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Satellite based Body Area Network

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ABSTRACT
A Body Area Network is a Wireless Network of wearable computing devices. With the advancement of microelectronics, communication and medical sciences, a Body Area Network, with the help of bio-signal sensors can collect relevant vital medical parameters in real-time and transfer it into a network for proactive healthcare and emergency mitigation services. In this paper, an attempt has been made to bring out the challenges for the development of a Satellite based Body Area Network. The paper discusses on the feasibility for the development of such a network, considering the available and future technologies. In this paper, the author addresses on the architecture, design, and development issues of such a novel network and come up with the applications and outcomes with possible services, which this type of network can offer both on a national and global scale. A Satellite based Body Area Network does not exists now, so the author also tries to bring out the necessary technological challenges, which may be faced for the realization of such a network and deployment of associated services.

General Terms
Protocol, Health Care, Wi-Fi, DVB-RCS, Stroke, Heart Attack

Keywords
Body Area Network, Proactive Health Care, Satellite, WSN

1. INTRODUCTION
A Body Area Network is a wireless network [5] of wearable computing devices. With the advancement of microelectronics, communication and medical sciences, a Body Area Network [24], with the help of bio-signal sensors can collect relevant vital medical parameters in real-time and transfer it into a network for proactive healthcare and emergency mitigation services. The concept of Body Area Network has been discussed in [15-20].

The relevant patient data collected from these wearable devices can be stored in a Central Server. There can be artificial intelligence based Expert Systems software running on the Central Server, which taking these values of patient parameters, can generate automatic decisions about the actions to be taken thereafter.

The parameters which can be measured by these type of wearable devices [5] includes blood pressure, pulse, temperature, saturation point of oxygen in blood and many other parameters [15-20]. With the advancement of sensor technology, more relevant physiological parameters can be monitored which in itself is a separate emerging field of technological advancement [14, 21]. Certain devices can also generate an ECG or EEG of the patient. From the real-time measurement of these values, the Expert System can infer an incipient cardiac arrest or stroke for the patient [15, 20].

Once an emergency is signaled, the patient can be immediately informed and his corresponding doctor be intimated by generating automatic Short Message Service (SMS) or auto generated voice call services. The server will maintain a database of all possible contacts to be communicated in case of an emergency scenario. If the data indicates no emergency but shows a rising trend of certain symptoms, then likewise the patient will be informed for health checkup or change in medication. The decision may be automated using Expert Systems or medical specialist’s view may be incorporated. A hybrid approach can also be followed, by first informing the patient about a predicted emergency and subsequent confirmation by doctors about the severity of the condition.

Myocardial Infraction or Heart Attack and Stroke posses the greatest threat to people throughout the world. In Canada, one person faces heart attack every 7 minute. Heart attack and stoke combined cost the Canadian an approximate $20.9 billion every year in physician services, hospital cost, and subsequent decreased productivity. Most of the time death occurs out of hospital and 90% Canadians are at risk of heart disease.

The situation in India is still worse with heart disease and stroke the number one killer in rural and urban India. Approximately four people die of heart attack in India every minute within an age group of 30-50. Approximately 25% heart attacks happen to people less than 40 years age. More alarming is the fact that 900 people die everyday under the age of 30 years.

Considering the situation, a preventive methodology for addressing this problem is an essential requirement. New innovative techniques need to be investigated and the use of space assets should be looked into to provide an integrated solution to the problem taking help from all technological advancements.

Many a time, heart attack or stroke are caused by an increase in blood pressure and can be predicted in advance. However, the methodologies to be applied to predict an incipient heart attack or stroke, is a separate discipline of medical research and needs special attention to make this type of advanced services.

