# An Investigation into the Integration of Three E-learning Open Source Software: Bigbluebutton, Opencast Matterhorn and Synote

# ABSTRACT

*The affordability and reliability of internet connections around the world has increased the feasibility of e-learning as a tool to aid the traditional face to face classroom learning or to facilitate distance learning for students that are in different locations or have different time schedules around the world. Several tools and platforms have been developed to aid this concept, some of which can be broadly classified as online course content creation and management systems like Moodle, Sakai, Blackboard etc., slidecasting applications like Synote, Slidecaster 2.0, Slideshare etc., web conferencing tools like BigBlueButton, Adobe Connect pro, WebEx etc., lecture capture and management systems like Panopto, Opencast Matterhorn, Galicaster amongst others. While some of these platforms are proprietary licenced software e.g. Panopto, Adobe Connect pro, WebEx etc., others are free software developed by the open source community and are categorised under GPL, LGPL or other open source software classifications e.g. Moodle, BigBlueButton, Opencast Matterhorn etc.*

*This report investigates the feasibility of creating a completely licence free and effective collaborative e-learning system for higher education by integrating three open source software systems. Firstly, BigBlueButton, a web conferencing tool that supports synchronous capturing of video, audio, presentation, chat and the computer desktop, it's embedded player can however play only the synchronised recording of the slides, chats and audio captures; the video and desktop captures cannot be played by the software's embedded player. Secondly, Opencast Matterhorn, a lecture acquisition, processing, distribution and playback system and lastly Synote, a web based application that annotates video and audio recordings with bookmarks, notes, tags and captions. It has a transcribing service for transcribing media recordings into text and also provides a platform for searching parts of the recording using bookmarks, notes, tags or captions already created on such media, it can however not record the media itself.*

*The capturing capabilities of BigBlueButton is to be used for capturing the media, the processing and distribution capabilities of Opencast Matterhorn is to be used to process the media (desktop and camera recordings from BigBlueButton) into a format compatible with Synote (typically mp4 for video recordings and mp3 for audio recordings), the media is then distributed to Synote for media transcription and annotations via Matterhorn RSS/ATOM feeds. The result shows that a working system that will enrich the e-learning community can be achieved without incurring any licencing fee by integrating these three open source applications.*

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**Footnote:** All footnotes in this report were accessed on the 13th of September 2012; footnotes are subject to change in the future.

# CHAPTER 1: INTRODUCTION

## 1.1 INTRODUCTION

E-learning can be defined as the use of telecommunication technology to deliver learning contents for educational and training purposes usually for people at different geographical proximity [1]. With the advent of the World Wide Web, especially with the popular web 2.0 [2], e-learning tools have experienced tremendous advancement. Many universities, training institutions and companies are taking advantage of the different state of the art e-learning tools that have been developed to aid the traditional class room learning or to provide a virtual environment where people at different geographical locations around the world are brought together for learning purpose and information sharing; a term popularly known as collaborative learning. Some advantages of e-learning as identified by Donsong Zhag et al [3] are as follows:

- Time and location flexibility
- It can be learner centred and self-paced [4, 5, 6, 7]
- it is cost effectiveness
- it can reach a global audience
- It can provide unlimited access to knowledge as well as knowledge reuse and sharing

E-learning has been observed as the preferred choice for learning rather than the normal traditional class room method [8, 9] and is being widely implemented within the higher education industry [10]. Despite the existence of so many e-learning tools, some of these tools provide only basic functionality; some of which are only text based which can quickly become uninteresting; more sophisticated systems provide learning contents with text, video, sound and image, however, most of them still provide limited interaction and flexibility [3]. For example, users might want to ask question and receive a feedback immediately rather than just reading a blog or a wiki or downloading a training or lecture notes from the internet, others might want to add annotations (e.g. notes, tag) at a specific point in a media in other to facilitate a quick search to that specific point without having to wait until the media gets to the point that contains the keyword that they have searched for. Users might also want media contents to be transferred to different devices such as iPads, iPhones and laptops in specific formats that are compatible with such devices; the list of likely possibilities are endless.

There is currently no holy grain solution that captures the various aspects of creating and managing e-learning contents which can be broadly categorised as **lecture capturing and processing**, **learning management systems** (chats, wikis, blogs, discussion forums, video conferencing, file download etc.), **live web conferencing** and **annotation systems** (e.g. placing comments directly on slides or making some notes on a specific part of a media recording). While most of the already existing e-learning tools are commercial and are available at huge prices or through yearly support plans, some are developed by the open source community (mostly by Universities) and are available for free. Open source software has played a major role in alleviating the cost associated with cost of computing systems in recent years [11]. Mark Aberdour [12] identified some major advantages and disadvantages of open source software; the merits includes **ease of customisations**, **flexible data models and architectures**, **vendor services and support** usually in the form of forums, email lists, documentations and knowledge bases. Other advantages include **avoiding vendor lock-in** and saving of **licencing cost;** as this software are free. Some major disadvantages include increase in **maintenance cost** due to extensive use of third party extensions, it might also involve **expert knowledge** to install and maintain.

The main focus of this report is on three open source software developed within the e-learning environment namely BigBlueButton[1], Opencast Matterhorn[2] and Synote[3]. BigBlueButton is an open source web

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[1] http://www.bigbluebutton.org
[2] http://www.epiphan.com/products/product.php
[3] http://www.synote.org

conferencing systems that provides a platform where people could hold live meetings and record such meetings for future playback. Audio capture, webcam capture, desktop capture, chatting and slides upload are the major highlights of this software. However, it can only record and playback the chats, slides and audio from such recordings and does not support out of the box playback of the video and desktop capture; it however support the playback of this media by integration with Opencast Matterhorn.

Opencast Matterhorn is a media capture software developed by thirteen higher education institution with the aim of providing live lecture capturing, processing and playback of lectures delivered in a typical classroom environment [13], it supports mainly hardware capture device which are provided by third party companies such as Epiphan[4], Ncast[5] and Entwine[6] at different price ranges.

Synote is an award winning web based open source annotation and slidecasting system developed at the University of Southampton for annotating media contents with notes, tags and captions to facilitate easy searching of a particular segment within a media content without listening to the whole media content until it gets to the keyword we have searched for [14]. Users can also transcribe their recording into text using the automatic translation tool provided by the software; Synote does not however have the capability to capture media.

This report provides an integration of these three rapidly growing e-learning software; the recording capability of BigBlueButton is to be used for capturing media, particularly the desktop and webcam captures, these captures are sent automatically to Opencast Matterhorn, which processes the media by converting it into an HTML5 format supported by Synote (mp3 for audio recordings and mp4 for video recordings) and makes it available for distribution through its RSS/ATOM feed. Synote consumes the RSS/ATOM feed generated by Opencast Matterhorn and automatically plays back the recording and makes it possible to annotate the recording as well as text transcription.

## 1.2 THESIS STRUCTURE

The rest of this report is structured as follows;

- Chapter 2 takes a look at various tools that have been developed to aid e-learning.
- Chapter 3 explores the architecture and functionality of BigBlueButton, Opencast Matterhorn and Synote.
- Chapter 4 explains the integration of BigBlueButton, Matterhorn and Synote as well as some testing.
- Chapter 5 contains the conclusion and also provide insights into some future studies.

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[4] http://www.epiphan.com/products/product.php
[5] http://www.ncast.com
[6] http://entwinemedia.com/media_capture/

# CHAPTER 2: REVIEW OF E-LEARNING TOOLS

## 2.1 EXISTING E-LEARNING TOOLS

Different software has been developed over the years targeted at different e-learning sectors and problem domains. For the purpose of simplicity, these e-learning systems will be grouped into four major categories:

- **Learning Management Systems**
- **Web Conferencing Systems**
- **Lecture Capture Systems**
- **Slide casting Systems**

Note that some of the tools explored can conveniently fit into more than one category, but they will be listed in a category that seems to best describe what they do. Emphasis will be given only to E-learning Systems used for educational purposes in primary schools, secondary schools, colleges and universities.

## 2.2 LEARNING MANAGEMENT SYSTEMS (LMS)

Also called **Content Management Systems**; these are usually web based systems created for the sole purpose of designing, documenting, reporting, tracking and sharing of educational materials online. As the web became more interactive, several LMS have been designed by both proprietary software providers and the open source community at large.

Pearson **e-College**[7] founded in 1996 as Real Education; is a Software-as-a-Service provider of learning software. Its major software **Pearson Learning Studio** powers many online programs globally, offering a personalized learning environment to over 9 million students.

**ILIAS**[8] is an open source LMS created in 1997; built with PHP programming language and supports collaborative learning; mainly used as a knowledge and collaboration platform [15].

**Blackboard**[9] is the leading provider of LMS in the world with over 80% stakes in the LMS industry in North America in 2007 [16]. According to Peter Bradford et al [17], blackboard was formed in 1997 with the vision of providing an easy way for college professors to put up course information on the web. In 1998 it merged with **CourseInfo LLC**; a course content Provider Company in Cornell University. It also acquired **MadDuck Technologies**; a Richmond based competitor in 2000, **CampusWide Access Solutions** from AT&T and **CEI SpecialTeams** from iCollege Inc in 2001; all of which are its e-learning competitor. Another competitor; **Promethius** was purchased from George Washington University in 2002, in 2003, assets of transaction system company SA cash was acquired. 2006 witnessed the complete merger with **WebCT** one of its major and probably its biggest competitor. In 2008, it acquired NTI Group, a company offering mass notification services, 2009 witnessed the creation of its mobile platform and acquisition of **ANGEL Learning**; another LMS competitor, 2010 witnessed the partnership with McGraw Hill and acquisitions of **Elluminate** and **Wimba**. Blackboard presently has 6 major platforms; **BlackboardLearn**, **BlackboardConnect**, **BlackboardAnalytics**, **BlackboardMobile** and **BlackboardTransact**. Its BlackboardLearn platform is currently used by more than 20 million daily around the world.

**OLAT**[10] is an open source LMS implemented in Java; it was created at the University of Zurich in 1999, it currently has 70,000 users and is used in nearly 50 institutions in Switzerland.

**Desire2Learn**[11] is a leading provider of Software-as-a-Service LMS. The company formed in 1999, supports more than 8 million learners in healthcare, higher education, government and corporate organisations. It has a

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[7] http://www.ecollege.com/Background.learn
[8] https://www.ilias.de/docu/
[9] http://www.blackboard.com/About-Bb/Who-We-Are/Platforms.aspx
[10] http://www.olat.org/px
[11] http://www.desire2learn.com/about/discover/

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complete Learning Suite which includes **Desire2Learn Learning Environment**, **Desire2Learn ePortfolio**, **Desire2Learn Analytics**, **Desire2Learn Learning Repository**, **Desire2Learn Mobile** and **Desire2Learn Capture**.

**Claroline**[12] was developed in 2001 at Universite catholique de Louvain in Belgium; it's an open source PHP LMS that focuses on online collaboration and learning.

**Moodle**[13] is an open source LMS implemented with PHP modules in 2002 with focus on collaborative creation of contents as well as user interaction; Moodle is another household name in the LMS industry with over 66,000 sites actively running on it with approximately 60,000 users in 216 countries around the world.

**ATutor**[14] is a web-based open source LMS designed with PHP in 2002, it was developed to address the issue of making e-learning available to disabled and visually impaired people; accessibility and adaptability are its focal point.

**Sakai**[15] is a free open source software designed with Java's service oriented architecture; released in 2005, it presently has two main products; the **Sakai CLM** (Collaboration and Learning Environment) and the new **Sakai OAE** (Open Academic Environment). Sakai is mainly used for collaborative teaching, learning and research. The Sakai CLE currently has over 4 million educational users around the world.

**Dokeos**[16] is a simple open source e-learning software developed with PHP, JavaScript and HTML. It was formed as a fork of Claroline LMS; it comprises of three main tools namely; a **learning management system**, **rapid learning authoring tool** and **videoconferencing tools**[17]. It currently has over 4 million users; there are also plans to release a mobile version which is now in its beta phase.

Other open source LMS Solutions includes **Canvas**[18]**, Chamilio**[19], **E-front**[20], **Fedena**[21], **Metacoon**[22], **WebWork**[23] and **DotLRN**[24]. Other proprietary LMS solutions include **Absorb LMS**[25], **Alpha Study**[26], **CCNet**[27], **JoomlaLMS**[28], **SharePointLMS**[29] and **Inquisiq LMS**[30].

## 2.2.1 COMPARISON OF OPEN SOURCE LMS MARKET

An analysis of some open source LMS market was conducted below; the analysis as presented in [12, 18] was based on the requirement of different LMS market sectors such as **large scale market (Table 1)**, **small and medium sized business (Table 2)**, **Government and public sectors (Table 3)**, **educational sector (Table 4)** and **rapid rollout (Table 5)**; this is not really a sector, but the LMS are analysed based on how quickly they can be deployed.

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[12] http://www.claroline.net/histoire-de-claroline/
[13] http://moodle.org/stats/
[14] http://sourceforge.net/projects/atutor/
[15] http://www.sakaiproject.org/sakai-products
[16] http://dokeos.com
[17] http://www.cedma-europe.org/newsletter%20articles/Kineo/Product%20review%20-%20Dokeos%20(Nov%2008).pdf
[18] http://www.instructure.com/
[19] http://www.chamilo.org/
[20] http://www.efrontlearning.net/
[21] http://www.projectfedena.org/
[22] http://metacoon.net/
[23] http://webwork.maa.org/
[24] http://www.dotlrn.org
[25] http://www.absorblms.com/
[26] http://www.alphastudy.com/home/
[27] http://www.zumosoftware.com/products.htm
[28] http://www.joomlalms.com/features/
[29] http://www.sharepointlms.com/
[30] http://www.inquisiqr3.com/

**Table 1: Top 4 LMS in the large scale market (Adapted from [18])**

| Functionality | dotLRN | ilias | Moodle | Sakai |
|---|---|---|---|---|
| HR and Financial system integration | 2 | 2 | 2 | 4 |
| Classroom learning in course catalogue | 10 | 10 | 10 | 10 |
| Detailed reports on usage, results, costs, feedback | 9 | 8 | 7 | 10 |
| Competency profiling | 0 | 10 | 0 | 0 |
| Self-enrolment | 10 | 10 | 10 | 10 |
| Batch registration of users | 10 | 10 | 10 | 10 |
| Ease of rebranding | 6 | 6 | 10 | 10 |
| **Percentage Score** | 67 | 80 | 70 | 77 |

- **ilias** is the top performer in this group.

- A unique feature of ilias is called **competency profiling**; which simply means some learning objectives; for example pre-test for skill-gap analysis or an assessment that must be passed before the learning objective can be achieved.

**Table 2: Top 4 LMS in the small and medium sized business (Adapted from [18])**

| Functionality | Atutor | Ilias | Moodle | Sakai |
|---|---|---|---|---|
| Competency profiling | 0 | 10 | 0 | 0 |
| Assessment engine | 10 | 10 | 10 | 10 |
| Content authoring | 10 | 10 | 10 | 10 |
| Collaboration tools | 10 | 8 | 10 | 10 |
| Ease of rebranding | 10 | 6 | 10 | 10 |
| **Percentage score** | 80 | 88 | 80 | 80 |

- **ilias** is once again tops in this market due to its competency profiling feature that makes it possible to measure skills with job roles to determine areas of improvement.

- Although, **Atutor**, **Moodle** and **Sakai** all outperform **ilias** in collaboration tools and Ease of rebranding.

**Table 3: Top 4 LMS in Government and public sectors (Adapted from [18])**

| Functionality | Ilias | Moodle | Sakai |
|---|---|---|---|
| Extensible using web services | 10 | 10 | 10 |
| Learner feedback and evaluation | 10 | 10 | 10 |
| Detailed reports on usage, results, cost, feedback | 8 | 7 | 10 |
| Batch of users | 10 | 10 | 10 |
| Collaboration tools | 8 | 10 | 10 |
| Competency profiling | 10 | 0 | 0 |
| Individual learning plans | 10 | 10 | 10 |
| **Percentage score** | 94.3 | 81.4 | 85.7 |

- **ilias** once again is tops here due to competency profiling, excluding competency profiling out of the ratings definitely makes **Sakai** take top spot.

**Table 4: Top 4 LMS in the educational sector (Adapted from [18])**

| Features | ATutor | Ilias | Moodle | Sakai |
|---|---|---|---|---|
| *Assessment engine* | 10 | 10 | 10 | 10 |
| *User/collaboratively created resources* | 10 | 10 | 10 | 10 |
| *Accessibility* | 8 | 5 | 5 | 8 |
| *Personalised preferences* | 10 | 10 | 10 | 10 |
| *Lesson planning* | 0 | 0 | 0 | 0 |
| *Self-enrolment* | 10 | 10 | 10 | 10 |
| *Activity sequencing and scheduling* | 5 | 10 | 10 | 10 |
| *Batch registration of users* | 10 | 10 | 10 | 10 |
| *Collaboration tools* | 10 | 8 | 10 | 10 |
| *Extensible using web services* | 10 | 10 | 10 | 10 |
| *Student admin system and integration* | 2 | 2 | 2 | 2 |
| **Percentage score** | 77.3 | 77.3 | 79.1 | 89.1 |

- **Sakai** takes top spot here, but **Moodle** seems to have greater visibility and penetration in this sector.

- **ATutor** and **Sakai** are both WCAG 1.0 AA compliant[31]; hence are ahead in the accessibility category while the other two are not clear about which accessibility statement to follow.

**Table 5: Top 4 LMS for rapid rollout (Adapted from [18])**

| Features | ATutor | Claroline | Dokeos | Moodle | OLAT | Sakai |
|---|---|---|---|---|---|---|
| *Assessment engine* | 10 | 10 | 10 | 10 | 10 | 10 |
| *Self-enrolment* | 10 | 10 | 10 | 10 | 10 | 10 |
| *Batch user registration* | 10 | 10 | 10 | 10 | 10 | 10 |
| *Learner feedback and evaluation* | 10 | 10 | 10 | 10 | 10 | 10 |
| *Ease of rebranding* | 10 | 10 | 10 | 10 | 10 | 10 |
| **Percentage score** | 100 | 100 | 100 | 100 | 100 | 100 |

- The table clearly shows that majority of the LMS are worthy solution for rapid rollout if the objective is to get an LMS out as soon as possible with minimal tweak.

## 2.3 WEB CONFERENCING SYSTEMS

These are tools mainly used to support lectures, online meetings, trainings, presentations and collaborative learning usually via the internet using either standalone applications installed on the computer or web based application. They include functionality such as audio, video, desktop, whiteboard and webcam sharing to mention a few [19]. The highlight of web conferencing tools is the possibility to schedule and participate in a live meeting with high number of attendees [20] and also without geographical limitations. The disadvantages of web conferencing tools include the cost incurred in procuring equipment such as web-cameras, headset and high speed internet access [21]. The web conferencing market is dominated by proprietary software but some open source solutions still exist.

