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Diploma Thesis

Multimedia trends and development

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DIPLOMA THESIS ASSIGNMENT

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1. Introduction
2. Objectives of thesis and methodology
3. Literature overview
4. Multimedia trend in internet media
5. Comparison of multimedia technologies
6. Conclusions
7. Bibliography
8. Supplements

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Bibliography:

Shannon, Horn: Microsoft Silverlight 3 : a beginner's guide. New York : McGraw-Hill, 2010. ISBN:978007159043

Bruce Hyslop: Creating a Web video in Silverlight. Berkeley, CA : Peachpit Press, 2009. ISBN:9780321554222

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Head of the Department

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Dean

In Prague: 28th February 2011

Statutory declaration

I declare that I have completed my diploma thesis using all of the mentioned resources and after professional consultations with Ing. Miloš Ulman.

Prague, ………………….…… …………………….……
Jan Jelínek

Acknowledgement

Multimedia trends and development

Trendy a vývoj multimédií

Multimedia trends and development

Summary

This thesis aims at techniques that help us with processing video files or their streaming.

The first part of this thesis deals with basic facts and techniques that are connected with multimedia on the Internet. From the theoretical point of view things such as YouTube, Ustream or different video formats are introduced. The second part of the thesis is practical. It includes creating of a sample video and following comparisons of video files which are coded in different formats. The comparison of these formats is the main goal of this part of the thesis.

Trendy a vývoj multimédií

Souhrn

Tato práce se zaměřuje na techniky, které nám pomáhají se zpracováním video souborů nebo na jejich streamování.

První část práce se zabývá základními fakty a technikami, které jsou spojené s multimédii na Internetu. V teoretické části práce budou zmíněny kapitoly, jako například YouTube, Ustream nebo různé druhy video formátů. Druhá část práce je čistě praktická. Obsahuje vytvoření video souboru a jeho následný export v různých video formátech. Porovnání těchto video formátů je hlavním cílem této části práce.

Klíčová slova

multimedia, streamování, televize, Flash, video formáty, renderování

Index

1 Introduction

As you can see according to the name of this thesis: Multimedia trends and development, this thesis will describe usage of multimedia and its intrusion to the internet. Another part will explain the differences between multimedia technologies.

When an internet user wants to know what is happening in the world, he will visit one of the news portals. These days he will most likely come across news in video format. These short videos together with photographs describe the events much better than just plain text. That is why all the major portals aim to have video on their pages.

The usage of video presents the dillema of choosing the right technology to bring video to the internet. Today the two main avenues are to use either Flash or Silverlight. These two technologies will be described later in this thesis.

YouTube has become a huge phenomenon in last two years. It is the biggest storage of videos in the world. If you want to find a video, chances are you will find it on the YouTube. The fact that users can upload almost any video to YouTube is complicated with the possibility of copyright infringement. Music videos belong to this issue. Many companies have discovered that they can use YouTube as an ideal venue to give the user the possibility to find all their videos in one spot. That is why companies such as BBC, CNN, Discovery Channel, The New York Times and others have created channels on YouTube. That is also why YouTube will be described in this thesis as well. BesidesYouTube, USTREAM is also a popular way to present videos and broadcast on the internet. USTREAM provides similar services as YouTube, with the one main difference being that enables you to broadcast live.

2 Objectives of thesis and methodology

2.1 Objectives

The goal of the first part of this thesis is to explain the multimedia trend in internet media such as the intrusion of video into the internet. This trend can be seen throughout the internet. News portals are prime examples. Next to photography we can find more and more videos that show us actual events from all over the world.

The second part of this diploma thesis compares several video formats and tries to find the differences via several different types of comparison . All the most important video formats which are used on the Internet and during video streaming are included in these comparisons. At the end of the practical part, one more comparison will be made and that is to compare two videos, where one of them will be more static and the other one more dynamic.

2.2 Methodology

The most important facts and figures that are connected with internet video streaming will be explained one after another in the literature overview. Among these topics will be technologies such as Adobe Flash, Microsoft Silevrlight, servers such as YouTube or Ustream. At the end the main video formats will be introduced together with the basics of video streaming.

In the practical part of this diploma thesis the author will compare different video formats. The first step will be to shot and edit two video samples, because the author does not want to use downloaded video. The comparison will be divided into two main parts. First video sample will be rendered in HD ready and Full HD resolution and these two samples will be compared afterwards. Among the comparisons will be CPU usage during rendering or playback, rendering time and file size.

In the second part the author will compare the first video sample in HD ready resolution with a second video sample, which will be in HD ready as well, but the video itself will be little bit more dynamic, with more colors included. We want to know if there is a significant difference in CPU usage during playback of dynamic and less dynamic video samples.

3 Literature overview

3.1 Multimedia trend in internet media

Currently in the world of internet multimedia find its way into more and more areas of our lives. At the beginning of this era, the internet was slow and it was used mainly for sending electronic mail and maybe for reading the news. As the internet got faster and faster and easier to obtain, more possibilities appeared for users and for service providers from different areas.

World news portals are prime examples. The first step was just to transform the printed version of the newspapers into digital ones, electronic, so the people could read the news everywhere. Together with electronic newspapers went digital photos, which were posted next to the articles. As the internet grew faster and more suitable technologies became attainable, the idea to post videos next to the photographs was born. Video can convey much more than still pictures. Today if you visit the web site of any well know newspapers, you will most likely find many videos, perhaps even live streams, because it is not very difficult to provide live stream from different events all around the world. As a matter of course, internet television must be mentioned when one speaks of streams. It is not only newspapers, however, which try to use the internet for their business. Television stations throughout the world have their web pages, where they run electronic versions of their broadcast. Great examples are BBC or CNN, but even in the Czech Republic all the TV stations have their internet counterparts, where people can watch some of their programs. One positive to this technology is that not only these big players can have internet streams: the technology is there for anybody to have their own small internet television.

With the expansion of the internet and smart mobile devices, it is ever easier and easier to read your favorite newspapers or watch favorite show almost everywhere. A few years ago it was amazing that you could download or listen to your favorite music, but today we have quite a different phenomenon. This phenomenon are videos, music clips, and even feature length movies. The best example is the server YouTube. This server allows one to watch almost any video in the world. But this is not the only service provided. The amazing thing is, that you can easily upload your own videos. Of course users must obey the law, copyrighted videos or videos which are restricted should not be

uploaded, but the important thing is the opportunity presented to users to upload. YouTube is not the only server that provides such services. There are more, for example Ustream. It is a quite similar service provider, but it is more focused on live video streaming. These providers have one thing in common, they are both used by the above mentioned television stations and newspapers and other companies or people. These companies have their own channels, where they can post all their videos or clips. On the other hand videos from servers like YouTube are often embedded to newspapers sites, so they do not have to shoot their own videos. It is amazing how it is all connected and it seems to be quite simple.

In order to provide all these amazing services there must be technology to support them, and that is what this thesis is about. To provide video we need a video format: codecs and other things and it is the same with audio and streamed tv. Most people are familiar with terms such as Flash, MPEG or streaming- it is exactly these things will be described in the following text. The first part will be about Flash and Silverlight, which both can be used for creating rich internet applications, but both can deliver video and audio as well. Most of the videos on the internet use precisely these technologies. The other parts will be dedicated to already mentioned YouTube and Ustream. At the end the basic facts about streaming and basic video formats will be mentioned.

3.2 Flash

3.2.1 History
Adobe Flash is a platform that is used for making websites richer in a way of adding video, animations and overall interactivity. It manipulates with graphic, both vector and raster and it supports streaming of audio and an Object-oriented language called ActionScript is supported.These are the basic facts. Now we will take a closer look at its history.

At a beginning there was Jonathan Gay. This guy was interested in building a designing buildings. As time passed he stared with creating computer games in Apple II Basic. His first games were Space Invaders. Soon he switched from Basic to Pascal and wrote his first graphic editor. When Jonathan entered a high school he met Charlie Jackson, who wanted to start Macintosh software company and Jonathan perfectly fit into his plans, because he was a programmer, he was a student and so he did not need much

money. Jonathan continued creating games and working for Jackson. *"I began writing games. First came Airborne!, then Dark Castle and Beyond Dark Castle. The second game was such a hit it paid my way through college. Writing games was an important part of my computer education (and the beginning of my inspiration for Flash) because I learned about animation, digitized sound, and how to synchronize the two. Most importantly, I learned that fast and responsive software is fun to use."* [1] After this game success Jonathan continued inventing graphical editors. Still at school he created Super Paint II with added post script and after graduation Intellidraw. This graphical program was a success and forced Jonathan to start his own company.
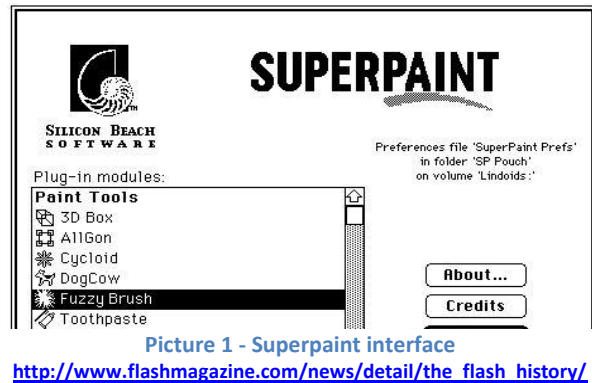
Picture 1 - Superpaint interface
http://www.flashmagazine.com/news/detail/the_flash_history/

"*At the time, the hot new concept in the personal computing world was pen computing (you could write on the screen with an electronic pen rather than using a keyboard). A company called Go was building an operating system. So in January of 1993, I convinced Charlie Jackson to invest some money and we started FutureWave Software to dominate the market for graphics software on pen computers."* [2] As a tool for writing directly to computer screen the Future Wave company started to create Smart Sketch. They wanted to make drawing on computer really easy. Unfortunately the business with the GO company was canceled by AT&T, which bought GO and left FutureWave Software right before finishing Smart Sketch. This was a problem but Jonathan end Charlie managed to sell some Smart Sketch editor. One of the best sells was to architect working on Bill Gates' house.

But this did not solve the problem so they decided to continue with Smart Sketch and make it run under Windows and Macintosh and this move brought them new strong competitors. Illustrator and Free Hand. *" In the summer of 1995, we were at SIGGRAPH and got lots of feedback from people that we should turn SmartSketch into an animation product. We were starting to hear about the Internet and the Web, and it seemed possible that the Internet would become popular enough that people would want to send graphics*

and animation over it. So we began to add animation to SmartSketch".[3] At the time they were using Java to extend web browsers to play animations. But the player they invented in Java was horribly slow. Fortunately Netscape company invented their API plug-in and this was the way how to make the player faster and with better performance. This played was ancestor of Macromedia Flash Player.

Because the software was now focused mainly to animation, its name was changed to FutureSplash Animator. After some time Jonathan and Charlie decided to sell their company, because they were tired by running it. Unfortunately the attempts were not successful. So they shipped FutureSplash Animator in May 1996. The success came quite soon. MSM company wanted to create the most TV-like experience on the internet and they become big fans of FutureSplash and used it for their project. Another famous client was Disney Inline. They used FutureSplash for their Disney Daily Blast project. Disney used FutureSplash as well as Macromedia Shockwave. *"In November of 1996, Macromedia had heard enough about us through their relationship with Disney and approached us about working together. We had been running FutureWave for four years with a total investment of $500,000. The idea of having a larger company's resources to help us get FutureSplash established seemed like a good one. So in December 1996, we sold FutureWave Software to Macromedia, and FutureSplash Animator became Macromedia Flash 1.0."*[4] The name Flash is contraction of Future and Splash. As a last step in creating Adobe Flash, in 2005 Adobe Systems acquired Macromedia and Adobe Flash was born.

