Proposal / Application
for
ICT-Related Development
and Research Grant

“Remote Patient Monitoring System
With Focus on Antenatal Care for Rural Population”

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Associate Professor
(Project Director)

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Next Generation Intelligent Networks Research Center (neXGIN RC),
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# List of Abbreviations and Acronyms

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<tr>
<td>EE</td>
<td>External Evaluators</td>
</tr>
<tr>
<td>ICT</td>
<td>Information and Communication Technologies</td>
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<tr>
<td>IPR</td>
<td>Intellectual Property Rights</td>
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<td>JPD</td>
<td>Joint Project Director (Co-Director)</td>
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<tr>
<td>MC</td>
<td>Milestone Chart</td>
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<td>MD</td>
<td>Monitoring Department</td>
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<td>MoIT</td>
<td>Ministry of Information Technology</td>
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<td>PAC</td>
<td>Project Appraisal Committee</td>
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<td>PD</td>
<td>Project Director</td>
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<td>PI</td>
<td>Principal Investigator (Organization)</td>
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"Principal Investigator" means the person, company, partnership, undertaking, concern, association of persons, body of individuals, consortium or joint venture which receives funding from the Company to execute a research and development project."

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<tr>
<td>R&amp;D</td>
<td>Research and Development</td>
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<td>SED</td>
<td>Solicitation and Evaluation Department</td>
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Introduction

National ICT R&D Fund was created in January 2007 by Ministry of IT with the vision to transform Pakistan's economy into a knowledge-based economy by promoting efficient, sustainable, and effective ICT (IT and Telecommunications) initiatives through synergic development of industrial and academic resources. Collaborative efforts between academia, research institutions, and industry are greatly encouraged to ensure that local economy can reap the monetary benefits of investment in research. This organization has significant funds available for proposals that are geared towards creating ICT related technologies.

Research grants will be awarded for high-level and promising ICT-related development and research projects by individuals or groups from academia and/or industry actively involved in the development and research individually or collaboratively. These projects should be based on either a universally known technology or a new technology developed by the applicant and should be aimed at achieving economically viable systems, products, or processes beneficial to the nation.

The grant will normally be provided for a period of up to two years – renewable every year based on the performance. The grant will cover the honoraria of the project and co-project directors, salaries of researchers, stipends for student research assistants, and supporting staff. It will also cover travel(s) within and outside the country for project-related activities and for project-related scientific conferences. The grant may be used to purchase very specific unavoidable equipment kept to the bare minimum, consumable materials, and other items needed for the project. The grant can also be used to cover the training expenses of the personnel associated with the research project.

Submission Procedure

Duly filled applications in all respects along with any documents should be emailed to helpdesk@ictrdf.org.pk. A hard copy should also be submitted by registered post or by fax at our mailing address given below. On receipt of the applications the proposals will be evaluated internally as well as externally as laid down in our policy documents. The PD may need to revise the proposal in light of the evaluator’s recommendations.

There is no deadline for submission of the application; however the application should be submitted at least three months prior to commencing the project.

Joint Funding

The project proposal may be jointly funded by ICT R&D Fund and other funding agencies/industry. The efforts to obtain joint funding will be at the discretion of the Principal Investigator (PI) – Organization to which Project Director belongs. However any such information must be provided to ICT R&D Fund. The funds released will be provided to the PI.
Agreement

A written agreement will be made between National ICT R&D Fund and PI. The PI will undertake to administer the grant according to the agreement and to provide laboratory space, and other facilities necessary for the project. The equipment purchased with ICT R&D Fund for the approved project will remain the property of ICT R&D Fund. The laptops will be returned to ICT R&D Fund after completion of the project. The grantee is required to submit a final narrative and financial report within one month of the completion of the project. The IPR issues will be sorted according the policy in vogue.

For further information, please contact:

Solicitation and Evaluation Department,
National ICT R&D Fund,
6th Floor, HBL Towers,
Jinnah Avenue, Blue Area, Islamabad
Tel.: (+92-51) 2811059-60-62-63
Fax: (+92-51) 2274746
Website: www.ictrdf.org.pk
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## 1. Project Identification

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<td><strong>Remote Patient Monitoring System</strong></td>
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<td><strong>With Focus on Antenatal Care For Rural Population</strong></td>
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<th>C. Project Director (PD):</th>
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<tr>
<td>Name: Dr. Mudassar Farooq</td>
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<tr>
<td>Designation: Associate Professor</td>
</tr>
<tr>
<td>Organization: National University of Computers &amp; Emerging Sciences (FAST NU)</td>
</tr>
<tr>
<td>Mobile # :</td>
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<tr>
<td>Email: <a href="mailto:muddassar.farooq@cs.uni-dortmund.de">muddassar.farooq@cs.uni-dortmund.de</a>, <a href="mailto:muddassar.farooq@udo.edu">muddassar.farooq@udo.edu</a></td>
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<tr>
<th>C1. Joint Project Director (JPD):</th>
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<tbody>
<tr>
<td>Name: Dr. Abdul Aziz Awan</td>
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<tr>
<td>Designation: Program Manager Health</td>
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<tr>
<td>Organization: Human Development Fund (HDF)</td>
</tr>
<tr>
<td>Mobile # : 0333 549 3357</td>
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<td>Email:</td>
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<tr>
<th>C2. Contact Person:</th>
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<tr>
<td>Name:</td>
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<td>Designation:</td>
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<td>Tel. # :</td>
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<td>Email:</td>
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<p>| C3. Project Team: | (Please attach the curriculum vitae of key research / development personnel, if available and PD, JPD. Please follow the format included in Annexure A.) |</p>
<table>
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<tr>
<th>Title / Position</th>
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<tr>
<td>Team Leads</td>
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<tr>
<td>(Design Engineers) (1)</td>
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<tr>
<td>Web Server Developer (2)</td>
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<tr>
<td>Application Developer (3)</td>
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<td>Hardware Developer (4)</td>
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<tr>
<td>(Student Researchers) (5)</td>
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<tr>
<td>Engineering Students</td>
<td>8</td>
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<tr>
<td>Medical Student</td>
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<tr>
<td>(Expert Consultants)</td>
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<tr>
<td>Medical Consultant (Gynecologist)</td>
<td>1</td>
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<tr>
<td>Sociologist Consultant (same as JPD)</td>
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<tr>
<td>Support Staff (Medical Support Team)</td>
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<tr>
<td>Health Coordinator</td>
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<td>Lady Health Visitor</td>
<td>1</td>
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<tr>
<td>Trained Birth Attendant</td>
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<tr>
<td>Lady Health Workers</td>
<td>4</td>
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<tr>
<td>Contract Staff</td>
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<tr>
<td>Project Coordinator</td>
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<tr>
<td>Notes:</td>
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<tr>
<td>(1) Design Engineers should have a minimum qualification of BE (Software/Electrical/Telecom).</td>
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<tr>
<td>(2) To develop, test and maintain the main server at hospital with Electronic Medical Record system and Clinical Decision Support System; and to develop, test and maintain the project website.</td>
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<tr>
<td>(3) To develop, test, integrate and maintain the reliable communication infrastructure, local and remote monitoring applications on PDA.</td>
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<tr>
<td>(4) To develop, test and maintain the data gathering module; to develop, test and integrate the proposed medical sensors; and the patient identification system.</td>
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<tr>
<td>(5) Three students with web development expertise to assist the web server developers; three students with software development expertise to assist the application developer; two engineering student and one medical student to assist the hardware developers.</td>
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D. Organization (The Principal Investigator):

(Please indicate the name, address, telephone and fax of the Organization acting as Principal Investigator.)

Name: Next Generation Intelligent Networks Research Center (neXGIN RC), National University of Computer and Emerging Sciences (FAST-NU)
Address: H-11/4, Islamabad
Tel. #: 111 128 128 Fax #: 410 3846
Website: www.nu.edu.pk

E. Other Organizations Involved in the Project:

(Please identify all affiliated organizations collaborating in the project, and describe their role/contribution to the project.)

E1. Industrial Organizations:

| # | Organization Name | Role / Contribution |
### 1.

2.

### E2. Academic Organizations:

<table>
<thead>
<tr>
<th>#</th>
<th>Organization Name</th>
<th>Role / Contribution</th>
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### E3. Funding Organizations:

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<th>Organization Name</th>
<th>Role / Contribution</th>
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### E4. Other Organizations:

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<tr>
<th>#</th>
<th>Organization Name</th>
<th>Role / Contribution</th>
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<tbody>
<tr>
<td>1.</td>
<td>Human Development Fund (HDF), Islamabad</td>
<td>Deployment and Evaluation of the project</td>
</tr>
<tr>
<td>2.</td>
<td>Rawalpindi General Hospital, Rawalpindi</td>
<td>Deployment and Evaluation of the project</td>
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### F. Key Words:

(Please provide a maximum of 5 key words that describe the project. The key words will be incorporated in our database.)

Remote Patient Monitoring, Mobile health care, Bio-telemetry, Antenatal Care, Maternal Health Care

### G. Research and Development Theme:

(If the proposal belongs to a theme specified by NICT R&D Fund, please identify the Research Theme.)

- **Key Area**
  Multi-Sectoral Support Program

- **Research Theme/Area**
  Use ICT in biotechnology and pharmaceutical industries

- **Research Theme/ Area Code**
  Objective B: Effective Use of ICTs in biotechnological research, pharmaceutical and health sectors

### H. Project Status:

(Please mark ☑)

☑ New  ☐ Modification to previous Project

☐ Extension of existing project
I. Project Duration:

| Expected Starting Date (mm/dd/yyyy): | 1st April, 2008 |
| Planned Duration in months:         | 28 months |

J. Executive Summary:

The primary objective of this project is to develop a reliable, efficient and easily deployable remote patient monitoring system that can play a vital role in providing basic health services to the remote village population of Pakistan at their door step. This system can enable expert doctors to monitor patients in remote areas of Pakistan. As a result, the patients no longer need to travel long distances to reach to the nearest basic health units and then just be examined by a mere GP. The project will identify the most important issues in the design of a remote health care monitoring system and will develop a low cost solution, which will be provided to the lady health workers (LHWs) for this purpose.

The goal of the project is to design a generic remote health care system with a focus on antenatal care. Our aim is to use advancements in Information and Communication Technology (ICT) to develop a monitoring system that could enhance the quality of health care provided by the lady health workers. Presently, the antenatal care is being provided by little-educated lady health visitors who perform all the steps of patient care manually. They take readings of patient’s physiological data using instruments which are difficult to handle and require manual tuning etc. Then, they record this data into printed forms manually. Finally, the collected forms are sent to a doctor who goes through all of them looking for any symptom of abnormality. The doctor then takes decision regarding the patient’s treatment.

We propose to develop an automated system that will replace all this hectic activity. The proposed system will be able to gather this physiological data, transmit it, record it, find any abnormality and then assist the doctor in the decision making process.

The basic model consists of a data gathering module, a PDA, a remote server providing Clinical Decision Support System and electronic medical record keeping, and any web-enabled remote terminal (e.g. doctor’s laptop) which could be used to access services provided by the web-server.

The working of this basic model is as follows. The lady health worker is required to attach the data gathering module to the patient’s body using wearable straps etc. provided with the module. The module (consisting of medical sensors) will record the patient’s data and forward it to the PDA through a wired channel (e.g. USB or serial port). The PDA will contain an application for local monitoring of patient’s data that would display the current readings. When all the readings have been taken, the PDA will connect to a remote server and transfer the data to it. The remote server will process the data, invoke the Clinical Decision Support System to perform analysis of data, invoke the Electronic Medical Record service to record the readings in the patient’s history and provide feedback to the PDA screen notifying the decision given by the Clinical Decision Support System.

This model is realized by using intelligent wearable medical sensors controlled by a data gathering module. The sensor nodes are attached to the bodies of the patient and...
provide medical information to the data gathering module's processor. Data gathering module consists of a central microprocessor controlling the operation of a number of medical sensor modules. The central microprocessor gathers data from the sensors and passes it on to the PDA through a serial to USB interface.

The PDA carried by the lady health worker acts as a base station for transmission of patient’s data to the main server in the hospital. Its software part consists of a device driver for detecting and handling data gathering layer, and a local application interface which displays the gathered data for local monitoring and sends it to the main server for medical analysis. The feedback from server is displayed on the PDA. The PDA also provides an interface for entering patient’s data manually or reading it automatically using the patient identification system.

The main server in hospital will run a web server to provide the services of clinical decision support system and electronic medical record system to the requests from PDAs carried by the lady health workers. The web server will also handle requests from doctor’s terminal and provide reports about the patients’ situation. An electronic medical record system will be used to store the incoming data to the patient’s record. The clinical decision support system will provide automated analysis of data and assist the doctor in decision making process. The applications will be developed with ease of use in mind. To train the personnel using the application, help system and tutorials will be designed and distributed. Presentations will also be given on the use of software and installation of hardware.

The whole system cannot be efficiently developed without its deployment in a practical scenario. This practical deployment will also help in regular evaluation of the system and will lead to its further improvement. For this specific purpose, a controlled population group of pregnant ladies will be setup along with the expert advice of doctors from a teaching hospital. For this purpose, the evaluation framework has a setup based on following two organizations: Human Development Fund (HDF) and Rawalpindi General Hospital (RGH).

To evaluate the performance of the proposed system, some performance indicators have been defined. The evaluation framework will evaluate the system deployed in the controlled population group on the basis of these indicators. These performance indicators include increase in lady health workers’ capacity, number of correct referrals, reduction in complexities in birth process through timely preventive measures, amount of correct information available during emergency cases; and ultimately reduction in infant and maternal mortality ratios in the controlled population group.

The whole project is a 28 month effort culminating in the release of a remote patient monitoring system after practical deployment and testing in the real world environment. With focus on antenatal care, the success of this project means better child and maternal health care. Maternal care is not associated with an exclusive segment of society. It is an issue of all households. So, better maternal care will ultimately result in the creation of a better society that has progressive trends.
2. Objectives of the Project

A. Scope and Introduction of the Project (Abstract):

(Please describe the current state of the art specific to this research topic and the motivation and need for this work.)

The primary objective of this project is to provide low-cost and reliable solution to the problem of provision of expert health care to patients in remote areas of Pakistan. The development of the project is focused on the health sector’s needs.

The current medical statistics clearly show that the situation is catastrophic. Only 31% of the total births are attended by skilled personnel (World health statistics, WHO, 2007). This leads to Infant mortality rate in Pakistan being highest among SAARC countries standing at 70 deaths per 1,000 live births (‘The State of Pakistan’s Children, 2006’, SPARC, Islamabad.) Moreover Pakistan also has the highest maternal mortality rate in South Asia (“Infant-maternal mortality rate in Pakistan highest in S. Asia”, Dawn June 21, 2007).

The objective of this project is to change this situation. But being agriculture based country, most of Pakistan’s population lives in far flung and remote areas where accessibility is an important issue. These people do not have access to medical care as the health services infrastructure in these areas is nil. The density of doctors in the population is very scarce. According to the World health statistics by WHO for 2007, Pakistan has one physician for 1351 people, a nurse for 3225 people, a midwife for every 6666 people, a pharmacist for 20000 people and a dentist for every 20000 people. Moreover, many of the doctors (especially the specialist doctors) prefer to serve in urban areas where they have access to all facilities of life.

