Practical advices for setting up IP streaming services.

1. Overview of the problem.

"I want to stream. I am new to it. How do I go about it?"
"I have a DSL with static IP. Now I can set up a streaming service out of my home computer and serve the world!"
"I was referred to the company who charges $5000 for month. How do I know I am not paying too much? How do I know my customers are satisfied?"
"After I bought the services, I discovered that my corporate firewalls block everything except HTTP port 80. But the demo was presented at their office and everything worked great… Looking for a new job now…"

Rapid development of IP networks and last mile technologies has created the possibility of setting up streaming services for virtually anybody with Internet access.
Home DSL users, small businesses, technology and media companies, entertainment and telecommunications companies – they all want establishing streaming services to be as easy as setting up web server for their web sites.
"Why should it be more difficult?" they ask. "We want it right here and right now".

Unfortunately, the technology in its current state does not provide simple way of setting up streaming services. The main reason for that is – streaming is a distributed technology involving many computers, networks and large amounts of bandwidth.

On today's market one can find hundreds of offers & free products for streaming solutions, beginning with free ones providing good quality and free ones providing bad quality and ending with offers costing tens thousands of dollars monthly, providing good quality and the same providing real bad quality.
They all use different players, servers, protocols, formats, software encoders, hardware encoders, web interfaces.

How does one make decision in this wild technology world?
The only thing that really helps is education – one needs to learn the technical side of the subject.
In this article we will try to emphasize the major practical aspects of the streaming technology from the service provider perspective.

2. Understanding the BANDWIDTH requirements.

The most important component involved in streaming and the least understood by majority of non-tech people who wants to stream, is the **BANDWIDTH.**
When you buy a simple webcam, you will find a CD with great looking Video-over-IP applications and you will read: "Anybody can see your webcam anywhere in the world. Just be connected to Internet."
This is a typical example of misleading marketing information, so common in today's consumer technology.

Large amounts of bandwidth are required to stream audio/video.

What does that mean?
Consider a stream flowing over a network. Network transmission ability is its bandwidth. Stream's data rate is its bitrate. Only when bandwidth >= bitrate, the stream can be delivered to end point in timely manner.
What happens if the bandwidth is less than the bitrate? File viewers experience buffering; live viewers experience broken audio/video and latency.

Bandwidth and bitrate are usually measured in kbps (kilobits per second), which means how many bytes (each byte is 8 bit) of data stream through network per second.
LAN bandwidth is typically controlled by routers.
Modern routers are capable to transmit data at 100 mbps (100 Megabit = 100,000 kbps) and 1 gbps (Gigabit = 1,000,000 kbps) data rates.
Most common Internet connections provide the following data rates: Modem (56 kbps), ADSL (256 – 2000 kbps download speed; 128 – 1000 kbps upload speed) and T1 (1500 kbps).

Since uncompressed raw stream of audio/video samples/images can only be streamed by LANs, audio/video is being compressed before streaming, so that the bitrate can fit into network bandwidth. This process is called encoding.

Encoding takes place for both media files and live media streams.
It is done by codecs. While encoding, the quality of audio/video degrades since audio/video encoding throws some image information in order to provide better compression. Good modern codecs provide 1/20 – 1/100 compression rates without high degradation of images/sound.

Codecs quality differs for one-pass real-time live encoding and multiple passes files encoding. Most of the codecs are more file oriented and less live oriented.
Codecs can be of two types: VBR (variable bitrate) and CBR (constant bitrate).

The best today's video codecs are WMV, On2 and Real Video codecs; numerous H.264 (MPEG4 Part 10) proprietary implementations and also widely available MPEG4 implementations from Microsoft and DivX.

The best today's audio codecs are WMA, AAC, Dolby AC3, free Ogg and good old MP3.

From theory to practice – what is the bitrate of good quality audio/video files and live streams?

Video bitrate depends on: Image size, number of images per second (framerate), amount of movement on the scene and luminosity of the scene.
The following table shows average bitrates of good quality live streams and files. All codecs mentioned above produce more or less the following values with 10-20% deviations.

