Satellite Based Interactive Distance Education: A scalable and quality learning model

Saraswathi Krithivasan, Malati Baru,and Sridhar Iyer
KR School of Information Technology
Indian Institute of Technology, Bombay
{saras,malati,sri}@it.iitb.ac.in

Abstract
Dissemination of high quality education to a large number of geographically spread participants is a growing need in many countries. Indian Institute of Technology, Bombay, successfully deployed a novel satellite-based model of Distance Education Program (DEP). The key objectives of DEP are not only to impart quality education to a large number of participants but also to provide a live two-way interactive classroom environment. The feedback from the participants shows that DEP has been very effective for enhancing the expertise of a large number of working professionals as well as teachers from other engineering colleges.
In this paper we discuss the key features of DEP – Interactivity, scalability and reusability and give a comprehensive report of a three-year study on DEP. We discuss the underlying economics that arises out of scaling such a program and present the current status of DEP. We believe that the live interaction with the faculty and peer-to-peer interaction among participants that is provided by DEP greatly enhances the effectiveness of distance learning. We feel that such a model can be easily adopted by other institutes elsewhere.

1. Introduction

In developing countries, although numerous qualified engineers graduate every year, there is a vast gap between the resources required and the professionals available in any field of the industry [1]. Typically there is also a need to upgrade the expertise of the teachers in the regional institutes, which has a direct impact on the quality of education across the country. Hence, dissemination of high quality education to a large number of geographically spread participants is an important and challenging problem [2].

Indian Institute of Technology, Bombay (IITB), one of the premier institutes in India, took up this challenge and successfully deployed a novel model of Distance Education Program (DEP) [3] from 2002. The objectives of DEP are:

- Imparting education by transmission of IITB courses to a large number of participants.
- Creating a live two-way interactive classroom environment for the participants.
- Deploying a scalable solution to reach increasing participants across the country.
- Providing a cost effective solution for the participating centers in terms of affordable technology and minimal recurring charges.

DEP uses a satellite based (VSAT) network with IITB as the transmitting center from where the lectures originate. IITB is connected to several receiving . Remote Centers (RCs) across the country. DEP uses a 512 kbps bandwidth dedicated broadcast data channel and 16 kbps point to point control channel. Through DEP, the remote participants have live and synchronous access to the teaching of IITB faculty [4]. The feedback from the participants shows that DEP is a boon for working professionals, students and teachers across the country.
In this paper we present a comprehensive report of a three-year study on DEP. We discuss the key features of DEP, its scalability and economic viability. We feel that such a model can be easily adopted by other institutes elsewhere.

2. Distance Education Models

Distance education provides a great deal of flexibility and is a preferred mode of learning for students and working professionals who are unable to attend fulltime colleges. Furthermore, distance education through Open Universities (OU) is the most preferred way to meet the ever-increasing demand for quality education in remote areas in developing countries [5]

There are several models of distance education. These can be classified into four major categories:

1. Traditional model
2. Web based model
3. Internet streaming model
4. Satellite broadcast model

A detailed discussion of each model is beyond the scope of this paper. In the following sections we provide a brief discussion of each model and justify our selection of the satellite based model for DEP.

2.1 Traditional model

Before the advent of Internet, distance education was mainly through the dispatching of course contents by mail. We term this as the traditional model [6]. Even though minor variations exist, usually in this model, geographically dispersed students register with an institute/university. The interface between students and institute is called a study center. Study centers are established at various locations and students can attend limited interactive sessions at these centers. The students appear for the periodic exams conducted by the institute and are awarded degrees/certificates after evaluation.

This is a viable model for distance education in developing countries as the costs involved are low, both for institute as well as for students. One example of a very successful implementation of this traditional model has been at the Indira Gandhi National Open University (IGNOU) in India. IGNOU has more than 1,187,100 students, 1133 Study Centers and 48 Regional Centers across the country [5].

However, the drawbacks of this model are that the student does not have a day-to-day live interaction with the faculty. The peer-to-peer interaction is also reduced which might result in a decrease in the effectiveness of the learning [7].