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[31] http://www.w3.org/TR/WCAG10/

**Dim Dim**[32] began in 1996 as an open source software designed to fit various requirements and learning needs of different users; it was recently acquired by salesforce in 2011. It requires no download or installation of any software, its ease of use is seen when starting a conference, defining user roles or importing users [22].

**WebEx**[33] was founded in 1996 to produce creative ideas using collaborative work. Users can share all sort of multimedia contents which include audio, video, documents as well as their desktop [19]. WebEx was however acquired in 2007 by Cisco as a complimentary product for its audio/video web conferencing hardware products [24].

**FuzeMeeting**[34] was created by FuzeBox (founded in 1998) to create a browser based virtual and collaboration environment for sharing information.

**GotoWebinar**[35] is a citric online family range of products for holding events and webinar online. Another range of its product is the **GotoMeeting**[36] used for holding online meetings. The company was established in 2001 in Karlsruhe, Germany.

**Open Meetings**[37] was launched with a vision of creating a popular open source web conferencing platform in 2006. It has been downloaded over 250,000 times but does not however have an active user community as BigBlueButton (another open source web conferencing system); which is limiting its improvement. It is currently offered as a hosted service but can also be installed on a local server [19].

**Fast Viewer**[38] was founded in 2008; it currently provides a virtual environment for communication w suitable for customer service, support service, remote maintenance and sales support.

**BigBlueButton** is an open source web conferencing tool that was first created in 2007 at Carleton University. It cost nothing to download; only a server is required to host the software. It facilitates sharing of audio, video, documents, webcam and desktop amongst others. It has similar functionality with Adobe Connect Pro and is supported by a very active user community [19].

**Lotus Sametime Unyte Meeting**[39] is an on demand web conferencing services created by IBM after the acquisition of **WebDialogs** in 2007[40] [24]

**SaasBoard**[41] is a web conferencing software created by Neuronet INC in 2008. It provides a Software-as-a Service web conferencing and collaboration tool.

**Live Meetings**[42] was originally acquired by Microsoft through the acquisition of Placeware; one of the first web conferencing software vendor. It is targeted at users that require an on-demand conferencing especially in sales and marketing [24]. Microsoft also has an online version of it called **LyncOnline**[43].

**Adobe Connect Pro**[44] is a web conferencing tool that supports the creation and management of virtual classrooms, online meetings as well as group collaboration. It enables both educational institutions as well as

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[32] http://www.dimdim.com/
[33] http://www.webex.com/
[34] https://www.fuzebox.com/about
[35] https://www.gotowebinar.com
[36] http://www.gotomeeting.co.uk
[37] http://incubator.apache.org/openmeetings/
[38] http://www.fastviewer.com/portrait_en.html?ActiveID=1172
[39] https://www.webdialogs.com/join/default.asp
[40] http://www-03.ibm.com/press/us/en/pressrelease/22210.wss
[41] http://www.neuronet.co.jp/en/company.html
[42] http://office.microsoft.com/en-us/live-meeting-help/
[43] http://www.microsoft.com/en-us/office365/lync-online.aspx
[44] http://www.adobe.com/products/adobeconnect.html

corporations to hold trainings, meetings and lectures [19]. Its user interface is fairly simple for both the trainer and the trainee [23] and is highly customizable.

**WizIQ**[45] is a web conferencing tool whose popularity has increased in recent time. It's an online platform that facilitates teaching and learning of any subject in real time via a virtual classroom [19]. It is a platform that connects students with interest in a particular field or subject to teachers in that field. Both teachers and students need to register and create a profile which takes minimal effort to do.

**Yuuguu**[46] is an easy to use web conferencing and screen sharing software; it is highly customizable within a short period of time and suite users without expertise knowledge.

**Yugma**[47] provides an easy to use software as service web conferencing solution to individuals, small businesses and large enterprises.

**Zoho Meeting**[48] is designed to be an online meeting place designed for business owners to meet their remote customer online showcasing sales demo and other forms of presentations.

**BlackBoard Collaborate**[49] was formed as a result of acquisition of two multimedia companies called **Wimba** and **Elluminate**. It helps create a virtual classroom, meeting space or offices for users and offers a collaborative and interactive learning experience.

**WebHuddle**[50] is a new open source web conferencing tool that is still in its beta period of release; the service is free to use during this period and since its open source; it can also be download and installed on the local machine.

**VenueGen**[51] is a 3D browser based virtual meeting software developed by Venue Network to add more flavour than the conventional 2D web conferencing software.

**Team Hangout**[52] is a free web based conferencing application designed to share screen, voice or video. It is a useful solution to quickly share work with friends without the need of any sophisticated software installation. It also has a Facebook application that can allow sharing of work with the users' friend list on Facebook.

**Team Viewer**[53] is a remote control and online meeting software for remote controlling any computer on the internet or sharing contents on online meetings.

**Bankle Meeting**[54] is a rich web conferencing and collaboration tool for holding live web meetings, scheduled meetings, webinars and e-learning sessions.

Other web conferencing tools include **spreed**[55], **RHUB**[56], **iLinc**[57], **FaceMe**[58], **eLecta Live**[59] and **buddyMeeting**[60]

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[45] http://www.wiziq.com/
[46] http://www.yuuguu.com
[47] https://www.yugma.com/products/webinar.php
[48] http://meeting.zoho.com
[49] http://www.blackboard.com/platforms/collaborate/overview.aspx
[50] https://www.webhuddle.com/aboutpage.jsp
[51] http://www.venuegen.com/
[52] http://www.teamhangout.com/
[53] http://www.teamviewer.com/en/index.aspx
[54] http://banckle.com/apps/meeting/overview.html
[55] http://www.spreed.com/eu
[56] http://www.rhubcom.com/
[57] http://www.ilinc.com/
[58] http://www.faceme.com/
[59] http://www.e-lecta.com/webconferencing.asp
[60] http://www.buddymeeting.com/

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## 2.3.1 COMPARISON OF WEB CONFERENCING SYSTEMS

**Table 6: (Part I) Analysis of the functionality of major web conferencing tools** (Adapted from techsoup[61] and socialbrite[62])

| APPLICATION | Adobe Acrobat ConnectPro | DimDim | GoToWebinar | IBM Lotus Live | Microsoft Office Live Meetings | Cisco WebEx Meeting | Yugma Pro | YuuGuu | Zoho Meeting | BigBlueButon |
|---|---|---|---|---|---|---|---|---|---|---|
| **SETUP** | | | | | | | | | | |
| Software Required | No downloads, supports instant web conferencing for any Windows, Mac, or Linux operating system. | No downloads, supports instant web conferencing for any Windows, Mac, or Linux operating system. | No downloads for participants, supports instant web conferencing for any Windows or Mac operating system. | No downloads, supports instant web conferencing for any Windows, Mac, or Linux operating system. | No downloads, supports instant web conferencing for any Windows, Mac, or Linux operating system. | No downloads for participants, will run on any internet server or smart phone mobile device. | No downloads, supports instant web conferencing for any Windows, Mac, or Linux operating system. | No downloads for participants, will run on any internet server or smart phone mobile device. | No downloads. Will run through Firefox and Internet Explorer with plug-ins. | No download for participants, adobe flash is compulsory, supports instant web conferencing for any Windows, Mac, or Linux operating system. |
| Licence | Proprietary | Proprietary | Proprietary | Proprietary | Proprietary | Proprietary | Proprietary | Proprietary | Proprietary | LGPL |
| Invitation Tools | Online calendar and meeting scheduler, Microsoft Office Compatibility | Instant or Planned Meetings with smart URLs. Invitations from DimDim, Local Email Addresses, or smart URL can be used as simple log in. | Automated email templates, instant or planned webinars and meetings, webinar registration pages | Instant or planned meetings. Link to registration page, email sent through IBM, or instant meeting | Linked into Microsoft Outlook as an Add-In, providing 'Meet Now' button to create ad hoc meetings. | Send meeting invitations and reminders using an automated phone call, text message, email from your local client, or IM. | Registration Page, Email Templates | Instant Meetings or Automatic Email Templates. | Invitations from the Zoho Meeting web page or conference in from the presenter. | Instant or Planned Meetings (via external software API such as Sakai, Moodle or Drupal ) |

**Table 6: (Part II) Analysis of the functionality of major web conferencing tools**

| COLLABORATION | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Screen Sharing | Desktop and Applications | Desktop and Applications | Desktop and Applications | Desktop and Application | Desktop and Applications | Desktop and Applications | Desktop, Shared File Space, Single Application Sharing | Desktop and Applications | Desktop | Desktop |
| Multiple Presenters | Yes | Yes - Max of 4 | Yes | Yes | Yes | Yes | Yes | Yes | Yes | No |
| Annotating Tools | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | No | Yes, but not recorded for playback |
| Text Chat | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes |
| Teleconferencing | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes |
| VoIP | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes |
| Mobile Access | | Yes | No | | No | iPhone and Blackberry devices | Yes | Yes | No | Yes |

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[61] http://www.techsoup.org/learningcenter/internet/page5975.cfm
[62] http://www.socialbrite.org/2011/01/19/comparison-top-web-conferencing-services/

**Table 6: (Part III) Analysis of the functionality of major web conferencing tools**

| OTHER | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Recording | Yes | Yes with Pro and Webinar | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes |
| Other Product Offerings | Adobe ConnectNow (up to 20 participants) and Adobe ConnectPro (up to 1500 participants) | DimDim Free (up to 10 participants), DimDim Pro(up to 50 participants), and DimDim Webinar(up to 50 person meetings and 1,000 attendee events), DimDim Business | GoToMeeting - for meetings of 15 people or less which is included in a GoToWebinar subscription(up to 1000) | IBM Lotus Live Meetings(up to 200 participants), Events(up to 1000 participants), Connections, Engage, Notes and iNotes | Professional (up to 250 participants per meeting) and Standard Editions(up to 1250 participants per meeting) | WebEx Support Center (up to 10 participants), WebEX Training Center (up to 1000 learners), WebEx Event Center (up to 3000 people) | Yugma Skype Edition, Yugma Free, Yugma Pro 20/50/100/500 | Yuuguu Plus and upgrades available. (30 users for single user) | Use with Zoho Chat and Zoho Show (up to 100 participants) | None, up to 80 participants depending on server configuration but practical limit of 25 users |
| Polling and Survey | Yes | Yes with Pro and Webinar | Yes | Yes | Yes | Yes | Quick Poll and Q&A | Yes | No | No |
| Post-Meeting Reports | Yes | Yes with Pro and Webinar | Length of stay in meeting and interest metrics | Participant roster and polling | Yes | Yes | Registrant and Attendee information available | Customizable | Session Reports | No |
| Trial Version | 30-day | DimDim Free | 30-day free trial for Pro, Webinar & Business | 30-day | Yes | 14-day - up to 25 people per meeting | Yugma Free (up to 20 participants). Yugma Pro trial is 15 days | Entry level is free - up to 5 participants | Free Edition - one host and one participant and 30 day free trial | None, free to use |

## 2.4 LECTURE CAPTURE SYSTEMS

These are systems that are used for recording events or classroom activities using specific software/hardware and making the recordings available electronically. The media which can be **audio only**, **audio and video only**, **audio, video and slides only** are usually stored on the internet for playback on laptops, mp3 players or iPods [25]. This market is also dominated by proprietary software producers. Some advantage of lecture capture systems as highlighted in Erping Zhu and Inger Bergom [25] are:

- Provision of additional material (e.g. archived lectures, to demonstrate difficult concepts e.g. printmaking, tutorial for lab sessions, presentations by guest speakers)
- Allows student to learn and review materials at their own pace.
- An alternative when students miss classes
- Allows flexibility in note taking

**MediaSite**[63] was designed by Sonic Foundry in 2001 to provide a platform to manage, capture, deliver, search and analyse videos from lectures, online trainings, conferences etc.

**Presentation2Go**[64] was developed at Wageningen University in the Netherlands; it is designed for effortless recording, storage and live streaming of lectures, presentation, online meetings etc.

**Panopto**[65] created in 2007 is a creator of innovative video capture and management software. Panopto provides webcasting, video recording, video content management, search, editing etc. to any laptop or iOS device.

**Cattura**[66] was founded in 2008 by a group of educational technology experts; it captures, encodes, analyse, enrich and publish course contents and live educational activities to an array of open video and learning management platforms.

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[63] http://www.sonicfoundry.com/who-we-are
[64] http://www.presentations2go.eu/index.php/products/overview
[65] http://www.panopto.com/
[66] http://www.catturavideo.com/

**Matterhorn**[67] was released in 2010 as an open source lecture capture software for the management of audio and video content targeted at the educational sector.

**Galicaster**[68] is an open source software created by Teltek Video Research in 2011 to provide solutions for recording educational media contents such as lectures and conferences. It also provides integration with other open source video conferencing software like **AccessGrid** and **Matterhorn**.

**Polycon**[69] is a telepresence, video and voice provider; its product **RealPresence** interoperates with businesses, mobile, social application and devices. It acquired **Accordent technologies**; a leading provider of lecture capture technologies in 2011.

**Echo360**[70] captures audio and video sources and existing course visuals from symposiums, camera etc.; it transforms AAC course audio and H.264 video and VGA sources into ready-to-play rich media and podcasts.

**Desire2Learn Capture**[71] provides organizations with the ability to effortlessly capture and broadcast media presentation with video, audio and visual aids to online audiences.

**Tegrity Campus**[72] provides a fully automated lecture capture solution used in traditional, hybrid and online courses to record classroom activities.

**Camtasia Relay**[73] is a screen recording software that facilitates lecture capture, presentations and meetings from virtually everywhere and on any platform.

**Vidizmo**[74] is an innovative lecture recording software that schedules and record live classrooms or meetings and transfer the recording to major learning management systems or content management systems for on demand viewing.

**ProfCast**[75] is used for recording lectures; it comprises of PowerPoint and/or Keynote slides for creating enhanced podcasts.

**Qumu Quick Capture**[76] is a browser based capture tool for simultaneous recording of the screen, webcam and audio source.

Other lecture capture device include **screenwatcher**[77], **perfectnotes**[78], **encoded media lecture capture**[79] and Cisco's **digital media suites**[80].

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[67] http://opencast.org/matterhorn/
[68] http://wiki.teltek.es/display/Galicaster/Galicaster+project+Home
[69] http://www.polycom.co.uk/
[70] http://echo360.com/
[71] http://www.desire2learn.com/products/capture/
[72] http://www.tegrity.com/
[73] http://www.techsmith.com/camtasia-relay.html
[74] http://www.vidizmo.com/Solutions/LectureCapture.aspx
[75] http://www.profcast.com/public/index.php
[76] http://www.qumu.com/
[77] http://www.screenwatch.com/pages/evalmain.html
[78] http://www.perfectnotes.com/
[79] http://red-solutions.co.uk/solutions/encodedmedia/emEdu_lecturecapture.asp
[80] http://www.cisco.com/en/US/products/ps9339/Products_Sub_Category_Home.html

## 2.4.1 COMPARISON OF LECTURE CAPTURE SYSTEMS

**Table 7: (part I) Lecture capture system comparison** (Adapted from itc.und.edu[81])

| | Panopto | Tegrity | MediaSite | Echo360 | Galicaster | Matterhorn |
|---|---|---|---|---|---|---|
| **What is captured ?** | Captures video, audio, screen activity. Abitliy to record audio/video, powerpoint/Keynote from a Mac | Captures video, audio, screen activity | Captures video, audio, screen activity. Capture from a Tablet PC, Document Camera or Electronic Whiteboard. Records Full Motion Video | Captures video, audio,screen activity | Captures video, audio,screen activity | Captures video, audio, screen activity |
| **System Type** | Software based | Web based (no software hardware required) | Appliance-Based;one server supports 20 recorders | Appliance-Based for full video capture; podium PC requires only software, but captures only screen and audio | Software based | Appliance-Based but can be software based through TheRecMatterhon or integration with third party open source software such as BigBlueButton and Galicaster |
| **Licence** | Proprietary | Proprietary | Proprietary | Proprietary | open source (CC) | open source (CC), source is available under (ECL) |
| **Accesibility** | Generated by a leader in automatic captioning, Automatic sync Technologies. Requires an AST account (AST will charge for their service independently) | Tegrity does support accessibility, and closed captioning specifically; closed captioned file for lecture recordings can be easily imported into and synchronized with Tegrity lecture recordings in standard.txt and .srt formats. Automatic caption also generated by through AST integration. | Automated Closed Captioning (with additional service) Standard Closed Captioning | Automatically apply section 508 closed captions as needed. Integrated closed captioning and screen reader versions of the lectures support students with disabilities | Can support captioning with third party software integration | Has an option to specify if caption is required or not during capturing or during uploading of a recording. Can also use Opencaps for captioning |
| **Room hardware required** | None required. Works with existing room hardware (cameras, computers,microphones). | None required. Works with existing room hardware (cameras, computers,microphones). | Requires Mediasite Ex Server and Mediasite Recorder. Room integration with Creston & AMX | Recording appliance for video; otherwise works with existing hardware. | None required. Works with existing room hardware (cameras, computers,microphones). | Recording appliance for video; otherwise works with existing hardware |
| **Publishing option** | Can publish to LMS, Web portals, RSS/ATOM | Tegrity Store and Deliver Service, iPhone app | Organize and Secure your content through Multiple Catalogs (Private and Public), RSS | Can publish to LMS, iTunes U, Web portals, RSS, VLE and E-mail | Can publish to matterhorn and AccessGrid. | Can publish to LMS, Web portals, RSS/ATOM, Progressive and Streaming Server |

**Table 7: (part II) Lecture capture system comparison**

| | | | | | | |
|---|---|---|---|---|---|---|
| **Media Storage** | Local storage; hosting option and in the Cloud | Tegrity Store, Deliver Service Tegrity Virtual Appliance and in the Cloud | Mediasite Servers and the Cloud | Published and stored on local servers and the Cloud | Published and stored on local servers, media can be ingested to third party softwares like matterhorn | Published and stored on local servers |
| **Interactive feautures** | Time-stamped note taking on slides using LiveNotes | Time-stamped note taking on slides using PowerNotes, iPhones App allows student to mark points that they did not understand in a presentation, also, student recording is possible. It also has an integration with facebook | Create polls for audience or share a presentation link with time-stamped bookmark | Student can bookmark key points within a lecture and engage with classmates on course content through discussion threads. | None | None |
| **Mobile Support** | Yes | Yes | Yes | Yes | Yes | Yes |
| **Live Streaming** | Yes, via CourseCast Live | Yes, if enabled | Yes, Live and ON-Demand Streaming;can pause live recoding | Yes | Possible through third party software | Yes |
| **Playback Option** | Automatic creation of RSS feeds and audio (mp3) files which viewers can listen to on portable media devices such as iPhones or iPods. Premium version offers new support of H.264/MPEG4 enabling viewers to watch recordings (video+audio) on portable media devices such as iPhones and iPods. | Browser, iPod and iPhone, Mp3 players, Mobile Device, Download, Android Devices, Facebook integration. | iPads, iPods, iPhones, Mobile Devices, Windows Media Player or Silverlight, RSS by subscribing to a user's favourite Mediasite Catalogues. | Browser, iPod, Mp3 players, iTunes, Smart Phones, RSS | Through third party software | Browser, iPod and iPhone, Mp3 players, Mobile Device, Download |
| **Reporting** | CourseCast Analytics; presenters can find graphs and data on what viewers are watching, their recordings, frequency of watching and which part of the recording are mostly viewed. | Tegrity Reporting Service provides visibility to Tegrity usage, as well as cross-correlating that information with grades and class completion rates. Monitor performance, instantaneously generate usage reports, and customize settings. | Reports number of views, time viewed, Number of Responses; who's watching what, when and how long. Server utilization statistics | EchoSystem's data reporting provides Understand viewing habits, most popular lectures, the point within a lecture that received most traffic and system capacity. | Possible through third party software | Engage player displays the most viewed point in a recording |

## 2.5 SLIDECASTING SYSTEMS

This is a term used to describe systems that are specially designed to synchronize slides and audio together. It is often referred to as podcasting; synchronizing PowerPoint with audio [26]. According to Adam Perryman [27] a slidecasting application could also support **playing of videos**, **user interaction**, **annotation of media content, transcript production**, **printing of useful content in a presentation** and **content restriction.**

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[81] http://itc.unt.edu/sites/default/files/Lecture_Capture_Systems_Comparison_Chart_rev2010721.pdf

**Synote**[82] is a web based slidecasting and annotation application for creating synchronized annotations (bookmarks, notes, tags, captions, links) otherwise known as 'synmarks' on media recordings such as audio, video, slides/images and generated media transcript. It also facilitates searching and replaying part of a media recording based on the annotations earlier created on them.

