Unified M-Learning Model through Interactive Education Satellite

A Proposal for an Arab Homeland Education Satellite

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***Abstract*—in this paper, we propose a unified and interactive mobile learning (M-Learning) model to help with expanding and spreading education in the Arab Homeland countries. The model utilizes a new competitive spot beam satellite communication technology, which enables efficient channel allocation, where communication channels can be allocated to specific and precise areas. The proposed model is referred to as the interactive Arab education satellite (IAESat).The communication satellite can efficiently and effectively cover the entire Arab Homeland and reaches a wide area and mobile users that cannot be reached otherwise. The model implements existing interactivity components to enhance the learning process and meet international standards in education.**

***Index Terms*—E-Learning, M-Learning, interactive learning, education satellite, spot beam communication.**

I. INTRODUCTION

Electronic learning (E-Learning) is about the transmission of learning content using communication and information technologies (CIT). Conventional learning involves identifying of information, conceptualizing, and making meaning to enhance user's knowledge base, understanding and skills, as well as finding the time and space for learning is left to the individual [1, 2]. The total E-Learning solution comprises the integration of three elements: content, technology and services [3]. This concept is also underpinned by the assumption that learners will be responsible for the cognitive tasks that will lead to learning.

In E-Learning, the information and communication systems, whether networked or not, serve as specific media to implement the learning process, and content is delivered via the Internet, Intranet/Extranet, audio or video tape, satellite TV, and CD-ROM. It can be self-paced or instructor-led and includes media in the form of text, image, animation, streaming video and audio. E-Learning definition abounds to [4]:

- The convergence of the Internet and learning, or Internet-enabled learning.
- The uses of network technologies to create, foster, deliver, and facilitate learning, anytime and anywhere.
- The delivery of individualized, comprehensive, dynamic learning content in real time, aiding the development of communities of knowledge, linking learners and practitioners with experts.
- A phenomenon delivering accountability, accessibility, and opportunity to allow people and organizations to keep up with the rapid changes that define the Internet world.
- A force that gives people and organizations the competitive edge to allow them to keep ahead of the rapidly changing global economy.

E-Learning is also known as distance learning (D-Learning) [5]. However, a recent form of learning, namely, mobile learning (M-Learning) was introduced due to the tremendous advancement in Internet technologies, and the exponential growth in the processing power, availability, and affordability of wireless mobile devices while becoming more affordable.[6, 7].

The Arab-Homeland consists of 22 countries occupying an area close to 10 millions Km^2 and housing more than 350 millions citizens. Figure (1) shows the geographical maps for the Arab-Homeland, and Table (1) lists the name, area, population, population density, the gross domestic product (GDP), and income per capita (IPC) for all Arab-Homeland countries [8]. When examining the figures in Table (1), differences in area, population, population density, GDP, and IPC, between Arab countries appear quite obviously.

Many of the Arab-Homeland countries have large areas with low population, meaning that the population is wide spread over large areas of land. The GDP of Saudi Arabia close to 600 billions compared to Comoros Island with only 0.7 billions. However, many countries have low GDP and therefore lack proper education. Overall, the annual GDP of the Arab countries is exceeding 2.5 Trillions. Table (1) also shows that the IPC is ranging from $90149 in small country like Qatar to $6347 large country like Egypt. With its diverse demography, the Arab Homeland constitutes an excellent example for launching mobile-based education to provide education to all people in such diverse area. However, providing mobile education requires high performance connectivity for remote locations in countries with large area, small population, and with low income. This would be infeasible through conventional technologies due to high initial and operating costs. Therefore, the most obvious solution is to use the newly evolving approach that is based on establishing connectivity through interactive satellite system. In this paper, in order to enhance, meet the needs of, and widen the education system in all Arab countries, we propose a unified and interactive M-Learning model that utilizes a satellite-based communication channels, which is referred to it as the interactive Arab-Homeland education satellite (IAE-

Sat). This model looks very promising as it can provide education anywhere anytime efficiently and cost-effectively.

