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ANALYSIS AND QUALITY ASSESSMENT OF PEER-TO-PEER IPTV SYSTEMS

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ABSTRACT

At present, Web portals offering streaming of stored video contents or live TV channels have become a rapidly emerging new Internet service. We investigate the traffic characteristics, performance and perceived quality of available IPTV services which use peer-to-peer (P2P) overlay networks, called P2PTV. We analyze gathered traces of a comprehensive measurement study to determine the structure of P2PTV applications and the employed protocol stack with its related message flows. Furthermore, we compare the quality of different peer-to-peer dissemination systems and illustrate drawbacks and weaknesses of the approach.

Index Terms— peer-to-peer service, IPTV, traffic characterization, QoS/QoE

I. INTRODUCTION

Nowadays, network operators and Internet service providers have assigned the highest priority to the integration of triple-play including VoIP, video streaming and video on demand as well as IPTV services into the portfolio of their evolving next generation networks. It is expected to become a billion dollar market in the next years and a key driver of next generation networks with their advanced Web-based integrated multimedia services.

The ITU-T Focus Group IPTV defines IPTV as multimedia service that is transported by IP networks and that provides the required level of quality of service and quality of experience as well as security, interactivity and reliability (cf. [5]). Many new IPTV offers are free of charge since the business models are based on other marketing mechanisms than selling access and bandwidth like private TV, e.g. Premiere World, or cable companies. They are ad-supported with advertising in a way similar to the traditional commercial TV exploiting the Web 2.0 capabilities and new widget overlays. From the perspective of network design and performance engineering, key issues concern the quality and scalability of the transport as well as the resulting quality of experience of the customers covering both access and end-to-end transport delays, loss of video data as well as the perceived quality of a received sequence of video frames. Apart from traditional client-server architectures currently used by TV broadcasters new peer-to-peer overlay networks are deployed to cope with the enormous bandwidth demand of flash crowds of Internet spectators.

Many progressive companies among the broadcasting networks like BBC have already recognized the Internet as a new transport channel and such Web portals based on Web 2.0 technology as new service environment. Therefore, they are already testing new peer-to-peer technology as dissemination and transport platform of their contents. The overlay technology is able to shift parts of the dissemination cost away from the content service provider towards the transport service provider and the users. Integrated into new video portals, it can offer additional features without any need of set-top boxes exploiting the capabilities of Web 2.0 technology such as news updates, discussion forums, immediate ratings of show events, voting services or user chats.

In our contribution we study peer-to-peer (P2P) dissemination of TV contents by the conventional Internet as transport platform (see also [1], [3], [4]). At the end of 2007 we have performed a comprehensive measurement study and gathered traces of new P2PTV providers like Joost, Zattoo and PPLive (cf. [7], [10], [9]). Based on a detailed statistical analysis of the peer-to-peer dissemination and transport service, we have gained useful insight into the quality and performance of the peer-to-peer overlay system and the patterns of the realized packet streams which can serve as quality indicators.

II. ANALYSIS OF P2PTV SYSTEMS

During the last trimester of 2007 we have performed a comprehensive measurement study based on several testbeds with stationary and mobile clients (see Figs. 1, 2). Then we have analyzed the gathered traces to determine the structure of the P2PTV application and overlay network as well as the employed protocol stack with its related message flows.

It has been the objective to study basic quality and performance issues of the P2P dissemination and transport system. They are derived from the following 5 criteria:

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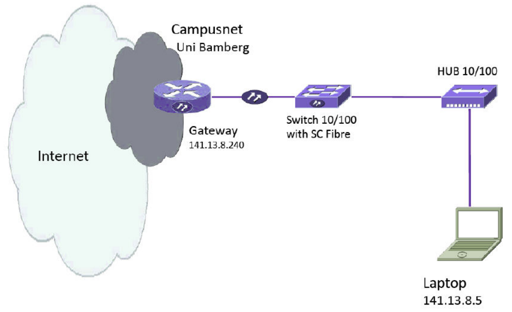