The attainment of Millennium Development Goals is as yet elusive. The failure of existing systems in this regard is evident from the fact that Maternal Mortality Ratio in Pakistan increased from 350 per 100,000 live births to 400 during year 2000 to 2005 (Pakistan Millennium Development Goals Report 2005 (PMDGR05), page 45, Planning Commission Centre for Research on Poverty Reduction and Income Distribution Islamabad, September 2005). The MDG for Pakistan is to achieve an MMR of 140 per 100,000 live births by the deadline of year 2015. The MDGs related to child and maternal care can be achieved only through a coordinated health care system. The Government of Pakistan has a plan of expanding the lady health workers’ network and introducing 50,000 more lady health workers during 2005-10 (PMDGR05, page 49). Therefore, to bring about a change, we need to develop a low cost infrastructure which would provide basic monitoring and care to these people in remote areas by providing the existing workforce of lady health workers with an infrastructure which links them to the tertiary health care units/hospitals.

B. Specific Objectives Being Addressed by the Project:

(Please describe the measurable objectives of the project and define the expected results. Use results-oriented wording with verbs such as ‘to develop..’, ‘to implement..’, ‘to research..’, ‘to determine..’, ‘to identify.’ Fill in the relevant sub paras below.)

B1. Research Objectives:

The primary objective of this project is to develop a reliable, efficient and easily deployable remote patient monitoring system that can play a vital role in providing basic health services to the remote village population of Pakistan at their door step. This system can enable expert doctors to monitor patients in remote areas of Pakistan. As a
result, the patients no longer need to travel long distances to reach the nearest basic health units and then just be examined by a mere GP. The project will identify the most important issues in the design of a remote health care monitoring system and will develop a low cost solution, which will be provided to the lady health workers (LHWs) for this purpose.

The goal of the project is to design a generic remote health care system with a focus on antenatal care. Our aim is to use advancements in Information and Communication Technology (ICT) to develop a monitoring system that could enhance the quality of health care provided by the lady health workers. A direct consequence of this system in the long duration is to save lives of mother and child; reduction of Infant Mortality Ratio (IMR) and Maternal Mortality Ratio (MMR) is our end objective. This project is proposed inline with the Millennium Development Goals (MDGs)* planned by the United Nations Development Program (UNDP). The following two MDGs are targeted by this project:

- **MDG 4. Reduce child mortality**
  - *Indicator: Infant Mortality Ratio (IMR)*
  - *Target: Reduce by two thirds the mortality rate among children under five*

- **MDG 5. Improve maternal health**
  - *Indicator: Maternal Mortality Ratio (MMR)*
  - *Target: Reduce by three quarters the maternal mortality ratio*

(*) For details about United Nations’ Millennium Development Goals (MDGs), visit their website: http://www.undp.org/mdg/tracking_targetlist.shtml

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3. Research Approach

A. Literature Review Summary:
(Give a summary of your literature review in the proposed area.)

The field of telemedicine and remote patient monitoring is ‘hot’ both in the developed and developing world nowadays. A brief review of the past and current research work related to our project is given below.

**A Wireless PDA-Based Physiological Monitoring system for Patient Transport [1]**

This project proposes a mobile patient monitoring system, which integrates personal digital assistant (PDA) technology and wireless local area network (WLAN) technology. At the patient’s location, a wireless PDA-based monitor is used to acquire continuously the patient’s vital signs, including heart rate (HR), three-lead electrocardiography (ECG), and blood oxygen saturation (SpO2). Through the WLAN, the patient’s bio-signals can be transmitted in real-time to a remote central management unit, and authorized medical staff can access the data and the case history of the patient, either through the central management unit or the wireless devices. A prototype of this system has been developed and implemented. The results also show that the wireless PDA model is superior to the currently used monitors like Bluetooth etc both in mobility and in usability, and is, therefore, better suited to patient transport.

![Diagram](image.png)

**Fig. 1: Wireless PDA-Based Physiological Monitoring system [1]**

Fig. 1 shows the architecture of the project. The telemedicine system consists mainly of two parts—1) the mobile unit, which is set up around the patient to acquire the patient’s physiological data, and 2) the management unit, which enables the medical staff to tele-monitor the patient’s condition in real-time. The management unit is from either a fixed computer within an existing hospital network or a mobile laptop via WLAN.

The mobile unit in this project is comprised of a designed vital-sign signals acquisition module and a Pocket PC (HP iPAQ H5450). Multiple vital-sign parameters, which include the
three-lead Electro-Cardiograph (ECG), blood oxygen saturation (SpO2), and heart rate, can be measured by this unit. The management unit consists mainly of a fixed personal computer or a laptop, and the management program. The management unit can be installed in different systems depending on different applications of tele-monitoring. It is normally located in the nurse’s station and provides a user-friendly interface for tele-monitoring a patient’s vital-sign signals. The management terminal can receive patients’ physiological data from the remote mobile units via the WLAN or the Internet.

A prototype of this PDA-based telemedicine system has been designed and tested. For intra-hospital transport of critical patients, experienced senior staff can online monitor the patients and advise for unexpected condition, and thus, may prevent further deterioration of the patient condition. Under such circumstances, online monitoring or consultation is helpful. Therefore, the remote monitoring during transport would be beneficial for a better quality care of the patient.

In this project, a mobile patient monitoring system has been designed, developed, and tested. A pulse oximeter was integrated with a three-lead ECG monitor on a wireless PDA platform, which provides real-time and store-and-forward modes. The monitor in the new system has a significantly reduced size and weight, and thus, improves the portability of the monitoring device. Besides, WLAN also greatly increases the flexibility and usability for tele-monitoring. The clinical evaluation reveals that this mobile patient monitoring system is user-friendly, convenient, and feasible for patient transport.

**Article: Mobile Phones for Mother and Child Care (A case study of Egypt) by Patricia N. Mechael, i4d monthly digest, May 2005 [2]**

This article evaluates the strategy of using mobile phones as a tool for promoting maternal, newborn and child health (MNCH) in developing countries, using Egypt as a case study. The author notes that Egypt has a large number of mobile phone subscribers (8 million of the world’s 1.52 billion subscribers) and increased fixed line installations. Furthermore, Egypt has the health infrastructure to integrate technology to better respond to health needs.

The author suggests that Information and Communication Technology (ICT) can play a strategic role in providing child and maternal health care in developing countries like Egypt. ICT can be the impetus to meet the Millennium Development Goals planned by UNDP. The author goes on to suggest that the country’s (Egypt) citation by the World Health Organization (WHO)'s World Health Report 2005 as having made significant progress in addressing maternal and child health is mainly due to the increased availability and use of mobile phone services in the country.

The author has identified two direct benefits from the use of mobile phones in maternal and child care: reduced response time to obstetric emergencies through the use of mobile phones to contact formal and informal means of medical transport (leading to reduction in risk of complications and death during childbirth) and consultation between health professionals (e.g., between traditional birth attendants (“dayas”) and nurse mid-wives, and nurse mid-wives and physicians).

According to the author, the indirect benefits of extensive use of ICT are: increased ability for women to work outside of the home resulting in increased household income, savings in financial resources from transportation that is no longer necessary due to telephone access.
and increased education opportunities, particularly for young women.

The author concludes that "the impact of mobile phones on maternal, newborn, and child health in poor countries depends on whether it is achieved as a by-product of its general integration into society or through direct engagement."

Remote Patient Monitoring in China [3]

A low cost, real-time patient monitoring platform designed to improve the current medical services in China’s community healthcare system for the (Bottom of the Pyramid) BOP population is basically implemented through community and village doctors (C/VDs). In this project data is gathered by the sensor unit and transmitted to the server through a medical hub. The data is then stored in the server and displayed in the Medical Assistant’s (MA) system. C/VDs analyze the data with available functions and make the preliminary diagnosis while requesting assistance for remote consulting with specialists located in higher-tier hospitals.

This project is supported by Shanghai Leading Academic Discipline Project T0102. The current system is composed of three parts: the smart sensor unit, the server unit, and MA unit. Some vital-sign signals such as electrocardiogram (ECG), skin temperature (ST), pulses, and respiration are detected and acquired by sensors before being transmitted to the remote server unit located at higher-tier hospitals and viewed on the MA screen. Some user-friendly interfaces have also been designed for the easy use of C/VDs. Currently more than 1 million C/VDs, who mainly deal with the BOP population, are active all over China. These doctors, who have been given a basic medical training by the Chinese government, often offer people simple medical diagnosis and treatment. Due to their limited knowledge, they are not able to provide complete medical assistance to patients. The objective of the project is to design an affordable patient monitoring system for C/VDs that can gather real-time bio-signals; store, display, and analyze data and communicate information between servers and terminals. The C/VDs can use the system for on-the spot diagnosis as well as remote specialist consultations in higher-tier hospitals for further medication.

Overview of the system

This system is the initial design of an interactive medical monitoring system that aims to provide an end-to-end medical service at an affordable cost. In this system, the bio-measurements are delivered to a server by C/VDs. The MA can download data from the server and display the waveform through a Web browser. Functions in the browser help C/VDs to make an analysis. If desired, C/VDs also can derive additional information that may be required for diagnosis.

The C/VDs can operate this system easily through the user-friendly interface. They can observe the ECG, skin temperature, and pulse and respiration waveforms on the screen and make the preliminary diagnosis for further treatment. By clicking a button, these signals can be sent to the server in higher tier hospitals (through a medical hub) and C/VDs can ask for remote consultation from medical specialists. The medical specialists in higher-tier hospitals can easily access the medical information on a per-patient basis through the server. (e.g., ECG readings recorded by time). This system also provides real-time access to the patient’s bio-data.
Figure 2 shows the architecture of the implemented system. This system consists of three units:

- a smart sensor unit, which is worn on the patient’s body to register the required bio-data
- the server unit, which enables medical staff to remotely monitor a patient’s condition in real time through a computer within an existing network
- the MA unit, which allows C/VDs to access and query the medical bio-data, recorded in the server as well as for remote consultation by specialists.

**The sensor unit**
The designed sensor unit is composed of three modules: a vital-sign signals gathering module, a data-converter module, and a medical hub module. The vital signals such as ECG, temperature, and pulse and respiration can be gathered using smart sensors. The obtained analog vital-sign signals are amplified and filtered (especially 0.5–50 Hz for ECG signals) before being converted to digital format. The programmable integrated microchip PIC16F873 with a ten channel analog digital converter is connected to a transceiver chip. Four digitized source data are transferred serially to the medical hub, which is then transmitted to a receiver at 19.2 kb/s.

**The server unit**
The server unit consists of data processing software, a database, and a Web site. The data-processing software is developed based on the platform of C++, which can input or output data either automatically or on demand. One SQL 2000 database is created for storing data from the various monitored patients and guarantees the data integrity. The Web site, which was developed using ASP and PJAVA applet, displays all the necessary patient information including bio-data waveforms. The Web site can be accessed using any IE Explore viewer running on Microsoft Windows or Windows CE systems with a Java virtual machine (JVM).
Medical assistant unit

The connection between the MA unit and the server unit is based on browser/server architecture because many MA units would work in parallel. A WinCE.net-based tablet PC is chosen in this design as the MA unit hardware (size: 224 × 182 × 28 mm³; weight: 760 g) due to sufficient screen size for displaying data waveforms and the sufficient memory to install a CE database. A demo is designed using embedded visual C++ for storing data from the server. A user-friendly interface was designed by specially considering the level of computer knowledge and convenience of C/VDs.

The wireless connection between the server and MA units in this design was based on WLAN 2.4G (IEEE 802.11 b) with speeds up to 11 Mb/s. The transmission of data from the sensor unit to the server unit was tested using client/server architecture. At present, the transmission channel in the project is one way (from the sensor to the server) and the sensor unit serves as the client end. ECG signals have been gathered and compared with the standard data. To improve the current project Shanghai University, the Shanghai public health bureau, and local government are carrying out a pilot project. The local government has agreed to pay the expense of the proposal. The project is for examining functions of the designed system and will be done in JiaDing District, in rural Shanghai. Two or three community healthcare points (CHPs) will be chosen and the VDs will be trained.

But the system needs to be improved in several aspects before the system can be marketed. According to the initial estimation, at least US$25 per month is needed to support a working system, even though the system is free for patients but it is expensive to operate. Apart from this, technical improvements which are necessary before a product is made according to the design specifications, include the following:

- a) User-friendly interface for data communication.
- b) Medical information management.
- c) Medical information security.

Telemedicine in India

As far as telemedicine in India is concerned, two government institutions are taking the lead in the field. One is the Indian Space Research Organization (ISRO) and the other is the ministry of information technology. One of its departments at the ministry of communications and information technology launched a pilot project in 1999 named ‘development of telemedicine technology’ [4] with the objective of reinforcing the healthcare system of the country. Key specifications of the project included:

- To identify appropriate technological tools and services for implementing telemedicine technology at three premier tertiary level hospitals in the northern parts of India, namely the All Indian Institute of Medical sciences (AIIMS), New Delhi; the Post Graduate Institute of Medical Education and research (PGIMER) at Chandigarh and Sanjay Gandhi post graduate Institute of Medical Sciences (SGPGIMS) at Lucknow (Uttar Pradesh).
- To develop and carry out system integration to enable telemedicine technology for establishing telemedicine services (tele-consultation and tele-diagnostic facilities for the specialties of radiology, cardiology, pathology and tele-education) at three tertiary level hospitals.
• To train clinicians in the use of telemedicine technology.

In addition to this, ISRO plans to launch the statewide Orissa telemedicine network to provide physicians in this impoverished state with tele-consultation and education programs. The agency is also launching telemedicine projects in several other areas that have been particularly underserved by healthcare professionals: the Andaman & Nicobar islands, far to the east of India in the bay of Bengal; Lakhshdeep island, off the southwest coast; and the Leh mountain areas in the Himalaya range in the state of Jammu and Kashmir [5]. ISRO has also provided access to its V-SAT (very small aperture antenna) communications infrastructure. Apollo Hospitals’ new but small hospital, based in the village of Aragonda is one V-SAT user. The 40-bed hospital was newly built and equipped with modern computer tomography, ultrasound, echocardiography, automated laboratory equipment, incubators, and electrocardiogram equipment. A pediatrician and a general surgeon were made available in addition to general doctors. Using both store-and-forward and real-time technologies such as videoconferencing, some 200 tele-consultants have been provided to this village alone from specialists in Chennai. Data is managed through a locally developed software package, Mediscope. With the decision to provide space segment bandwidth without charge to the identified users to catalyze the telemedicine growth in the country, just the five nodes connected through INSAT satellite to a single super specialty hospital in the beginning has culminated into a one of the largest space based telemedicine network in the country which has since then grown to more than 60 nodes in which 45 remote rural district hospitals are connected to about 15 super specialty hospitals in different cities [6]. The SATCOM-based solution has been very successful in India because of its diverse topography and inadequate transportation and medical infrastructure in the remote regions of the country.

Centre for Development of Advanced Computing (C-DAC), Mohali, formerly known as Centre of Electronics Design and Technology of India (CEDTI), is a premier institute of the Ministry of Communications & Information Technology, Govt. of India, involved in the research, design, development and deployment of advanced information technology products and solutions. The centre also specializes in embedded & VLSI technology, bio-medical, electronics, telemedicine and entrepreneurship development. Centre for Development of Advance Computing is working in the field of telemedicine since 1999, and has successfully developed state-of-the-art telemedicine application packages namely, ‘Sanjeevani’ [7] and ‘e-Sanjeevani.’ As a pilot project (C-DAC) established telemedicine technology at six major locations in India. These locations were subsequently connected to nearby districts and primary health centers to make a telemedicine hub. The first endeavor was on establishing telemedicine sites at All India Institute of Medical Sciences, New Delhi, Post Graduate Institute of Medical Education and Research, Chandigarh and SGPGIMS, Lucknow. This has now been expanded in the second phase to connect three more medical colleges namely, Indra Gandhi Medical College Shimla, Medical College Rohtak and Medical College Cuttack. The telemedicine software package was developed in-house under the expert guidance of the doctors in these hospitals.