This section provides an introduction to the general domain of this paper. The rest of the paper is organized as follows: Section 2 reviews previous experiences in using satellite-based education. In addition, in Section 2, some advanced satellite communications technologies are discussed. The unified M-Learning model and the main components of the proposed IAESat are discussed in Section 3. Section 4 describes the operation procedure and lists the advantages of IAESat. Finally, in Section 5 conclusions and recommendations for future work are pointed-out.

Figure 1. The geographical map of the Arab-Homeland.

TABLE I.
LIST OF ARAB-HOMELAND COUNTRIES AND THEIR AREAS, POPULATIONS, POPULATION DENSITIES, GDP, AND IPC.

Country	Area (Km^2)	Population	Population Density	GDP ($ Billion)	IPC
Bahrain	750	1 234 596	1646	28.275	27214 (2009)
Kuwait	17820	3 566 437	167.5	140.589	3984 (2010)
Oman	309550	2 845 000	9.2	74.431	25984 (2009)
Qatar	11437	1 696 565	123.2	102.147	90149 (2010)
Saudi Arabia	2149690	257 313 766	12	618.744	23701 (2010)
Arab Emirates	83600	4 675 593	97	182.876	40175 (2010)
Yemen	555000	23580 000	44.7	58.218	2457 (2009)
Gaza Strip	360	1604235	4118	0.77	3100 (2009)
Iraq	438317	31234000	71.5	111.5	3570 (2009)
Jordan	92300	6407085	56.4	35.3	5956 (2010)
Lebanon	10452	4224000	404	58.576	14988 (2010)
Syria	185180	22505000	118.3	105.238	5043 (2009)
Egypt	1002450	79089650	82.3	469.604	6347 (2010)
Algeria	2381740	35423000	14.6	255.189	7104 (20010)
Mauritania	1030700	3291000	3.2	6.326	2037 (2009)
Libya	1759541	6420000	3.6	96.138	14884 (2010)
Morocco	710850	32200000	71.6	193.15	48886 (2010)
Tunisia	163610	10432500	63	86.086	8254 (2009)
Sudan	2505810	43939598	16.9	54.681	2464 (2010)
Somalia	637657	9359000	14.6	5.731	600 (2009)
Djibouti	23200	818159	37.2	1049	2549 (2010)
Comoros Island	2235	691000	275	722	1159 (2009)
Total	13041549	852550184		4454.569	

II. REVIEW OF PREVIOUS EXPERIENCES

This section presents an overview of three satellite based educational programs, namely, the Italian satellite (ItalSat) [9], the Indian national satellite (InSat) system [10], and the Indian educational satellite (EduSat) [11]. An overview on recent advances in satellite communications technologies is provided here. Furthermore, since the proposed solution can be embedded with existing satellite projects such as the Arab satellite (ArabSat) and the multimedia exchange network over satellite (MENOS) hub [12].

A. Satellite-based educational programs

Three well-known satellite-based educational programs are briefly described below, one adopted by the Italian government, and the other two adopted by the Indian government.

1) Italian Experience in ItalSat

The concept of multiple spot beam communications was successfully demonstrated in 1991 with the launch of ItalSat [8, 9], which is a satellite-based education program developed by the Italian Research Council (IRC). With six spot beams operating at 30 GHz (uplink) and 20 GHz (downlink), the satellite interconnects TDMA transmissions between ground stations in all the major economic centers of Italy. It does this by demodulating uplink signals, routing them between up- and downlink beams, and combining and remodulating them for downlink transmission.

In ItalSat, laser beams can also be used to transmit signals between a satellite and the earth, but the rate of transmission is limited because of absorption and scattering by the atmosphere. Lasers operating in the blue-green wavelength, which penetrates water, have been used for communication between satellites and submarines.