If we look at the more recent history, we should mention Open Screen Project. This project was announced in May 2008 and its goal is to provide a consistent interface for wide range of devices such as personal computers, mobile devices or consumer electronics. *"The Open Screen Project is working to enable a consistent runtime environment -- taking advantage of Adobe® Flash® Player and, in the future, Adobe AIR™ -- that will remove barriers for developers and designers as they publish content and applications across desktops and devices, including phones, mobile Internet devices (MIDs), and set top boxes. The Open Screen Project will address potential technology fragmentation by enabling the runtime technology to be updated seamlessly over the air on mobile devices. The consistent runtime environment is intended to provide optimal performance across a variety of*

operating systems and devices, and ultimately provide the best experience to consumers."[5] Among the steps leading to this goal are for example removing restrictions on use of SWF and FLV specifications, removing licensing fees or publishing the device porting APIs for Adobe Flash Player. This project is supported by number of industry leaders such as LG, Motorola, Nokia, Samsung and many others. One year later, 2009, a fund was established. "*At the GSMA Mobile World Congress, Adobe Systems Incorporated (Nasdaq:ADBE) and Nokia Corporation (NYSE: NOK) today announced a $10 million Open Screen Project fund designed to help developers create applications and services for mobile, desktop and consumer electronics devices using the Adobe Flash® Platform.*"[6]

3.2.2 Flash technology

The main format the flash files are in is SWF format. Contraction SWF stands for Shock Wave Flash. This format has .swf extension. These .swf files can be played by Adobe Flash Player either in browser through special plug-in or in a standalone player. Another possibility how to play .swf files is so called projector.
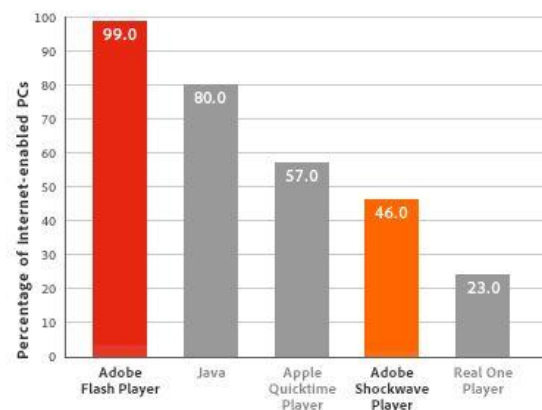
Picture 2 - Adobe Flash expansion
http://www.adobe.com/products/player_census/flashplayer/

This is self-running SWF movie. There are several plug-ins that allow us to play .swf files on different operating systems such as Microsoft Windows, Linux, Apple Mac OS X. These plug-ins are for example Adobe Flash Player or Adobe Integrated Runtime. According to Millward Brown survey from 2010, over 99% of internet users have SWF plug-in installed. Evan game consoles support SWF files but the scale of usage is limited. The similar situation is among cell phones. Only iPhones do not support SWF files, but Apple politics will be mentioned later.

Another important part of this topic is Flash Video. Flash Video is container file format through which the video is delivered on the Internet using Adobe Flash Player. But not all versions of this player support Flash Video. The early versions do not. Support of this container started with version 6. As we were talking about SWF files, Flash Video could be embedded within SWF files.

In fact there are two file formats known as a Flash video. The first is FLV and the second one is F4V. F4V is newer one and it is supported starting Flash Player 9, FLV was originally developed by Macromedia. Both formats are supported by Adobe Flash Player, but there are some differences. "*Starting with SWF files published for Flash Player 6, Flash Player can exchange audio, video, and data over RTMP connections with the Adobe Flash Media Server... One way to feed data to Flash Media Server (and thus on to Flash Player clients) is from files in the FLV file format. Starting with SWF files published for Flash Player 7, Flash Player can also play FLV files directly with MIME type video/x-flv. An FLV file encodes synchronized audio and video streams. The audio and video data within FLV files are encoded in the same way as audio and video within SWF files.*"[7]

"*Starting with SWF files published for Flash Player 9 Update 3 (9,0,115,0), Flash Player can play F4V files. The F4V format is based on the format specified by ISO/IEC 14496-12: ISO base media file format. A large part of the F4V format involves metadata. When Flash Player loads an F4V file, various stream properties are made available to a running ActionScript program via the NetStream.onMetaData property. The available properties differ depending on the software used. The F4V file format supports an assortment of optional tag boxes that can occur within a moov box.*"[8]

As it was mentioned before there is no support of Flash Video in iPhones. One of the reasons is that according to Apple that video playback does not take an advantage of hardware acceleration. Adobe responded by releasing Flash 10.1 which takes that advantage and then released Flash 10.2 beta in December 2010 which support multicore CPU hardware acceleration. Another reason could be the security issue according to Apple boss Steve Jobs.*"In a letter posted on the Apple website, he argued that Flash had "one of the worst security records in 2009", "has not performed well on mobile devices", and "is the number one reason that Macs crash""*[9] Audio is another important part of multimedia files. Audio component of SWF, Flash Audio, is usually encoded in MP3 or AAC. Flash Audio could have 11, 22 and 44,1 kHz sample rate. That means in does not support the classical TV or DVD sample rate. That is 48kHz.

Important part that should be mentioned is ActionScript. ActionScript is an object-oriented language developed by Macromedia. It has similar syntax and semantics as a Java.

This language is intended mainly for developing websites and software, where either Adobe Flash Player is used or there are embedded SWF files. ActionScript is open-source language and it is free of charge, so anyone can use it without any restrictions.

The first version of ActionScript was version 1.0. "*ActionScript 1.0 was introduced in Flash Player 5. It had ECMAScript-based syntax and semantics. With the release of Flash Player 6 and Flash Player 7, the language received some semantic tweaks but remained essentially the same.*"[10] This version was designed for making just simple 2D vector animations. It offered just few features and had very limited scripting possibilities. With later versions some new features arrived allowing to create web-based games or rich Internet applications.

Then ActionScript 2.0 come. This language is scripting programming language. "*ActionScript 2.0 was introduced in Flash MX 2004 and Flex 1.0. This new version of the language also worked in both Flash Player 6 and Flash Player 7 because ActionScript 2.0 is actually a layer on top of the ActionScript 1.0 runtime. As a result, ActionScript 2.0 isn't as high-performance as it could be, because under the hood it's still using the same object model as ActionScript 1.0*"[11]

Last version of ActionScript introduced is version 3.0. It come with launching Adobe Flash Player 9 an it is object oriented programming language. This version is being compiled a run on a re-written version of ActionScript Virtual Machine. "*Adobe began working to completely rewrite the ActionScript Virtual Machine (AVM). The result was a highly optimized virtual machine known as AVM2, along with a new version of the ActionScript language to target it. Although AVM2 will be the primary virtual machine for ActionScript code execution going forward, Flash Player will continue to support the older AVM1 to ensure backwards compatibility with existing and legacy Flash content.*"[12]

For creating all the things we listed above, such as games or web applications, we need a tool. Adobe provides Adobe Flash Professional. It all started with FutureSplash Animator, then continued through Macromedia Flash 1-9 to Adobe Flash Professional CS3-CS5. The creation of this tool was described in history part.

There has been problems with indexing pages created e.g. in Flash or Silverlight, because these pages are full of images, videos and other dynamic contents and it is hard for

search engines to index these pages in contrast with pages written strictly in HTML. "*Adobe has created a standardized format for its Flash development suite that will allow search engines to index dynamically generated content, which was not previously possible. What does this mean for the industry? Frankly, it means that "existing and future" Flash sites will be more accessible to search engine crawlers which will result in many previously invisible websites being indexed and ranked in search results. Google is already incorporating the new capabilities into their search platform, and Yahoo! reportedly still "has some work to do."* "[13] Good example of indexing multimedia contents is YouTube. "*YouTube, uses a SWF-based video player, and is extremely visible on the web. Part of the site's success in terms of visibility is attributed to its HTML and other content on each page that work together to effectively to make the SWF content more visible to search engines. So, although a YouTube video may have very little searchable text, search engines know what's in a video based on its HTML title and description.*"[14]

It was mentioned before that Adobe Flash plug-in was installed on 99% of computers. Let's take a closer look at this fact. The numbers can differ a bit according the place we are looking at, but still it is somewhere between 95% - 99%. It seems Adobe Flash Player performs better at Windows then on Mac OS or Linux, but with Flash 10.1 the situation changed and the performance on Mac OS has improved. But not only Windows, Mac OS or Linux are supported. The Adobe Flash Player supports other systems such as Android, Symbian, Palm OS or Pocket PC. In the mobile devices market the situation is a little bit different, because Apple does not support Flash in their mobile devices such as iPhone or iPod Touch. Because these devices are highly spread it decreases the number of Flash used among the overall mobile devices population. But other mobile platforms such as Android support Flash. "*Andy Rubin, VP of engineering for Google and one of the chiefs behind Android smartphones, just slipped a little bombshell into an interview with the New York Times' Bits blog. In it he says that Flash will be coming with the Froyo version of Android.*"[15]

3.2.3 Flash and security

Quite often the Flash is being connected with security risks. We mentioned above, that one of the reason why Apple does not support Flesh is its vulnerability. But Apple is not the only one who pointed at this problem. "*For example, someone could upload what appears to be a picture to a social-networking site but which is actually a Flash file*

designed to execute malicious code in the browser when the file is opened. Anyone who views that picture could be compromised, said Mike Murray, chief information security officer at Foreground Security."[16] Few other examples: US-CERT which is United States Computer Emergency Readiness Team advised not to use Flash using NoScript, At the CanSecWest – computer security conference it was recommended not to install Flash at all. In year 2010 Adobe announced critical vulnerability several times for their products and for Android users. These users were recommended to disable Flash. As a last example of a critical issues we can mention announcements made by Symantec and McAfee. Symantec declared that remote code execution was the second most attacked vulnerability in 2009 and McAfee predicted that especially Acrobat Reader and Flash would be the primary target for the attackers in 2010.

As a HTTP cookie Flash also has similar type of cookies. These small pieces of text are used to save information about the individuals and their use of web. "*Using previous versions of Flash, developers could save information between sessions by using 'normal' cookies, but the process was considered difficult for developers to implement. Placing a normal web cookie requires the use of a scripting language outside of Flash (Javascript or ASP, for example). Placing a Local Shared Object only requires the use of ActionScript-- the scripting language that controls Flash movies. In its newest version, Flash MX, Macromedia introduced the Local Shared Object, which provided an easier way to store information. Flash cookies can be considered to be equivalent to 'normal' cookies, save for a few minor differences.*"[17] User can disable placing these cookies to his computer or he can remove cookies which were already placed. Cookies are stored in normal files, so it is not difficult to find them and erase them.

3.2.4 Alternative way

If you want to create web pages full of multimedia, to create rich internet applications, you do not have to use just the Flash. There are several other possibilities. Lets mention some of them. First would be Silverlight. Silverlight will be describes closely in the following part of the thesis, so just few facts about it. Silverlight was developed by Microsoft in 2007 and it supports multimedia, graphics and animation. Another possibility is to use HTML 5. It is still under development but even now you can find pages where HTML 5 is used. With HTML 5 you can use audio and video without additional plug-ins. This could be strong competitor to Adobe Flash in the future. As a last example we can

mention Java. Java requires more programming skills but you can use it to create interactive pages, present videos or other media. Great tool is JavaFX which is platform for creating rich internet applications. These applications can be used in desktop, browser or mobile devices. Another platforms will be added later.

3.3 Silverlight

Microsoft Silverlight is a framework for creating and running rich internet applications. The first version was released in 2007. Like a Adobe Flash it focuses on multimedia, animations and graphics. Another similarity is that it is provided as a plug-in for browsers. The Silverlight applications and user interface are declared in Extensible Application Markup Language (XAML) and programmed using a subset of the .NET Framework. Let's take a closer look at architecture and components of Silverlight.

Two main parts are .NET Framework for Silverlight and Core presentation framework. Lets describe the first one in detail. "*A subset of the .NET Framework that contains components and libraries, including data integration, extensible Windows controls, networking, base class libraries, garbage collection, and the common language runtime (CLR).*

Some parts of the .NET Framework for Silverlight are deployed with your application. These "Silverlight Libraries" are assemblies not included in the Silverlight runtime and are instead shipped in the Silverlight SDK. When Silverlight Libraries are used in your application, they are packaged up with your application and downloaded to the browser. These include new UI controls, XLINQ, Syndication (RSS/Atom), XML serialization, and the dynamic language runtime (DLR)."[18]
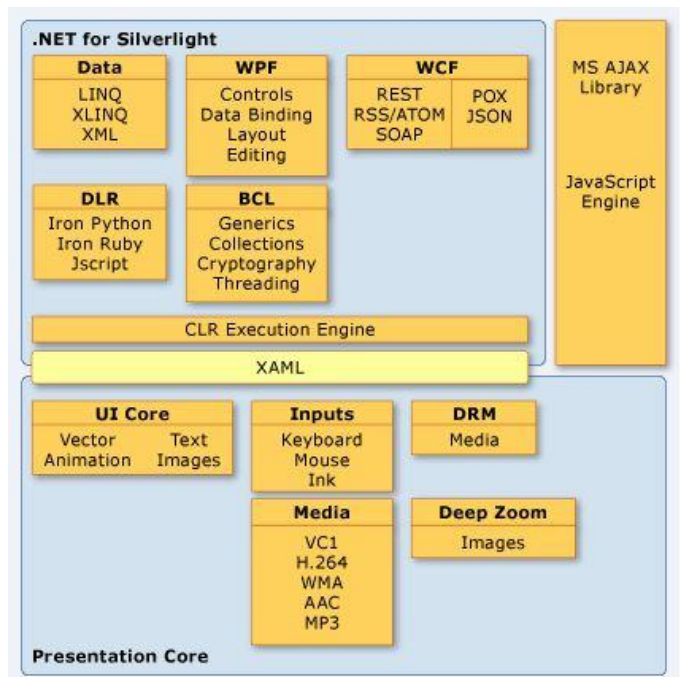
Picture 3 - Silverlight main pars
http://msdn.microsoft.com/en-us/library/bb404713.aspx

.NET framework components.