2.2 Web based model

Ease of Internet access has led to the setting up of online education portals by many Universities across the globe. We term this as the web-based model [8]. In this model, a university announces a number of courses for which the students register and have access to the course content (slides, notes) through the medium of Internet. The students appear for periodic online exams for the purpose of certification. Such a model provides access to "anytime anywhere education" and has proved to be useful for working professionals. There are many tools to facilitate web based learning such as WebCT [9] etc.

One example of a highly successful online university education model implemented is at the University of Phoenix, USA[10] It was among the first accredited universities to provide college degree programs over the Internet.

The main prerequisite for this model is that every student should have his/her own system and a good Internet connectivity to access the course contents.

This model is not very suitable for distance education in developing countries where the PC penetration levels may be very low, and the cost of implementing such model may be very high. Another drawback of this model is the missing element of classroom environment and lack of peer-to-peer interaction within the student community [11].

2.3 Internet streaming model

Streaming is a method of data transfer in which a multimedia file can be viewed while it is being downloaded. The advantage of streaming is that it does not require local storage of the entire multimedia file and can also support real-time access to live events. We term this as the Internet streaming model [12].

The five major steps involved in streaming are: choosing the format, encoding the content, storing the content and delivering the content to the client media player. The streaming model can be implemented in three ways: live streaming, on demand streaming, and simulated live streaming [4]. In live streaming, the live feed from a lecture is encoded on the fly and is relayed to a streaming server. The streaming server in conjunction with the web server uses one of the many protocols like HTTP, RTSP to serve the file over Internet to the participants. In on demand streaming, the video files of a lecture are encoded off line at various bit rates and stored on the streaming server. The participant has the option of choosing the appropriate encoded video, based on the bandwidth available. This mode also offers participants the flexibility to pause/replay the files as well as access them at any time and from any place. In simulated live streaming, the files are stored on the streaming server but start streaming at predetermined time slots. Hence even though the lecture is not live, all participants have to login to the session synchronously and do not have the flexibility to view at their own convenience. Simulated live streaming attempts to capture a traditional classroom effect, where the groups of participants are required to view the lecture videos synchronously, even though they might be geographically dispersed. There are various tools such as Centra [13], Isee [14], to facilitate streaming based learning.

While using this model, a university typically augments the course video streams with an online support system that provides functionalities like whiteboard, messaging and chat to the participants.
Some universities where the streaming model has been implemented are the Rensselaer Polytechnic Institute [15] and Stanford University [16].

While Internet streaming is a flexible model, it requires reliable and dedicated minimum bandwidth for good quality reception. The availability of bandwidth is often a major constraint in reaching remote areas in developing countries.

2.4 Satellite broadcast model

The satellite broadcast model typically has a source center where the content originates and is transmitted to various remote centers using a VSAT channel.

The five major VSAT delivery mechanisms are, One-way data transmission, two-way data transmission, one-way audio/video transmission, one-way video, two-way audio transmission, and two-way audio/video transmission. There are many tools such as VCON [17], OneTouch [18] available to facilitate satellite based learning.
This model has many significant advantages like, the unlimited reach even to remote locations, reliability, fast deployment and low set up costs, easier network management and maintenance. This model also allows for incremental expansion to large numbers of remote centers. Additionally, bandwidth costs can be amortized over the number of centers.

After weighing the pros and cons of various models with respect to our objectives, the satellite broadcast model with the two-way audio/video delivery mechanism was selected for DEP implementation. In the next section, we describe the various features of the DEP model.

3. The DEP Model

The Distance Education Program (DEP) at IIT Bombay uses a satellite based network. It consists of a central transmitting site (IITB) and a number of geographically dispersed Remote Centers (RCs) receiving the transmission, synchronously.

3.1. The DEP network

The DEP network as shown in Figure 1 has a high bandwidth [512 kbps], half duplex, broadcast data

channel and a low bandwidth [16 kbps], full duplex, point-to-point control channel.

