The Issues And Trends of Remote Medical Care

by

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What is This Study?

- **History:**
- 1949 - Holter monitor invented telemetric cardiac monitoring used clinically in 1960's
- 1989 – MedPhone 1st Telemedicine system diagnose & treat patients needing defibrillation
- 2000 – Robot surgery approved by FDA da Vinci Surgical System

- **What is the study about?**
  - The research paper discusses the issues and trends of remote medical care.
  - The concept of remote medical care has been proposed using wired or wireless access to link patients with doctors.
  - Some of the newest remote medical care systems consist of a
    - Communication subsystems,
    - Vital signs data auto-uploading,
    - Periodic monitor
    - Remote surgery
    - Security
    - Remote diagnosis.

- **What are the study findings:**
  - The trends indicate that the future of remote medical care is boundless.
    - A growth industry that will save millions of dollars & lives.

  - Important issues with remote medical care are privacy and security concerns

Introduction

- Advances in remote medical care have opened up new opportunities in healthcare systems.
- Integration of existing specialized medical technology with pervasive, wireless wearable health monitoring sensors is pushing to new limits.
- Pervasive sensor technologies co-exist with the installed infrastructure, augmenting data collection and real-time responses.
- Sensors are particularly important to the world's elderly, whose health needs to be assessed regularly or monitored continuously.
- Traditionally personal medical monitoring systems such as Holter monitors (a portable/wearable ECG device) can collect data for up to 24 hours.
- The recorded data is subsequently retrieved and analyzed by a clinician [3].
- Usage has been limited due to many factors:
  - Using it only to collect data for off-line processing
  - Users comfort (due to numerous wires, rigid form & adhesive and electrodes)
  - Lack of integration of individual sensors
  - Interference on a communication channels shared by multiple devices
  - No support for massive data collection
  - Knowledge discovery and reliable interpretation of the recorded data.

Introduction

- To address these problems, advanced ECG monitoring systems are emerging like:
  - Offline continuous data collection capabilities
  - Detection and signal a warning in real-time adverse events
  - Body sensor networks (BSN) and pervasive monitoring systems for patients.
- A lot of wearable systems have been proposed:
  - Integrated wireless transmission
  - GPS (Global Positioning System) sensors, and local processing
  - Off the shelf mobile computing devices (PDAs or Smart Phones)
- An example is CardioNet [6] - a remote heart monitoring system where ECG signals are transmitted to a PDA and then re-routed to the central server by using the cellular network.

Introduction

- In the area of robotics I believe that surgery and interventional radiology will be transformed through the integration of computers and robotics much in the same way that manufacturing was revolutionized by a similar automation several decades ago.
- Haptic devices, a form of robotics, are also relevant for simulations to train medical personnel.
- The most prominent application of robots in medicine today is the performance of high precision surgery by minimal invasive robotic methods.
- Here the surgeon does not have contact with the patient, but performs the operation using haptic interfaces to control robotic actuators.
- SpineAssist platform (Mazor Surgical Technologies Ltd. Caesarea, Israel) , which enables highly accurate pre-operative planning and placement of spinal fusion screws and supports related surgical interventions.
- It consists of a miniature robot that glides freely above the patient's spine.
- During spinal procedures, the system guides the surgeon in real time to pinpoint the exact location and trajectory of the implant based on the pre-surgical plan.

Introduction

- In the area of RFID systems Healthcare facilities will benefit from stopping the loss of thousands of dollars worth of equipment each year and staff members spend countless hours searching for mobile assets such as infusion pumps, x-ray machines, wheelchairs and patient monitoring devices.
- An RFID tracking system provides the visibility to immediately locate assets and personnel. RFID tracking systems also provide a means of tracking patients within the hospital and can help in maternity wards to stop infant theft.
- RFID also provides a means of identifying patients immediately and in combination with databases containing patient records can provide instant information of a patient's medical profile (blood type, medications taken, allergies etc..).
- This would revolutionize healthcare for people involved in emergency situations (fires, car accidents etc..), because first responders like EMT's and firemen will have all of the patients vital information on there PDA and by able to tailor the administration of emergency medical services more effectively to the patient, helping patient survivability

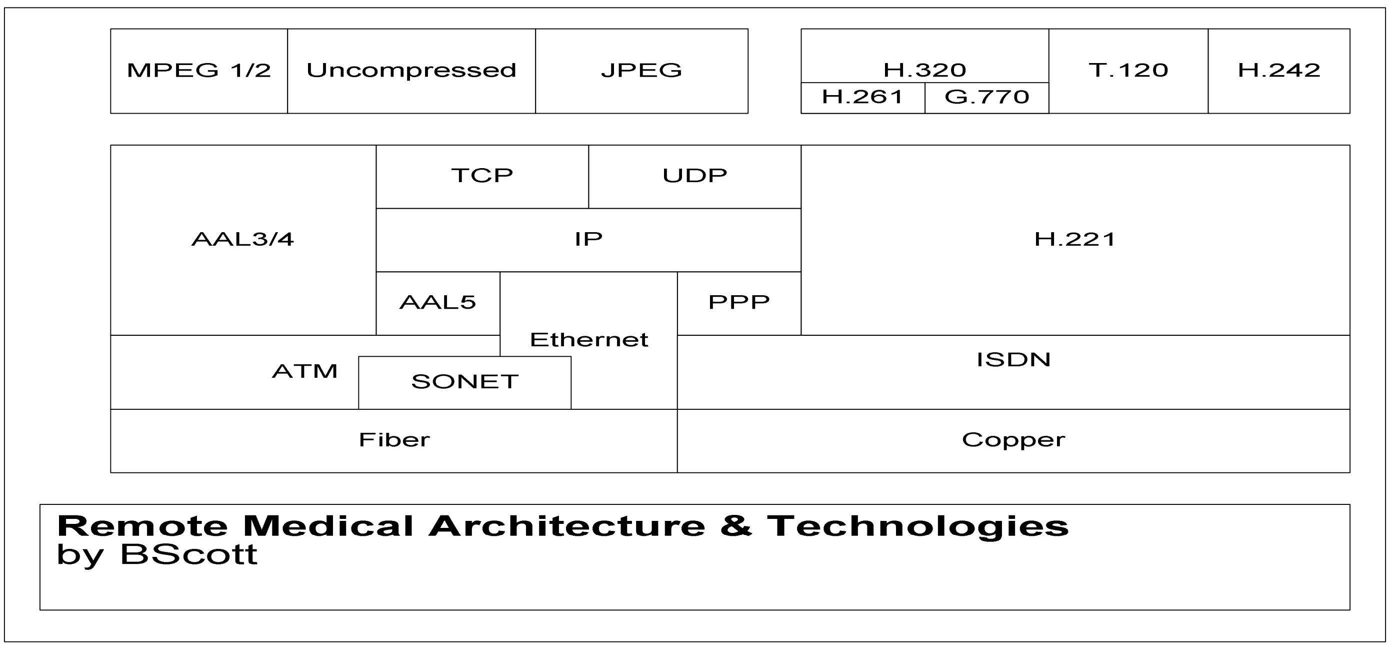
Introduction

- The combination of remote monitoring, wearable sensors, robotics and RFID within the context of remote medical care will allow vast data collection and so the ability of mining this data for next generation clinical trials.
- The implications and potential of wearable health monitoring technologies are paramount
  - Enable the detection of early signs of health deterioration
  - Notify health care providers in cases of emergency
  - Help find correlations between changes in lifestyle (stress, diet, exercise) & physiological signals
  - Bring down the cost and attendance to regular office visits to physician.

- Data collected is stored and integrated into a comprehensive patient health record which is used to:
  - Help physicians make more informed diagnosis.
  - Benefit survivability in emergency scenarios and during surgery
  - Mitigating surgical errors
  - Allow for surgical instrument and patient tracking.
  - Reduce staffing labor costs
  - Bring healthcare to remote locations and developing countries
  - Promote health
  - Enhance and support the quality of life.

Introduction

- Basic remote medicine network architecture (seen below) has a number of protocol stacks.
- MPEG-1 and MPEG-2 standards define methods for compressing high-quality audio and video.
- MPEG-1 supports compression of VHS quality video and CD quality audio into a 1.2 Mbps bitstream or higher quality at proportionally higher bitrates. MPEG-2 is more flexible and supports compression of wide ranging quality video and audio beyond that of MPEG-1 and approaching that of HDTV into a bitstream up to 100 Mbps.
- At the main profile and main level, MPEG-2 can compress 720x480 video at 30 frames per second into a 5-15 Mbps bitstream.
- **Figure1**



Medical Monitoring

- Advances in semiconductor and communication technologies have enabled development of body sensor networks that employ intelligent sensors which communicate wirelessly over the internet with personal and medical servers.
- These networks generally tend have a multi-tiered system architecture.
- Some body sensor networks employ wireless sensors that communicate with a PDA at the first level using Bluetooth or Zigbee protocols. ZigBee is the set of specs built around the IEEE 802.15.4 wireless protocol.
- The 802 group is the section of the IEEE involved in network operations and technologies, including mid-sized networks and local networks.
- Group 15 deals specifically with wireless networking technologies, and includes the now ubiquitous 802.15.1 working group, which is also known as Bluetooth.
- ZigBee devices are actively limited to a through-rate of 250Kbps, compared to Bluetooth's much larger pipeline of 1Mbps, operating on the 2.4 GHz ISM band, which is available throughout most of the world.
- The PDA then communicates with medical servers over the internet using GSM/GPRS cellular networks at the second level, while at the third level, hospitals, emergency services, physicians and nursing homes are connected using a network of remote healthcare servers and databases.

