Biomedical Engineering Sciences

Hospital at Home

Topic 1

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1. Introduction

Vision

Hospitals mean the place when we can gain back our health. However nobody wants to spend longer time at these healthcare institutes, when it is not needed, because people feel more comfortable at their own home. We should also mention the risk of severe infections in hospitals. Furthermore it is more economical to discharge treated patients as early as possible, so this is the interest of insurance companies too. However, the risk of re-hospitalization must be as minimal as it can be.
A solution can be using a sufficient monitoring system at home. There are several kinds of mobile healthcare devices, which can be used at home under professional supervision. They are called Personal Health Devices (PHDs). We decided to develop an Android application which can ensure a reliable, standard-based data transmission between Personal Health Devices and mobile phones/tablets and which is able to transmit the measurement results to the server of a telemedicine centre in a relevant hospital.

Goal of the project

This project intends to implement the Hospital@Home system to enable mobile healthcare devices and patients to monitor the vital bio signals of patients after discharge. It can minimize the risk of re-hospitalization and it is also economical for the healthcare system. Purchasing the necessary devices and implementing a telemonitoring system costs lesser in comparison to maintain a bed in a hospital. Furthermore the patients can feel themselves in safety at their ordinary environment.
The system will use medical devices and mobile platforms to transmit the vital data to the care centre in the hospital where physicians can analyse the incoming data and react if it is needed. They can call the patients on their mobile phones or in case of emergency they can send an emergency car to the home of the patient.
The system should be modular in the term of architecture to provide option for further extensions. To fulfil the demand of interoperability we need to implement the communication and data transmission in a standard based way. Therefore we are planning to use IEEE and IHE standards and the guidelines of Continua Health Alliance during the development.
The project cooperates with our partner UTAD university in Vila Real, in Portugal and in the next semester we will work together with a Master Student from the Electrical and Computer Engineer Master Program. Through the existing cooperation between UTAD university, CHTMAD Hospital Centre in Portugal, and UAS Technikum Wien, it is possible to setup a laboratory at the CHTMAD hospital for testing the technologies developed within this project.

State of the art

Telemedicine in general

“Telemedicine is the use of medical information exchanged from one site to another via electronic communications to improve a patient’s clinical health status.” This definition stands at the homepage of the American Telemedicine Association. One field of telemedicine is remote patient monitoring which uses devices to remotely collect and send data to a home health agency for interpretation. These applications include specific vital signs, for example ECG. Such services can be used to supplement the use of visiting nurses. [1]

In the future of healthcare systems home care and home monitoring will have a fundamental role: “Ultimately, health care organizations that do not adapt to the home care imperative risk becoming irrelevant. It seems inevitable that health care is going home.”-says the New England Journal of Medicine. [2]

The European Health Telemetics Association made the first eHealth action plan in Europe. [3] It introduced electronic prescriptions and health cards to new information systems that can reduce errors and waiting times. The second plan is for the years 2012-2020. The goal is to provide smarter and safer health services. Furthermore it includes mobile health (mHealth) too. [4]

Products available on the market

PHM (Patient Home Monitoring)

PHM is an acquisition-oriented, fast-growing and profitable company offering patients with heart disease and other chronic health conditions home-based services in the US. [5] According to their webpage they are in the state of finding investors, so it is only a vision for the future.

Philips

Philips is one of the leading healthcare companies and it also offers home monitoring systems. They have 2 main products: Philips Telecare and Philips Telehealth.

The Telecare system means a simple emergency button, which alerts the hospital if somebody needs medical help. [6]

In the Telehealth system patients can choose from several medical devices such as scales, blood pressure monitors, ECG Rhythm Strip Recorder or Pulse Oximeters. The TeleStation collects the vital sign data from the mentioned devices via wireless connection. It also prompts patients to answer health assessment survey questions. The web-based Clinical Software streams the vital sign data to the physicians or nurses. The process is the following: the telehealth equipment is installed to the patient’s home. After that the patient can send his or her vital signs to a website of a home health agency. The telemonitoring nurse monitors the patient daily and alerts the patient and care team when results fall outside pre-defined limits. [7]

VitalPoint® HOME Monitor

VitalPoint® HOME is a revolutionary remote patient monitoring system that connects patients in the comfort of their own homes to their health care provider's office. They offer a single-unit device which measures blood pressure, blood oxygen saturation, pulse rate, weight, glucose level, prothrombin time, temperature and fluid status, furthermore it collects electrocardiogram data. [8] Their system consists of the medical device and the so-called Remote Doctor Consultation (RDC) software, which allows physicians and patients to make remote consultations.

Herzmobil Tirol

In the Herzmobil Tirol project [9] a Tele-Monitoring-System for Cardiovascular Disease was developed.
It supports communication between patients and physicians and it can be used for the management of heart failure therapies.
After discharge from the hospital the patient get an NFC enabled mobile device for monitoring blood pressure, body weight and medication.