The network consists of nodes at IIT Bombay as well as various RCs. The 512 kbps channel is a Demand Assigned Multiple Access (DAMA) [19] channel and only one center can use it for data transfer at a time. Other centers remain in receive mode when the station having control of the 512 kbps channel transmits. The 16 kbps full duplex channel is a Time Division Multiple Access (TDMA) [19] channel and is available for data transfer at all times to all the centers in the network.

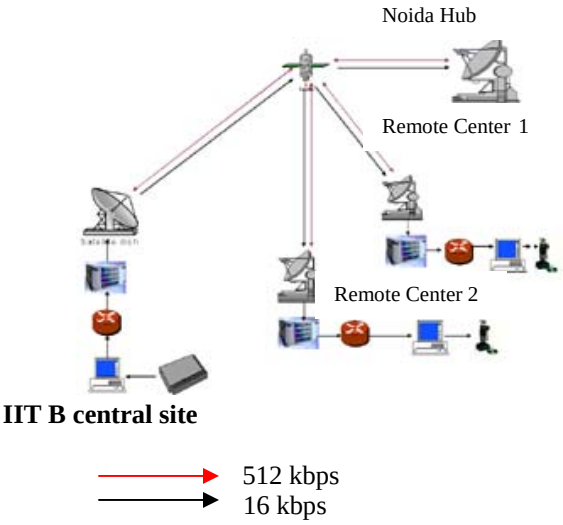

Figure 1: The DEP Network

The network at the central site has a large 3.8 meters antenna and a small 1.2 meters antenna separately for the data and control channel. The computer used for starting the multicast at the central site encodes the signal to an H323 format before sending it out for transmission. The equivalent receiving computer at the RC decodes the signal. At both the central site and the RC, the signals are routed through an up/down converter, a chassis, a router and an indoor unit.

Figure 2 and Figure 3 illustrate the setup at the central site and the RC.

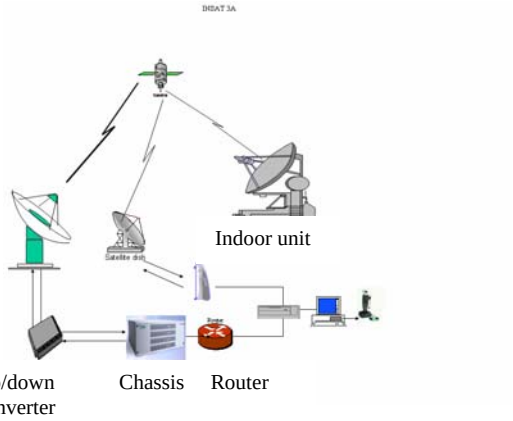

Figure 2: The IITB network setup

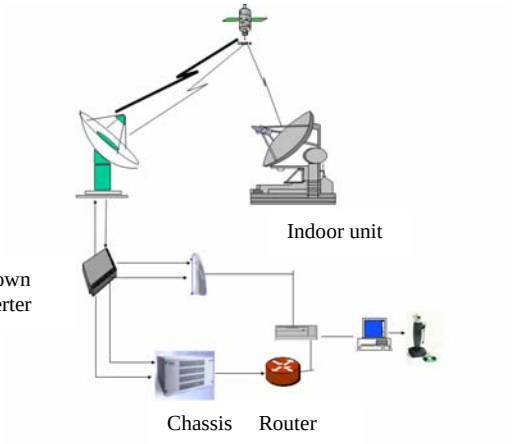

Figure 3: The RC network setup

3.2. The DEP operations

The workflow involved in offering a course through DEP is as follows:

1. **Pre-course activities**: At the commencement of every semester, the courses offered are announced by advertising on the DEP website, through local newspapers and notifications to all engineering colleges. In consultation with the faculty the schedule is announced, the course notes are created and for distribution. The registration of participants is done using an indigenously developed online software, "Tejas"[20] shown in Figure 4**.** The participants are given a window of two weeks to add/drop courses. The course home pages are made ready with resources, announcements, contact details, course schedules as shown in Figure 5