Medical Monitoring

- The requirements for a medical networked sensor system depend on the particular application and deployment environment.
- A networked sensor system designed for ad hoc deployment in an emergency situation will have very different characteristics than one being deployed permanently in a hospital.
- For example, the permanent deployed system can make use of fixed, powered gateway nodes which provide access to a wired network infrastructure while the ad-hoc deployment may have to choose the gateway among sensor nodes using some leader election algorithm.
- In sensor applications, the patient's physiological data is transmitted to a more powerful medical server.
- Data is usually transferred at periodic intervals and analyzed by the service provider.
- The frequency of data collection is much higher than in many other systems.
- In emergencies systems data is captured and analyzed in real time.
- Due to intermittent communication and message retransmissions the medical server has to process out of order messages so, event ordering, time-stamping and synchronization is required to have a feedback response in real-time.

Medical Monitoring

- M-health [2] integrates mobile computing, medical sensor, and communication technologies for mobile health applications.
- Wireless Body Area Network (WBAN) of intelligent sensors represents an emerging technology for system integration with great potential for unobtrusive ambulatory health monitoring.
- Lowest level of data flow hierarchy of M-health consist of intelligent physiological sensors integrated into WBAN for example:
  - ECGs
  - EMGs
  - EEGs
  - Motion sensors, etc called as sensor node (SN).
- Messages from SN are collected by network controller (NC) & processed on personal server (PS).
- A personal server application can run on a PDA, cell phone or home personal computer.
- Typically all messages from SN are saved and retransmitted to the medical server (MS).
- Communication between PS and internet gateway is accomplished using standard WLAN and WAN technologies, GSM/GPRS, UMTS and other wireless local and wide area network technologies.
- WBAN systems typical architecture is shown in the figure below where:
  - Lowest level encompasses a set of intelligent physiological sensors
  - Second level is the personal server (Internet enabled PDA, cell-phone, or home computer)
  - Third level encompasses a network of remote health care servers and related services (Caregiver, Physician, Clinic, Emergency, and Weather).
- Each level represents a fairly complex subsystem with a local hierarchy employed to ensure efficiency, portability, security, and reduced cost.[5]

Medical Monitoring

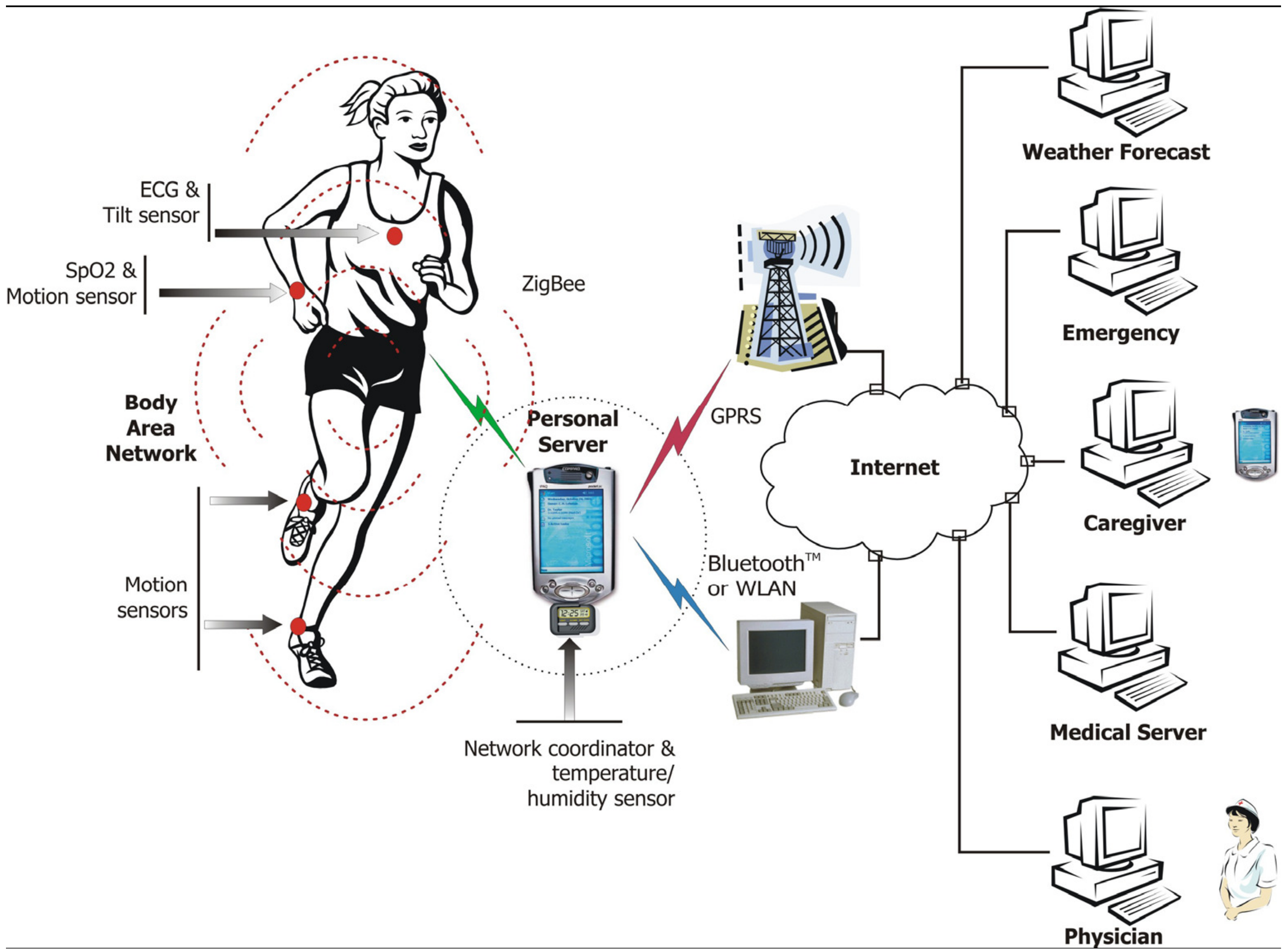


Figure2 Wireless Body Area Network of Intelligent Sensors for Patient Monitoring taken from [5]

Medical Monitoring

- The figure below illustrates an example of information flow in an integrated WBAN system.

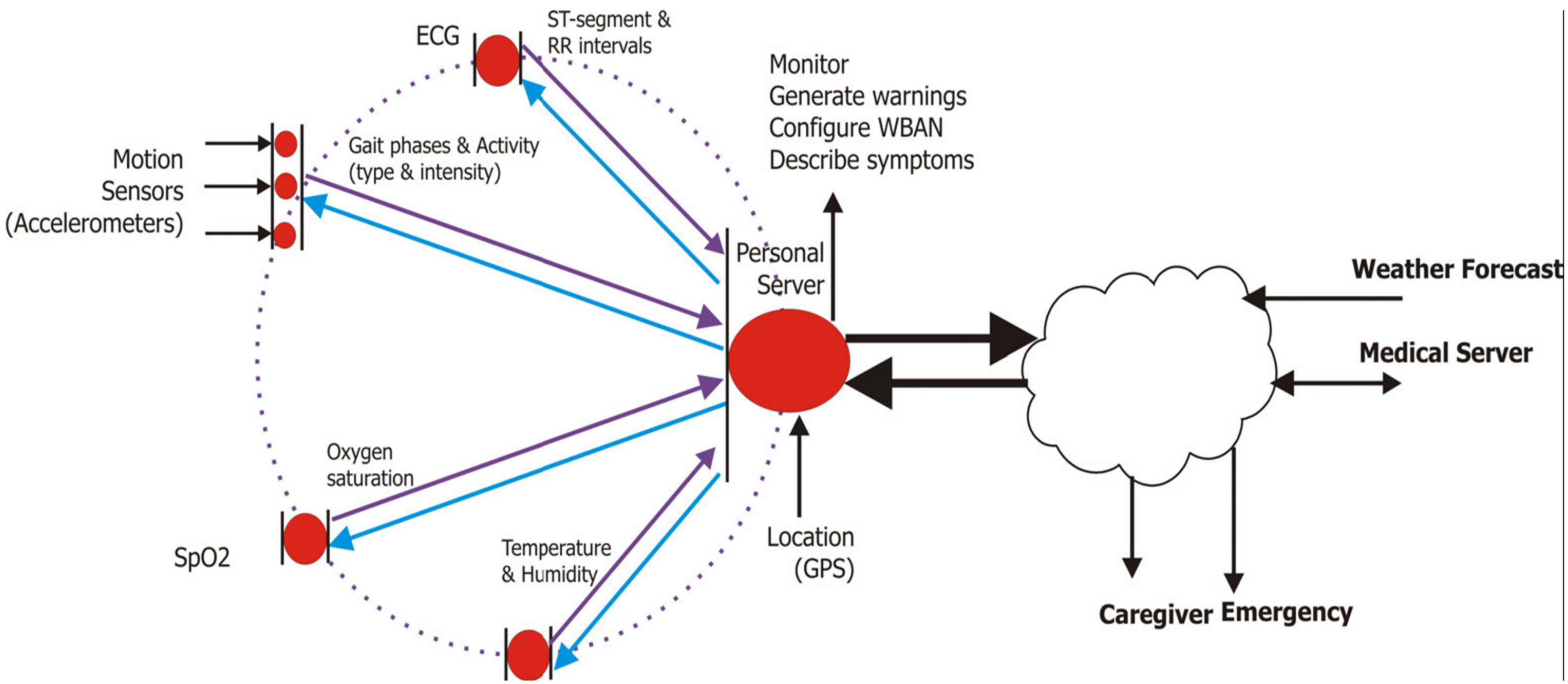


Figure 3 taken from [5]

Medical Monitoring

- An example of a WBAN activity sensor worn on a person's ankle with symbolic representation of acceleration components is depicted below.

