Turning Internet-based TV into Reality

Delivering Video Streams Over the Internet

White Paper

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Preface

PeerTV is providing the following white paper as its own modest contribution to the promotional and educational process that needs to occur for Internet-based TV (also known as Over-the-Top TV) to become widespread service offering. The document focuses on architectural issues and business considerations when building such service, especially the video delivery part, as represented by the cost utilized CDN.

PeerTV's products, providing the TV connectivity to Internet-based TV (the IP STB) and the application gateway (MX Gateway) providing the key building block for creating a compelling user experience are not described here as the intention is to provide a general, product-independent analysis. For more information on PeerTV's products and solutions, please refer to our web site, at: http://www.peertv.com

Target Audience

The intention is to provide basic and some in-depth information to entrepreneurs considering Internet-based TV, or Over-the-Top TV as a viable alternative to a broadcast service such as cable or satellite. The document assumes some familiarity with the technical aspects of Internet streaming and video, yet most of it can be understood by those focusing on the content side of things yet need to evaluate cost aspects of such service.

Abstract

This document presents viable solution for large-scale provision and delivery of video content. It focuses on concept and design architecture, usage of multiple servers, streaming gateways, and other transport mechanisms, along with a system for using one or more of the analyzed solutions, for efficiently deliver video content to a broad multi-regional audience.

1. Overview

The explosion in the amount of quality video available on the public Internet has created monumental shifts in attitudes over the past year about whether online video will be a viable and growing market for magnetization of video assets. The shift in attitudes has been most notable among large content owners such as TV networks, but is also seen in providers of online video destination sites, as well as both back-end publishing and syndication capabilities, and CDNs that are helping to enable these services as they provide necessary bandwidth, caching and video acceleration services.

1.1. Definition

Video is basically another type of content that flows over the public Internet. But unlike most of the contents, as WEB and data, video has its own unique characters that demand much more allocated resources for it to be delivered in the right manner over the public Internet.

Delivering video streams over the public Internet is more demandable than just video download since the allocated resources, like bandwidth and delay, have to stay steady as long the video stream is being viewed.

The following table clarifies some of the ‘buzz words’ used in the world of video over Internet, and by that differs the ‘video stream’ from what it is not.

CPE	Home multimedia device that presents the network video content over the home TV. Theses kinds of devices are Streamers, Media-Centers and IP-STB.
Video Stream	Video content that is accessible over the Internet and is being delivered as a stream to a PC or a CPE.
Internet TV	Delivering video streams of TV channels over the public Internet as live broadcasts.
VOD	Delivering per demand video streams of TV programs or full size movies over a private network.
IPTV	Delivering high quality video (TV, movies, games) over a well-managed private network. IPTV is the Telco substitute to the Satellites and Cables operators.
3Play	Delivering IPTV,VoIP and Internet over one single broadband connection.

1.2. Market Drive

The market drive for video stream over Internet is built from different business models that suite variety of video content profiles.

One market drive can be based on delivering popular video clips for free with Ad-support. Another market drive can be based on paid high quality movies, which can be viewed as a VOD.

The following table shows some examples of different market drive for delivering video over the Internet.

CPE-TV/STB-based	**Complementary TV** ▪ Use home broadband connection to custom STB ▪ Streaming (lower quality) or secure store-and-play ▪ Examples: Early Deutsche Telekom, Hansenet, BT	**Multi-Channel IPTV** ▪ Delivers substitute to DBS/cable ▪ Quality depends on broadband bandwidth ▪ Only broadband providers can offer Examples: Fastweb, Free, France Telecom, AT&T, Verizon
PC Based	**Classic Internet Video** ▪ Consumer interest grows ▪ Mostly ad-based model ▪ Experiencing renaissance ▪ Examples: MTV, ESPN Motion, AOL Video, YouTube	**TV-on-PC** ▪ Replicates the TV experience on the PC ▪ Uses broadband, not a tuner card Examples: BSkyB, Time Warner Cable trial in San Diego
	Limited on demand or streamed programming	**Full multi-channel TV and VoD programming**

One thing is in common to all these market drives; all of them need a Content Delivery Network to carry over the video stream from its origin down to its destination at the client PC-CPE device.

Content Delivery Network (CDN) is a complete manageable operation of applications and network devices that form together a mechanism to deliver video streams over the public Internet or over private networks.

2. Network and Infrastructures

A CDN is built over different network elements, which form together its capability to deliver video streams from origin to destination, from content owner to viewer. The major network elements are:

2.1. Infrastructures

Infrastructures include hardware and facilities which are the physical layer of the CDN structure.

2.1.1. Servers

The most basic unit of the CDN structure is built from a high-end robust network server. The network server's hardware should be reliable and equipped with redundant crucial components like CPU, FAN and Power Supply. Servers should back-up each other in case of hardware or network failure.
The servers host the applications that manage and control the CDN operation end to end.

2.1.2. Data-Center

The CDN servers are hosted in a Data-Center, which provides all resources needed to the servers' operation. These resources include cabinets, power, AC and temperature control, monitoring, on-site tech support and surveillance.
The Data-Center also provides connectivity to the Internet via network service providers. The network servers should be connected to at least two Tier1 network service providers to form a reliable CDN.
A CDN provider should not host all its servers in one Data-Center location even though it can serves all it needs. It is highly recommended to share the CDN servers in at least a second Data-Center for redundant and load balancing design.

2.2. Network Service Providers

Network Service Providers provide the infrastructure that actually carry over the video stream from its origin, video servers at the Data-Center, down to its destination, PC/CPE at the Home-Network.
The video stream flows through several segments on its way to the end point; where a different Network Service Provider serves each segment.

2.2.1. Global Network Provider

Tier-1 is a global Network Service Provider that owns its network infrastructure (fibers, switches, etc) and therefore can manage and control all network aspects like bandwidth, delay and jitter.
Global CDN like Akamai and LimeLightNetworks connect their Data-Centers via Tier-1 providers to form a fast and reliable video streams delivery network between their Data-Centers.
Most of the ISPs are peering each other via Tier-1 providers.
Tier-2 provider is defined as a Network Service Provider that acquires network resources from a Tier-1 provider and therefore has less control over its network.

2.2.2. Internet Service Providers (ISP)

Internet Service Provider provides Internet access to the end points of the Internet like business and home users. The ISP on one side is connected to the Internet via Tier-1 providers and on the other side connected to the end users via broadband DSL/Cable providers. In some region/countries the broadband provider is also the ISP (regulation restrictions).

2.2.3. Broadband Providers

Telco and Cable operators provide broadband DSL and cable infrastructure straight to the end user Home-PC/CPE over the so-called ‘Last-Mile’ segment. The broadband provider provisions the end user bandwidth allocation.

2.3. Home Network

The increasing of broadband networks with the decreasing of PC prices have encouraged households to have more than one PC at home. To share the single home broadband connection to Internet, a router, switch and WLAN devices where installed, to form the so called Home – Network.