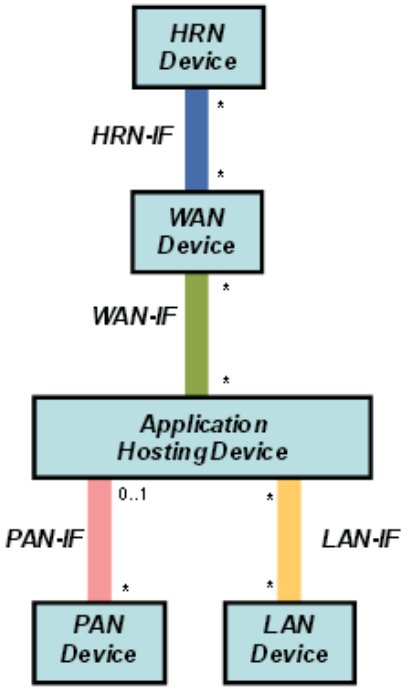
Technologies in use

Device connectivity

This section contains Design Guidelines that apply to PAN (Personal Area Network) physical devices. These can be personal healthcare devices or Application Hosting Devices. Figure 1 shows the reference architecture of Continua Health Alliance.
In general, device Design Guidelines are kept in the section corresponding to the standard that applies to the guideline. However, these Design Guidelines apply generically to devices in the PAN interface.

The Continua 2012 Guidelines incorporate the following new features:

- Three new device classes for the wired (USB®)/wireless (Bluetooth®) PAN as well as Sensor LAN (ZigBee®) interface: Basic 1-3 Lead ECG, Body Composition Analyzer, and Heart Rate Sensor
- Two new device class for the low-power wireless PAN (Bluetooth® Low Energy) interface: Blood Pressure Monitor, and Heart Rate Sensor
- A revision of the Glucose Meter device class for the wired (USB®)/wireless (Bluetooth®) PAN as well as Sensor LAN (ZigBee®)interface
- Consent enforcement on the HRN interface. [10]



1. Figure: Continua reference architecture [10]

Continua Alliance has selected the following wired and wireless solutions to serve as the Continua transports for the PAN interface:

- Wireless – Bluetooth Health Device Profile for Wireless PAN and Bluetooth Low Energy (LE) Services and Profiles for the Low Power (LP) Wireless PAN
- Wired – USB Personal Healthcare Device Class [10]

Wide Area Network

In the Continua End-to-End Reference Architecture, the WAN Interface (WAN-IF) connects an Application Hosting Device (AHD) to a WAN Device (WD).

The Continua WAN-IF Design Guidelines are focused on enabling the interoperable transmission of messages related to device observations across a Wide Area Network. By enabling Continua device data to be securely and interoperably exchanged, personal health data can be liberated from the dead-end of device displays in order to provide insight to service providers and care specialists. This information can be used to drive more intelligent processes that will reduce overall cost and improve the health and wellness of consumers. [10]

Health Record network (HRN)

The purpose of the HRN interface is to transfer patient information from a Continua WAN device (HRN Sender) to either another WAN device or an electronic health record device (HRN Receiver). The WAN device (HRN Sender) can be the Remote Patient Monitoring (RPM) server of a Disease Management service provider or the Application Server of an Aging Independently or Health & Fitness service provider. The patient information for transfer may include a report summarizing the patient‘s current status, a detailed listing of specific patient results, readings from one or more personal health devices, or a combination of these. The electronic health record device may contain a hospital‘s Enterprise Health Record (HER), a physician‘s Electronic Medical Record (EMR) or a Personal Health Record service (PHR) used by the patient. [10]

Research reports, recent findings

E-Care at a Distance: Opportunities and Challenges

This article has reviewed care-at-a-distance programs that use technologies to reach patients at home and in underserved regions. Many programs have been shown to result in both positive patient outcomes and reduction of costs. The majority of the published articles show the effectiveness of such programs. However, the literature also shows that better-designed, controlled studies with larger numbers of patients are needed to allow replication of programs in other regions. Major drivers in the development of this field include new communication technologies, particularly mobile devices, new interoperability technologies, and growing evidence on effective implementation. Major challenges include the need to implement complex privacy and security requirements, data integration, licensing and credentialing, and reimbursement. Growing populations coupled with a limited number of healthcare providers pose both a challenge and an opportunity for finding innovative ways to deliver affordable and effective health care. Continued investments in research and implementation are necessary to reach scalability of solutions to meet global needs. Measuring outcomes will be key to providing evidence for the future growth of these coordinated care networks. [11]

Efficacy of Hospital at Home in Patients with Heart Failure

Conclusions The literature to date on Hospital at Home in Heart Failure patients is limited and based on small studies of modest quality that lack standardized definitions and interventions. In the context of these limitations, Hospital at Home appears to increase time to readmission, improve health-related quality of life, and reduce costs of index hospitalization compared to routine hospitalization

in select patients with decompensated HF. Hospital at Home does not significantly reduce readmissions or mortality, but the present study is underpowered to detect a statistically significant difference in these outcomes. Larger clinical trials are warranted to assess the effect of Hospital at Home schemes on clinical outcomes and long-term costs to health care systems. [12]