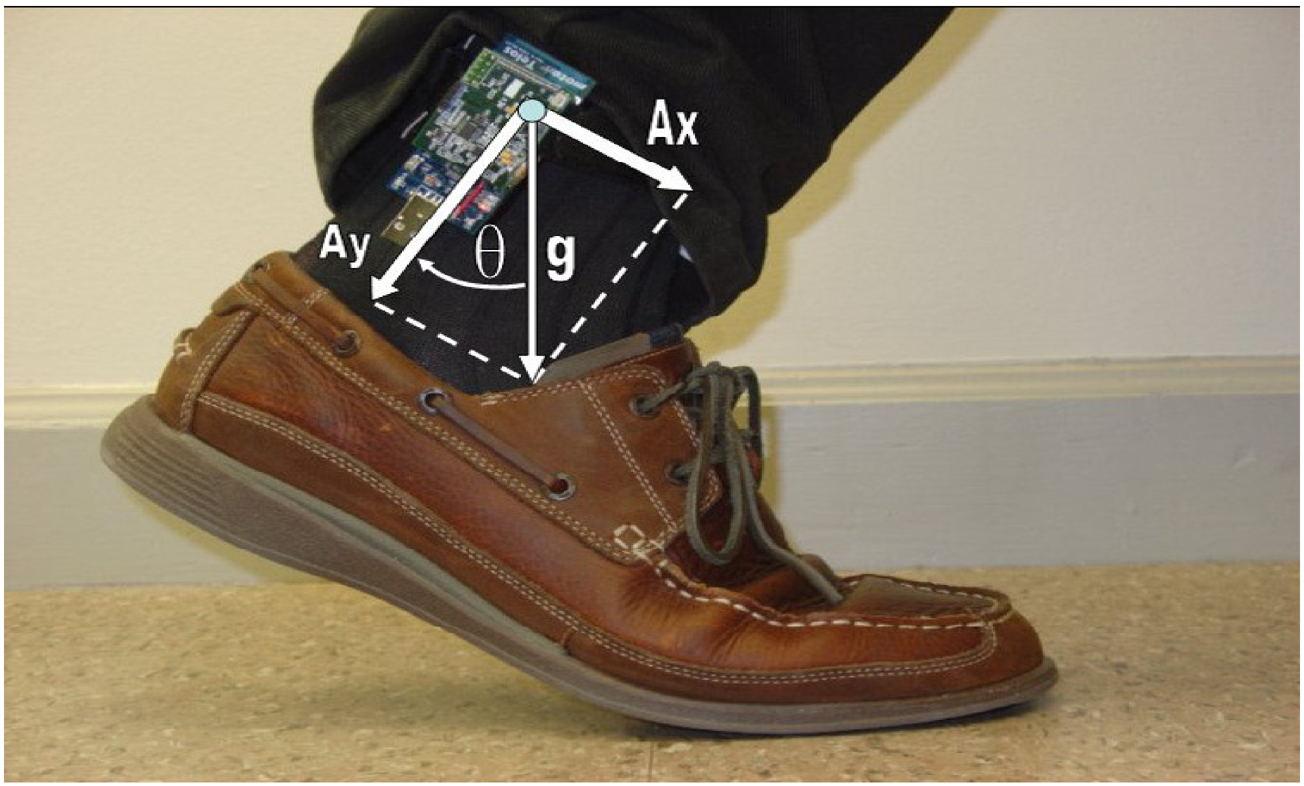


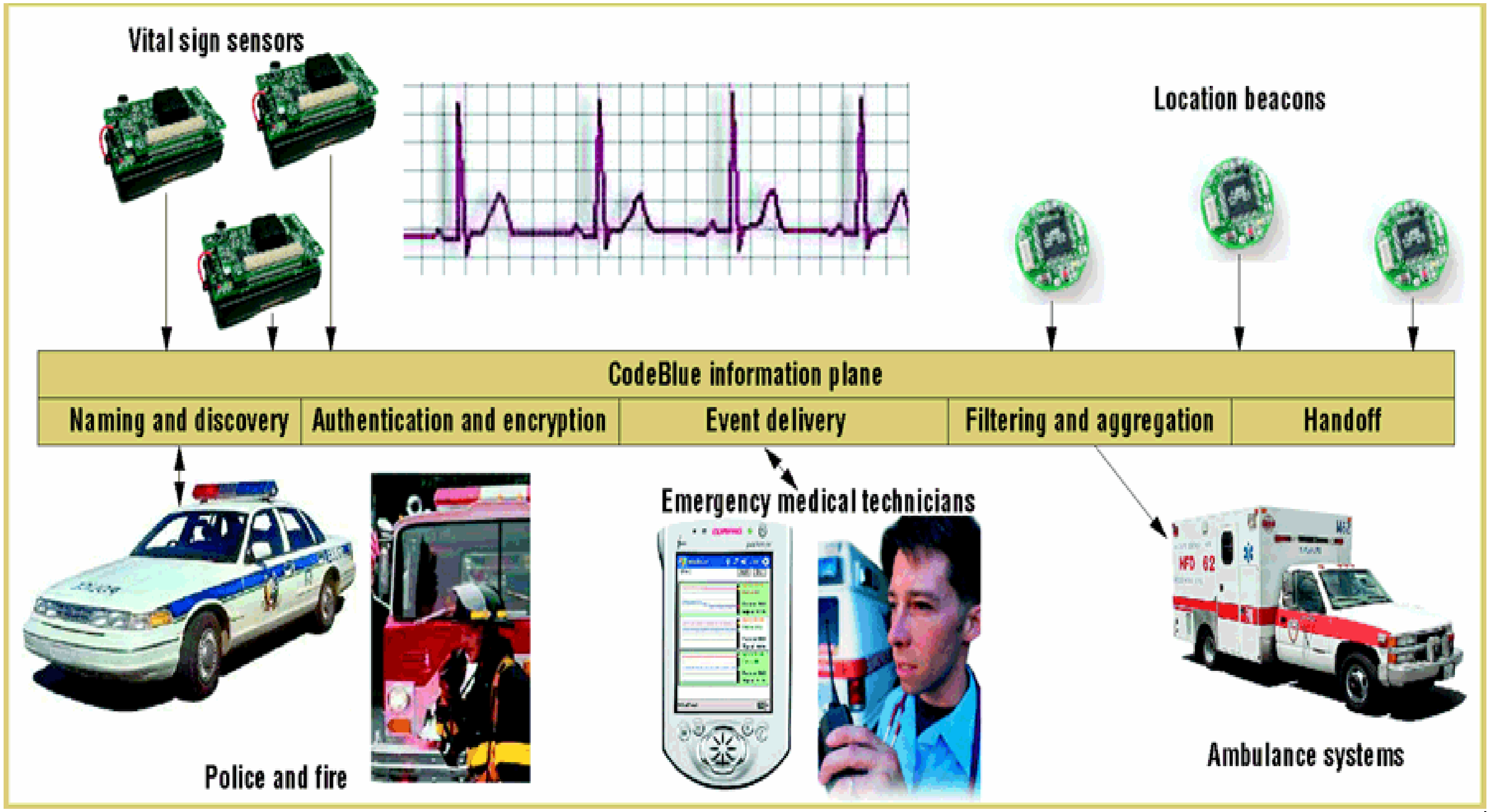
Figure 4 taken from [5]

Medical Monitoring

- CodeBlue [6] which is a wireless infrastructure intended to provide common protocol and software framework in a disaster response scenario.
- Architecture developed at Harvard University which allows wireless monitoring and tracking of patients and first responders.
- This system integrates low-power wireless wearable vital sign sensors, handheld computers and location tracking tags.
- CodeBlue software framework provides protocols for:
  - Resource naming and discovery;
  - Publish/subscribe multi-hop routing
  - Authentication and encryption provisions
  - Credential establishment and handoff
  - Location tracking
  - In-network filtering and aggregation of sensor-produced data.
- A simple query interface allows emergency medical technicians to request data from groups of patients