A pilot project on ‘Development of Telemedicine Technology and its Implementation’ was approved for implementation by the Department of Information Technology, Ministry of Communications and Information Technology, Govt. of India and it has been implemented over the ‘telemedicine network’ connecting PGIMER, Chandigarh, SGPGIMS, Lucknow and AIIMS, New Delhi on ISDN lines. The objectives of this pilot project are outlined below:
• To run and implement successfully the telemedicine technology over the telemedicine network, connecting the three locations at PGIMER, Chandigarh, AIIMS, New Delhi
and SGPGIMS, Lucknow.

- To establish a dedicated satellite communication facility using very small aperture terminal and thereby networking medical centers in northern part of peninsular India.
- To establish a telecommunication technology network which can provide a comprehensive range of high-quality health services to rural and remote areas in India.
- To purchase cost-effective hardware needed for transmitting data and images of adequate diagnostic quality.
- To enable well-established image & data archiving, printing for graphics, images and video data.
- To train the doctors and patients to use the telemedicine technologies effectively and optimally with a view to develop their faith and confidence in these technologies.
- Documenting the technology and extending it to specialty centers within India and worldwide.

Subsequently, the efforts are still underway to establish a number of telemedicine sites at different locations in the state of Himachal Pradesh, which is a remote and hilly state of India. C-DAC is also working on implementation of telemedicine technology in rural areas of Punjab and in Chandigarh [8].

Telemedicine in Himachal Pradesh

The project envisages the customized development of telemedicine application titled ‘Sanjeevani’ and its subsequent deployment in the rural areas. ‘Sanjeevani’ is an integrated telemedicine solution based on ‘Store & Forward’ concept of telemedicine. As many as 24 locations have been identified for deployment of the project. These locations vary from community/primary centers to civil/regional hospitals and IGMC, Shimla. The telemedicine application will comprise the basic tele-radiology, tele-pathology and tele-cardiology modules. This telemedicine application will deliver specialized healthcare to the patients of underserved rural areas of Himachal Pradesh at a very low cost.

At present, the position of healthcare in these rural areas is not good. The number of primary healthcare centers in the state of Himachal Pradesh is less and most of the medical infrastructure is not in the proximity to a large section of its population. In the rural areas of Himachal the large percentage of population suffers from curable diseases, but which remains untreated due to lack of resources. The application will enable the provision of specialized medical care, services and treatment to the patients in the far flung, remote and inaccessible areas of Himachal Pradesh. The objectives of the project are as follows:

- To develop a customized telemedicine application for the rural and remote areas of Himachal Pradesh in order to provide specialized medical care to the patients in a convenient but affordable manner. This will involve connecting the community health centers/primary health centers and block level/district level hospitals in the rural areas to IGMC, Shimla for an expert advice. As many as 14 such centers/hospitals are being connected in Phase I and rest will be connected in Phase II. The connectivity will be further extended to PGIMER, Chandigarh over the existing telemedicine linkage.
- To establish seamless connectivity over diverse communication environments in the state.
- To develop software interfaces with low cost medical diagnostic equipment so as to offer a very low cost telemedicine solution for rural areas.
- To introduce new software/hardware features in the existing telemedicine technology for developments not covered already.
- To give a boost to the production of low cost medical diagnostic equipments for
telemedicine technologies in India.

- To spread medical education among the medical professionals for their continuous education at a very low cost, even to far off places in rural areas.
- To develop it as a pilot project for subsequent implementation in all over India.

Telemedicine set up implementation at various health institutions in Himachal Pradesh will be based on the network that can be classified into the following categories:

**Phase I:** Installation of the identified equipment and to link two medical colleges in the state;
**Phase II:** Linking with all the identified hospitals;
**Phase III:** Integration with Hospital Information System (HIS)

Implementation of telemedicine application software ‘Sanjeevani’ in Himachal Pradesh will provide benefits to the population in the following ways:

- A best possible healthcare facility will be available to all of them.
- No unnecessarily movements of the patients to the specialty hospitals.
- Since majority of the potential population for this telemedicine application earns their livelihood through daily wages, they will not only be saving time, but also their hard-earned money, if they avail this facility.
- The cost involved in the treatment using telemedicine technology shall definitely be manifold less than the healthcare cost now being borne by this population.

**Telemedicine in Punjab**

The aim of this C-DAC project is to deploy the customized telemedicine application at a wider network, covering the rural areas of Punjab. The application will enable the provision of specialized medical care, services and treatment to the patients in the far flung, remote and inaccessible areas of Punjab, from where it is extremely difficult for the patients and their families to commute to the specialty hospitals. The browser-based telemedicine application named ‘e-Sanjeevani’ is an outcome of the advancement over the existing desktop application ‘Sanjeevani’. This telemedicine application will deliver specialized healthcare to the patients of underserved rural areas of Punjab at a very low cost. This package has been lab tested on LAN (10/100 Mbps) and is running on a public website named http://www.esanjeevani.in/. The main outcome of the project is to deploy ‘e-Sanjeevani’ in all the districts of Punjab but the intermediate output is to deploy and test it at as many as 20 locations, which have been identified in collaboration with Punjab Health Systems Corporation.

Deployment of ‘e-Sanjeevani’ will help the poor and needy living in remote and urban places where specialist doctors are not available. The deployment of this project by C-DAC, Mohali will effectively help the underserved and underprivileged community of Punjab. An interested reader will find more information about the telemedicine in India in [9] and [10].

**MobiHealth – innovative 2.5 / 3G mobile services and applications for healthcare**

*University of Twente - Center for Telematics and Information Technology – APS [11]*

The MobiHealth project addresses the problem of testing the 2.5 and 3G markets by developing new value-added services and applications in the area of mobile healthcare. On the one hand, 2.5 G networks are today underutilized due to the lack of innovative services. As a result, the deployment of 3G technologies risks being delayed and the advances and momentum gained in Europe in mobile services during the last few years is in danger of being lost. On the other hand, the health sector faces serious and increasing problems in the
management of resources for disease prevention, follow-up and remote assistance of patients. The citizen mobility at a pan-European level is increasing, with thousands of citizens crossing European country borders daily for purposes of entertainment, leisure, shopping and business. Thus, the introduction of new pan-European mobile health and Para-health personalized services, based on 2.5 and 3G technologies will provide new markets and opportunities allowing both citizens and the industry to profit from.

MobiHealth is opening up new application areas for 2.5 and 3G communication technologies, providing the possibility for key-actors (ranging from operators and Small/Medium Size Enterprises (SMEs) to service providers and hospitals) to gain experience with new mobile value-added services. MobiHealth aspires to create market demand for the new mobile health value-added services and applications, thus boosting the development, deployment and use of 2.5 and 3G communications.

MobiHealth represents the convergence of different technologies to enable personalized and mobile health services. On one hand, wearable devices for communication, vital constants measurement and even fitness applications are today commercially available at low prices. On the other hand, the notion and concepts of Body Area Networks are under development, targeting the problem of relaying signals from the multitude of wearable devices. The function of a BAN is to integrate all the wearable devices such as PDAs, mobile phones and watches that a person carries with him during the day. Furthermore, GPRS networks are available today in most European countries and provide a globally accessible and easy-to-use communication platform. The innovation of MobiHealth lies in one part in the integration of these three technologies in a flexible and generic system – the MobiHealth BAN – with the development of the required software that will provide an open platform for the creation of new, personalized services in the area of mobile health, and in the other part, in the introduction of a complete and integrated service platform that can be taken up by any Small/Medium Size Enterprise (SME) or service provider wishing to start up a new health related service.

The second part of the MobiHealth innovation lies in the actual services that are proposed. MobiHealth proposes new services that will allow the monitoring of vital constants for out of hospital patients. Moreover, MobiHealth improves current practice by allowing continuous monitoring of constants such as pulse rate, temperature, etc, whereas today, these measurements are sampled at intervals only. With continuous monitoring, the treating doctor will have timely information on the patients’ condition and will be able to provide better advice and suggest better treatment.

Finally, MobiHealth innovates by proposing and trialing other new services that can be implemented by SMEs based on existing technologies. The MobiHealth BAN, being generic, can be easily customized to provide services to the sports community, the medical research community, the study of causes of chronic diseases (e.g. asthma or epilepsy) and the detection and prevention of serious acute events (e.g. sudden infant death, stroke, etc.). GPRS networks are available in most European countries and different operators are setting up UMTS test sites. A study made by Ericsson Consulting indicates an enormous market and business potential for new health services based on wireless communications.

The studies for Germany, United Kingdom and France show that the number of individuals suffering from common chronic diseases (diabetes, asthma, stroke, hypertension and coronary artery disease) exceeds 50 million. Finally, the technological and medical risks of MobiHealth include radio interference or interference with medical equipment. The medical
risks may be the possible side effects that the new technology might introduce to the patients e.g. possible electromagnetic hazards associated with cell phone usage.

Remote Non-Intrusive Patient Monitoring  
University College Cork Ireland [12]

The Tyndall-DMS-Mote is a wireless sensor device that can monitor patients' vital signs non-intrusively within and outside their home. A patient’s real-time vital sign readings (dynamic data) and archived records (static data) need to be managed, correlated and analyzed in a cohesive manner to produce effective results. The Data Management System (DMS) has been developed to intelligently manage this data. Limited computation is available to clients executing on the sensor node. In this project, a Mobile-DMS-Client executes on a Nokia 9500 Communicator. This client complements the Tyndall-DMS-Mote in its ability to locally process large amounts of data thus reducing the need to communicate data to a remote server for computation. When external interaction is required e.g. to a knowledge base or a staff PDA, the DMS can supply information via a context aware agent middleware. Agents effectively encapsulate, extract and interpret real world context aware information ensuring that physicians get the "correct" data in real time round the clock. Patient vital sign readings are taken by Tyndall-DMS-Motes in a noninvasive non-intrusive manner.

Figure 3 shows the Mobile-DMS-Client and how it monitors an outpatient's blood pressure level in a non-intrusive non-invasive manner. Localized processing and sensing at the patient point of care provides a higher degree of monitoring as it reduces the need to interact with external information servers. An intelligent agent middleware (Jade) provides the context capabilities to function within a pervasive medical environment. Working alongside the agent platform is a rule-based system which triggers predefined actions based on a set of DMS
rules. An outline is given of the DMS blood pressure ontology model which enables semantic regions to be defined. This approach effectively correlates multiple data sources thus improving the quality of service (i.e. delivery of “correct” data).

**The Mobile Patient : Wireless Distributed sensor networks for patient care and monitoring by University of Notre dame, Brunel university, and university of Miami [13]**

In this project, the concept of a three layer distributed sensor network for patient monitoring and care is introduced. The envisioned network has a leaf node layer (consisting of patient sensors), an intermediate node layer, consisting of the supervisory processor residing with each patient, and the root node processor residing at a central monitoring facility.

The authors discuss the problems of bandwidth between the patient node and the root node, and the processing bottleneck of the root node. The main aim of the project is to give basic ideas about mainly solving these two bottlenecks. The authors also reviewed previous works on telemedicine using 2G networks, and they have shown that the bottleneck of battery life of the patient's node device etc. even exists in new 3G and 4G networks. Therefore, they have suggested assigning weights to the different patient nodes and their respective sensors. The fact is that when all sensors correspond with their respective patient nodes they can generate a significant amount of bursty data; therefore, it is imperative that different bottlenecks are dealt in an acceptable manner. The authors suggest that the root node with the doctor can assign weights to different patient nodes on the basis of their criticality and then the weights are also given to their sensors according to the fact that which particular sensors are important in a particular patient's case. In this project, a patient can be intelligently disconnected from the root node if he does not remain critical anymore and he can get the attention of the doctor's root node the moment he becomes critical again. The bit rates and bandwidths to a particular set of patient nodes are assigned keeping in view of their assigned weights.

![Three Level DSN](image)

The concept of wireless three-level DSN for patient monitoring and care is elaborated in Figure 4. The allocation of resources in such a network is a function of the critical state of
the patient i.e. bandwidth is distributed among nodes according to the critical state of a patient communicated between the top two layers and according to the sensors’ importance communicated between sensors and the patient’s supervisory node. Such a scheme minimizes not only the bandwidth requirements at the root node but it also optimally distributes bandwidth between sensors as well. Moreover, it improves the energy efficiency as well because of the importance oriented connect/disconnect mechanism between the patient and the root node.

**CodeBlue: An Ad Hoc Sensor Network Infrastructure for Emergency Medical Care**

Harvard and Boston university [14]

CodeBlue is a wireless infrastructure intended for deployment in emergency medical care that integrates low-power wireless vital signs sensors, PDAs, and PC-class systems. CodeBlue is intended to enhance first responders’ ability to assess the patients in the field, ensures seamless transfer of data among caregivers, and facilitates efficient allocation of hospital resources. The system is intended to scale to very dense networks with thousands of devices and it shall operate in extremely volatile network conditions. Therefore, the system demands an adhoc but reliable data delivery, a flexible naming and discovery scheme, and a decentralized security model.

CodeBlue is a wireless communication infrastructure for critical care environments. CodeBlue, as mentioned before, is designed to provide routing, naming, discovery, and security for wireless medical sensors, PDAs, PCs, and other devices that may be used to monitor and treat patients in a number of health care environments. It is designed to scale across a wide range of network densities, ranging from sparse clinic and hospital deployments to very dense, ad hoc deployments at a mass casualty site. CodeBlue utilizes a publish/subscribe model for data delivery, which allows sensing nodes to publish streams of vital signs, locations, and identities to those PDAs or PCs accessed by physicians and nurses can subscribe to. To avoid network congestion and information overload, CodeBlue supports filtration and aggregation of events as they flow through the network. For example, physicians may specify that they should receive a full stream of data from a particular patient, but only critical changes in the status for other patients under their treatment. The use of adhoc networking allows the “mesh” of connectivity to extend across an entire building or between multiple, adjacent facilities. Additional coverage, if necessary, is possible by placing the fixed nodes in hallways, rooms, or other areas. The system is self-organizing: loss of a given node or network can be rapidly detected and data is accordingly rerouted due to ever changing network topology.

CodeBlue is designed to provide reliable transmission of critical data through content-specific prioritization and dynamic scaling of the transmitter’s power. CodeBlue also supports a flexible security model allowing a range of policies to be implemented. For example, it is necessary that emergency medical technicians (EMTs) who require access to the patient’s data must be authenticated by the network before they are able to retrieve the patient’s information. One EMT must also be able to hand off access rights to another, when a new rescue team arrives on the scene of a disaster. Authentication must be performed transparently as the patient is transported from disaster site to a hospital, or transferred between hospitals. Access control must be decentralized to avoid reliance on a single authoritative system.
CodeBlue simplifies application development by providing a comprehensive infrastructure for connectivity of medical devices. In the hospital, data collected from wireless sensors can be relayed to fixed, wired terminals and integrated with the patient’s records in an existing hospital information system. At a mass casualty site, an ambulance-based system can record extensive data streams from each wireless sensor or PDA to support audits and billing.

Initial design of CodeBlue and prototypes of several of the sensors have been completed. The pulse oximetry mote has been completed and development of an ECG mote is currently underway. An adaptive spanning-tree multi-hop routing algorithm, based on the TinyOS Surge protocol has been explored, and dynamic transmission power scaling to minimize interference has been incorporated. A lightweight public key infrastructure based on elliptic curve cryptography is currently being investigated. A sophisticated programming model using abstract regions for routing, data sharing, and aggregation has also been developed by the CodeBlue team.