2) Indian Experience in INSat

The Indian National Satellite System (INSat) is a series of multipurpose geo-stationary satellites launched by the Indian Space Research Organization (ISRO) to satisfy the telecommunications, broadcasting, meteorology, education and search and rescue needs of India [8, 10]. Commissioned in 1983, INSat is the largest domestic communication system in the Asia Pacific region. It is a joint venture of the Department of Space, Department of Telecommunications, India Meteorological Department, and India Radio and Doordarshan. The overall coordination and management of INSat system rests with the secretary-level INSat Coordination Committee.

InSAT satellites provide 199 transponders in various bands (C, S, Extended C and Ku) to serve the television and communication needs of India. Some of the satellites also have the Very High Resolution Radiometer (VHRR), CCD cameras for metrological imaging. The satellites also incorporate transponder(s) for receiving distress alert signals for search and rescue missions in the South Asian and Indian Ocean Region, as ISRO is a member of the Cospas-Sarsat program.

3) Indian Experience in EduSat

With the success of the InSat-based educational services, a need was felt to launch a satellite dedicated for educational service and ISRO conceived the EduSat project in October 2002 [8, 11]. EduSat is the first exclusive satellite for serving the educational sector. It is specially configured to meet the growing demand for an interactive satellite-based distance education system for the country through audio-visual medium, employing Direct-To-Home (DTH) quality broadcast. The 1950 kg EduSat is launched from Satish Dhawan Space Centre (SDSC) SHAR, Sriharikota, into a Geosynchronous Transfer Orbit (GTO) by ISRO's Geosynchronous Satellite Launch Vehicle (GSLV). From GTO, EduSat reaches the 36,000 Km high Geo-Stationary Orbit (GSO) by firing, in stages, its on board Liquid Apogee Motor (LAM). In GSO, the satellite is co-located with KALPANA-1 and INSat-3C satellites at 74° east longitude. EduSat carries five Ku-band transponders providing spot beams, one Ku-band transponder providing a national beam and six extended C-band transponders with national coverage beam. It joins the InSat system that already has more than 130 transponders in C-band, extended C-band and Ku-band providing a variety of telecommunication and television services.

B. Advances in satellite communications technologies

Through the last decades, there has been tremendous development in satellite communications technologies [13, 14]. Satellite communications started with using multiple access based mainly on time division multiple access (TDMA), moving to bandwidth reuse through the use of spot beams, then the extraordinary hopping technology, and finally the low orbit systems technology. A brief definition for each of these technologies is provided below and further details can be found in [13, 14].

1) The Time Division Multiple Access (TDMA) Technology

Communications satellite systems have entered a period of transition from point-to-point high-capacity trunk communications between large, costly ground terminals to multipoint-to-multipoint communications between small and low-cost stations. The development of multiple access methods has both hastened and facilitated this transition. Satellite communication technology was based on using the TDMA technique for user allocation on the communication channel. With TDMA, each ground station is assigned a time slot on the same channel for use in transmitting its communications; all other stations monitor these slots and select the communications directed to them. By amplifying a single carrier frequency in each satellite repeater, TDMA ensures the most efficient use of the satellite's onboard power supply.

2) The Bandwidth Reuse through Spot Beam Technology

A spot beam is a satellite signal that is specially concentrated in power normally sent by a high-gain antenna so that it will cover only a limited geographic area on Earth. Beam widths can be adjusted to cover areas as large as the entire United States or as small as a state like Maryland. In addition, satellite antennas have been designed to transmit several beams in different directions using the same reflector.

Spot beams are used so that only earth stations in a particular intended reception area can properly receive the satellite signal. Spot beams allow satellites to transmit different data signals using the same frequency. Because satellites have a limited number of frequencies to use, the ability to re-use a frequency for different geographical locations (without different data interfering with each other at the receiver) allows for more local channels to be carried, since the same frequency can be used in several regions.

3) Frequency Hopping Technology

A method for interconnecting many ground stations spread over great distances was demonstrated in 1993 with the launch of NASA's Advanced Communications Technology Satellite (ACTS). The satellite uses what is known as the hopping spot beam technique to combine the advantages of frequency reuse, spot beams, and TDMA. By concentrating the energy of the satellite's transmitted signal, ACTS can use ground stations that have smaller antennas and reduced power requirements.