Figure 4: Online registration using Tejas

Figure 5: A sample course home page

2. **During each lecture:**
   - The faculty gives the lectures in a state-of-the-art studio cum classroom, as shown in Figure 6. The faculty has the option of using slides, whiteboard and multimedia clips to deliver the lecture.
   - The multiple audio, video feeds from the faculty, whiteboard, local participants, RC participant are all mixed in real-time by using online audio video mixers. A single audio - video feed is then transmitted to all RCs through the VSAT network. Block diagram of mixing is shown in Figure 7.
   - These lectures are now synchronously transmitted through the high bandwidth data channel of the DEP network to the various registered RCs, where the lecture is projected on to a large screen.
   - A classroom scenario at each RC has thirty to forty students viewing the lecture. Any participant from any of the RCs has the freedom to ask a question during the lecture. The desire to ask a question is communicated to the faculty through the low bandwidth control channel.
   - The faculty may grant the floor to the RC, in which case the high bandwidth data channel is transferred to the RC for uplink. The question being asked is heard by the faculty as well as the participants at all the other RCs. Subsequently, the floor is taken back by the faculty, the question is answered and the lecture continues.
   - The faculty can also invite participation from the RCs, by granting the floor independently.

Figure 6: A typical classroom session

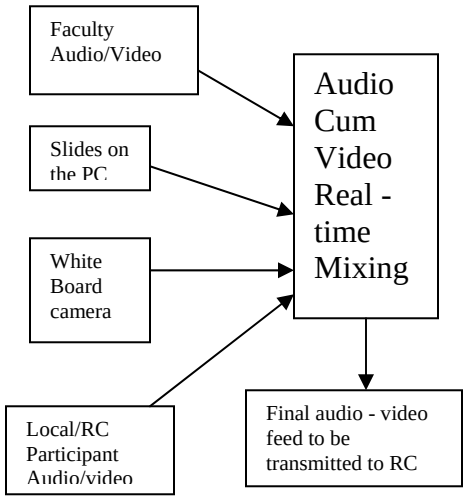

Figure 7: Real-time mixing of audio/video

3. **Course support activities:** A team of Teaching Assistants (TAs) provide the required support to run a course smoothly. The TAs maintain the course home pages, make regular announcements, upload necessary resources, conduct tutorials, announce assignments, upload

marks, provide offline support through email,FAQs and take periodic feedback from the participants.

4. **Evaluation:** Conducting exams across distributed RCs is a major challenge. The exam question paper is password protected and mailed to all RCs. The password is sent to RCs just one hour before the exam so as to allow them to make copies. The answer booklets are then dispatched to DEP and are graded centrally at IIT Bombay. The faculty is available during exam at the central site. The entire exam is monitored by the central site through the DEP network.
5. **After the course:** The lectures which are recorded during the course are captured, edited and archived on various media like CDs, DVDs and DV tapes. The archival enables reuse, and can also be used for reference by the faculty and participants in the future. In the event of any transmission glitches at any RC, a set of CDs for that particular session are sent for the benefit of participants at that RC.

3.3. The DEP administration

DEP administration happens at two levels: core functions at the central site and distributed functions at the RCs.

The core administration functions are:

1. **Program Management:** This includes activities like program planning and scheduling, coordination with service providers and RCs, program expansion planning, registration, data processing and report generation, and accounts maintenance.
2. **Studio Management:** This includes activities like ensuring trouble free transmission of lectures, continuous testing and maintenance of studio equipment, upgrading infrastructure as and when needed, and interaction with service providers for customer support.
3. **Content Management:** This includes activities like content dispatch to all RCs , Coordination with faculty and RCs , dispatch of CDs to RCs in the event of transmission failures, editing the lectures , transferring of contents to CDs, DVDs, DV tapes for archival.

The distributed functions at each RC include:

1. Marketing the courses through counseling and local announcements and displaying the promotional material.
2. Registration of participants and maintenance of their records.
3. Mentoring and tutoring of the participants during the course,
4. Conducting exams and dispatching answer sheets.
5. Maintenance of infrastructure used at the RC and coordination with service providers.
6. Continuous coordination with central administration team

The administration process has been streamlined across RCs by using indigenously developed software named “Tejas” [20]. Tejas was developed keeping in view the unique requirements of the DEP. The registration module is accessed by all the RCs to enter the participant’s data [21]. The other modules such as the faculty module, student module, report generation module, etc., help in the online integration of all activities. Tejas also allows the central site to monitor the status at each RC on a daily basis.