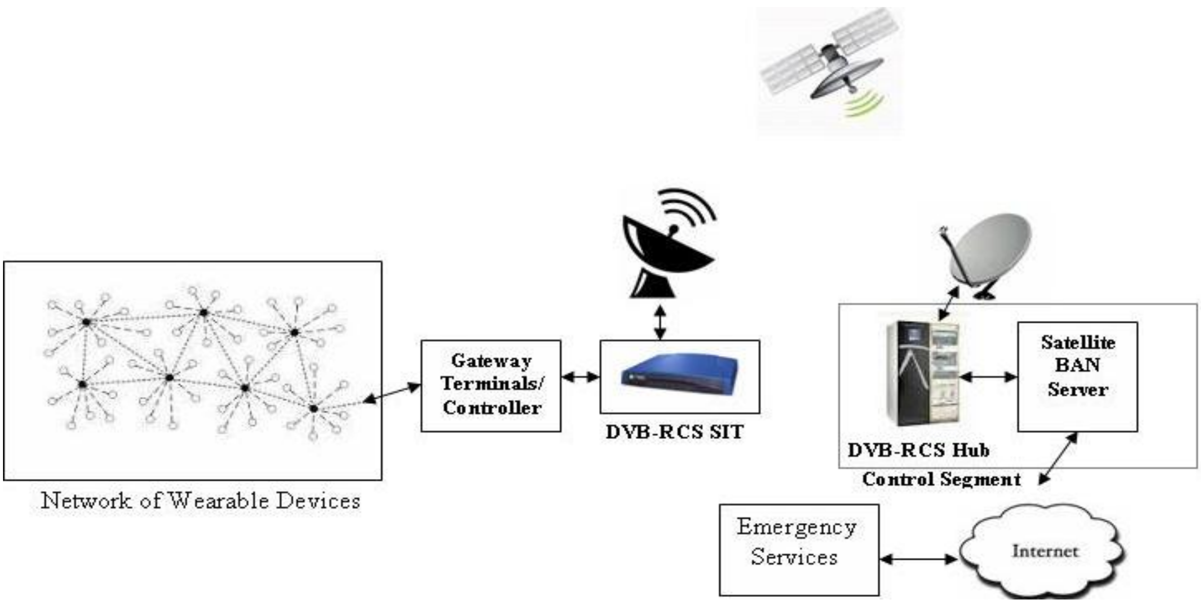

Fig1. Satellite Based Body Area Network Configuration for More Nodes

In this project, an attempt has been made to develop a satellite-based application, which can help in the prevention of heart attack and stroke. The infrastructure can be extended for many other life-threatening diseases [25, 26]. The aim is to provide the citizens of the country an aid so that heart attacks and stroke can be predicted and death cases minimized. The use of satellite technology will enable the services to be ubiquitous and provide the facilities even to the remotest places on earth thereby bridging the digital divide.

In section 2.0, a broad overview of the system description will be provided. Section 3.0 will describe on the type of user terminals to be used and the associated protocols to be followed. In section 4.0, the type of applications, which can be supported using this type of network, will be explained. Section 5.0 will explain the governmental and commercial side of the technology. Section 6.0 provides the conclusion.

2. SYSTEM DESCRIPTION

The system consists of the (i) Space Segment, (ii) Control segment and (iii) User Segment as shown in Fig1.

2.1 Space Segment

The Space segment is comprised of three GEO satellites covering the whole globe at 120 degree apart. Depending on the actual network configuration, low cost nanosatellites may also be used in the space segment in the future to assist in data delivery.

2.2 Control Segment

The control segment comprises of the Satellite HUB, the Server and associated Cloud where data is stored. The Expert System software and all associated techniques will be running on the server to generate prediction and transfer messages accordingly.

2.3 User Segment

The user segment mainly comprises of the wearable devices and the Satellite Gateway terminals. The details of the type of terminals needed depending on network configuration are described in Section 3.0. Depending on the type of application different types of terminals will be used.

3. TYPES OF TERMINALS

Different types of terminals and devices may be envisaged to be used in this type of satellite-based network. Depending on the node density and application to be used, following are some of the type of terminals. The terminals to be used are highly dependent on the application, needs to take care of the power dissipation, and associated issues pertaining to this case.