Stream media type	Single stream bitrate (kbps)	How many concurrent streams can your 100 mbps LAN deliver	How many concurrent streams can your 56 kbps Modem deliver	How many concurrent streams can your 128 - 1000 kbps upload ADSL deliver	How many concurrent streams can your 1500 kbps T1 deliver
320x240 20 fps video file or live stream	200 to 500	500 to 200	0	0-5 to 0-2	7 to 3
640x480 20 fps video file or live stream	640 to 1500	150 to 60	0	0-1 to 0	2 to 1
Two channel audio file or live stream	16 to 64	6000 to 1500	2 to 0	8-60 to 2-15	100 to 25

What can one learn from this table?

Practical consequences:

1. *You can hardly serve video over ADSL connection; may be you can show your webcam to your friend. Not more.*
   Audio server can probably be hosted on ADSL connection; but be careful – your upload speed drops when you download something. Not really recommended scenario.

2. *Even T1 corporate connection can hardly serve a dozen of concurrent video streams to the world. What a bad surprise for many companies!*

3. *You need LAN-type Internet connection to establish real multiple concurrent users streaming services (which costs a lot of money).*

Don't cry dear reader. This situation is bad but it's getting better every day, since bandwidth gets cheaper. So may be in the next millennium your website will be able to afford streaming of video clips like MSN and CNN do.

In the following chapters we will show what can still be done without huge expenses – and there are beautiful things that can be done!

3. Unicast vs. Multicast.

Streams can be sent from server to client (viewer) by Unicast or Multicast.
In Unicast mode there is a dedicated stream for each viewer traversing through the router.
In Multicast mode the same single stream is sent to all the viewers.
All modern routers support Multicast and can be configured to allow or prohibit it. In order for Multicast stream to arrive to a viewer, all routers between server and this viewer must allow multicast.

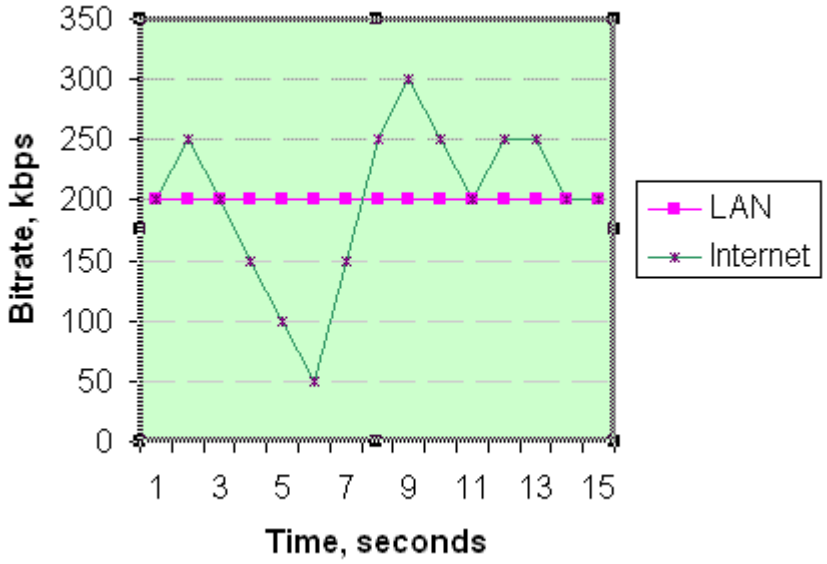
Multicast is prohibited by vast majority of public Internet routers.
If that wouldn't be the terrible truth, establishing streaming services would be highly available for anybody. May be time will come…

Practical consequences:
Multicast can save you bandwidth dramatically.
Plan for Multicast delivery only when streaming over the LAN.

4. LAN vs. public Internet.

Understanding the latency of live streams.
The major difference between streaming over LAN vs. Internet is amount of routers through which the stream has to traverse. This number is normally 1-2 on LAN but can be a dozen or more of highly busy routers on Internet. Therefore, the probability of short-time network congestions is much higher over the Internet.
As a result, the instant bitrate at which viewer receives the stream remains stable on LAN but fluctuates around its average value over the Internet.