**An Advanced Wireless Sensor Network (WSN) for Health Monitoring**

*University of Virginia (UVA) [15]*

The authors propose new system architecture for smart healthcare on the basis of Wireless Sensor Network (WSN) topology. It specifically targets aging assisted-living residents and others who may benefit from continuous, remote health monitoring. The project shows the advantages, objectives, and status of the design. An experimental living space has been constructed at the Department of Computer Science at UVA for evaluation of this project. Early results have suggested a strong potential for WSNs to open new research perspectives for low-cost, ad hoc deployment of multimodal sensors for an improved quality of medical care. While preserving resident comfort and privacy, the network manages a continuous medical history. Unobtrusive area and environmental sensors combine with wearable interactive devices to evaluate the health of spaces and the people who inhabit them. Authorized care providers may monitor residents’ health and life habits and can also watch for chronic pathologies. Multiple patients and their resident family members as well as visitors are differentiated for sensing tasks and access privileges. As the devices preferred
are mostly the ones which have minimal user input, so the system is in itself portable and unobtrusive. Due to wireless nature it is easy to deploy. The system is scalable, always on, reconfigurable and self organizing. The architecture is multi-tiered, with heterogeneous devices ranging from lightweight sensors to mobile components. It also incorporates powerful devices such as a MicaZ device from Crossbow (http://www.xbow.com/) and an environmental sensor board mounted on it.

![Diagram](image)

**Fig. 6** : Current configuration of the medical test-bed [15]

The medical sensor network system integrates heterogeneous devices, some of them are wearable on the patient and some placed inside the living space. Together they inform the healthcare provider about the health status of the resident. Data is collected, aggregated, pre-processed, stored, and acted upon using a variety of sensors and devices in the architecture. Multiple body networks may be present in a single system. Traditional healthcare provider networks may connect to the system by a gateway, or directly to its database. Some elements of the network are mobile while others are stationary. Some can use line power but others depend on batteries. If any fixed computing or communications infrastructure is present it can be used, but the system can be deployed into existing structures without retrofitting.

Currently the project is acquiring data through some motion sensors, some wearable sensors like accelerometers and GPS. The GPS data is used to reconstruct past activities and movement locations. There are temperature and humidity sensors for measuring habitat conditions. While a bed sensor and a pulse oximetry and EKG gives different parameters like breathing rate, heart rate, agitation, heart beat events, oxygen saturation and electrocardiogram. Stargate is used in backbone infrastructure MYSQL for data base management and PDA for end user GUI. A first experiment based on seven MicaZ motes, programmed to send motion events over the network containing the location of the user, was performed with no activity in the lab for one week. No false detections in the system were observed under these conditions. However, this experiment showed the necessity of enhancing the power management scheme to prolong the lifetime of the sensors. In another experiment, the supervision program located at the control station correctly displays the location of a mobile resident by polling the MySQL database for motion events.
A Distributed Bayesian Framework For Body Sensor Networks

Imperial College London [16]

Due to the dynamic nature of Body Sensor Networks (BSNs), both sensor nodes and communication links are prone to noise interference and failure. This makes integration of multi-sensory data for BSNs a significant technical challenge. This project demonstrates that distributed processing and inference with BNs is effective for BSNs. The structure of the network with hidden nodes enables the computations to be distributed and is ideal for utilizing the resource in a multi-hop network structure. The experimental results have shown that hidden node can effectively make use of intrinsic redundancy within the subnet to filter out unreliable information to maintain accuracy. In some previous work, Paskin and Guestrain [17] illustrated the use of message passing in distributed sensing systems by proposing a robust message passing algorithm which can be used for inference in a junction tree representation of a multiple connected BN. The hidden node insertion adopted by the authors is another way of transforming a multiple connected network into a single connected network, allowing simple Pearl’s message propagation algorithm to be used for model inference [18].

Confidence-based Data Management for Personal Area Sensor Networks

Brown university and U.S. Army Research Institute of Environmental Medicine [19]

This project is primarily a military project exploring the idea of embedding the sensor networks in the military uniform for soldiers thus measuring their body responses in different types of war theatres and conditions. The idea is to save the lives of the soldiers in harsh weather conditions both in war/peace operations. The “smart uniform” is the uniform that will monitor key biological parameters to determine the physiological status of a soldier. A soldier’s status can be determined accurately by combining the readings from several sensors using sophisticated physiological models. But, the physical environment and the low-bandwidth push-based personal-area network (PAN), introduce uncertainty in the inputs to the models. Thus the model must produce a confidence level as well as a physiological status value. This project explores how confidence levels can be used to influence data management decisions. In particular, it discusses the power-efficient methodologies to keep the confidence above a given threshold value. The authors contrast push-based broadcast schedules with other schedules that are made possible by the 2-way communication. Using confidence based data management, techniques have been discussed for optimizing the trade off between improved latency and power wastage due to the increased collision. These techniques are adjusting the sampling rates of the sensors for an optimized performance, introducing bi-directional communication in sensors and by exploiting the concept of redundancy at several levels to increase certainty of physiologic states.

Improving Patient Monitoring And Tracking In Emergency Response

The Johns Hopkins University Applied Physics Laboratory And Division Of Engineering And Applied Sciences, Harvard University, MA, USA [20]

The Advanced Health and Disaster Aid Network (AID-N), being developed at Applied Physics Laboratory of The Johns Hopkins University, explores and shows different cases in which the recent advances in wireless networking, medical sensors, and interoperability software can be employed to assist victims and responders in times of emergency.

The AID-N system has a great potential for improving today’s emergency response system,
especially in the disaster scenarios in which one has to respond to the mass casualty. This project has been built through extensive collaboration with medical professionals to develop a prototype to meet their needs. The key processes that could be improved using this technology are: patient monitoring, record generation and remote record review. AID-N has constructed hardware and software prototypes to address these areas and shows the potential of improving the efficiency of emergency personnel for these activities. Due to the chaotic nature of emergencies, this system faces the challenge of operating in difficult situations but most of the instruments are designed to be used in the controlled environment of a clinic. For example, the pulse oximeter sensor used by AID-N cannot function on patients with finger nail polish. In cold temperatures and/or high altitudes, the body responds through vasoconstriction in the peripherals, as a result, blood flow to the fingers is restricted and does not register accurately on the pulse oximeter. This patient monitoring feature will not be useful in all situations. In a mass casualty disaster, when the medics must triage many casualties quickly, they will not have the time to respond to alerts until all patients have been triaged. Medics expect the monitoring system to be most useful for patients who have been triaged and are waiting for ambulances. They can then use this system to prioritize the patients who need to be transported with the help of an ambulance to the hospitals.

This project is basically designed for dealing with situations of emergency. The authors also give the implementation details of the project. The project uses the wearable sensors of code blue project. The transmission between the responder’s tablet device and the mote utilizes MICAZ. The wearable sensors with pre-hospital patient care software were integrated by using the software (MICHAELS) created by the OPTIMUS Corporation. MICHAELS runs on the first responder’s tablet PC. In this implementation, Verizon’s EVDO coverage in the Washington, D.C., Metropolitan Area is used to transmit data to a central server on the network. The tablet PCs use EVDO wireless cards to obtain the network connectivity at high data rates from anywhere in the greater Washington area. Software on the tablet device receives live patient data from the mote and processes them to detect anomalies. A monitoring algorithm for vital signs has also been incorporated. The algorithm uses additional information such as the patient’s age, disease state (e.g., fever, congenital heart failure, and anemia), smoking history, and the environment (e.g., altitude) to adjust its thresholds for raising alarms. If additional information is not available, the algorithm uses a set of default values. This research is supported by National Library of Medicine USA.

Self-Powered Wireless Sensor Networks for Remote Patient Monitoring in Hospitals
Erik Jonsson School of Engineering and Computer Science, University of Texas [21]

This system allows health personnel to monitor a patient’s BP and heart-rate vital signs from a remote location without requiring the physician to be physically present to take the measurements. The system concept can be used for routing vital sign information to a central location within the hospital premises as well as to applications that require monitoring from within a patient’s home. The present design is modular in nature wherein every route point uses two router nodes that are self-powered drawing power from solar panels located close to overhead 34W fluorescent lights. Each node in a router pair operates at a 50% duty cycle which provides 100% availability at each route point. The router nodes utilize an intelligent power management strategy that minimizes the solar panel requirement and overall cost and size of the node. Initial tests have shown that it is possible to route a patient’s BP and heart-rate data to a central monitoring station within the hospital premises using real WSNs. Specific technical requirements in terms of the kinds of vital sign sensors to be used, how often to sample data, data transfer rates, network layout etc. are still being
investigated in the project. These requirements will be hospital specific based on the preliminary experiments and hospital requirements.

Fig. 7: Network structure [21]

Presently, the project group is looking into the layout of one floor of the Erik Jonsson School of Engineering and Computer Science at the University of Texas at Dallas. Router pairs will be placed every ten meters at different strategic locations to facilitate multi-hop routing. Tests are being done by the group to document the network capabilities and limitations such as the maximum allowable data traffic, the router nodes that can handle maximum data traffic, and techniques to distribute the traffic accordingly. These tests, in turn, will help to document the network's limitations and calculate how often to sample vital sign data before routing it through the network. Later, tests are planned to be conducted within a hospital environment to determine the rate of the packet loss. The present system uses a readily available commercial BPM monitor to acquire the patient's data. Also, the feasibility of designing a basic location algorithm, based on the fixed hospital router infrastructure to track a patient's movement is being investigated.

The system is based on sensors transmitting data to different MICAZ boards. These MICAZ boards have a range of 10-20 meter, therefore, a number of boards or motes can be present in a particular environment. As these boards transmit data among themselves and then it finally reach the main board, therefore it is very important to have adhoc routing in such a network because any node that collapses is detected and routing is done to create new paths from destination to the source (patient). The problem of power consumption is solved by the solar cells. Basically this system is designed for deployment in a fixed environment such as a hospital environment where many sensors are placed and then the routing network is created among the nodes.
Conclusion:

The field of telemedicine has seen a tremendous technical development in the developed countries. Sustained efforts are also underway in the developing countries like China, Egypt and India in this field. Though a lot of work has been done in different avenues of Telemedicine [22]-[42] like wireless transmission, video conferencing between patients and doctors, development of special wireless sensors and wearable sensors. However, little research is done in developing a low cost remote patient monitoring system that can be of significant value in providing basic health services to the patients at their doorsteps.

Taking all these factors into consideration, we suggest that it is the right time for the development of an indigenous remote patient monitoring system. Even if any of the above mentioned projects (e.g. CodeBlue) is completed before our project, it will be proprietary and thus very expensive for a developing country like Pakistan to purchase. Moreover, the social and cultural aspects of Pakistani society, especially those living in remote villages, are completely different from a western society. The success of a social project like this depends upon the efforts spent on overcoming these social barriers. The indigenous development will also lead to the grooming of experts in this field and thus reliance on foreign experts will diminish slowly and gradually. This will create a critical mass of Bio-medical researchers in the country that is necessary to develop even more challenging projects in future.

References:


2. P.N. Michael: Mobile Phones for Mother and Child Care (Case Study of Egypt), London School of Hygiene and Tropical Medicine, UK May 2005 (Article in: i4d monthly digest, May 2005)


B. Development / Research Methodology:

(Please describe the technical details and justification of your development and research plan.)

The research methodology of this project has been developed through extensive 'brainstorming' procedure and we propose following conceptual block diagram for the purpose of the reader's understanding.

Fig. 1: Brainstorming diagram to develop research methodology
1. Introduction

The primary objective of this project is to create an automated patient monitoring system for the antenatal care of women in remote areas. Presently, the antenatal care is being provided by little-educated lady health visitors who perform all the steps of patient care manually. They take readings of patient’s physiological data using instruments which are difficult to handle and require manual tuning etc. Then, they record this data into printed forms manually. Finally, the collected forms are sent to a doctor who goes through all of them looking for any symptom of abnormality. The doctor then takes decision regarding the patient’s treatment.

The automated system that will replace all this hectic activity at least should be able to gather this physiological data, transmit it, record it, find any abnormality and then assist the doctor in the decision making process.

2. System Requirements

The design of a system is determined by the requirements of the potential users of that system. Due to the diverse types and characteristics of possible measurements and various application scenarios, there are many different requirements imposed on telemedicine and remote monitoring systems.

We can divide these requirements into two categories: requirements due to mode of monitoring; and requirements due to the type of physiological measurements/symptoms that need to be monitored.

2.1. Mode of Monitoring

The mode of monitoring of patient is determined by the nature and seriousness of disease. A normal patient under observation may need to be monitored only at periodic intervals; whereas a critical patient must be under constant monitoring.

Remote monitoring systems can, in general, be divided into two basic modes of operations: periodic checkups mode and continuous monitoring mode.

2.1.1. Periodic Checkups Mode

A typical patient under normal circumstances can be monitored at periodic intervals. The periodic checkups will be performed by the lady health worker. In this mode, it is rather easy to establish a reliable and error-free communication channel that can preserve all relevant characteristics of the transferred medical signals, regardless of the communication service used (TCP/IP connection, mobile services like SMS/MMS etc.).

2.1.2. Continuous Monitoring mode

Continuous monitoring mode is required for critical patients. In this mode, the patient’s physiological data is under constant surveillance. However, the doctors suggest that the patients in critical condition should be admitted to the hospital instead of being provided with remote monitoring. This mode is particularly useful in emergency scenarios.
2.2. Type of data to be monitored

Depending upon the type of measurements, the requirements for the continuous monitoring mode can be more or less stringent. Different measurements result in different amount of data with different intervals. This results in a variety of bit-rate requirements that must be handled by the remote monitoring system. The design of the system must carefully take into account the maximum bit-rate required. The increasing bit-rate corresponds to an increase in energy expenditure as well. Below are some examples of different bit-rate requirements for different types of measurements.

2.2.1. Very low bit-rate data

Information about the blood pressure can be properly presented if sampled once every minute which, using 16 bits per sample, gives throughput of 0.3 bit/s.

2.2.2. Low bit-rate data

ECG signal requires at least three leads, 200 samples per second and at least 8 bits per sample. In this case the required throughput is 4800 bit/s, but it can be reduced to 600 bit/s using data compression techniques.

2.2.3. Medium bit-rate data

If full 12 leads’ ECG is required, then required throughputs for uncompressed and compressed data are 19200 bit/s and 2400 bit/s respectively.

2.2.4. High bit-rate data

Diagnostic audio signal requires between 32 and 768 kbps.

2.2.5. Very high bit-rate data

Diagnostic video stream can require up to 15 Mbps.

2.3. System requirements for this project

The key physiological parameters that must be measured for antenatal care range from very low bit-rate data to medium bit-rate data. Moreover the antenatal patients usually do not require constant monitoring. Instead, only periodic checkups can suffice to identify any complications before they arise. A patient that needs to be constantly monitored should be admitted to the hospital. Keeping these system requirements in view, the system shall be developed for periodic checkups mode for patient monitoring.

3. Infrastructure Development

We propose an automated remote patient monitoring system that would be easy to use, would enable accurate readings of patient’s data, keep electronic record of patient’s current and previous health situation and provide instantaneous abnormality detection in the
patient’s data. The proposed system would improve the efficiency and quality of service provided by lady health workers. The envisioned concept provides the individual patient with improved mobility and allows him/her to roam freely outside of treatment centers, thus facilitating him/her to do his/her daily work.

The detailed infrastructure of the remote patient monitoring system is described below.

3.1. Basic Model

The basic model consists of a data gathering module, a PDA, a remote server providing Clinical Decision Support System (described later) and electronic medical record keeping, and any web-enabled remote terminal (e.g. doctor’s laptop) which could be used to access services provided by the web-server.