3.1 Terminals using Wireless Sensor Network

In this type of networks, where there are more number of wearable devices being deployed, each device may communicate with the next using protocols of wireless sensor networks [6], [8], and [9] as shown in Fig1. There will be a central node, which will act as a gateway for the transfer of data from the devices to the network as shown in Fig1. However, considering the constraints of the wearable devices in terms of energy resource, computational power, available memory and small size specialized protocols need to be investigated or protocols used in wireless sensor networks suitable modified for handling this type of network [22, 23]. Moreover, protocols should handle network topology changes and security to handle the confidentiality of medical data. The MAC protocols to be used for such a network may be adopted as used for WSN [42, 43].

The gateway terminal will be responsible for the control of the nodes. There may also be the formation of clusters [6] with some nodes in the vicinity. Each node will communicate to the cluster head and cluster heads will communicate data to the gateway terminal.

The gateway terminal will have connectivity to a Satellite Interactive Terminal (SIT) [3] using VSAT or DVB-RCS [1], [2], [4] standard. An overview of DVB-RCS standard and associated technology can be obtained in [7, 10-13]. The Satellite Interactive Terminals will provide bidirectional connectivity via satellite. It will take data from the gateway terminal on LAN and transfer the data to the DVB-RCS HUB [7] via satellite. The DVB-RCS Hub [7] will be connected to Server where the actual processing of data will take place. The Server will also be connected to the Internet and may use the Internet cloud for data storage or archival and have connectivity with other emergency services.

Hence, individual wireless sensor networks of wearable devices or local Body Area Networks can be connected via satellite using satellite interactive terminals to transfer data to the central HUB. The Satellite Interactive Terminals can use Ku/Ka band for high throughput data transfer.

This type of service or network topology will be needed when the node density is more and aggregate data transfer from the body area network is more. However, in this case the Satellite Interactive Terminals are at fixed place. Therefore, the data from the body area network comes to the Gateway Device and through Satellite Interactive Terminals gets to the server. Grid computing techniques may also be used in case the data stored in very high [35].

3.2 Terminals Supporting Mobility

In this case, the number of deployed wearable devices is less so hop-by-hop transfer may not be possible. This is the scenario when an individual person needs this sort of service and there are not much people in the vicinity using this service. For hop-by-hop transfer, there is a need for higher node density. In this application individual wants to use wearable devices at home or on the move to get proactive medical assistance.

In this case, the small wearable devices can connect to the Gateway devices using Wi-Fi technology or Ultra Wide Band (UWB) technique. The issue of energy consumption and lifetime of sensors especially those implanted is described in [31-33]. The Gateway device will accept data using Wi-Fi or other relevant standard and transmit directly to satellite using L/S band. This Gateway device may be kept fixed in any open to sky location at home or can be kept in Car/Train/Bus if mobile services are needed.

These Gateways accept data using Wi-Fi standard or Ultra Wide Band and transmit in L/S band using Mobile Satellite Network techniques. The use of L/S band will provide the flexibility of operation in mobile condition.

Depending on the traffic load and the nature of services, appropriate terminals may be selected. This type of terminals may also be used to gather data from a number of wearable devices using Wi-Fi and send to the satellite. The data rate requirements for various sensor nodes depending on applications are described in [47]. The transmit power requirements considering use close to human body is discussed in [23, 34]. The problems associated with the position of the sensors in a human body and associated communication challenges are described in [30, 36-41].

In the future, buses, trains and ships may be provided with this type of devices which can gather data from wearable devices using Wi-Fi and send to central Hub using Mobile Satellite Network. This is the scenario where community services may be provided inside public vehicles. Travelers with wearable devices can transmit the relevant data using Wi-Fi and get preventive medical care.

3.3 Communication using Satellite Phones

In this case, wearable devices may use Bluetooth techniques [44] or better use IEEE 802.15.4 [45] or ZigBee [46] to send data to Satellite phones carried by individual patients. The satellite phones carried by patients will accept data from wearable devices via Bluetooth and send to the central server using satellite. The satellite phone in this case should have a provision for data input capability and have the provision to work in 3G mode. This will be highly personalized solution, as the satellite phones will not have much capability for higher throughput data transfer. This has a very good commercial potential for satellite phone manufacturers.

4. APPLICATIONS

In this section, a brief overview has been provided for all the different applications, which can be provided using the proposed technology.

