Enabling on-demand Internet Video Streaming Services to Multi-terminal Users in Large Scale

Zhijia Chen, Chuang Lin (Senior Member, IEEE), Xiaogang Wei

Abstract — *In the ubiquitous era of streaming multimedia over the Internet, an increasing number of users are accessing to Internet video services through varieties of terminals, e.g PC, Set-Top Box IPTV and mobile phones, etc. Whereas extending streaming media to multiple ends adds much to consumer electronic industry, the challenge remains on how to provide on-demand services to heterogeneous users with different bandwidth requirement, access manner, QoS demand, etc. The success of a large-scale video streaming system relies heavily on how they address the critical issues in QoS, scalability and heterogeneity, yet no single system has delivered the expected scale and quality for commercial applications. Thus this paper provides a complete portfolio of solutions for providing multiple Internet video streaming services (live video broadcast, video on demand, video downloading) on 3 Screens (PC, TV, mobile), through a unified Peer-to-Peer (P2P) video platform. Upon manageable P2P framework, different terminals access are supported and end user bandwidth are utilized to scale the system. With our multi-process server management, efficient topology organization, enhanced UDP transmission and intelligent content distribution, our P2P streaming media platform is proved to have lower operation cost and higher user quality. The significance of such paper lies not only in the proposed system framework and on-field engineering techniques to enable an enterprise-grade and telecom-class application, but also the industrial insights inside designing such commercialized large-scale platform with full consideration of function, process, configuration and cost*[1].

Index Terms — Peer-to-Peer, Video Streaming, 3-screen, Video on Demand.

I. INTRODUCTION

With the booming of Internet applications and entertainment electronics, we are moving towards a ubiquitous era of streaming multimedia over the Internet: anyone can access the media content on the Internet anywhere, anytime, for any purpose [2]. A survey conducted by StreamMedia.com and the Aberdeen Group indicates that over 74.1% of business and personal users access streaming media (live video broadcast, Video on Demand (VOD), Web TV, etc) at least 2-3 times per week. According to a forecast from IDC, Internet video services will generate over $1.7 USD billion in revenues by 2010[1,8].

However, providing on-demand video streaming services to large-scale end consumers is perhaps one of the greatest unfulfilled promises of the Internet, mainly facing challenges in three aspects[2]: 1) *Scalability*. With millions of users viewing the Internet video services simultaneously, the system usually has high bandwidth burden. A commercial system needs to scale well with large crowd of users and avoid service degrading along with the user increase. 2) *Quality of Service (QoS)*. Though P2P (Peer-to-Peer) based File Sharing [3,4], live video broadcast [5,6] and Video on Demand (VoD) [7,9] systems overcome the performance bottleneck of traditional server/client paradigm by sharing the peer bandwidth to increase system scalability, it is far from achieving the streaming quality that satisfies the end customers, especially for High Definition(HD) videos. With the dynamics of P2P networks, it is challenging to build a platform to meet the strict requirement on data rate, delay, packet loss, etc., and provide differentiated streaming quality to end consumers. 3) *Heterogeneity.* Nowadays, not only traditional PC users are getting access to the streaming services, but also the TV users, mobile phone users, PDAs, etc., are requiring for streaming videos. Whereas extending streaming services to multi-terminals add promising market opportunity to consumer electronic industry, the challenge remains on how to provide on-demand services to heterogeneous users with different bandwidth and access manner. Though existed streaming systems [6,7,11-15] have addressed a subset of those issues, merely none provided a comprehensive solution to address them together and deployed a platform-level implementation [2,8].

In this paper, we build a unified P2P video platform for providing multiple streaming services (live video broadcast, video on demand, media downloading with Digital Certification) to multiple consumer terminals (PC machine, IPTV Set-Top Box (STB) and mobile phones, etc). Our platform utilizes manageable P2P network as the base content distribution approach, and combines the streaming techniques and intelligent Content Distribution Network (CDN) framework to build a QoS-guaranteed commercial platform. Our multi-process server management increases server utilization, the peer topology organization achieves efficient peer selection, and the intelligent content distribution enables the system to handle large crowds for hot content. Our enhanced UDP transmission solves the former problems of TCP such as low transmission speed and intranets transmission barrier, and further addresses the high packet-loss frequency of current UDP protocol.

[1] This work was supported in part by grants from NSF China (No. 60673187), and 973 Program of China (2009CB320504). This work is done with industrial cooperation and permission of Force Tech Inc.

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Contributed Paper
Manuscript received October 15, 2009

Despite widely available academic proposals for video streaming[1,2,5-15], we are mainly interested in how to build a platform that works in real deployment. Based on our former theoretical explorations [16, 17,2], this paper provides the on-field engineering techniques in building the real system with full consideration of domestic Internet, e.g. ISP transferring, NAT problem. In steering for large-scale implementation, we not only introduce the system modules (e.g., how we organize server and peers), processes (from video capture, editing, to cross-region transmission, and edge content distribution), but also on-field system configurations (e.g. Set-Top Box) and deploy budget, through numerical examples and implementation case samples.

Rest of the paper is organized as follows. Section 2 presents our system architecture and design principles. Section 3 specifies streaming services on different terminals. Section 4 introduces our industrial implementations. Section 5 concludes the paper.

II. 3-SCREEN VIDEO STREAMING ARCHITECTURE

A. Platform Architecture

Based on a manageable P2P and CDN hybrid framework, our streaming media platform can be divided into data layer, management layer, transmission layer and user layer. As shown in Fig.1, it mainly includes the following components:

P2P Database Server (DBS): At data layer, DBS is responsible for taking all dynamic data the Central Control Server (CCS) cluster needs to store, and for sending proper data information cached in edge servers to CCS.