- Data – supports Language-Integrated Query (LINQ) and LINQ to XML features, which ease the process of integrating and working with data from disparate sources. Also supports the use of XML and serialization classes for handling data
- Base class library – a set of .NET Framework libraries that provide essential programming functions, such as string handling, regular expressions, input and output, reflection, collections, and globalization
- Window Communication Foundation – Provides features to simplify access to remote services and data. This includes a browser object, HTTP request and response object, support for cross-domain HTTP requests, support for RSS/Atom syndication feeds, and support for JSON, POX, and SOAP services
- Common language runtime – provides memory management, garbage collection, type safety checking, and exception handling
- Windows Presentation Foundation – Provides a rich set of controls, including Button, Calendar, CheckBox, DataGrid, DatePicker, HyperlinkButton, Li stBox, RadioButton, and ScrollViewer
- Dynamic language runtime – Supports the dynamic compilation and execution of scripting languages such as JavaScript and IronPython to program Silverlight-based applications. Includes a pluggable model for adding support for other languages for use with Silverlight

The other part is Core Presentation Components. That includes: "*Components and services oriented toward the UI and user interaction, including user input, lightweight UI controls for use in Web applications, media playback, digital rights management, data binding, and presentation features, including vector graphics, text, animation, and images. Also includes the Extensible Application Markup Language (XAML) for specifying layout.*"[19]

Core Presentation Components

- Input – this part takes care about inputs from devices such as keyboard, mouse, drawing or other input devices
- UI rendering – according to the name this part renders bitmap and vector graphics, animations and text
- Media – playback of audio and video files (.wmp, .mp3…)
- Deep zoom – this feature enables zooming and panning around high resolution images.
- Controls – this is a support of extensible controls that are customizable through styling and templating
- Layout – enables positioning of UI elements
- Data building – through this you can link data objects and UI elements
- DRM – digital rights management of media assets
- XAML – this part provides parser for XAML markup

"*The architectural approach that Microsoft has taken with Silverlight—making it possible to dynamically load XML content that can be manipulated through a DOM interface—is appealing to web developers because it is more consistent with conventional Ajax techniques. Silverlight also benefits from support for common dynamic programming languages like Ruby and Python, which are more flexible and syntactically expressive than JavaScript or ActionScript.*"[20]

3.3.1 Supported file types

Silverlight supports media files through MediaElement Class, which represents object containing audio, video or both. Three basic containers are supported: Windows Media, MP4 and MP3. Windows Media container contains 2 audio codecs – WMA Professional and WMA Standard. Another audio codec is MPEG-1 Layer III contained id MP3 container. MP4 container represents H.264 and AAC-LC. The support of H.264 is possible since Silverlight 3 was released.

These codecs are supported across all supported browsers. For using these codecs you do not have to have Windows Media Player, Windows Media Player ActiveX control or Windows Media plug-in.

Development of Silverlight RIA applications is possible in any .NET programming language, because any development tools which can be used with .NET languages can be actually used for creating Silverlight applications. But they have to target Silverlight Core CLR for hosting the application. For designing UI you can use Microsoft Expression Blend, which is a tool for creating graphical interfaces for web and desktop applications that blend the features of these two types of applications. Another tool for creating Silverlight applications is Visual Studio. This tool can be used for creating wide range of products such as console and graphical user interface applications, web sites or web applications. Tools listed above was developed mostly by Microsoft and it would be good to mention an example of open-source tool. Such a tool is for example Eclipse. Eclipse is a multi-language software development environment. "*The purpose of this project is the creation of open source tools integrated with the Eclipse development platform that enable Java developers to use the Eclipse platform to create applications that run on the Microsoft Silverlight runtime platform. Specifically, the project will be an Eclipse plug-in that works with the Eclipse Integrated Development Environment (IDE) and Eclipse Rich Client Platform (RCP) to provide both a Silverlight development environment and greater interoperability between Silverlight and Java, to facilitate the integration of Silverlight-based applications into Java-based web sites and services. The project has been submitted to the Eclipse Foundation and released as an open Eclipse project.*"[21]

Quite important part is Search Engine Optimization. If you want to increase chances that you page will appear higher in a result page, you should think how to make your page accessible for search engines. Classical pages are easy to index by crawlers, because they are full of text content (it depends how the pages are made of course), but pages made in Silverlight or Flash are full of graphic
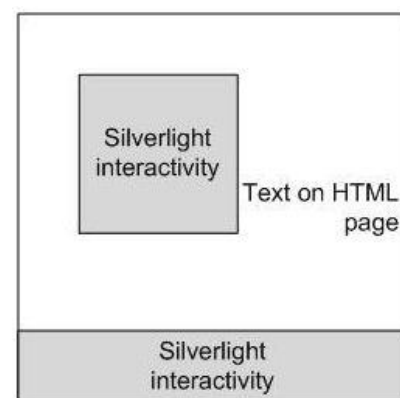
Picture 4 - Islands of text and Silverlight interactivity
http://www.silverlight.net/learn/white papers/seo-for-silverlight/

and multimedia and this fact makes it more difficult for search engines to index such pages. "*Search engines are geared toward recognizing HTML content. At this time, they do not recognize Silverlight content natively. This is similar to the search engine support for other objects on the HTML page, such as script blocks, CSS blocks, media files, and ActiveX controls. To make Silverlight content indexable by search engines, you can use approaches that search engines are already familiar with, such as combining the islands of Silverlight content with HTML metadata about that content.*"[22]

3.3.2 Silverlight versions

Till now there are 4 versions of Silverlight and 5th version is under development. The basic facts about these versions will be described in the following list.

1. **Silverlight 1** – this first version was developed under WPF/E name, which means Windows Presentation Foundation/Everywhere and was released in 2007.
2. **Silverlight 2**
3. **Silverlight 3** – this version was announced at the International Broadcasting Convention 2008 in Amsterdam and unveiled in Las Vegas in 2009.The final version was released in the same year. New features was added but I would like to mention the media ones. "*Media has been a strong point in Silverlight since day 1, but we've added some features based on customer feedback including support for new media types like H.264 and AAC encoding. Additionally we've added support for RAW audio/video pipeline support, which will enable developers to provide audio/video decoding outside the runtime and render in Silverlight – opening up some new areas for wide support for 3rd party codecs.*"[23] This version also offers 1080p smooth streaming.
4. **Silverlight 4** – beta version of Silverlight 4 was unveiled in 2009 in Los Angeles at the Professional Developers Conference. The final version was released on April 2010. Among new features there are support of Google Chrome, support of web cameras and microphones, enhanced animation effects and many others.
5. **Silverlight 5** – this last version was announced in December 2010 at the Silverlight Firestarter event. The Beta should be released in the 1st half of 2011 and the final version should be released at the end of 2011. This version will support e.g. GPU accelerated video decode, support of GPU accelerated 3D graphics or 64-bit browser support.

3.4 YouTube

3.4.1 History

As you know, YouTube is a portal you can upload different videos to, create channels with these videos or just browse and watch videos uploaded by other people or companies. The history and basic facts will be described in the following text.

The YouTube was founded in 2005 by three people: Chad Hurley, Steve Chen and Jewed Karim. Both Steve Chen and Jewed Karim studied at University of Illinois at Urbana-Champaign and Chad Hurley studied at Indiana University of Pennsylvania. Basic idea was to create a website, where people can easily share their videos.

YouTube started as a venture-funded company with help of Sequoia Capital. This company provided an investment 11.5 million US dollars between November 2005 and April 2006. Sequoia Capital is a well-known venture capital company in Silicon Valley. Among the companies which were founded with the assistance of Silicon Capital are companies such as Apple, Google, PayPal, Cisco Systems, Oracle, Electronic Arts or NVIDIA. (stranka sequoia) The first headquarters of YouTube was in San Mateo in California. It was situated above pizzeria and Japanese restaurant. The company uses their domain name since February 14, 2005 when it was activated. But usage of this domain name was not without problems, because a company with similar website name existed. The website was www.utube.com and the owner of this site, Universal Tube & Rollform Equipment took YouTube to court in November 2006. The reason was, that because the similar name, their webpage was overloaded by the people looking for the YouTube site. *"It's killing us," said Ralph Girkins, president and owner of the 22-year-old business. "All my worldwide reps use our Web site. Customers all over the world use it to bring up photos of the machinery, descriptions and specifications there."Girkins says his site, which has been online since 1994, got 68 million hits in August.*"[24] As a result Universal Tube changed their domain to www.utubeonline.com

A beta test of the site was offered to the public in May 2005. It was six months before the site was lunched officially. After that the site had more and more viewers and the numbers reached 100 million videos watched per one day. In July 2006 the numbers of

videos uploaded reached 65,000 every day. Following statement was announced in May 2010: "*U.S. Internet users watched nearly 34 billion videos in May, with Google Sites ranking as the top video property with 14.6 billion videos, representing 43.1 percent of all videos viewed online. YouTube accounted for the vast majority of videos viewed at the property. Hulu ranked second with 1.2 billion videos, or 3.5 percent of all online videos viewed.*"[25]

Another fact that proves that YouTube is number one among the sites providing online videos is that according to YouTube 35 hours of new videos are uploaded every minute. Most of the videos uploaded come from outside the US. Approximately three quarters of the videos. In a year 2008 in the article in the Daily Telegraph it was written: "*Last year it was said that YouTube consumed as much capacity as the entire internet took up in 2000.*"[26]

One of the biggest events for YouTube occurred in October 2006. The Google announced that it had acquired YouTube." *Internet search leader Google Inc has closed its $US1.65 billion ($A2.17 billion) acquisition of top online video-sharing site YouTube, setting a new record in the valuation for user-generated media sites.In a statement, Google said it had issued 3,217,560 shares to pay for YouTube.*"[27]

The whole acquisition was finalized in November 2006.

In November 2008 YouTube signed an agreement with company MGM and other similar companies such as Lionsgate or CBS. Now they are allowed to upload and present their full-length movies or television episodes. Another advantage is that they can join these videos with advertisement. Because people can upload almost any video to YouTube, there are problems with copyrights. Hollywood companies such as MGM are strongly against this way of posting their movies. That is why YouTube is trying to cooperate with these companies and tries to do something with this problem. "*YouTube has also developed a system called VideoID. It allows media companies to spot unauthorized clips of their material on the site, and then either remove the clips or leave them up and sell ads on them. As part of its deal, MGM will begin scouring YouTube for studio clips, from properties like the James Bond and Rocky franchises, and pulling many of them from the site.*"[28] These companies cooperating with YouTube decide which video should be

removed and which one can remain on the site. Usually they support remained movies with advertisement. This move of joining with these companies was made to create a competition with companies such as Hulu. This company has similar agreements with NBC, FOX or Disney. Unfortunately these services are not supported in the Czech Republic. Most of them are intended for US or UK.

In March 2010 YouTube started free streaming of different content. One of them was Indian Premier League and its cricket matches. "*The YouTube deal involves every country outside the US – a significantly larger scope than reports had suggested. It was thought that YouTube would only stream live matches to countries that did not have TV deals with the IPL.*
The two-year deal gives the Google-owned YouTube the exclusive rights to stream IPL matches online, with the two companies splitting revenue from sponsorship and advertising."[29] YouTube claimed that this was the first free broadcast of major sporting event that was broadcasted worldwide. On March 31, 2010 the YouTube changed the design of the pages. The intent was to capture the user and force him to stay longer at the site. The changes at the site were based on the way how the users actually use the site.

3.4.2   Legal issues

Providing millions of vides uploaded by internet users is connected with certain legal issues. YouTube has been criticized by the owners of the original videos for failing to obey the copyright law. When a user uploads a video on YouTube he is told not to upload the video (music video, TV shows, concerts or advertisements) unless he has all the permissions from the original authors or he is author of all parts of the video. "*This warning, however, seems to be taken by most people as a bit of casual advice along the lines of "I wouldn't go out without an umbrella if I were you". After all, the site is awash with concert footage, sporting moments and comedy clips, most of which have been put there by the public in direct contravention of the rules. In fact, it's partly this wholesale disobedience that has made YouTube so popular.*"[30] Not many users pay attention to this message and there are still lots of unauthorized clips of copyrighted material on YouTube. The copyright holders have to check the site themselves and they have to issue a takedown notice. This way the video can be removed from YouTube.