Figure 1: Actual viewer bitrate over 15 seconds time period, when streaming 200 kbps live unicast stream over the LAN vs. Internet.



As one can see, despite its fluctuating behavior, the Internet bitrate also sums up to 200 kbps in average over 15 seconds period. However at any point of time the Internet viewer might receive significantly less data than the average bitrate and therefore the playback needs to pause and wait until enough data is received. In order to compensate on such short-term stream gaps and still provide smooth playback, streaming players buffer several seconds of stream before starting playback. Some players buffer always; some let you specify whether to buffer or not.

Practical consequences:
When streaming live over public Internet, viewer stream latency may reach several seconds; therefore live video conferencing is very difficult, even if average bandwidth is sufficient. Of course, latency may grow indefinitely when bandwidth is not sufficient.

Security - is it important in your case?
Security comes to the scene when streaming over the Internet. That applies to both live and files streaming.
The first aspect of it is – how to make the stream protected so that only intended recipients will get access to it. That is related to DRM, although full DRM implies more restrictions – copy protection etc.
When traversing public routers, streams can potentially be seen or ripped by hackers sniffing network traffic.

Practical consequences:
Identify stream protection requirements and choose appropriate solutions. While most of the streams don't need to be protected, in some cases SSL is required to protect the communication channel. Some streaming software and solutions such as VPN provide adequate channel protection.

The second security aspect is making your server computer secure. In order to stream to the Internet, custom network ports often need to be open in the organization firewall, allowing potential attacks. Poorly developed server software may have flaws allowing hackers to execute their code by sending unusual requests to the server.

Practical consequences:
Try to avoid opening custom ports in the outside firewall. However do not be paranoid about it. If you like some server software of hardware that requires ports open in your firewall, search Internet for Bug / Flaw reports on these products.
If you don't find anything, you have a green light for using it.

5. Bandwidth again – where to put the server: CDN vs. regular ISP vs. my company T1 vs. my home DSL.

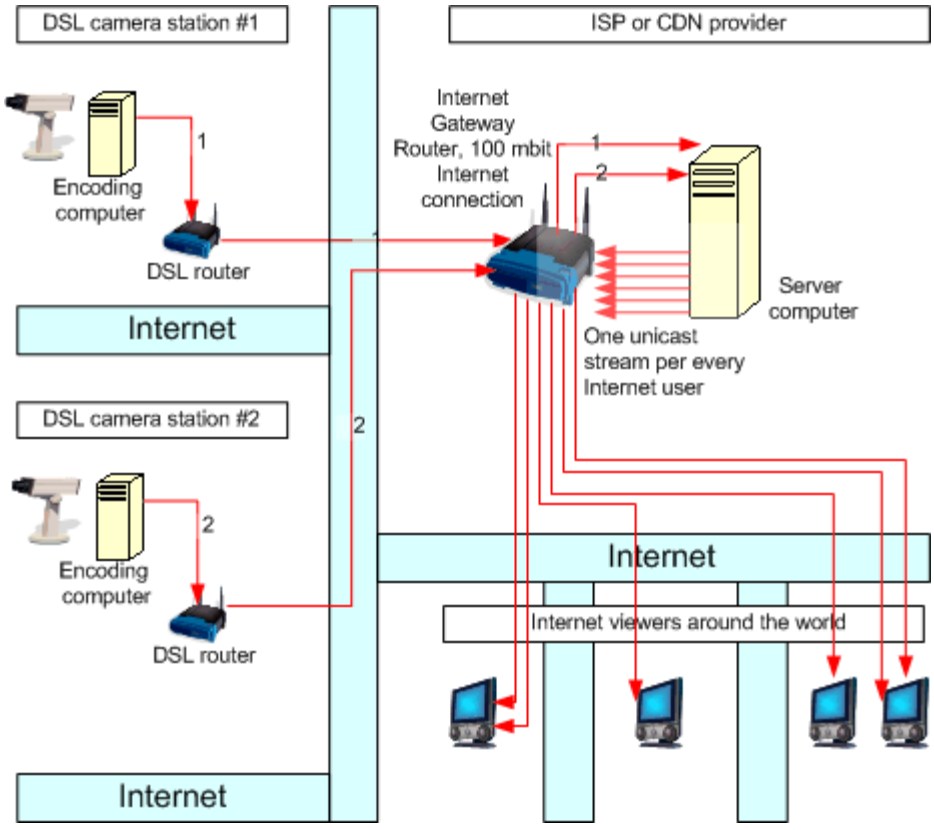
As we showed previously, hosting a server over a DSL or even T1 connection is not a great idea since the upload bandwidth is not sufficient for multiple concurrent users. T1 can probably serve for live audio services such as Internet Radio.