P2P Central Control Server (CCS): At management layer, CCS handles all servers, mainly for information processing and interaction. CCS conducts load and connectivity analysis of the servers and assigns the most proper edge server as the seed to stream to peers. CCS is divided into two layers, one for central control and one for region control.

Intelligent Content Distribution Network (CDN) Module: At transmission layer, CDN module provides shortened packet delivery from source to dedicated edge caches. Combined with intelligent content distribution, users in different regions can conveniently access content from nearby edge servers and other users. The reliable CDN distribution also facilitates the data transfer across worldwide regions.

P2P Transmission and Delivery Server (TDS): As the edge streaming server, TDS in at the bottom layer of CCS and CDN, and is responsible for accepting new users and streaming the users, with the guide of CCS. TDS deals with all the local content and stream for both video upload and download.

Multi-terminal Accessing Server (MAS): At user access layer, the Multi-terminal accessing server is responsible for judging and accepting users that access with multiple terminals. Different access servers are deployed to guide user requests based on their terminal type. The PC user gets access to the platform through WEB server, and IPTV user through EPG server and mobile terminals through WAP server.

P2P client side: our P2P client software enables the video transmission among users and TDS servers. The client software has versions for PC, Set-Top Box(STB) IPTV and mobile phone respectively. Users can either access the platform in C/S mode or P2P mode based on their needs and available bandwidth. In most cases, users, especially PC and TV users, are encouraged to access in P2P manner. In case of server bandwidth inefficiency, all PC and TV users are defaulted in P2P access mode.

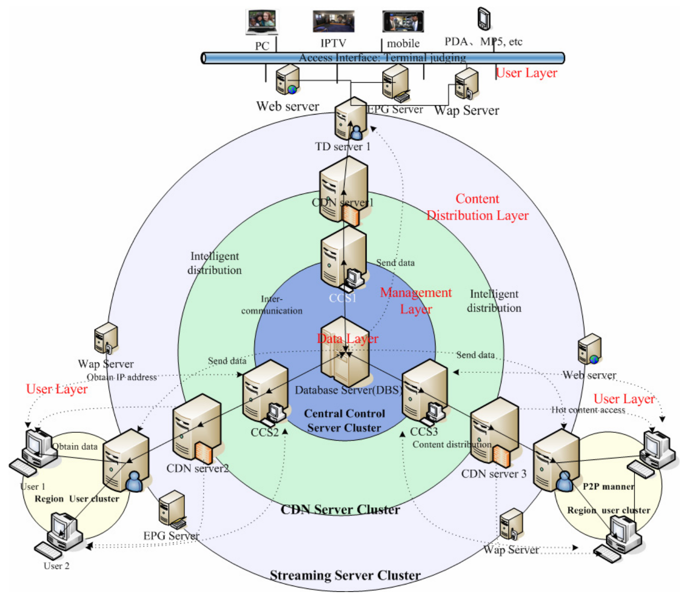

Fig. 1 3-screen Streaming Platform Architecture

In our decentralized P2P system, all information of user access, server working, content resources, node processing, etc, are managed through centralized management system, which contain network information management and framework placement management. The *network information management* exists among the overall P2P distribution network, from user requests, server indexing for content resource and user information, feeding back for user network information list, user content accessing, P2P manner content transmission, to the final video playing on end users. All those steps are scheduled by CCS which facilitated full and convenient manageability. On the other hand, the *framework placement management* mainly concentrates on the management for content distribution. Combined with the intelligent hot content distribution function, the users in different regions can conveniently access content from nearby edge servers and other users. Local access is set to be in high priority, which saves backbone network resources and avoids cross-ISP and cross-region traffic. This to some extent saves the former problem that P2P applications take up too much network bandwidth, and enables P2P to satisfy the application requirement of telecom-class operators, achieving the true and high philosophy of P2P streaming technology, i.e "more users=less cost + higher quality".

The general streaming process include: Firstly new user sends requests to CCS, then CCS searches for TDS server and users with requested content, and sends back available sources nearby user's IP domain to requesting users. Peers with requested content are set as priority and then the less-loaded servers, which promotes P2P content sharing and keeps averaged workload among edges servers to achieve global server load balancing (GSLB). Fig.2 further shows our logic structure to organize such platform to provide live video, video on demand and interactive video services to end Internet users. As a service platform, our streaming system has no requirement for terminal type and media format, with full support for heterogeneous users through Internet. Based on P2P VOD, P2P video live broadcast, CMS (Content Management System), interactive chatting and web conferencing application systems, etc., the system is built as one-stop video streaming service platform.

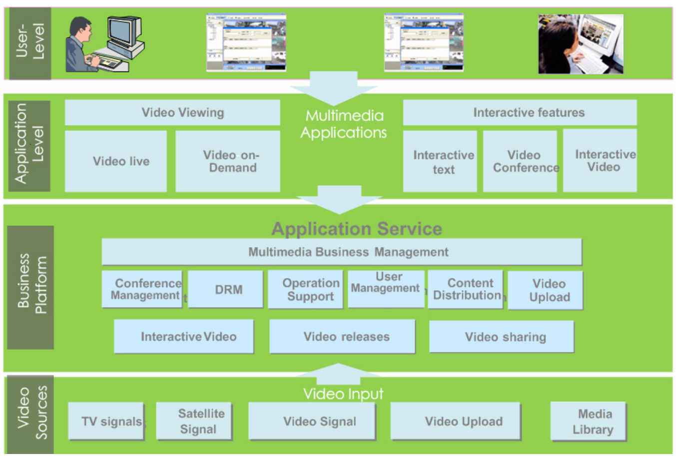

Fig.2 Platform Logic Structure

B. System Designing Principle

1) Distributed Architecture

For content storage, the platform adopts the distributed storage mode and makes all distributed content store among the user network, thus decreasing users' dependency on servers and releasing the bandwidth pressures. Meanwhile, since users can obtain program data form multi-sources, they have more stable content source and avoid re-buffering/ discontinuity during the video playing.