In the next section we discuss the key distinguishing features of DEP.

4. Key DEP Features

The key distinguishing features of the DEP are: live synchronous lectures with interactivity, technical and administrative scalability and content reusability. We discuss each of these below:

4.1. Interactivity

The DEP model provides a live classroom experience to participants at the RCs. As explained in section 3, DEP uses a one-way high bandwidth data channel and a two-way low bandwidth control channel. So, when a participant wants to ask a question, the request is communicated to the faculty through the low bandwidth control channel. When the faculty grants the floor, the high bandwidth data channel is transferred to the RC. Subsequently, the faculty takes the floor back and answers the question.

The two-way audio video communication between the central site (IITB) and the Remote Center (RC) adds tremendous value to the program. As the transmission is synchronous, live, and interactive, the model gives a live classroom feel to the participant.

4.2 Scalability

In order to take DEP to large number of geographically dispersed remote centers, scalability of the technology as well as administrative processes is necessary. We examine each of these below:

- *Technology:* DEP uses a satellite-based (VSAT) network, which is inherently scalable and reliable. This makes the learning experience consistent across the RCs. As the satellite’s footprint covers the entire country, expanding the program to include an RC in any part of the country is relatively simple. A new RC needs to install only the VSAT receiving infrastructure to receive the transmission from the central site.

- *Administration:* DEP Administration happens at two levels: core functions at the central site and distributed functions at the RCs. The distributed administration and logistics management at the RCs simplifies the processes of student

management, and coordination, thereby resulting in the scalability of the program.

4.3 Reusability of the Content

The lectures, including the interaction with the RC participants, are recorded, edited and archived on data CDs, DVDs and DV tapes. These are not only available to the faculty for future reference but can also be used for subsequent retransmission of the courses. Based on this idea, an extension model was implemented successfully. The details of this extension are given in section 6.3.

In the next section we present the responses and reactions of all the stakeholders of DEP and the conclusions arrived at, in the process. The effectiveness of DEP is also analyzed in this section

5. DEP analysis and inferences

The effectiveness of any program can be determined by analyzing the feedback from the various entities involved.

***1. Faculty feedback*:** The faculty who has participated in DEP has been asked to respond to questions like

a. Experience of teaching through DEP?
b. Quality of participants?
c. Technology used in DEP?
d. Interaction of RC participants?
e. Support provided by DEP team?
f. Offer a course through DEP again?

Feedback from twenty DEP- faculty is summarized below in Table 1.

a. Experience of teaching through DEP Excellent - 80% Good - 10% Average - 10%
b. Quality of participants in DEP was Good – 50% Average - 30% Below average – 20%
c. Technology used in DEP was not interrupting their lectures Not interrupting - 95% Interrupting - 5%
d. Interaction of RC participants Satisfactory – 75% Not satisfactory – 25%
e. Support provided by DEP team Excellent – 90% Good – 10%
f. Offer a course through DEP again Yes – 95% No – 5%

Table 1: Faculty feedback

An interesting observation made by one faculty was "*Because of the pressure of being captured on camera and being seen by other participants at remote centers, the local students were better prepared for the class and participated in discussions in a more meaningful way. This made my classes more lively and interesting."*

2. Participant feedback: The participants have been asked to respond to questions like

a. Course material satisfactorily covered?
b. Faculty presentation skills?
c. Interaction with faculty was adequate through the remote technology?
d. Reception of Lectures at RCs?
e. Support provided at RCs?
f. Recommend the DEP courses to others?