4) Low Orbit Technology

The latest development in satellites is the use of networks of small satellites in low earth orbit (2000 Km or less) to provide global telephone communication. The Iridium system, for example, uses 66 satellites in low earth orbit, while other groups have or are developing similar systems. Special telephones that communicate with these satellites allow users to access the regular telephone network and place calls from anywhere on the globe. Anticipated customers of these systems include international business travelers and people living or working in remote areas.

C. The MENOS Hub

MENOS is a revolutionary networking concept used to exchange multimedia content over satellite [12]. It is intended primarily for professional broadcasters, allowing them to share video and audio material among several sites scattered across a large geographical area. It has been designed to provide these broadcasters not only with the fastest and most cost-effective technologies to perform the media exchange, but also with a complete range of tools to facilitate the related coordination tasks and improve people collaboration across the network.

In traditional satellite contribution systems, television and radio material is exchanged as real-time transmissions from one ground station to another. This requires the reservation of a satellite segment for fixed time duration, a manual line-up procedure, and expensive uplink equipment. At the receive site, the transferred material needs to be used on the fly or recorded. The coordination between the two stations, or between the stations and the network operating center, must typically be done via terrestrial or mobile telephony.

MENOS is fundamentally different with IP as the core-protocol, all exchanged material transmits through a central hub station, which also provides permanent two-way satellite IP connectivity among all remote stations. The multimedia content can be transmitted in real-time or be transferred as data files. It can also be retained in the central hub station for archiving and later access by other stations. The reservation of the bandwidth and the line-up procedure are automatic and the uplink stations are smaller and much less expensive than traditional systems. In general, the two-way IP connectivity is ideal for voice over IP (VoIP) coordination channels, e-mail exchange, Intranet and Internet access and other collaboration tools.

1) MENOS System Architecture

A MENOS system consists of a redundant central platform (hub) connected to a number of remote sites, each equipped with a satellite interactive terminal (SIT). The terminal is able to transmit or receive data to and from the hub. The data can be exchanged between the hub and the terminal or between two terminals via the hub. From the terminal to the hub, the data is transmitted either on a dedicated single channel per carrier (SCPC) carrier, or on a return channel shared dynamically in time and frequency with other terminals. Low rate data, such as Internet and Intranet exchanges, VoIP, radio exchange and low bit rate file transfers, are typically sent using the multiple frequency time division multiple access (MFTDMA) channels, while real time television transmission and fast file transfers are operated in SCPC.

All transmissions are first received by the central hub. If necessary, the transferred material can be automatically archived in the central hub for later use by the remote stations. Data is transferred from the hub to the stations on one of two MFTDMA multiplex carriers, i.e., multiple channel per carrier (MCPC). The first one regroups all the video transfers and the second one regroups the Internet data, the file transfers and the VoIP calls.

Different types of MENOS remote stations are available, depending on the type of applications performed at the remote site.

- Data SITs only provide data and VoIP connectivity and can be used for Internet, Intranet, VPNs, and interactive collaboration tools
- Radio SITs provide all the service of a Data SIT in addition to radio exchange services
- Television SITs provide all the service of a Data SIT in addition to television exchange services

MENOS terminals can also be integrated into mobile units, in the form of digital satellite news gathering (DSNG) trucks or flyaway kits.

III. THE PROPOSED INTERACTIVE ARAB EDUCATION SATELLITE (IAESAT)

This section provides a description of the proposed interactive Arab education satellite (IAESat) for all Arab Homeland countries. The proposed solution can be accomplished as a new project or can be embedded with existing projects such as ArabSat and MENOS hub.