Future trends, visions

1. Increasing acceptance as a standard of care

Medical imaging was the first field to fully embrace telemedicine, and medical professionals have relied on long-distance transmission of imaging for more than four decades. In its infancy, the practice was referred to as “teleradiology”: sending x-rays from facility to facility for fast use and analysis. This practice is so common today that the term is barely recognized; it’s become a de facto standard in almost all hospitals. Today x-rays, CT scans, MRI results, and other information is routinely shared by medical practitioners separated by hundreds or even thousands of miles. As this kind of sharing becomes the rule rather than the exception, one can expect to see it addressed and assumed in the regulations which govern healthcare at the state and federal levels. [13]

2. International collaboration

In its infancy, the use of telemedicine across national borders was relatively rare. A few pioneering charities made use of it to allow long-distance analysis of medical data. Now that worldwide data transmission networks are much more robust and medical regulations have grown familiar with telemedicine, the infrastructure is in place to deliver much better medical care to foreign countries. While there are definitely still issues to overcome, (e.g. cultural bias, trade policies, payment schemes, and international certification) the profit potential of long-distance medicine is becoming enormous. The sheer possibilities will lead healthcare providers to iron out the last difficulties, making international medicine a common practice in the future. [13]

3. Mobile health

Commonly referred to as mHealth, Mobile Health is one of the most exciting new ramifications in telemedicine. The possibility of widely distributing medical information to individuals (both practitioners and patients) using mobile technology is extremely promising. The possibilities are vast and encouraging, even though a thorough understanding of how these programs should work (and be paid for!) is still years away. The continuing growth of wireless communications technology will doubtless help bring mHealth initiatives to maturity in the years to come. [13]

4. New remote clinical services

Since radiology has proven to be such an effective field for outsourcing via telemedicine, many hospitals are now looking at the possibility of splitting off many other specializations. Psychiatry, neurology, and many other disciplines are ripe for decentralization employing telehealth practices. [13]

5.Transforming healthcare delivery and payments

It’s a development of a technique that allows to receive health care and health consulting remote and pay for that remote instead visiting the clinic and reduce the effort on the patient. [14]

Analysis

User requirements

In this project there are agents and managers who are communicating with each other. Personal Health Devices can be considered as agents and tablets/mobile phones behaves like managers who are running Android based manager applications. They have different resources and requirements.

- **Agents typically have:**
  - Limited capabilities (RAM, ROM, CPU)
  - Connection to a single Manager
  - Limited power resource (small battery)
  - Low cost (consumer device)
  - Fixed configurations (data type and format does not change)
  - Intermittent connections (disconnect when inactive)
- **Managers typically have:**
  - Richer capabilities (RAM, ROM, CPU)
  - Connections to multiple Agents
  - Wall power or larger batteries
- **Exchange protocol:**
  - Places more burden on Managers than Agents
  - Supports multiple data types (episodic, streaming, store and forward)
  - Designed to be transport portable (Bluetooth, USB, etc.)
  - Optimizes data exchange
  - Enables efficient reconnections
  - Targets personal health in home and mobile environments. [15]

The telemonitoring team and their roles

Telemedicine is the future of healthcare in this time due to the fact of provision in effort and money and reduce the dangers of infections resulting from the stay in the hospital. [16]
At present we discuss in our project general patient monitoring without the need of patient staying in the hospital.
All patient monitoring steps at home require cooperation between the patient and the team members who are responsible for the care of the patient. Four kind of roles can be differentiated in the telemonitoring process: patient, physicians in the hospital, care givers at home and telehealthcare professionals.

Patient

The patient stands in the middle of the system, because his or her wellbeing is the most important for everyone in the group. In case of telemonitoring the patient has more responsibility for his or her own status than usual, because he or she has to carry out measurements in a predefined order and he or she is the responsible for monitoring his or her own vital signs. Of course if the patient is not able to do it he or she can ask for professional caregivers who will visit him or her and carry out the necessary examinations.

Traditional scenario of medical care in hospitals when patient arrives to the hospital suffering from an acute sickness or a sudden medical condition of high glucose or high pressure and many others disease, emergency department will receive the patient apply first aid to stabilize his or her status. Then the supervisor doctor orders a group of necessary tests which differ according to the patient's condition. So it's varying from blood tests to radiological images and measure bio signals of patients.

After identifying a pathological problem, the medical staff in the hospital makes the necessary treatment steps for the patient then the patient is transferred to a room in the hospital to follow up the his or her situation continuously. After passing the patient from the dangerous phase, he or she stays in the hospital for a period ranging between 3 to 5 days to monitor the vital signals and make sure that the life-threatening phase is over. This time costs a lot of money for the healthcare system in comparison to carry out monitoring at the patient's home.

So the idea behind our project to transfer the patient to his or her home after making sure that he or she has passed out of danger and continue the monitoring at his home. It is necessary to send the measurement results to a doctor or a telehealthcare professional in the hospital and follow their instructions constantly.

Monitoring patients at home is very effective who had sudden pathological problem that disappear when its cause disappear, so usually in case of acute diseases. However it is not very effective with chronic patient who face chronic diseases like cancer because in this case the possibility to return he patient to the hospital is very high. The risk of emergency cases is relatively high too, for that the project will lose its basic idea to reduce treatment costs because readmitting patient will cost more money.