For server organization, we adopted the distributed framework to deploy servers based on manners of function, region, requirements, etc. The P2P streaming servers are divided by functions and make each handling their specific role. The system service is specialized by assigning more resource in areas with high requirements and sparing less resource in area with small users, leading to improved resource utilization and overall service value.

2) Enterprise-grade and telecom-class application

In providing an enterprise-grade and telecom-class application, the platform embeds following features:

Security: our platform has strict configuration for user name, password and authority, and sets classification for administrator authority. The system can thus well control the user access and manage the right of the media content to authorized users in avoiding unauthorized operations. The system embeds good trigger mechanism for security, which effectively keeps a statistic and control of the user connections and enables system alert function to inform irregular cases.

Dependability: Our system adopts CDN for initial content distribution and intelligently supports more users at the root node. With well combination of P2P and CDN, the system is built as a telecom-class platform with high dependability, achieving stable operation over time duration of 7*24*365.

System Scalability: For function scalability, our system is designed with module concept and can flexibly re-design based on operator' needs. Without huge system adjustment, new function can be extended. For capacity scalability, our P2P system can support a concurrent user of around 10,000 per single server with 10M bandwidth. The platform provides streaming services to the same scale of users with only 1/20 of the bandwidth and server requirement in C/S paradigm.

User Quality of Experience (QoE): 1)User-friendly bandwidth control. While viewing the video service, the client side of the our P2P streaming system only takes up 60%~70% of user's available bandwidth, leaving abundant bandwidth resource for user's additional Internet operations. 2) P2P Caching Function. Efficient content caching function is enabled on memory and hard disks. While the user is viewing the video, the downloading is carrying on with 3-5 times of the speed for video playing, which ensures the smooth playing of the video. In case of network dynamics or failure, users can still access the pre-fetched content for continuous playing and resume the downloading progress after the network is recovered. 3) Real-time data delivery. The system achieves high-speed P2P transmission for video content in process of video slicing, compression and stream recombining. The video content is delivered to the overall network with efficient utilization of user upload/download bandwidth.

3) Multiple protocol, format and rate support

To suit the needs of heterogeneous users with multiple terminals, our system is designed to support multiple transmission protocol, video formats and rates. The system widely supports protocols like mms, rtsp, http, file, etc. The mms and http protocol enables the content transmission in Internet video live broadcasting, Satellite TV live broadcasting, and file virtual broadcasting stream, etc. The rtsp protocol supports easy selection of video progress in VOD application to ensure user experience. The file stream is used for distributing VOD content so that the video file in the server can be accessed by absolute path, which simplifies operation process and increases system working efficiency.

As for video formats, our streaming system supports a broad range of main video formats, including: MPEG 1, MPEG 2, MPEG 4, 3GP, MP3, H.261, H.263, H.264, ASF, WMV, RM, RA, RMVB, AVI, WAV and etc. The system thus has better compatibility, avoiding the complication of frequent format transferring, and enabling the video sharing and playing on different terminals. For end users rate, our system allows users to select the video rates that best suits its accessing bandwidth, thus delivering differentiated quality of services to users with different ability.

4) Open Structure

Our P2P streaming system is developed with an advanced three-level structure based on series of C/C++ standards, along with the combination of C#、JAVA and assembly language, having good adaptability for crossing platforms and working on UNIX, Linux and Windows. With the middleware provided by third-party, the system can conveniently transplant varieties of hardware platform, operation system and WEB server platforms. The system has source code interface for both JAVA and C#, making the system highly compatible and cooperate with other systems conveniently. In addition, our P2P streaming system uses the web manner interface for management and provides user-friendly information and error notice, making it possible for common users to handle the operation on such system easily.

Fig. 3 Multi-process and load balancing server list

C. Technical Enablers of the platform

Server management with Multi-process and load balance: Since common streaming system cannot fully utilize the resources (memory, CPU, etc) of servers with high-end configuration, the software's inefficient usage results in high waste of hardware resources. With multi-process handling function, our media streaming system can better utilize and save hardware in reasonable environments. In our media streaming system, one physical server can start 10-20 logic servers and adjust the workload among those logic server units and other physical servers. Along with the load balancing function, the physical and logic servers can have averaged amount of user access to guarantee all servers work in balanced load and avoid idle or over-loaded servers. Fig.3 shows the server working status on our background management system. With same IP address and different ports, the multi-process technique enables one server to run several concurrent logic servers, with each handling different streaming services/clients independently. Meanwhile, the last column of the figure shows the concurrent user number on each logic server. With load balance function, the user traffic is guided to achieve averaged working load on each server.