A. The IAESat model

The generic framework of the unified M-Learning model described in [15] is used in IAESat as this framework was developed a generic methodology for building a satellite TV based Interactive M-Learning (STV-IML) system. The framework consists of three major components; these are:

1. Centralized Broadcasting Center (CBC), which consists of several sub-components such as live and recorded broadcasting facility, earth station, a satellite channel connected to a well-known satellite, video servers, and video storage devices, web servers, short-message-session (SMS) servers, and so forth.
2. Client side (educational site), where several educational sites can be connected to the CBC and can share the resources for reception and broadcasting of educational material. The typical setting required by an educational site is minimal and consists of a satellite dish connected to a set top box with Digital Video Recorder (DVR). It may require Internet con-

nection. An educational site can operate its own media production and auditing units. A mobile broadcasting van can also be used for live and mobile broadcasting and live event coverage.

3. Communication and broadcasting channels: Four types of communication channels were proposed in the STV-IML framework for broadcasting, reception, and interaction, namely, interactive channel, download channel, satellite reception on client side, and satellite broadcasting.

In order to implement the unified M-Learning model, first it is required to establish a satellite broadcasting capabilities by constructing an earth station connected to a spot beam satellite. A broadcasting center and a production and auditing centers are to be established and may well be integrated with a centralized M-Learning center managed by educational sites. Viewers can interact with education programs using available interactivity components.

B. *Components of IAESat*

The proposed IAESat educational satellite consists of the following main components:

1. Communication satellite with spot beaming technology
2. Remote stations with VSAT terminals
3. Main hub station with archiving capabilities
4. Centralized broadcasting station
5. Centralized content development and class scheduling
6. Distributed and mobile broadcasting stations
7. Interactive and non-interactive class rooms

Figure (2) depicts the main components and configuration of the proposed system and in what follows a brief description is given for each component.

1) *Communication satellite with spot beam technology*

IAESat is based on using spot beam technologies because they enable IAESat to deliver more local channels to specific, precisely defined areas, which improves its ability to compete with cable broadcasters. The communication satellite uses beams that cover the entire Arab Homeland. To provide local broadcast coverage, channels intended for only one local area are scrambled so users elsewhere cannot view them. The new spot beam satellites are designed to project spot beams at selected areas, allowing the same radio frequencies to be reused in different areas, thus increasing the channel capacity. For example, by focusing over a very small area, like Amman, the frequency can be reused in several other places like Baghdad, Cario, Riyad, etc. Where these cities are used as examples, and will not actually share the same spot beam frequency. With highly powerful spot beam satellites, we can direct different spot beam projections to the Arab Homeland and deliver a lot more local programming to those specific areas. Each spot beam can have an approximate diameter of 500 Km, making them powerful satellites.