A sample feedback summary from a recent course with sixty participants is shown below in Table 2.

a. Course material satisfactorily covered Yes – 91% No – 9%
b. Faculty presentation skills Good – 93% Average – 7%
c. Interaction with faculty was adequate through the remote technology Yes - 92% No - 8%
d. Reception of lectures at RCs Good Quality - 95% Average Quality -5%
e. Support provided at RCs. Good - 85% Needs Improvement - 15%
f. Recommend the DEP courses to others Yes - 97% No - 3%

Table 2: Participant feedback

One of the participants had mailed us saying "I was a DEP student for Mobile Computing and wanted to inform you that because of upgrading my knowledge through this course, I have been offered a new job. I wanted to convey my thanks to the faculty and the DEP team."

3. Remote Center feedback: All the coordinators of participating RCs of DEP meet every semester to give their feedback to the central site and offer suggestions about ways to improve the program and increase registrations. One of our RC coordinator has said "*We are very proud to be associated with an impressive program like DEP which in turn is serving our local participants.*" One of our corporate RC said "*DEP program is enabling us to upgrade the skills of our employees. Through DEP access to the distinguished guest lectures is also proving to be very helpful."*

4. Service Provider Feedback: The network maintenance and service provider is also very committed as they are eager to be a part of DEP, not for commercial reasons but because it also addresses the social cause of spreading education to remote areas in the country.

Based on the feedback presented above, we found that :

- The faculty unanimously enjoyed offering courses through DEP,
- Participants have benefited from the courses,
- RCs were glad that the remote participants were getting access to IIT lectures

Hence we believe that DEP as a quality learning environment is effective.

In the next section we discuss some extensions models of DEP.

6. The DEP Extension models

The DEP primary model described in section 3, presently uses VSAT technology to transmit the courses to the RCs. The model requires the RC to invest a high initial amount for the VSAT receiving infrastructure. Also, a participant has to travel and physically be present in the class for the lectures. In order to address these issues, DEP has been extended with some infrastructure additions to arrive at the following four additional models:

6.1 Leased line model
6.2 Internet streaming model
6.3 Retransmission model
6.4 Local RC backup model

6.1 Leased Line Model

In this model, a new RC that is set up may receive the transmission from an existing RC through a leased line instead of directly through the VSAT, as shown in Figure 8.

Such a model is useful when a new RC joining DEP is located at a short distance away from an existing RC, which already has the VSAT receiving infrastructure. The new RC can connect through a leased line to an existing RC, thereby avoiding the high initial VSAT setup costs. The recurring leased line cost also works out to a nominal amount because of the short distances involved.

We have implemented two such leased line RCs, which are operating successfully. The participant attending the course at a leased line RC is basically not affected because of the difference in infrastructure. The only drawback in this model is that the leased line RC is completely dependent on the VSAT RC for connectivity to DEP.

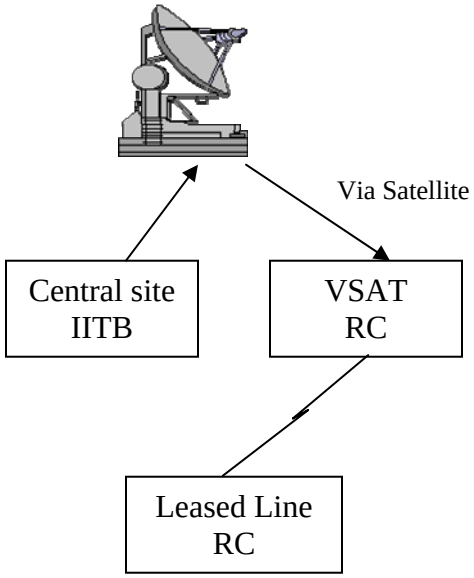

Figure 8: The Leased Line RC model

6.2 The Internet streaming model

In this model, the video lectures are encoded and streamed by a streaming server. The course lectures are transcoded for streaming by compressing and encoding at multiple appropriate bit rates. Participants can access these lectures globally over the Internet. This set up is shown in Figure 9

Such a model enables working professionals with flexibility to access the course from anywhere, anytime and leverages existing content to expand the reach of DEP. This is especially useful for streaming the lectures over the Internet, to corporate clients.