Medical Monitoring

- **Figure 6 The CodeBlue infrastructure taken from [6]**



Medical Monitoring

- This projects research interests targeted many areas like the
  - Integration of medical sensors with ultra low power wireless networks
  - Wireless ad-hoc routing protocols for critical care
  - Security
  - Robustness
  - Prioritization
  - Hardware architectures for ultra-low-power sensing
  - Computation
  - Communication
  - Interoperation with hospital information systems
  - Privacy and reliability issues
  - 3D location tracking using radio signal information
  - Adaptive resource management
  - Congestion control
  - Bandwidth allocation in wireless networks

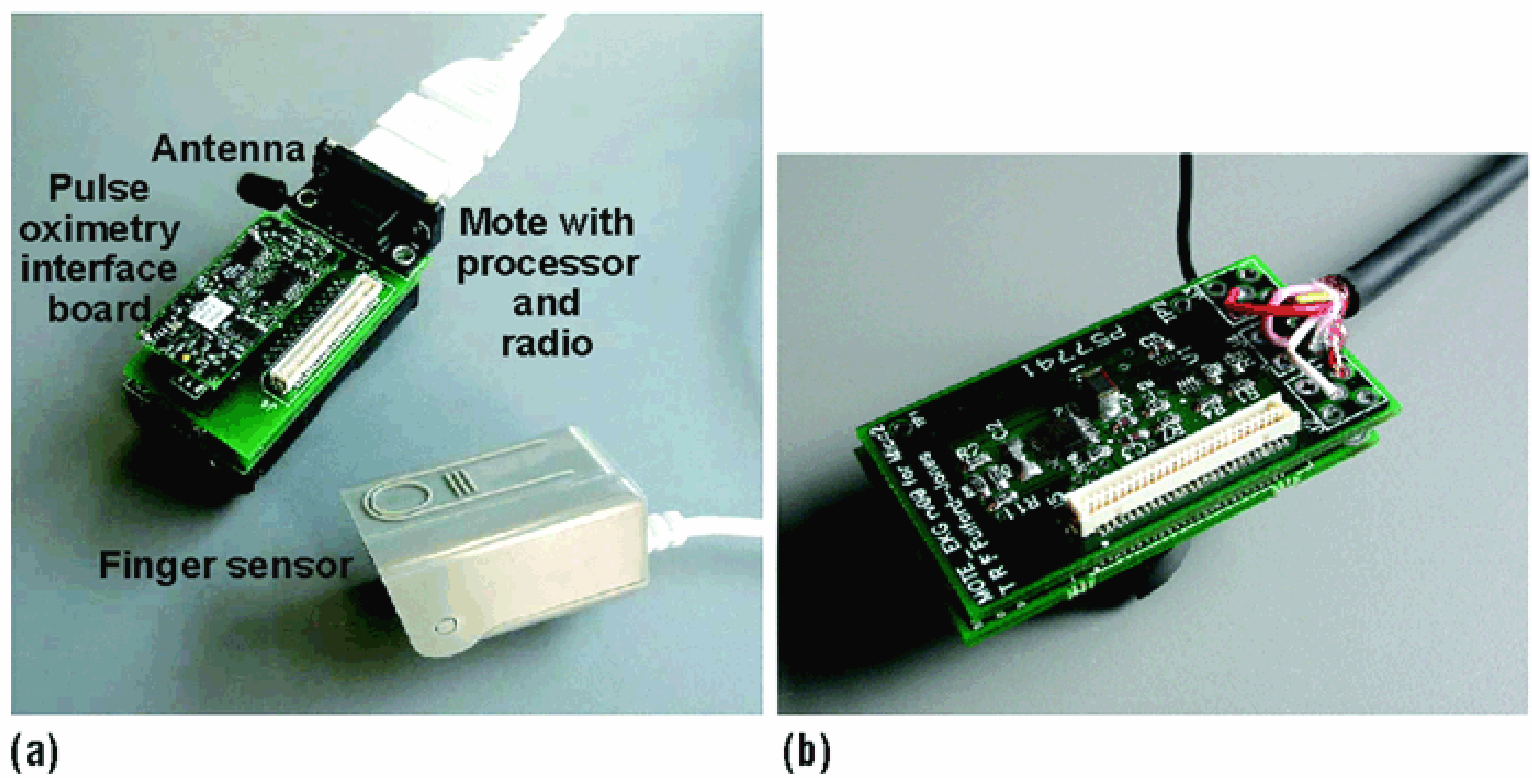
Medical Monitoring

- CodeBlue 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.
- It also operates on a range of wireless devices, from resource-constrained motes to more powerful PDA and PC-class systems.

•Figure7 The screen shows real-time heart rate and blood oxygen saturation data from 3 patients taken from [6]

Medical Monitoring

- **Figure 8 Mote-based (a) pulse oximeter and (b) two-lead electrocardiogram taken from[6]**



Remote Surgery

- Experiments have been performed on the feasibility of remote surgery for more than a decade.
- First trans-Atlantic procedure in 2001 - Lindbergh operation involving a Zeus robot
- The experiment showed that the robot can be well controlled under 500 ms latency [4].
- NASA has conducted Thirteen Extreme Environment Mission Operations (NEEMO projects) since 2001 in its underwater sea habitat, Aquarius in Florida.
- There were 3 focusing on remote surgery recently. The 7th NEEMO project took place in October 2004, and the mission objectives included a series of simulated medical procedures with Zeus, using what is termed teleoperation and telementoring [6].

Remote Surgery

- During the 9th mission in April 2006, the crew had to assemble and install an M7 mobile surgical robot, and perform real-time abdominal surgery on a phantom.
- Throughout the procedure, the time delay went up to 3 s using a microwave satellite connection to mimic the Moon–Earth communication link.
- The 12th project ran in May 2007, where operations were performed on a simulated patient with the M7 and Raven robots.
- They measured the capabilities of surgeons controlling the robots from Seattle in simulated zero gravity environment.
- These projects showed the effectiveness of telementoring, the possibility to operate even with 1 s of latency and proved the capabilities of the new robotic systems.

Remote Surgery

- Remote surgery brings many new challenges compared to conventional robotic surgery.
  - First, remote operate over long distances, the remote surgery system should be
    - Stable for the large latencies experienced over global-scale operation
    - System must also be stable in the presence of the jitter and packet loss characteristics of usual Internet traffic.
  - Second, during communication blackout, a backup system should be in place to complete any ongoing surgical procedures and in the absence of force feedback, the surgeon remotely operating the robot relies on stereo video feedback.
  - Finally, it is beneficial to provide haptic feedback to the surgeons, since it helps minimize damage to the tissues and organs during long-distance procedures