Fig. 1. Test-bed with a stationary client

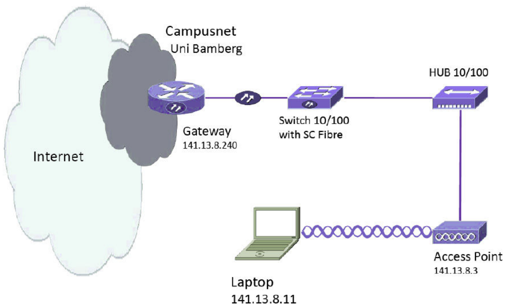


Fig. 2. Test-bed with a mobile client

1) *Perceived quality:* It is investigated which level of perceived quality the P2PTV application offers to the user and whether the received video and audio streams exhibit dropouts, jerking frames or block errors in the frames.
2) *Protocol stack:* We have analyzed the protocols applied for control and video traffic and their related message exchange. In particular, the signaling and management message exchange including authentication and peer control has been studied.
3) *Overlay structure:* The overlay network has been analyzed to determine the number of peers per P2PTV session, their geographical distribution, the preference distribution among peers and the realization of a tit-for-tat load distribution strategy.
4) *Overhead analysis:* The overall amount of transported traffic, its video and control proportion and the resulting overhead have been analyzed.
5) *Traffic characteristics:* The structure of the transferred packet streams including inter-arrival times (IAT) and packet length were analyzed. Further, the individual peer connections and the overall traffic stream of a P2PTV session were studied including an analysis of the distinct inbound and outbound traffic portions of a P2PTV client.

Considering the perceived quality (1), the used protocols (2) and the transport overhead (4), we have realized that Joost [8] has used https for registration and authentication services before the data transfer. The latter is implemented on top of UDP using the error-resilient and most efficient MPEG-4/AVC video encoding with 1 Kbyte sized chunks arising from video frames. Zattoo has applied http for registration and authentication as well, but it used both TCP and UDP for purposes of the data transport. However, its MPEG-4/AVC encoding has been less effective than Joost. The required bandwidth of both services varied between 500 to 1000 kbps. Compared to Joost with its least transport overhead of 13 %, Zattoo generates the highest overhead of 56 % (see Table I). Obviously, an ineffective protocol design by less experienced programmers of the basic peer-to-peer transport service is the potential reason. It is reflected by Joost's clearly arranged packet structure compared to Zattoo's irregular layout (see Figs. 3,4).

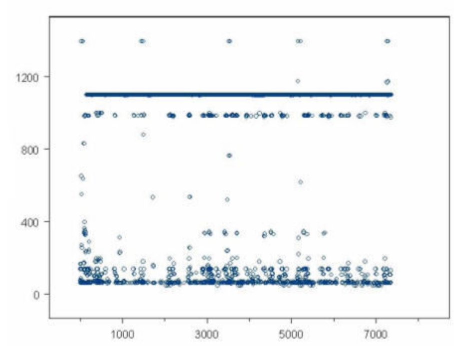


Fig. 3. Packet length distribution of a Joost trace

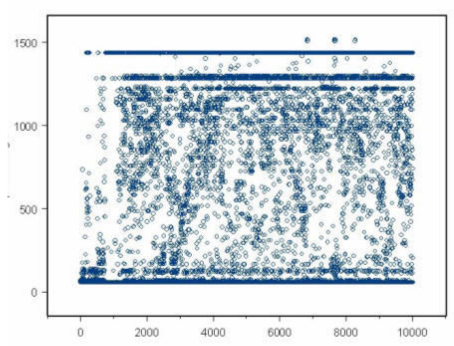


Fig. 4. Packet length distribution of a Zattoo trace

In contrast to that, due to its earlier development PPLive uses the less effective MPEG-2 video encoding which causes difficulties w.r.t QoE in wireless environments. The video chunk transport employs both TCP and UDP connections which generate high overhead (see Table I). It has a clear layout of the realized packet lengths (see Fig. 5). Moreover,

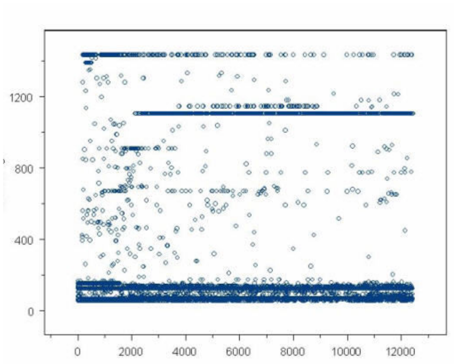


Fig. 5. Packet length distribution of a PPLive trace

a plot of the time series of the packet length profile arising from the transferred messages clearly illustrates that the transport of video chunks (orange) closely follows the request pattern (green) of the client (see Fig. 6). PPLive