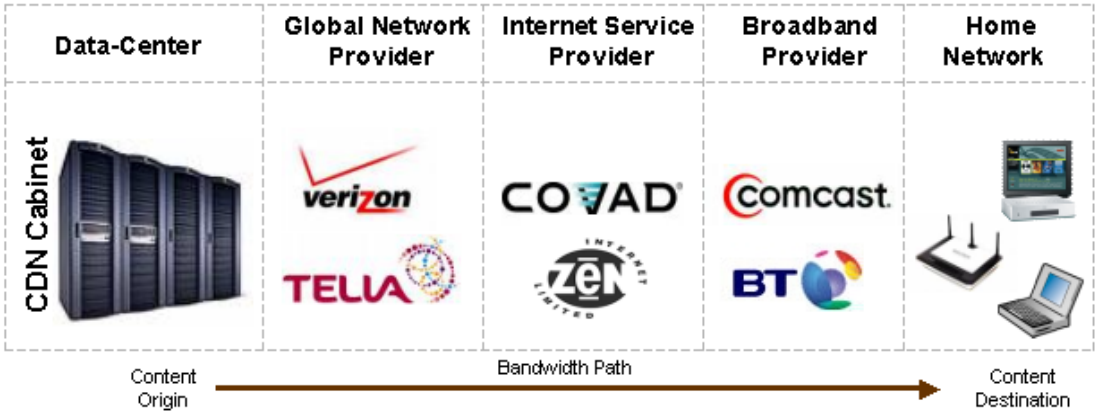

Figure-1: CDN Network Infrastructure

Figure-1 outlines the network segments and infrastructures needed for to a CDN to deliver video streams from the content origin at the Data-Center down to its destination at the Home-Network.

3. Content Delivery Components

Many different components are involved when delivering a video stream over the Internet; from the content owner to the content viewer. Those components are grouped together in three groups: Content handlers, Content Delivery Network (CDN) and System.

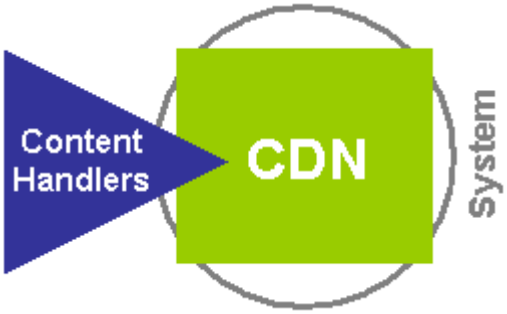

Figure-2: *Content Delivery components*

Figure-2 shows the relationship between the groups. The Content-Handlers group handles the content and uploads it into the CDN. The CDN have to deliver the content over the Internet per user request. The System is responsible of managing all CDN operation aspects.

3.1. Content Handlers

Video content exists in many different forms and formats, which are mostly not adapted to the Internet delivery methods. Most of the desired video content, like broadcast TV channels and movies, are being view over conservative media transports like Satellite or Cable STBs and DVDs. Therefore, the desired video contents have to be adapted to new media formats that are supported by the Internet delivery network.

This adaptation process include the following steps:

Capture: The existing video content has to be captured into digital media storage in the first place. Broadcast video can be captured with PC video card or encoder appliance. At the end of the capturing process the video should be stored as a raw video ready for the editing process.

Edit: The captured video has to be cleared out from any additional parts that were related to the previous media like commercials, promos (broadcast) and legal rights (DVDs). Those parts are not interesting the new potential viewers over the Internet since they are not located in the broadcaster or DVD store local area.

Encode: The video content has to be encoded to a video format that is supported by the preferred Video Streaming Server (i.e. WMS, Apple).

The encoding process is the most important one since it setup the video quality, frame size and the bandwidth utilization.

Upload: Once the encoded video is ready it has to be uploaded to the CDN where it can be delivered to any desired viewer. The encoded video can be uploaded in two methods; online or offline. Online uploading is used where a live event (i.e, broadcast news, sports) source is being captured and encoded and therefore should be delivered immediately. The encoded video will be uploaded in the same rate it was originally encoded. Offline uploading is used when the video content is part of an offline broadcast or an item in a VOD library. The encoded video will be uploaded into the CDN storage at any convenience time.

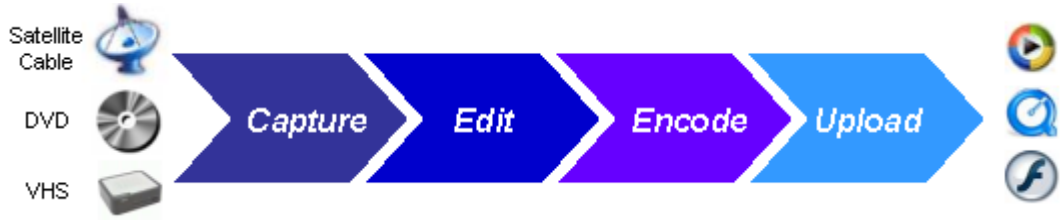

Figure-3: Content Handlers Components

3.2. CDN

The CDN mission, as it stated from its name 'Content Delivery Network', is to deliver video stream over the Internet from the content owner to the content consumer. The CDN is structured from different components, which together handle the complex process of content delivery. This process includes content management, handling content request and content delivery.

3.2.1. Storage and Indexing

The content should be organized and indexed for it to be accessible once a relevant request has been arrived. Encoded video files should be stored offline in a storage system located next to the video streaming servers. Content from live resources, like broadcast encoders, should be indexed with their direct URLs.

3.2.2. WEB

The WEB site is the most common interface to accept video content request from end users. Other sources of request are customized video clients (like Joost, iTunes) and stand alone video players. The WEB server should handle the user request by identifying, authenticating and responding to it according to the video content owner policy. Once the request has been approved

it should redirect it to the requested video content, file or stream, according to the routing component decision.

3.2.3. Authentication

The Authentication application is required to allow or deny users' request for protected video content. This application should interact with the video-streaming server in order to approve the delivery of the video stream to the authenticated user.

3.2.4. Routing

The routing component has one of the most important roles in the CDN process. The routing component role is to decide from where within the CDN storage or live source the video stream will be pulled out and what streaming server should deliver it. Best routing decision will result high quality video stream delivery and optimized resource allocation within the CDN process. The routing component outcome is based on updated information that is being collected periodically from the CDN components.

3.2.5. Streaming Server

The streaming server is the CDN component that actually delivers the video stream over the Internet to the end user. A streaming server would ideally deliver maximum streams of any video content to any user's location at the best performance. The streaming server will provide the best performance, means maximum stream connections, when it has to deliver minimum unique video contents to maximum users requests.
It is the Routing component job to redirect unique video content requests to the right streaming video server.

Figure-4: CDN Components

3.3. System

The System component is a collection of different applications that manage, control and support the CDN operation.
It includes the following applications:

3.3.1. Data-Base (DB)

The DB is the System's infrastructure where all the static and dynamic information is being stored and used for online and offline processes. For example, when a new video content is added to the storage then its meta-data is stored in the DB table that might be called 'content index'. This meta-data would be used by the Routing component to locate the nearest video content to the user's location. Another type of DB table could host all the users' information for authentication, historical actions and billing purposes.

3.3.2. Billing

A Billing system is needed to create and mange users' accounts activities for video content owners who choose to bill their video content consumers.

3.3.3. Health Monitor

The Health-Monitor role is to provide updated status reports on the CDN's components and on the CDN operation overall functionality. The essentiality and the reliability of the Health-Monitor's status reports are crucial for the CDN operation functionality; it just won't be able to operate without it!