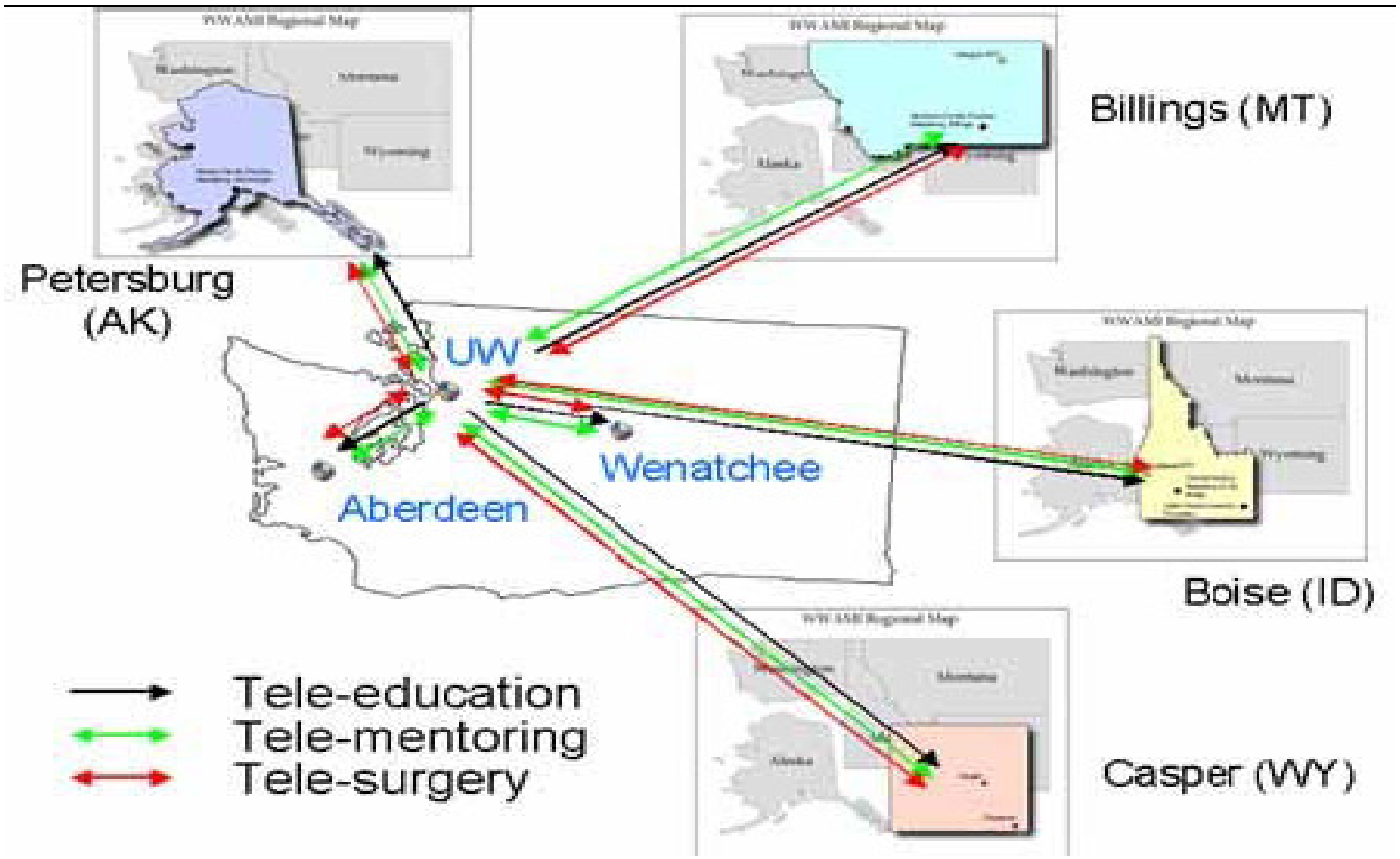
Remote Surgery

- Telementoring - an advanced form of telemedicine, where an experienced surgeon can guide and teach practicing surgeons new operative techniques utilizing current enabling video, robotics, and telecommunications technology.
- Surgical telementoring is very significant because it offers a technological solution to places around the world where few if any surgeons exist.
- Some of the advantages offered by this concept are
  - Enhancing surgeons' education
  - Increasing patients' access to experienced surgeons
  - Decreasing the complications due to inexperience with new procedures

- A system currently being used between Seattle, WA and Aberdeen, WA. combines the well-established telemedicine networks (WWAMI program) with SOCRATESTM an FDA-approved, surgically-dedicated industrial system for improving patients' healthcare and enhancing surgical educations in the operative sites.[12]
- This program has potential to bring enormous benefits to patients obtaining consultation and supportive care from highly experienced surgical specialists, while remaining within the care of their local surgeons and institutions.

Remote Surgery

- **Figure 9 Overview of global WWAMI network taken from[12].**



Remote Surgery

- The SOCRATES™ [12]links both sites with a PolyCom FX: PolyCom FX has four ISDN lines with 512 kilo-bits per second (Kbps). The PolyCom FX was chosen because it independently bridges up to four sites, and has the capability to utilize H.320 (i.e., ISDN or T-1 lines) or H.323 (i.e., internet) protocols.
- This helps each site provide video teleconferencing over the internet, which would be of great value if any of these sites decide to implement an intranet-based video teleconferencing system within their institutions. It is also supported for mobile use and PolyCom Viewstations.

Figure 10 The SOCRATESTM Robotic Telecollaboration System taken from [12]

Security

- Security is an important issue within remote medical care.
- Areas like access control and privacy are most important to hospitals.
- These issues are hard enough to control when the patient is located in a traditional setting at hospital, but they become more complex when the patient is located at another medical facility or within their home and the physician is not authenticated within that facilities computer system.
- The problem becomes even worse when sensor systems are used for home healthcare, including wireless security and the transmission of daily activity information.
- Healthcare Insurance Portability and Accountability Act of 1996 (HIPAA) - current privacy and security regulations for hospitals and patients
- HIPAA defines privacy as an individual’s interest in limiting who has access to his personal healthcare information and specifies that security measures must encompass all the administrative, physical, and technical safeguards in information.
- The government defines security as the protection of information and information systems from unauthorized access, use, disclosure, disruption, modification, or destruction in order to provide confidentiality, integrity, and availability.
- Security issues usually occur in medical offices where more than one person is responsible for collecting and entering clinical data, so it can be difficult to determine the author of entries in a paper chart, but in remote systems the person id is recorded and saved to database tracking tables.

Security

- The 2 main security concerns or electronic health records are transmission and access.
  - Access security is the healthcare delivery organization’s ability to ensure that system access is granted only to appropriate individuals.
  - Transmission security is the healthcare delivery organization’s ability to ensure that transmitted data is safe from potential security threats during its transmission.

- Concerns about transmission security occur during a wireless network implementation.
- The Wired Equivalent Privacy (WEP) protocol was designed to provide the same level of privacy as a wired network, but due to security concerns over the WEP standard, experts continue to debate whether WEP alone is sufficient for HIPAA transmission security.
- Because of this healthcare organizations are forced to use a hybrid of WEP and other security protocols for wireless networks.
- In an ambulatory practice, management of a healthcare organization is done by the physician owners.
- The owners can grant remote access to EMR systems via a point-to-point connection or over the Internet.
- The point-to-point connection is usually a direct T1 or dial-up connection which offers inherent transmission security.
- The healthcare organization must take steps to ensure that all data transmitted is secure over the remote access that it is providing.
- HIPAA guidelines it states that SSL is a minimum requirement for all Internet-facing systems which manage electronic patient healthcare information.
- EMR”S security policy is based on role based security model where employees are defined as clinical staff, management, IT staff; and administrative staff. In order to gain access to the EMR each user and role must be authenticated.

Security

- The HIPAA rules also apply to Wireless Body Area Network (WBAN) systems.
- These systems involve the communication of health-related information between sensors and servers, all communication over WBAN and Internet should be encrypted to protect user's privacy.
- Uses of public and private key encryption are addressed in several recent studies.
- In TinyECC [1] authors report running times of 6.1 seconds for signature generation and 12.2 seconds for signature verification using 160-bit keys, on the 8-bit Atmel ATmega128 CPU of Crossbows MICAz platform.
- In [10] the authors present a protocol based on TinyECC for securely establishing a communication channel to a base station using ECC (Eliptic Code Cyrptology).
- In [4] ECC implementation on MICAz nodes with a performance of 1.96 seconds is achieved. The results reported in these early studies are encouraging, but more research on private-key and public-key cryptography schemes for sensor networks is needed.
- Such encryption schemes must be integrated into an appropriate authentication and authorization framework.
- The security requirements in brief are:
  - Secure communication links with healthcare providers
  - Robust network security
  - Secure sensing and monitoring devices (4) Stronger patient-provider authentication.

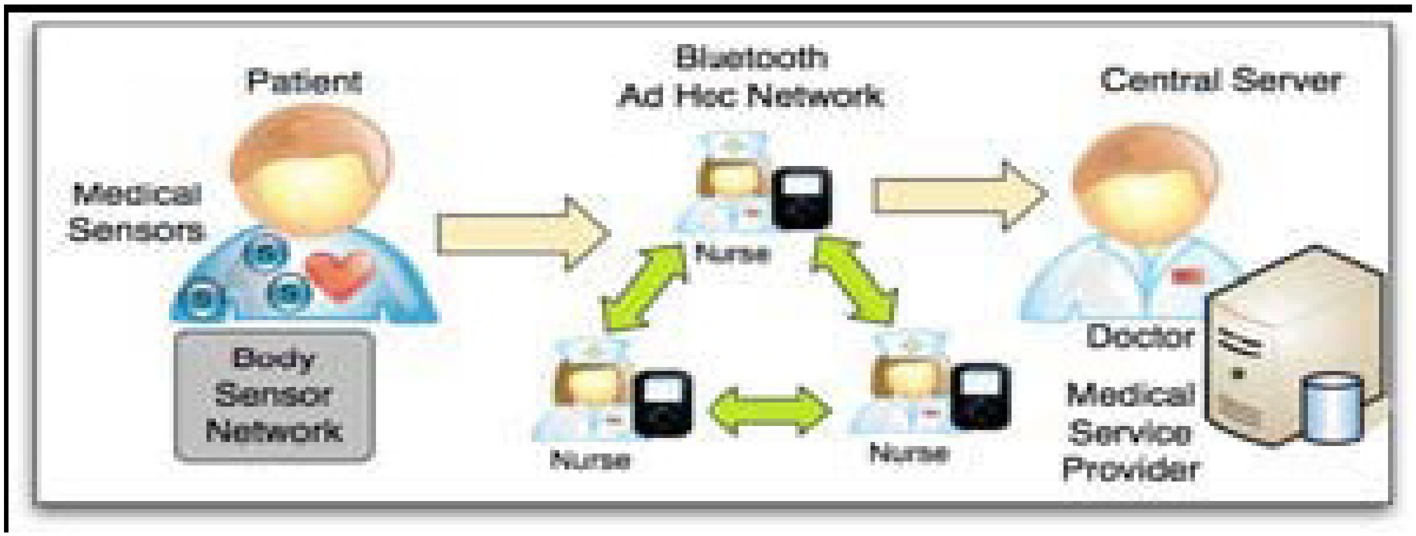
Support

- Support care networks are used for the cooperating and sharing of information among different stakeholder’s doctors, nurses, patients and families with the common goal of improving patient quality of life.
- One such system is a service-oriented mobile multichannel context-aware architecture, called ERMHAN (Emilia Romagna Mobile Health Assistance Network), that provides services for care network support.
- Its purpose is to create an extensible set of services allowing patients to stay at home in a familiar environment while being cared for, and at the same time support the cooperating activities of care providers working in mobility, in different organizational domains and with different roles, towards the improvement of the patient’s life quality.[3]