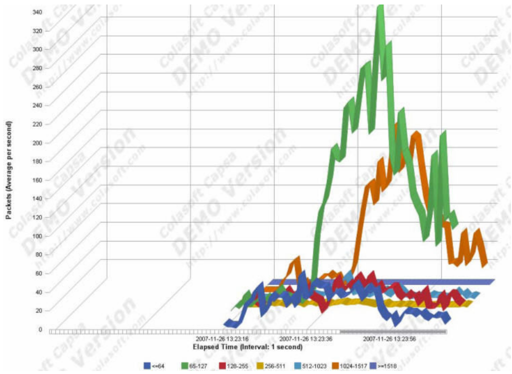


Fig. 6. Time series of realized packet length distribution of a PPLive trace

generated a high average throughput in the range of 800 to 1000 kbps due to the high demand of the MPEG-2 encoding. The media dissemination was not very efficient and generated many transport errors (see Fig. 7). However,

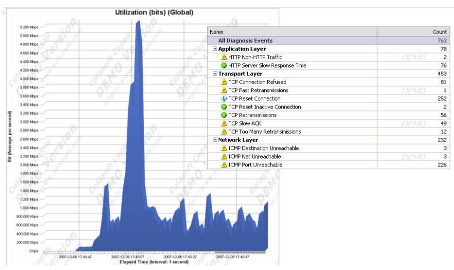
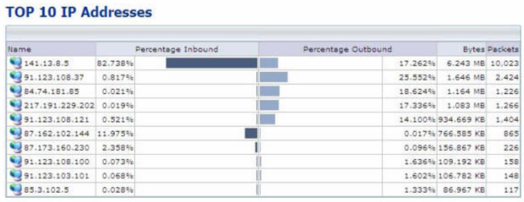


Fig. 7. Throughput and error profile of a PPLive trace

all systems have generated a very low utilization of the available bandwidth, i.e. less than 2%. In this respect, an improved capacity-aware P2P transport is recommended.

Regarding the overlay structure (3) all services had a locality bias. Due to its Chinese origins and the dominant Chinese contents of PPLive more than 90 % of the peers in the overlay resided in Asia. In 11/2007 Zattoo disseminated contents only among peers in Germany, Netherlands and Switzerland whereas Joost's peer distribution has been biased to Europe (58%) and North America (38%) with a few sites in Africa (4%).

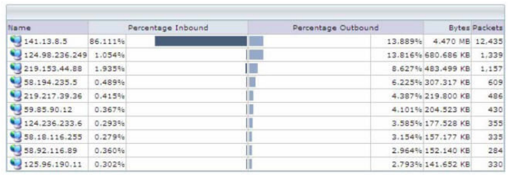
The non-uniform distribution of feeding and receiving peers generating the inbound and outbound flows constitutes the main problem. In a typical Zattoo or PPLive trace only a very few peers are major sources or destinations of chunks (see Figs. 8, 9).



TOP 10 IP Addresses

Name	Percentage Inbound	Percentage Outbound	Bytes	Packets
141.13.8.5	82.738%	17.262%	6.243 MB	10,023
91.123.108.37	0.817%	25.552%	1.646 MB	2,424
84.74.181.85	0.021%	18.624%	1.164 MB	1,226
217.191.229.202	0.019%	17.336%	1.083 MB	1,266
91.123.108.121	0.521%	14.100%	934.669 KB	1,404
87.162.102.144	11.975%	0.017%	766.585 KB	865
87.173.160.230	2.358%	0.096%	156.867 KB	226
91.123.108.100	0.073%	1.636%	109.192 KB	158
91.123.103.101	0.068%	1.602%	106.782 KB	148
85.3.102.5	0.028%	1.333%	86.967 KB	117

Fig. 8. Peer distribution of a typical Zattoo trace



Name	Percentage Inbound	Percentage Outbound	Bytes	Packets
141.13.8.5	86.111%	13.889%	4.470 MB	12,435
124.98.236.249	1.054%	13.816%	680.686 KB	1,339
219.153.44.88	1.935%	8.627%	483.499 KB	1,157
58.194.235.5	0.489%	6.225%	307.317 KB	609
219.217.39.36	0.415%	4.387%	219.800 KB	486
59.85.90.12	0.367%	4.101%	204.523 KB	430
124.236.233.6	0.293%	3.585%	177.528 KB	355
58.18.116.255	0.279%	3.154%	157.177 KB	335
58.92.116.89	0.360%	2.964%	152.140 KB	284
125.96.190.11	0.302%	2.793%	141.652 KB	330

Fig. 9. Peer distribution of a typical PPLive trace

All compared systems did not implement a true tit-for-tat strategy. Analyzing all traffic relations among the involved peers, we checked this condition by a visual inspection of the relation between the realized throughput T (bps) and hop distance as delay D indicator. A good system should maximize the resulting power metric $P = T/D$ and realize a cluster of points around a vertical line near the origin (see Figs. 10, 11).