**Slidecasting 2.0** is a collaborative slidecasting application that was developed by the University of Vienna (only currently available to members of the same university) to facilitate live annotations (e.g. notes) on slides during a lecture and associating such annotations to specific points on the slide during a live lecture. After the lecture is concluded, students can also edit, add, delete and read annotation in a fashion synonymous to a wiki [28].

**Slidecast**[83] is a web based application that synchronizes slides, multimedia presentations, charts and chats for distribution over the internet. It currently comes in three modes; **SlideCast Lite**, **SlideCast Presents** and **SlideCast Webinar**.

**SlideShare**[84] is a web based application for the creation and distribution of slidecast. It is the most widely used web based slidecasting application around the world with 60 million monthly visitors and 130 million page views.

## 2.5.1 COMPARISON OF SLIDECASTING SYSTEMS

**Table 8: Comparison of slidecasting applications**

| | Synote | SlideCast | SlideCasting 2.0 | SlideShare |
|---|---|---|---|---|
| **Slides** | Yes | Yes | Yes | Yes |
| **Audio** | Yes | Yes | No | Yes |
| **Video** | Yes | Yes | No | Yes |
| **Transcript Production** | Yes | No | No | Yes |
| **Security (password)** | Yes | Yes | No | Yes |
| **Printing of Slides** | Yes | Yes | Yes | Yes |
| **Collaboration technique** | Bookmarks; notes, caption, tags, links | Attendee can ask private question directed at the presenter, real time polls, chatting with presenter and amongst the attendees | users can add live annotations and can edit, delete, read and write annotations on slides after recording | Comments can be added to the slides |

## 2.6 SUMMARY

In summary, the LMS industry is dominated by both proprietary software and open source software; of which **Blackboard** is a dominant name in this sector, but some open source solution like **Sakai** and **Moodle** also exist which are also gaining good ground. The web conferencing industry is dominated by proprietary software providers like **Adobe Connect Pro** and Cisco **WebEx** amongst others; the open source community is represented by **BigBlueButton** and **OpenMeetings** respectively. The lecture capture industry is also dominated by proprietary software providers with **Panopto**, **Tegrity** and **Echo360** being household names, **Opencast Matterhorn** and **Galicaster** provides an open source alternative. The slidecasting industry has the fewest

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[82] http://www.synote.org
[83] http://www.slidecast.com/index.php
[84] http://www.slideshare.net/

number of software with **Slideshare** being the most popular in this industry; **Synote** provides an open source alternative.

Since the goal of this project is to provide an open source solution that will enrich the E-learning community at zero licencing cost, BigBlueButton was chosen to provide a virtual meeting place as it offers good enough functionality when compared with other proprietary web conferencing providers; it also has a very active community which has been pivotal in its development when compared to other open source alternative like OpenMeetings; there are also plugins for integration with existing major LMS like Moodle, Sakai and Atutor etc. which facilitates the creation and scheduling of live web conferencing meetings from within the LMS.

Apart from the lack of major interactive features (e.g. note taking), Matterhorn provides most of the functionality offered by most proprietary lecture capture software, It also has a seamless integration with BigBlueButton that facilitates processing of desktop and lecture capture from BigBlueButton for distribution to LMS or other e-learning software using its RSS/ATOM feeds. The seemingly lack of interactive feature in Matterhorn can be compensated for by integration with slidecasting applications such as Synote which offers more interactivity with slidecast or video recordings. When compared with other major slidecasting applications, Synote provides good enough features, if not even better than other proprietary software providers especially the popular Slideshare. It can be said that open source solution can compete with their proprietary counterparts.

# CHAPTER 3: BIGBLUEBUTTON, OPENCAST MATTERHORN AND SYNOTE

## 3.1 BIGBLUEBUTTON (BBB)

BigBlueButton is a web conferencing application built on over fourteen open source component; it runs on Mac, UNIX and PC computers. Some of the open source components software used are Ubuntu[85], Flex SDK[86], Ghostscript[87], Grails[88], ActiveMQ[89], Image Magick[90], MySQL[91], Nginx[92], Red5[93], SWF Tools[94], Apache Tomcat[95], Open Office[96], Freeswitch[97], Redis[98] and Popcorn.js[99]. The current version as at of writing is version 0.80 released on the 18th of June 2012. The BBB source codes can be downloadable from Git Hub[100].

## 3.2 ARCHITECTURE OF BIGBLUEBUTTON

Figure 1 below describes how each open source components in BBB are connected together and how they function. Figure 2 gives more insight into how the core server side Red5 applications are connected together.
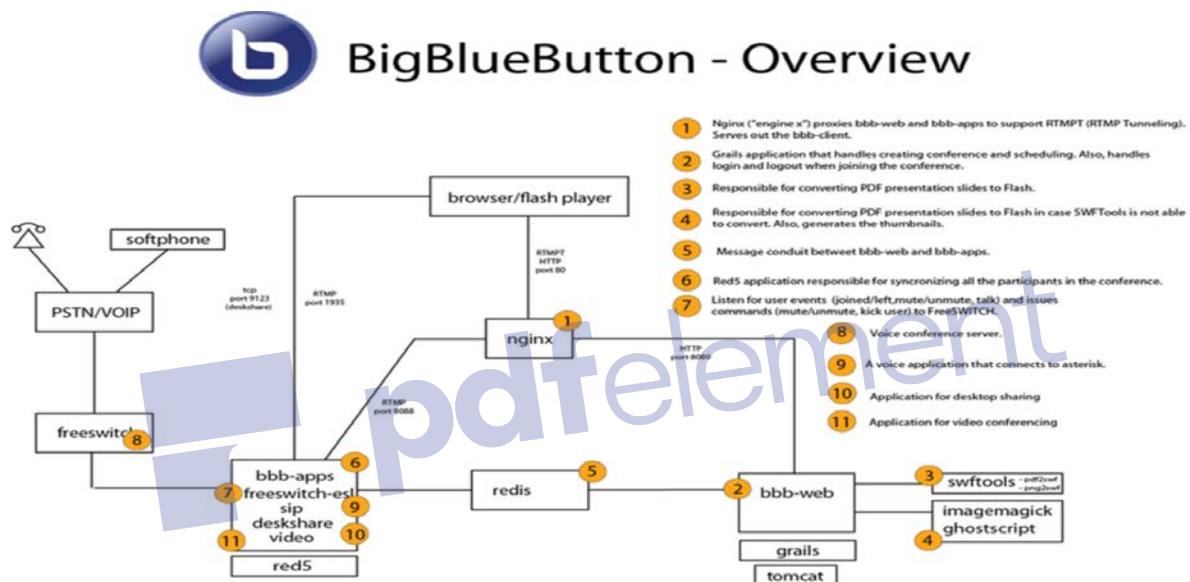


Figure 1: Overview of BigBlueButton components[101]

**1) Nginx** is a web and reverse proxy server used in BBB for the purpose of HTTP tunnelling; whereby a client connects with the port 80 (mostly when a user's corporate firewall blocks access to other port except 80)

[85] http://www.ubuntu.com/
[86] http://sourceforge.net/adobe/flexsdk/wiki/About/
[87] http://www.ghostscript.com/
[88] http://grails.org/
[89] http://activemq.apache.org/
[90] http://www.imagemagick.org/script/index.php
[91] http://www.mysql.com/
[92] http://nginx.org/
[93] http://www.red5.org/
[94] http://www.swftools.org/
[95] http://tomcat.apache.org/
[96] http://www.openoffice.org/
[97] http://www.freeswitch.org/
[98] http://redis.io/
[99] http://popcornjs.org/
[100] https://github.com/bigbluebutton/bigbluebutton
[101] http://code.google.com/p/bigbluebutton/wiki/ArchitectureOverview

instead of the usual port 1935 used by BBB for Real Time Messaging Protocol (RTMP). It also route calls to BBB clients to tomcat (port 8080) when BBB API is called from a third party integration application.

**2) Bbb-web** is a Grails application that handles creation and management of conferences. It also handles the login in and logging out feature of the BBB client.

**3) Swftools** is responsible for converting pdf presentations to flash.

**4) Imagemagick** and **Ghostscript** attempts to convert presentations to pdf if swftools fails.

**5) Redis** is an advanced key-value store that sends message update about the presentation conversion to **bbb-apps**; which consist several sever side Red5 applications namely presentation, voice, chat and participant applications (see Figure 2).

**6) Red5** server side applications for synchronizing all participants in the conference.

**7) Freeswitch-event socket library** listens for user events such as when users are talking, joining the conference, muting and un-muting or leaving the conference. It also issues commands such as mute, un-mute and kick user (evicting someone from the conference) to FreeSWITCH.

**8) Freeswitch** is a voice and chat conferencing server.

**9) Sip** is a signal controlling protocol used for controlling voice application over the internet when connecting with Asterisk.

**10) Deskshare** is a red5 application for desktop sharing.

**11) Video** is a red5 application for video conferencing.
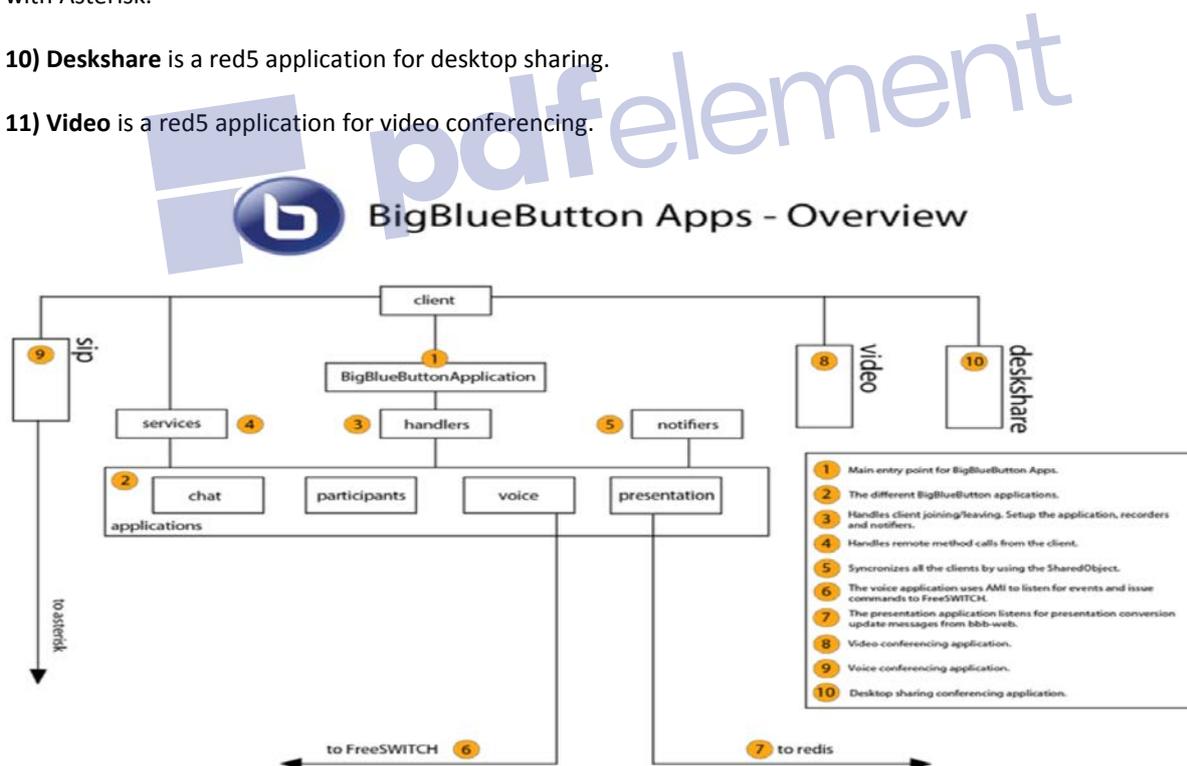


Figure 2: Overview of Red5 server side applications[102]

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[102] http://code.google.com/p/bigbluebutton/wiki/ArchitectureOverview

## 3.3 INSTALLING BIGBLUEBUTTON v 0.80

There are basically two ways of installing the BBB server:

- Using a Virtual Machine
- On Ubuntu Desktop/Server 10.04 Version (32 bit or 64 bit)

### 3.3.1 INSTALLING BIG BLUE BUTTON v 0.80 ON VIRTUAL MACHINE (BBB VM)
**REQUIREMENTS**

- VMWare Player[103] (or VMWare Workstation) for UNIX or Windows
- VM Fusion[104] for Mac
- Minimum of 2G of RAM
- DHCP Server for acquiring an IP Address on boot

**INSTALLATION**

A detailed guide on how to install BBB VM is provided in Appendix A. Refer to appendix for installation details. Installing BBB on VM is good for testing purpose but not recommended for deployment environments.

### 3.3.2 TROUBLESHOOTING BBB VM INSTALLATION

In attempting to install BBB on a VMWare Player, the first attempt was not successful as the VMware could not access the internet. It was discovered that the VMware Player network setting was set to **NAT** and not **Bridge Mode.** This is a common problem experienced when installing on VMware Player. After changing the network settings to Bridge Mode, BBB was still not accessible from the web browser. With the help of the BBB community[105] it was discovered that even after changing the network settings from NAT to Bridge mode, there was still a need to type the command **"sudo /etc/init.d/networking restart".** Other installation issues could be rectified by checking the installation page[106].

### 3.3.3 INSTALLING BIG BLUE BUTTON v 0.8 ON UBUNTU 10.04
**REQUIREMENTS**

- 2GB of memory (4GB is better)
- Ports 80 (used by nginx), 1935 (used red5), 9123 (used for desktop sharing) must be accessible.
- Dual-core 2.6 GHZ CPU (quad core is better)
- Port 80 is not used by another application
    - To verify, installation of **lsof** was done by typing **"sudo apt-get install lsof"**
    - Then port 80 can be checked by running **"lsof –I :80"**
- 50G of free disk space (or more) for recordings
- The locale of the server must be en_US.UTF-8
    - Running **"cat /etc/default/locale"**, this produces a response like **LANG="en_US.UTF-8"**

**INSTALLATION**

A detailed guide on how to install BBB on Ubuntu 10.04 is provided in Appendix B. Refer to appendix for installation details.

### 3.3.4 TROUBLESHOOTING BBB UBUNTU INSTALLATION

The first attempt at installation was done on an Ubuntu 10.10 server. After following all the steps outlined on the BBB installation page the installation failed with the package errors. The BBB community stated that it is highly recommended to install BBB on only Ubuntu 10.04 version as other versions have not been tested. The OS was downgraded to 10.04 the installation was successful without any errors. Another problem encountered was after the installation; it was discovered that the audio (speaker and microphone) where not working at all

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[103] http://www.vmware.com/products/player/
[104] http://www.vmware.com/products/fusion/overview.html
[105] http://code.google.com/p/bigbluebutton/wiki/Support
[106] http://code.google.com/p/bigbluebutton/wiki/BigBlueButtonVM

on the system the installation was done (DELL XPS L7202X, 12GB RAM, Intel (R) Core (TM) i7-2720QM CPU @ 2.20GHz (8 CPUs), ~ 2.2GHz). The kernel version of Ubuntu 10.04 desktop installation was upgraded from 2.6.32-41-generic –pae to 2.6.38-15-generic –pae; which is an older version with more bug fixes and the audio devices started working. Other installation issues could be rectified by visiting the installation page[107] (there is also an interactive video about the installation).

## 3.4 USING BIGBLUEBUTTON TOOLS

This is a shell script used for modifying and managing BBB configuration and processes; it is also a useful tool for troubleshooting BBB on both the Virtual Machine and Ubuntu installation.

- **--setip <hostname/IP Address>:** e.g. **bbb-conf --setip 192.168.56.1** will change the IP address associated with all BBB components to 192.168.56.1. This is particularly useful if the IP address of the machine hosting BBB changes or BBB runs on a machine that has DHCP enabled and thus the IP address changes every time the machine restarts or loses internet connection. It is better to run BBB on a machine with static IP address to prevent frequent IP address change.
- --**clean**: Clears log file and restart BBB server. A good way to restart the server afresh.
- **--check:** Checks the BBB servers current settings and outline any potential problem. It is a useful debugging command to identify errors especially with BBB installation.
- **--checkout <repo>:** used from checking out BBB from github.
- **--conference <conference_module>:** Used for switching conference module in Asterisk. Valid options are **"meetme"** and **"conference"**.
- **--debug:** Check log files for errors.
- **--salt:** Displays the current security salt for BBB API. This is useful when integrating BBB with third party software like Moodle, Sakai, Atutor because these software requires the salt value from BBB to work properly.
- **--setup-samba:** Only available on BBB VM, it sets up a samba share for development
- **--setup-dev [web|client|apps]:** it sets up a development environment for bbb-web, bbb-client and bbb-apps.
- **--start:** Starts all the BBB processes.
- **--stop:** Stops all the BBB processes.
- **--watch:** Watch log flies for errors every 2 seconds, usually used after cleaning out log files using bbb-conf –clean.
- **--zip:** Zip up log files for error reporting.