Intelligent content distribution: Our P2P streaming server holds the function of intelligent content distribution based on popularity, which includes content popularity prejudging and content distribution guiding. The system presets the strategy that when the content popularity in some area reaches certain boundary, i.e. over 1000 accesses per seconds, the *content popularity prejudging system* judges it as hot content and the *content distribution guiding system* then distributes the content to the local streaming server and properly adds more server/bandwidth resource in such location to support more user access. For content like new movies or hot videos that is predicted to have high user access, with the guide of CCS, the system utilize additional edge CDN servers for content distribution and to some extent handle the flash crowd issue. The user influence is achieved by redirecting users to access the local or nearby servers, thus relieving the server pressure and backbone burden due to concentrated user access.

Enhanced Transmission Protocol: we develop our own private UDP protocol as the transmission protocol for P2P streaming system. Though traditional TCP protocol has its advantage for stability, its weakness in low transmission speed and difficulty in transferring intranet firewall and NAT equipment prevent it from being the ideal protocol for P2P streaming media. On the other hand, the UDP protocol has high transmission speed and can transfer NAT, but has weakness in packet loss and security guarantee during transmission. To solve such problem, our P2P streaming system combines the benefits of both and develops a private UDP protocol that can transfer in high speed without data packet loss and is able to transfer intranet firewall and NAT. For the main four kinds of NAT types, three of the intranet can be transferred and the left one can support the connection with public IP, which greatly improves the system connectivity. This new transmission protocol minimizes the possible data packet loss, guarantees the completeness and consistency of the streaming media content, and is able to transfer intranet firewall and NAT equipment to fully utilize the P2P node bandwidth behind the public IP, which is a critical problem in China with many intranet users. Fig. 4 shows a general process for transferring NAT with UDP.

1. Peer P1 and P2 within private network builds connection with public server S through UDP protocol
2. NAT equipment A1 and A2 builds transfer status and rule
3. A1 and A 2 assigns temporary port number for P1 and P2 respectively
4. P1 and P2 connects each other's NAT equipment through assigned port.
5. A1 and A2 transfers data packets to A and B with formerly built rules.

Fig.4. NAT transferring with UDP

Efficient Peer organization and selection: Due to the real-time characteristic of live streaming application, we adopt a mesh and tree hybrid structure for peer organization based on NICE [10]. As shown in Fig.5, all peers are organized in a layered tree for data transmission. Meanwhile, peers in each tree layer are assigned to a region cluster for peer management. For data delivery, every lower layer obtains data from upper layer and peer in each cluster gets data from the high-speed leader node of the cluster. In case of node failure, peer can obtain data from other cluster or upper layer. For a simple numerical example, with a video rate of 500kbps, if layer one has N node, with each node handling p peers of the lower layers, at layer m, we have $N*p^{m-1}$ nodes. If we set $p=2, m=10, N=200$, the system can support a scale of over 20,000 users, with the delay between layers in 1-3s.

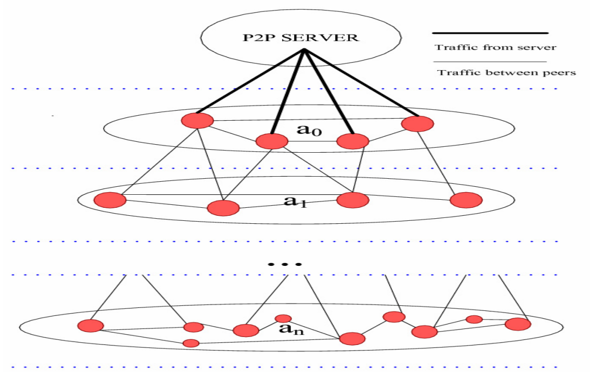

Fig. 5 NICE-based peer organization topology

To choose node to download from multiple choices, peers with following feature are set as priority: high IP similarity, low network latency, and high data transmission rate and low packet rate. Our P2P solution enables the accessing of media content from neighbors with intelligent node searching. The following vicinal content access schemes are implemented: 1) End System Multicast [11]. Scheduling based on bandwidth, multiple encoding and location vicinity. 2) Topology matching. Dynamic matching of logical and physical topology. 3) IP-preferred. Scheduling service based on IP domains.

During downloading, server nodes are given lower priority so that peers can first obtain data from available peers. The node-priority scheme is achieved based on following formula(nodes with higher score will be selected):

$$Node_{score} = \frac{K}{2 + rtt/500} * (rtt_{\min}/rtt)^2 * Percent_{rec}{}^2 * F \quad (1)$$

$$Node_{score}(now) = \frac{Node_{score}(pre) + 3 * Node_{score}}{4} \quad (2)$$

K is a preset constant parameter and peers are set with higher value than the server node. A typical setting is as follows: Source server K=700; edge server CS K=800; regular peer K=1000; peer within same region K=1300. rtt is the dynamic network latency between nodes and $rtt_{\min}$ is the minimum static latency. $Percent_{rec}$ is the successful data receiving percentage, which is equal to 1-*packet loss percentage*. F is the current bitrates and K is empirical value.

III. STREAMING SERVICE SPECIFICATION

To suit the wide demands of users, our platform supports all typical kinds of streaming services(live video broadcast, video on demand and video downloading) on 3 screens(PC, IPTV and mobile streaming, see Fig.6). Since both us and other researchers have reported a lot work on implementation on PC[2, 8-15, 17], we mainly concentrate on the specification on TV and mobile phone in this part.