4. Content Delivery Network (CDN) Design

This CDN design goal is to propose a viable solution for large-scale provision and delivery of live and on-demand video content. It focuses on concept and design architecture, usage of multiple streaming video servers and other transport mechanisms, along with a system for using one or more of the analyzed solutions, for efficiently deliver video streams to a broad international audience.

4.1. Design goals

This CDN architecture proposal should fulfill a series of goals, namely:

- Allow the use of any media format and/or streaming protocol, but do not rely on any particular choice;
- Make use of regional CDN facilities (Data-Centers) where they exists, but do not rely on their existence;
- Allow the CDN to easily grow and scale, thus permitting new streaming servers to be freely added, typically within network sections where do exists higher demand for the service.

Figure -5 presents the overall CDN Architecture Model, which contains all of the basic components needed to create a scalable end-to-end video content stream delivery network.

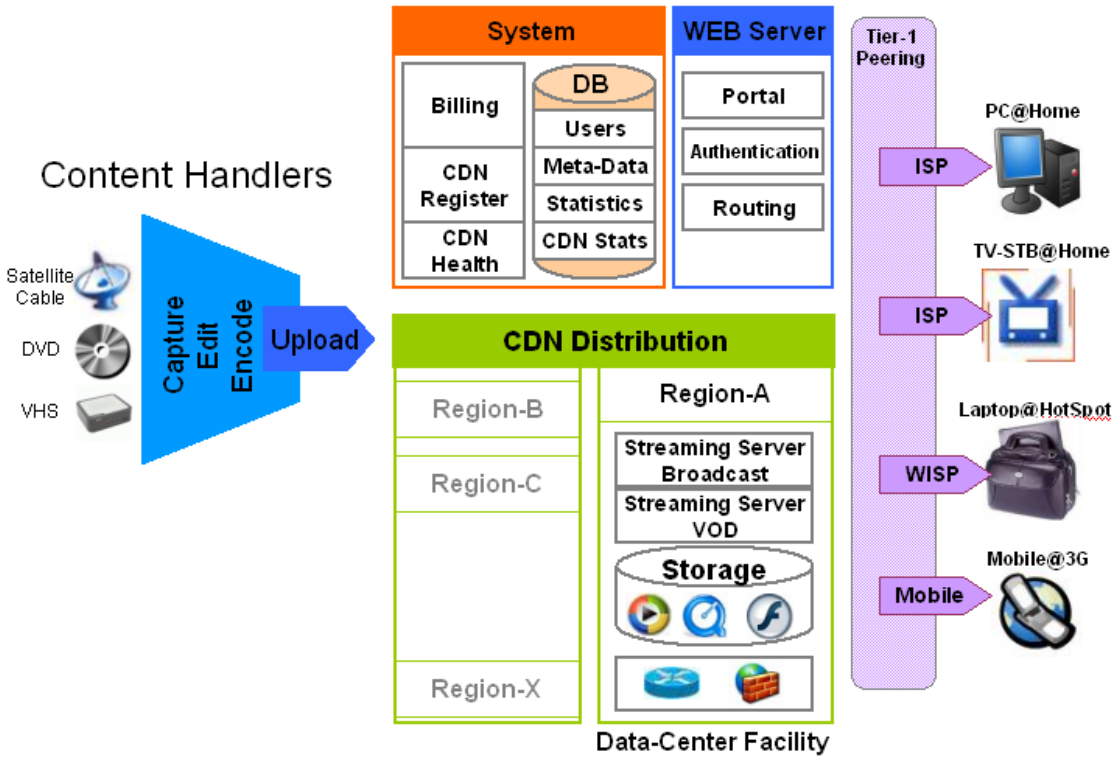

Figure-5 CDN Architecture Model

The basic CDN structure should include one WEB-Server component, one System component and one Region CDN Distribution unit hosted in a Data-Center.
For redundancy consideration, secondary units of WEB-Server and System are required. For expansion purpose, additional CDN Distribution units within the same Region or a complete new CDN Distribution unit in a new Region are required.
Content-Handlers and Clients can be added as long the CDN Distribution units can support the load.

In the following sections, each of the CDN operation processes will be outlined from this Architecture Model and will be explained separately.

4.2. CDN Scalability

A CDN has to be scalable in order to increase the delivery volume within existing region or when expanding to a new region with high potential new users. CDN scalability is archived by increasing the CDN Distribution capacity with the additional of new streaming servers. Once a new streaming server is installed it has to announce its existence to the CDN System by following the registration procedure as it outlined in Figure-6.

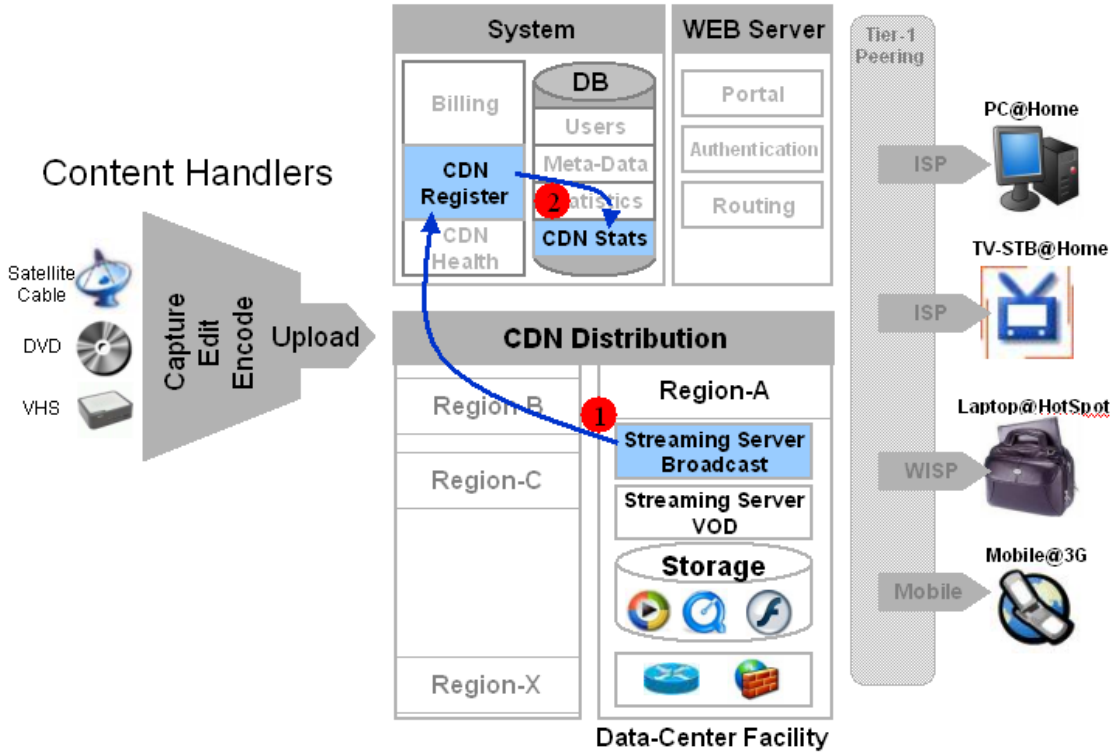

Figure-6 Dynamic CDN Scalability

- Step#1: The streaming server sends a registration request to the CDN Register module.