## 3.5 TRYING OUT BIGBLUEBUTTON

After successfully installing BBB, it was accessed via the web interface by typing the IP address of the server and a welcome page was displayed as seen in figure 3 below; this page is customizable as will be seen in Section 3.6. Figure 4 displays the Demo API page that can be customized and adapted as an administrative page as BBB v 0.80 does not really have one due to the fact that majority of BBB users use it in conjunction with either their own systems through the third party BBB API or in conjunction with third party LMS or CMS. Figure 5 explains the functionalities that are available in the virtual meeting environment of BBB.
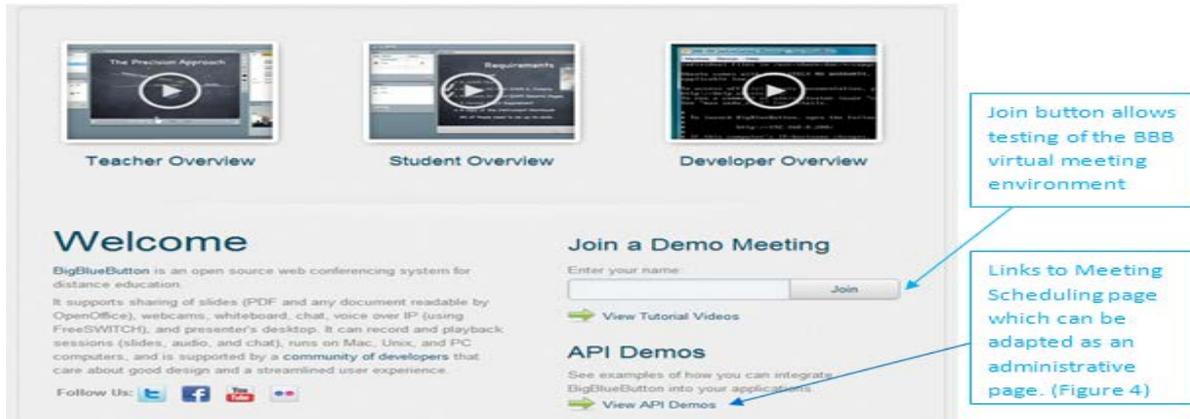
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[107] http://code.google.com/p/bigbluebutton/wiki/InstallationUbuntu

**Figure 3: BigBlueButton welcome page**



**Figure 4: BigBlueButton Demo API page (Adapted from BigBlueButton demo[108])**

**Join** allows users to join a demo meeting, **Join Selected** allows users to join a particular course from a list of already predefined courses, **Join Password** allows users to join a list of already predefined courses with password protection, **Join & Upload** enables a presenter to join and upload its own slides. **Join and Upload (URL)** allows a presenter to join and upload one of the already predefined slides, **Record** makes recording of the web conferencing session possible, however, only the chat, presentations and voice can be recorded and played back because BBB uses a thin media player build with popcorn.js. **Record (Matterhorn)** enables playback of Desktop and Webcam by ingesting the files to a Matterhorn server. However Matterhorn needs to be installed first (see Section 3.9) and integrated with BBB (see Section 4.1) before this can work. **Create** allows users to create a meeting and send the URL of the meeting to attendees to join. **Activity** display the different virtual meetings and the people currently attending, it also displays there role i.e. if they are the moderators or just viewers. **Persona** and **OpenID** provides login facilities via e-mails.

From Figure 5, the **Audio Participant** segment list how many people are participating with their audio device enabled, there are also buttons to **Mute** and **Mute All;** the presenter can mute specific users or all users that have their audio device enabled. **Conference participant windows** display the list of everyone participating in the conference, it also provides the option to switch the presenter and a button that participant can click to raise up their hands if they have anything to say; this is particular useful if all the participants audio are muted. **Share Screen** (available to presenter only) can be used to share the presenter's desktop to all participants, also, the presenter needs to have Java running on the browser because the screen sharing application in BBB is

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[108] http://demo.bigbluebutton.org/demo/demo1.jsp

a Java Applet running in a browser; there are websites that can help check if Java is installed[109]. **Audio Controller** button can be used for audio muting and reconnection. **Share Webcam** can be used to enable Webcam Sharing.
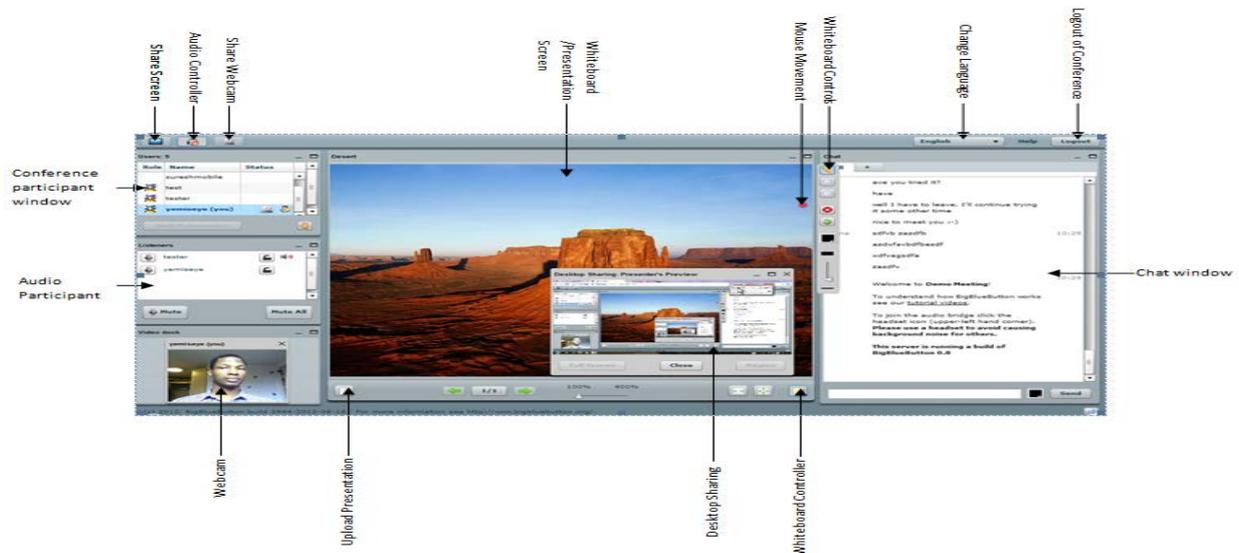


**Figure 5: BigBlueButton conference environment (Adapted from BigBlueButton demo[110])**

**Whiteboard/Presentation Screen** are windows where uploaded slides within the meeting environment are displayed and where whiteboard controls can be used. **Mouse Movement** icon (for presenter only) can be used by the presenter to point to specific point in a presentation; note however that the mouse movement are not recorded if the sessions are recorded for playback purpose. **Whiteboard Controls** are series of controls such as highlighters and basic shapes that are used to mark points within a presentation. **Change language** provides an option for selecting your preferred language. **Logout of Conference** enables participant to exit the conference. **Chat window** displays all public chats from those participating in the conference, there are also possibilities for private chats to a specific person in the conference. **Whiteboard Controller** can be used to enable and disable the Whiteboard Controls. **Desktop Sharing** displays the Desktop of the Presenter. **Upload Presentation** can be used to upload presentations within the meeting environment. The **Webcam** is displayed when the Share Webcam button is clicked.

## 3.6 CUSTOMIZING AND INTEGRATING BIGBLUEBUTTON

Due to the lack of an administrative page BBB, the most popular way of creating and customizing an administrative page for scheduling and inviting people to join a live web conference is by integration with third party software. Plugins are available for WordPress[111], Joomla[112], Drupal[113], Moodle[114], Sakai[115], TIki Wiki CMS[116], eFront[117], RedMine[118], Foswiki[119], Atutor[120] and Fedena[121]. It is also possible to create an application

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[109] http://www.java.com/en/download/index.jsp
[110] http://demo.bigbluebutton.org/client/BigBlueButton.html
[111] http://wordpress.org/extend/plugins/bigbluebutton/
[112] http://extensions.joomla.org/extensions/communication/video-conference/14317
[113] http://drupal.org/project/bbb
[114] http://moodle.org/plugins/view.php?plugin=mod_bigbluebuttonbn
[115] https://confluence.sakaiproject.org/display/BBB/Home
[116] http://doc.tiki.org/BigBlueButton
[117] http://docs.efrontlearning.net/index.php/BigBlueButton
[118] http://www.redmine.org/projects/redmine/wiki/PluginBBB
[119] http://foswiki.org/Extensions/BigBlueButtonPlugin
[120] http://atutor.ca/atutor/modules/index.php
[121] http://projectfedena.org/plugins

25

that connects to the BBB API[122]; in other to make a call to BBB API what is needed is to make an HTTP request to a URL (URL of the server installation) with query parameters supplying the information needed for the call, the API returns an XML response. Some API calls include calls to **Create Meeting**, **Join Meeting**, **is Meeting Running**, **End Meeting**, **Get Meeting Info**, **Get Meetings**, **GetRecordings**, **Publish Recordings** and **Delete Recordings**. Both integration and customization through third party plugins or by creating an external application that calls the BBB API require the security salt of the BBB server, a quick way to get the security salt is by typing the command **"sudo bbb-conf –salt"**; the salt is also located in the directory **"/var/lib/tomcat6/webapps/bigbluebutton/WEB-INF/classes/bigbluebutton.properties"** by looking for the line **"beans.dynamicConferenceService.securitySalt=<value_of_salt>".** It is also important to note that communication within the BBB environment cannot be regarded as safe as emphasis was not given to any form of security measure apart from the security salt required mechanism for API calls.

Another way of creating an administrative page is to modify the already created demo welcome and API pages (see Figure 3 and 4) that are available on BBB. The welcome page in Figure 3 is located in the directory **"/var/www/bigbluebutton-default/index.html"**. Figure 6 below displays the welcome page from Figure 3 with the wordings **API DEMO** changed to **Meeting Scheduler Interface** and **View API Demos** changed to **Join and Create your own meeting**. It is also possible to bypass this page and display the API demo pages (Figure 4) directly by changing the header segment to:

```
<!DOCTYPE html>
<html>
<head>
<meta http-equiv="Refresh" content="0;url=/demo/demo3.jsp" />
</head>
</html>
```

This redirects all calls to the BBB server to demo page 3 (see Figure 4)



**Figure 6: Welcome page with little changes to wordings**

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[122] http://code.google.com/p/bigbluebutton/wiki/API

The API demo pages are located in **"/var/lib/tomcat6/webapps/demo/"**.  Modification was done on the demo3.jsp (Join Password) page by opening in Notepad++[123] and editing the code to add a new module (COMP 6003: Safety Critical Systems) as shown in the code snippet below and Figure 7.

```
meeting = new HashMap<String, String>();
//meeting title
allMeetings.put( "COMP6003: Safety Critical Systems", meeting );
//welcome message
meeting.put("welcomeMsg", welcome);
//moderator password
meeting.put("moderatorPW","prof123");
//viewer password
meeting.put("viewerPW","student123");
//The extension number for the voice bridge (use if connected to phone system, this must be a
unique 5 digit number)
meeting.put("voiceBridge","82013");
//The logout URL (use if you want to return to your pages
meeting.put("logoutURL","/demo/demo3.jsp");
```



**Figure 7: API demo page with little changes to demo3.jsp**

It is also possible to configure, brand and theme the BBB Client (see Figure 5).  To configure the BBB client,  the **config.xml** is what is need and it can be located in the directory **"/var/www/bigbluebutton/client/conf/config.xml"** some of the changes that can be made include reposition the default arrangement of different components within the BBB Client e.g. repositioning the chat box from the top left corner to another location, there is also an option to allow the presenter to remove users from the conference, automatic desktop and webcam sharing are also possible without clicking on the share desktop and webcam button on the client, resolution of webcam can also be set ,  there is an option to enforce that allows only the presenter to share its webcam which can be useful if there is only one presenter that everyone should focus on e.g. a virtual classroom. In other to brand and theme the BBB client (Look and Feel), there is need to set-up a development environment[124]. Lastly, as earlier stated; BBB also interfaces and send webcam and desktop to Matterhorn for playback and further processing; which is the focus of this report.

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[123] http://notepad-plus-plus.org/
[124] http://code.google.com/p/bigbluebutton/wiki/DevelopingBBB

## 3.7 OPENCAST MATTERHORN (Matterhorn)

Matterhorn is an open source lecture capture, processing and playback system developed by thirteen partnering institution after evaluation of pre-existing systems such as VirtPresenter of the University of Osnabruck, REPLAY developed at ETH Zurich [29], PuMUKIT developed at the University of Vigo, Recollect system from the University of Saskatchewan and Webcast Next Generation developed by UC Berkeley where evaluated and found not to meet the range of functionality that universities require [29]. Its present version is version 1.3; source code can be checked out using subversion on Jira[125], but as at of writing this report, version 1.4 is under testing and will soon be available.

## 3.8 ARCHITECTURE OF OPENCAST MATTERHORN

The Matterhorn architecture can be divided into two main components, the **Matterhorn Core** and the **Capture Agent**. The overall application design relies on Java OSGI model; Matterhorn uses the Apache Felix[126] implementation of the OSGI R4[127] [29]. It also relies heavily on other open source technologies like solr[128] (Local search index), red5 (Streaming server), tesseract[129] (text analysis) and also, gstreamer[130] and ffmpeg[131] which are both used for encodings.

## 3.9 INSTALLING OPENCAST MATTERHORN v 1.3

There are basically two main installations to be done when installing Matterhorn, the installation of the Core and the Capture Agent.

### 3.9.1 INSTALLING THE CORE (CORE)

In real sense, the Matterhorn Core is not really a core but a collection of services based on the service oriented architecture (SOA). Installation of the core can be done on a separate machine or distributed machine (Installing the **Admin**, **Worker** and **Engage** Services on separate machines which is highly recommended for deployment environment[132]).

REQUIREMENTS

- Linux Server (Ubuntu/Debian/Linux and CentOS distributions), Mac OS X
- 2-4GB RAM Recommended
- Storage size of 350GB
- Intel P8700 processor or other equivalent or faster processor Recommended

INSTALLATION

Due to resource limitations, the installation of the core was done on a single Ubuntu 10.10 machine. Installing the core on a dedicated server could be a very tricky as one needs to follow the steps outlined on the Matterhorn website which are not too explanatory[133]. An easier and detailed installation step is available in Appendix C.

### 3.9.2 INSTALLING THE CAPTURE AGENT (CA)

The capture agent is a hardware device that is usually installed along presentation and sound stations in lecture theatres; it records automatically without an operator by polling for schedules from the Matterhorn core; after the lecture ends, the media will be ingested and sent to the core for processing. Matterhorn support hardware captures from third party providers such as Epiphan. Table 9 displays some of the known

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[125] http://opencast.jira.com/source/browse/MH
[126] http://felix.apache.org/site/index.html
[127] http://www.osgi.org/Main/HomePage
[128] http://lucene.apache.org/solr/
[129] http://code.google.com/p/tesseract-ocr/
[130] http://gstreamer.freedesktop.org/
[131] http://ffmpeg.org/
[132] http://opencast.jira.com/wiki/display/mh13/Install+Across+Multiple+Servers+v1.3
[133] http://opencast.jira.com/wiki/display/mh13/Install+Source+Linux+v1.3

good hardware capture solutions (See Appendix D for full details of installation). It is also possible to add non supported capture hardware through custom configurations.

**Table 9: Reference Capture Agent Hardware**

| Component | Known Good Hardware | Vendor Link | Notes |
|---|---|---|---|
| Processor and Motherboard | Intel P8700 Processor Jet NF93R 4GB DDR2 800 RAM | Logic Supply | 2-4GB of RAM is recommended.  If using a capture card that does not have hardware support, consider faster processors.  Opencast will use multiple cores if they are available |
| Enclosure | Casetronic C137 Mini-ITX Case | Logic Supply | Mounting brackets are available as well.  This case is nice because it can be rackmounted in an A/V rack as well as has plenty of room for cooling. |
| Storage | 2.5" SATA Drive, 320GB | Logic Supply | A faster drive (7200 RPM) is prefered to a slower drive (5400 RPM). Bigger drives will hold more historical copies of captured lectures on the appliance. |
| Video Capture Card | Hauppauge PVR350 Hauppauge HVR1600 PV-143PV-149 | various various bluecherry | Has native MPEG2 capture but generates significant heat.  Other Hauppauge MPEG2 cards should work. Only works with Ubuntu Server, not Ubuntu Desktop |
| VGA Capture Card | VGA2USB VGA2USB-I VGA2USB LR VGA2USB LR-I | Epiphan Epiphan Epiphan Epiphan | External, if a smaller enclosure is used. Internal, appropriate for Casetronic eclosure. External with higher quality framerates. Internal with higher quality framerates. |

## 3.9.3 TROUBLESHOOTING THE INSTALLATIONS

The first attempt to install the CA had series of error, after trying to find out what the problem could be from the online documentations and the Matterhorn user community[134]. It was discovered that the problem was installing both the Matterhorn core and capture agent on the same machine; the installation script of the CA overrides that of the Core. An installation of the capture agent was also done on a separate machine, but using Oracle virtual machine[135]; Ubuntu 10.04 LTS was installed on a Windows OS host. After installation the capture agent failed to start. It was discovered that the CA was unable to communicate with the host OS (e.g. audio device and webcam) for capturing. Another exception message "**java.lang.OutOfMemoryError: PermGen space**" was encountered while building Matterhorn by executing the command below (see Appendix C for full installation details)

> **export MAVEN_OPTS='-Xms256m -Xmx960m -XX:PermSize=64m -XX:MaxPermSize=256m'**
> **cd /opt/matterhorn/matterhorn_1.3.1**
> **mvn clean install -DdeployTo=/opt/matterhorn/felix/matterhorn**

The server was out of memory as the memory space available on the machine was less than 2GB. Memory space was freed by running the command **echo 3 > /proc/sys/vm/drop_caches** and then increasing the **MAVEN_OPT** to **MAVEN_OPTS='-Xms256m -Xmx960m -XX:PermSize=512m -XX:MaxPermSize=512m'** . Lastly, an error message **"Media Analyzer Error"** was encountered while installing the core, this was because the installation of **Third-party tools** was omitted (see Appendix C)

## 3.10 TRYING OUT MATTERHORN

To access the Matterhorn Administrative page, the IP address or the fully qualified name is typed on the web browser with the necessary port 8080 added in front. The admin login page appeared as seen in Figure 8. The default username is **"admin"** and the password is **"opencast"** which can be later changed in the **config.properties** file located in **"/opt/matterhorn/felix/conf/"** directory.

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[134] http://opencast.org/matterhorn/community
[135] http://www.oracle.com/us/technologies/virtualization/oraclevm/overview/index.html

**Figure 8: Admin login page**

After a successfully login in, the welcome page was displayed as seen in figure 9. Clicking on **"Go to Media Module"** displays the media module interface which displays recordings that are available for playback using the Engage player embedded in Matterhorn, RSS/ATOM feed of the recording are also available as well as capabilities for search the recordings (Figure 10). Clicking on the **"Go to Admin Tools"** displays the administrative environment as seen in Figure 11.