4.1 Proactive Health Care in Rural Areas

The Satellite based Body Area Network will provide opportunity to rural people to take advantage of the latest technological developments. Wireless Body Area Network [5] and proactive health care facilities will first emerge in developed countries and cities having advanced technological infrastructure. In rural areas where there is no Internet connectivity, critical patients have no way to be served for advanced health care. Using this satellite based system; rural proactive health care facilities may be established with coordination from the respective local administration. In case of emergency, local rural health care units may be intimated for necessary corrective action.

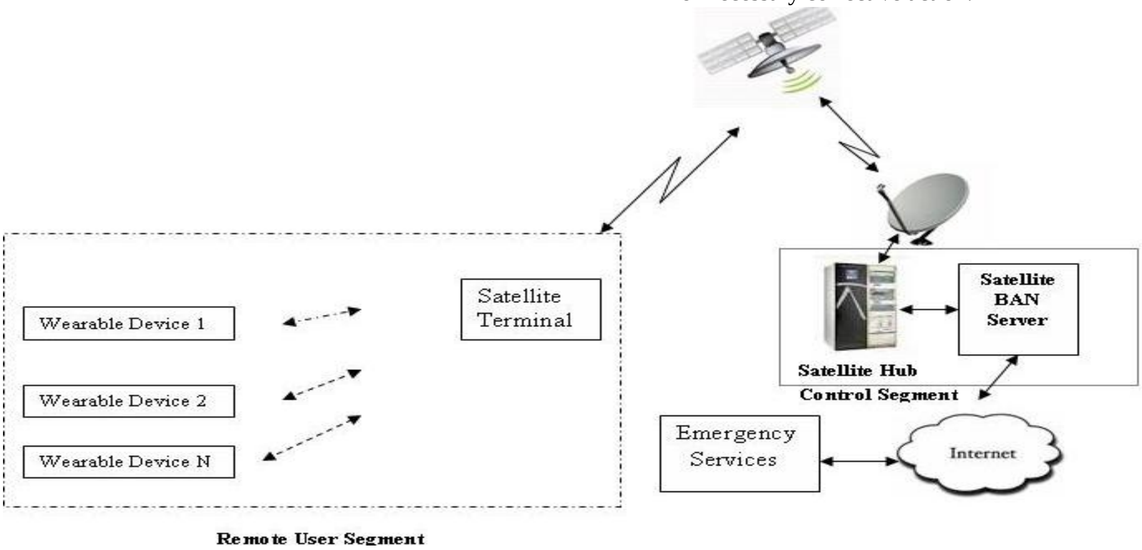

Fig2. Satellite Based Body Area Network Configuration for Mobile Services

4.2 Health Care in Maritime Environment

There are a huge number of people traveling in ships and out of the terrestrial communication network and proper medical services. The proposed Satellite based Body area Network will provide patients traveling in ships with necessary advice. The vital parameters of passengers in ships may be monitored and emergency suggestions may be provided. If any problem is detected on ship, medical team onboard the ship may be made aware of the incipient emergency. In case of extreme emergency, relief efforts may be initiated.

4.3 Health Care of Astronauts

Space environment is always challenging for astronauts and the proposed satellite based network may be used to monitor the health of astronauts and give them a-priori preventive medication. For example, crews working in the International Space Station (ISS) may take help of this type of Global Satellite Body area Network and their health can be monitored on a real-time basis. The real time data will also facilitate in the research on micro-gravity and how it changes with time and circumstances.

4.4 Elderly Patient Health Care

Throughout the world, the issue of providing health care to elderly people is a major challenge [27]. Majority of elderly people stay alone and are not able to take action in case of emergency. This technology will be coupled with GNSS techniques and the position of the patients will be transmitted to the Server. Hence, in case of emergency elderly people may be alerted, their family members informed and ambulatory services may proactively reach the precise destination of the elderly person and provide proper health care and hospitalization services. This framework may be used for many value added services taking advantage of the latest development in biomedical sensor technology [28, 29].