- Step#2: The CDN Register module accepts and processes the registration request and then creates a new streaming-server entity in the DB CDN Stats table.

The registration request should provide the streaming server profile as like Server-ID, Region-ID, Type (WMS/Apple/Flash), hardware capabilities (CPU, RAM) and other useful information. At the end of the registration process the CDN has actually scaled up its distribution capacity by one stream server unit.

In the other way around, the CDN-Register module should un-register a streaming server once it has been removed from the CDN structure.

4.3. Content Ingestion

A CDN, as a platform for video content distribution contains many video files and URLs from different types of sources. All of the content have to be stored and indexed in the CDN Storage and System DB for it to be located immediately once a matching request should arrive. Figure-7 outlines the Content Ingestion procedure from the point it is being uploaded by the Content Handler into the nearest CDN Storage (Label#1) and then being indexed in the DB Meta-Data table with all the video content relevant information. The System should replicate the video content into others Region CDN Storages based on its popularity.

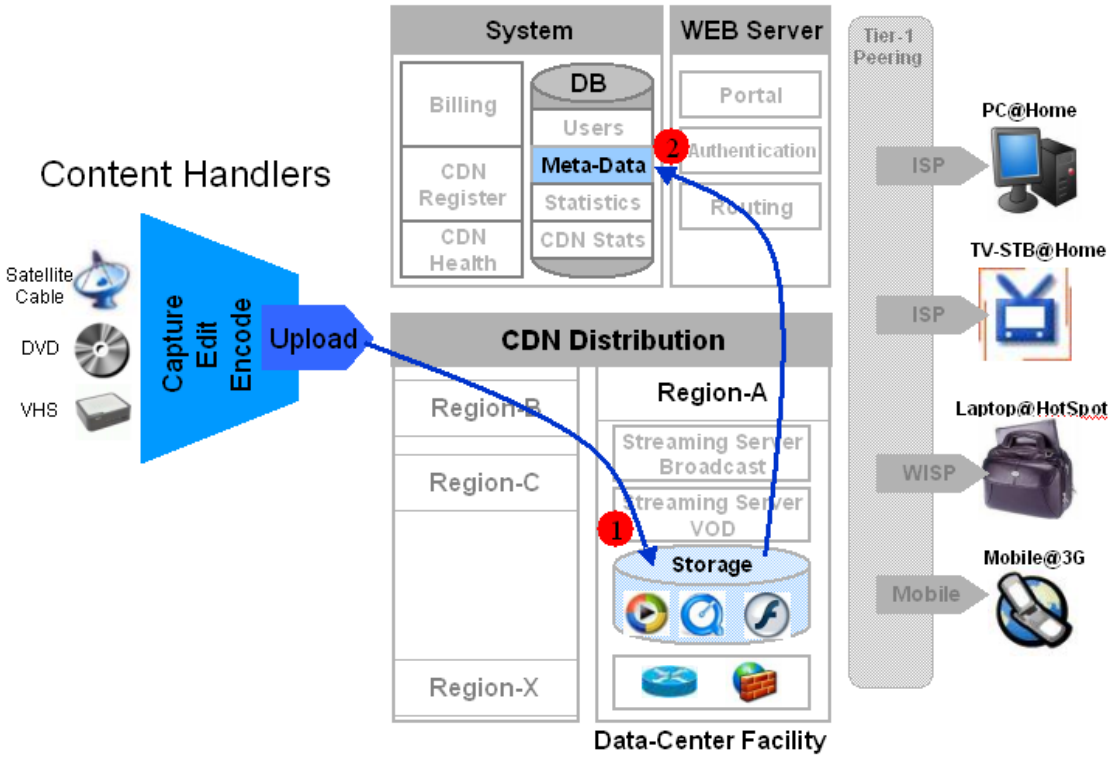

Figure-7 Content Ingestion

4.4. CDN Health

The CDN Distribution components have to be monitored constantly in order to maintain the CDN Health for it to function in the most reliable and efficient way. The System CDN-Health module should periodically query each streaming server and storage unit in all regions and then update their records in the DB CDN-Stats table. The information that should be pulled out from the streaming servers and storage units should include:

- Availability – Is it alive or dead
- Load – how busy it is and how many new stream connections it can delivery with the left resources.
- Bandwidth – how much BW capacity is being consumed by the existing stream connections and how much is free for new connections.
- Content type – what type of content is being delivering (Live/On-Demand, format, rate).
- Service area – what are the IP addresses of the clients' requests.
- Quality assurance – checking log files and key parameters to provide indications about the overall operation of the streaming server.

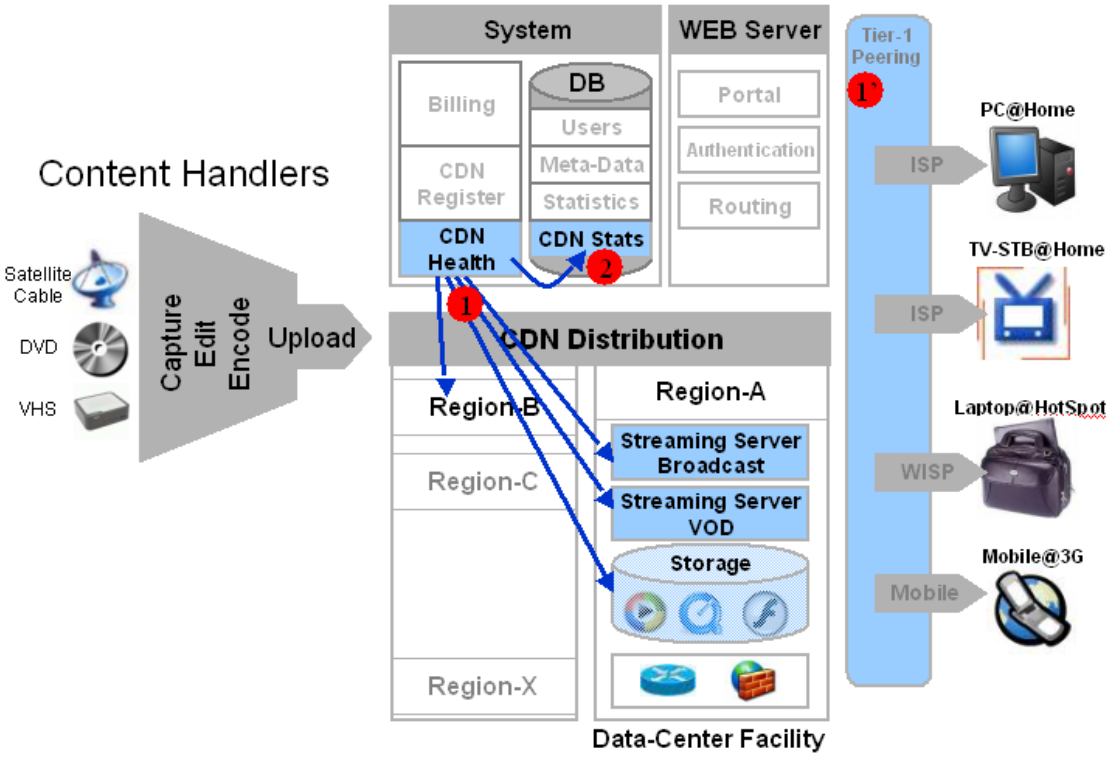

Figure-8 CDN Health Monitoring

Figure-8 describes the straightforward procedure of the CDN Health monitoring process.