**Figure 9: Welcome page**
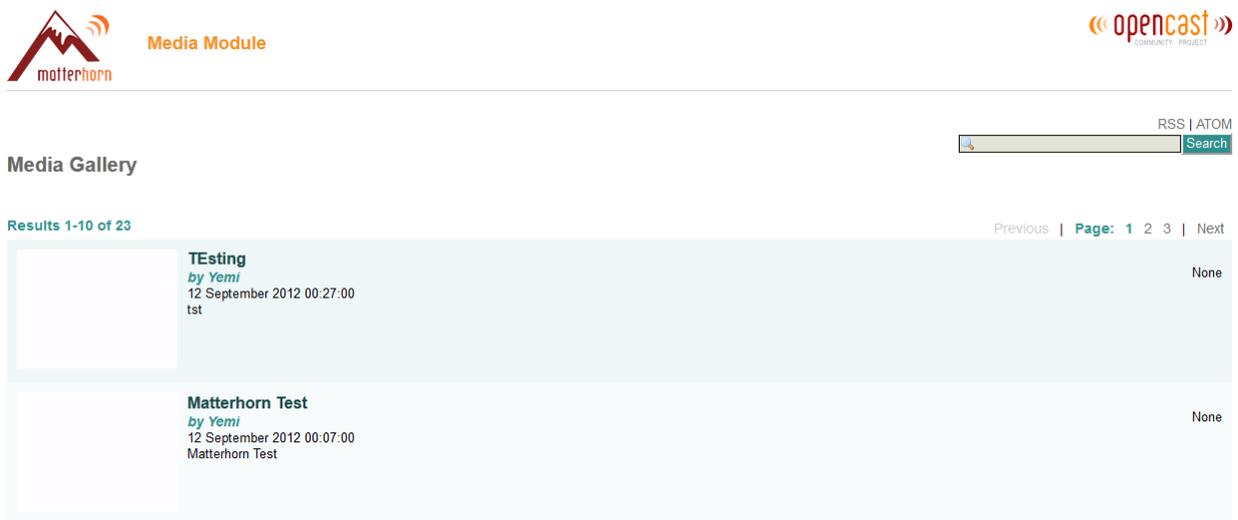


**Figure 10: The Media Module interface**

**Figure 11: Administrative page user interface**

From Figure 11 above, users can schedule recording or upload recordings by clicking on the **Schedule Recording** or **Upload Recording** button respectively. When scheduling a recording, the user has an option to specify the **title**, **presenter**, **series**, **capture date**, **capture time**, **capture agent**, **processing instructions** (determines the format the recording with be encoded e.g. **avi**, **flv** etc. and the distribution channel the recordings will be sent to e.g. download server, streaming server, RSS/ATOM feed etc.), **if the recording is to be published immediately or held for caption addition or trimmings** and **if the recording is to be played back just once or more than once** (see Figure 12).

**Upload recording** has a similar interface to Figure 12 only that there is no need to specify a capture agent, recordings can be uploaded which can be done from either the file system or from the Matterhorn inbox located at **/opt/matterhorn/felix/inbox (media can be placed in this directory for upload)**. Clicking on the **Series** tab displays the available recording series, **Capture Agents** display the capture agents installed and there current configuration. **Statistics** displays useful information about the mean time taken during the various media processing steps (Figure 13).



**Figure 12: Scheduling a Recording**

**Figure 13: Server Statistics**

## 3.11 MATTERHORN CAPTURING AND MEDIA PROCESSING
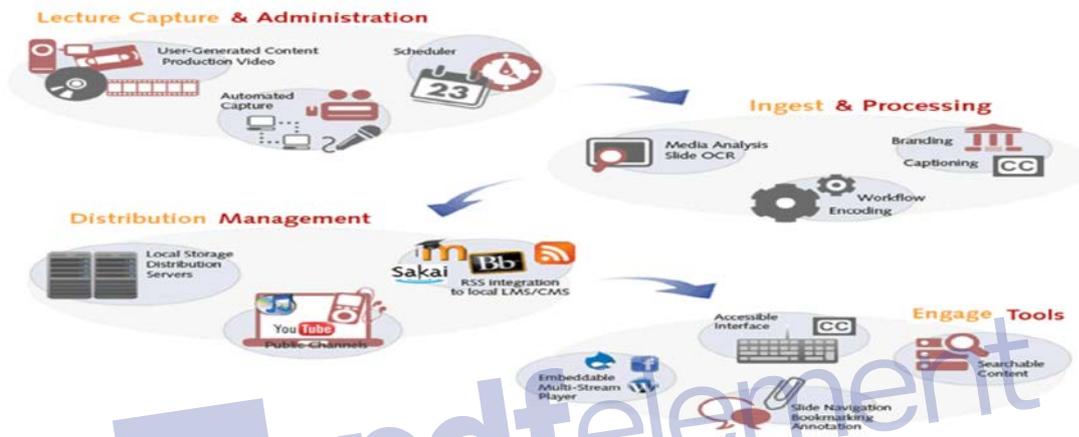


**Figure 14: An overview of Matterhorn capturing and media processing**[136]

**Lecture Capture and Administration:**  As earlier stated the primary way to capture on Matterhorn is through a hardware capture agent. User generated video content can also be uploaded for processing. Once the recording is captured or uploaded, a  **MediaPackage** is created and the media is ingested into the Matterhorn inbox which triggers a workflow. Other activities that take place at this stage include **Media trimming**.

**Ingesting and Processing:** During scheduling/uploading if the check box "**Processing should be paused to allow for"** is checked (Figure 12), the media is not processed and appears in the **"On Hold"** section (Figure 11), user can then add captioning information or upload a caption file. Other processing that takes place includes **advanced media analysis**, and applying **encodings** specified by the configurable **workflow**.

**Distribution and Management:**  During processing of media encodings specified in a workflow, the media are published to local storage or distribution servers, progressive download or streaming server (lighttpd, Red5 and Wowza Media Server; Wowza is recommended for streaming H.264/mp4 encodings as Red5 has problem working with this format), RSS/ATOM feeds for integration with third party application or LMS.

**Engage Tools:** During the distribution of the processed media, the processed media is sent to the engage player, the engage player is encoded to support flash movies. Some other engage tools include basic media player, two-screen media player that facilitates viewing of lecturer and the slides he/she is presently synchronously, RSS/ATOM feed links, there is also a facility to check the most viewed part of a video recording

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[136] http://opencast.org/matterhorn/features#capture

and lastly authorization; allowing administrators to determine which group has access to particular series of recording.

## 3.12 SOFTWARE BASED CAPTURE AGENT

Since the goal of this project is to provide a completely licence free solution, buying a hardware device will defeat the purpose and so a list of software based capture agent are explored.

### 3.12.1 CUSTOM ENCODINGS

Since Matterhorn relies on open source technologies such as gstreamer and ffmpeg, it is possible to capture the screen and webcam by specifying various custom encodings after installing the capture agent as described in section 3.9.2, however, this will involve some experimentation and some changes from machine to machine as not one solution can work on all machines. One of such encoding was created to capture the webcam as seen in appendix E. More encodings can be seen on the Matterhorn website[137].

### 3.12.2 SCREENCASTING SOFTWARE

There are varieties of screen recording software available; both proprietary and free. Some of the free ones include **Camstudio**[138] and **Ezvid**[139] on Windows OS, **RecordMyDesktop**[140] and **RecordItNow**[141] for Linux etc. In this report RecordItNow was used for screen capture purpose because it has an ffmpeg and MEncoder for recording in **wmv**, **mpeg2**, **flv** and **avi** formats and it is also free (see Figure 15).

The media was captured in mpeg2 format. Once captured, it needs to be sent to Matterhorn for processing. There are basically two ways of doing this:

- By using the **Upload Recording** from the administrative interface and uploading the recorded screencast with the radio button **"Local hard drive"** checked. (see figure 16)
- By copying or saving the file to the Matterhorn inbox (**/opt/matterhorn/felix/inbox**) and checking the radio button **"Designated inbox on server".** (see Figure 16)
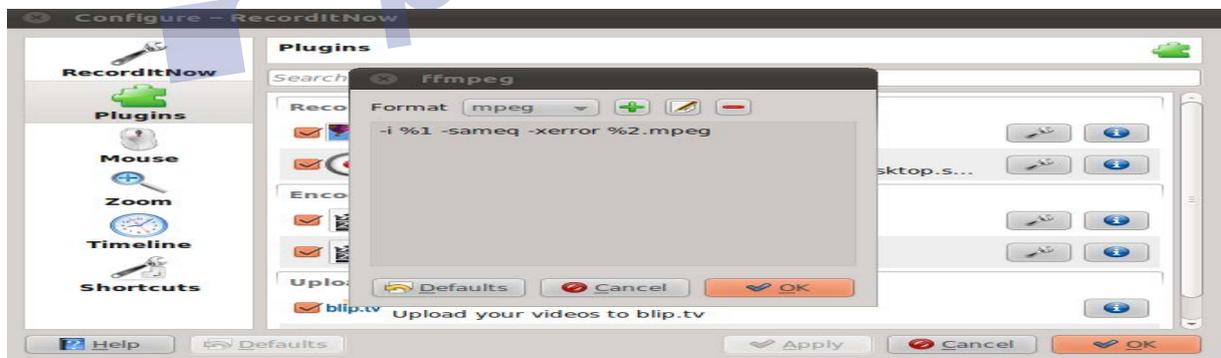


**Figure 15: RecordItNow Settings**

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[137] http://opencast.jira.com/wiki/display/mh13/Custom+Capture+Devices+v1.3

[138] http://camstudio.downloadasaurus.com/

[139] http://www.ezvid.com/

[140] http://recordmydesktop.sourceforge.net/about.php

[141] http://recorditnow.sourceforge.net/

**Figure 16: Uploading Recordings**

- By using the Matterhorn Ingest **REST API** to create a MediaPackage and then send the MediaPackage to the Matterhorn inbox; this automatically triggers a workflow operation for Matterhorn to process the recording[142].

These processes are not automated as it might require some more action on the user's part before recording are sent to Matterhorn.

### 3.12.3 GALICASTER CAPTURE AGENT

This is a Linux based open source capture agent designed by Teltek Video Research to work with Matterhorn core. It can register as a regular Matterhorn CA and can be a good alternative to a hardware capture agent. It features include Live audio and video feedback over a touch interface, visual alarm on poor or no audio input, manual and automatic starting, stopping and pausing of recordings, remote monitoring via VNC amongst others. Due to time constraint, Galicaster functionality was not tested in this report.

### 3.12.4 THEREC MATTERHORN (TheRec)

TheRec Matterhorn was recently released in August 2012 by the Opencast Community to produce a Windows based capture agent that can work with the Matterhorn Core. TheRec Matterhorn has similar functionality to Galicaster CA and can be an alternative especially for deployment on Windows OS.

**REQUIREMENTS**

- Windows 7, Dual Core processor with at least 2Ghz,
- 2GB RAM, 5 MB HDD for the Software, approx. 8 GB/h HDD of multi-stream recordings.
- A webcam or a DV-camera is recommended.

TheRec can capture as many simultaneous av-stream from DirectShow devices installed on the computer. Because of the dependency on DirectShow, a variety of capture devices on windows e.g. DV-cameras, USB-webcams, hardware VGA-grabbers (such as the Epiphan VGA2USB devices) and even software VGA-grabbers are supported. TheRec is intended for manual recording as there is no record scheduling capability possible at the moment. There is also a need to install a software based VGA-grabber and the Matterhorn Remote Inbox (MHRI) for full functionality. (See Appendix F for full installation details)

Figure 17 Displays TheRec interface; Users can specify various input include parameters such as series, title, author, date, time and description, It was also noted that choosing the date and time does not mean that recording will be scheduled at that date or time as this functionality is not yet supported. Users can also choose which devices to capture which in this case we have captured the system microphone, integrated webcam and screen capture recorder (software VGA-grabber). There is also an option to choose where recordings are saved by clicking on **File -> Options** on the Menu bar, clicking on the start capture button starts a recording immediately. After capturing, The MHRI (see Figure 17) was used to attempt to ingest the file to

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[142] http://demo.opencastproject.org/docs.html?path=/ingest

the Matterhorn core but the ingestion failed, all efforts to rectify the issue proved abortive and no effective solution was found to resolve the issue probably because the tool is new and designed to work with Matterhorn v 1.4 which is yet to be released.
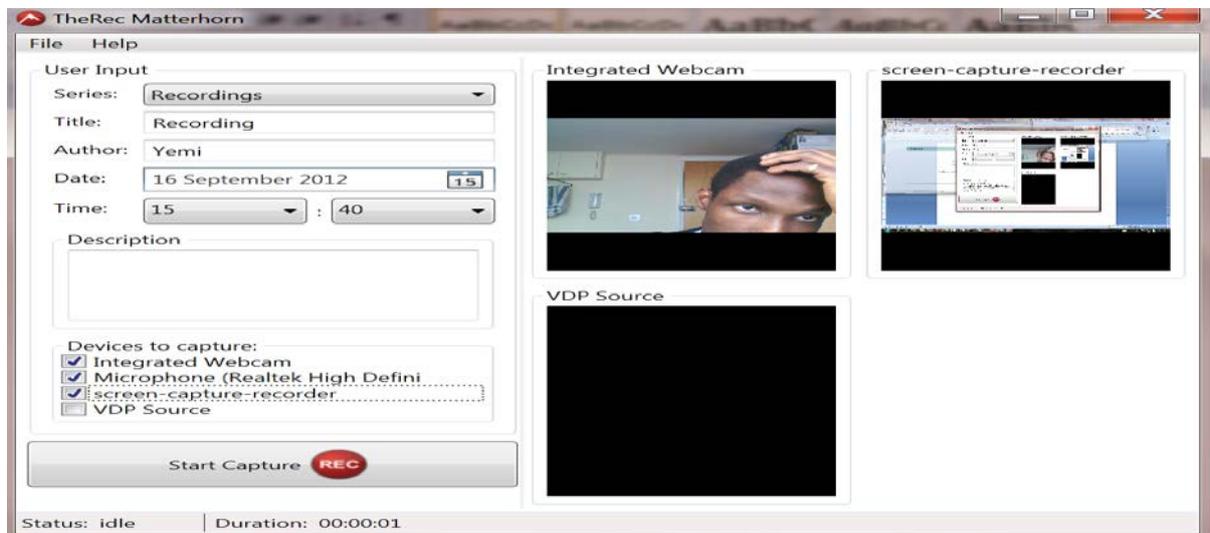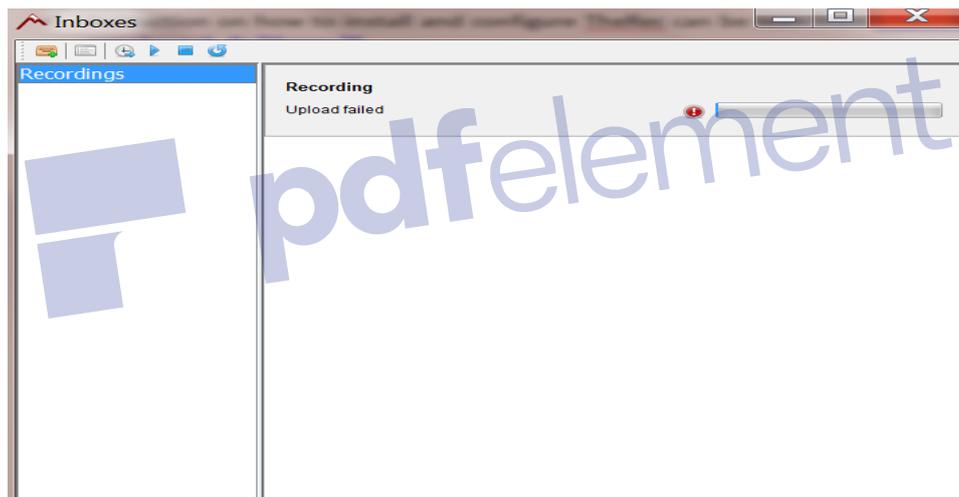


**Figure 17: TheRec Matterhorn User Interface**



**Figure 18: The Matterhorn Remote Inbox with failed Injection**

## 3.12.5 BIGBLUEBUTTON

BigblueButton can also serve as a capture agent with Matterhorn. It can capture and send the desktop recordings and webcam recordings to the Matterhorn core. This was chosen as the preferred option for integration with Matterhorn as it was found to be the most effective when compared to the other solutions. There is a possibility of creating a virtual classroom as well as recording traditional classroom lectures. Other solutions do not provide virtual classroom functionality but just normal desktop and camera recordings; also it is Operating System (OS) independent; it can be accessed through the web browser on any OS once deployed.

## 3.13 MATTERHORN 1.4

As at of writing this report, the opencast community released the Opencast Matterhorn version 1.4 which is now undergoing rigorous test by the community. Some of the expected addition to this release includes:

- Big File Upload (>2GB) currently supported by Firefox and Google Chrome

- Another tab called the **Episode** tab will be added which will facilitate the editing/deleting of recordings from a simple user interface.
- JMX based Monitoring
- Support for multiple encoding profiles per compose operation

## 3.14 SYNOTE

Synote is a free open source web based slidecasting and annotation system developed at the University of Southampton to make annotation and finding of media content easier, while some systems enable users to enter text synchronized with media contents e.g. Panopto and Tegrity, others facilitates annotating of the whole media content e.g. comment and star rating in YouTube[143]; it also provides an annotation system but media are not searchable using this annotation. It is evident that none of these systems provides a full annotation system like Synote. Synote facilitates the creation of synchronized annotations (bookmarks, tags, notes, links, images and text caption) which are ordered by timestamp of which part of a media recording the annotations refers to, this are known as Synmarks [14], this makes it possible to search parts of a video using the already created annotations hence one needs not to search the whole recording to get to the place we are interested, all that is needed is simply creating a note or a tag on them and searching those media when we need them with those notes or tags. Synote also has an automatic IBM hosted transcribing service for translating voice to text automatically but is currently available at the University of Southampton only due to licencing issues. There is no need for installation because it is freely available for use at **www.synote.org** but local installation is also possible[144]**.** The source code can also be downloaded from GitHub[145].