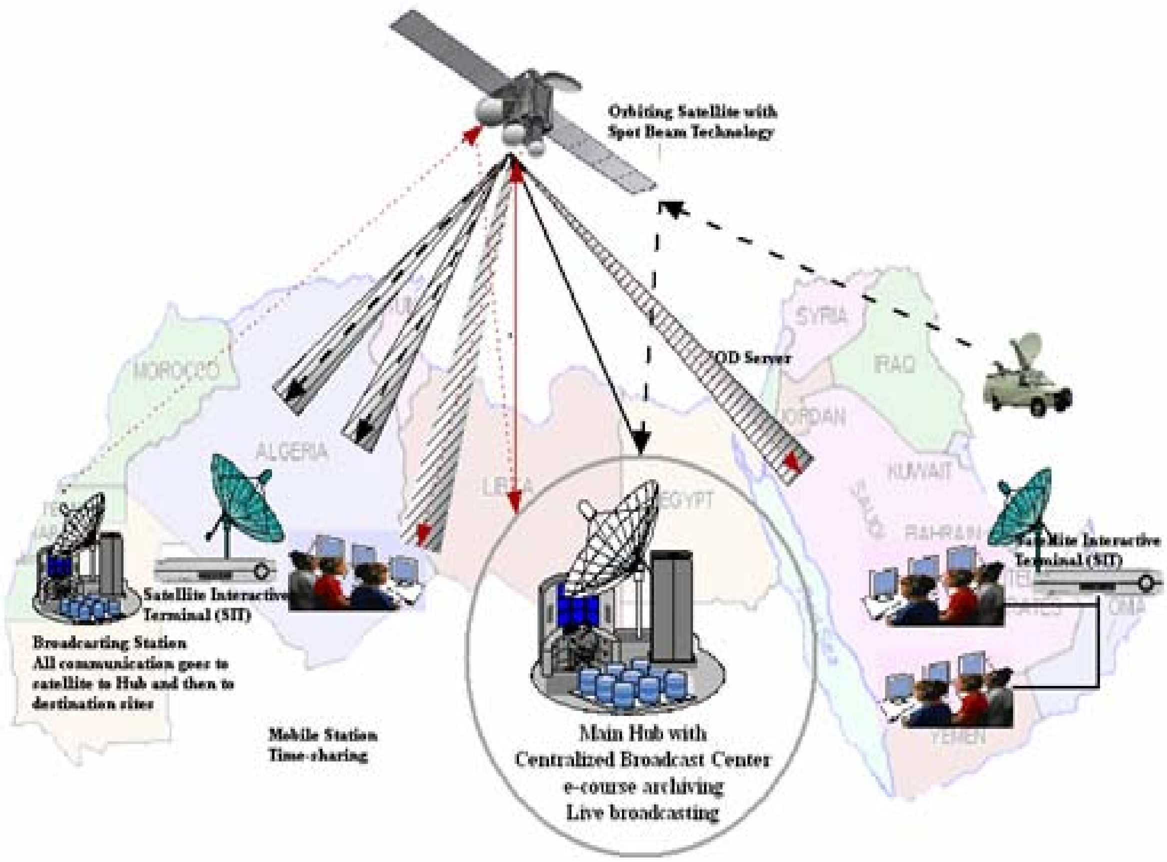

Figure 2. The main components of the IAESat.

2) Remote stations with VSAT and SIT terminals

A typical remote station constitutes an interactive receiving end (classroom) consisting of a variety of components such as a satellite dish, special satellite receiver, computers, router, multimedia equipment, E-Learning software. The two distinguish components that can be used as remote stations are: the Very Small Aperture Terminal (VSAT) and the Satellite Interactive Terminal (SIT) which are explained below:

- VSAT is a low cost business terminal with small antenna. It is a two way data terminal or one-way data link depending on the situation. The most common VSAT configuration is the Time Division Multiplexing (TDM)/TDMA star network. VSAT has a high bit rate outbound TDM carrier from the hub to the remote earth stations, and one or more low or medium bit rate TDMA inbound carriers. Remote user sites have several low bit rate Data Terminal Equipments (DTEs) operating at 1.2 to 9.6 Kbits/s. These are connected through the VSAT network to a centralized host processor.
- SIT is a satellite receiver with broadband Internet connection. The multiplexer of SIT exchanges video content with the multiplexer of the MENOS hub for:
  - Live TV contribution/distribution (reserved channel).
  - High speed streaming on reserved channel or best effort file transfer.
  - Store and forward: short time storage in the SIT or long term archiving in the network hub. These exchange sessions are synchronized and activated automatically by the hub's Multimedia Reservation Server (MRS). The TV SIT is connected to the MENOS hub via two satellite subsystems: a Multiple Frequency TDMA (MF-TDMA) broadband subsystem for data and voice communication, and a Reservation Access Multiple Access (RAMA) subsystem for video and fast file transfers.

3) Main hub station with archiving capabilities

Part of the VSAT network, is the hub, which is a centralized high performance earth station (with an antenna of up to 9 m in diameter). The proposed communication network is constructed using a STAR topology with the hub at the center of the star. The hub plays an important role in enhancing the performance and efficiency of the proposed M-Learning systems, as:

- The hub is considered as the heart of communication between the satellite and the remote stations.
- All stations are connected to the hub at all times.
- The hub provides remote stations with broadband internet services, and voice services.
- The hub works as a centralized operational center that provides collaboration and media exchange between connected remote sites. It also performs automatic configuration of transmission and multiplexing of transmitted signals for live broadcasting from one station to other stations.
- The hub can be used to broadcast programs to all the connected stations, or it can be used to direct specific programs to specific stations utilizing the spot beam technology in the satellite.
- All types of broadcast are archived at the hub facilities for later use.
- Any remote station that requires communication with a different station must go through the hub facilities first.