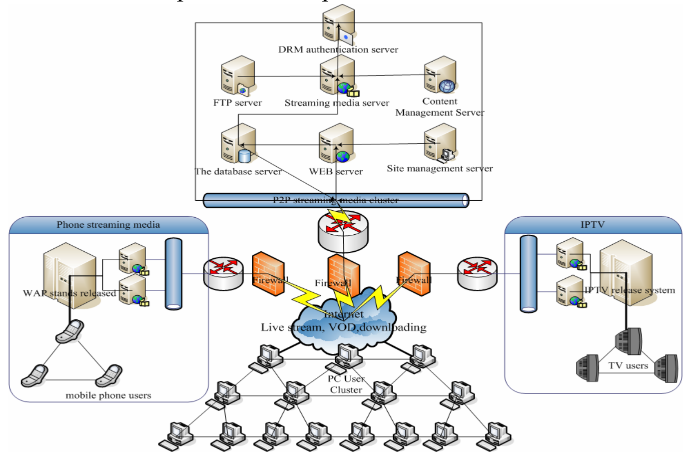

Fig. 6 multiple services on multiple terminals

A. *On-demand Streaming Services*

P2P Video On Demand (VOD): our P2P VOD subsystem provides service for users to view on-demand video content in P2P manner. Through the file breaking, segmentation and recombination, the P2P VOD media transmission is enabled, so that users can cache certain video content for sharing with other while viewing the VOD file. Since the data cached exist in segment/chunks, the system can again start connection, download and play of the video after the user skips certain segment to change the video progress. So the users can view the real video on demand for the whole program, without limitation on the duration of downloaded video. In comparison with the MS MediaServer system, with the same hardware, our P2P streaming solution can scale 3-5 times in VOD service and 5-10 times in live video broadcasting.

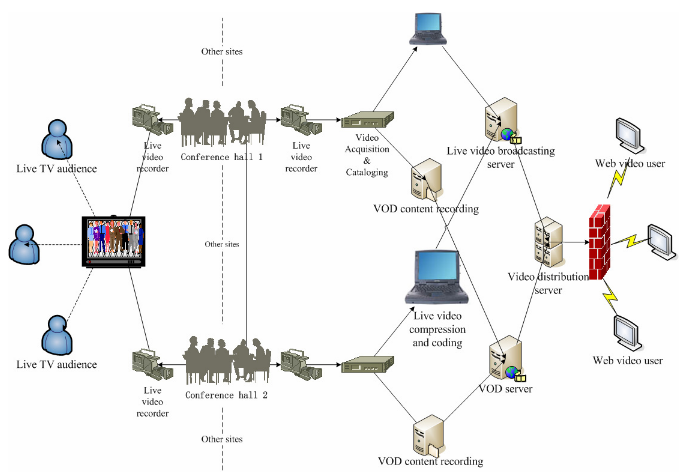

Fig. 7 Live conference live broadcasting and VOD

P2P Live Video Broadcasting Service : The platform can provide live broadcasting function for multi-channels, and enable operators to broadcast the cabled TV program, conference scene, arts program, long-distance class over Internet, etc. Fig. 7 shows a lifecycle for broadcasting the video service from program recording, editing to final broadcasting over Internet, for both live broadcast and VOD.

Downloading service with Digital Certification: Though VOD and live broadcasting service provides powerful on-line viewing function, some users still cannot view the expected video quality through Internet and some others may prefer to view their favorite videos for several times. So our platform also supports full downloading function with wide program formats supported and RESUME function enabled during downloading process. Meanwhile, the program for downloading is encrypted through standard DRM certificate architecture, so that the Internet operators can limit the user viewing time and frequency through digital certificate. A typical *implementation case* for program downloading service is as follows: in a long-distance Internet education system, students can download the courseware and view the content in authorized times. Once the authorization expires, the courseware also becomes invalid and cannot be viewed again. Such strategy not only protects the content copyright but also saves the bandwidth consumption by avoiding concentrated viewing of the courseware over Internet.

B. *IPTV media streaming*

In recent upsurge for IPTV services, Internet TV system for live broadcasting service becomes an important component in the IPTV service series. Internet operators can customize multi-channel Internet TV programs based on target user needs, e.g. on-the-spot broadcasting, television relaying, TV Show broadcasting, etc. With the extending of IPTV services, TV holders only need to add one Set-Top Box to get access varieties of video content they like, by clicking the tele-controller and achieve the advanced function like interactive manipulation and scheduled recording.

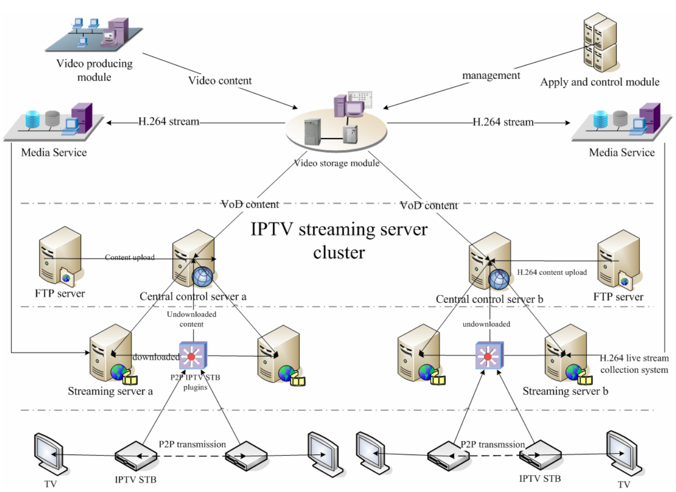

Fig. 8 IPTV streaming framework

For implementation, the set-top box embeds the our P2P IPTV live broadcasting/VOD client side, which is the terminal system for receiving the video content distributed from our P2P streaming server. Additional mobile disk may be affiliated to cache for live video or downloaded file. As shown in Fig. 8, the client side of IPTV live broadcasting/VOD system accesses video content in P2P manner, in which users can share their local cached content for other users that are viewing the same video content. The client side of the P2P IPTV VOD system can download the video content at 3-5 times of speed of video playing, which well ensures the stable and smooth video viewing.