Synote was developed using the Grails framework. It comprises of a web client, web server and database application. **The Synote Web Server** in conjunction with the **Synote Client** is responsible for provision of services and dynamic web pages for users to manage their personal information, multimedia resources as well as user access permissions. The Synote player was developed using Google Web Toolkit (GWT) plugging[146] , it also facilitates searching of media content.
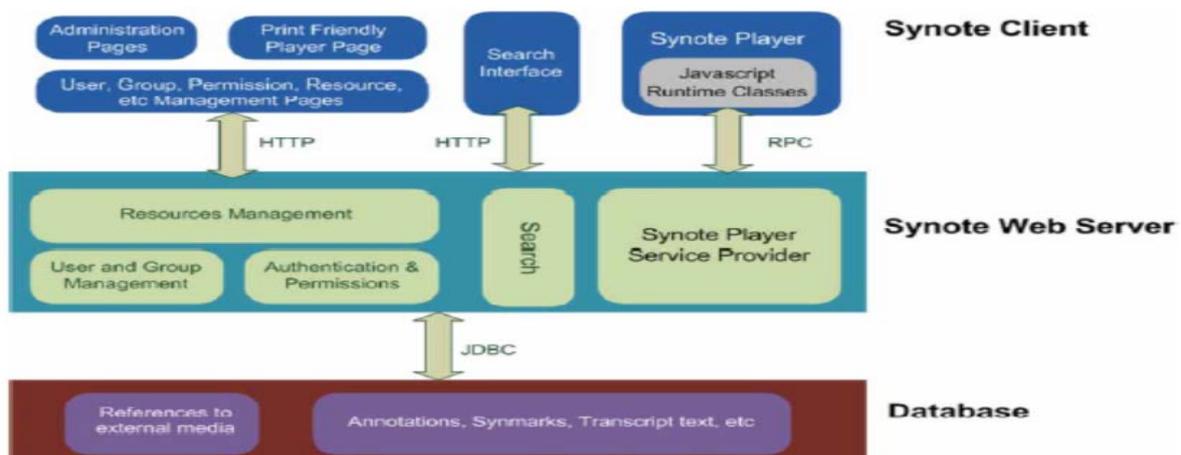
## 3.15 ARCHITECTURE OF SYNOTE



**Figure 19: Architecture of Synote (Adapted from [14])**

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[143] http://www.youtube.com/

[144] https://github.com/yunjiali/Synote/wiki/Development-Environment-Setup

[145] https://github.com/yunjiali/Synote

[146] http://grails.org/plugin/gwt

The **Database** keeps information such as links to media resources e.g. audio, video and image slides, Synmark, transcript resources and annotations; it is important to also stress that due to copyright issues, Synote does store media but just links to where the resources are located. Synote database was designed with MySQL[147] and Synote classes are mapped to it via Hibernate[148].

## 3.16 TRYING OUT SYNOTE

The Synote home page (see Figure 20) provide functionality such as **registering new users**, **creating user group**, **user guide**, **recording list** as well **login in** and **login out** functionality.  A user needs to first create a login account to use Synote. After creating a login account, clicking on the Recording tab displays Figure 21. In Figure 21, users can create new recordings by clicking on the **Create Recording** and specifying the **Title**, recording **URL**, **Descriptions**, **Tags**, **Recording Permission** (which can be Private, Read, Write and Annotate), **group permission**, **searching media content** (which can contain Synmarks, titles and transcript text) and also a **transcribing service** (see Figure 22). Also in Figure 22, users can create presentations from narrated PowerPoint slides as well as synchronized transcript if they are available on the PowerPoint Slides notes [14]. By clicking on the Print button on  Figure 21, users can specify which **part of a recording to print**, **Synmark part of a presentation**, **Synmark from specific users**, **transcript**, **presentation slides** and other **Synmark settings** as seen in Figure 23; a **preview** button is also available to check what the print out will look like. By clicking on the **Replay** button on Figure 21, the Synote interface is displayed; this is made up of four main components, the **Multimedia** segment, **Synmarks**, **Transcript** and **Presentation** segments as seen in Figure 24.

The **Multimedia segment** has an embedded player which is responsible for the playback and rewinding media; it also has capability for media resizing. Synote supports all major formats such as WAV, MP3, AVI, MPEG, FLV and MP4 through media players such as Windows media player[149], JW player[150] and QuickTime Player[151] on Windows and MAC Operating Systems; it chooses the appropriate player to use based on the users platform and the file format.



**Figure 20: The Synote Home Page**

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[147] http://grails.org/plugin/mysql-connectorj

[148] http://grails.org/plugin/hibernate

[149] http://windows.microsoft.com/en-US/windows/products/windows-media-player

[150] http://www.longtailvideo.com/players

[151] http://www.apple.com/quicktime/download/

**Figure 21: The Recordings interface**



**Figure 22: Creating Recording interface**

The **Presentation segments** are slide images created from the multimedia segments, all slides have a start and end time and are automatically highlighted by the system when a video or audio recording is playing [14]; there is also a button to turn Auto scroll off which prevents automatic scrolling of presentation in sync with media recordings. **Transcript segments** creates transcript from the Multimedia segment automatically, transcript can also be uploaded (.srt caption file), there are also facilities to add/edit synchronization points, editing transcript text and Auto scroll capabilities. There are also facilities users to highlights all Synmarks, owner's Synmarks or their own Synmarks or switch off Synmarks which saves processing time and is highly recommended, the currently spoken word from the Multimedia segment is also highlighted in the transcript segment.

The **Synmark segment** is responsible for the creation, editing and deleting of Synmarks; each of which has a generated ID, start time, end time, title, notes (which can contain information including valid html codes) ,tags and link to next Synmark (specifying the ID of the next Synmarks)(see Figure 24) . There are options to enable Autoscroll as well as a button to toggle between viewing the full Synmarks on a recording and some segment of it, users can filter Synmarks to view owner's Synmarks, all Synmarks and the user's Synmarks. When creating or editing a Synmark, the start and end time is very flexible; and can be entered directly as seen in Figure 25 (Start: 10:04, End: 10:43) or a user can also highlight some transcript segment and clicking on the **Create** button in the Synmark segment automatically adds the start and end times (see Figure 26). There are also possibilities to update the start or end time to the current time by clicking on the **update** button, users can increase or decrease the Synmarks time by a second by clicking on the **Plus** or **Minus** buttons respectively.

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**Figure 23: Printing Setup Page**



**Figure 24: The Synote Playback Interface**



**Figure 25: Creating or Editing a Synmark Window**

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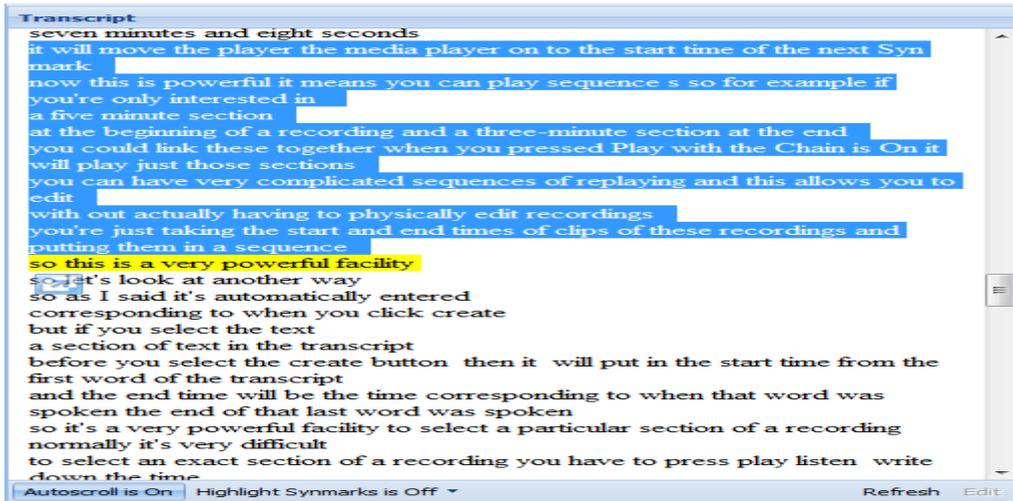
**Figure 26: Synote Transcript Segment**

Synote has been tested and can be used on a variety of browser such as Google chrome, Internet explorer, Safari and Mozilla Firefox also, it facilitates live note taking during lecture recording via Twitter API; this notes are automatically created as Synmarks after the lecture.

# CHAPTER 4: INTEGRATION AND TESTING OF BIGBLUEBUTTON, SYNOTE AND OPENCAST MATTERHORN

## 4.1 INTEGRATING BIGBLUEBUTTON AND OPENCAST MATTERHORN

From a technical point of view, BBB records the slides, chats, desktop and webcam when BBB **Create** API is called with parameter "**record**" set to **true**. After the session ends, BBB will run one or more ingest and processing script which processes the captured data into a format suitable for playback. When BBB runs these scripts two types of video files are created; one with webcam + audio and the other with the desktop + audio. The Matterhorn **ingest** and **processing** scripts scales the resolution of the desktop video to 640x480 before they are being sent to Matterhorn. The full installation details are available in appendix G.

## 4.1.1 TESTING THE BIGBLUEBUTTON AND OPENCAST MATTERHORN INTEGRATION



**Figure 27: Creating a Matterhorn Recording on BBB**



**Figure 28: Matterhorn finished processing Media from BBB (The first recording in the list specifically)**

## 4.2 INTEGRATING OPENCAST MATTERHORN WITH SYNOTE

There are basically two ways Matterhorn can integrate with third party software one is by using the REST API and the other is the RSS/ATOM Feeds which contains information such as the URL of the recording, title, duration etc. Several REST Service exist and are used for various purposes of some of which are for creating **workflows**, **text analysis**, **scheduling**, **ingesting recording**, **searching of recording** etc. Considering the task at hand, the RSS/ATOM where found to be appropriate because it was found to be easier and effective.

## 4.2.1 CREATING CUSTOM ENCODINGS USING FFMPEG

Synote will prefer HTML5 compatible media and so the recordings sent from the BBB server is to be encoded in the **mp4** and **mp3** format for video recordings and audio recordings respectively. The transcription service of Synote does not work effectively with mp4 files but works fine with mp3 files; with that in mind, an mp3 format is also needed for the mp4 video for transcription purpose only. By default, Matterhorn RSS/ATOM feeds are encoded in **avi** format for videos and **m4a** for audio recordings. In other to configure the RSS feeds to produce recordings in mp4 and mp3 formats, a new **encoding** and a **workflow** file is needed. Firstly an encoding file called **"mp3-mp4.properties"** was created and placed in the location **/opt/matterhorn/felix/conf/encoding**. This file basically contains media properties and ffmpeg commands to encode the videos. An mp4/H.264 high definition (HD) encoding was created to encode recording created in other formats (see Appendix H).

The next step involves the creation of a **workflow file**; to specify where recordings are to be distributed and in what format they should be distributed to such places. The workflow file is a vital part of the processing capability of Matterhorn. The mp3 and mp4 encodings earlier created in the **mp3-mp4.properties** file are referenced by the workflow. The Matterhorn workflow files are located in the directory **/opt/matterhorn/felix/conf/workflows**. A Workflow was created to ensure that the RSS/ATOM feeds are encoded in mp4 and mp3 format respectively this was called the **"mp4-mp3.xml"** workflow (see Appendix I). Figure 12 displays the administrative interface with the **processing instruction** containing the **mp4-mp3.xml** workflow(**Encode mp3 and mp4 format**) displayed; Figure 29 displays the ATOM feed from the new mp3-mp4 workflow. **deskshare** is the desktop capture while **muxed audio webcam** is the webcam capture. Appendix J contains an extract from the RSS/ATOM feed.

### TEsting
12/09/12 00:27

Media files
- muxed_audio_webcam.mp4 (MPEG-4 video)
- muxed_audio_webcam.mp3 (MP3 audio)
- deskshare.mp4 (MPEG-4 video)
- deskshare.mp3 (MP3 audio)

### Matterhorn Test
12/09/12 00:07

Media files
- muxed_audio_webcam.mp3 (MP3 audio)
- muxed_audio_webcam.mp4 (MPEG-4 video)
- deskshare.mp4 (MPEG-4 video)
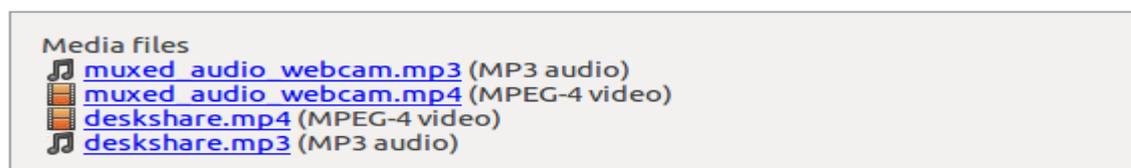- deskshare.mp3 (MP3 audio)

**Figure 29: ATOM feed**

## 4.2.2 CONSUMING THE RSS/ATOM FEED FROM MATTERHORN

Now that the encodings are now in the mp3 and mp4 formats that Synote would prefer and since Synote was developed using grails, a Grails service that can be utilized by Synote in the future will be created.

## 4.2.3 DEVELOPING THE GRAILS SERVICE

Grails was first installed on a windows machine; the full installation details are available on the grails website[152]. A service was created to consume the RSS/ATOM feeds from Matterhorn every one minute; the information is then stored in a temporary cache for further analysis. The choice of using a cache memory as the first storage point is for Synote to analyse the information from the cache before taking any actions e.g. there will be no need to create a new recording if their are no new recordings in the cache. Another problem to resolve is to ensure that there are no duplicate recordings created by Synote; to prevent this, the time of the last or latest feed was recorded; Synote will only create new recordings for feeds whose recording time are greater than the last recording time during the last check of the cache storage . Also there is a possibility of missing out on some new recordings; e.g. if 50 new recordings are now available in the last one minutes and the Matterhorn RSS feed can only display a maximum of 20, some feed would not be seen by the service. Matterhorn has a feed configuration file located in the directory **"opt/matterhorn/felix/conf/feeds"**, the default feed published by Matterhorn is the "**latest.properties feed"** and one of the configuration parameter allows specification of feed size (See Figure 31) which can be adjusted to any value wanted. Also, the cache size can also be specified as will be seen later.



**Figure 30: Matterhorn feed configuration file**

A grails service **RSSConsumptionService** was created in the **org.synote.integration.matterhorn** package directory; the full content of this file is in Appendix K. There are five important methods in this service; the **atmfeeds** method which consumes the ATOM feed and the **rssfeeds** method which consumes the RSS feed. The URL of the RSS and ATOM feeds where passed as input to a groovy XML parser and the following information were extracted from the Atom feed:

- **Recording Title**
- **Author**
- **The URL of the desktop recording in mp4**
- **The URL of the desktop recording in mp3**
- **The URL of all recordings including the mp4 and mp3 version of the webcam recording**

---

[152] http://grails.org/Installation

Also, the following information were extracted from the RSS feed

- **The recording published date/time**
- **Length of recording**
- **Last Recording date/time (needed for tracking new recordings)**

These are the information Synote will probably use for automatic creation of recordings. Other methods include **getRss**; which retrieves the RSS feed contents from the cache, **getAtom** retrieves the ATOM feed content from the cache. These are two useful methods Synote can call to retrieve cache content. updateCache method gets the latest RSS and ATOM feed from the atmfeeds and rssfeeds methods respectively and stores them in a cache. Though grail has its own default cache implementation, EhCache plugin was found to be more convenient and simpler. This was installed by typing the command **"grails install-plugin cache-ehcache".**

A simple cache configuration is shown below. The name of the **cache** is specified as **testcache**, **eternal** is set to **false** which means the cache memory is discarded once it is read, **overflowToDisk** is also set to **true** which means when the cache memory is full, items can be saved on the disk. **maxElementsInMemory** is used to specify the cache memory space or size, while **maxElementsOnDisk** specify the disk storage size allowed.

```
Cache {
        name 'testcache'
        eternal false
        overflowToDisk true
        maxElementsInMemory 10000
        maxElementsOnDisk 10000000
}
```

The Matterhorn Cache configuration for the Grails service was placed in the **"conf/spring/resources.groovy"** folder. The content of the file is shown below:

```
// Place your Spring DSL code here
beans = {
    matterhornCache(org.springframework.cache.ehcache.EhCacheFactoryBean) {
        eternal = true
        maxElementsInMemory = 10000
    }
}
```

The cache value **eternal** is set to **true** which means that even if there is no new feeds, old feeds are still available in the cache memory. **maxElementsInMemory** is set to 10000. In other to schedule a job that will check the cache at regular predefined interval, there is also a need to install a scheduler; the quartz grails plugin was found to be efficient for this purpose. Quartz plugin can be installed by typing the command **"grails install-plugin quartz"**; the configuration file is also needed and was installed by typing the command **"grails install-quartz-config".** A **"jobs"** scheduling folder is created in the **grails-app** folder. A groovy file called "**matterhornJob**" was created as shown below. This simply states that a simple job should be scheduled to start 1 second after the application is started (startDelay) and executed every 60 seconds (repeatInterval). When this job is running, the updateCache() method from the RSSConsumptionService class is called; this in turn reads the latest feeds from the Matterhorn server and updates the cache.

```
package org.synote.integration.matterhorn
class matterhornJob {
   static triggers = {
    simple name: 'MatterhornJob', startDelay: 1000, repeatInterval: 60000
   }
   def RSSConsumptionService
   def execute() {
```

