AfriMeet: An Internet meeting tool designed for low bandwidth and unstable network conditions

Tresor Mvumbi, Zafika Manzi, Flora Kundaeli

Supervised by Hussein Suleman

Department of Computer Science

University of Cape Town

Contents

1. Project description

Low bandwidth and unstable Internet connections make most Internet conferencing solutions unreliable for South Africa and developing countries in general (Egido, 1998). This project aims to design a developing-country-aware application to host online meetings where multiple participants can share audio, presentations and video. The assumption is that with some key architectural restructuring, the user experience can be substantially improved, even with poor Internet service conditions. The restructuring could include the prioritization of audio, video key framing and the pre-fetching of static data like presentation slides.

2. Problem statement

Most of the current online meeting tools were developed with the assumption of stable Internet connections with large amounts of bandwidth. Consequently, when they are applied to the African context, the user's experience is greatly affected and the product's usability drops, making it unreliable (Egido, 1998). Internet conferencing solutions provide a virtual environment with tools and features for remote meetings among geographically dispersed participants. These features may include audio-video communication, slide presentations, text chat, agenda and whiteboard sharing. When the Internet connection quality declines, those features are directly impacted. Problems such as indeterminate audio, frozen presentation slides and very poor video quality may arise, resulting in an unpleasant user experience (Claypool & Tanner, 1999). These problems can impact the communication to a point where the Internet conferencing solution is almost useless (Egido, 1998).

Not all the features of Internet conferencing tools are impacted the same way by Internet connection problems. In addition, they do not have the same effect on usability and user experience. Therefore research will be conducted to determine how an internal architectural restructuring can positively enhance the usability and user experience. The research will focus on investigating how to reprioritize features in order to get the best tradeoff between quality and usability with constrained Internet connections. The main research questions are:

- Is it possible to build an effective audio-conferencing tool that works with low bandwidth conditions?
- Is it possible to build an effective video-conferencing tool that works with low bandwidth conditions?
- Is it possible to build an effective text chat tool that can work with minimal bandwidth?
- Is the pre-loading of static data feasible with low bandwidth?
- Is it possible to construct a system that manages meeting procedures (presence, hand-raising, etc.) efficiently despite varying Internet conditions?

Contrary to previous design approaches, this project will assume a very poor Internet connection. Further investigations on how to deliver an acceptable user experience with this constraint will be conducted. The resulting product should function reliably with both limited and high speed Internet service.

3. Procedures and Methods

The problem stated in the preceding section will be solved by using techniques and methods adopted from previous related work. Having investigated experiments that use different approaches in handling online meetings with low bandwidth, and considering current Internet conferencing tools, techniques that best suit the problem were identified and extracted. These techniques are then merged with different ideas to form an approach that addresses and solves the problem. The objective is to produce a software solution that will adequately meet and satisfy the user's needs regardless of their location and bandwidth allowance.

A good-hand raising implementation will help to effectively use the available bandwidth. For example, only the audio and video from the participant holding the floor will be streamed. To optimize the bandwidth usage, each participant will either receive or send a stream. All the static content (presentation slides, meeting agenda, participant pictures, etc.) will be preloaded at all participant posts. This approach will avoid real time streaming of the content and help preserve the bandwidth.

3.1 Development Environment

Java 2 Standard Edition (J2SE) will be the main development platform. J2SE represents an object-oriented mature technology that has been reliably tried and used for network programming, multimedia and multi-threaded applications (Munaf, 2007). Another motivation for choosing J2SE is that it is platform-independent and supports distributed computing. Finally, J2SE relies on a large and very active Java community. Thus there is a large choice of development tools, third party libraries and documentation.

3.2 System Design

The software development methodology used will be based on an iterative approach. The whole process will take three iterations, each comprising of an initial design stage, an implementation stage and an evaluation of the system. Figure 1 illustrates this process. The advantage of using this approach is that it allows repetition of all the development stages to improve the system.