The working of this basic model is as follows. The lady health worker is required to attach the data gathering module to the patient’s body using wearable straps etc. provided with the module. The module (consisting of medical sensors) will record the patient’s data and forward it to the PDA through a wired channel (e.g. USB or serial port). The PDA will contain an application for local monitoring of patient’s data that would display the current readings. When all the readings have been taken, the PDA will connect to a remote server and transfer the data to it. The remote server will process the data, invoke the Clinical Decision Support System to perform analysis of data, invoke the Electronic Medical Record service to record the readings in the patient’s history and provide feedback to the PDA screen notifying the decision given by the Clinical Decision Support System.

This model is realized by using intelligent wearable medical sensors controlled by a data gathering module. The sensor nodes are attached to the bodies of the patient and provide medical information to the data gathering module’s processor. The data gathering module is connected to the PDA through USB or serial port. The PDA is carried by the lady health visitor. It collects and forwards the data observed at sensors attached to the patient’s body to the main server typically located at a tertiary health care center. The communication between PDA and the main server is done through TCP/IP, GPRS or SMS/MMS (whichever is
available in the area or the least costly in case of multiple services availability).

3.2. **Architecture**

The proposed architecture for data gathering and transmission is described below. It has been divided into two parts: hardware and software.

3.2.1. **Hardware**

3.2.1.1. **Data Gathering Module**

Data gathering module consists of a central microprocessor controlling the operation of a number of medical sensor modules. The central microprocessor gathers data from the sensors and passes it on to the PDA through a serial to USB interface. The design of medical sensor modules is discussed below.

3.2.1.1.1. **Medical Sensor Modules**

The sensor modules are to be used for gathering physiological data from the patient. The design of these modules is determined by the type of measurement required. A typical module consists of electrodes, protection circuitry, signal sampling, filtering, amplifying and preprocessing blocks and an output interface which is usually an analog-to-digital converter (ADC). In some cases, temporary storage buffer space is also required.

The typical measurements made by sensor modules include Electro-Cardiograph (ECG), Electroencephalogram (EEG), blood pressure, blood oxygenation, breathing, heart rate, body temperature and many more. Some of these modules have been developed in different research institutes across the world. For use in this project, we will use some of the existing modules, while some new modules will be built if there are no existing modules for the specific measurement or the existing modules are inconvenient for integration in small, wearable sensors.

The design of these modules has three necessary restrictions: small size (for ease in mobility), low energy expenditure (to enhance the battery lifetime) and most importantly safety for patient (i.e. no harmful radiations etc.).

![Fig. 3: A typical biosensor](image)

A device which converts one form of energy to another is a transducer while sensor is a special kind of transducer which takes in Physical parameters and gives Electrical Output.
Biosensors produce an output (electrical) which is proportional to the concentration of biological analytes. We have biosensors based on bio-potentials and different blood levels regarding oxygen, pH and pCO2 to measure vast range of body parameters. Bio-potentials arise from cells, and more generally from organs. They hold rich physiological and clinical information. For example, action potentials give information on fundamental ion channel biophysics and molecular aspects of any pathology.

There are some electrochemical sensors such as Potentiometric, Amperometric, FET based and Conductometric. These sensors are neurochemical sensors for dopamine, nitric oxide etc. A number of optical sensors are used in Pulse Oximetry and obviously some thermal sensors are used in implanted rectal or intestinal probes. Some of the bio-sensing principles are given below and they are used for different kinds of parameter sensing.

<table>
<thead>
<tr>
<th>Analyte</th>
<th>Method of assay</th>
</tr>
</thead>
<tbody>
<tr>
<td>Glucose</td>
<td>Amperometric biosensor</td>
</tr>
<tr>
<td>Urea</td>
<td>Potentiometric biosensor</td>
</tr>
<tr>
<td>Lactate</td>
<td>Amperometric biosensor</td>
</tr>
<tr>
<td>Hepatitis B</td>
<td>Chemiluminescent immunoassay</td>
</tr>
<tr>
<td>Candida albicans</td>
<td>Piezo-electric immunoassay</td>
</tr>
<tr>
<td>Cholesterol</td>
<td>Amperometric biosensor</td>
</tr>
<tr>
<td>Penicillins</td>
<td>Potentiometric biosensor</td>
</tr>
<tr>
<td>Sodium</td>
<td>Glass ion-selective electrode</td>
</tr>
<tr>
<td>Potassium</td>
<td>Ion-exchange-selective electrode</td>
</tr>
<tr>
<td>Calcium</td>
<td>Ionophore ion-selective electrode</td>
</tr>
<tr>
<td>Oxygen</td>
<td>Fluorescent quenching sensor</td>
</tr>
<tr>
<td>pH</td>
<td>Glass ion-selective electrode</td>
</tr>
</tbody>
</table>

(Source: Lecture slides taken from http://www.jhu.edu/nthakor/teaching/prt/Lecture%206_Sensors_Ch_2.ppt)

A brief overview of the types of sensors are given below:

- **Electrochemical sensors**: These sensors are of three types: Potentiometric sensors, Amperometric sensors and Conductometric sensors.
  - Potentiometric Sensors: These involve the measurement of the emf (potential) of a cell at zero current. The emf is proportional to the logarithm of the concentration of the substance being determined.
  - Amperometric Sensors: An increasing (decreasing) potential is applied to the cell until oxidation (reduction) of the substance to be analyzed occurs and there is a sharp rise (fall) in the current to give a peak current. The height of the peak current is directly proportional to the concentration of the electroactive material. If the appropriate oxidation (reduction) potential is known, one may step the potential directly to that value and observe the current.
  - Conductometric: Most reactions involve a change in the composition of the solution. This will normally result in a change in the electrical conductivity of the solution, which can be measured electrically.
- **Blood Gas Measurement**: It involves fast and accurate measurements of the blood levels of the partial pressures of oxygen (pO2), carbon dioxide (pCO2) as well as the concentration of hydrogen ions (pH) which are vital in diagnosis. Oxygen is measured indirectly as a percentage of Haemoglobin which is combined with oxygen (sO2).

\[ sO_2 = \frac{[HbO_2]}{[Hb]} \times 100 \]

We have pH, pO2, and pCO2 electrodes to measure these parameters.

- **Optical Biosensors**: They link changes in light intensity to changes in mass or concentration, hence, fluorescent or colorimetric molecules must be present. Various principles and methods are used: Optical fibres, surface plasmon resonance, Absorbance, Luminescence. Infrared spectroscopy is given on the right so that the working principle can be easily understood. In Absorbance and Fluorescence, we have different dyes which change color according to different levels of pH etc. The pulse oximeter is a spectro-photometric device that detects and calculates the differential absorption of light by oxygenated and reduced hemoglobin to get sO2. A light source and a photodetector are contained within an ear or finger probe for easy application.

- **Glucose sensors**: They make use of catalytic (enzymatic) oxidation of glucose. The setup contains an enzyme electrode and an oxygen electrode and the difference in the readings indicates the glucose level. Affinity approach is based on the immobilized competitive binding of a particular metabolite (glucose) and its associated fluorescent label with receptor sites specific to the metabolite (glucose) and the labeled ligand. This change in light intensity is then picked up.
The sensors which we would apply will be based on the same principles we have seen above and more like piezoelectric sensors and MEMS etc. We will use some of the sensors and electrodes from foreign companies like Vermed Inc, and then incorporate extra range in some of the sensors. Otherwise the sensors used in the code blue project of Harvard can also be purchased. So in this way some of the already built sensors and some which we will produce will be used to measure important vital signs of the patients.

### 3.2.1.1.2. Proposed Medical Sensor Modules

The consultant gynecologist in our team has suggested that the major causes of maternal death are hypertension and anemia. For antenatal care, we propose to develop sensors for measuring following signals:

- Pulse
- Blood Pressure
- Temperature
- Heart Beat
- Hemoglobin
- Albumin
- Blood Sugar

Apart from these sensor modules, extensive medical tests requiring specialized medical equipment and operators (e.g. CTG of fetus, ultrasound etc.) will be carried out in hospital when suggested by the doctor in his/her feedback to the lady health worker.

### 3.2.1.2. PDA for Lady Health Worker

To take readings of patient’s data, the lady health visitor attaches the medical sensor modules to the patient’s body, and connects the data gathering module to the PDA through the USB cable. The PDA sets up communication with the data gathering module through a device driver. It transmits this data to the hospital’s main server and displays feedback received from the hospital’s server. A software abstraction layer will be provided to ease the process of development of local application as well as interaction with the main server at
hospital through wide area wireless medium (GPRS).

### 3.2.1.3. Reliable Communication Infrastructure

An error free and reliable communication infrastructure is needed for transmission of data from the PDA, carried by lady health worker, to the main server in hospital and reception of feedback containing medical diagnosis from the server to the PDA. GPRS will be used as it is provided by almost all mobile phone companies. The communication infrastructure will be able to communicate on more than one mobile phone services. The system will switch to the service available in the region. We plan to introduce satellite connectivity to the system for use in areas where no other service coverage is available. Error free communication will be ensured by using prevailing error detection and correction algorithms.

The records of all transmitted data will be kept for retransmission and comparison purpose. Moreover, if the transmission fails due to unavailability of the mobile service coverage in an area, the data will be transmitted as soon as the service becomes available. No intervention will be required from the LHW for the repeated transmissions.

### 3.2.1.4. Main Server at hospital

The main server located at a teaching hospital will act as the brain of the whole system. This server will receive different patients’ data from the PDAs carried by the lady health workers. The server will analyze the data for the abnormalities using the clinical decision support system. The server will record the data into the patient’s database using electronic medical record system. The feedback based on the clinical decision support system’s analysis will be sent to the consultant doctor’s laptop/PDA for approval/confirmation. The doctor’s advice and instructions for the patient will be forwarded to the PDA of the lady health workers. However, the interaction does not need to be synchronous in real time. The server will also serve requests for reports based on the patient’s data and individual patient records requests from the concerned clients. The automated services provided by the server will reduce the workload of doctors and other hospital staff and increase their efficiency.

### 3.2.1.5. Patient Identification System

As the purpose of this whole system is to automate the process of antenatal checkups and reduce the interventions of lady health workers to a minimum, the identification of patients shall also be automated. Identity cards using smart card technology shall be issued for each patient. These cards will contain the personal details, medical history record and unique identifier for each patient. The lady health worker shall swap the card through a card reader attached to the PDA and the patient’s data will be automatically read and loaded in the application. This data will be sent along with the medical data obtained by the sensors.

### 3.2.2. Software

#### 3.2.2.1. Data Gathering Module

The microprocessor in the data gathering module will be programmed to perform the following functions. On startup, it initiates and checks the status of the sensor modules attached to it. The communication with PDA is setup by initializing the USB to serial controller. After this, the microcontroller waits for a request of data from application layer of
PDA. In response, it transmits the requested data to the PDA. On termination of USB connection, the microcontroller shuts down the sensor modules. The microcontroller is also capable of changing the configurable parameters of certain sensors on request from the PDA.

3.2.2.2. PDA

The PDA carried by the lady health worker acts as a base station for transmission of patient’s data to the main server in the hospital. Its software part consists of a device driver for detecting and handling data gathering layer, and a local application interface which displays the gathered data for local monitoring and sends it to the main server for medical analysis. The feedback from server is displayed on the PDA. The PDA also provides an interface for entering patient’s data manually or reading it automatically using the patient identification system.

The PDA will also store automatically scheduled tasks for the lady health worker, making it easier for her to keep track of her duties. These tasks could be updated remotely by doctor from the hospital to give advice for a particular patient. Thus, the efficiency of lady health workers will be increased as their schedules will be automated and updated from a central office.

An abstraction layer will be developed for handling the device setup and control of data gathering module. The abstraction layer on the PDA will hide the device setup of data gathering module and other hardware specifics from the application level. It will provide simple API calls which will make the job of application development easy.

3.2.2.3. Web server Architecture

The main server in the hospital will run a web server to provide the services of clinical decision support system and electronic medical record system to the requests from the PDAs carried by the lady health workers. The web server will also provide a webpage allowing the user to upload the recorded data in the form of a file. This data will be incorporated in the database like normal records. The web server will also handle requests from the doctor’s terminal and provide reports about the patients’ situation. The web server will mainly consist of a dynamic webpage server, a database server and dynamically linked libraries (dlls) implementing the clinical decision support system. The dynamic page server will serve pages written using a server side scripting language like PHP or VB. The database server will be used to link the incoming data to the patient’s record. This will be accomplished using electronic medical record system. The clinical decision support system will provide automated analysis of data and assist the doctor in the decision making process. It will also provide to the lady health workers with the doctor’s advice regarding each patient.

4. Application

The need of an automated analysis, decision and response in case of emergency leads us to the inclusion of a clinical decision support system. As the end users of this system are humans, a user-friendly interface must be provided. This interface is required at three points in the proposed architecture: a local application at PDA, an interface for the medical staff to register a new patient and an application for the doctor’s workstation.
4.1. **Clinical Decision Support System (CDSS)**

A clinical decision support system (CDSS) is a computerized program which analyses the patient's physiological data (e.g. ECG, Heart beat, body temperature etc.) in order to find out symptoms of any abnormality. These symptoms are used by the CDSS to estimate the current health situation of the patient. The decision support system is also capable of making decisions based on the diagnosis of estimated health situation.

In the architecture under discussion, we propose to create a hybrid of model-driven decision support system and knowledge-driven decision support system. Model-driven decision support system makes decisions based on the statistical model of the patient's data. Knowledge-driven decision support system provides specialized problem solving expertise stored as facts, rules, procedures, or in similar structures. A hybrid system will augment the knowledge base with the statistical model to make an improved decision. Thus, the resulting system will be less vulnerable to ‘false alarms’.

A decision support system (DSS) can be ‘passive’ (only makes suggestions for diagnosis), ‘active’ (formulates diagnosis and takes decisions) or ‘cooperative’ (formulates a diagnosis but it needs to be verified by a consultant). We propose a cooperative DSS which will reach the diagnosis through this hybrid decision making model. Then, it will present the diagnosis as well as proposed decisions/actions to the medical consultant who will verify the situation and decide whether or not the alarm is true.

There are many open-source as well as commercial clinical decision support systems available in the market. The open source decision support systems will be preferable to proprietary systems. Among the open source systems under consideration, EGADSS (Evidence based Guideline And Decision Support System - http://egadss.sourceforge.net/) and CARE2X (CARE2007 - http://www.care2x.org/) are the potential candidates. The components from these open source decision support systems shall be modified according to the requirements of the project. These modified components will provide basis for development of our CDSS.

The proposed CDSS consists of four major components: (a) the data management system, (b) the model management system, (c) the knowledge engine, and (d) the user interface.

[Fig. 6 : Clinical decision support system model]
4.1.1. The Data Management System

The data management system is an important part of the CDSS. It consists mainly of a database system used to store the patient’s physiological data so as to retrieve it when required. The database can be created using any specialized open source or commercial database system available in the market. The data can be retrieved using SQL queries to the database.

4.1.2. The Model Management System

The Model management system is the brain of the CDSS. It is responsible for creating a health model and comparing the data in the database with the model to formulate a diagnosis. It works in conjunction with the knowledge engine to diagnose the patient and to take decisions.

4.1.3. The Knowledge Engine

The Knowledge Engine contains the facts, rules, structures and procedures which are based on expert knowledge. Simply stated, it is a rule base which contains the decision making rules based on the previous experiences and the expertise of the physicians. The structural development and accuracy of the rules contained in the knowledge engine determine the accuracy of the diagnosis made by the CDSS.