4) Centralized broadcasting station

Located at the center of the star network along with hub facilities, this station broadcasts the unified E-Learning material to the rest of the network. Broadcasts include live classes as well as pre-recorded E-Learning material. This center contains an archive of all produced material and exchanged media. Any member station can search through the central station contents, whether archived or live, and can join the sessions. The hub facility decodes the contents to make it available for the client station.

5) Centralized content development and scheduling

Since the objective of this project is to produce and distribute unified E-Learning materials to member educational institutions, it is very important to establish a centralized commission for the purpose of organizing content development using well-document quality procedures. The core responsibilities of the commission include:

- Solicitation of highly qualified lecturers in the region
- Subject coordination and syllabus creation
- Adjustment of syllabus based on feedback
- Maintain copyrights and quality of produced materials
- Production of actual live or pre-recorded lessons
- Arranging for online examinations
- Produce statistics and research studies, and organize conferences
- Develop and maintain live-lessons schedules

6) Distributed and mobile broadcasting stations

These stations are owned by individual countries, universities, or any interesting institutions. These stations can also help members of this education system with developing and producing their own specialized materials, and communicate with the main hub through, for example, the orbiting satellite, which then retransmit the signals to the specified destinations.

7) Interactivity and non-interactive classrooms

User interaction is an important component and factor that needs to be carefully considered in designing and building a M-Learning system, like IAESat. This is because it targets wide and different categories of users of different backgrounds. Fortunately, the enormous advancement in hardware and software technologies enable system developer to build a system that can meet all rage of users, services, and applications interactivity.

Interactivity components may include TV-based technologies; such as: traditional TV, interactive TV (ITV), and IP based TV (IPTV). To be truly interactive, the viewer must be able to alter the viewing experience or return information to the broadcaster. This "return path" or "back channel" can be established by telephone, mobile SMS (text messages), radio channels, digital subscriber line (ADSL), cable channels, etc [15]. Satellite viewers can return information to the broadcaster via their regular telephone or ADSL lines or other data communication technologies [15]. They will be charged for this service according to the national billing standard. Further discussion on user interaction technologies can be found in [15].

IV. OPERATION OF IAESAT

All operations of the IAESat go through the main hub which constitutes the heart of the star network. Signals and broadcast requests leaves broadcast stations directly to the orbiting satellite, which in turns send those signals to the hub to determine their destinations. The hub sends the signals back the satellite with proper destination information. The satellite using its spot beam capabilities, resend the signal to the proper destination.

The main features of the proposed project include:

- Use of advanced satellite communication technologies, namely, the spot beam technologies, which enables customization and personalization of satellite communication and reuse of satellite frequencies.
- Use of VSAT terminals is an easy and non-expensive solution to build remote classes.
- Use of star network with a hub station has several advantages such as overcoming the limitations with time sharing, transmission configuration.
- Establish a high commission on E-Learning insures proper management of production and distribution of contents using quality standards.

V. CONCLUSIONS

This paper presented a description of a unified M-Learning model through interactive education satellite to widen education in the Arab Homeland States, which is referred to as IAESat. The model utilizes the new spot beam satellite communication technology to ensure allocation and customization of local channels to specific and precisely defined areas. Using spot beam technology improves the satellite capability to compete with other existing wire and wireless communications technologies. The communication satellite can efficiently and cost-effectively cover the entire Arab Homeland and reaches a wide area and mobile users that cannot be reached otherwise. The model also implement advanced interactivity component to meet the standards of the learning process.

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