Support

- A Bluetooth-based Health-Net architecture for patient monitoring, data recording and alarm dissemination. Data collected by body sensors can be sent to the provider host by many different ways like 3G, 802.15.4, WiFi and Bluetooth.
- The problem with these systems is that they are not allowed in hospitals.
- Cell phones and WIFI interfere with medical equipment ZigBee is not used because of scarce commercial penetration and significant interference vulnerability to WiFi interference.
- Bluetooth appears to be the option for P2P data exchanges (patient to patient; patient to nurse; nurse to nurse) especially in a system called NurseNet.
- NurseNet [14] architecture consists of 3 components – patient, nurse, and AP/Central Database/Doctor all equipped with a Bluetooth device.
- Patients have sensors attached to their body, and the data collected from sensors is stored on a Bluetooth-enabled mobile device.
- Patient's device passes the medical data to a caregiver (say, nurse) device that then transfers the stored data over Bluetooth P2P to the database.
- This delivery can occur either directly (i.e. the same caregiver receives and then delivers the data to server), or indirectly, (i.e. two or more nurses help each other transfer the data to the server).

Support



- In a real world scenario NurseNet could be used by the military in a MASH unit.
- Basically a tent with patient beds located a few meters apart with nurses walking around.
- While doing rounds the nurses download their records.
- At the office they upload the patient data to the medical database.
- Nurses can share data among themselves in a P2P manner.
- A patient cannot share data with other patients because of privacy and security reasons.

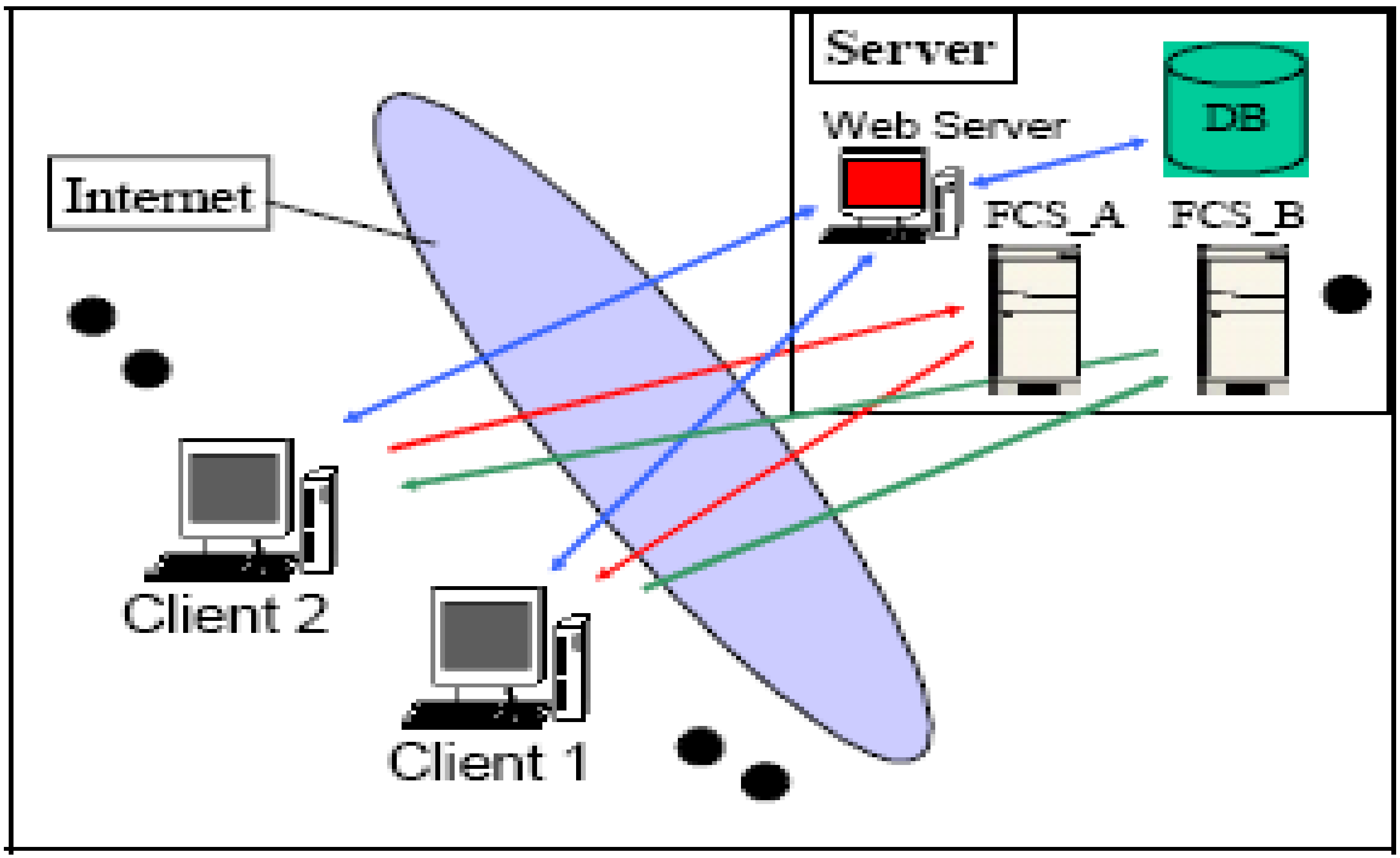
Support

- In contrast to systems based on bluetooth other remote medical support systems use a more hybrid design that combines the internet and cell phone usage for communication.
- This system is also different from others because it uses a doctor agent for dispensing advice.
- This system consists of a
  - Communication subsystem,
  - Vital signs data auto-uploading
  - Referring subsystem

- The communication subsystem has a multi-point communication function by using video images and voice.
- The system also has a function for providing and storing the medical-care data in a database.
- The subsystem uses a Web server and Flash Communication Servers (FCSs).
- The clients are simple Windows-XP PCs.
- The Web server contains the database that stores medical-care data. The system environment is shown in the figure and table below

Support

Figure 13 Structure of communication subsystem taken from [15]



Support

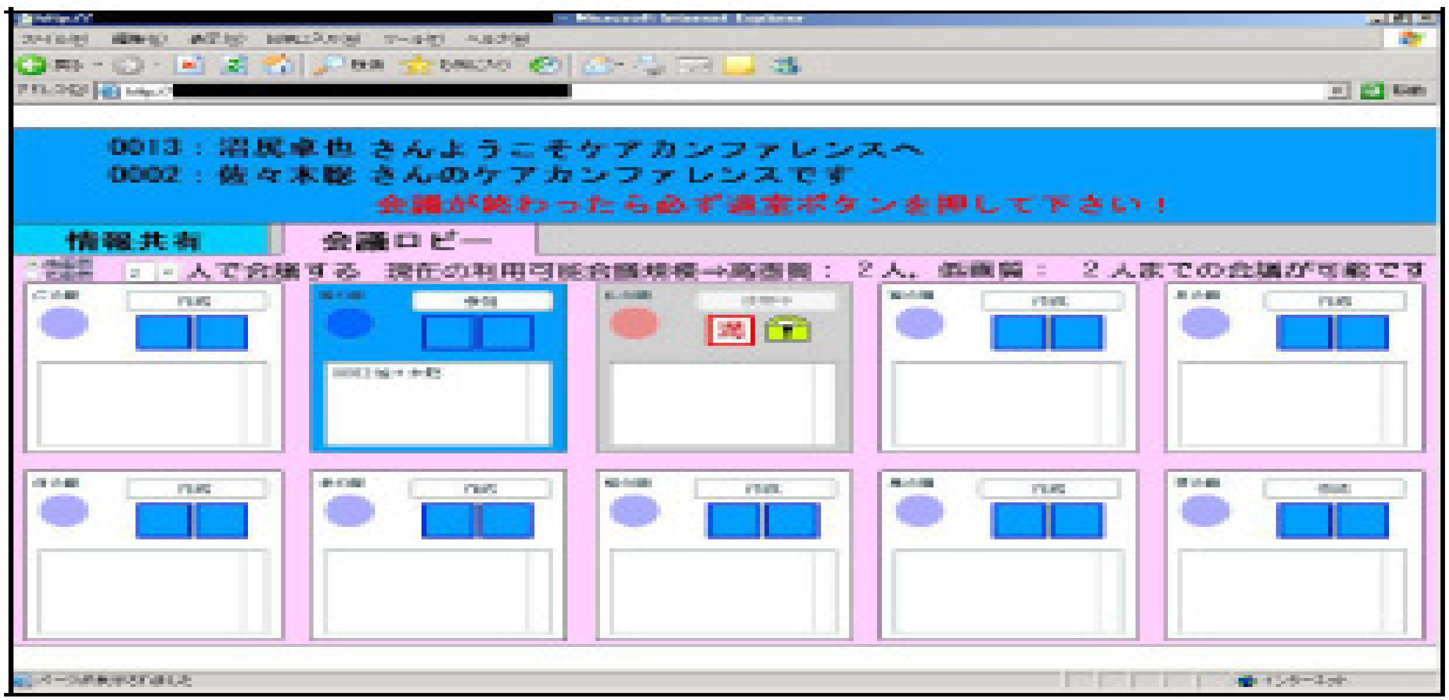
Table 1 System environment taken from [15]