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```
try {
    RSSConsumptionService.updateCache()
  }
catch (Exception ex) {
    log.error ex.message
}
  }
}
```

## 4.2.4 TESTING THE GRAILS SERVICE



**Figure 31: RSS feed from the command Line**



**Figure 32: ATOM feed from the command Line**

Figure 33: Combined RSS and ATOM Feed on a Groovy Page.

## 4.3 TESTING BIGBLUEBUTTON

BigBlueButton was tested on Linux Ubuntu 10.04 LTS OS with Intel(R) Core(TM) i7-2720QM CPU @ 2.20GHz (8 processors) with 3GB of memory and internet speed of 170Mpbs Download/90Mpbs Upload. 5 to 20 clients were created from several browsers within a few machine within Southampton with audio enabled and just the webcam of the presenter and its desktop. The audio was observed to be good even as the number of clients increased, but there was some little creaky sound noticed which stopped after inserting a headset. The memory usage was fairly constant with the following CPU averages across the 8 processors within the range:

- **5 users** - Average 15% CPU usage
- **10 users** - Average 20% CPU usage
- **15 users** - Average 27% CPU usage
- **20 users** - Average 32% CPU usage

At this same rate it can be deduced that around 50-55 people can conveniently connect on this machine without expecting any audio problems. The result might be different if all 20 users are sharing there webcam as well.

## 4.4 TESTING OPENCAST MATTERHORN

The Matterhorn server was tested to ascertain the time taken to process media recordings (video recordings). All tests were carried out on a Linux Ubuntu 10.04 LTS OS with Intel(R) Xeon(R) CPU X5650 @ 2.67GHz with 2GB of memory and internet speed of 170Mpbs Download/90Mpbs Upload. See table 10 and figure for result details. Prior to the test, the server memory utilization was around 50% and the CPU usage was between 10-20%. Table 10 explains the performance and Figure 34 shows that the time of processing is dependent on media size.

**Table 10: Analysis of processing time for avi format video on Matterhorn**
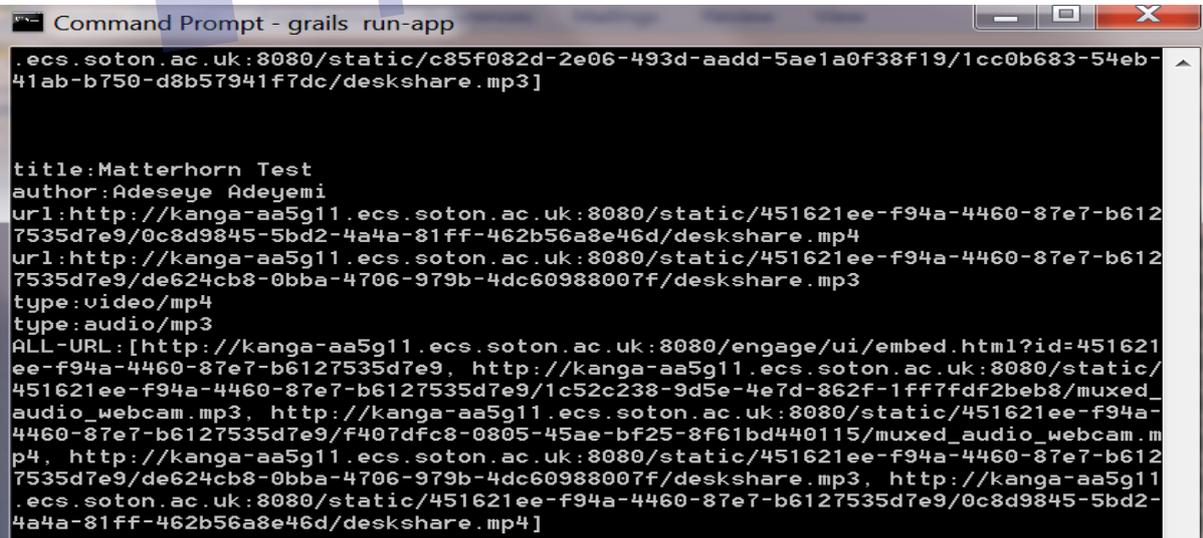
| Duration (min) | File Size (MB) | file format | Time to Upload to server (min) | Time taken to process Media | CPU usage after uploading (%) | Memory usage after uploading (%) | Comments |
|---|---|---|---|---|---|---|---|
| 0.5 | 16 | avi | None | 5 | 10-20 but 100% after 3 minutes of processing, but went back to the normal range (10-20) one minutes later | 50 | No real effect on the CPU or Memory, but 100% CPU utilization for 1 minute when processing media for RSS feed (mp4 format only) |
| 1 | 8 | avi | None | 5 | 10-20 but 100% after 3 minutes of processing, but went back to the normal range (10-20) one minutes later | 50 | No real effect on the CPU or Memory, but 100% CPU utilization for 1 minute when processing media for RSS feed (mp4 format only) |
| 30 | 300 | avi | 1 | 47 | 10-20 at the beginning but 100% utilization after 1 minute till the end after which it was normal again for some few seconds towards the end of processing | 54 | Massive effect on the CPU little effect on Memory, CPU utilization was 100% while processing the media to the engage formats (flash audio and video) and RSS feed downloads (mp3 and mp4) |
| 88 | 702 | avi | 2 | 132 | 10-20 at the beginning but 100% utilization after 1 minute till the end after which it was normal again for some few seconds towards the end of processing | 62 | Massive effect on the CPU little effect on Memory, CPU utilization was 100% while processing the media to the engage formats (flash audio and video) and RSS feed downloads (mp3 and mp4) |
| 110 | 1240 | avi | 2 | 174 | 10-20 at the beginning but 100% utilization after 1 minute till the end after which it was normal again for some few seconds towards the end of processing | 65 | Massive effect on the CPU little effect on Memory, CPU utilization was 100% while processing the media to the engage formats (flash audio and video) and RSS feed downloads (mp3 and mp4) |
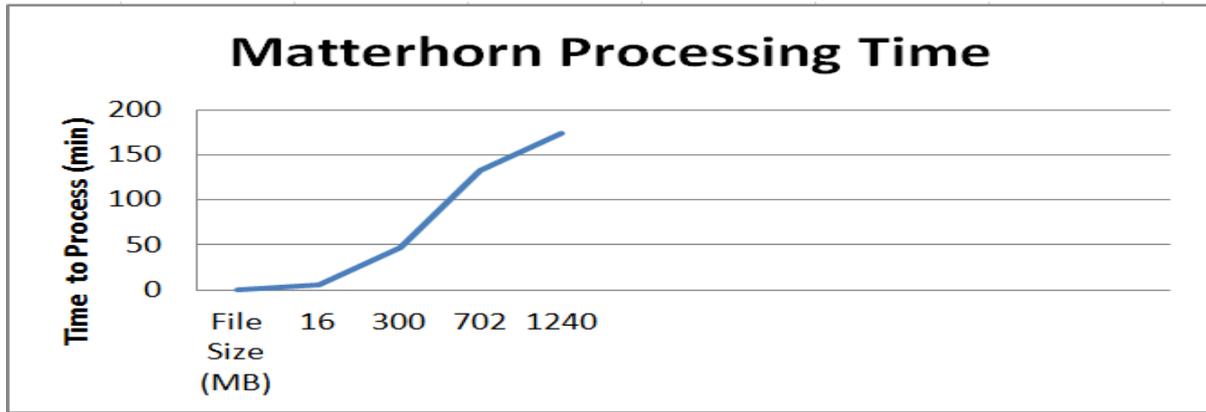
**Figure 34: Matterhorn graph indicating increase in processing time as media increases in size**

## 4.5 TESTING RECORDINGS FROM BBB TO MATTERHORN

The BBB was used as a capture agent and media were captured and sent to the Matterhorn server for processing. ). All tests were carried out on a Linux Ubuntu 10.04 LTS OS with Intel(R) Core(TM) i7-2720QM CPU @ 2.20GHz (8 processors) with 3GB of memory and internet speed of 170Mpbs Download/90Mpbs Upload. Both Mozilla Firefox and Google Chrome were used for this test. It was observed that during the conference, the 8 processors of the BBB had values ranging from between 10%-60% but memory was static at around 30%. The Matterhorn core CPU was at 100% every time the encodings for the **engage player** (flash video and audio); **feeds** (MP4 and MP3) are encoded as well when the server tries to **extract segments from presentations** but was in the normal 10-20% region when not processing this media; also memory usage was between 50-60%. Figure 35 (right side) displays the time taken to send recordings from BBB to Matterhorn as well as the time taken for Matterhorn to process the media. It is also important to note that media captures of 4GB are not ingested automatically into Matterhorn; there is a need to manually ingest the files for processing from the Upload Recording of the administrative UI and then choosing



| Recording Time (min) | file format sent | Time taken to send recording | Time taken to process recording |
|---|---|---|---|
| 5 | flv | 7 | 17 |
| 30 | flv | 17 | 24 |
| 60 | flv | 25 | 65 |
| 90 | flv | 40 | 110 |
| 120 | flv | 59 | 140 |
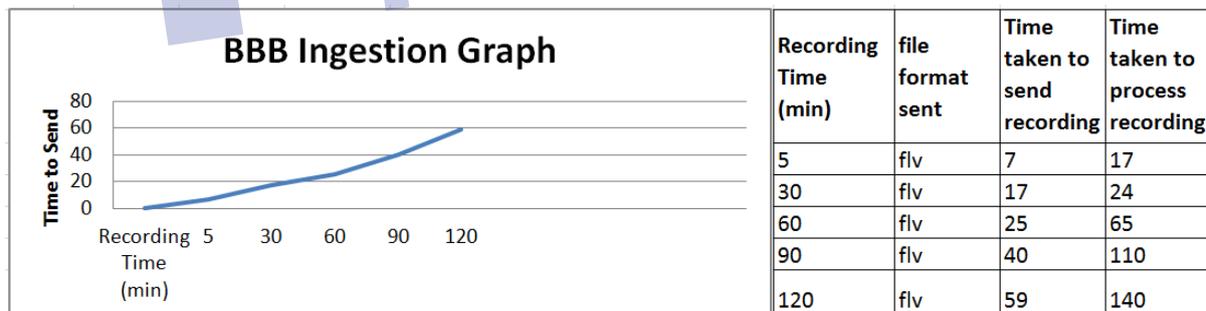
**Figure 35: Time taken to sent media increases as recording duration increases**

It can also be seen from Figure 35 (data on the right hand side) that the time to process **flash** videos is considerable lesser than **avi** files used in Table 10.

## 4.6 TESTING RECORDINGS IN SYNOTE

The URL of the RSS feed generated by Matterhorn from the test conducted in section 4.5 where used to create recordings on Synote; the recordings were created without any problems; facilitating annotation of the recordings. See figure 36 for details.

Figure 36: BBB Recordings playback on Synote with annotations on the right

## 4.7 DELETING RECORDINGS IN BIGBLUEBUTTON, MATTERHORN AND SYNOTE

It is interesting to note that none of the software provides an interface button to delete recordings after they are no longer needed. For BBB, presentations are stored into **/var/bigbluebutton/meetings/<meeting-id>/presentations/**, Deskshare records are stored into **/var/bigbluebutton/deskshare/**, video records are stored into **/usr/share/red5/webapps/video/streams/<meeting-id>/**, freeSWITCH records are stored into **/var/freeswitch/meetings/**. For Matterhorn, the ingested files from BBB are stored in the location **/opt/content/download**, Synote does not store media. In other to delete these recordings, one needs to manually do so or write a **cron** job that automatically runs at specific time. It is expected that Matterhorn 1.4 solves this issue by providing a delete button from the administrative UI. Also BBB has a Moodle Plugin[153] that facilitates deleting of media recordings from within Moodle.

## 4.8 SUMMARY OF INTEGRATION

The integration of BBB with Matterhorn is by simply copying the files generated by BBB and automatically ingesting the file to Matterhorn for processing, similar to the REST ingest API used in Matterhorn. After the media is sent, Matterhorn processes the media in mp3 and mp4 formats for its RSS/ATOM feed, the Grails service developed for Synote reads the RSS/ATOM feed and use the information from the feed to create recordings for playback in Synote. Figure gives a pictorial view of the implementation
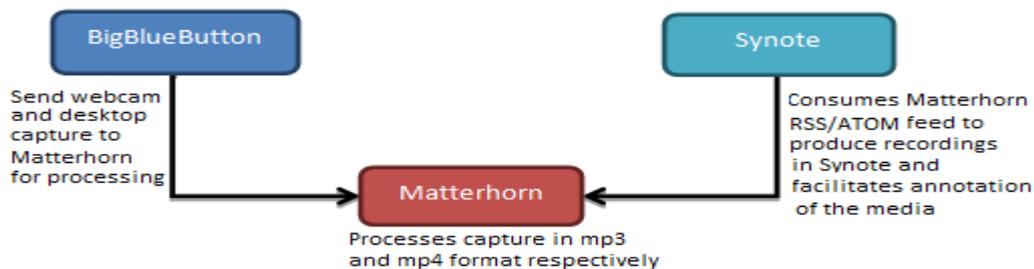


Figure 37: Final Integration

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[153] http://moodle.org/plugins/view.php?plugin=mod_recordingsbn

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# CHAPTER 5: CONCLUSION AND FUTURE WORK

## 5.1 CONCLUSION

This report has analysed the various e-learning tools that are currently used within the e-learning domain comparing mostly open source software with proprietary software. Categorization of e-learning tools was made into four major groups which include LMS, web conferencing systems, capturing systems and slidecasting systems. Moodle, Sakai, Ilias are good open source LMS systems solution. BigBlueButton has fairly good functionality when compared with some proprietary solutions like Adobe Connect Pro or Cisco webEx. Opencast Matterhorn provides a good open source alternative to Panopto or Tegrity as lecture capturing systems while Synote provides a very good open source slidecasting and annotation system when compared with other proprietary slidecasting applications.

The preference of BigBlueButton for capturing purpose was due to the fact that it can be used to capture both the traditional classroom teaching and create a virtual live meeting environment for people in different geographical locations, it is also OS independent; its browser based. However, it still has some limitations in terms of security, also, the maximum number of people that can participate in a conference is 80 which is small when compared to proprietary software but might just be adequate for educational use; being also free is a plus as adopters do not need to pay for some licencing cost that can run into a few hundred or thousands pound per year. The desktop and webcam captures from BigBlueButton where sent to Opencast Matterhorn for media processing, Matterhorn's capability to process media for different purposes and format were utilized as recordings where encoded for distribution via RSS/ATOM feeds in the handy and popular mp4 and mp3 formats (which Synote prefers), Matterhorn however lacks good interactive features that users can use to engage with media recordings; Synote was utilized to bring the media content closer to the user by facilitating annotation and transcription on such media and also providing the possibility of searching recordings based on annotation which is a rarity in most applications including the popular Youtube.

A grails service was developed that can be integrated into Synote to consume the RSS/ATOM feeds from Matterhorn. The information extracted from the feed is then used to playback the recording on Synote allowing for media annotations, transcription and searching of media contents based on those annotations. A viable solution that can enrich the e-learning community as well as aid the traditional classroom learning has been developed at zero licencing cost. However, it is also important to note that most open source software's relies heavily on other open source components and might require upgrades at frequent intervals; it will also at most times require some deep technical knowledge to install, configure and manage yet a whole lot of money can be save by avoiding licencing cost of commercial software and deploying them.

## 5.2 FUTURE WORK

Since BigBlueButton also has plugins for integration with open source LMS systems such as Moodle or Sakai, it will also be possible to provide an integration that includes this major open source with this project e.g. an integration of **Moodle-BigBlueButton-Matterhorn-Synote** is possible and can be investigated. As Matterhorn 1.4 is currently under testing and will be released in the nearest future, a proper investigation into the use of TheRec Matterhorn can be performed which can serve as software based lecture capture agent for Windows OS; Galicaster can also be properly investigated to provide a Linux based alternative. In Synote, the live note taking via Twitter can be replaced by possible integrating it with Vienna University's Slidecasting 2.0 slidecasting software which facilitates annotation of slides during lecture recordings can be an alternative. The REST API in Matterhorn can also be investigated as a possible integration solution with Synote. Lastly, since BigBlueButton, Matterhorn and Synote has mobile versions already released or in the process of being released, it will also be interesting to provide a mobile integration of these three software and the list might go on and on.

## APPENDIX A: INSTALLING BIGBLUEBUTTON ON VIRTUAL MACHINE

**(**Adapted from http://code.google.com/p/bigbluebutton/wiki/BigBlueButtonVM)

- Download and uncompress the the BigBlueButton VM from sourcefourge (http://sourceforge.net/projects/bigbluebutton/files/) and open the enclosed folder.

- Double-click on the bigbluebutton-vm.vmx icon. This should start the VMWare Player/Workstation (or VMWare Fusion on the Mac) and boot the VM. Note: Make sure the networking is set to **Bridged**, not NAT. (if set to NAT, change to bridge mode and type the command "**sudo /etc/init.d/networking restart"**

- It takes around 10 minutes for complete installation, the default username is "**firstuser"** and the default password is **"default"**. For security reasons, there is also need to change the default password at the first login attempt.

## APPENDIX B: INSTALLING BIGBLUEBUTTON ON UBUNTU 10.04 LTS

**(**Adapted from http://code.google.com/p/bigbluebutton/wiki/InstallationUbuntu)

- Firstly, there is need to give the installation machine access to the BBB package repository for 0.8 by pasting this command in the terminal:

```
# Add the BigBlueButton key
wget http://ubuntu.bigbluebutton.org/bigbluebutton.asc -O- | sudo apt-key add -

# Add the BigBlueButton repository URL and ensure the multiverse is enabled
echo "deb http://ubuntu.bigbluebutton.org/lucid_dev_08/ bigbluebutton-lucid main" | sudo tee
/etc/apt/sources.list.d/bigbluebutton.list
echo "deb http://us.archive.ubuntu.com/ubuntu/ lucid multiverse" | sudo tee -a /etc/apt/sources.list
```

- Next, there is a need to ensure that the latest packages are being used and the server is up-to-date before installing BBB by typing the command **sudo apt-get update** and **sudo apt-get dist-upgrade**

- There is also need to install Ruby as it is used by the record and playback infrastructures. First there is a need to install the following dependencies to compile ruby by typing the command:

  - ✓ **sudo apt-get install zlib1g-dev libssl-dev libreadline5-dev libyaml-dev build-essential bison checkinstall libffi5 gcc checkinstall libreadline5 libyaml-0-2**

  - ✓ Next, a file named install-ruby.sh must be created (type the command **cat > install-ruby.sh**). Then copy and paste the script below on it (navigate to the location of the file and type **gedit install-ruby.sh**): If **gedit** is not installed; type the command **sudo apt-get install gedit** and try again.

```
#!/bin/bash
cd /tmp
wget http://ftp.ruby-lang.org/pub/ruby/1.9/ruby-1.9.2-p290.tar.gz
tar xvzf ruby-1.9.2-p290.tar.gz
cd ruby-1.9.2-p290
./configure --prefix=/usr\
        --program-suffix=1.9.2\
        --with-ruby-version=1.9.2\
        --disable-install-doc
make
sudo checkinstall -D -y\
        --fstrans=no\
        --nodoc\
        --pkgname='ruby1.9.2'\
        --pkgversion='1.9.2-p290'\
        --provides='ruby'\
        --requires='libc6,libffi5,libgdbm3,libncurses5,libreadline5,openssl,libyaml-0-
```

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```
2,zlib1g'\
                --maintainer=brendan.ribera@gmail.com
sudo update-alternatives --install /usr/bin/ruby ruby /usr/bin/ruby1.9.2 500 \
                --slave /usr/bin/ri ri /usr/bin/ri1.9.2 \
                --slave /usr/bin/irb irb /usr/bin/irb1.9.2 \
                --slave /usr/bin/erb erb /usr/bin/erb1.9.2 \
                --slave /usr/bin/rdoc rdoc /usr/bin/rdoc1.9.2
sudo update-alternatives --install /usr/bin/gem gem /usr/bin/gem1.9.2 500
```

✓ The script can be executed by typing the command **chmod +x install-ruby.sh** to make it executable and then typing the command **./install-ruby.sh** to run the script.

✓ After the installation is completed, type **ruby –v**

> **$ ruby -v**
>
> ruby 1.9.2p290 (2011-07-09 revision 32553)

✓ Next type **gem -v**.

> **$ gem -v**
>
> 1.3.7

✓ Finally to make sure gem can be installed, type **sudo gem install hello** (BBB does not need the gem hello; this was done just to make sure gem is working properly.

```
$ sudo gem install hello
Successfully installed hello-0.0.1
1 gem installed
Installing ri documentation for hello-0.0.1...
Installing RDoc documentation for hello-0.0.1...
```

- BigBlueButton can now be installed by typing the command **sudo apt-get install bigbluebutton**: if installing behind an HTTP Proxy server, an error is thrown from the package bbb-record-core. To rectify this, there is a need to manually install the gems (http://code.google.com/p/bigbluebutton/wiki/InstallationUbuntu#Unable_to_install_gems)

- For the purpose of interactively testing the server, a Demo API can be installed by typing the command **sudo apt-get install bbb-demo**. It can be removed later by typing the command **sudo apt-get purge bbb-demo**.

- After installation, there is a need for a clean restart, type the commands **sudo bbb-conf –clean** and **sudo bbb-conf –check**.