High availability video server needs to be hosted at ISP or Content Delivery Network provider. While ISP may be good for sending 50-100 concurrent streams, CDN is required for handling more with good user experience.

The main difference between ISP and CDN is quality of service – while CDN guarantees you the instant bandwidth, ISP does not. ISP shares all its bandwidth between all ISP users; you may have good bandwidth today and really bad tomorrow when your co-location neighbor uploads huge files.
For live video conferencing services, CDNs are the ultimate choice.
CDNs are extremely expensive and only large companies can afford it.

When streaming files, the instant stable bandwidth is a little less important and ISP can be a good choice.
Also, when streaming not very high framerate / bitrate live video feeds, such as surveillance / site monitoring feeds, ISP hosting may provide adequate quality as well. Streaming live TV, however, involves high framerate and image quality; single TV feed may take times more bandwidth than single surveillance feed. Again, all depends on the number of concurrent viewers that you want to serve.

Figure 2: Organizing high availability video surveillance server for Internet viewers. Cameras are installed at multiple sites with ADSL internet connection.
Media Server is hosted at ISP. Recommended for monitoring of childcare, pet clinics, construction sites, farms etc.



Note that good ADSL upload may enable sites / stations to host 2-3 cameras. There is only a single feed from each camera being uploaded to the ISP server, regardless of viewers number. The whole solution cost is a cost of dedicated server hosted at ISP.

Practical consequences:
Be realistic about potential concurrent number of users for your service. Host dedicated server at ISP for streaming video files and non high-bitrate live feeds. Identify users that sit on the same LAN and try to serve them with single live stream using local multicast retransmission (see further chapters).

6. Streaming delivery protocols.

Servers send media streams to the viewers or listeners using variety of network IP-based protocols: plain TCP, UDP, RTSP and RTP (these real time protocols can be based on both TCP and UDP transport), HTTP.

Two aspects should be taken into consideration when choosing delivery protocols:

1. Quality of delivery.

The purpose of specialized streaming protocols is to handle packet loss, network congestions and other transport problems. While theoretically these protocols seem to be more appropriate for streaming, the practice shows that they can not completely compensate on network problems. When the network is not stable and bandwidth is not sufficient, ALL protocols have problems to adjust, sooner or later, and the streaming quality in real multi-user environment degrades, despite of many implementers' claims of perfect error resilience and dynamic recoveries.

2. Penetration ability of the protocol.

Many corporate firewalls block streaming protocols in order not to spend bandwidth on video streaming. However HTTP is always allowed, on standard port 80.

Practical consequences:
Try to choose streaming products and services where the viewer program receives streams via HTTP port 80. Consider RTSP and such only if you have control over firewalls.

7. Organizing live audio / video broadcasts.

Hardware encoders and IP video cameras vs. Software encoders.

Hardware encoders and IP cameras don't require PC power for encoding, they are reliable in the sense that they run internal operating system dedicated for encoding, unlike PC-based software encoders that share PC resources with other applications running on PC. Many hardware encoders and all IP cameras have built-in Web Servers; therefore PC is not required for streaming live video as well.

The dramatic disadvantage of these is – most of them stream video in point-to-point (pear-to-pear) model; the viewer receives stream directly from the encoder.
They can't stream to a central server. Software encoders are more flexible, most of them can stream to a central server, enabling the scenario depicted on **Figure 2**.
You can not implement **Figure 2** architecture based on most of hardware encoders or IP cameras, since video quality for each viewer will degrade as number of viewers grows. (ADSL splits upload bandwidth between multiple viewers).