Physicians

The profession of doctor of medicine covers all activities based on the findings of medical science carried out directly on patients or indirectly for patients. In particular, they include examinations for the existence or absence of physical and mental diseases or disorders, disabilities or malformations and anomalies of a pathological nature, treatment of such conditions and prevention of diseases. [17] .

And we mean here the doctors in the hospital who decide if it is possible to continue monitoring the patient at home and decide the time to discharge the patient from the hospital. After discharging the patient from hospital it is possible this doctors to be telemedicine professionals who follow the results of the home monitoring (vital signals to the patient or others) for the patient. The doctors are

responsible for the decision to readmit the patient to the hospital when needed and instruct about the medication that the patient should take; they also send instructions for the patients at home and for care givers.

Care givers

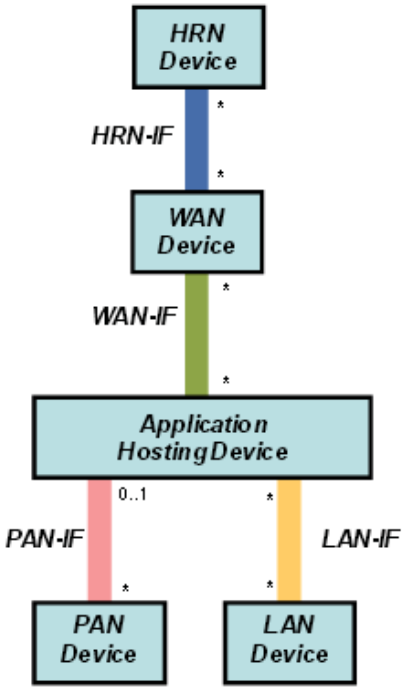
While patient at home it is necessary to have a care provider accompanied the patient at home ,this care provider can be home health nurse caring for a patient in his home , the nurse who is already on-site is able to obtain a diagnosis and begin treatment quickly for the patient. She can administer the medication under the direct supervision of a doctor who may be hundreds of miles away. [18]
The home health nurse follows the patient's situation closely and performs the responsible doctor's instructions sent from the hospital in a periodic manner.
It is also possible that one of the patient's relatives or his family could act in place of the nurse and the person would be the one contacted in case of the occurrence of unnatural results from devices monitoring the patient in the home.

Telehealthcare professional

Telehealthcare professional can be one of the doctors in the hospital, follow up of the patient's condition, observe the results coming from the monitoring devices in the patient’s home to the hospital server and send the instructions about medications and other necessary procedures to the patient.
It is also possible that general care nurse in the hospital could act in place of the telehealthcare professional and she must be able to nursing and care of people of all age groups with physical or mental illnesses; nursing and care of disabled, seriously ill or dying persons; nursing contributions to rehabilitation, primary health care, health promotion and disease prevention in intramural and extramural settings; co-operation in diagnostic and therapeutic tasks on a doctor’s orders. [19]
She observes the results coming from the monitoring devices at home and till the doctor in charge if any emergency case happens.
The telehealthcare professional is responsible for the decision to readmit the patient to the hospital (if he was a doctor) when emergency case happens and he contacts with the care provider who accompanied the patient at home when receiving unnatural results from monitoring devices need for special procedure or readmit the patient to the hospital.

Continua Architecture

One of the requirements, that we should implement standards in our system, so our system architecture is based on the Continua Health Alliance Guidelines.



2. Figure: Standard based architecture of the Hospital at Home system [10]

The system above (figure 1) is consisting of 5 different Actors. First of all we need a PAN or a LAN device which are monitoring the vital data of the patient. As an Application Hosting Device we use a smartphone. In our case the WAN device means a Web Service which pushes the incoming data to than HRN device, which is the server of the hospital or the telemedicine centre.
The connection between the PAN and LAN devices and the Application Hosting Device should be wireless. The first data transmission happens between the measurement device and the smartphone (PAN-IF). For this we use low-energy Bluetooth connection. As a next step the smartphone sends the data towards the Web Service via HTTP connection (WAN-IF). At the end the Web Service pushes the data to the telemedicine server using HTTP again (HRN-IF).

Scenarios of use

There are several kinds of possibilities to use monitoring systems at home:

Disease Management

Agent Examples: Pulse oximeter, Heart rate monitor, Blood pressure monitor, Thermometer, Weighing scale, Glucose meter, ECG 1 – 3 lead, INR, Insulin pump, Body composition analyzer, Peak flow, Sleep Quality Monitor, Sleep Apnoea Breathing Therapy Equipment, Continuous Glucose Meter

Health and Fitness

Agent Examples: Heart rate monitor, Weighing scale, Thermometer, Cardiovascular fitness and activity monitor, Strength fitness equipment, Physical activity monitor

Independent Living (Aging Independently)

Agent Examples: Disease management devices plus Independent living activity hub, Medication monitor

In the Hospital@Home project we are focusing on the first case, the disease management. As we mentioned the main goal is to make the discharge from the hospital as early as possible with the help of the telemonitoring system.