Between years 2007 and 2008 several companies sued YouTube for not doing enough to prevent users to upload copyrighted material.

Viacom company owns MTV, VH1, Comedy Central or Nickelodeon and sued YouTube for 1 billion dollars because over 160,000 unauthorized videos were uploaded onto YouTube and they were viewed more than 1.5 billion times. Viacom also told YouTube to remove 100,000 unauthorized clips. "*Viacom said its demand came after YouTube and Google failed to install tools to "filter" the unauthorised video clips following negotiations. "Their business model, which is based on building traffic and selling advertising off of unlicensed content, is clearly illegal and is in obvious conflict with copyright laws."* "[31] Another example of suit is a case of Premier League. "*The organization said the video-sharing website had "knowingly misappropriated" its intellectual property by encouraging footage to be viewed on its site.*"[32] Because of these suits YouTube developed a system called Video ID that was mentioned above. The system checks all the uploaded videos and compare them with a database of copyrighted material. In June 2010, Viacom's suit was rejected.

Another legal issue problem could be controversial or offensive content. Because people can upload any video, it is possible that they upload videos containing defamation, pornography or other materials that violated YouTube's rules. We can mention two cases of braking this rules.

The first one relates to anti-semitic videos posted on YouTube. "*The videos hosted on YouTube include clips of a 1940 anti-Semitic propaganda film "Jud Suess" and two music videos of outlawed German far-right rock band Landser, which show footage from World War II depicting Nazi military operations.*"[33] In this case German officials asked Google (as YouTube owner) more than 100 times to remove this content. Unfortunately some of these videos were on YouTube for almost a year.

The second case is from England. In 1989 there was a disaster in Hillsborough in England where 96 people died during football match. Some man placed an offensive video on the site. This act insulted many people in England. "*Hillsborough Family Support Group secretary Phil Hammond, whose 14-year-old son Philip was one of the 96 victims of*

the 1989 tragedy, today said he was shocked and sickened by the YouTube entry which is entitled "muppets on a fence"."[34]

One of the possible ways to fight against these controversial videos is to tag such a video. Users themselves can tag videos, if they find them, and these tagged videos are checked by YouTube team. This team works 24/7 and when they find this video unappropriate they will remove it from the site.

The last thing are user comments. But this topic is common with any other internet portals that allow users to place comments under articles or videos. Quite often these comments are full of offensive, aggressive or homophobic words. It is similar with the topic above. When people from the servers find such a comment they usually remove it from the page.

Together with the possibility of placing almost any video on YouTube and the fact that internet is spread all around the world goes the fact that many countries block or censor pages such as YouTube. Among these countries are for example China, Marocco or Iran. Strictly forbidden topic for China is Tibet and its fight for independence. "*The site has been carrying a graphic video released by Tibetan exiles, which shows hundreds of uniformed Chinese troops swarming through a Tibetan monastery - a group of troops beat a man with batons.*"[35]

3.4.3 Video technology

Following paragraphs relate to technical site of YouTube. First we mention will playback. That means what you need to be able to play YouTube videos. Another part will introduce topics connected with uploading. For example when they allow you to upload videos of unlimited length. Then codecs and quality will be mentioned followed by 3D videos or platforms.

To be able to view YouTube videos you need Adobe Flash Player plug-in installed in the browser. Adobe Flash is as well part of this thesis and it was described above. So just few words for reminder. Adobe Flash Player plug-in is one of the most common things installed on computers. "*Flash software is used to deliver around 75% of online video and is the key technology that underpins websites such as YouTube and Google Video.*"[36] With HTML 5 and its new features there are new possibilities how to play video and audio.

YouTube knows that and so in January 2010 they launched an experimental version of their site. This site uses advantages of HTML 5 so you do not have to have Adobe Flash plug-in installed in your browser. This is possible because of new tags <audio> and <video>. In the cell bellow you can see example of a code using these tags.

```
<video width=“640“ height=“360“ src=“file.mp4“ autobuffer>
<br> You must have an HTML 5 capable browser
</video>
```

"*This YouTube page demonstrate some of the capabilities of HTML 5 but it's nearly impossible predict at this stage if HTML 5 (or the Open Video format promoted by Mozilla) can make any impact on the ubiquitous Flash Player which, some estimates suggest, exists on more than 90% browsers.*"[37]

Uploading topic is very important in the case YouTube because its main purpose is to let users to upload and share videos. In these days you can normally upload video of 15 minutes length but when YouTube started, it was possible to upload longer videos. At the beginning you could choose Director account and you were allowed to upload longer videos then with other accounts. Today Director accounts still exist but in the terms of length you have the same rights as someone with different account. In March 2006 a 10-minute limit was introduced. "*Clearly the hope is that the 10-minute limitation will result in most TV shows and other longer programs staying off of YouTube. Will the free-wheelin' copyright infringement come to a close? It's doubtful, because a 10 minute limitation doesn't really stop people from uploading unauthorized content. After all, Napoleon Dynamite is 82 minutes long, and YouTube is packed with ripped scenes and satires, a good portion of which are not examples of fair use. But now, YouTube is giving it the old college try. The popularity of the site doesn't hinge on the portion of its contents that derive from infringement, but a YouTube sans TV and movie clips is a different YouTube than some of its users are used to.*"[38] In July 2010 this 10-minute limit was increased to 15 minutes. "*According to a Thursday post on YouTube's blog, increasing the limit was the most requested feature by YouTube users, though it had to be put on hold while the company worked on other projects and behind-the-scenes infrastructure.*"[39] The

advantage of using longer videos belongs to the partners of YouTube. The size of the video is normally limited to 2GB. But if you use special Java-based Advance Uploader, the size increase to 20GB.

In December 2010 YouTube announced that even users with normal accounts would be able to upload videos with unlimited length. But only if they have good history which follow certain guidelines and copyright. "*The new feature has been a long time coming, and it's made possible by YouTube's Content ID system. Content ID is a pretty incredible set of technology — it can take any new video uploaded to the site and match it against YouTube's massive archive of copyrighted video that's been submitted by cable networks, movie studios, and other partners.*"[40]

Along with the length and size go formats of the video files. YouTube support wide range of container formats such as .AVI, .MKV, .MOV, .MP4, .DivX, .FLV, .ogg and .ogv. So you do not have to be worry that you will not be able to upload your video. These containers mentioned above include video formats such as MPEG-4, MPEG and WMV. It is also possible to use 3GP so you can upload video from your cell phone. For the best result you should upload your clip in best quality and if it is possible the video should be de-interlaced. Interlaced videos are supported as well, but YouTube prefers de-interlaced.

When YouTube started it offers videos just in one quality level. It was resolution 320x240 pixels and used H.263 Sorenson Spark codec with mono MP3 audio. You can find this resolution even today but since then lot of things changed. In June 2007 people were given a chance to watch YouTube on a cell phone. The option to watch videos in 3GP was added. Another great change was adding a possibility to watch the videos in high quality. That increased the resolution to 480x360 pixels. But that was not enough so YouTube added a support of 720p HD videos in November 2008. Along with this change the aspect ratio was changed from 4:3 to widescreen 16:9. With this change YouTube changed default video codec to H.264/MPEG-4 AVC. In November 2009, 1080p HD quality was added and as a last quality improvement in July 2010 YouTube announced that they had launched support of 4k video format. "*YouTube on Friday announced that its player now supports 4k, a standard resolution for films that measures 4096x3072 pixels. As YouTube Engineer Ramesh Sarukkai explained in the announcement on YouTube's*

official blog, "4K is nearly four times the size of 1080p," and it dwarfs even Imax, which projects films in the slightly smaller 2k format, with its 2048?1080-pixel resolution."[41]

In July 2009 YouTube started to provide videos in 3D. You can find all the 3D videos on special YouTube page. To be able to watch the videos in 3D, you need eithed classic anaglyph glasses or you can use special stereoscopic player.

Maybe you noticed that sometimes YouTube videos are posted on different pages. For example blogs or some news portals. This is possible because together with videos on YouTube there are also pieces of HTML. You can use these pieces to embed the video to your site. Perfect example is social network Facebook. People quite often share YouTube video on their walls. Through these videos you can go straight to YouTube page and see the original placement. But it is not possible to embed every video you want. The owner of the video can disable the possibility to embed it. He can of course disable the comments under the video or ranking the video.

The thing that everybody notices is that it is not possible to download videos from YouTube website. Now there are some exceptions such as President Barack Obama's weekly addresses, but usually it is not possible. "*While users have long been able to grab YouTube clips both with Flash rippers and H.264 stream downloaders, this would be the first time such an option has appeared on the site as an official offering. The new option gives users a full-quality H.264 file--the very same copy that's sent out to YouTube-capable set top boxes and iPhones.*"[42] So if users want to download certain video, they have to use special third party web sites or applications. YouTube partners have the chance to let users download their videos for a small fee. This fee could be paid through Google Checkout.

Platforms are another important part of this section. It is obvious that you can watch YouTube videos on personal computers, but today when lots of smart phones and tablets are on the market, it is important to allow users to watch YouTube clips on these devices.

In June 2007 YouTube Mobile was launched and Real Time Streaming Protocol is used for it. RTSP is used for establishing and controlling media sessions between end points. But unfortunately it is not possible to watch all the videos on a mobile version of YouTube. Support of Apple devices works since June 2007 as well but YouTube had to

start decoding the videos into H.264, because this video standard was preferred by Apple. This operation took several months. Another possible way how to watch YouTube is TV. Because lots of TVs are connected to the internet directly or people use game consoles connected to the internet together with TV, since June 2009 you can use YouTube for TV or YouTube XL. "*It's part of Google's plan to distribute its products far and wide beyond the traditional computer and into places like the living room, where the television reigns supreme. Last year, for example, the search giant struck deals to pipe YouTube videos directly to connected Sony Bravia TVs, Panasonic Viera TVs, the Apple TV device and TiVo's digital video recorder.*"[43]

As a last fact about YouTube we will mention localization. Today lots of counties have the site in their own languages and more of them tries to reach this advantage. Following statement was said October 2010. "*Back in August, YouTube said it plans to provide support for a grand total of 40 languages by the end of 2010. "By the end of this year, our goal is to offer the YouTube experience in 40 languages, doubling the number we started with at the top of 2010. With each new rollout, we hope to make YouTube a bit more accessible to more people, regardless of where in the world they might live," said Product Manager Brian Truong back in August.*"[44] One thing connected with national versions of YouTube is blocking some of the videos according IP address. Because of the copyrights some videos are accessible only in certain countries. That is why sometimes you can read message "This video is not available in your country".

3.5 USTREAM

Ustream is a quite similar website to YouTube, but there is one elemental difference. Whilst YouTube provides videos uploaded by users which are mainly on demand, so you can watch them whenever you want, Ustream gives you a possibility to broadcast your videos life. So you can register, create your channel and somehow have your own internet television.

The site has more than 2,000,000 registered users with more than 1,500,000 hours of life streamed video broadcasted every month. "*Since its launch in March of this year, more than 115,000 people have joined Ustream.TV broadcasting one million unique*

viewer hours per month. Each day, 5,000 hours of video are broadcast on Ustream.TV with up to 300 simultaneous broadcasts taking place, attracting hundreds of thousands of viewers. Recently, popular recording artists The Plain White T's broadcast a live concert exclusively on Ustream.TV to more than 150,000 fans around the world."[45] Quite interesting fact is that this site was used by almost all candidates to help their campaign during 2008 United States presidential election. With a help of this site, candidates allow greater number of people to ask question and participate in political debates. As an example we can mention senator Mike Gravel who was the first presidential candidate who streamed a debate on Ustream. Through Ustream he was able to answer questions and comments both from normal people and other presidential candidates. Since then many notable people used Ustream services. For example Hillary Clinton, Barack Obama or John Edwards.

3.5.1   History

The very beginning of Ustream has similar foundation as YouTube and that is three men. In this case John Ham, Brad Hunstable and Gyula Feher. The first two met each other during their studies at U.S. Military Academy at West Point. Gyula Feher joined them later in Ustream business.

John Ham interned NASA and New York Stock Exchange at West Point and graduated in Aerospace Engineering. After this he was commissioned as a 2nd Lieutenant in US Army.

Brad Hunstable graduated in Engineering Management and was commissioned as a Captain in the US Army.

During the time when they serve in the Army together they teamed-up for web-based digital photo enterprise. This project was developed by Dr. Gyula Feher. Later Hunstable and Ham were separated and sent to different locations so their photo business had to cease operations. Ham was sent to Korea and Hunstable worked directly for Department of Defense. When they finish their duties they got together with Feher and started Ustream business.