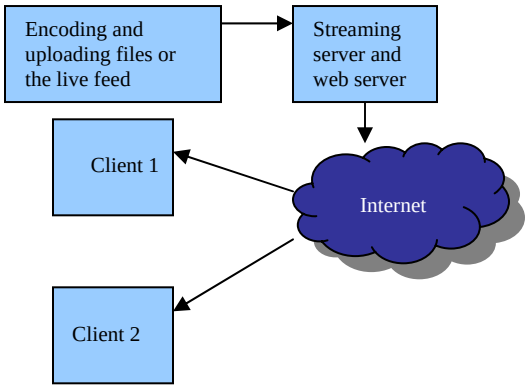

Figure 9 : The Internet Streaming model

We have tested this model on a pilot basis. The content offered was a graduate course on Mobile Computing. The content was available at two encoded rates of Low bandwidth (64 kbps) and High bandwidth (384 kbps).

The participants were from many countries including China, SriLanka, Dubai, Singapore, USA, and UK. Some local corporations including Satyam, and MBT also participated in the pilot. Around 45 access accounts were created. The participants attending the courses through this model were satisfied with the course content and delivery mechanism but were constrained due to the connectivity at their end. As the quality deteriorates for files encoded at lower data rates, the participant is forced to view a lower data rate file because of the connectivity available. The need for extra offline support in this model has also been emphasized by all participants.

Some inferences from the pilot streaming are:

- A minimum encoding rate of 384 kbps is required to ensure that the source file can be viewed at good quality.
- Given the above constraint, this model would work for organizations within India as well as users in countries who enjoy high bandwidth connectivity.
- A support system, such as chat, discussion board, to provide interaction with the faculty and other participants is important for the effectiveness of this model.

6.3 Retransmission Model

This model leverages the course content of previous offerings of a course. The recorded lectures are re-transmitted along with limited live interaction. This model can be implemented only when the live course offering is carefully planned and structured in such a way that is also effective in the retransmission mode. A detailed discussion on structuring courses to facilitate retransmission is beyond the scope of this paper. Since RC participants see the lecture on the screen even during a live lecture, the retransmission mode is equally effective from their perspective.

A pilot was carried out by offering a course on Distributed Systems using the archived lectures. The faculty member was available in the studio during the retransmission, for interacting with the new participants. The faculty member also had the option to pause the retransmission at any point and to introduce new live explanations of the concepts.

We found that this model considerably reduced the faculty load, while being as effective for the RC participants. We also found that since an archived lecture includes the faculty's interaction with the earlier participants, the new participants benefit from it and this adds to their learning.

The feedback of participants in this model indicates that such a retransmission is almost as effective as a fresh live transmission. Thus such a retransmission model adds value to DEP by giving the faculty the flexibility of not having to redo the entire course. Using this model, we have so far offered around twelve courses and continue to offer one or two courses every semester.

6.4 The Local RC backup model

This model involves setting up of an alternate mechanism for transmission in the event of the primary $VSAT_1$ network failing. A local RC is created at the hub (IITB) for backup. Normally, the local RC behaves as a downlink center to the DEP network, as shown in Figure 10**.** In case of failure of the primary network, the source feed from the classroom is routed through the $VSAT_2$ of the local RC. The local RC now becomes the uplink center for transmitting the session to all other RCs.

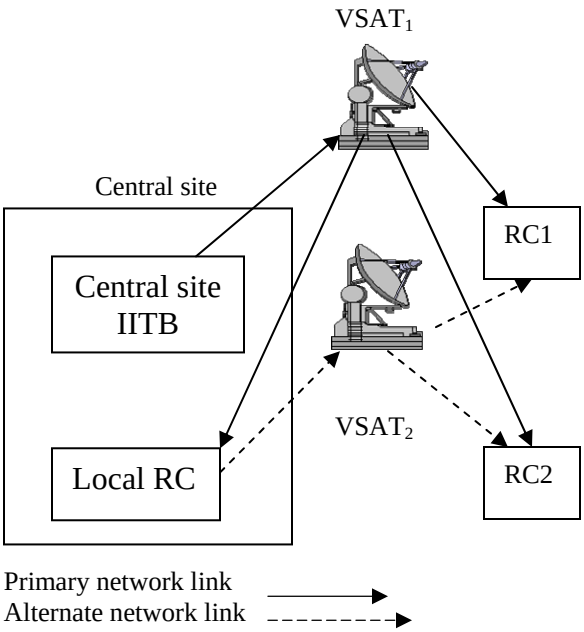

Figure 10: The Local Remote Center backup model

We have successfully used this model during transmission failures of the primary $VSAT_1$, thereby ensuring uninterrupted reception at the RCs.