4.5. Client's Request and Content Delivering

At this stage the CDN is ready to accept clients' requests for video contents as they are presented on the WEB Server portal.
The complete procedure of the video content delivery process is described in Figure-9.

- A WEB Server is ready to accept and handle requests for video content
- The System has an overall management control on the CDN Distribution Regions components
- The video content files and URLs sources were loaded in the storages units and indexed in the System DB.
- The CDN Health module reports on fee resource availability to serve new clients' request.

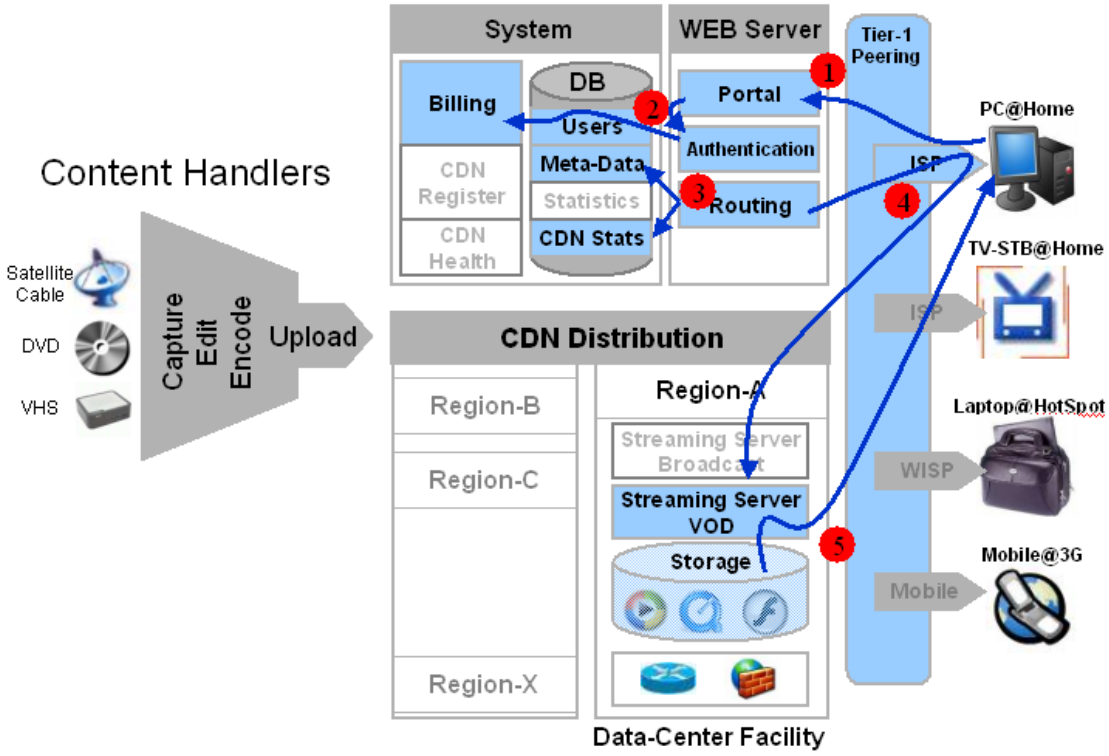

Figure-9 Client Request and Content Delivering

For the purpose of this explanation it is assumed that a VOD service is proposed on the WEB portal.

- Step#1: A client's request for a VOD movie has arrived to the WEB Server's portal
- Step#2: The portal checks with the authentication module the user's login validation and then checks the client's credit account in the billing system. Once the client has been approved to view the desired movie, the request is forwarded to the routing module.
- Step#3: The routing module accepts the client's request and follows these steps:
  - Detects client's location from his own request (IP address source -> ISP -> Region –> Country ->City).
  - Queries the DB Meta-Data table for the targeted movie and pull out its indexes that will provide the movie's format, encoding rate and storage location.
  - Based on the client's location and the movie copies storage locations, the routing module queries the DB CDN-Stats table for the best streaming server id that has the capability to will deliver the movie stream to the client.
  - The routing module delivers the chosen streaming server id to the portal module.
- Step#4: The portal module redirects the client's request to the chosen streaming server.
- Step#5: The chosen streaming server acts as following
  - Validates that the request has been redirected from the Portal module (key exchange)
  - Pulls out the desired movie file from the targeted storage unit and initiates a stream connection to user's client.
  - Reports back to the System DB Statistics table about the streaming session (start time-end time-actual rate, transmitted bytes, etc).

5. CDN Models: BUY & MAKE

The main goal of an Internet broadcaster or of any large-scale content owner is delivering video content over the Internet to maximum potential clients at the minimum cost.
This goal can be achieved either by BUYing CDN services or to MAKE an owned CDN.

Chapter 4 has described how to MAKE a CDN by design and operation consideration. In this chapter the CDM MAKE option will be tagged with costs in order to compare it with the CDN BUY option.

5.1. Definition

5.1.1. CDN MAKE

CDN MAKE means, designing, implementing, operating and maintaining a complete content delivery network with supporting of content owners and their clients.
Making a CDN is usually a decision taken by a service provider who's basing its business plan on serving content owners that wish to expose their video content to as many potential clients over the Internet. A large-scale broadcaster with its own video content might also consider the option of making its own CDN for the purpose of serving its own content consumers.

5.1.2. CDN BUY

CDN BUY is the option of buying video content delivery from a service provider who owns and operates a CDN MAKE. Buying CDN services is the natural choice for small-medium content owners who cannot afford the MAKE option.
There are CDN service providers like Akamai, LimeLightNetworks and VitalStream who provide global distribution networks.. There are also the so-called national CDNs who provide local video distribution services. Most of the CDN services providers support the mainstream video stream formats like WMV (Windows Media) and Flash but lack the adaptation of new coming video formats like the H.264/MP4 format.

5.2. Cost Structure

	MAKE	BUY
G-Byte Transfer	N/A	Per usage with minimum commitment. MRC
G-Byte Storage	Setup. NRC	Per usage with minimum commitment. MRC
Applications	Setup. NRC	Per application. MRC
1Mbps BW	Per usage with minimum commitment. MRC	N/A
Hosting/Collocation	Per x1U space. MRU	N/A
Staff	Full operation. Tech, provision, administration. MRC	Minimum. Provision, administration. MRC
Maintenance	Hardware/Software. MRC	N/A

5.3. CDN Cost Analysis

5.3.1. CDN Requirements

Number of clients to serve	1,000 - 100,000
Number of unique VOD Movies	1,000
TV Quality Stream rate	512,000 [bps]
Coverage area	2 Regions
Clients Usage	1:10
Daily Hour average	3 Hours
Average cost of 1Gbyte transfer	$0.5
Average cost of 1Mbps	$20
Monthly income per client	$29

5.3.2. CDN Basic Cost Analysis

CDN BUY or MAKE include setup and operational costs which at the bottom line set the total cost of serving one client per month.