Because the founders ware involved in the Army, the main idea why to invent something like Ustream, was to give their friends serving abroad, mainly in Iraq, a chance

to communicate with their relatives back home. Because there is not enough free time in war zone, such a thing like Ustream would give them a possibility to talk to all the relatives and friends at once. The idea that general public would use such a thing was discussed as well so Ham and Hunstable contacted Gyula Feher, who they met at West Point, to help them with required development. Ustream itself was founded in 2006. Their first test of their product was streaming of a concert. They had a notebook and camera in the audience and they were sending a stream to their test server.

Ustream is not the only server providing online streamed videos. There are several others on the market. Since launching public beta of Ustream in 2007, the company has grown significantly in a political, entertainment or technology area. "*Ustream.TV is partnering with business leaders across many industries to bring the Ustream.TV live, video broadcast platform to an even greater number of users. The company today announced it is partnering with Bebo, the global social network, to integrate its one-to-many live video streaming application into Bebo Open Media (see separate press release). Other partnerships include meebo that integrates Ustream.TV into the web-based IM provider's new platform, bringing a new form of interaction to Meebo users. Using the Ustream.TV platform, Hollywood has already broadcast live on from the red carpet premieres of ABC's "Dirty Sexy Money," FX's "Nip/Tuck" and the new Warner Bros. film, "Fred Claus."* "[46] But despite this growth the competitors grew faster. In the following table you can see a comparison.
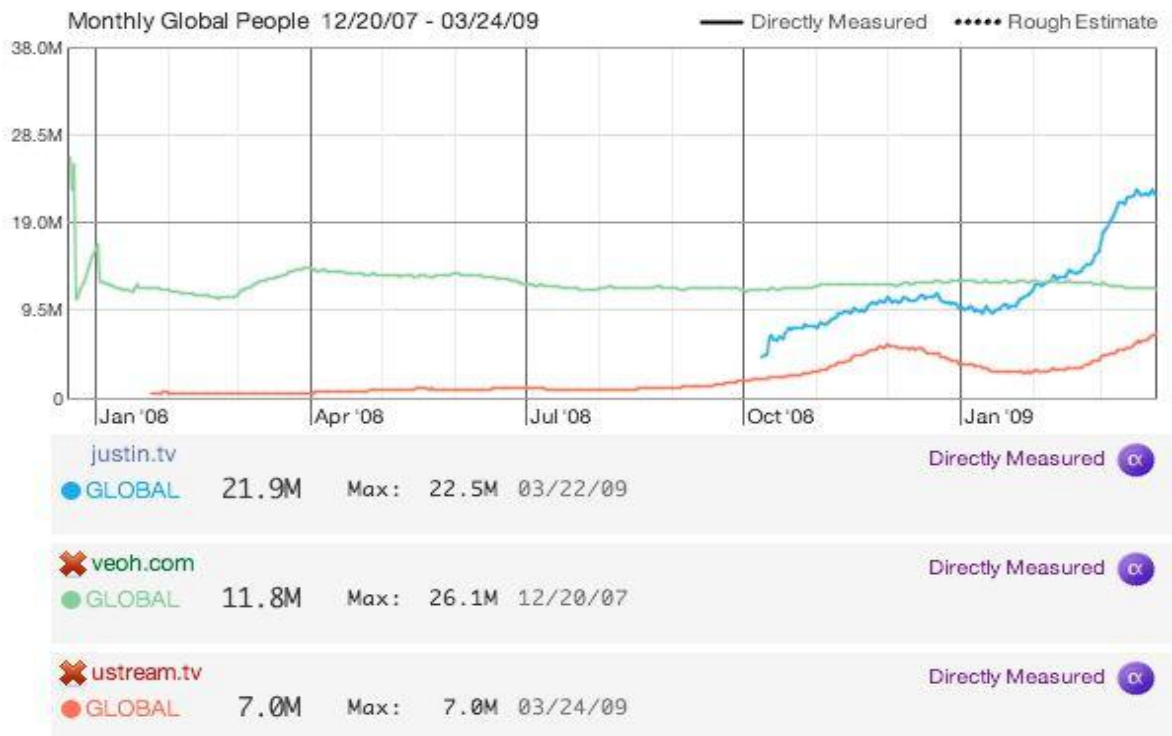
The question is why for example Justin Tv is much better than Ustream. There are few possible reasons. "*First, the site is very responsive and most of the channels load quickly and use a high quality encoder, with a fast refresh rate. Second, the pages arrange the channels by total number of viewers, which means the top listings are at least interesting to watch. Third, the site seems to encourage channel-switching, catering to a jaded TV-watching audience and keeping them on the site longer.*"[47] As we mentioned that most of the videos are uploaded to YouTube from outside of US, we can see the same trend here in Ustream. Most of the streams are generated outside of the United States.

Lets talk about payments for using Ustream. For normal users using the Ustream is free of charge. This is the same as on YouTube. But if you are a company or you want to look more serious, you can use Ustream feature called Watershed. For using watershed you pay per viewing hour. The advantage is that there is no advertisement on the page and instead you can place your own advertisements or logos onto the page. *"Dr. Gyula Feher, founder and CTO, says, "Watershed was designed and developed to be the most flexible platform for live, interactive video. With that in mind, the solution offers everything from*

plug-and-play widgets to robust API integration solutions. And our Pay-As-You-Go pricing means no monthly fees, no contracts, and no wasted bandwidth for our customers. As a value proposition to the market, Watershed truly marks an industry watershed moment." "[48]

These were the basic facts about Ustream, one of the possibilities how to stream your videos online.

3.6   Video streaming

Today when the fast internet is reachable for almost everybody streaming video is not something unusual. But years before with dial-up connection it was almost impossible to watch video stream. You had to wait long time watching just the sign buffering. But nowadays the situation is completely different. Real TV stations have their internet pages, where most of them provide either live streaming or at least videos on demand. Of course this is not only real TV issue. There are servers such as YouTube or Ustream, which were mentioned before, and these servers provides the same services. Life or on demand videos. Another examples could be news servers. In the Czech Republic we can name iDnes or iHNed and in the world it could be BBV or CNN. Even you can stream a video from your computer and that is exactly what many people do. In the following part I would like to mention the basic principles of video or audio streaming.

Lets start with distinguishing normal downloading and streaming. When you download a video file from a page, it is usually stored somewhere on a server and you just click the hyperlink to this video. If the video is small, it is not a problem to wait till it is downloaded. But today when the videos are long and in high resolution you will probably wait for some time. But with high speed internet it is not that bad. There are some advantages and disadvantages of classic downloading. Long time waiting mentioned above is one of the disadvantages. On the other hand advantage could be fast moving back and forth through the movie or the fact that the movie is stored on your computer for the future.

However the streaming works differently. As the word stream suggest it is constant stream of video or audio or both of course. The main difference from downloading is that you can start watching the video almost right after the start of the downloading

(streaming). It depends on a speed of your internet connection, but with usual connection you should not wait too long or you should not have some drop-outs. Another advantage is possibility to stream live events. This method is called webcast or netcast. When you want to watch streamed video, you can normally choose from several quality choices. If you have slower internet connection and you choose HD quality, you will probably wait for a long time to be able to watch such video. In this case you should choose lower resolution so there will be no problems with watching this video. In case of streaming the whole file is not stored in your computer.

Then there is another way, something between downloading and streaming. The way it works is that part of a video is downloaded to your computer and then played. Meanwhile the other parts are downloaded. This is called progressive downloading.

To be able to stream the video, you need a special stream server. It is not a special piece of hardware. It is special application running on a usual internet server. This server has several advantages. **"*The ability to handle much larger traffic loads. The ability to detect users' connection speeds and supply appropriate files automatically. The ability to broadcast live events.*"**[49] As an example of such a software we can mention:

- Helix Universal Server – among supported formats are RealMedia, Windows Media, Quicktime or MPEG-4 (formats will be described later)
- Apple Quicktime Streaming Server – this one supports e.g. MPEG-4 or 3GPP
- Macromedia Communication Server - this one is specialized in Flash-based video

This was the streaming from the server side point of view. Now let's take a look what is going on on the user's

Picture 6 - How streaming works
http://computer.howstuffworks.com/internet/basics/streaming-video-and-audio3.htm

computer. If you want to watch a video stream you need either plug-in for your browser or stand alone player. You may know the warning that your computer is unable to play this or that video, because needed plug-in is missing. We have to start at the server side again. The video files are usually encoded in one of the following formats: QuickTime, RealMedia, Windows Media, Adobe Flash. This formats will be described in the following parts if literature overview. Movie in one of these formats is then streamed to your

computer. Usually you need special player or plug-in for every one of these formats. Some pages let you decide which format you want to use by giving you a choice of the player. Another thing you have to choose is the quality of the stream according to your internet connection. It could go from low resolution to TV or HD resolution or you can use smooth streaming (if it is available). Smooth streaming is kind of streaming where server itself decide what quality will be delivered according to the speed of the internet. The decision is not made just once at the beginning of the action but it is being made during


Picture 7 - How streamig works 2
http://computer.howstuffworks.com/internet/basics/streaming-video-and-audio3.htm

the whole streaming process. That means if your speed oscillates up and down the quality is optimized according to that. "*The QuickTime, RealMedia and Windows Media players can work as stand-alone players with their own menu bars and controls. They can also work as browser plugins, which are like miniature versions of the full-scale player. In plugin mode, these players can look like an integrated part of a Web page or pop-up window.*"[50] The Flash format is a bit different." *It usually requires a Flash applet, which is a program designed to decode and play streaming Flash files. Programmers can write their own Flash applets and customize them to fit the needs of a specific Web page. Flash is becoming a more popular option for playing streaming video. It's what YouTube, Google Video and the New York Times all use to display videos on their sites. The video below, which demonstrates what would happen if you shot your TV, plays in a Flash applet.*"[51]

These were the basics of the video streaming. Now let's take a look at the process of creating streamed video. With today's tools and fast internet it is not difficult to have

our own stream. First thing you need is to shoot some pictures. You can use classic film video camera or digital one. The material from the camera, raw material, will usually be in high resolution. So first you have to edit the video you want to stream and then you have to export it in format of your choice and in lower resolution then original. For these

operations you can use a video editing programs, such as Adobe Premiere or Sony Vegas or you can use programs that only change the properties and formats of the video, e.g. ProCoder or some freeware programs. There are lot of things you can change, but I think the most important ones
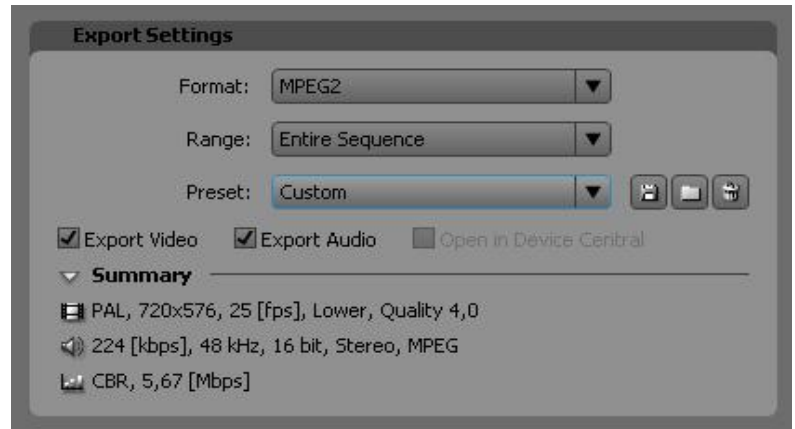
Picture 8 - Premiere export settings
Made by author

are resolution, bitrate and format. The picture on the right captures Export Setting from Adobe Premiere Pro. As you can see in the summary, among settings there are resolution 720x567, bitrate 5,67 Mbps and the video will be in MPEG2. Of course you can change lots of things e.g. sound quality. If you change stereo to mono you will make the video smaller as well. Basically you should make the video small enough to be easily streamed, but it should look and sound good enough as well. Sometimes it is really hard to find this point. If you have the final video, just upload it to the server, from where it will be streamed to the users.

You have several options, you can run your own server with streaming services, but this can be expensive for you. In that case you can purchase steaming services."*In much the same way that you sign up for a website hosting plan, you can get yourself a hosting plan which specializes in streaming media. This is a far more realistic option for most people.*"[52] Or there is another possibility mentioned above and that is either YouTube for on demand videos or Ustream for live streaming. (you can choose any other server, that provides similar services)

3.7   Video formats and players

In the prior parts we discussed platforms such Adobe Flash and Silverlight for creating rich internet applications, pages full of animations and other dynamic content. Then we discussed YouTube, Ustream. Websites which give you chance to present your video either live or on demand. As a last part we mentioned basic facts about video streaming. All these things have one thing in common and that is video formats. When you are creating your video, it is shot in certain format. When you edit it and export, it is in another format. And finally the videos streamed from a server are in different formats as well. So in the following part the main and most common video formats will be described.