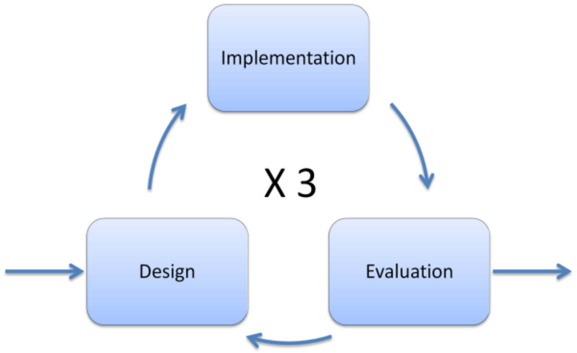


Figure 1: Iterative design process

Lu et al. (2010) suggested that a Client-Server architecture is the best approach for Internet conferencing tools. Based on this, the solution will comprise of a central meeting hosting server where several participants will connect to join the meeting. This Client-Server process will occur over the Internet, supporting one or more conferences.

The participant list will determine the number of users connected to the system and the number of multimedia streams (audio, video, presentation and chat) needed. The floor control mechanism will act as router that manages the interaction and flow of data between users.

3.2.1 Client application

The client is responsible for displaying a user interface, which will enable interaction with the overall system. The client will use a computer, microphone, speakers and a webcam. The captured audio signal will be sent on a continuous live stream, whereas the captured images will be sent to the server at a very low frame rate (e.g. one image per minute) to improve bandwidth use. In most forms of communication, hearing the audio is more important than visualizing the speaker, therefore more emphasis and effort will be placed on the delivery of a good quality audio signal (Daly-Jones & Monk, 1998). Therefore a good audio codec for compression is needed. A chat feature will be incorporated to complement the audio and assist in communication. This feature will enable communication to continue even when the audio stream is affected due to a change or fluctuation in the available bandwidth. The ability of the system to adapt to bandwidth fluctuations makes it different from most existing meeting solutions, as they do not cater for lower bandwidth.

The system will support two presentation formats: PowerPoint and Portable Document Format (PDF). These presentations will be pre-loaded onto all the clients as they contain static content. The user will be able to navigate the screen interface using a mouse and click the desired features. A participant list that shows the people present in a meeting will be added. In addition, a hand-raising feature will be offered for users to express their opinions and request access to speak. Some of the hand-raising expressions will include: raise hand, drop hand, agree, applause and exit meeting. These will help manage and maintain clear meeting procedures. If time allows, a meeting agenda and a whiteboard feature will be implemented into the meeting system.

3.2.2 Server application

The server will run on a single machine and contain the framework that holds and links the components together. Upon receiving images and data from clients over the network (Internet), the server distributes them to other clients belonging to the same meeting. The server should be able to keep track of the number of meetings simultaneously occurring and also maintain a list of participants in each meeting. This will enable data from the floor holder to go to the appropriate attendees and avoid having confidential data sent to the wrong meeting. The server will maintain a record of all logged on attendees and each meeting that they are participating in. The details associated with each person will include their username, password, IP address and unique ID. The server will receive and publish the status changes of participants.

3.3 Design Challenges

The main design challenge is getting the system to work in an unreliable network. Eliminating problems in the sound quality could be a challenge due to the fluctuating bandwidth. In addition, problems may arise when integrating the three different parts of the system into one framework. Figure 2 illustrates the overall architecture of the Internet conferencing application.

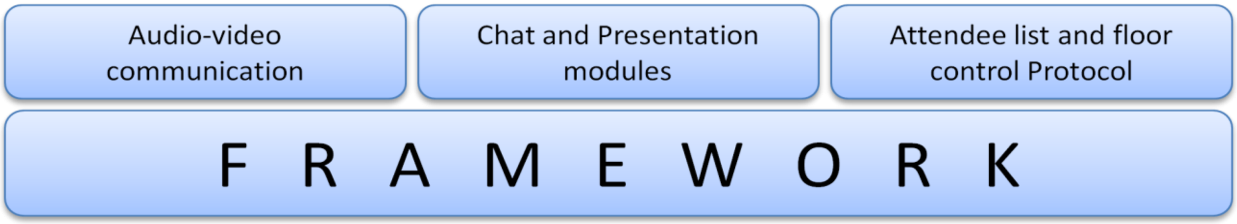

Audio-video communication
Chat and Presentation modules
Attendee list and floor control Protocol
F R A M E W O R K

Figure 2 : Internet conferencing software architecture

Obtaining the desired interoperability among the above three sections might prove challenging as each component will be developed by different people. Another problem could be finding the appropriate webcams and microphones that will work more efficiently and enable easier processing of the data. The challenge of learning new libraries from third parties within the project time-line is expected.

3.4 Evaluation

The tests that will be conducted on the software are listed below. For all these tests, the software will be deployed in a low bandwidth environment and given to users to perform certain tasks.