We collected five different use cases, when using the Hospital at Home system would be relevant. These are the followings:

- hypotonic crisis
- hyperglycemic crisis
- anaphylactic shock
- salmonellosis
- appendicitis

Specific use cases

Hypotension

Hypotension, or low blood pressure, means that the pressure of blood circulating around the body is lower than normal, or lower than expected given the environmental conditions. However, 'hypotension' is a relative term – one person may have low blood pressure compared to others of similar physical characteristics, but may be perfectly healthy. Low blood pressure is only a problem if it has a negative impact on the body. For example, vital organs (particularly the brain) may be starved of oxygen and nutrients if the blood pressure is too low for that particular person [20]

Reasons

What's considered low blood pressure for a person may be normal for someone else. Most doctors consider chronically low blood pressure too low only if it causes noticeable symptoms. Low blood pressure has many different causes including:

- Emotional stress, fear, insecurity or pain (the most common causes of fainting)
- Dehydration, which reduces blood volume
- The body's reaction to heat, which is to shunt blood into the vessels of the skin, leading to dehydration
- Blood donation
- Internal bleeding, such as a perforated stomach ulcer
- Blood loss from trauma, such as a road accident or deep cut
- Pregnancy
- Medications for high blood pressure, depression or certain heart conditions
- Diuretics, which produce fluid loss
- Allergic reaction to certain drugs or chemicals
- Some forms of infection, such as toxic shock syndrome
- Heart disease, which can hamper the pumping action of the heart muscle
- Some nervous system disorders, such as Parkinson's disease
- Addison's disease (where the adrenal glands fail to produce sufficient blood-pressure-maintaining hormones). [20]

Treatment possibilities

Low blood pressure that either doesn't cause signs or symptoms or causes only mild symptoms, such as brief episodes of dizziness when standing, rarely requires treatment. In the case that the patient has symptoms, the most appropriate treatment depends on the underlying cause, and doctors usually try to address the primary health problem (dehydration, heart failure, diabetes or hypothyroidism) rather than the low blood pressure itself. When low blood pressure is caused by

medications, treatment usually involves changing the dose of the medication or stopping it entirely. So there are verities of treatment methods and it depends on several factors such like health status, age, and the type of low blood pressure. [20]

Some of the conditions causing hypotension may present with shock, requiring urgent lifesaving treatment. Shock is most commonly defined as the life-threatening failure of adequate oxygen delivery to the tissues, due to decreased blood supply or increased demand, resulting in decreased end-organ oxygenation. If left untreated, shock results in end-organ damage and death. Tissue hypoperfusion may occur without hypotension, but in clinical practice, shock is commonly diagnosed when both arterial hypotension and organ dysfunction are present. ABC measures are the first priority in all critically ill patients. Stabilisation of airway and breathing is a priority, followed by restoration of circulating volume and perfusion of peripheral tissues. Administration of supplemental oxygen, with continuous pulse oximetry, may be adequate to maintain oxygen saturation. In more severe cases, intubation and ventilation may be required. Early and frequent monitoring of blood pressure is an important part of perfusion assessment, and an initial fluid bolus should be administered to patients with evidence of intravascular hypovolaemia. All patients require an ECG and, in more severe cases, continuous cardiac monitoring may be indicated. Tachycardia, altered cognition or reduced level of consciousness, diaphoresis and oliguria are all pointers to the presence of shock. [21]

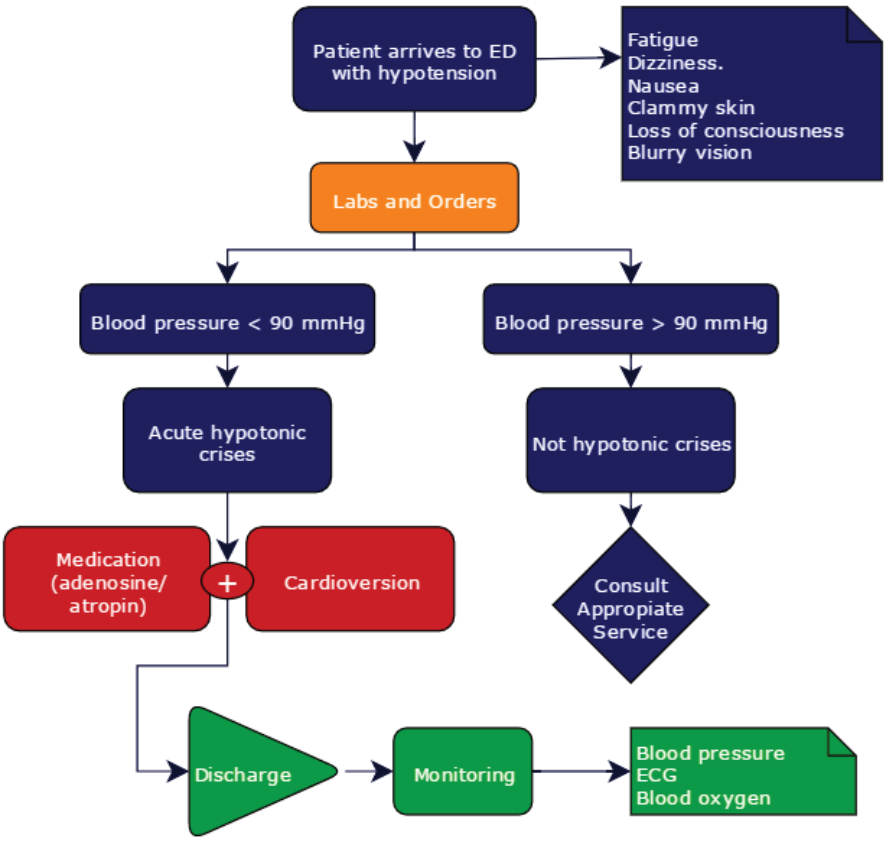
The following should be performed in all patients with acute hypotension, including patients with shock, where the diagnosis may not already be clear:

- FBC (a low haemoglobin may or may not be present with haemorrhage, an elevated WBC count may be indicative of infection or inflammation)
- Serum electrolytes and blood glucose
- Serum liver transaminases and bilirubin
- Serum troponin
- D-dimer (may be normal or elevated with PE)
- Coagulation profile
- 12-lead ECG (may be followed by cardiac telemetry, and 24-hour ECG in patients with suspected dysrhythmia)
- Pulse oximetry recording
- Thyroid function tests (TSH and free T4) may also be considered in older adults [21]

Medications: Several medications, either used alone or together, can be used to treat low blood pressure that occurs when you stand up (orthostatic hypotension). For example, the drug fludrocortisone is often used to treat this form of low blood pressure. This drug helps boost your blood volume, which raises blood pressure.
Doctors often use the drug midodrine (Orvaten) to raise standing blood pressure levels in people with chronic orthostatic hypotension. It works by restricting the ability of your blood vessels to expand, which raises blood pressure. [20]

Telemonitoring possibilities

The main outcome and measures to be monitored at home is the blood pressure and be sure that it's enough high. Some experts define low blood pressure as readings lower than 90 mm Hg systolic or 60 mm Hg diastolic [20] and this value is related to many factors like: the gender, age, health status and medication which patient are token.
So after the first treatment in the hospital either with a kind of infusion or with medication and ensure that the health status is stabilized, meanwhile a blood sample is taken and being analysed. After that the only thing the health provider can offer to the patient is the monitoring, which can be achieved at home.
The main and most important parameter must be monitored is the blood pressure to be sure that it's in a safe rang and the patient is not in a danger .
And it must be assembled with an ECG device and oximeter to monitor the cardiac signal and the oxygenation of the blood to collect more details about the blood circulation. And in this opportunity the patient can be discharged earlier from the hospital with the same quality of the health care.
The devices in charge are wireless blood pressure monitor and it can be embedded with an ECG monitor and additionally an oximeter on the finger. And in such emergency cases there will be a call directly to the patient or to the accompany person at home.



3. Figure: Hypotension treatment pathway

Hyperglycemic crisis

Hyperglycemic crisis is a metabolic emergency associated with uncontrolled diabetes mellitus that may result in significant morbidity or death. the fasting plasma glucose in hyperglycemic crisis rises to the 126mg/dl or more (>= 7 mmol/l) and more than 200mg/dl (2 hour post-prandial) [22], acute interventions are required to manage hypovolemia, acidemia, hyperglycemia, electrolyte abnormalities, and precipitating causes. Despite advances in the prevention and management of diabetes, [23] its prevalence and associated health care costs continue to increase worldwide. Hyperglycemic crisis typically requires critical care management and hospitalization and contributes to global health expenditures. [24]

The two most serious hyperglycemic emergencies are diabetic ketoacidosis (DKA) and hyperglycemic hyperosmolar state (HHS). [25]

Reasons

- Carbohydrates: Eating food containing too many carbohydrates, a form of sugar. The body of a person with diabetes cannot process high levels of carbohydrates fast enough to convert it into energy. Blood sugar levels in patients with diabetes can rise within hours after eating.

- Insulin control: Not producing enough insulin action (either by injection of insulin or taking medicine which stimulates the pancreas to make more insulin). People with diabetes must control blood sugar by a combination of dietary discretion, taking medication, and physical activity. When food, exercise, and insulin are not balanced, blood sugar levels rise.
- Stress: Emotions can play a role in causing hyperglycaemia, but should not be used as an excuse for poor control of diabetes.
- Low levels of exercise: Daily exercise is a critical contributor to regulating blood sugar levels.
- Infection, illness, or surgery: With illness, blood sugar levels tend to rise quickly over several hours.
- Other medications: Certain drugs, especially steroids, can affect blood sugar levels. [26]

Treatment possibilities

The treatment in hospital usually begins with The initial laboratory evaluation of patients include determination of plasma glucose, blood ureanitrogen, creatinine, electrolytes (with calculated anion gap), osmolality, serum and urinary ketones, and urinalysis, as well as initial arterial blood gases and a complete blood count with a differential. An electrocardiogram, chest X-ray, and urine, sputum, or blood cultures should also be obtained [27] , after that the doctors begin with these steps:

Hydration

Hydration in Hyperglycemic crisis is accomplished by giving 1 L of 0.9% saline in the first hour(isotonic). If hypotension is not corrected after 1 L or if urine flow is less than 50-100 ml/hr, this rate should be continued for another hour. [28]

Insulin

Insulin treatment for both DKA and HHS is the same. All patients should be given 10-20U regular insulin. After that, they should be given 0.1 U/kg/hr continuous infusion of regular insulin. Anion gap, pH, and hyperglycemia should be monitored. If no improvement is seen within 2 hours, the dose should be doubled each hour until the desired results are seen [22]

Potassium

Most hyperglycemia affected individuals and when moved to the hospital suffering from low potassium blood, are given doses of potassium synchronized with ECG monitoring.