3.7.1   QuickTime

QuickTime player recognizes a lot of media formats, not only files with .mov extension, but in this part we will pay attention to the QuickTime Movie File Format, which is .mov. "*QuickTime movie files store media data in separate tracks. You create a QuickTime movie file by adding tracks that point to the media you want to use. The media may be embedded in the file itself or in a reference movie in another file. This track architecture is powerful and flexible, allowing you to store and synchronize multiple pieces of video and audio media in a single file.*"[53] There are lots of file types that can be stored in QuickTime movie file. Lets divide them into these:

- An audio track - This track contains audio media data of a certain duration, encoded with a particular audio codec, sample rate and bit depth. The track may be mono or contain two (stereo) or more interleaved channels of audio samples.
- A video track - This track contains video media data (a number of video frames) of a certain duration (determined by the track's frame rate), with particular horizontal and vertical dimensions, and encoded with a particular video codec.
- A single still image - This track contains media for a single still image. The image data has particular horizontal and vertical dimensions and is compressed with a particular codec.
- A timecode track - A track that contains a number count and frame rate that corresponds to the video frames in a video track. This track can be captured from a videotape or created later in any editing software.
- A text track - This track contains text information that changes at specified times. A text track could contain subtitles, or marker notes about a video or audio track.

As you can see almost everything can be stored in QuickTime, but it is very important to know the type of compression of these files in order to proper playback. You computer must be able to recognize the compression to encode the files. "*Compression is necessary for video and audio storage on computers because the data rates would otherwise be prohibitively high. And no matter how large computer storage devices become, compression is still desirable because it means faster transfer time and storing more information with less data.*"[54] The libraries inside the QuickTime support wide range of audio and video codecs and it is possible to install more of them in the case that the player does not recognize the compression.

QuickTime format was used as a basis of the MPEG-4 format and the JPEG-2000 standard. Because these file types have similar structure and contain many identical elements, they are distinct file types.

3.7.2 RealMedia

This technology was developed by RealNetworks company, which was founded in 1995 by Rob Glaser in Seattle, US. This man is ex-Microsoft executive.

RealMedia is classic container with .rm extension in which RealVideo and RealAudio are usually stored. Its main purpose is in streaming media. Following text will be mainly about RealVideo. The first version of RealVideo was released in 1997. This version was based on H.263 format. "*H.263 was developed to stream video at bandwidths as low as 20K to 24K bit/sec and was based on the H.261 codec. As a generarule, H.263 requires half the bandwidth to achieve the same video quality as in the H.261. As a result, H.263 has largely replaced H.261.*"[55] This format was used until Real Video 8. With this version the company replaced H.263 with proprietary video format.

3.7.3 Windows Media

This format was originally designed for internet streaming as a competitor to RealVideo. "*Video file based on the Microsoft Advanced Systems Format (ASF) container format and compressed with Windows Media compression; basically an .ASF file that is encoded using the Windows Media Video (WMV) codec; Windows Media audio files are saved with a .WMA extension.*"[56] The first version of Microsoft Media Video was WMV 7. This codec was introduced in 1999 and it was built upon implementation of MPEG-4 Part2. Developing of this codec led us to version WMV9. All versions of WMV support

variable bit rate, average bit rate and constant bit rate. The new version WMV 9 adds support of interlaced video, non-square pixels and frame interpolation. Another part of WMV 9 is a special profile called Professional. This profile is activated every time when the video resolution exceeds 300,000px. That means 528x576 and more. This features is there mainly because high-definition videos such as 720p or 1080p.

3.7.4 Adobe Flash

Adobe Flash, Flash video and Flash audio were described in separate part, so only basic information about Flash video will be mentioned in the following text. Flash video is a container file format for streaming both video and audio through internet. There are two types of Flash video: FLV and F4V. Video and audio are encoded in the same way as in SWF files. The F4V is a newer format and it is supported since Flash player 9 update 3. Both these video formats were developed in Adobe, but older FLV was originally developed by Macromedia. Nowadays Flash video file format is quite popular and it is used for embedded web video by many well known companies such as YouTube, Hulu or Reuters.

Flash video uses Sorenson Spark codec which is variant of H.263 video standard. Sorenson Spark is older codec for Flash video but it is widely compatible and available. It was the first video codec supported in Flash Player. In Flash Player 6 and 7 it is required. The Flash Player 8 and newer ones support playback of On2 TrueMotion VP6 video bit stream. This new compression is preferred in these players and provide higher visual quality then Sorenson Spark. On the other hand it is more complex in computational way so there might be some problems with running it on older systems. The Flash Player 9 supports

Picture 9 - Premiere export settings 2
Made by author

F4V mentioned above and H.264 video standard which offers even better quality then On2 VP6.

3.7.5 MPEG

The MPEG contraction stands for Moving Picture Experts Group. This group unites experts from different areas and was formed by ISO and IEC (both standards organizations). "*The Moving Picture Coding Experts Group (MPEG) was established in January 1988 with the mandate to develop standards for coded representation of moving pictures, audio and their combination.*"[57] Since 1988 the group has grown and today over 350 experts from more than 200 companies and organizations from about 20 countries take part in their meetings.

Lets take a look at the most well known MPEG standarts.

- MPEG-1 – the first three parts of this standard (systems, audio and video) were released in 1993. MPEG-1 standard is for coding of moving pictures together with audio files for digital storage up to 1.5 Mbit/s (ISO/IEC 11172). It was designed to encode audio and video into the bit rate of a Compact Disc and it was used on Video CD, SVCD or on DVD (in this case just low quality video). This standard was used in digital satellite or cable TV and to meet low bit rate it downsamples the images. This standard contains the famous MP3 audio format, because MP3 is actually MPEG-1 Audio Layer III. There is also a newer version of MP3 and that is MPEG-2 Audio Layer III.

- MPEG-2 – this standard (ISO/IEC 13818) is widely used for digital television signals. These signal can be broadcasted by terrestrial, cable or satellite systems. It is used for DVDs as well but unlike MPEG-1 it is not optimized for low bit rate. MPEG-2 adds interlaced video support. Video part of this standard is MPEG-2 Part 2/H.262. The MPEG-2 decoders are able to play MPEG-1 video streams. Sometimes MPEG-2 is used for high definition video, but usually MPEG-4 is used for this kind of media.

- MPEG-3 – this standard should not be confused with MP3. As it was written above, MP3 is audio layer in MPEG-1 or MPEG-2 video formats. MPEG-3 was intended for HDTV compression but finally it was found to be redundant and it was merged with MPEG-2. Because of this move there is no standalone MPEG-3 video format anymore.

- MPEG-4 - (ISO/IEC 14496) This standard has many features of MPEG-1 and MPEG-2 standards but it also adds many new features. Among new ones are e.g. 3D rendering support, object-oriented composite files or externally specified Digital Rights Management support. Same like other MPEG standards MPEG-4 is devided into several parts. As an example of two important parts we can mention Part 2, which includes ASP (Advance Simple Profile) which is used by codecs such as DivX, Xvid or Nero Digital. The second important part is Part 10 which is AVC/H.264 or Advanced Video Coding. This part is used by x264 encoder, Quicktime 7 or by high definition video. As it was mentioned in previous parts, H.264 is used by many video streaming servers, such as YouTube, Vimao or iTunes store or by technologies such as Adobe Flash or Microsoft Silverlight.

4 Comparison of multimedia technologies

4.1 Introduction

The basic facts and examples of multimedia technologies were introduced in the literature overview. Today's phenomenon of video streaming was shown in two examples: YouTube and Ustream. Both servers provide video streaming and both are used by well known and successful companies. This topic relates to the technologies which are used during the streaming. These technologies are Flash and Silverlight and were described above with the process of streaming itself. As a last part of the literature overview the most common video formats used today were listed and described.

The second part of this thesis is aimed at two main topics. In the first topic the author will describe the creation of the sample video file, which will be later used for measuring the CPU usage during playback of this sample video exported into the main video formats. These formats were described at the end of the literature overview. The CPU usage measurement is the main goal of the first topic, because the user is interested in the bulkiness of the particular video formats.

4.2 Video formats comparison

4.2.1 Creating of the sample video file

The first step needed for this comparison was to create our own video file, because the usage of a video downloaded from the internet was not ideal. For this we basically need two things and these are a device which will capture the video (video camera or camera able to shoot videos) and a piece of software in which the video will be edited and finally exported. The author used Full HD video camera and Adobe Premiere Pro software.

Lets look at the process of creating of the video itself. After we have the material stored on a SD card (it could be another storage methods such as DV, hard disc, or DVD, it depends which is supported by the video camera) we have to import it to the editing software. In our case it was easy, because all we needed to do was to insert the card into the reader and import it into Premiere. If we have a hard disc or DVD video camera it is more or less the same. But in case we have DVcam, we need a special reader for the cassette or we can connect the camera directly to the computer. The best way is via firewire connection. Unlike the other storage methods we have one big disadvantage and

that is that we have to wait until the material is transferred from the tape to the computer and it takes some time. More precisely the rate is 1:1. If the material takes 1 hour, we have to wait one hour till we can edit the video. In the case of e.g. SD card, we are limited just by transfer speed of USB.

When the raw material is in Premiere we can start with editing the video. We will not focus on editing principles in this thesis. The author prepared a video which is 30 seconds long and consists of several shots of car models. When the video is edited it is time to export it. Usually the user picks one format suitable for him and for the purpose of the video but for the purpose of this part of the thesis, we have to export the same video into several video formats. Because the video camera we used is Full HD, we can afford to export the video in high resolution. The author decided to export all the videos both in Full HD and HD ready. The difference is that the Full HD has 1080 vertical lines and HD ready has 720. To be more precise the video was shot in 1920x1080 progressive with approximately 13 Mbps VBR bitrate. For the last comparison, which will compare more static and more dynamic video, the author edited one more dynamic HD ready video, which will be compared with the first HD ready video sample, that is more static.

4.2.2   Exporting final video samples

Nowadays there are many different video formats, codecs and their combinations. In this part of the thesis the author chose 6 examples to study, what the result of the comparison of these examples will be. These examples are: WMV (Windows Media Video), FLV (Flash Video), F4V (newer version of Flash Video), MPEG-2, MPEG-4 and MOV (Quicktime video). These formats are used by YouTube, Ustream, iTunes, and news servers throughout the world so you will most probably come across them sometimes. That is why the author decided to study the CPU usage percentage when playing back these formats, to see if there are any interesting differences among them.

It is imperative to try to export all the videos with the export settings as similar as possible. Usually different formats have different options how to export the video, but there are a few which are the same for all formats. As mentioned above, one of them is resolution. the author decided to export videos in 1920x1080 (Full HD) and 1280x720 (HD ready). The literature overview described mostly formats and technologies for video streaming and the fact is that e.g. in Czech news servers the videos are streamed (both live

or on demand) in lower resolutions than HD, but e.g. YouTube gives us a possibility to watch the videos in HD or even higher (original resolution). That is why the author decided to choose high resolution, because in the future more and more videos and streams will be in HD.

Another thing connected with video streaming is bitrate. Bitrate tells us about the amount of the information transported in a time unit. For example Blu-ray discs have about 40 Mbps. On the other end of the scale we can mention standard definition television which has about 3,5 Mbps. Despite of the chosen high resolution the author decided to set the bitrate to 4,5 Mbps because this value is a bit higher than YouTube uses for its HD videos and today's internet speed should handle this bitrate without any problems.

Finally the author decided to export all the videos without the sound, because he wants to compare just the video element of the formats.

4.2.3 Exporting times

The first value which was measured and compared was rendering time. Although this is not the main thing to compare in this part of the thesis, it will be interesting to compare the videos by the rendering time as well.