Server / Client	Language	Environment
Client	Flash Action Script 2.0	Web browser with Flash Player 7
Flash Communication Server (FCS)	Action Script	Windows XP Professional
Web Server	PHP5.0.4	Apache1.3.3 on Vine Linux 3.1
Database	PostgreSQL	PostgreSQL8.0.1 on Vine Linux 3.1

Support

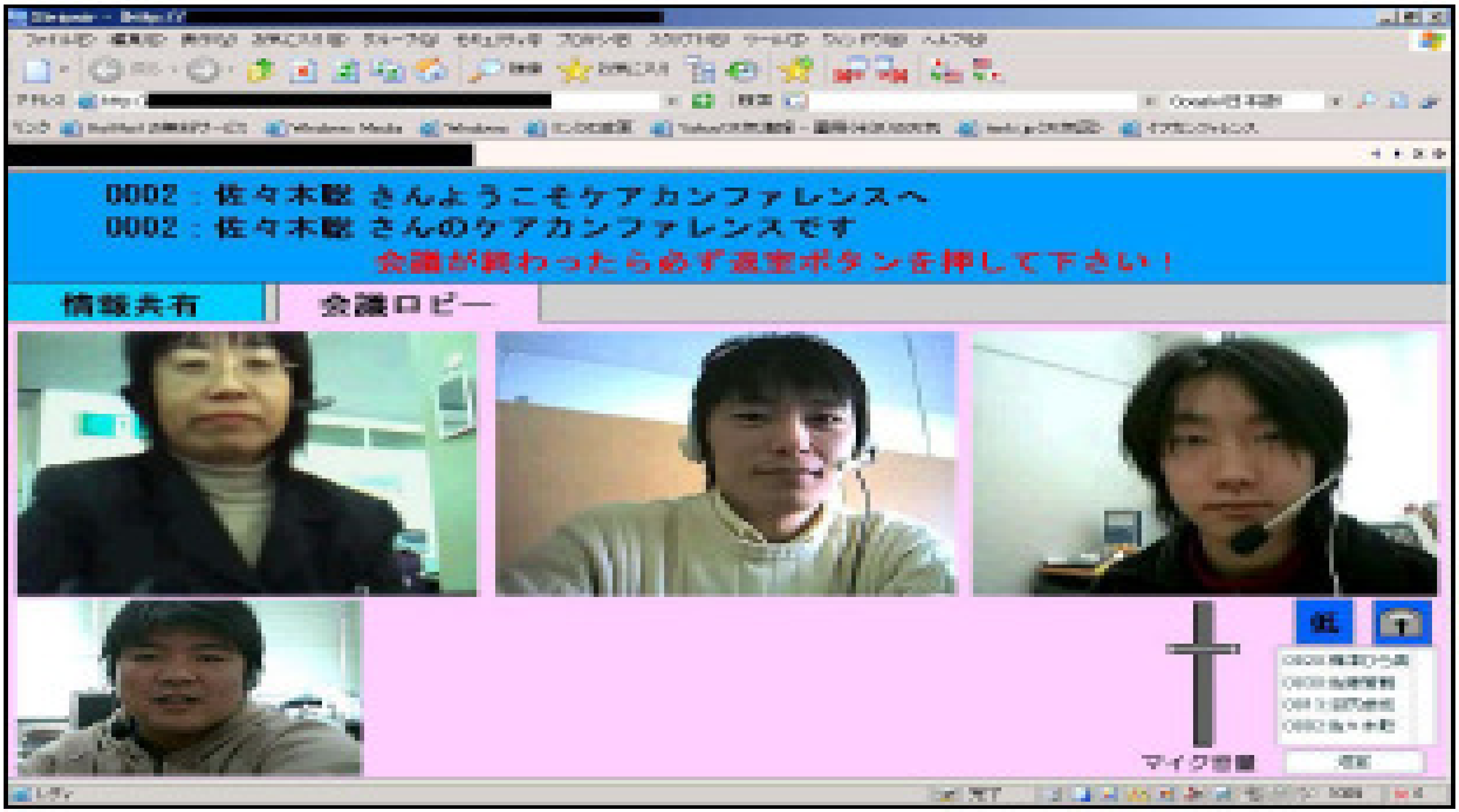
- System provides operations having many groups hold a conference simultaneously.
- Done by distributing the video images in several servers such as FCS_A, FCS_B and so on.
- Medical-care materials can be shared between conference participants.
- In the figure below the interface of a waiting room is shown as well as the conference room and medical care materials. The subsystem holds 10 group conferences at the same time.

Figure 14 Waiting room taken from[15]



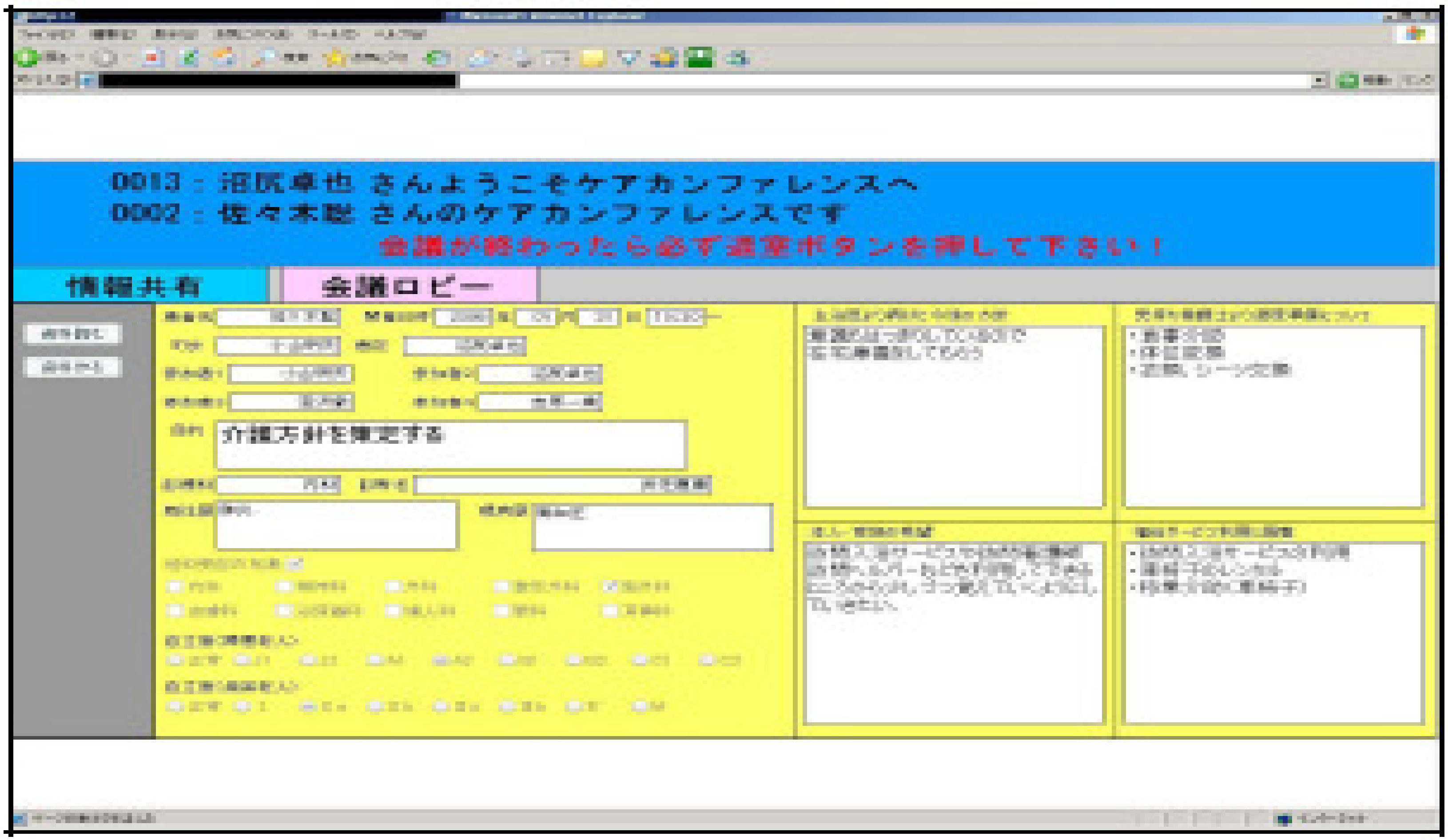
Support

Figure 15 Conference room taken from[15]