5.3.2.1. CDN BUY

CDN BUY charges per actual Gbyte transfer, so the total Gbyte transfer is in direct line with the client viewing duration and the rate of the video stream. Figure-10 shows the monthly Byte transfer according to the average daily hours and the video stream rate.

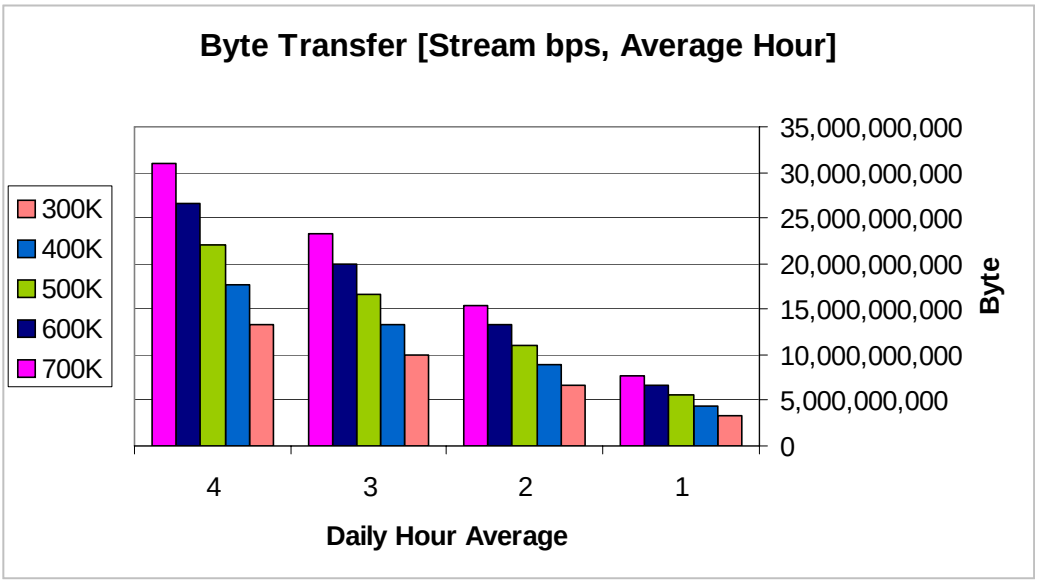

Figure-10 Byte Transfer per Duration and Stream Rate

In this analysis the average client usage profile average is 3 daily hours and 500kpbs stream rate.

The cost per client is shown in Figure-11 in direct line to the total Gbyte transfer.

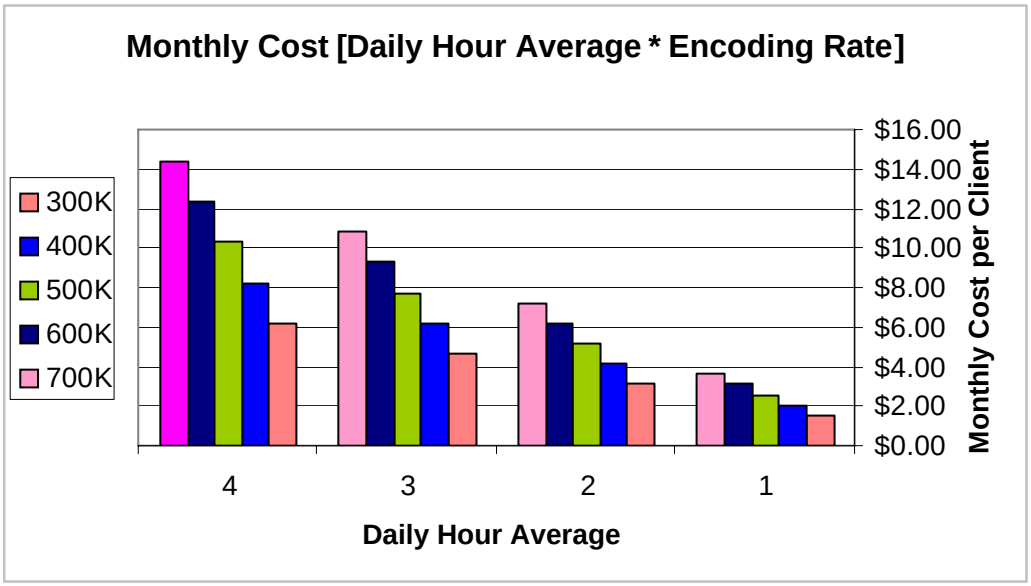

Figure-11 CDN BUY Monthly cost per Client

5.3.2.2. CDN MAKE

The CDN MAKE cost is built up from the CDN setup cost and the bandwidth consumption. The CDN is designed to support well known amount of clients so the setup fee is not depending much on clients' usage. The BW consumption, on the other hand, is totally proportional to the clients' usage ratio and its cost is varying in the same manner.

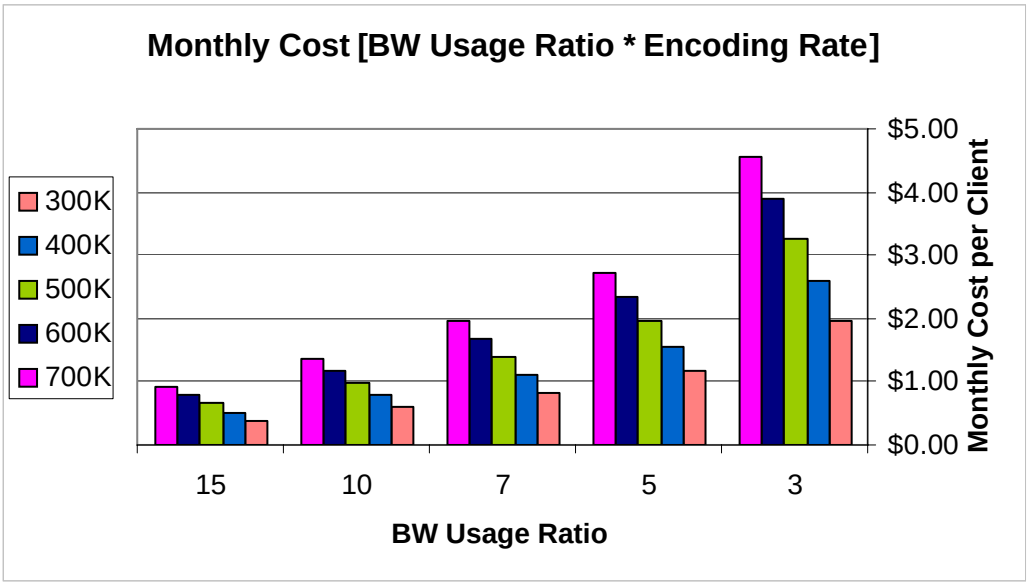

Figure-12 CDN MAKE BW cost

Figure-12 shows the BW cost (excluding CDN setup) per client in proportion to the clients' usage ratio. The more concurrent clients will watch at the same time the more BW has to be allocated for that period of time. For this analysis it is assumed a 500kbps at the average clients' usage of 1:10.

5.3.2.3. CDN Basic Cost Comparison

The CDN BUY basic cost is based on the total Byte transfer and the CDN MAKE basic cost is based on fix BW consumption. No other costs were taken into account at this stage of analysis. Figure-13 shows the basic monthly cost per client for CDN BUY and MAKE.