The client side supports wide range of media formats and can decode the intact video content to support high quality video playing effect. Meanwhile, our P2P streaming system supports the High Definition video stream based on H.264, and it also adopts professional encryption for DRM of video stream. Table I gives a sample Set-Top Box configuration in support for High Definition (HD) video P2P streaming.

TABLE I SET-TOP BOX CONFIGURATION FOR IPTV STREAMING

Service Function	
P2P Live Broadcasting, P2P VOD, P2P downloading	
Configuration Parameters	
CPU	300Mhz MIPS
Hardware decoding	Independent MAE audio/video decoding engine, supporting multi-formats hardware
Supported formats	H264/AVC,MPEG-4/2/1,wmv9,Divx,Xvid, AAC, MP3
File format	MPG , M2V, M2A, MP4,TS, wmv/asf,Divx AVI
Network stream protocol	ISMA1.0 ; RTP /UDP; RTSP; Unicast, Multicast
	MPEG-2 TS UDP over RTP
Description File format	SDP
MPEG-2 Transport	h.264 TS over Http, wmv over rtsp
Output	
Video	Composite,S-video; YUV components,VGA
Audio	RCA
Decoding	
Video	H.264/AVC 、 ISO13818(MPEG-2) 、 ISO 11172(MPEG-1) 、 ISO/IEC 14496-2:1999 (MPEG4 Video ASP/SP) 、 ISO/IEC 14496-3:1999 (AAC LC)、Wmv9*、Divx、Xvid
Rate	32kbps---100Mbps
A audio	PCM , MPEG-1 L2 , MP3*, AC-3*, AAC
Supported format	MPEG-2 TS UDP over RTP, MPEG-4 ISMA 1.0
Network connection	
high-speed Network Ports	RJ-45, 10/100Mbps, MDIX
protocol	IEEE802.3, IEEE802.3u, IEEE802.3x
Wireless WIFI access	IEEE.802.11b

C. *Mobile streaming*

Recently, streaming mobile platforms are regarded as the mobile value-added services with prosperous market and social values. Our platform enables audio/video streaming playing on China's existing 2.5G mobile network. Our mobile streaming system is a telecom-grade, distributed and scalable system, which adopts up-to-date H.264 compression, providing a complete solution for enabling 3G services like VOD on the 2.5G wireless network (GPRS, CDMA1X).

With a distributed structure over the mobile network, our 3G Value-Added Mobile Streaming Platform contains the following key components: a) *Mobile Streaming Server*: It's mainly responsible for providing streaming services by calling the video files on the streaming server through the streaming software, including the following sub-systems: Channel and media publishing sub-system; Content management sub-system; Index server sub-system; Log information collection sub-system; Database sub-system; Statistics and report sub-system. b) *Mobile Encoder*: for compressing and converting avi, dat, wmv, rm, rmvb, mpg, mov, asf video files into 3gp files. c) *Mobile Player*: for playing 3gp streaming files compressed by Mobile Encoder.

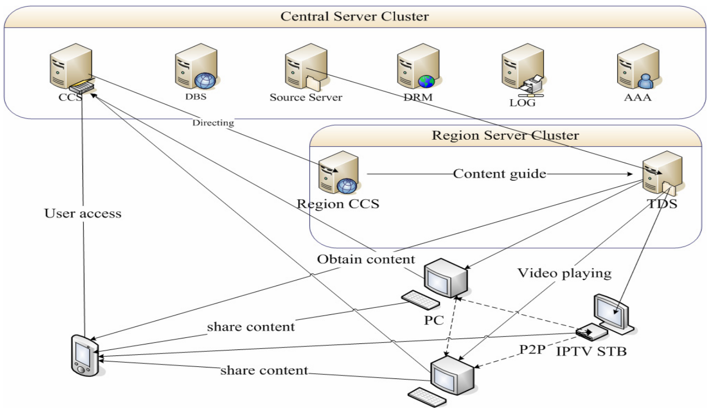

Fig.9 Mobile streaming System

1. A new mobile peer P sends a requesting message to central control server S
2. S searches the content from on-line PC user list; if found user with requested content, Transcode (PC, mobile), and *Stream* (P, PC)
3. *ELSE*, S searches the content from on-line IPTV user list; if found user with requested content, Transcode (TV, mobile), *Stream* (P, TV)
4. ELSE, S directs P to a region server cluster and returns an edge WAP server W_i
5. *if* available bandwidth of W_i outweighs the requesting bandwidth of P, *Stream* (P, W_i)
6. *Otherwise if* the cluster cannot serve P (no available bandwidth or requested media file), S conducts an overall search and returns another cluster to P
7. *If* no streaming resource is found, reject P

Fig.10. The Streaming Process of mobile user

The architecture of the Mobile Streaming Platform includes: 1) *User's platform*: the terminal layer of the P2P streaming mobile operation platform. 2) *Application supporting platform*: As the core layer of the platform, it enables the P2P VOD and live broadcasting applications. It embeds the function of streaming content collection, encoding, auditing, distribution, storage, cataloging and indexing, copyright protection (DRM) and content publishing, etc. 3) *Operation supporting platform*: the operation and management layer includes user management, certification and billing management, system monitoring management, statistical reporting management, the 3rd party operation management ,etc.; 4) *Service platform*: the service mode and realization layer of the platform. The available applications include video on-demand, digital TV live broadcasting, multimedia data broadcasting, interactive programs, video phone, Internet browsing, online education, etc.