At first let's take a look at a graph, which shows us rendering times of both HD ready and Full HD videos.
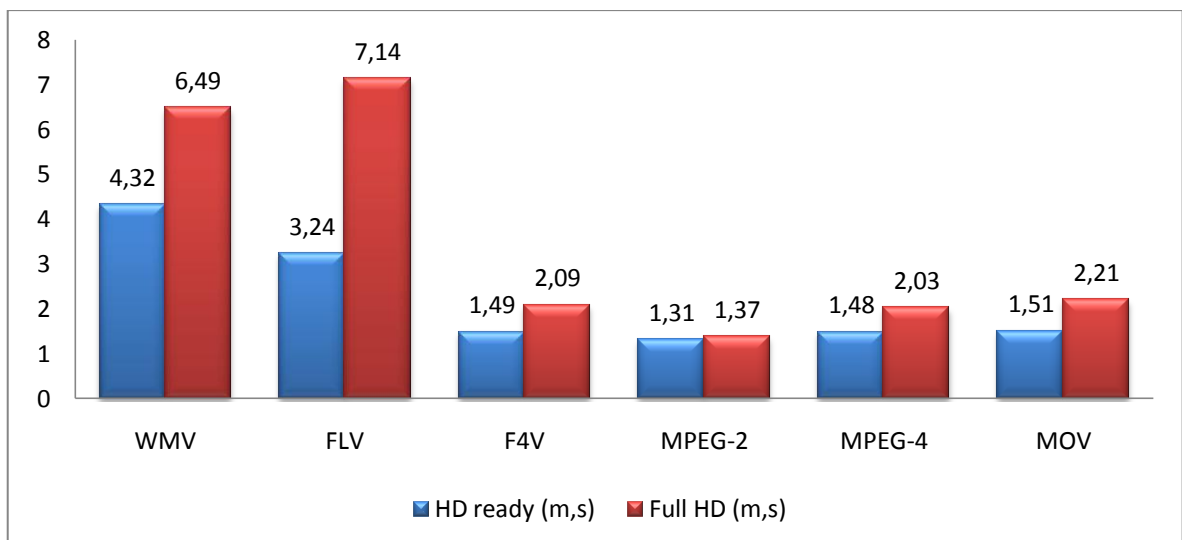
Graph 1 - Rendering times of both video samples
Made by author

In the graph you can see HD ready videos in blue color and Full HD in red color. As you can see the WMV format which was coded by windows media video 9 codec takes 4 minutes and 32 second to export. The second longest render time was measured during rendering FLV with On2VP9 codec. The render times of the other four videos are between 1,31 and 1,51 so we can say these videos are similar regarding render time.

Lets take a look at the red columns. We can see that these values are almost the same at first sight. The order of the format is the same as among the blue column values, except that this time WMV and FLV are switched. But WMV and FLV are still two formats which take the longest time to export. Another interesting fact we can read from both the blue and red columns is to compare the difference between HD ready and Full HD in particular formats. If we take the blue columns values as a 100 percent, then the red values columns gives us numbers which show increase of render time in the case of Full HD.

WMV 1080	FLV 1080	F4V 1080	MPEG-2 1080	MPEG-4 1080	MOV 1080
49,27%	112,74%	18,34%	6,59%	13,88%	27,02%

Table 1 - Render time percentage increase between HD ready and Full HD
Made by author

The same table will be shown for the rest of comparisons. This table shows that the formats have very different time demand in the case the resolution is changed from HD ready to Full HD. In the case of the older format of Flash video there is almost 113 percent increase in render time. On the other hand is MPEG-2, where the increase is only 6,59 percent.

4.2.4 File sizes

Another characteristic we can compare and that can be useful is the size of both the Full HD and the HD ready. In the case of our sample videos, the differences will be very small, but if someone wants to create a lot bigger video file, the size of it will most probably be quite important. The following graph will show us sizes of both HD ready and Full HD videos.
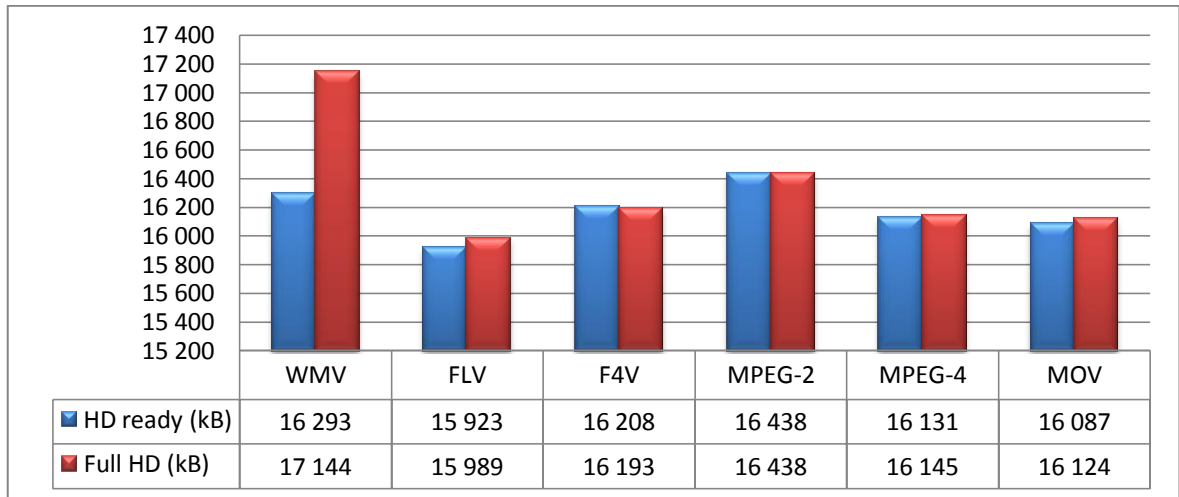
Graph 2 - Sizes of both HD ready and Full HD videos

Made by author

According to the graph, the size of each of the videos is approximately 16MB, the differences are quite small and may seem negligible. The thing we have to take into consideration is the video quality of the files. The bigger file size does not necessary mean better quality. It all depends on the export settings. In our case author tried to choose the setting as similar as possible but the differences in quality appeared among the videos. Most of the videos were similar and the quality was more or less great. But both MPEG-2 and MOV have worst quality then the other four. Of course if the quality settings such as bitrate are changed, the video quality increases rapidly, however, the file size increase as well. But because we need to have the same setting for all the videos (in our case quite low bitrate) this quality decrease may occur.

When we compare the sizes of both resolutions, interesting fact appears. The increase in resolution and render time is quite significant, but the increase in file size is almost none. In one case the difference is actually negative.

WMV 1080	FLV 1080	F4V 1080	MPEG-2 1080	MPEG-4 1080	MOV 1080
5,22%	0,41%	-0,09%	0	0,09%	0,23%

Table 2 - File sizes percentage increase between HD ready and Full HD

Made by author

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4.2.5 CPU usage during video render

The last sub-topic to mention is comparison of the usage of CPU during exportation of the video samples. The main topic is to compare CPU usage as well, but during the video playback. This main comparison will be shown and described later. To measure CPU usage, the author of this thesis used Performance monitor, which is integrated into Windows 7. It is possible to check CPU usage for individual processes in this tool and that is very handy for this comparison. Let's explain what we mean by the term CPU usage. When a CPU does nothing, it uses 0 percent. Each process which uses CPU need some percentage of its performance. For the following graph the process of Adobe Premiere was measured during the exportation of each video.

The Following graph shows us rendering CPU usage of both HD ready and Full HD videos.
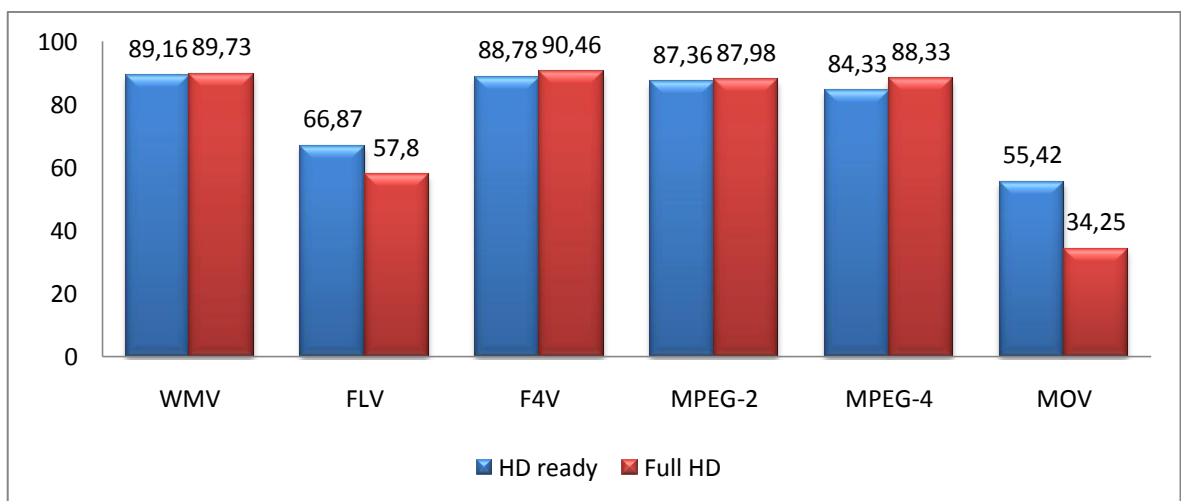
Graph 3 - HD ready and Full HD rendering CPU usage (%)
Made by author

At first take a look at red column values. It is obvious that rendering of the videos is very demanding for the CPU. Most of the videos use almost the whole CPU capacity, but MOV and FLV formats use significantly less CPU capacity. Obviously all measured values would be different in a case that different computer was used. Now let's check the Full HD values.

This red values have almost the same progress as a in the case of HD ready videos. The same four video use almost the whole CPU capacity and two videos use less CPU capacity. It is a bit strange that during rendering of video with higher resolution, the CPU
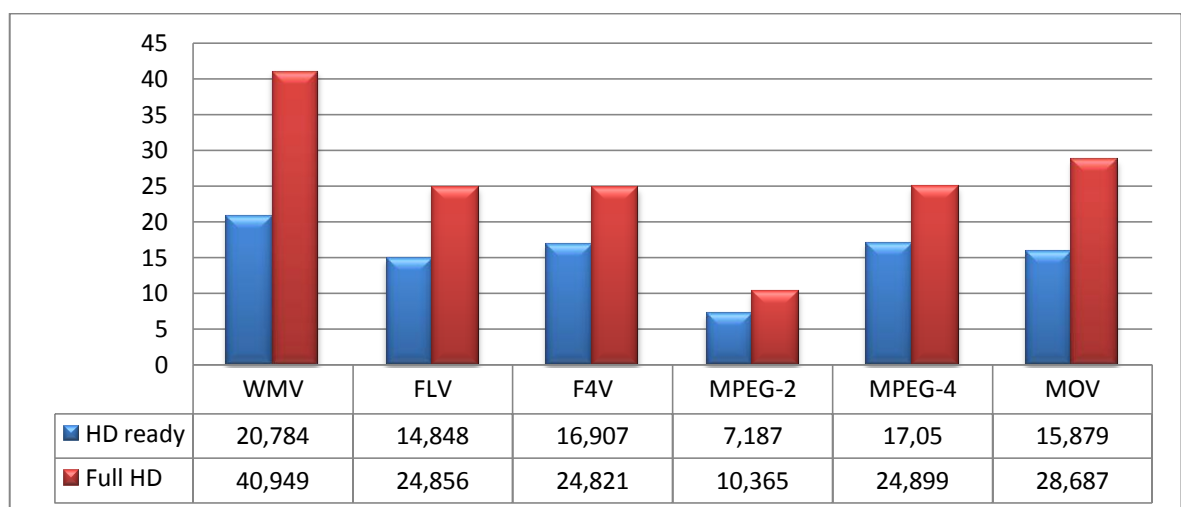
is less used in some cases. In this CPU usage comparison the table with percentage increase of the values will not be posted, because the differences are very small.

These were the comparisons of values which are connected with creating of the sample videos. But the main reason why we created these videos is to compare how demanding they are in a way of CPU usage during their playback.

4.2.6 Video samples playback comparison

The comparison of playback CPU usage will be shown in the following text and graph. To compare all the video formats we use the same tool as during render CPU usage, but this time we have to take a look at the process of video player. For the measurement the author decided to use Media Player Classic – Home Cinema, because all the videos can be played with this player and so it is possible to compare them. The precise results would be different with different PC configuration, but it would be good to mention the configuration on which the tests were done. It is Intel Core 2 Duo, 2,66 GHz with 4 GB RAM. Operation system is Windows 7 64bit. The goal of the comparison was not to find out precise values, but to compare individual video formats among each other.

The HD ready values, which are blue, will be described first. As it is seen, there is big difference between this graph and the graph above. It is clear that rendering of the videos is much more demanding for the processor than just playing individual videos.

	WMV	FLV	F4V	MPEG-2	MPEG-4	MOV
■ HD ready	20,784	14,848	16,907	7,187	17,05	15,879
■ Full HD	40,949	24,856	24,821	10,365	24,899	28,687

Graph 4 - Both HD ready and Full HD playback CPU usage (%)
Made by author

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Let's start with WMV format, which has the highest measured value from HD ready formats. The number 20,784 is an average from more measurements. Highest measured value was 21,13% and lowest value was 20,40% so the difference between these two values is less than 1%.