4.5 Medical Data Collection and Archival for Research

The Satellite based Body Area Network will allow the provision for collection of huge amount of patient data [21], which can be used for medical research and case study. The way the vital parameters change before a major heart attack or stroke will be recorded and archived. Using these data, research may be pursued to find better prediction algorithms for incipient heart attacks. If a Global Network is established, this can help in understanding how people from different regions of the world behave to stress and other issues. The role of climate, seasonal changes, temperature, stress or other life style related issues have on health care of patients can be investigated and analyzed, which in turn will help in overall research and advancement in treatment methodologies.

4.6 Remote Intensive Care Unit (ICU) Management

In many of the hospitals, maintaining the ICU is a challenge with less doctors and nurses. This type of network may be used to find out which of the patients need immediate attention from a central place thereby helping in the functioning of the ICU. Doctors may also remotely monitor ICUs.

5. SERVICES

5.1 Public Services

Both government and private entities can use this network. One of the primary roles of any government is the health care of its citizens. This project will be very helpful for government health care departments. The huge amount of scientific data will help in medial research. Government may create a policy of providing these services to people with problem certified by a health agency or to all after a certain age. This will reduce the hazards and create a good governance example. The actual policy and regulations need to be finely worked out regarding who should be provided this type of facility and is highly linked with the respective countries political will and economic condition.

5.2 Commercial Services

In this section, an attempt has been made to bring out some of the commercial services, which may be offered using the proposed network as follows.

5.2.1 Proactive Health Care Insurance

Every individual pays a sizeable amount of money for health care related issues. At present, people spend money in taking Medical Insurance to protect their medical expenses. During the time of an emergency, the Insurance companies have to bear a huge cost related to the hospitalization or surgical necessity.

It will be a very good commercial proposal for the Medical Insurance Companies to provide this type of Proactive Health Care services at an extra premium. They may also launch separate services for providing this type of facilities. People suffering from or at a risk of particular diseases may take the services and it will be a helpful service considering the human threat from these types of diseases in the future. Proactive Health Care Insurance may turn up to be a huge commercial business for Health Care Insurance Companies.

5.2.2 Data Archival Service for Hereditary Diseases

Some people have family history of heart attack/stroke or other hereditary diseases. Many a times it has been seen that people with hereditary cardiac problems gets attack at a very early age. There can be a commercial service where people with hereditary disease may like to keep their relevant medical history permanently stored by paying an extra premium. This may help the successors to get better medical health care and help them fight with their hereditary problems in a more efficient way. Once the medical history or the exact cause of death is available to medical consultants better preventive medication may be possible. With the rise of biotechnology and genetic engineering in the future, effort may be made to alleviate these hereditary problems at a very early stage.

5.2.3 Elderly Health Care Service

Commercial hospitals may provide emergency elderly health care service. Elderly people may provide money and take plans from these commercial health care companies/ hospitals, which promises to provide them help in emergency and general preventive health care. This is a good commercial proposal considering the huge number of elderly population staying alone. The commercial hospitals may also provide a regular proactive health care by remotely monitoring elderly people health. In case of changes in health condition arrange for visit by medical team suggesting them with proper medication, life style changes, and even provide them with necessary psychological support. There may be coordination with professional health care attendants to take care of elderly people, once their health risks are anticipated.

This service is highly recommended as in many cases elderly deaths are found because of lack of medical care or people attending them.

6. CONCLUSION

The project attempts to envisage a Satellite based Body Area Network, which can revolutionize the way of preventive healthcare. Considering the increasing threat and heavy death toll of diseases like heart attack and strokes, this technology can use the space assets, create a major reduction in the number of death cases, and even reduce the chance of hospitalization by proactive health care action. This paper has described the envisaged system description with the types of terminals to be developed for this type of service depending on the network size and application concerned. The paper has also described the different types of applications, which can be developed using this network, and attempted to bring out the respective advantages. The paper has also envisaged the public and commercial aspects and services using this technology, which can provide value added services to the customers. Satellite based proactive health care is a novel approach to solving the problems of health care and is ubiquitous in its approach and accessible to all. The future aspects of the technology have also been discussed which could revolutionize the way we think of medical health care and increase the longevity of humans in this planet.

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