4.1.4. The User Interface

The interaction of CDSS with physicians is only possible through a user interface. The user interface allows the medical consultant to verify the correctness of the diagnosis and decisions of the CDSS. It also lets the consultant change its settings etc. A detailed interaction interface is discussed in the section 4.5.

4.2. Electronic Medical Record System (EMR)

An Electronic Medical Record (EMR) system keeps track of patient's medical history and assists in the report creation process. Integrated with clinical decision support system, it provides initial data (previous medical record of concerned patent) to the CDSS for comparison with current data. EMR stores the new data as well as the results of the analysis performed by CDSS. An EMR, specifically designed for antenatal care will be implemented for this purpose.

4.3. Local Monitoring Application

The local application at PDA will focus on displaying the patient’s information for local monitoring. As the system is to be used by not-so-well-educated lady health workers, the information will be displayed in a simplistic manner so as to minimize the level of training required to operate the application. The application will also provide a configuration panel to adjust settings for connection to remote server located at the hospital. The application will also provide necessary controls to adjust the parameters of certain sensors. This application will be based on the APIs already developed in the abstraction layer of the PDA's software. Along with the display of data, this application will also notify the user with the help of alarms in case any measurement goes out of its normal bounds. The application will notify the user if some sensor is not responding for some time. For transfer to remote server, this
application will also provide some data compression techniques. This will help in reducing
the payload of the information sent to the remote server. The communication with the remote
server will be made secure by using state of the art cryptographic techniques.

The local monitoring application will also provide the lady health worker with an editable field
to enter the verbal input/complaints of patients and LHW’s findings. These findings will be
transmitted to the hospital server along-with the physiological data of the patient. It will be
recorded in the database and displayed on the remote monitoring application when the
doctor views that particular patient’s data.

The local monitoring application will also provide the facility to record the data offline and
transmit it later. This feature can be used to transmit the data while being away from the
patients, thus saving them from the hazards of radiations of the radio waves. The application
will also have a provision for saving the data recorded offline in a file. If GPRS is not
available in a region, this file can be copied on a memory stick and uploaded to the server
later from some other region or using a different medium e.g. internet on telephone.
Moreover, the LHW will be able to retrieve these saved records later if needed.

4.4. Registration Interface

Every new patient’s information must be added to a database in the hospital’s server. This
purpose will be accomplished by providing a software interface to the medical staff as well as
on the Lady health worker’s PDA. It will support entry of a patient’s complete information,
medical history and unique id which will be used across the whole system to uniquely identify
the patient. Once an entry is done, all the specific information will be stored in a new entry in
the hospital’s database. Space will be allocated for recording of patient’s data. This interface
will require use of login username and password to protect patient’s privacy. After the
registration, the patient will be issued with an identity card based on smart card technology
for use in the patient identification system discussed earlier.

4.5. Remote Monitoring Application

By using the remote monitoring application at his/her laptop/PDA, a doctor will be able to
login to the server and view a patient by patient situation as well as an overview of overall
scenario. The application will provide the doctor with the stored data from database. The
monitoring display will provide counters, graph displays and a digital signal processing
toolbox for analysis of data signals. This toolbox will help the doctor in analyzing the signal
for some characteristics using techniques like Fourier transform, Wavelet transform etc.
which will be very useful in case of certain measurements e.g. ECG signal. The medical
history of patient will also be available to the doctor.

The doctor will be provided with a response screen thorough which he/she may ask specific
questions from the patient/lady health worker and receive the response immediately. The
doctor may also make suggestions to the patient regarding use of medicines, dietary habits,
light physical exercise and other matters. The doctor’s remarks and advice will be added to
the database as well as sent to the lady health worker’s PDA to inform her and the patient of
the doctor’s advice. In case of emergency, the doctor may advise the patient to reach
hospital or an ambulance may be sent for the patient with all required equipment/medicines.
4.6. Requirements in remote monitoring application development

4.6.1. Ease of use and training facilities

The applications will be developed with ease of use in mind. To train the personnel using the application, help system and tutorials will be designed and distributed. Presentations will also be given on the use of software and installation of hardware.

4.6.2. Records privacy and security

The patient records kept in the hospital’s database are sensitive information. Although the whole system infrastructure may belong to the hospital, the patient’s medical record pertains to the patient. A privacy policy and control will be developed to filter access to the patients’ data. Data must be available during emergencies, but access should leave a non-repudiable “trail,” so abuses can be detected. For this purpose, a logging utility will be added to the system to keep track of all access activities.

It must be noted that the privacy of records is not a significant concern at this stage especially in Pakistan; therefore, the features about record privacy are not required in this initial prototype. Therefore, the features described in the above paragraph will be added in the future development.

4.6.3. Role-based access control and delegation

Doctors should be able to forward patient’s case to another doctor. Nurses might need to access the data. The patient might be interested in knowing his own medical history. Therefore a role-based access control and delegation will be provided, which will handle access privileges like “read but not copy,” “view but not save,” etc. Also, patients may have read but not write privileges for the collected sensor data, in order to avoid fraud.

4.6.4. Optional individual birth-plan

To avoid having to make certain decisions amidst labor contractions, individual childbirth preferences will be collected from patients who are willing to formulate the birth-plan. This birth-plan along-with the patient’s history will be available for access by the doctor and labor room staff. This birth-plan will include patient’s preferences regarding issues related to labor, delivery, after-delivery, baby and cesarean birth (if necessary).

5. Evaluation Framework

The whole system can not be efficiently developed without its deployment in a practical scenario. This practical deployment will also help in regular evaluation of the system and will lead to its further improvement. The evaluation framework for the proposed system is described below.

5.1. Organizational setup

The primary focus of this project is on providing an automated antenatal care system for population in remote areas. For this specific purpose, a controlled population group of pregnant ladies is needed along with the expert advice of doctors from a teaching hospital.
For this purpose, the evaluation framework has a setup based on following two organizations: Human Development Fund (HDF) and Rawalpindi General Hospital (RGH).

5.1.1. NGO: Human Development Fund (HDF)

HDF is a non-government organization dedicated to improve the condition of backward areas of Pakistan. Their program for development includes the economic development program, social development program, political development program, human development program and health program.

HDF health program was initially introduced in district Mardan (N.W.F.P) and Shamsabad (a small town of district Hyderabad in Sindh) in collaboration with APNA SEHAT in 2000. Later on, in 2003 this collaboration ended and HDF took charge of health programs in these two regions along with new initiatives in Islamabad and Rahim Yar Khan. In Lahore health program was started in April 2004 in collaboration with Department of Community Pediatrics, King Edward Medical College. Through a gradual expansion strategy health program has been implemented in Zhob, Karachi Kachi Abadi’s and Azad Jammu & Kashmir regions in 2004, 2006 and 2006 respectively.

5.1.1.1. Health Program of HDF

Keeping in view the current health profile of Pakistan, HDF envisions its health policy to be centered on the core needs of the communities, making every possible effort to achieve Millennium Development Goals (health goals) through its own interventions and collaborative efforts with other relevant government and non governmental initiatives.

5.1.1.2. Focus

Health program of HDF basically focuses on provision of primary preventive health care services to the communities with necessary emphases on primary curative health services and community education.

5.1.1.3. Vision

“To create informed, healthy communities who are not only aware of their health problems but are also willing to take action to solve them, either through our (HDF) projects developing linkages with government agencies or lobbying with the elected representatives for their rights”.

5.1.1.4. Mission

To strengthen HDF’s non political movement for positive social change and community empowerment through provision of universal primary health care by aligning its health and wellness program with organization’s integrated development model.

5.1.1.5. Goals of HDF’s Health Program

HDF has started health programs in eight regions of the country in order to achieve following specific goals that are aligned with Millennium Development Goals (MDGs).
➢ Eradicate extreme poverty and hunger
➢ (a) Achieve universal primary education
   (b) Enhance quality of education (HDF’s goal not based on MDGs)
➢ Promote gender equality and empower women
➢ Reduce child mortality
➢ Improve maternal health
➢ Combat HIV and AIDS, malaria and other diseases
➢ Ensure environmental sustainability
➢ Mobilizing communities into self sustainable organization to enhance their quality of life (HDF’s goal not based on MDGs)

5.1.1.6. HDF Health Model

Current health model of HDF has been designed to cater for the primary preventive needs of communities in particular and primary curative needs in general.

A Community Health Center (CHC) is the center stage of activities in a given community. One CHC will deliver services to one HDF Unit i.e. 1000 selected households located in the neighborhood of CHC location.

A public health experienced doctor (preferably a lady doctor) is usually the in-charge of regional health program, having the services of one Lady Health Visitor (LHV), four Lady Health Workers (LHWs) and two Trained Birth Attendants (TBAs) in each unit. The services of a dispenser cum vaccinator are available for every two units. In each region the designation of the doctor/lady doctor is of Health Coordinator. LHWs and TBAs (Community Health Team: CHT) are preferably local and inducted in the HDF team after being imparted a comprehensive training.

Apart from looking after the OPD and attending delivery cases, Health Coordinator (HC) supervises all the in-house and field activities of health staff. She/He conducts the monthly planning and is responsible to implement it as per guidance from the National Office. HC leads the community health team in terms of their community based activities through an organized planning, monitoring and evaluation system. She/he is also responsible for ongoing training of the health staff particularly regarding community health education programs. Employees Health wellness Plan’s activities would also be coordinated and implemented through HC.

LHV assists the doctor in all the above mentioned areas along with active involvement in all community based activities e.g. provision of maternal and child health care at home and social mobilization through community health team (LHWs and LHWs). LHV is in fact the immediate supervisor of Community Health Team (CHT). LHV is incharge of unit having Community Health Team working under her. She makes sure the daily community visits of CHTs and collection and compilation of data. LHV also maintains all data in registers kept in CHC. LHV is responsible to carry out follow up visits to the households (having health issues) identified during LHWs’ home visits. Coordination and Conduction of health seminars and community meetings is another responsibility of LHV.

Dispenser cum vaccinator is mainly responsible for arranging and dispensing medicines, performing lab tests apart from helping LHV in other activities. He also performs the duties of Male Motivator, responsible to interact and coordinate with the male community regarding their organization, and active involvement in CHC management, conduction and participation
in community health activities e.g. seminars, community meetings, medical camps etc. Dispenser actively participates in immunization activities in coordination with local government’s vaccinator.

![Health Coordinator Lady doctor/male Doctor (M.B.B.S) with experience in public Health](image1)

![Lady Health Visitor (LHV)](image2)

4 Lady Health workers (LHWs) One each for 250 Households (For each unit)

Dispenser Cum vaccinator

2 Trained Birth Attendants (TBAs) (For each unit)

Fig. 7 : HDF health model

5.1.2. Teaching Hospital: Rawalpindi General Hospital (RGH)

To provide expert advice on antenatal care issues, a consultant gynecologist from Rawalpindi General Hospital has been involved in the project. She will provide assistance and expert opinion in the development of medical sensors, clinical decision support system and issues related to the patients’ health.

5.2. Information Flow in proposed Evaluation Framework

Among the different organizations involved, the proposed architecture will be setup for evaluation. The information flow in this proposed architecture will be as follows:

The data gathered by Data gathering module from patient’s body will be transmitted to the main server in teaching hospital through the PDA carried by Lady Health Worker. The main server in hospital will disseminate the results of CDSS to the Community Health Center and the lady health worker. The medical records of patients will be made available to the Community Health Center as well as the National Office of HDF. For this information flow, dedicated server will be setup in Rawalpindi General Hospital, and dedicated terminals will be provided to Community Health Center as well as National Office. The communication among RGH, CHC and National Office of HDF will be through the world wide web (internet).
5.3. Controlled Population Setup

An evaluation strategy for testing the proposed system has been planned. A group of one thousand pregnant women is divided into four parts, each one attended by a lady health worker. The lady health worker visits the patients’ home on periodic basis and takes readings using the proposed system. A doctor and a dispenser are also provided to the group. The whole system is connected to a teaching hospital for expert medical advice.

The Community Health Center of HDF in Islamabad rural region will be targeted as it is nearest to the participating organizations. This CHC is in control of one unit (1000 households) selected from the poor population of rural areas of Islamabad. The services of CHC staff (Doctor, LHV, TBA and dispenser) will be obtained. The performance of the proposed system in this controlled population will be evaluated.
5.4. Performance Indicators

To evaluate the performance of the proposed system, some performance indicators have been defined. The evaluation framework will evaluate the system deployed in the controlled population group on the basis of these indicators. Some of these indicators are short term while some are long term. The performance indicators are given below:

5.4.1. Number of correct patient referrals

The increase in number of patient referrals will show that the system is capable of detection and diagnosis of pregnancy related abnormalities for patients.

5.4.2. Lady Health Workers’ workload capacity

As an important objective of the system is automation of process and thus decrease the workload of lady health workers, the system would be efficient if it enables the lady health workers to perform checkups of a greater number of patients in the same amount of time, and with same amount of effort as without he proposed system.

5.4.3. Number of complexities in birth process

To reduce the number of complexities during delivery process by timely detection and
treatment of problems is an important objective, and thus an important performance indicator of the project.

5.4.4. Amount and correctness of information available for emergency patients

When an emergency patient is brought to the operation theater, the amount of correct information available about her medical condition plays an important role in preparing doctors to treat the patient. As the system will provide easily accessible electronic medical record of patients as well as equip the lady health workers with equipment for instant checkup of patient and transmission of this data to hospital, the system would be efficient only if it provides correct and timely information of all the critical physiological parameters of the patient.

5.4.5. Maternal Mortality Ratio in controlled population (Long term indicator)

Inline with Millennium Development Goal of reducing maternal deaths in the country, this project is mainly focused on antenatal care. So, in the long run, all previous indicators converge into the indicator of reduction of Maternal Mortality Ratio in the controlled population.

5.4.6. Infant Mortality Ratio in controlled population (Long term indicator)

Reduction of Infant Mortality Ratio is also an important long term objective and indicator of success of this project.

6. Goals/Challenges to be met

In the process of development and deployment of the system, following challenges are expected and they must be met in the way:

6.1. Reliability, Error free and Robustness

The system must be reliable, error free and robust. To ensure reliability, redundancy must be added to the system. To ensure error free operation, error checks will be introduced at all levels.

6.2. Hazard free for patient

The effect of sensor’s transmission and operation radiations on patient is the greatest concern about remote monitoring. To ensure hazard free operation, a comparative study of different wireless technologies will be undertaken. The results of this study shall be used to design the least hazardous modules for monitoring purpose.

6.3. Security

The security of system against attacks must be ensured using available security mechanisms. However, security against attacks can only be provided to a certain extent as it means a tradeoff with efficiency of the system. Moreover, as this is only an initial prototype, therefore, the features for security will be added in the future development.
6.4. Integration in existing health systems

Efforts will be made to integrate the newly developed system into the existing health systems. This would be necessary so as to ensure minimal change in the existing infrastructure.

6.5. Privacy

To ensure the privacy of patient, a role-based access control will be developed. Moreover a logging utility will also be added to the system to keep track of all activities. It must be noted that the privacy of records is not a significant concern at this stage especially in Pakistan, therefore, the features about record privacy are not required in this initial prototype. Therefore, the features described in the above paragraph will be added in the future development.

6.6. Cost factor

Cost is another important factor in the deployment of a new system. Although the cost of setup in this system will be high, yet the cost of operation and maintenance should be affordable.

6.7. Scalability

Although the user based design has no known scalability issues as yet, however this factor shall be studied in the project and a solution to this problem will be provided.

7. Workflow of the Project

The Workflow Chart of the project is given below. The phases mentioned are described in detail in the next section.