1. A test to determine if the audio-conferencing works with low bandwidth conditions.

   Users will be requested to carry out meetings using only the audio feature of the Internet meeting tool. This will test the effectiveness of the audio transmission.

2. A test to determine if the video-conferencing works with low bandwidth conditions.

Users will be requested to carry out meetings using the audio and video feature of the Internet meeting tool. The focus will be on whether the video is able to function with low bandwidth and whether video increases the sense of presence for the users.

3. A test to determine if the text chat is effective and works with minimal bandwidth.

   Users will be requested to carry out meetings using the chat feature of the Internet meeting tool. This will test whether chat is able to function with limited bandwidth.

4. A test to determine if the pre-loading of static data is effective with low bandwidth.

   The actual time needed to pre-load all static data will be measured. This pre-loading phase is bandwidth consuming, so audio/video communication during this stage is ineffective. Based on the precedent measurement, an evaluation will weigh the impact of pre-fetching on the whole meeting process.

5. A test evaluating whether the system is able to manage meeting procedures efficiently despite varying Internet conditions.

   To evaluate how effectively the system manages meeting procedures with varying Internet conditions, users will be required to use the system and give feedbacks. A questionnaire will be used to report theses feedbacks. The user will rank the sense of presence during the meeting process and the effectiveness of the floor control mechanism.

6. A test to assess the system performance.

   For this, users will be requested to log onto the meeting as many times as possible using different user names each time. Therefore for each given bandwidth, the maximum number of users the system can support will be determined.

The test on the first prototype will assess the technical feasibility of each main feature. The second prototype will merge all the features, a test on it will assess the overall effectiveness of the meeting process. Insights from these two tests will lead to the final prototype on which a complete evaluation will be run to assess the system performance.

4. Ethical, Professional and Legal Issues

Since the project is based on the user's experience, users will be needed to help to evaluate the online meeting system. Therefore ethics clearance from the University will be required. The participants for the evaluation phase will be provided with all information regarding the test procedure and the confidential nature of collected data. The Internet conferencing software will be developed from scratch. Free and open source tools, development platforms and third party libraries will be used.

5. Related work

The problem of delivering a good user experience with limited Internet access is covered by several research areas. Claypool & Tanner (1999) suggest that the effects of unstable transmission on the audio stream can be reduced with buffering techniques. On average, a video stream uses around 10 times more bandwidth than an audio stream (Chen, 2002). Therefore with low bandwidth conditions, prioritization of audio over the video leads to better communication quality (Hargreaves & McCown, 2008). To preserve a good sense of presence and for better meeting immersion, a lower priority video stream can be maintained. A frame rate minimization technique can also be applied along with a good compression scheme to reduce the video bandwidth requirement (Chen, 2002). However, when the bandwidth seriously decreases, the video stream can be cut and replaced by a static picture representing the participant. Chen (2002) experiment on gesture detection in video conferencing revealed that postures alone did not work well in small group discussions because of difficulties with floor control. His floor control mechanism permitted a user to be in either three states. Users were either in control of a shared resource, waiting for control or observing others activities. Takao (1999) examined the effects of varying the number of people one could view simultaneously on the screen. His results revealed that displaying multiple participants yielded better group decision quality than a single view of the current speaker only. Scholl et al (2005) used text chat and video and found that most users found the application useful. However it would be wiser and beneficial to incorporate video, audio and text chat all into one design for operation in low bandwidth conditions, so that features could adaptively complement each other when one failed.

6. Anticipated outcomes

6.1 System

The project end-product will be a Client-Server Internet conferencing software. The server side will host the meeting and will be the central hub for communication. It will host more than one simultaneous meeting. The client application will offer the user a virtual graphical environment to effectively participate in remote meetings. The system will have a high tolerance of networking problems and be independent of the underlying Operating System.

6.2 Expected Impact

The success of this product will greatly benefit organizations in developing countries where unstable and low bandwidth connections prohibit them from participating in online meetings. With this product, online business meetings will be possible between remote participants across different countries despite bandwidth differences. This will greatly reduce the costs of travel expenses and further reduce the time wasted traveling to meetings. In addition, various results from experimentations run during the project could be helpful for future research on development of Internet based solutions for low bandwidth and unstable Internet conditions.