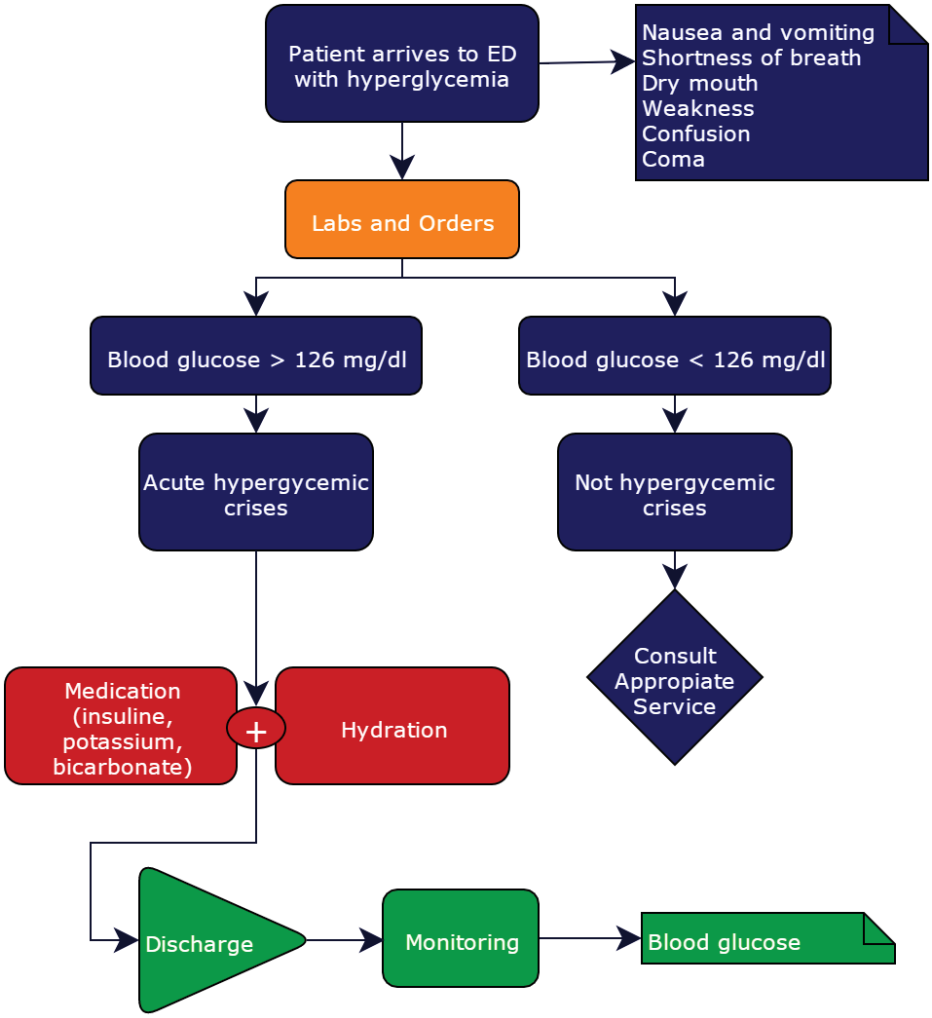
Bicarbonate

Not given as one dose only in emergency cases (shock, coma) [22]. After that the patient stays in the hospital 4-5 days to monitor the patient specially the glucose level in the blood [29]. They do 4-5 sugar tests during the day.

Telemonitoring possibilities

After took necessary blood tests (plasma, glucose) and urine test when the patient arrived to the hospital, doctors conduct necessary treatment steps which we mentioned in the previous paragraph, then the patient is put under observation for a period ranging between 4 to 5 days, during this time doctors just monitor the patient take periodic blood tests, the most important one is glucose test, taken at rate of 4 to 5 times a day. This time costs the patient more money due to staying at hospital

and health services and may also expose the patient to risk of infections or viruses which are the biggest danger in all hospital where the subject of the infection poses a real challenge for many hospitals. That's why after undertake all ambulatory steps and achieve relative stability for hyperglycemia patient, permission will be taken from supervisor doctor allowing take the patient out from the hospital. We continue monitoring the patient at home where we need glucose blood test device which is easily available and we can conduct observation at home and send the results to the doctor or hospital supervisor to follow-up patient condition consistently.



4. Figure: Hyperglycemic crisis treatment pathway

Anaphylactic shock

Anaphylaxis is a severe, potentially life-threatening allergic reaction. It can occur within seconds or minutes of exposure to something you're allergic to, such as a peanut or the venom from a bee sting. [30]

Reasons

The immune system produces antibodies that defend against foreign substances. This is good when a foreign substance is harmful (such as certain bacteria or viruses). But some people's immune systems overreact to substances that shouldn't cause an allergic reaction. When this occurs, the immune system sets off a chemical chain reaction, leading to allergy symptoms. Normally, allergy symptoms aren't life-threatening. But some people have a severe allergic reaction that can lead to anaphylaxis. Even if you or your child has had only a mild anaphylactic reaction in the past, there's still a risk of more severe anaphylaxis.
A number of allergens can trigger anaphylaxis, depending on what the patient is allergic to.