Such a model also enables us to check/monitor the Audio/Video reception quality at an RC, and to troubleshoot or analyze the technical problems faced by the other RCs.

7. Economics and scaling

DEP being satellite based has an operational cost, which is more than conventional models of distance education. Nevertheless such a model is economically viable because most of the cost is in setting up the studio at the central site and the satellite bandwidth, both of which are borne by the central site. Setting up of a new remote center (RC) requires only 10% of the central site investment. The revenue model also apportions a share of the fees to

the RC (40% in case of DEP), thereby making it attractive for the RCs. The DEP model can be easily scaled by:

- Increasing the number of RCs and thereby the remote participants.
- Offering foundation level, undergraduate, and postgraduate courses across different disciplines.
- Utilizing the bandwidth by also transmitting to the RCs, any short-term courses, workshops, seminars and invited distinguished lectures, which may be held at the central site.

Also, an added advantage of conducting short-term industry-specific specialized courses over DEP is that it offers working professionals a chance to enhance their skills without having to travel to a central location.

8. Current DEP status

Over the past seven semesters, DEP has offered a wide range of courses in the fields of subjects like Embedded Systems, Mobile Computing, Distributed Systems, Communication Networking, Database Management, Digital Signal Processing, Data Structures etc: Besides the regular semester long course , numerous guest lectures by eminent faculty and short term courses have also been conducted

Details of number of people trained through DEP are given in Table 3. A total of 43 long-term (semester long) courses and around 25 short-term courses and invited lectures were transmitted over the past seven semesters.

SEMESTER	Registrations	
	Long-term	Short-term
Pilot Program (Mar-May'2002)	78	-
Fall (Aug-Dec'2002)	145	-
Spring (Jan-May'2003)	389	-
Fall (Jul-Dec'2003)	288	260
Spring (Jan-May'2004)	293	1060
Fall (July-Dec'2004)	562	810
Spring (Jan - May 2005)	596	344
Total	**4825**	

Table 3: Number of people trained through DEP

Figure 11 depicts cumulative registrations for long-term courses over the past seven semesters.

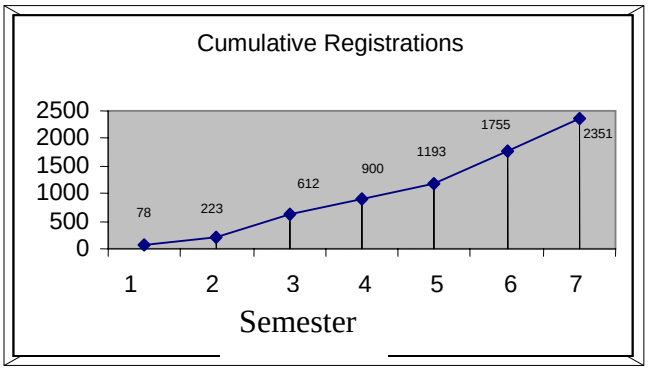

Figure 11 Cumulative graph of registrations

In summary, over the past seven semesters DEP has benefited around 5000 participants from RCs across the country.

9. Conclusion

In this paper we have described DEP, a satellite based distance education model, having the key features of interactivity, scalability and reusability. We have also described some DEP extension models, including leased line centers and Internet streaming. Since a satellite-based model does not typically allow transmission across the country borders, and the increase in the use of broadband technology around the world, the streaming model promises great potential for growth in the near future.

DEP is effective for enhancing the expertise of teachers, and providing quality education to students and working professionals from geographically diverse areas. We feel that such a model can be easily replicated in other countries also.

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