![Workflow Diagram](attachment://Fig. 10 : Workflow Diagram)
C. Project Activities:

(Please list and describe the main project activities, including those associated with the transfer of the research results to customers/beneficiaries. The timing and duration of research activities are to be shown in the Gantt chart in Section 7.)

The complete project will result in the release of a product that would be readily deployable for remote monitoring purposes. The Workflow Chart of the complete project is given in the previous section. A breakdown of project into phases is given below:

Project Breakdown

Phase I – Planning phase

Activities

This is the initial phase of the project. This phase will be performed by group discussions among the design engineers and the consultants. The problem at hand will be defined and the requirements of the infrastructure will be discussed. The medical consultant will identify the medical problems and requirements for the sensors and what physiological data of the patient needs to be collected. Moreover, the medical consultant will also give suggestions about the application’s interface and the clinical decision support system. The sociologist will identify the social issues regarding the project and the group will strive to come up with solutions of these issues. The design engineers will formulate their design methodologies in view of the suggestions provided by the consultants. As the project involves hardware and software development at a considerable scale, expertise in both domains needs to be developed. The student researchers hired will be acquainted with the project, trained according to the development requirements and groomed to provide the manpower required for the timely completion of the project. The project website shall also be setup during this phase.

Deliverables

- (P1) Design document: A design document shall be published at the end of this phase containing:
  - Project overview
  - Requirements identification
  - Proposed solutions
  - Identification of equipment
  - Roles and responsibilities
  - Documentation format
  - Detailed scheduling
  - Evaluation framework

- (P2) Team of student developers: The expertise building phase will culminate in formation of a team of student developers ready to do practical work of the project.

- (P3) Project website: A project website will be setup during this phase containing the following sections:
  - Project overview
  - Team overview
  - Schedule of the project
  - Current status of project
  - Documentation section
  - Downloads section
  - Feedback section
Phase II – Primary development phase

Activities
This is the primary development phase of the project. In this phase, PDA application for monitoring of the patient will be developed. The lady health worker carrying the PDA will perform the patient checkup and enter the physiological data manually in the application interface. The basic functional core of clinical decision support system will be developed. Data gathering module will be developed for automatic gathering of patient’s physiological data.

Deliverables
- (PD1) PDA application with manual entry: A graphical user interface will be developed which will enable the lady health worker to enter the patient’s identification and physiological data manually on the PDA.
- (PD2) Clinical decision support system (basic functionality): The basic functionality of clinical decision support system will be implemented.
- (PD3) Data gathering module: The data gathering module (without medical sensors) will be developed and USB communication of this module with PDA will be setup.

Phase III – Secondary development phase

Activities
In this phase, peripherals for automation of data gathering and processing will be developed. A robust, error free and secure communication path will be established between the application running on PDA and the main server in hospital. Moreover, communication setup between the workstations residing in involved organizations will also be established according to the information flow diagram (fig. 8) shown in the previous section. To process the data sent by the PDA application, a web server will be setup at the teaching hospital. Electronic medical record system will be developed and integrated with the web server to store the received data. Three medical sensors shall be developed and integrated with the data gathering module. These sensors will measure pulse, blood pressure and temperature of the patient.

Deliverables
- (SD1) Communication infrastructure setup: A robust, error free and secure
communication path will be established between the application running on PDA and the main server in hospital. Moreover, communication setup between the workstations residing in involved organizations will also be established.

- **(SD2) Main server setup:** A web server will be setup to serve requests from PDA as well as the CHC and National office of HDF.
- **(SD3) Electronic medical record (EMR) system:** The electronic medical record system will be setup and integrated to the web server.
- **(SD4) Medical sensors development:** The medical sensors to be developed in this phase are:
  - (S1) Pulse
  - (S2) Blood Pressure
  - (S3) Temperature

![Timeline for Secondary development phase](image)

**Fig. 13 : Timeline for Secondary development phase**

### Phase IV – Tertiary development phase

**Activities**

In this phase, the development of fully functional clinical decision support system will be completed and it will be ready to provide decision support for all situations related to antenatal care. The development of monitoring application on PDA, remote monitoring application for doctor, record viewing application for HDF offices, scheduling and reminders application for lady health worker and patient registration application shall also be completed in this phase. An electronic patient identification system will be developed. Identification cards will be issued to all registered patients. Lady health workers will swap the patient’s card through card reader attached to PDA and the patient’s profile will be automatically loaded in to the application.

**Deliverables**

- **(TD1) Clinical decision support system (full functionality):** The development of fully functional clinical decision support system will be completed and it will be ready to provide decision support for all situations related to antenatal care.
- **(TD2) Applications development:** The development of monitoring application on PDA, remote monitoring application for doctor, record viewing application for HDF offices, scheduling and reminders application for lady health worker and patient registration application shall be completed.
- **(TD3) Patient identification system:** A patient identification system using identification cards based on smart card technology will be established and integrated to the applications on PDA.
**Phase V – Final development phase**

**Activities**

In this phase, medical sensors for measurement of hemoglobin, heartbeat, albumin and blood sugar will be developed. Any leftover component will be completed and all peripherals shall be integrated to form a unified working product.

**Deliverables**

- (FD1) Medical sensors development: The medical sensor modules to be developed in this phase are:
  - (S4) Hemoglobin
  - (S5) Heart beat
  - (S6) Albumin
  - (S7) Blood sugar

- (FD2) Integration of the complete system: Integration of complete system will take place in this phase.

**Phase VI – Evaluation phase**

**Activities**

An elaborate evaluation framework for this project in the light of HDF health model has been described in the previous section. The project will be developed in the form of modules which will be integrated together to form the final product. These modules will be tested, evaluated and improved in the evaluation phase. The evaluation phase will continue throughout the process of development. At the end of this phase, a document shall be released identifying the degree of success of the project in light of the success indicators defined in the previous section.

**Deliverables**

- (E1) Evaluation Results Document: At the end of this phase, a document shall be released identifying the degree of success of the project in light of the success indicators.
Phase VII – Technology Transfer/Diffusion Phase

Activities
As the success of this project relies to a great extent upon efficient use of this system by the lady health workers for monitoring of patients, great emphasis is placed upon the training of LHWs. This phase starts after the completion of the primary development phase and will continue till the end of the project. Workshops comprising of training sessions will be arranged after completion of every significant development phase. During this phase, user manuals and video tutorials shall be published, source code and other details of the project shall be made available on the project website, introductory seminars for doctors shall be held and training sessions for Lady Health Workers shall be arranged.

Deliverables
- (T1) User Manuals and Video Tutorials: User manuals shall be printed and distributed, video tutorials shall be made available for the end-users.
- (T2) Introductory Seminars: Seminars for doctors will be arranged to introduce them to the use of the new technology.
- (T3) Training Sessions: Training sessions for lady health workers will be arranged to produce necessary technical competence for handling the equipment.

D. Key Milestones and Deliverables:

(Please list and describe the principal milestones and associated deliverables of the project. A key milestone is reached when a significant phase in the project is concluded, e.g. selection and simulation of algorithms, completion of architectural design and design documents, commissioning of equipment, completion of test, etc.) The timing of milestones is also to be shown in the Gantt chart in Section 7.

The information given in this table will be the basis of monitoring and release of funds by the National ICT R&D Fund.
<table>
<thead>
<tr>
<th>No.</th>
<th>Elapsed time from start (in months) of the project</th>
<th>Milestone</th>
<th>Deliverables</th>
</tr>
</thead>
</table>
| 1.  | 5 months                                         | Completion of planning and team development | • Design document  
• Team of student developers  
• Project website |
| 2.  | 14 months                                        | Completion of primary development phase | • PDA application with manual entry  
• Clinical decision support system (basic functionality)  
• Data gathering module |
| 3.  | 14 months                                        | Completion of secondary development phase | • Communication infrastructure setup  
• Main Server setup  
• Electronic Medical Record (EMR) System  
• Medical sensors development |
| 4.  | 24 months                                        | Completion of tertiary development phase | • Application development  
• Clinical decision support system (full functionality)  
• Patient identification system |
| 5.  | 24 months                                        | Completion of final development phase | • Medical sensors development  
• Integration of the complete system |
| 6.  | 27 months                                        | Completion of evaluation phase | • Evaluation results document |
| 7.  | 28 months                                        | Technology transfer activities including release of user manuals and video tutorials, introductory seminars and training sessions for end-users | • User manuals and video tutorials  
• Introductory seminars  
• Training sessions |

(Please add more rows if required.)

4. **Benefits of the Project**

A. **Direct Customers / Beneficiaries of the Project:**

(Please identify clearly the potential customers/beneficiaries of the research results and provide details of their relevance, e.g. size, economic contribution, etc.)

The majority of Pakistan’s population lives in rural areas with nonexistent health infrastructure. These people shall be the primary beneficiaries of this project. These people form a majority of population as well as are the main sustainers of the agricultural sector of
the quality of life of these people shall improve as a result of this project as health care services will be provided to them at their doorsteps.

With focus on antenatal care, the success of this project means better child and maternal health care. Maternal care is not associated with an exclusive segment of society. It is an issue of all households. So, better maternal care will ultimately result in the creation of a better society that has progressive trends.

The primary customers of this system will be the Health Care Organizations and hospitals. They will be able to deploy this low cost and highly reliable infrastructure in the areas where there is none at present. This would result in an increase in the quantity as well as quality of service of the overall health service being provided in the country. By taking advantage of this newly designed system based on technological revolutions in the field of communications and embedded systems, the government of Pakistan would be able to realize its vision of providing medical facilities to all of its citizens in a cost efficient manner. This would naturally lead to an improvement in the current catastrophic situation in the health sector.

B. Outputs Expected from the Project:

This project, being the first of its kind, will bring about a technological revolution in the health sector by introducing infrastructure based on modern technology and communication advancements. This would initiate a wave of interest in the research field (especially Bio-Engineering which is nearly non-existent at present) in the country. New research will result in new advancements and thus the field of Bio-Engineering which has been ignored for so long, will come to academia/industry spotlight.

The Health Sector will benefit from the advancements in communication technology and will be able to improve the quality of health service in the country by providing health care at the customer’s doorstep. Collaboration of Academia, Information Technology sector and the Health sector will result in increased use of Information and Communication Technology (ICT) in the field of Bio medical engineering. This project will also empower the lady health workers by providing them training in the use of modern and technologically advanced equipment.

On National level, this would result in an increase in the coverage of health facilities across the country. This project will enable the government to fulfil its dream of providing basic medical facilities to all its citizens especially those living in remote areas. As a result of this project, the people living in remote areas will be delivered with a better quality health service.

C. Organizational / HRD Outcomes Expected:

Expertise development is an important part of this project. A trained and well-groomed team of expert developers will emerge from this project. This team would be capable of handling further development projects and shall prove an important and productive asset of our nation. The project involves collaboration of engineers and researchers with doctors, a sociologist, lady health workers and patients. So the project would nurture research oriented ties between the representatives of different professional fields.

The project will result in an increase in the quality and quantity of research work going on in the concerned research organizations. By inducting student researchers into the project and
providing them financial support, the project will initiate the research culture in the organization’s students and lessen the burden of their fees and other expenditures.

The project will encourage and promote an increased use of technological advancements in the daily record maintenance by hospital staff and decision making process by the doctors. The training of lady health workers (LHWs) for using modern technologically advanced equipment will increase their technical competence and prove an effective mean of improving their educational capabilities. They will be linked to specialist doctors in teaching hospitals, which will further improve their patient management skills.

D. Technology Transfer / Diffusion Approach:

(Please describe how the outputs of the project will be transferred to the direct beneficiaries/customers. Please also state if the project outputs are sustainable, i.e. if they can be utilized without further external assistance.)

A multi-dimensional approach towards technology diffusion is envisioned. As the project will result in the development of an infrastructure, therefore, proper documentation and guidelines towards the deployment of the infrastructure is a necessary process. To achieve this objective, following steps will be taken to ensure proper technology transfer to the beneficiaries of the project:

- **User Manuals/Guides**: The project will be completely documented and user manuals will be published to assist the end-user in use of the products. The manuals will be multilingual (English and Urdu) for the benefit of non-English speaking people. The user manuals and guides shall contain graphics illustrating the complete process of deployment of the product as well as common guidelines and safety precautions related to the use of the product.

- **Video Tutorials**: Along-with printed manuals, video tutorial lessons shall be published and disseminated among the beneficiaries of the project. The augmentation of video tutorials with printed manuals will ensure effective use of the product.

- **Project Website**: In the era of Information Technology, internet has become the primary source of information. A website dedicated to the project will be created, published and maintained. The website shall be regularly updated about the current status of the project. The research work will be available online as well as user manuals and tutorials in electronic forms will be available for download.

- **Collaboration with NGOs**: We have established collaboration with an NGO named Human Development Fund (HDF). The already well established health regions run by HDF will be used for evaluation of this project. HDF will also provide manpower as well as resources to diffuse the resulting technology in the far-flung areas of the country and thus extend the reach of medical care to people in those regions.

- **Introductory Seminars for Doctors**: Doctors and medical specialists will be the service providers in the resulting infrastructure. The infrastructure will provide a clinical decision support system and its integration with the existing hospital information systems. To use this new technology, introductory seminars will be arranged for doctors to help them use it effectively. Moreover training sessions for doctors and other hospital staff will be arranged to effectively diffuse the technology.

- **Training Sessions for Lady Health Workers**: As the infrastructure will be developed to address the lack of health care facilities in the remote areas of the country, proper
technical staff will be needed to deploy and maintain the infrastructure in those areas. Instead of hiring new employees and burdening the already inadequate health budget of the government, existing country wide network of lady health workers will be targeted. Training sessions will be arranged for lady health workers to produce necessary technical competence for handling the equipment. To entail services of a few lady health workers in the project, short-term incentives like monthly stipends will be given to those who will actively participate in the project.

- **Technology diffusion for further development**: To enable future development and extension of the project, detailed documentation of the project shall be maintained at all stages of development. The source codes shall be commented and made available to future researchers under Mozilla Public License (MPL). The benefit of using MPL is that it allows integration with non open-source components. This will go a long way in making the technology diffusion widespread. Further technical assistance could be provided on demand.

5. **Risk Analysis**

A. **Risks of the Project:**

(Please describe the factors that may cause delays in, or prevent implementation of, the project as proposed above; estimate the degree of risk.)

(Please mark ✔ where applicable)

<table>
<thead>
<tr>
<th></th>
<th>Low</th>
<th>Medium</th>
<th>High</th>
</tr>
</thead>
<tbody>
<tr>
<td>Technical risk</td>
<td>✔</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Timing risk</td>
<td>✔</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Budget risk</td>
<td></td>
<td>✔</td>
<td></td>
</tr>
</tbody>
</table>

A1. **Comments:**

Our team is technically capable of completing this project. Moreover, expertise development has been planned as a distinct phase of the project. The need of technical help in the medical and social field will be met by inducting a medical consultant and a sociologist respectively. Thus, the technical risk involved is low. Properly trained technically competent staff, well-defined objectives and comprehensive research methodology ensures timely completion of the project. So, the timing risk is low. The expenditure division and resource allotment has been done with extreme care. However, the maintenance of the PDAs and medical sensors given to lady health workers can be costly as long as there is no cost-effective and reliable resource for repairing the digital equipment locally. Also, multiple organizations are involved who will share the budget. This shows that the budget risk is medium. To counter this risk, the contingency for the project has been kept at 2% of the total budget instead of the usual 1%. Moreover, the budget division between the organizations involved in the project has been clearly identified in the annexure B.
6. **Contractual Matters**

<table>
<thead>
<tr>
<th>A. Contractual Obligations under this Project:</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>(Please indicate any contractual obligations with third parties that will be entered into for this project.)</em></td>
</tr>
</tbody>
</table>

Since all the work will be done by the non-contractual staff. Moreover, we do not intend to have any third party agreements. So, there will be no contractual obligations under this project.