Fig.9 shows an overview of our mobile streaming system. Fig.10 further shows the process on how a phone user obtain shared video content with other users, e.g. PC and TV.

IV. INDUSTRIAL IMPLEMENTATION

Joint with the industrial efforts [18], our system has successfully supported the live broadcasting/VOD applications with over 100,000 users for tens of Medias in providing national program like Online Spring Festival Gala of China, Confucius Culture Festival, etc. Due to concerns on patents, this paper mainly provides the system designing principle and function specifications. To illustrate our industrial implementation, here we report a sample case of our system for providing worldwide streaming services.

A. System implementation

In real implementation, the full lifecycle of providing a video streaming program generally include three steps: 1. local video capture and release (see Fig.11); 2. cross-region stream transmission from local server to servers in target region, e.g. different countries; 3. Content receiving and distribution to end users in target region (See Fig.12)

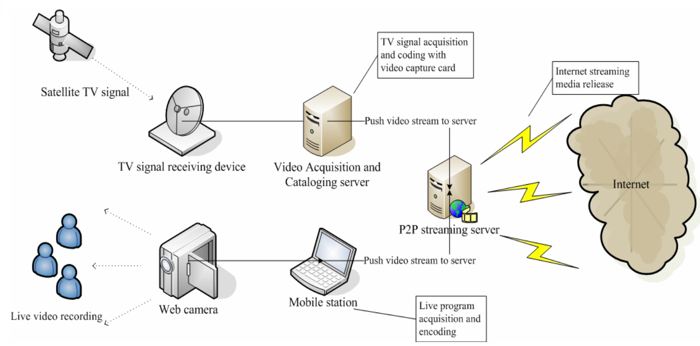

Fig. 11 local video capture and release

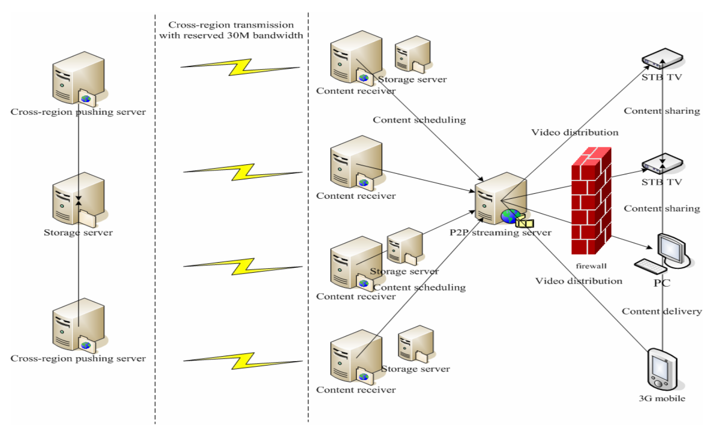

Fig.12 cross-region transmission and terminal video distribution

Fig.13 shows a snapshot of our management system for web TV. With such system, media operators can easily add servers for providing streaming services, add live/vod channels, view server and channel resources, and enable hot link protection with anti-link setting. In the demo system, we have 58 channels, a total of 50,000 users with 9,000 concurrent users currently on line.

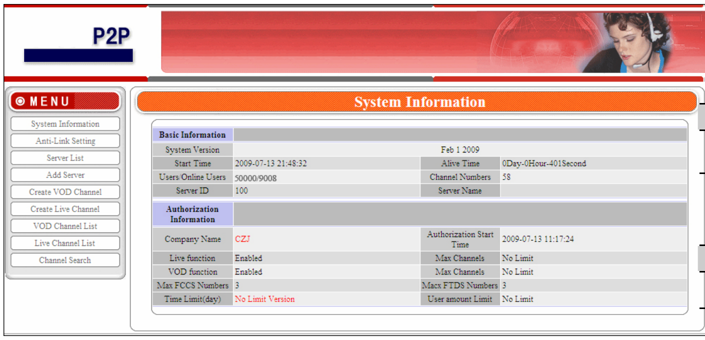

Fig.13 web TV management system

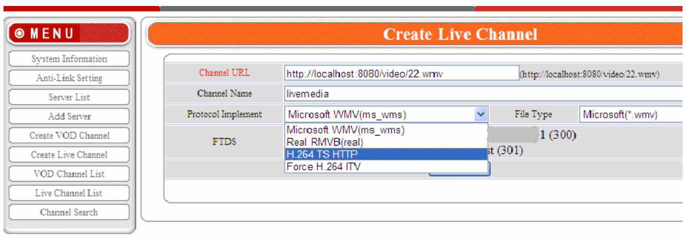

Fig. 14 adding new live channel

Fig.15 VOD channel list

Fig. 14 shows how we add live channels with the setting for video source and different formats. And fig. 15 shows a list of sample VOD videos on the platform.