Support

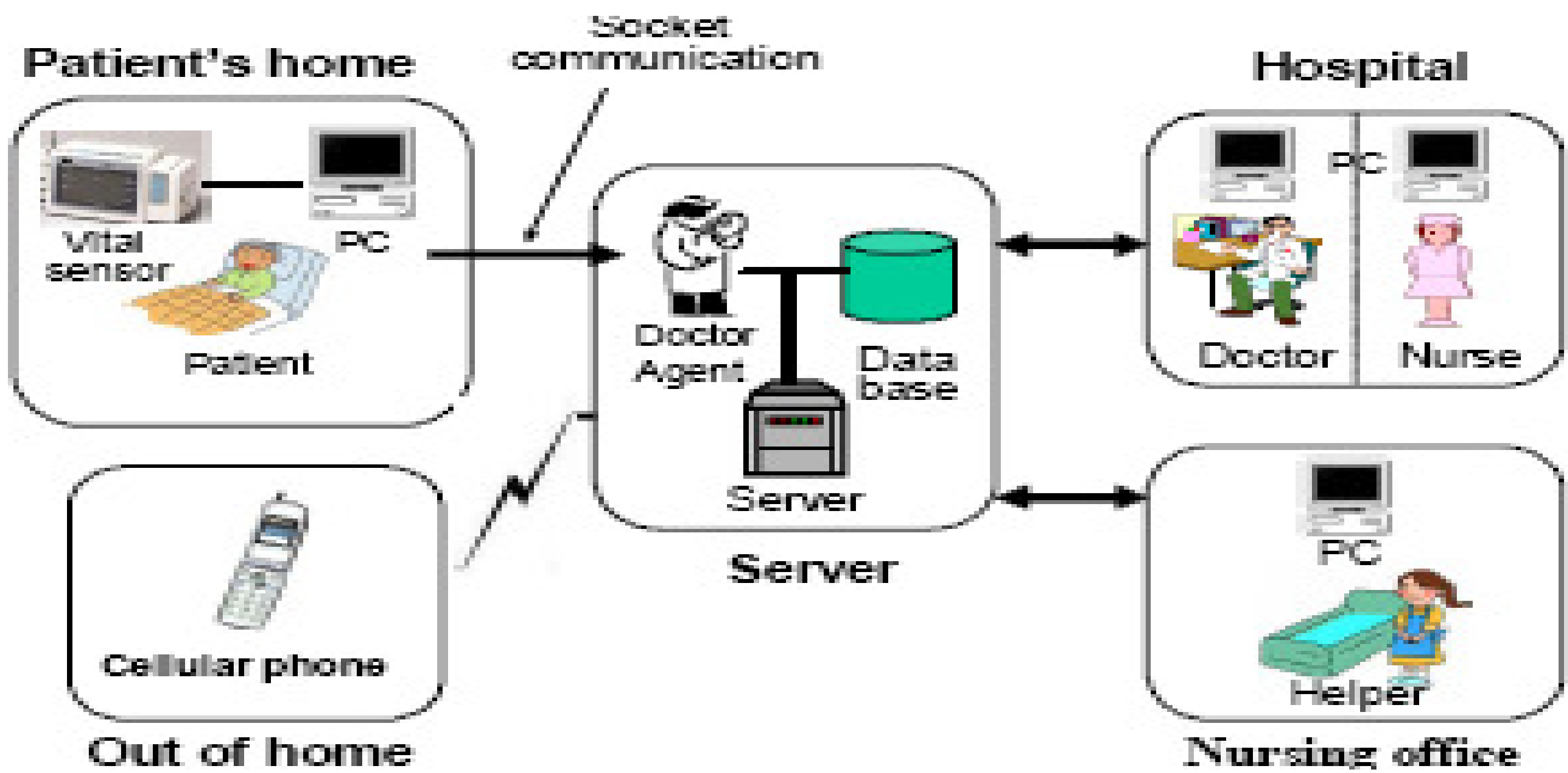
Figure 16 Medical care materials taken from[15]



Support

Vital signs data auto-uploading and referring subsystem uses as clients the vital sensor, Windows-XP PCs and cellular phones, while the Linux machine is used as a server. The subsystem structure is shown below:

Figure 17 Structure of vital signs data auto uploading and referring subsystem taken from [15]



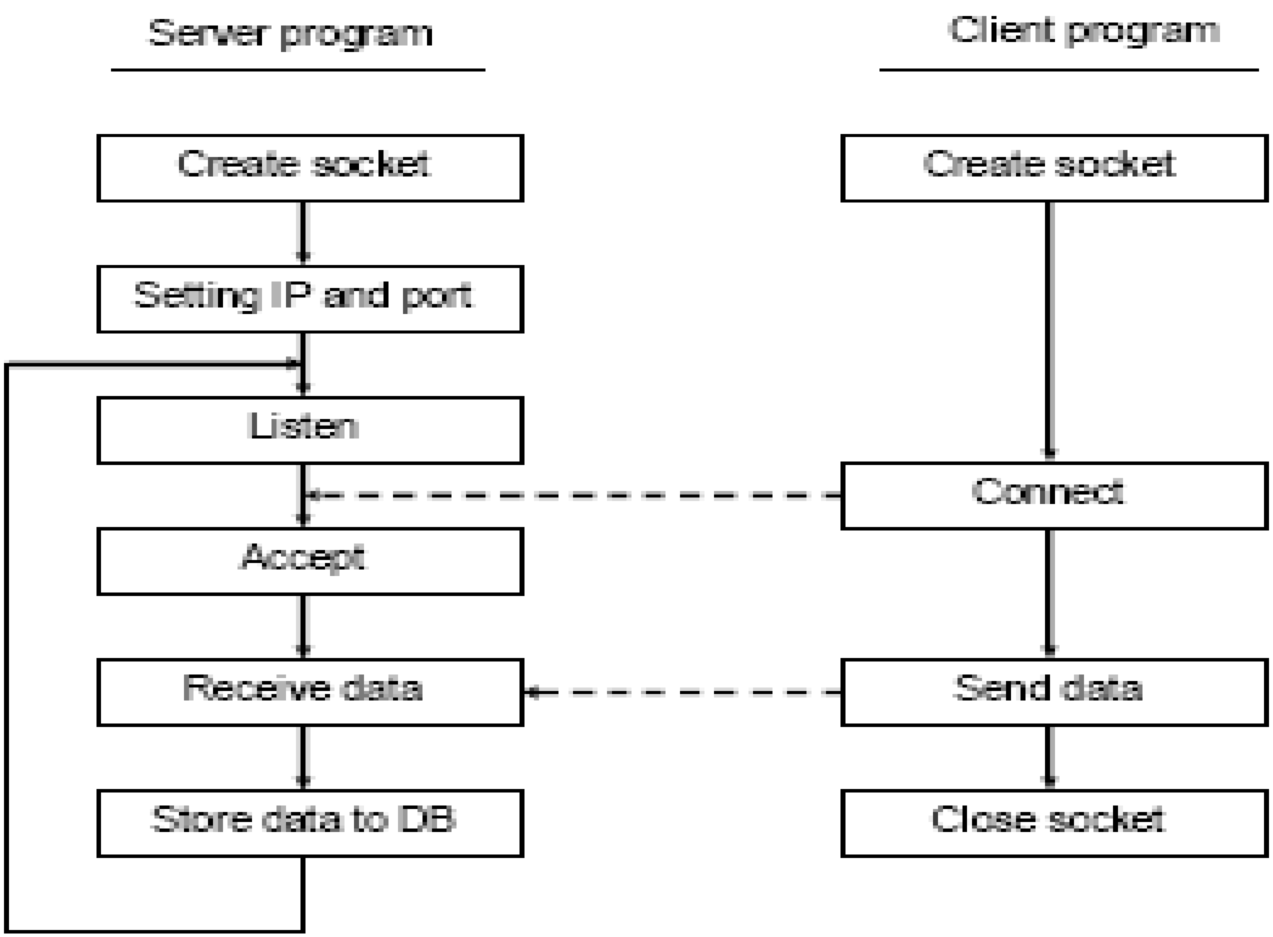
Support

An RS-232C serial interface transmits the vital signs data from vital sensor to the local PC. The measured results of the vital sensor are sent to the PC in csv format and are saved in the PC.

Figure 18 Vital sensor taken from [15]

Support

Figure 19 TCP socket communication taken from[15]



Conclusion

- Future of remote medical care is boundless.
- A growth industry that will save millions of dollars & lives.
- Entering a period where science fiction meets science fact.
- Currently robots are making medical rounds in hospitals
  - Visiting with patients
  - Perform remote surgery.
- Future physician may never physically meet any of his patients.
- Possible that the hospital of the future may be your own home.
  - A place where during a doctor's visit you will sit in a recliner talking with your physician through your Internet enabled TV
  - You will still wait an hour before seeing the doctor, but you will be comfortably in your own home and not in a doctor's office.

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