<table>
<thead>
<tr>
<th>B. Ownership of Intellectual Property Rights:</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>(Please indicate the organization(s) that will own the intellectual property rights that may arise from this project.)</em></td>
</tr>
</tbody>
</table>

FAST-NU will possess the ownership of the intellectual property rights.

<table>
<thead>
<tr>
<th>C. Competent Authority of the Principal Investigator (Organization).</th>
</tr>
</thead>
<tbody>
<tr>
<td>Name: Dr. Aftab Maroof</td>
</tr>
<tr>
<td>Designation: Director, FAST-NU, Islamabad</td>
</tr>
<tr>
<td>Email:</td>
</tr>
<tr>
<td>Date: ____________________ Signature :</td>
</tr>
<tr>
<td>Name: Dr. Amir Mohammad</td>
</tr>
<tr>
<td>Designation: Rector, FAST-NU, Islamabad</td>
</tr>
<tr>
<td>Email:</td>
</tr>
<tr>
<td>Date: ____________________ Signature :</td>
</tr>
</tbody>
</table>
7. Project Schedule / Milestone Chart

(.Project schedule using MS-Project (or similar tools) with all tasks, deliverables, milestones, cost estimates, payment schedules clearly indicated are preferred.)

![Gantt chart for the proposed project](image-url)

Fig. 18: Gantt chart for the proposed project
8. Proposed Budget

Please use the embedded Excel Worksheet for providing budget details.

Double click the icon to open the worksheet.

(Also refer to annexure B for Distribution of Budget between FAST NU and HDF)
Annexure A – Curriculum Vitae

Please provide relevant information and also attach CVs of key research / development personnel (if available) and PD, JPD.

A. Professional Information

1. Name: Dr. Muddassar Farooq
2. Title or Position Held: Associate Professor
3. Experience: (yrs) 6 years
4. Email Address: Muddassar.farooq@cs.uni-dortmund.de

B. Research Papers in Relevant Area

Peer reviewed Research Book
Muddassar Farooq. Intelligent Network Traffic Engineering through Bee-inspired Natural Protocol Engineering (The manuscript of the book has been approved by the editorial board of Springer to be published as a book in Natural Computing Series).

Book chapter

HEC approved Journal Papers


Peer reviewed conference papers


9) M. Zubair Shafiq, Mehrin Kiani, Bisma Hashmi and Muddassar Farooq, Extended Thymus Action for Reducing False Positives in AIS based Network Intrusion Detection Systems, Genetic and Evolutionary Computation Conference (GECCO-


Honors and Awards
2) Nominee, Best paper award from Swarm Intelligence track at GECCO 2005, Washington, USA.
3) Received NUST scholarship for MEngSc studies in UNSW.
5) Member Editorial Board. Serving on the editorial board of Springer’s new Journal of Swarm Intelligence.
6) Associate Editor. Serving as an Associate Editor of Journal of Artificial Evolution and Applications, Hindawi Publishing Corp.
9) Associate Editor. Organized a special session on Swarm Intelligence at International Conference of Artificial Intelligence, 2005 and was the associate editor of the conference proceedings.

C. Courses Taught in Relevant Area

### D. Thesis / Projects Supervised in Relevant Area

**Title:** BeeHiveAIS  
**Organization:** Universitat Dortmund, Dortmund, Germany  
**Major outputs:** A novel security framework inspired by the principles of Artificial Immune System, for nature inspired routing protocols in general and BeeHive in particular.

### E. Grants Received in Relevant Area

<type here>

### F. Industrial Work Done in Relevant Area

**Title:** Telecommunications, Protocol Engineering  
**From:** October 2001  
**To:** February 2006  
**Position held:** Research Scientific Officer  
**Major outputs:**  
1) Routing Protocol Development, Beehive  
2) Security Framework for BeeHive, BeeHiveAIS

**Title:** Bee-Adhoc  
**From:** October 2001  
**To:** January 2006  
**Position held:** Project Manager  
**Major output:** Energy efficient, scalable, secure routing protocol for Mobile Adhoc Networks (MANETs)

**Title:** SAADI  
**From:** October 2001  
**To:** January 2006  
**Position held:** Project Manager  
**Major output:** Modular and adaptable scheduler for Linux operating system
Title: BURAQ
From: March 2000
To: October 2001
Position held: Supervisor
Major output: A Set of configurable processor tools that streamline the process of rapid development and prototyping of a new DSP and its software.

Title: DSP Processor Toolkit
From: September 1999
To: March 2000
Position held: Project Manager
Major output: Design, development and implementation of software tools for a new 16 bit fixed point DSP processor with a SIMD architecture.

Title: Summa Four Network Management System
From: February 1999
To: July 1999
Position held: Software Engineer
Major output: Designed, developed and implemented a distributed management software system for the telecommunication switch Summa Four.

Title: ACMI
From: August 1996
To: August 1997
Position held: Design Engineer
Major output: Design and developed a data acquisition system to record the flight data of an aircraft.
Please provide relevant information and also attach CVs of key research / development personnel (if available) and PD, JPD.

A. Professional Information

1. Name: Dr. Abdul Aziz Awan
2. Title or Position Held: Program Manager Health
3. Experience: (yrs) 14 years
4. Email Address:

B. Research Papers in Relevant Area

<type here>

C. Courses Taught in Relevant Area

<type here>

D. Thesis / Projects Supervised in Relevant Area

<type here>

E. Grants Received in Relevant Area

<type here>

F. Industrial Work Done in Relevant Area

Organization: Human Development Foundation
Organization Type: Human Development
Designation Program: Manager Health
Location: Islamabad, Pakistan
Tenure: May-2007 To Date

Organization: National Commission for Human Development
Organization Type: Human Development
Designation: District Program Manager Health
Location: Mardan, Pakistan
Tenure: Feb-2005 To Mar-2007
Description:
Monitoring, evaluation, reporting, analysis and training of the staff
for the following programs:
Primary Health care, National ORS Program and National School health program.

Organization: Basic Health Unit
Organization Type: Government Hospital
Designation: Medical Officer
Location: Attock, Pakistan
Tenure: May-2002 To Jan-2005
Description:
1-To deal with out-door patients
2-To deal with indoor patients
3-To deal all sorts of surgical & Medical emergencies
4-To vaccinate the kids <1 years
5-Health Management Information System-Reporting
6- To conduct and monitor Polio Days activities

Organization: Ghazi Barotha Contractors
Organization Type: Hospital
Designation: Medical officer
Location: Attock, Pakistan
Description:
1-To deal with out-door patients
2-To deal with indoor patients
3-To deal all sorts of surgical & Medical emergencies
4-To vaccinate the kids of the workers
5-Health Management Information System-Reporting
6- To conduct and monitor Polio Days activities

Organization: Waleed Surgical Hospital
Organization Type: Private Hospital
Designation: Medical Officer
Location: Attock, Pakistan
**Tenure:** Mar-1994 To Sep-1996

**Description:**

1-To deal with out-door patients
2-To deal with indoor patients
3-To deal all sorts of surgical & Medical emergencies
### Annexure B – Distribution of Budget between FAST-NU and HDF

#### FAST-NU budget distribution

<table>
<thead>
<tr>
<th>Designation</th>
<th>Year1</th>
<th>Year2</th>
<th>Year3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Salaried Personnel</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>PI</td>
<td>120,000</td>
<td>120,000</td>
<td>40,000</td>
</tr>
<tr>
<td>Medical Consultant #</td>
<td>240,000</td>
<td>240,000</td>
<td>80,000</td>
</tr>
<tr>
<td>5 x Design Engineers</td>
<td>2,400,000</td>
<td>2,550,000</td>
<td>900,000</td>
</tr>
<tr>
<td>9 x Student Researchers</td>
<td>972,000</td>
<td>972,000</td>
<td>324,000</td>
</tr>
<tr>
<td>Project coordinator</td>
<td>300,000</td>
<td>300,000</td>
<td>100,000</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>4,032,000</strong></td>
<td><strong>4,182,000</strong></td>
<td><strong>1,444,000</strong></td>
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<tr>
<td>Research Materials</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Books, Softwares etc</td>
<td>200,000</td>
<td>100,000</td>
<td></td>
</tr>
<tr>
<td>Server hosting cost ##</td>
<td>84,000</td>
<td>84,000</td>
<td>28,000</td>
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<tr>
<td>GSM/GPRS connectivity</td>
<td>90,000</td>
<td>120,000</td>
<td>40,000</td>
</tr>
<tr>
<td>Hardware development *</td>
<td>350,000</td>
<td>250,000</td>
<td></td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>694,000</strong></td>
<td><strong>554,000</strong></td>
<td><strong>68,000</strong></td>
</tr>
<tr>
<td>Major equipment</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4 x Laptops</td>
<td>280,000</td>
<td></td>
<td></td>
</tr>
<tr>
<td>5 x Workstations</td>
<td>250,000</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1 x UPS</td>
<td>10,000</td>
<td></td>
<td></td>
</tr>
<tr>
<td>8 x PDAs</td>
<td>240,000</td>
<td></td>
<td></td>
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<tr>
<td><strong>Total</strong></td>
<td><strong>780,000</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Other direct expenses</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Travel+Boarding/Lodging</td>
<td>270,000</td>
<td>270,000</td>
<td>135,000</td>
</tr>
<tr>
<td>University Overheads</td>
<td>300,000</td>
<td>300,000</td>
<td>100,000</td>
</tr>
<tr>
<td>Minor modifications</td>
<td>100,000</td>
<td>100,000</td>
<td>25,000</td>
</tr>
<tr>
<td>Technology Diffusion</td>
<td>60,000</td>
<td>180,000</td>
<td>100,000</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>630,000</strong></td>
<td><strong>850,000</strong></td>
<td><strong>360,000</strong></td>
</tr>
<tr>
<td><strong>Total Cost</strong></td>
<td><strong>6,136,000</strong></td>
<td><strong>5,586,000</strong></td>
<td><strong>1,872,000</strong></td>
</tr>
<tr>
<td>Designation</td>
<td>Per Visit</td>
<td>Frequency</td>
<td>Per Month</td>
</tr>
<tr>
<td>-------------</td>
<td>-----------</td>
<td>-----------</td>
<td>-----------</td>
</tr>
<tr>
<td>Staff</td>
<td>Co-PI ###</td>
<td>6,000</td>
<td>72,000</td>
</tr>
<tr>
<td></td>
<td>HC ###</td>
<td>4,000</td>
<td>48,000</td>
</tr>
<tr>
<td>LHV</td>
<td></td>
<td>416.66</td>
<td>12/month</td>
</tr>
<tr>
<td>LHW</td>
<td>Lump Sum</td>
<td>2,000</td>
<td>24,000</td>
</tr>
<tr>
<td>TBA</td>
<td>Lump Sum</td>
<td>1,000</td>
<td>12,000</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>18,000</td>
</tr>
<tr>
<td>Monitoring</td>
<td>Fuel Cost</td>
<td>2,000</td>
<td>30,000</td>
</tr>
<tr>
<td>From National Office</td>
<td>500</td>
<td>625</td>
<td>7,500</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>3,125</td>
</tr>
<tr>
<td>Pick and Drop of Field staff (within the region)</td>
<td>Fuel Cost</td>
<td>400</td>
<td>8,000</td>
</tr>
<tr>
<td></td>
<td>Maintenance cost</td>
<td>100</td>
<td>2,000</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>10,000</td>
</tr>
<tr>
<td>DSL Connection At CHC</td>
<td>2,000</td>
<td>2,000</td>
<td>24,000</td>
</tr>
<tr>
<td></td>
<td>Total Cost</td>
<td>33,125</td>
<td>397,500</td>
</tr>
</tbody>
</table>
Annexure C – Details of special equipment and hardware development

The details of equipment and components required for hardware development in the project has been given below. Please note that the equipment identified and prices quoted are for reference only. The actual equipment to be bought or to be developed might be different from those identified. The justification and approximate cost estimate of the required equipment is given below:

1. Data Gathering Module:
   - FPGA: FPGA is needed for the development of data gathering module; this module will be a very essential and main part of the project. As the FPGA will obtain data from seven sensors, process it and transmit it to the PDA application, so its memory and processing requirements are high. To cater for these essential requirements, we have opted for Virtex-5 FPGA from XILINX. The starter kit for Spartan 3e provides an integrated testing environment for the sensors and is therefore required during the development and testing phase. The overall cost for these components is $1800 approx (after including shipping & handling charges and custom tax).

2. Smart Card Technology for Patient Identification System:
   - The development of Patient Identification System requires smart card technology. The development cost will be about $75 while the deployment and distribution of these cards among the controlled population for evaluation purposes will require an additional amount of $325.

3. Medical Sensors Development:
   - The development of electronic circuits requires specialized testing equipment such as an Oscilloscope, Function Generator, regulated power supply and accessories etc. The estimated overall cost for these components is $2200 approx (after including shipping & handling charges and custom tax).
   - The development of medical sensor modules requires PCB boards, microcontrollers, electrodes, MEMS devices (e.g. MEMS accelerometer for pulse sensor), connecting leads/straps (to be attached to the patient) and the overall packaging of system as a box. The average estimated cost for each medical sensor module is $600. Therefore, the overall estimated cost for development of seven sensor modules is $4200. Please keep in mind that some of these sensors (e.g. Hemoglobin sensor, Albumin Sensor) are not commercially available and must be developed from scratch. Even in the case of sensors which are commercially available, some of them must be modified for small size constraint whereas others are too costly to be bought as stand-alone product. For example, one such commercially available monitor costs $3200 for sensing heart rate, blood pressure, temperature and amount of oxygen dissolved in blood. Therefore, our estimated cost of $600 for each sensor is justified as it is significantly lower than the cost of commercially available solutions.
1. Data Gathering Module

For data gathering module, Field Programmable Grid Array (FPGA) board will be required for polling, processing and other signal processing operations on the data received from the sensors; moreover, FPGA will also setup communication with the PDA. An FPGA board and a starter FPGA kit have been identified below.

![XILINX VIRTEX 5 Development Board](image)

XILINX VIRTEX 5 Development Board
Price: US$ 1195

![XILINX SPARTAN-3 PCI Starter Kit](image)

XILINX SPARTAN-3 PCI Starter Kit
Price: US$ 315

2. Medical Sensors Development

Some of the existing medical sensors and monitors will be used and modified for use in the project while some new ones will be developed if they are not available in the market or if it is not cost efficient to procure them into this project due to size or design issues. Some of the potential sensors and monitors for induction in this project are identified below.
Automatic Blood Pressure Monitor
(Micro Life) £35.00

Function generator
(BK Precision) $390.00

Oscilloscope
(Tektronix) £800.00

MEMS based electrodes and accelerometers
(Vermed and MEMSIC)

ECG leads/Electrodes
PIC 18F4455 Microcontroller
Microcontroller Programmer
Printed Circuit Board

3. Smart Card Technology for Patient Identification System
For patient identification, smart card technology will be used. Some of the existing smart cards, smart card readers and writers are identified below:

SLE-5542 Smart Card
(Contact Type) $1.32

Mifare-1K Smart Card
(Contactless Type) $0.84

SLE-4442 & Mifare Smart Card
(Dual Type) $2.45
Reader/Writer for Contact Type Smart Cards

Reader/Writer for Contactless Type Smart Cards

Single Sided Card Printer

(SL500L with RS-232/USB Interface) $25

MFRC531 Development Kit
For Mifare Smart Cards

SLE015B OEM Module
With RS-232 Interface $20