	Versatel

ftd.de	Financial Times Deutschland	News Portal	IP Transit	Gruner+ Jahr AG & Co
France Televisions VoD	France Televisions	Video on Demand	CDN	Akamai
GameShadow Software Download	GameShadow	Software Download	CDN	Limelight Networks
Geizkragen.de	Geizkragen	Information Aggregator	IP Transit	DTS Systeme
Google Apps	Google Inc.	SaaS	IP Transit	Google
Google Talk	Google	Instant messenger, Internet Telephony	P2P	Google
guenstiger.de	guenstiger.de	Information Aggregator	IP Transit	Inet People Hostmaster
handelsblatt.com	Handelsblatt	News Portal	IP Transit	circ IT GmbH
Hostel Website	Hostel David	Hostel Web Representation	IP Transit	Strato AG
IAHGame Patches	Infocomm Asia Holdings Pte Ltd (IAHGames)	Software Download	P2P	BitTorrent
Intel Driver Download	Intel	Software Download	CDN	Akamai
InterContinental Website	InterContinental Hotel Group	Website	CDN	Akamai
Intra Select VPN	T-Systems	IP VPN	Direct Homing	T-Systems
L'Equipe Homepage	L'Equipe	News Portal	CDN	Akamai
Lionsgate Films	Lionsgate	Video Download	P2P	BitTorrent
Machinima Films	Machinima	Movie and Clip Download	P2P	Vuze
Managed IP-VPN	Global Crossing	IP VPN	Direct Homing	Global Crossing
Managed IP-VPN	TFM Networks	IP VPN	Direct Homing	TFM Networks
Managed Voice over IP Networks	T-Systems	VoIP	Direct Homing	T-Systems
Maxdome VoD	ProSiebenSat.1 Media & United Internet	Video on Demand	CDN	Akamai
Ministry of Sound TV	Ministry of Sound	Music	P2P	Vuze
MSNBC Webcast	MSNBC	Clip Stream	CDN	Limelight Networks
Music Album "The Morning Benders"	+1 Records	Music Download	P2P	Lime Wire
Mydeo Enterprise Media Delivery	Mydeo	Clip Stream	CDN	Limelight Networks
MySpace Website	MySpace	Social Network	CDN	Limelight Networks
neu.de Website	Neu.de GmbH	Partnerbörse	IP Transit	Colt Telecommunications
NXTbook Media Online Brochures	NXTbook Media	print materials for web use	CDN	Mirror Image
NY Post Homepage	NY Post	News	CDN	Akamai
Orvis Web Shop	Orvis	Online Store	CDN	Mirror Image
PanTerra On-Demand Platform SaaS	SUTHERLAND NETWORKS	SaaS	Direct Homing	Panterra Networks
Paramount Pictures VoD	Paramount	Video Download	P2P	BitTorrent
PetStore Web Shop	PetStore	Online Store	CDN	Mirror Image
Rajshri Media VoD	Rajshri Media	Video on Demand	CDN	Limelight Networks
Sage Club Website	Sage Club	Club Homepage	IP Transit	Neue Medien Muennich GmbH
SAP for medium sized businesses	AlliedPanels Entwicklungs- und Produktions GmbH	SaaS	Direct Homing	Freudenberg IT
SchuelerVZ Website	Verlagsgruppe Georg von Holtzbrinck GmbH	Social Network	CDN	Panther Express

Second Life	Linden Labs	Software Download	IP Transit	Amazon
Sega Software	Sega	Game Distribution	P2P	BitTorrent
shopwahl.de Website	LeGuide.com Group	Shopping Directory	IP Transit	Colt Telecommunications
Showtime Films	Showtime	Movie, Series	P2P	Vuze
Siemens A&D Software	Siemens A&D	Software Download	CDN	Akamai
Sipgate Internet Telephony	Sipgate	Internet Telephony	P2P	Sipgate
Skype Internet Telephony	eBay	Instant messenger, Internet Telephony, Filesharing	P2P	eBay
Sony Ericsson Software	Sony Ericsson	Software Download	CDN	Akamai
Sony Pictures Films	Sony Pictures	Movie	P2P	Vuze
Spacenations Online Game	Spacenations	Browsergame	IP Transit	IPX Server GmbH
SPD Website	SPD	Website	IP Transit	PIRONET NDH AG
Superbowl Commercial Clips	IFILM	Video, TV, Games	CDN	Limelight Networks
StudiVZ Website	Verlagsgruppe Georg von Holtzbrinck GmbH	Social Network	CDN	Panther Express
tchibo.de Website	Tchibo	Online Shop	IP Transit	Easynet GmbH
Ten Mile Tide Music Album	Ten Mile Tide	Music	P2P	Kazaa
TheCrown Online Game	TheCrown	Browsergame	IP Transit	manitu hosting
T-home Entertainment VoD	Deutsche Telekom	TV, Video Streaming	Direct Homing	DTAG
Triumph VoIP	Triumph	VoIP	Direct Homing	DTAG
U-Verse VoD	AT&T	TV, Video Streaming	Direct Homing	AT&T
Videoload VoD	Deutsche Telekom	Video Streaming	IP Transit	DTAG
Warner Bros. Films	Warner Bros.	Video Download	P2P	BitTorrent
welt.de Website	Die Welt	News Portal	IP Transit	Arcor
Windows Live Messenger	Microsoft	Instant messenger, Internet Telephony	P2P	Microsoft
World of Warcraft Software	Blizzard	Software Download	CDN	Limelight Networks
World of Warcraft Software	Blizzard	Software Download	P2P	BitTorrent
www.blog.de Website	Mokono GmbH	Blog Site	IP Transit	IP Exchange GmbH
Yahoo Messenger	Yahoo	Instant messenger, Internet Telephony, Filesharing	P2P	Yahoo
Zattoo IP TV	Zattoo	P2P TV	P2P	Zattoo
ZDF Mediathek VoD	ZDF	Video On Demand	CDN	Akamai