Sample Output

## APPENDIX C: INSTALLING OPENCAST MATTERHORN CORE ON UBUNTU 10.10

**(**Adapted from http://opencast.jira.com/wiki/display/mh13/Install+Source+Linux+v1.3)
**Prepare** (root privileges is needed to run Matterhorn commands)

- **Create Matterhorn installation directory and assign it to your username and group**

  ✓ sudo mkdir -p /opt/matterhorn
  ✓ sudo chown $USER:$GROUPS /opt/matterhorn

- **Install Subversion**

  ✓ sudo apt-get install subversion

- **Check out Matterhorn source**

  ✓ svn checkout http://opencast.jira.com/svn/MH/tags/1.3.1/opt/matterhorn/matterhorn_1.3.1

- **Install Openjdk 6, Maven and Apache**

  ✓ sudo apt-get install openjdk-6-jdk
    echo "export JAVA_HOME=/usr/lib/jvm/java-6-openjdk" >> ~/.bashrc
    source ~/.bashrc

  ✓ sudo apt-get install maven2

  ✓ Download Apache Felix version 3 by typing in the web browser the url:
    **archive.apache.org/dist/felix/org.apache.felix.main.distribution-3.2.2.tar.gz**

    - **Unarchive** (Navigate to the location where the file has been downloaded and type the command **tar xvf org.apache.felix.main.distribution-3.2.2.tar.gz**)

    - **Move file to the Matterhorn directory** ( type the command **mv felix-framework-3.2.2 /opt/matterhorn/felix** )

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- **Make a load directory and copy felix documents to installation directory**

  ✓ mkdir /opt/matterhorn/felix/load
    cp -rf /opt/matterhorn/matterhorn_1.3.1/docs/felix/* /opt/matterhorn/felix/

- **Install Gstreamer for demo capture agent**

  ✓ sudo apt-get install gstreamer0.10-plugins-base
    sudo apt-get install gstreamer0.10-plugins-good

  ✓ If the Ubuntu version is 11.04 or higher type also **sudo apt-get install libglib2.0-dev**

## Configure (root privileges is needed to run Matterhorn commands)

- Configure the main config flie by typing **sudo gedit /opt/matterhorn/felix/conf/config.properties**

  ✓ Set the server URL by looking for the line **org.opencastproject.server.url=http://<the URL of your server with port>**

  ✓ Set the storage directory, e.g. look for the line **org.opencastproject.storage.dir** and set to **/opt/matterhorn/content**. e.g. **org.opencastproject.storage.dir=/opt/matterhorn/content**

## Configure multi-tenancy option (root privileges is needed to run Matterhorn commands)

- Verify the server and port configuration in the file **/opt/matterhorn/felix/load/org.opencastproject.organization-mh_default_org.cfg** and apply appropriate change if needed.

  ✓ server=<the URL of your server without port>
    port=<the port you are running matterhorn on, typically 8080>

## Build (root privileges is needed to run Matterhorn commands)

- **Matterhorn**

  ✓ export MAVEN_OPTS='-Xms256m -Xmx960m -XX:PermSize=512m -XX:MaxPermSize=512m'
    cd /opt/matterhorn/matterhorn_1.3.1
    mvn clean install -DdeployTo=/opt/matterhorn/felix/matterhorn

    A successful built ends with something like this:
    [INFO] ------------------------------------------------------------------------
    [INFO] BUILD SUCCESSFUL
    [INFO] ------------------------------------------------------------------------
    [INFO] Total time: 50 seconds
    [INFO] Finished at: Thu Jul 08 07:15:20 PDT 2010
    [INFO] Final Memory: 56M/265M
    [INFO] ------------------------------------------------------------------------

- **Third Party tools (very important)**

  ✓ Navigate to the third party directory **/opt/matterhorn/matterhorn_1.3.1/docs/scripts/3rd_party** and open the README file; this basically contains information about how to install the 3rd party tool, but the commands to run are basically:
    - export HOME3P=<3rd_party_directory>  # use absolute path, not "."
      export SUDOPWD=<sudo_password> # if needed

## RUN (root privileges is needed to run Matterhorn commands)

- Export environmental variables

    - ✓ echo "export M2_REPO=/home/$USER/.m2/repository" >> ~/.bashrc
      echo "export FELIX_HOME=/opt/matterhorn/felix" >> ~/.bashrc
      echo "export JAVA_OPTS='-Xms1024m -Xmx1024m -XX:MaxPermSize=256m'" >> ~/.bashrc
      source ~/.bashrc

- Run Matterhorn

    - ✓ sudo sh /opt/matterhorn/felix/bin/start_matterhorn.sh

- Browse http://localhost:8080
- Stop Matterhorn (optional)

    - ✓ sudo sh /opt/matterhorn/felix/bin/shutdown_matterhorn.sh

## RUN MATTERHORN AS A SERVICE (root privileges is needed to run Matterhorn commands)

- sudo cp /opt/matterhorn/matterhorn_1.3.1/docs/felix/bin/matterhorn_init_d.sh /etc/init.d/matterhorn
  sudo update-rc.d matterhorn defaults

- type **sudo gedit /etc/init.d/matterhorn** and change the value for MATTERHORN_USER to the user that should execute matterhorn: e.g. MATTERHORN_USER="user"

- Start Service

    - ✓ sudo service matterhorn start

- Stop Service

    - ✓ sudo service matterhorn stop

**(Sample installation can be seen at: http://kanga-aa5g11.ecs.soton.ac.uk:8080/welcome.html)**

## APPENDIX D: INSTALLING OPENCAST MATTERHORN CA ON UBUNTU 10.04 LTS (Adapted from http://opencast.jira.com/wiki/display/mh13/Install+Capture+Agent+v1.3)

### Pre installation notes
- It is highly recommended to install on 64bit version of Ubuntu due to the large files size generated
- It can only be installed on a Linux operating system.
- Note the kernel version by typing **uname -r** as this will be needed when choosing a driver version if Epiphan VGA2USB hardware device is to be used.
- The script requires internet connection to get the necessary third-party software and source code.
- You will be prompted several times for inputting certain configuration values.
- After the installation, a rebooting is required so that some settings are applied. If you choose not to reboot immediately, please bear in mind the system will not be functional until the machine restarts.

### Get installation script
- sudo apt-get install subversion
  svn co http://opencast.jira.com/svn/MH/tags/1.3.1/docs/scripts/ubuntu_capture_agent/
  ubuntu_capture_agent

## Install Capture Agent

- Go to the directory where you downloaded install.sh. Make sure the script has the execution permissions and install script:
  - ✓ chmod +x install.sh
    sudo ./install.sh

## Run Capture Agent

- it can be executed as a service by typing **sudo /etc/init.d/matterhorn start**
- Or by running the installation script at **/opt/matterhorn/felix/bin/ start_matterhorn.sh**

## Initialize a Test Capture

- To determine that the capture agent has been setup correctly:
  - ✓ Open a web browser and navigate to **http://servername:8080/capture** -- where servername is the name of the machine you installed the capture agent onto.
  - ✓ If they are unchanged, use the default username and password to log into the capture agent website.
  - ✓ Click on the "**Start Capture**" button at the bottom of the page to start a test capture.
  - ✓ Once it has confirmed that it has begun capturing, navigate back to **http://servername:8080/capture**.
  - ✓ Verify that the agent state at the top of the page has changed from idle to capturing.
  - ✓ Click on the "Stop Capture" button at the bottom of the page.
  - ✓ Once it has confirmed that it has stopped capturing, navigate back to **http://servername:8080/capture**.
  - ✓ Verify that the agent state at the top of the screen has transformed to idle.

## View the Test Capture

To verify the media captured by the capture agent:
  - ✓ Navigate to http://servername:8080/capture, hyperlinks to the media should be present at the bottom of the screen. Alternatively, media is cached on the agent at **$MATTERHORN_HOME/cache/captures**.
  - ✓ There should be one directory per capture containing one media file per capture device using the friendly name you specified during the install.
  - ✓ Copy these media files to another machine or playing them on the server with your favorite media player.
  - ✓ If the media files play correctly the capture agent has been installed and is ready to use.

## APPENDIX E: MATTERHORN CUSTOM ENCODINGS

**(**Adapted from http://opencast.jira.com/wiki/display/mh13/Capture+Agent+Configuration+v1.3 and http://opencast.jira.com/wiki/display/mh13/Custom+Capture+Devices+v1.3)

- This configuration was done on **DELL XPS L7202X, 12GB RAM, Intel (R) Core (TM) i7-2720QM CPU @ 2.20GHz (8 CPUs), ~ 2.2GHz** with an integrated Webcam to capture the Webcam pictures.
  - ✓ *# setting the input file is the same as setting the device, just choose a file instead of a device*
    **capture.device.H264Webcam.type=CUSTOM_VIDEO_SRC**
    **capture.device.H264Webcam.customProducer=filesrc location=/dev/video1 !**
    **ffdemux_mov_mp4_m4a_3gp_3g2_mj2 ! ffdec_h264 ! videoscale ! video/x-raw-yuv,width=1024,height=768 ! queue**
    **capture.device.H264Webcam.flavor=presenter/source**
    **capture.device.H264Webcam.outputfile=Webcam.mpg**
    **capture.device.H264Webcam.src=/dev/video1**
    *# define the names of the devices, or for a mock capture, the files*
    **capture.device.names=SCREEN,PRESENTER,MICROPHONE,H264Webcam**

## APPENDIX F: INSTALLING THEREC MATTERHORN

- Firstly, there is a need to install free software based VGA-capture software. This can be downloaded and installed from **https://github.com/rdp/screen-capture-recorder-to-video-windows-free**
- The next step is to install and configure TheREC Matterhorn and the Matterhorn Remote Inbox (MHRI)
    - ✓ Instruction on how to install and configure TheRec can be seen from **http://vm193.rz.uni-osnabrueck.de/therec/#**

    - ✓ **INSTALLING THE MHRI SCRIPT**
    (Adapted from **http://vm193.rz.uni-osnabrueck.de/mhri/#**)
        - Double click install.bat. You will be asked to execute the install task with administrator privileges.
        - The software is now copied to C:\Program Files\mhri-1.0.1 and will be autostarted after each login.
        - To start the software log out and in again or just double click start.bat in the program directory ("C:\Program Files\mhri-1.0.1").
        - Right click on the tray icon and select "Preferences".
        - Change the default values you want to have changed (e.g. server, username, password etc.).
        - Click "Ok".

    **STARTING THE SOFTWARE MANUALLY**
    - Make sure that no MHRI is currently running.
    - Make sure that no MHRI tray icon is being displayed
    - Double click start.bat in the program directory (C:\Program Files\mhri-1.0.1).
    - After a short delay the program icon will appear in the system tray close to the Windows clock as a tray icon.
    - Double click the tray icon to open the Inbox Overview or right click the tray icon to get more options.

## APPENDIX G: INTEGRATING BIGBLUEBUTTON WITH MATTERHORN

Due to the length of the steps involved, the installation details are not copied directly here but can be found at http://code.google.com/p/bigbluebutton/wiki/MatterhornIntegration)

## APPENDIX H: SAMPLE MP3 AND MP4 ENCODING

```
####
# Profile definitions for the encoding service.
#
# In order to understand how to configure a format, take a look a the
# documentation below:
#
# profile.<format>.name:
#    Name of the format, used in download dialogs of the frontend.
#
# profile.<format>.output:
#    Type of the distribution format.
#    [video|image]
#
# profile.<format>.suffix:
#    Extension that will be appended to the download.
#
# profile.<format>.mimetype:
#    Mime type used to provide proper content types.
#
# profile.<format>.input:
#    Track categories for which this format is applicable.
#    Known categories are:
#    - audio : for tracks containing only audio streams
```

```
#    - video : tracks containg video and probably audio
#    - enhanced-audio : for so-called enhanced audio tracks
##

profile.mp4-hd.http.name = HD-Video
profile.mp4-hd.http.input = visual
profile.mp4-hd.http.output = visual
profile.mp4-hd.http.suffix = -hd.mp4
profile.mp4-hd.http.mimetype = video/mp4
profile.mp4-hd.http.ffmpeg.command = -i #{in.video.path} -threads 0 -vcodec libx264 -profile high -preset medium -g 50 -deinterlace -
qscale 5 -r 25 -vf scale=-1:720 -acodec libfaac -ar 44100 -ab 128k #{out.dir}/#{out.name}#{out.suffix}

profile.mp4-vga-hd.http.name = HD-VGA-Video
profile.mp4-vga-hd.http.input = visual
profile.mp4-vga-hd.http.output = visual
profile.mp4-vga-hd.http.suffix = -vga-hd.mp4
profile.mp4-vga-hd.http.mimetype = video/mp4
profile.mp4-vga-hd.http.ffmpeg.command = -i #{in.video.path} -threads 0 -vcodec libx264 -profile high -preset medium -g 50 -deinterlace -
qscale 5 -r 25 -acodec libfaac -ar 44100 -ab 96k #{out.dir}/#{out.name}#{out.suffix}

profile.mp3.http.name = mp3
profile.mp3.http.input = audio
profile.mp3.http.output = audio
profile.mp3.http.suffix = -audio.mp3
profile.mp3.http.mimetype = audio/mp3
profile.mp3.http.ffmpeg.command = -i #{in.video.path} -ar 44100 -ab 128k -vn -f mp3 #{out.dir}/#{out.name}#{out.suffix}
```

## APPENDIX I: SAMPLE MP3 AND MP4 Workflow

Due to the verboseness of this code, the content are left out of this report, but are available on the Matterhorn server located at http://kanga-aa5g11.ecs.soton.ac.uk in the encoding folder (**opt/matterhorn/felix/conf/workflow/mp4-mp3.xml**)

## APPENDIX J: SAMPLE RSS AND ATOM FEED

**RSS FEED**

```
<item>
        <title>TEsting</title>
            <link>http://kanga-aa5g11.ecs.soton.ac.uk:8080/engage/ui/embed.html?id=df0e9f07-7fa0-4377-b278-4f30a1d1e2f7</link>
            <enclosure url="http://kanga-aa5g11.ecs.soton.ac.uk:8080/static/df0e9f07-7fa0-4377-b278-4f30a1d1e2f7/515838bd-205e-
            402c-a7c6-8e7f45102905/deskshare.mp4" length="20000" type="video/mp4" />
        <pubDate>Tue, 11 Sep 2012 23:27:00 GMT</pubDate>
        <guid isPermaLink="false">df0e9f07-7fa0-4377-b278-4f30a1d1e2f7</guid>
        <itunes:duration>00:00:20</itunes:duration>
        <itunes:author>test</itunes:author>
        <itunes:explicit>no</itunes:explicit>
        <itunes:keywords />
        <dc:title>TEsting</dc:title>
        <dc:creator>Yemi</dc:creator>
        <dc:contributor>None</dc:contributor>
        <dc:date>2012-09-11T23:27:00Z</dc:date>
        <dc:identifier>df0e9f07-7fa0-4377-b278-4f30a1d1e2f7</dc:identifier>
        <dc:language>English</dc:language>
    </item>
```

**ATOM FEED**

```
<entry>
        <title mode="escaped">TEsting</title>
                <link href=http://kanga-aa5g11.ecs.soton.ac.uk:8080/engage/ui/embed.html?id=df0e9f07-7fa0-4377-        b278-
        4f30a1d1e2f7 />
                <link rel="enclosure" type="video/mp4" href="http://kanga- aa5g11.ecs.soton.ac.uk:8080/static/df0e9f07-7fa0-4377-
        b278-4f30a1d1e2f7/915cd747-7238-4c98-be6e-06ea805a4db6/muxed_audio_webcam.mp4" />
                <link rel="enclosure" type="audio/mp3" href="http://kanga-aa5g11.ecs.soton.ac.uk:8080/static/df0e9f07-7fa0-4377-
        b278-4f30a1d1e2f7/5aa32ef4-2b8c-414b-be1d-afddf1e82d65/muxed_audio_webcam.mp3" />
                <link rel="enclosure" type="video/mp4" href="http://kanga-aa5g11.ecs.soton.ac.uk:8080/static/df0e9f07-7fa0-4377-
        b278-4f30a1d1e2f7/515838bd-205e-402c-a7c6-8e7f45102905/deskshare.mp4" />
        <link rel="enclosure" type="audio/mp3" href="http://kanga-aa5g11.ecs.soton.ac.uk:8080/static/df0e9f07-7fa0-4377-b278-
4f30a1d1e2f7/2b46ce77-de83-4b5a-a558-b9ac11512c13/deskshare.mp3" />
        <author>
        <name>Yemi</name>
```

```
</author>
<id>df0e9f07-7fa0-4377-b278-4f30a1d1e2f7</id>
<modified>2012-09-11T23:27:00Z</modified>
<issued>2012-09-11T23:27:00Z</issued>
<dc:title>TEsting</dc:title>
<dc:creator>Yemi</dc:creator>
<dc:contributor>None</dc:contributor>
<dc:date>2012-09-11T23:27:00Z</dc:date>
<dc:identifier>df0e9f07-7fa0-4377-b278-4f30a1d1e2f7</dc:identifier>
<dc:language>English</dc:language>
</entry>
```

## APPENDIX K: GRAILS SERVICE

```
package org.synote.integration.matterhorn
import net.sf.ehcache.Element
class RSSConsumptionService {

        def matterhorn //cache element
        Object atomkey = "atomkey"
        Object rsskey = "rsskey"
        def lastdate = 0 //used to track the most recent last date
        static mapping = {
                cache true
        }
  // update cache
        def updateCache ={
                def atmfeed = atmfeeds()
                def rssfeed = rssfeeds()
                matterhorn?.put(new Element(atomkey,atmfeed))
                matterhorn?.put(new Element(rsskey,rssfeed))
        }
  // Get atom feed from cache
        def getAtom = {
                matterhorn?.get(atomkey)?.value
                }
  // Get atom feed from cache
        def getRss = {
                matterhorn?.get(rsskey)?.value
                }
  // read atom feeds
    private def atmfeeds = {
                def urlatom = 'http://kanga-aa5g11.ecs.soton.ac.uk:8080/feeds/atom/0.3/latest'
                def items = []
                def atomFeed = new XmlParser().parse(urlatom)
                atomFeed.entry.each {item ->
                    items << [
                                        println("title:${item.title.text()}"),
                                        println("author:${item.author.name.text()}"),
                                        println ("url:${item.link[-1].'@href'}"),
                                        println ("url:${item.link[-2].'@href'}"),
                                        println ("type:${item.link[-1].'@type'}"),
                                        println ("type:${item.link[-2].'@type'}"),
                                        println ("ALL-URL:${item.link.'@href'}"),
                                        println("\n\n")
                    ]
                                items
        }

  }
// read rss feeds
    private def rssfeeds= {
              def urlrss = 'http://kanga-aa5g11.ecs.soton.ac.uk:8080/feeds/rss/2.0/latest'
                def rssFeed = new XmlParser().parse(urlrss)
                def items2 = []
                def inisize = rssFeed.channel.item.size() //use to specify the last item in the feed
                def cursize = rssFeed.channel.item.size() //use to specify the current item number in the feed
                        rssFeed.channel.item.each { item2 ->
                            if (inisize==cursize){
                                        lastdate = item2.pubDate.text()
                                }
```

```
                                cursize = cursize - 1
                items2 << [
                                println ("lastdate: ${lastdate}"),
                                println ("pubDate: ${item2.pubDate.text()}"),
                        println ("length: ${item2.enclosure.'@length'.text()}")
                ]
        items2
          }


    }
}
```

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