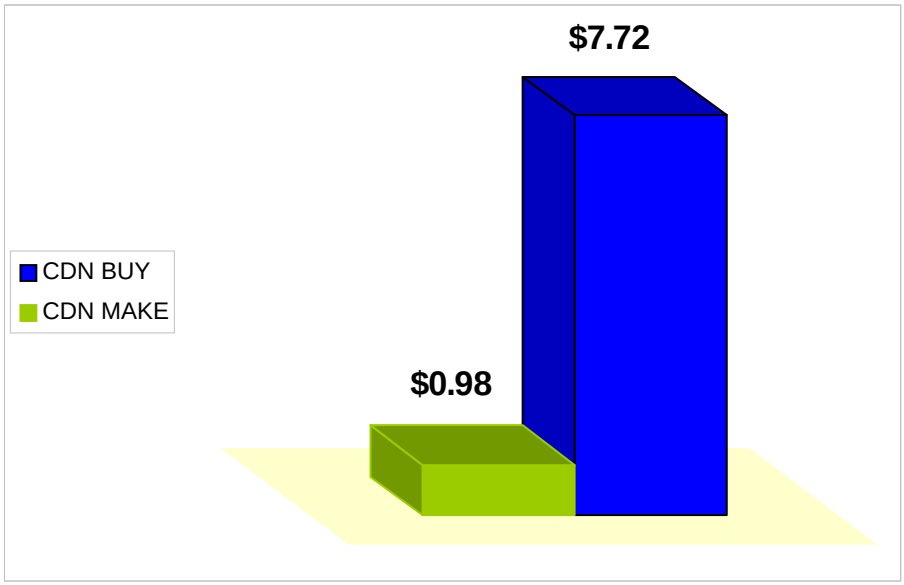

Figure-13 Basic Cost Comparison

5.3.3. CDN Operational Cost Analysis

Figure-13 has shown clearly that CDN MAKE cost per client is much cost effective than the CDN BUY cost per client. But this assumption is not always true as it look like because there are other parameters, like variation in the total number of clients and operational costs of setup and staff that might change this assumption upside down.
Figure–14 shows the cost per client analysis of both CDN models in variation of the total clients number.

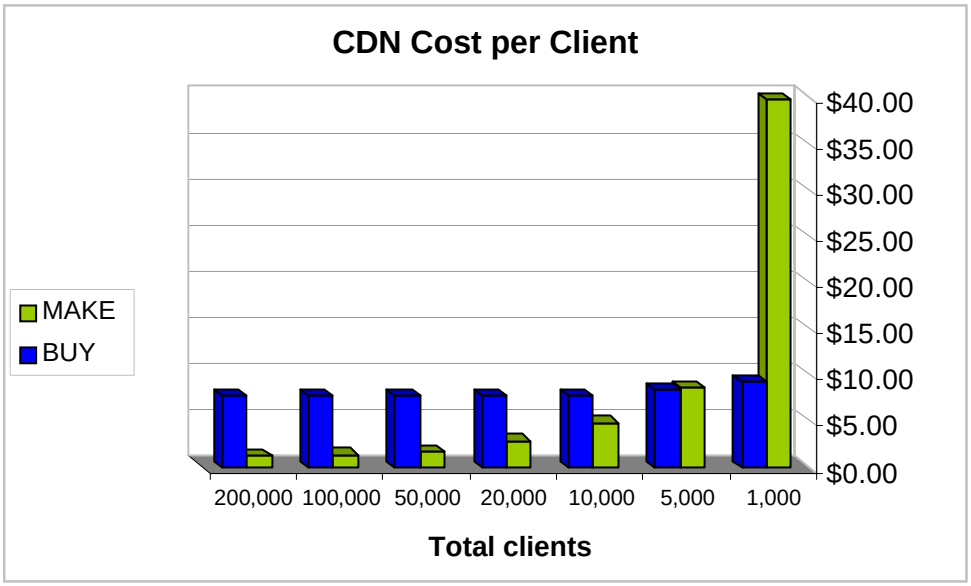

Figure-14 CDN Cost per number of clients

It can clearly seen that when there are less than 5,000 clients to serve then the CDN MAKE cost per client is much higher than the CDN BUY. It is actually not worthy to build a CDN for that little amount of clients.

Figure-15 shows the Gross-Profit per client assuming that the monthly income from each client is $29.

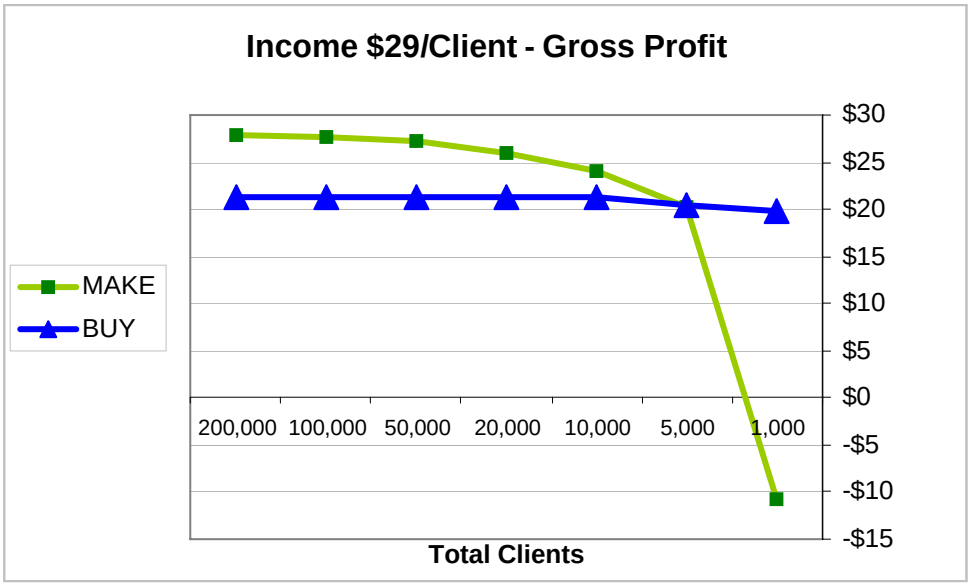

Figure-15 CDN Gross-Profit

To gain the best profit it will be wise to start distributing the video content with CDN BUY, gaining more than 5,000 clients and then switching to CDN MAKE. In this case the Gross-Profit graph will be optimized for best results as presented in Figure-16