6.3 Key Success Features

The main measurement of success will be the user's ability to actively participate in a meeting despite fluctuations in bandwidth and unstable networks. In other words, the system should not crash or totally close down when the bandwidth changes. In addition, the user's satisfaction level and experience should not be greatly sacrificed or jeopardized as a result of the bandwidth. As the bandwidth drops, the system should eliminate some features that use more bandwidth. However, these features will be restored depending on the current available bandwidth.

7. Project Plan

7.1 Risks and Risk Management Strategies

Risk	Losing a group member
Cause	This risk may occur if a team member leaves the honours degree or is unable to contribute to the project for any reason.
Likelihood	Low
Mitigation	The workload is subdivided so that each group member has fairly independent tasks

Risk	Data loss
Cause	This risk happens if there is a system failure or power cut and the work was not saved or backed up.
Likelihood	Medium
Mitigation	Frequent backup of software on different devices

Risk	Delay on study and implementation of third party libraries
Cause	A delay on finding, studying and implementation of third party libraries may compromise some main project deliverables.
Likelihood	Medium
Mitigation	Identify all required third party libraries and test them on a prototype. Take timely measures for non working solutions (replacement, project restructuring, etc.)

7.2 Timeline & Gantt Chart

The project work load is divided into sections with corresponding deliverables. Appendix A presents the project Gantt Chart.

7.3 Resources required

The following resources will be required:

- **Hardware:** Computers, microphones, speakers and webcams
- **Software:** Development platform (Netbeans and Eclypse)

  Third party libraries (to be decided)

  Operating System (any)
- **Networking**: Wireless router to simulate low bandwidth and unstable network conditions

  Internet access
- **Humans**: Users to test and evaluate the system

7.4 Deliverables and Milestones

The table below lists major milestones and deliverables.

	Milestone	Deliverable	Date Due
Project Proposal	✓	✓	19 May
Proposal Presentation	✓	✓	26 May
Project Web Presence	✓		14 June
First Prototype Demonstration	✓		25 July
Background chapter	✓		29 July
Design Chapter	✓		29 August
Implementation and testing chapters ,software coding and testing complete	✓		29 September
Final Software Implementation		✓	3 October
Final draft of report	✓		24 October
Final report	✓	✓	31 October
Poster	✓	✓	3 November
Web page	✓	✓	7 November
Project demonstrations	✓		8 November
Reflection paper	✓	✓	11 November
Final Project presentations	✓	✓	17 November

7.6 Work Allocation

This project is divided into three equal parts in terms of length and difficulty. The next sections describe each member's work allocation.

7.6.1 Tresor Mvumbi

Responsible for implementing the following:

- **Audio and Video communication**

  This will include the application of buffering techniques to provide an acceptable audio quality. It will also involve the prioritization of the audio stream over video and applying key framing and compression techniques to provide a usable low bandwidth video stream.

7.6.2 Zafika Manzi

Responsible for implementing the following:

- **Chat facility**

  Text chat does not use up much bandwidth and can reliably function when the audio and video channel cannot work.

- **Presentation Slide module**

  The presentation slides will be compressed, and then preloaded onto all client systems. When the presenter switches slides, only the ID of the current page is sent across the network to synchronize all the participants.

7.6.3 Flora Kundaeli

Responsible for implementing the following:

- **The attendee list**

  This is simply a list of the logged-on members in each meeting.

- **The floor control mechanism**

  This is responsible for providing rules for hand-raising that enable clear and organized meeting procedures. It is also responsible for identifying who is currently handling the floor in order to propagate their details to the other meeting attendees.

- **The Framework**

  This is the main structure that enables the proper flow of data between the server and the different clients. It is also responsible for linking the different components of the system together and aids the collaboration between chat, video, presentations and the audio mechanisms in a meeting.

REFERENCES

Chen, M. (2002). Achieving effective floor control with a low-bandwidth gesture-sensitive videoconferencing system. *Proceedings of the tenth ACM international conference on Multimedia - MULTIMEDIA '02*, 476. New York, New York, USA: ACM Press. doi: 10.1145/641108.641109.

Claypool, M., & Tanner, J. (1999). The effects of jitter on the peceptual quality of video. *Proceedings of the seventh ACM international conference on Multimedia (Part 2) - MULTIMEDIA '99*, 115-118. New York, New York, USA: ACM Press. doi: 10.1145/319878.319909.

Daly-Jones O, Andew Monk, L. W. (1998). Some advantages of video conferencing over high-quality audio conferencing: fluency and awareness of attentional focus. *International Journal of Human-Computer Studies*, *49*(1), 21-58. doi: 10.1006/ijhc.1998.0195.