We do not have to describe all the formats, but let's mention the least demanding format from this graph and that is MPEG-2 with usage 7,187%. That is significantly less then WMV and the other formats. Highest measured value was 7,58% and the lowest was 6,75. In the following table you can see the highest and lowest values of all HD ready samples.

Format	WMV 720	FLV 720	F4V 720	MPEG-2 720	MPEG-4 720	MOV 720
MAX (%)	21,13	15,11	17,57	7,58	17,56	16,63
MIN (%)	20,44	14,47	16,6	6,75	16,45	14,86

Table 3 - MIN and MAX HD ready playback CPU usage values
Made by author

From this table the MPEG-2 may seem to be the best choice for our video file, but as mentioned before, MPEG-2 and MOV have significantly worse video quality with this bitrate. We can improve the quality, but that would most likely increase the playback CPU usage numbers. The rest of the video formats have the same quality, which was perfect for streamed videos. Let's see if the values measured for Full HD videos will increase according to the increase of the resolution.

As it was expected all values are higher in comparison with the HD ready values and the formats with highest and lowest values are the same as well. Windows Media Video now demands almost 41 percent of CPU so the increase is almost 100 percent. On the other hand the least demanding format, MPEG-2, has approximately 44 percent increase. In the two following tables highest measured values, lowest measured values, and percentage increase will be shown.

Format	WMV 1080	FLV 1080	F4V 1080	MPEG-2 1080	MPEG-4 1080	MOV 1080
MAX (%)	41,54	25,29	25,11	11,13	25,34	29,43
MIN (%)	40,55	24,22	24,44	9,84	24,22	27,85

Table 4 - MIN and MAX Full HD playback CPU usage values
Made by author

The differences between the measured values in the table above are less than two percents.

WMV 1080	FLV 1080	F4V 1080	MPEG-2 1080	MPEG-4 1080	MOV 1080
97,02%	67,4%	46,8%	44,21%	46,03%	80,65%

Table 5 - Full HD Playback CPU usage increase
Made by author

As it was mentioned above and as is obvious from this table, the biggest increase occurs in the case of WMV. Almost 100 percent is quite a significant increase. We can observe the second biggest increase in the case of MOV. But it is necessary to mention that even if the increase is that high, the quality is still quite poor. It is the same case as MPEG-2. Both video formats are capable of providing perfect video quality, but that would mean to change the export settings which go together with size increase and therefore worse streaming possibilities, because of internet speed.

Now that all the comparisons have been made, we can summarize what was discovered. At the beginning we had raw material which was 1920 x 1080 which is Full HD resolution. This resolution gives us a possibility to create a video of excellent quality, but we decided to export it in high resolution however with the lower bitrate, so it corresponds with the literature overview and that is video for streaming. We used bitrate 4500kbps which is slightly higher than the bitrate used by YouTube. The formats chosen for the comparisons were Windows Media Video, Flash Video, MPEG and Quicktime Video. We divided Flash into older FLV and newer F4V. The same was done with MPEG, which was devided into MPEG-2 and MPEG-4.

The first comparisons which were possible were to compare the time needed to export videos, CPU usage of the process of the editing software during the exportation and finally the size of all exported videos.

Let's start with the file size comparison among HD ready videos, where the biggest file is MPEG-2 with 16 438kB. The other videos were slightly smaller. The smallest one is FLV with 15 923kB, so it is seen that the differences are quite slim. In the case of Full HD the situation is a bit different, because the biggest file is WMV with 17 144kB. the rest of the videos are around 16, so even if we changed the resolution, the size changed only a little bit.

In the render CPU usage comparison both HD ready and Full HD the values were almost similar. Rendering a video is quite a demanding process so the CPU was usually used around 90 percent. But there are two exceptions: LFV and MOV. These two formats used much less CPU than the others. The interesting thing is that the usage was smaller in the Full HD rendering than in the HD ready.

The final comparison that was possible during the creating of the videos was rendering times. From the graph it is obvious that two formats took a significantly longer time to be rendered. As the F4V,both MPEGs and MOV took about 1,5 minutes in the first graph and about 2 minutes in the second, WMV and FLV took from 3,5 to 4,5 minutes in the first graph and about 7 minutes in the second one.

When we compare all these measurements we can say that Windows Media Video was always among the formats with highest values.

Now we can summarize both graphs which show us playback CPU usage. The least demanding format according to the graph is MPEG-2. The values measured were quite low in both cases. On the other hand, the highest values were measured for WMV. Among the Full HD videos the values were almost twice as high as the rest. So we can say that Windows Media Video were at the leading positions in all comparisons that were made. The positions of the other videos changed during all the comparisons.

4.2.7 Additional comparison

During the writing of the practical part of this thesis, the author was asked a question several times. The question was about the comparison of the video the author had made and the video, that would be the same length, same resolution but it would be little bit more dynamic. The original video was quite static with just a few colors. People were interested if the results would be different. This idea was interesting, so the author decided

to shot another video with required attributes and compare it with the original HD ready video.

The process of creating the new video was just the same as in the first case. The author shot several shots of traffic and public transportation so there were lots of moving objects and lots of colors. The final video was quite different from the first one. All the comparisons made were the same as well but just the final comparison will be mentioned in the following graph and that is how much percentage of the CPU is used for the video playback. This was the main point in the questions the author was asked. Let's take a look at the following graph.
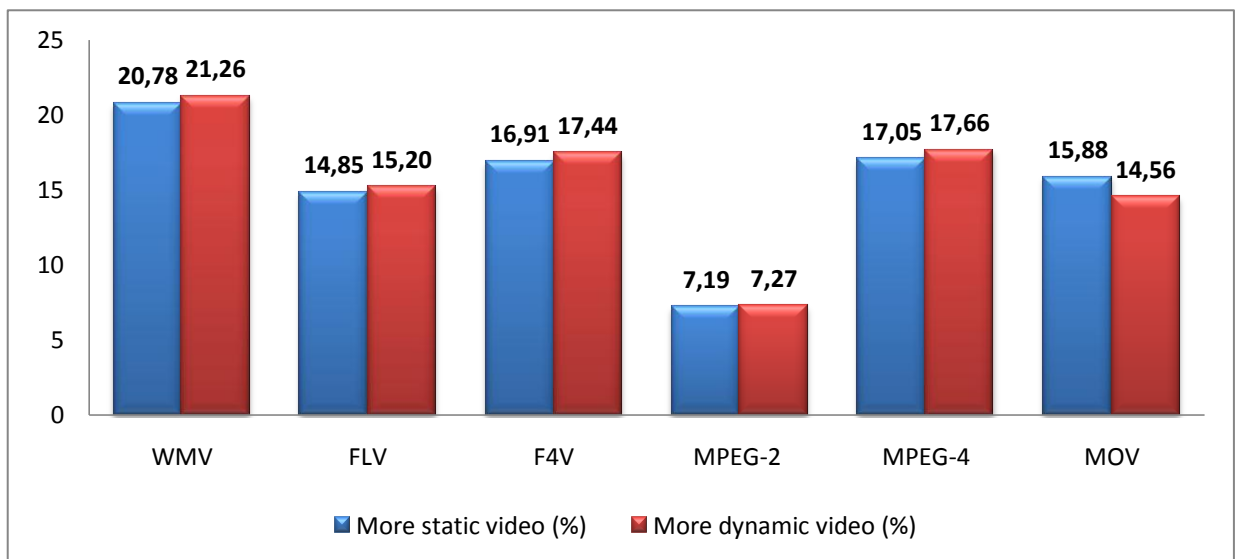
The results of this comparison were quite interesting. Although the results were according to what the author and people were thinking, it was suspected that the differences would be a little bit bigger. As it is seen from the graph above, the CPU usage was higher in every case except the last one. Even though the difference was quite small, the values measured for more dynamic video were higher than in the case of more static video. Only in the case of MOV video format was it vice versa.

Even though the MOV format was different than the rest of the videos, we can say that the results of this last comparisons proved that more dynamic video needs more percentage of CPU than more static video.

5   Conclusion

In the first part of this diploma thesis the author described important topics which are connected with the world of multimedia and video streaming. A brief summary of multimedia trends tracked the following developments: the intrusion of video into news portals where previously pictures were mainly used, and the popularity of servers such as YouTube and Ustream. These servers provide services that enable people to watch millions of videos or upload their own.

The following part of the literature overview was about Adobe Flash and Silverlight. These technologies are connected with rich internet applications but are also connected with video, audio or video streaming as well. These technologies were described in closer detail.A subsequent part aimed at the video streaming servers mentioned above. YouTube and Ustream are very popular today and many well known companies use these servers as an official avenue to gain more customers. As a great example, we can mention the latest landing of the Discovery space shuttle which NASA streamed live on its Ustream channel. Hundreds of thousands of people watched the landing.

The final part of the literature overview is connected with video streaming and video formats. The basics of streaming technology was explained as well as things needed to run your own video stream. The main video formats were mentioned. These formats were Flash Video, Real Media video, Windows Media Video, MPEG and Quicktime. These formats are connected with video streaming and most of them appeared in the practical part of this diploma thesis.

The practical part aimed at comparison of the main video formats. Because the author works with video and video streaming, he wanted to know if there were significant differences among the main video formats.

The first thing to do was to shoot and edit a short video that would be exported into the formats which would be later compared. The video formats were WMV, FLV, F4V,MPEG-2, MPEG-4 and MOV. Videos in these formats were exported twice. First as HD ready videos and second as a Full HD videos. These two groups were compared together and individual videos in each group were compared as well. To be able to compare the videos it was important to have the video setting as similar as possible.

Unfortunately the video formats have different types of settings so the author has decided to set the same bitrate for all the videos and export them without sound. The rest of the settings were left on default. The first comparison regarded rendering time. Specifically, how much time it takes to render video in different formats and resolutions. In the HD ready resolution the average time was about 1 minute and 40 seconds. Only WMV and FLV took little bit more time. WMV took 4 minutes and 32 seconds and FLV took 3 minutes and 24 seconds. Similar results occurred in the Full HD case. All videos took a little bit longer time to be rendered, as expected. The average time of four less time demanding videos is 2 minutes and 2 seconds. Again WMV and LFV took longer time to be rendered (WMV - 6 minutes and 49 seconds, FLV - 7 minutes and 14 seconds).

The second comparison was the size of the files. In this case all the sizes were around 16MB. The sizes were similar in both HD ready and Full HD resolutions so there was not big difference between these two resolutions. Again WMV format was in the lead with one of the highest values. The final comparison that was connected with rendering of the videos was CPU usage during rendering process. During this process similar values were measured for almost all videos. The average of most CPU consuming formats was 87%. Only FLV and MOV formats had significantly lower values. (FLV - 66.87% and MOV - 55,42%) The situation among Full HD videos was similar. Average was 89% and again FLV and MOV had lower values. (FLV - 57.8% and MOV - 34.25%) But again WMV format's values were among the highest values measured.

The last comparison between HD ready and Full HD videos was comparison of playback CPU usage. In the HD ready group of videos the highest values were measured for WMV format. On the other hand lowest values were for MPEG-2. When the resolution changed to Full HD, the situation was similar. Again the WMV format had the highest values and MPEG-2 the lowest. As it was expected the values increased with the increase of resolution. When we summarize all the comparisons, we can see that Windows Media Video format had the highest or at least one of the highest values in every comparison.

At the end of the practical part one last comparison was made, because the author was asked several times what the results would be in the case of a more dynamic video. The fact is that the first video was quite static so the author shot the second one, which was more dynamic with more colors and movement. The results were the same in terms of

video order according to playback CPU usage and most of them were higher than in the case of more static video. This proved the expectations, but it was expected that the differences would be bigger. The only video format which had lower values measured in the case of more dynamic video was MOV. Generally, however, we can say that as the video becomes more dynamic, the CPU usage increases.

According to the comparisons and trends, the author thinks that coding in H.264 is the perfect way to process videos. It has perfect image quality and the compression is fine. This codec is used in more video formats and is ideal for HD video. For normal PAL videos the author would use MPEG 2 and videos on news servers are exported in this format. Unfortunately nowadays HD video is not commonly used for providing news services on the Czech internet.

In terms of future development of multimedia on the internet, the author thinks that the intrusion will continue and more and more videos will be used for different activities on the internet. The difference between classic TV as we know it and internet TV will become smaller and smaller. The videos uploaded to the internet by users are becoming increasingly important. Prime examples are the uprisings in Libya and Egypt, and the disaster in Japan. Because of these user videos people were able to see what was happening and sometimes it was the only source of information. Unfortunately this way of providing information can be misused as well.

Another possible development is to charge people for using certain news portals. For example The New York Times server charges people for using their internet news services. It is possible that more servers will act similarly in the future. The author spoke with several people and some of them said they would pay for such services in case that these would be high enough quality.

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