Practical consequences:
Consider using hardware encoders and IP cameras only when serving small amount of concurrent viewers or when streaming over high-bandwidth LANs.

Live webcasting based on central media server.

When streaming live event, two major challenges exist:

1. Preparing the encoding station / hardware and delivery of the encoded stream to the central server location.
2. Distribution of this stream from the server to multiple viewers.

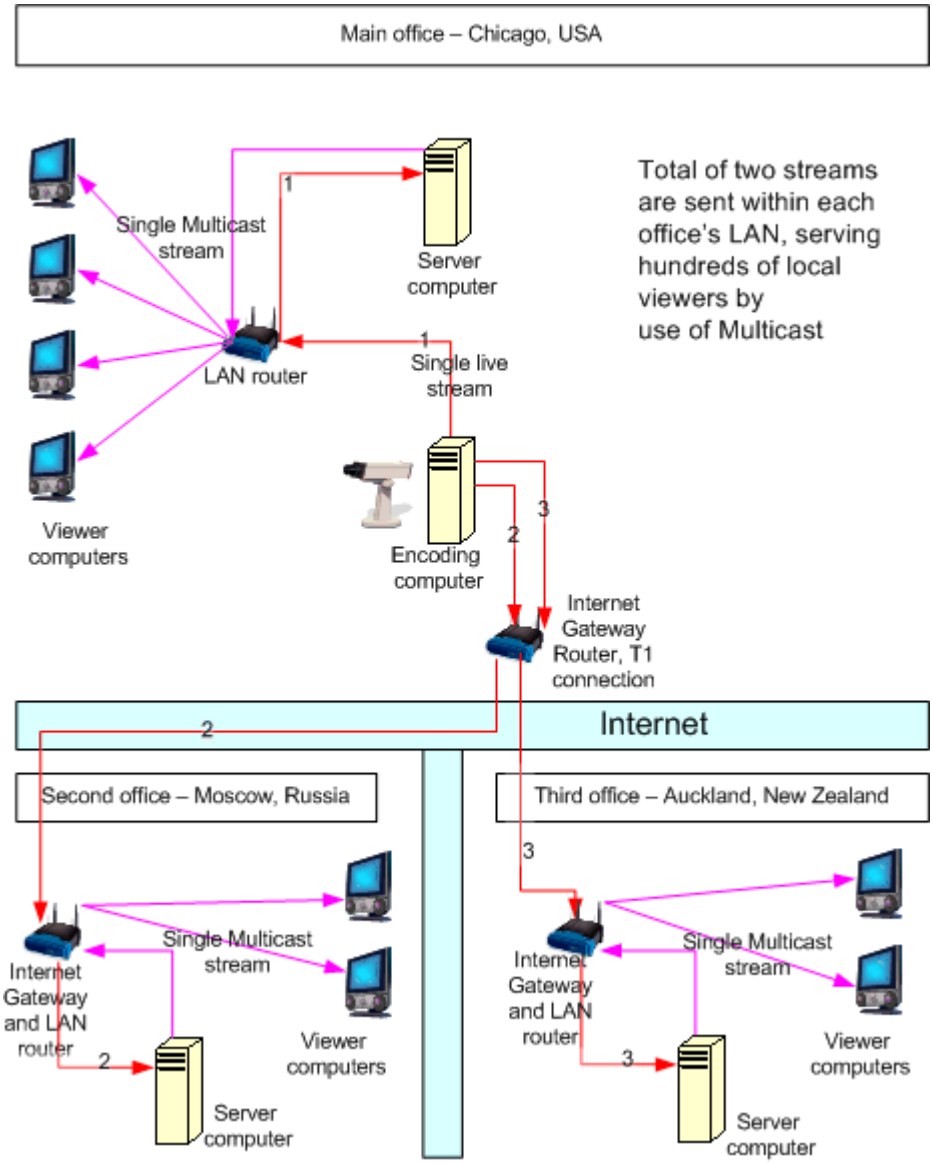
The first aspect involves choosing right video camera, capture card, audio equipment, lighting equipment and so on, in order to provide high quality video and sound coming to the encoder software / hardware. This is the topic for itself and we will be very brief about it: While a simple camcorder or even USB cam + microphone can provide decent quality via FireWire card or USB input, higher quality requirements may involve more professional equipment and specialized capture cards.