Egido, C. (1998). Video conferencing as a technology to support group work: a review of its failures. *Computer Supported Cooperative Work (CSCW)* (pp. 13 - 24). Morristown, USA: ACM New York, NY, USA ©1988.

Hargreaves, D. M. G., & McCown, B. R. L. (2008). Low-cost, low-bandwidth online meetings between farmers and scientists. *Proceedings of the 20th Australasian Conference on Computer-Human Interaction Designing for Habitus and Habitat - OZCHI '08*, 271. New York, New York, USA: ACM Press. doi: 10.1145/1517744.1517776.

Lu, Y., Zhao, Y., Kuipers, F., & Van Mieghem, P. (2010). Measurement study of multi-party video conferencing. *NETWORKING 2010* (p. 96–108). Springer. Retrieved April 26, 2011, from http://www.springerlink.com/index/8X27W207513N2312.pdf.

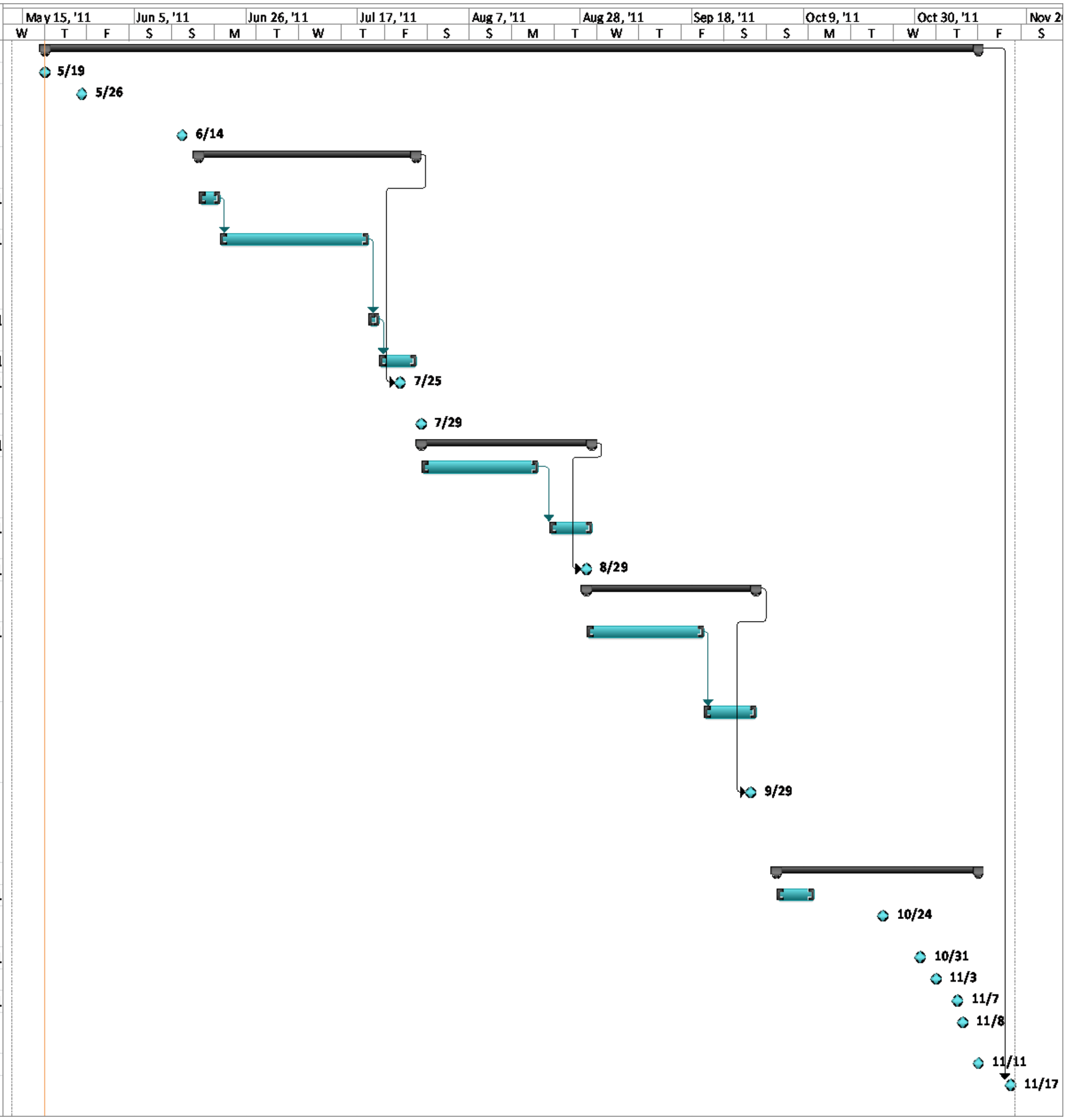
Munaf, MS. (2007). Java Advantages and Disadvantages. Retrieved May 12, 2011 from http://www.webdotdev.com/nvd/content/view/1042/204/