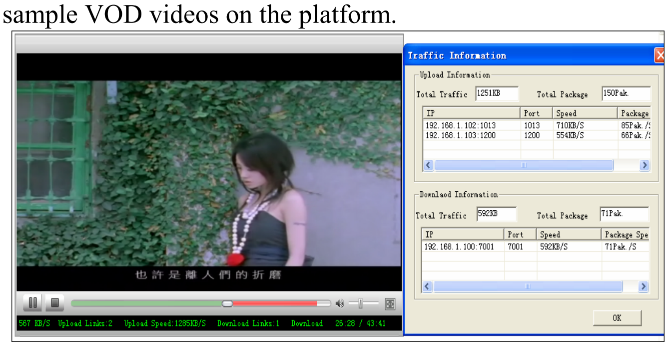

Fig.16 PC user screen and traffic information

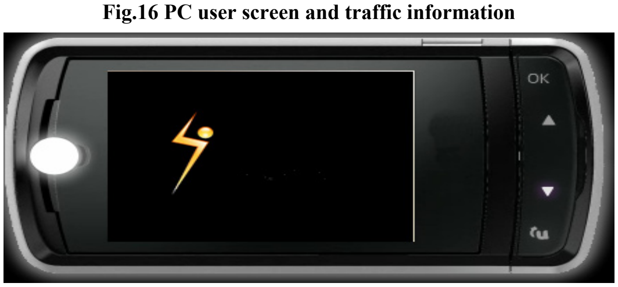

Fig.17 mobile client side

Fig. 16 gives a snapshot of our PC client side. The traffic information shows the video are downloaded at reasonable rate (592KB/S) to support smooth playing and peers are sharing well with each other during the VOD application. The progress dragging latency is within 1-2 seconds during the testing. In addition, Fig. 17 gives a snapshot of the mobile phone client side of our 3-screen platform.

TABLE II DEPLOYMENT BUDGET(TRADITIONAL IPTV)

Hardware					
Region	Type	No	Unit Price	Total Price	
oversea	Dedicated streaming server	65	20,000/ server	1,300,000	
Bandwidth					
Region		No	Unit Price	Total Price	notes
Cross-country		15	4,000/ month	60,000	1M/ channel
Oversea country		65	30,000/ month	1,950,000	100M
Total network investment(server+bandwidth)				￥3,310,000RMB	

B. Cost and Performance

Further, we compare the operation cost between our P2P IPTV and traditional IPTV. As shown in table II and III, in providing IPTV service to a concurrent of 10,000 users, our solution decreases the network investment cost (streaming server+Internet bandwidth) from 3,310,000RMB to 658,000 RMB, with 80% cost saving. In table III, we also gives the details on the number and type of servers needed (2 DBS; 1-2 CCS; 6-9 TDS), and the cost for High Definition video Setup-Top Box and the management software. This should provide much reference for implementing such scale of system.

TABLE III DEPLOYMENT BUDGET AND CONFIGURATION (OUR P2P IPTV)

Hardware					
Region	Type	No.	Unit Price	Total price	notes
China	content pushing server	1	5,000	5,000	PC config.
oversea	content receiving server	1	5,000	5,000	PC config.
	P2P streaming server	13	20,000	260,000	**2 DBS; 1-2 CCS; 6-9 TDS**
	HD IPTV Set-Top Box	10000	860	8,600,000	
	HD IPTV STB wireless	10000	85	850,000	
Software					
region	type	No.	Unit price	Total P	
China	Cross-region transfer sys.	14	5,000/channel	70000	
Oversea	P2P streaming system	5	120,000	600000	
	CMS system	1	120,000	120000	
Bandwidth					
region	Number	price/month	Total price	notes	
China	1	8,000	8,000	50M	
Oversea	13	30,000	390,000	100M	
Total network investment(server+bandwidth)			￥658,000 RMB		
Total investment(hardware+software+BW)			￥11,178,000 RMB		
Total cost per user			￥1117.8 RMB		

For web video service, during our recent industrial deployment at China local movie website, we attracted nearly 30,000 concurrent users in broadcasting 110 channels of movie files. The hottest top 2 movies attracted 2129 and 1379 users respectively. The performance summaries are listed in table IV. For a simple cost calculation, the traditional media server bandwidth usage is 28345 * 0.5M = 14.172G, but with the assistance of our P2P streaming system, the actual server bandwidth usage is only 1.465G, saving nearly 90% bandwidth consumption. This data is especially encouraging because it is obtained from real industrial deployment with well guarantee of user QoS. Compared with former C/S VOD system, our system can provide reasonable play rate, lower startup delay and dragging latency, with less server and bandwidth requirement.

TABLE IV PERFORMANCE SUMMARY OF P2P INTERNET VIDEO SYSTEM

Starting Date	Sep.25, 2009	Broadcast Duration	8 days
Total users	28345	Channel number	110
Movie rate	500-600kbps	Service type	Live media, VOD
Maximum CCS	6	Maximum TDS	35
Bandwidth used	1.465G	User on-line duration	656.6 s
Startup delay	10~15 seconds	Dragging latency	2 ~ 8 seconds

V. CONCLUSION

As more and more users are using and contributing to the Internet streaming services in way like video uploading/downloading, the streaming demands call for an ecosystem solution to suit the multiple streaming needs of multiple terminal users. In this paper, we provide a 3-screen solution for providing on-demand streaming services in large scale. Through function specification and sample cases, we explore what is inside in building a large-scale commercial platform, which should be of more value to the real implementation. The overall system is proved to have higher user experience quality with less implementation cost, e.g. a 80% cost saving for providing IPTV to 10,000 users, 90% bandwidth saving for providing web video to nearly 30,000 users with high QoS level. With the emerging of cloud computing paradigm, our work also adds much towards a cloud streaming platform to provide QoS-guaranteed streaming services on demand to any user anywhere through unified web access.

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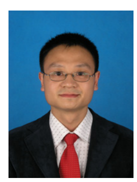

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