When doing onsite encoding, matters of delivering the stream to the server are quite simple; in case of offsite encoding it may become the most problematic step; often satellite uplinks need to be involved to provide satisfactory bandwidth when local terrestrial network infrastructure is poor.

The second aspect - delivery from server to viewers – greatly depends on network topology of those viewers. **Figure 2** above shows that you have to use bandwidth-expensive unicast delivery for Internet viewers. However you can take advantage of multicast if your viewers belong to the same LANs.

In case when both Internet and LAN viewers need to be able to watch, the streaming server must be able to deliver the same stream in Multicast and Unicast modes in the same time.
Software streaming servers such as Microsoft Media Services and Unreal Media Server can stream in Unicast and Multicast or both modes; the architecture depicted on the previous **Figure 2** and following **Figure 3** can be implemented with those servers.

Figure 3: Smart corporate event webcast, serving hundreds of concurrent viewers of local office LAN and of two foreign offices – based on existing company's T1 Internet connection.



The encoding machine has a single connection to local Media Server and two connections to overseas Media Servers set up in two foreign offices. Three unicast streams deliver live webcast to those Media Servers. Each Media Server retransmits it to local network with single multicast stream; that enables all viewers on the local network to playback the stream. Note that main office's T1 is perfectly capable of uploading two high quality streams to the foreign offices over the public Internet.
Such architecture can save huge budget to the company that decides to organize a webcast on its own. The alternative widely used by majority of the companies is to hire a CDN provider for handling webcast; CDNs charge thousands of dollars for such webcast.

8. Organizing on-demand (recorded files) streaming service.

As described in previous chapters, you need to host your server at ISP/CDN sites.

When preparing files for streaming, two parameters need to be taken into consideration:
1. Which file format to use – depends on the OS your viewers are using and on the quality of the codec used in this file format.
    For example, to support MAC viewers, you have to use QuickTime.
    The best choice for Windows is WMV.
2. File bitrate (which affects framerate, image/sound quality) – depends on a typical network connection of your audience.
    File encoders allow choosing different network profiles; the lower the profile (and file bitrate) the worse is audio/video quality.

9. Quality criteria for streaming software or services.

Whether you are choosing streaming software for "do it yourself" streaming or you are choosing ready to go streaming packages, you may need to consider the following criteria, depending on your needs:

Server or streaming services:
Reliability.
Ease of configuration and operation.
Programmatic configuration and control via SDK.
Live statistics and user activity report.
Audio/video formats served.
Live streams latency – adjustable buffering.
Security – are there custom network ports except HTTP 80 need to be open?

Viewer:
Can viewer be embedded into a web page?
Is viewer already installed on client PC? If not, what is the download size? Will people want to download it?
DRM / user authentication.
Does viewer support multiple platforms and hardware devices – Does my service need to support Windows, Linux, MAC, Mobile devices, Set-top boxes, and grandma's old sewing machine?

10. **Filtering out marketing fluff – be critical and technical, test and measure things, ask for evaluation versions and test drives, try to learn and understand the technical aspects of streaming products.**

    90% of Internet-based information about quality of streaming related products and services is marketing fluff.

    The reason for that is – this field is developing extremely fast; there are dozens of technologies, numerous quality parameters, it's very difficult to set up a real testing environment as it involves configuring networks, computers, routers, software. Decision makers can't absorb the new technologies at that rate.

    As a result, most of decision makers can't see the difference between hundreds of offers which look all perfect on the paper. Easy for marketers, frustrating for buyers, after the purchase, of course.

    Practical consequences:
    Learn about vendor products not from product descriptions and power point presentations but from performance of trial versions. When test-driving, do unconventional non-standard things - do more than vendor wants you to do, see how stable and reliable the product is.
    Don't stop at the first product that seems a good fit. Try several ones.
    Be critical, analytical and skeptical.

Unreal Media team, April 2006.