Takao, S. (1999). The effects of narrow-band width multipoint videoconferencing on group decision making and turn distribution. *ACM SIGSOFT Software Engineering Notes*, *24*(2), (p. 109-116). doi: 10.1145/295666.295678.

Scholl, J., Parnes, P., McCarthy, J. D., & Sasse, A. (2005). Designing a large-scale video chat application. *Proceedings of the 13th annual ACM international conference on Multimedia - MULTIMEDIA '05* (p. 71-80). New York, New York, USA: ACM Press. doi: 10.1145/1101149.1101160.

APPENDIX A

ID	Task Name	Duration	Start	Finish
1	**Project Implementatio**	**126 days**	**Thu 5/19/11**	**Fri 11/11/11**
2	Project Proposal	0 days	Thu 5/19/11	Thu 5/19/11
3	Proposal Presentation	0 days	Thu 5/26/11	Thu 5/26/11
4	Project Web Presenc	0 days	Tue 6/14/11	Tue 6/14/11
5	**Prototype design and implementation**	**29 days**	**Fri 6/17/11**	**Wed 7/27/11**
6	Framework : first implementation	2 days	Fri 6/17/11	Mon 6/20/11
7	Audio-video, chat, presentation,atter list, floor control implementation	20 days	Tue 6/21/11	Mon 7/18/11
8	Complete Framework	2 days	Tue 7/19/11	Wed 7/20/11
9	Testing Prototype	5 days	Thu 7/21/11	Wed 7/27/11
10	First Prototype Demonstration	0 days	Mon 7/25/11	Mon 7/25/11
11	Background chapter	0 days	Fri 7/29/11	Fri 7/29/11
12	**Design**	**22 days**	**Fri 7/29/11**	**Mon 8/29/11**
13	Prototype testing, design and further iterations	16 days	Fri 7/29/11	Fri 8/19/11
14	Design chapter write up	6 days	Mon 8/22/11	Mon 8/29/11
15	Design Chapter due	0 days	Mon 8/29/11	Mon 8/29/11
16	**Evaluation and testing**	**24 days**	**Mon 8/29/11**	**Thu 9/29/11**
17	First implementation, Experiment, Performance Test,	16 days	Mon 8/29/11	Mon 9/19/11
18	Final Prototype, Experiment, performance test, writeup	8 days	Tue 9/20/11	Thu 9/29/11
19	Implementation + testing chapters, software coding + testing complete	0 days	Thu 9/29/11	Thu 9/29/11
20	**Report**	**28 days**	**Tue 10/4/11**	**Fri 11/11/11**
21	Outline of report	5 days	Tue 10/4/11	Mon 10/10/1
22	Final draft of report	0 days	Mon 10/24/11	Mon 10/24/11
23	Final report handii	0 days	Mon 10/31/1	Mon 10/31/1
24	Poster due	0 days	Thu 11/3/11	Thu 11/3/11
25	Web page	0 days	Mon 11/7/11	Mon 11/7/11
26	Project demonstrations	0 days	Tue 11/8/11	Tue 11/8/11
27	Reflection paper	0 days	Fri 11/11/11	Fri 11/11/11
28	Final Project presentations	0 days	Thu 11/17/11	Thu 11/17/11


May 15, '11
Jun 5, '11
Jun 26, '11
Jul 17, '11
Aug 7, '11
Aug 28, '11
Sep 18, '11
Oct 9, '11
Oct 30, '11
Nov 2
W
T
F
S
S
M
T
W
T
F
S
S
M
T
W
T
F
S
S
M
T
W
T
F
S
5/19
5/26
6/14
7/25
7/29
8/29
9/29
10/24
10/31
11/3
11/7
11/8
11/11
11/17