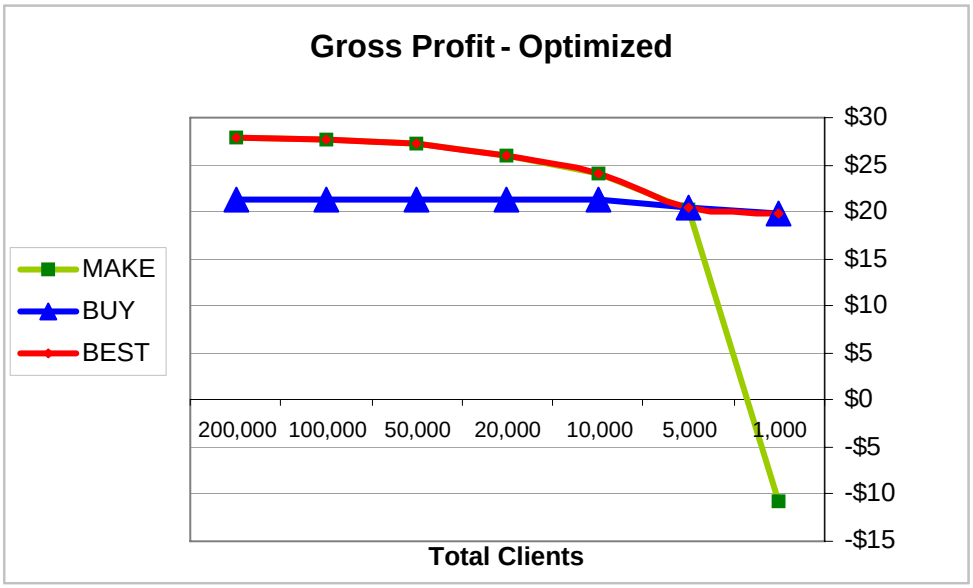

Figure-16 Optimized CDN Gross-Profit

5.4. Choosing the BEST CDN Model

In most cases, the video content is being delivered over the Internet either as a Broadcast stream or as a VOD controllable stream.
These two methods generate different traffic patterns, which should be taken into account when choosing the CDN model, BUY or MAKE.

Other considerations that should be taken when choosing the CDN model are, Time to Market, Coverage area and Scalability.

Choosing the right CDN model will provide the best quality stream with the best-cost effectiveness results.

5.4.1. CDN MAKE Vs. BUY

	MAKE	BUY
Operational Costs	Fixed, regardless of usage	Per usage
Cost Structure	Bandwidth 1Mbps unit. Unlimited Byte Transfer	Byte Transfer 1Gbyte unit. Unlimited bandwidth consumption.
Cost effectiveness for high usage	High. Setup cost divided by clients number	Low.
Commitment	Long	Short
Time to Market	Long	Short
Scalability	Per Design	On-Demand
Adaptation of new technologies	Fast	Slow
QoS	Controllable	Uncontrollable
Risk	High	Low
Profitable	High	Medium

The above comparison table outlines the advantages and disadvantages of each of the CDN options, BUY or MAKE.
The choice shouldn't be either BUY or MAKE, it can be also the combination of the two options by taking only the advantages of both options.

5.4.2. Broadcast Vs. VOD

	Broadcast	**VOD**
Bandwidth	High BW allocation on Peak-Time	Low - Average demand
Byte Transfer	High – unlimited usage	Low – limited usage
Storage	Low for live	High
Stream connections density	High	Low
Unique Stream	Low – many clients view the same video stream.	High – every client chooses different video at different time
Operation cost	Low cost	High cost
Income	Fixed	Per usage

5.4.3. Best of All

Each CDN model, MAKE or BUY, has its own strengths and weaknesses. Choosing either MAKE or BUY will provide a compromise solution but not the best one.

Combining both CDNs strengths will provide the best solution for most video content delivery requirements.

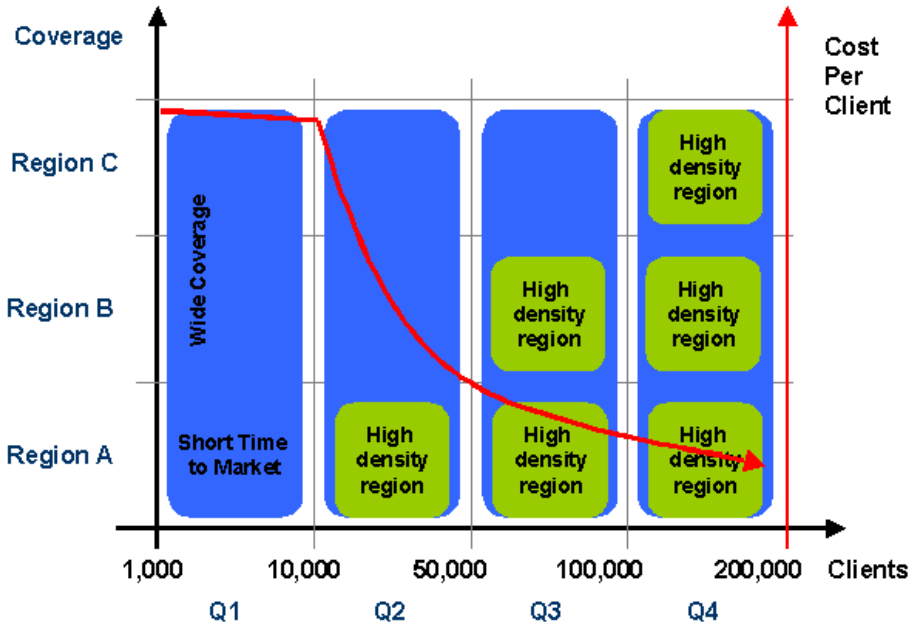

Figure-17 CDN MAKE&BUY Combination

Figure-17 shows how to combine the two CDN models to achieve the best results for delivering video content to large-scale number of clients spread in a wide coverage area.

As an example, it is assumed that a new operator (video content owner or service provider) is planning to deliver videos contents to more than 100,000 clients per day, who are spared on three different regions. The operator would like to start its service as soon as possible. The operator's budget is very tide and limited to the first year.

Q1: At the first stage, it will be for the best to start with the CDN BUY model as it can provides video stream delivery services with short time with nearly unlimited capacity and in all three coverage areas. Still, cost per client is very high but it is worthy because there are many unknown parameters like number of clients an their location. During this period, the operator should analyze the clients' profiles and video contents requests. With this valuable information the operator can start the design of a practical efficient CDN MAKE.

Q2: There are more than 10,000 clients that watch videos every day. 5,000 of them are located in Region-A and the rest are spread in Regions B&C. This is the right time for the operator to launch its CDN-MAKE-A operation in Region-A and start serving local clients. The spared resource will be used to serve other clients in Regions B&C. Still, some of the clients in Region-A will continue to get services from the CDN BUY in case where the local CDN MAKE got into overflow situation.

Q3: A 2nd CDN MAKE is operating in Region-B to support its local growing clients demands. CDN-MAKE-B together with CDN-MAKE-A are forming one multi-region CDN that can fully support two regions with enough spared resources to support many other clients in Region-C. CDN-MAKE-A & B can backup each in case of failure or in case of unpredicted heavy load in one of the regions (load-balance). With two operating CDN-MAKE there will be less clients handovers to the CDN-BUY and therefore less expenses over each client.

Q4: Adding a 3rd CDN-MAKE in Region-C will complete the overall CDN-MAKE structure. At his stage, the operator is able to serve more than 100,000 clients spared in a large area. The 3-Regional CDN MAKE operation with its high capacity and load-balancing mechanism can support heavy load of clients' requests (Peak Hours) with different patterns (Broadcast and VOD). From this point, the CDN MAKE can scale up to support much more clients' request. The CDN BUY will continue to function as a backup in critical situation and as a CDN for new areas, which cannot be served by one of the CDN-MAKE Regions.

By combining the CDN BUY & MAKE strengths the new operator could:

- Start operating in short time
- Launch its own CDN at the best conditions
- Maintain large scale, backed up and load balanced CDN
- Maintain low costs per client