In the wireless environment all P2P dissemination systems have shown a severe OoS degradation due to sporadic link errors. By means of its error-resilient AVC codec Joost has realized the best performance. In particular, Zattoo suffered severely from the counterproductive increasing traffic generated by an increasing error rate due to a low quality transmission profile with substantial collisions and the resulting delay by layer-2 ARQ activities on the wireless link (see Fig. 12).

Based on these sketched criteria, we have further analyzed the structure of the peer-to-peer overlay network and the

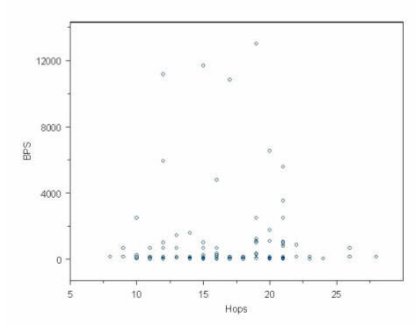


Fig. 10. Test of a power metric for a typical Joost trace

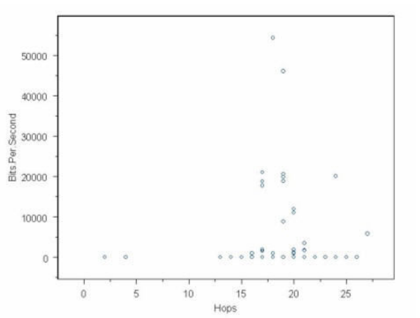


Fig. 11. Test of a power metric for a typical PPLive trace

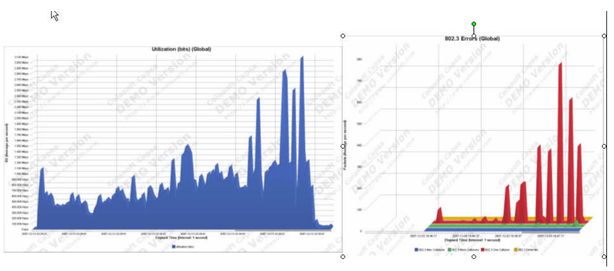


Fig. 12. Throughput and error behavior of Zattoo in a wireless environment

traffic characteristics of the used video transport by the Internet and provided a multi-level assessment of the overall P2PTV service at the user, overlay and packet layers. The resulting comparison of the P2PTV systems Joost, Zattoo and PPLive shown in Table I clearly illustrates that Joost provides both superior performance and a better perceived quality of service subject to stationary and mobile network conditions.

III. CONCLUSIONS

In conclusion, we are convinced that new video portals like Joost, Zattoo, Coolstreaming or PPLive (cf. [7], [10], [2], [9]), which use peer-to-peer technology for the content dissemination of stored videos, e.g. shows, and live TV channels, constitute a promising new revenue path for next

Criteria	Joost	Zattoo	PPLive
offered contents	stored videos, TV channels	stored videos TV channels	TV channels, TV channels
perceived video quality	+	-	- -
bandwidth utilization	1 - 2 %	0,3 - 0,5 %	0,5 - 2 %
adaption to access rate	- -	- -	- -
transport overhead	13 %	56 %	45 %
traffic characteristics	+ +	o	o
use of spatial locality	o	o	o
vulnerability to WLAN	+	o	-
transport efficiency	+	-	o

Table I. Comparison of P2PTV systems

generation Internet with a fast growing demand in the coming years. However, the embedding into Web services that provide the rich features of Web 2.0 technology and the related peer-to-peer traffic crossing the transport network towards a rapidly growing population of the stationary and mobile clients will generate many challenges for performance engineering.

Main challenges concern the efficient programming of the transport and video streaming mechanisms. According to our assessment Joost [7] currently provides the best performance and perceived quality. This expected outcome reflects its broad experience in peer-to-peer software design. The involved development company Joltid [6] and other project teams have gained it during previous successful P2P projects like Kazaa and Skype.

Nevertheless, we are convinced that there is still a lot of potential for further performance improvements since a tit-for-tat video dissemination strategy is not applied by the peers and the adaption to the access rate or the spatial locality of peers are not fully exploited up to now. Thus, further performance and quality improvements are still possible.

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