Common anaphylaxis triggers include:

- Certain medications, especially penicillin
- Foods, such as peanuts, tree nuts (walnuts, pecans, almonds, cashews), wheat (in children), fish, shellfish, milk and eggs
- Insect stings from bees, yellow jackets, wasps, hornets and fire ants

Less common causes of anaphylaxis include:

- Latex
- Medications used in anesthesia
- Exercise [30]

Treatment possibilities

During an anaphylactic attack, an emergency medical team may perform cardiopulmonary resuscitation (CPR) if you stop breathing or your heart stops beating. You may be given medications including:

- Epinephrine (adrenaline) to reduce your body's allergic response
- Oxygen, to help compensate for restricted breathing
- Intravenous (IV) antihistamines and cortisone to reduce inflammation of your air passages and improve breathing
- A beta-agonist (such as albuterol) to relieve breathing symptoms

So the treatment consists of three main parts:
Airway management: Establishing and maintaining an airway or providing ventilatory assistance may be necessary. Assess the level of consciousness and obtain blood pressure, pulse, and oximetry values.
Cardiac monitoring: Cardiac monitoring in patients with severe reactions and in those with underlying cardiovascular disease is important, particularly when adrenergic agonists are used in treatment. ECG and Pulse oximetry are used in the cardiac monitoring.
Intravenous access: The IV line should be of large caliber due to the potential requirement for large-volume IV fluid resuscitation. Isotonic crystalloid solutions (ie, normal saline, Ringer lactate) are preferred. A keep-vein-open (KVO) rate is appropriate for patients with stable vital signs and only cutaneous manifestations. If hypotension or tachycardia is present, administer a fluid bolus of

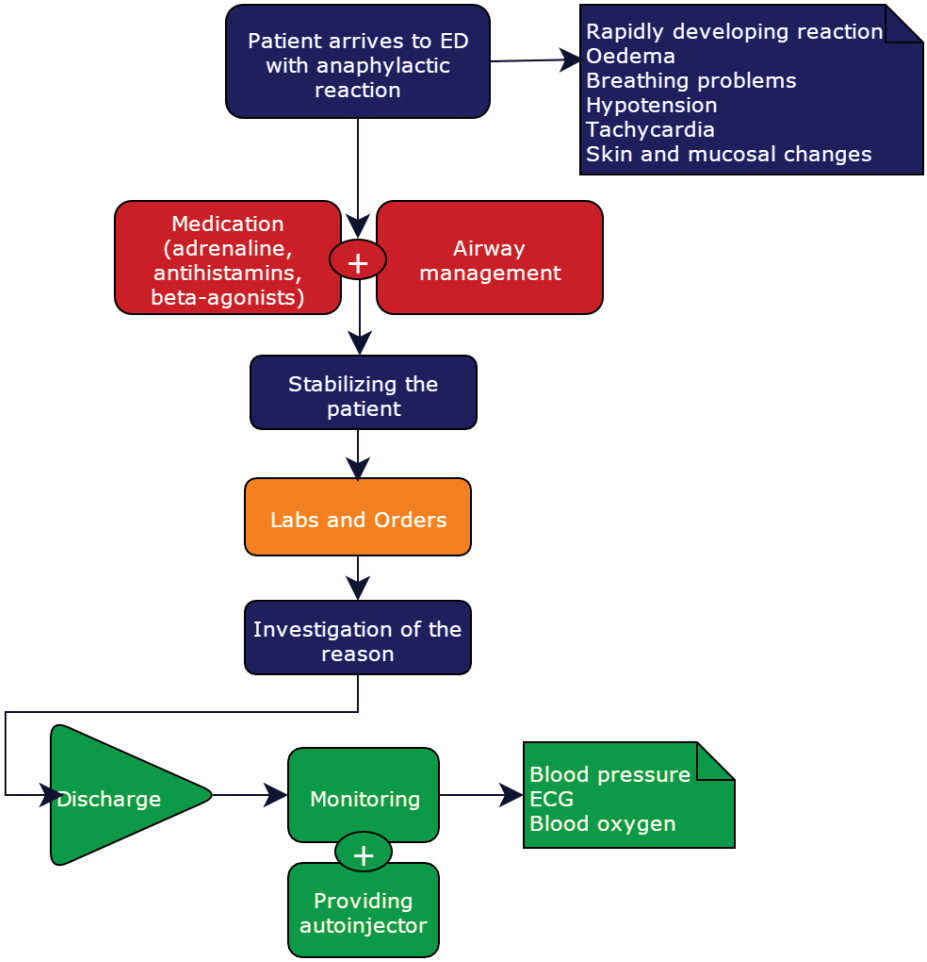
20 mg/kg for children and 1 L for adults. Further fluid therapy depends on patient response. Large volumes may be required in the profoundly hypotensive patient. [31]

Telemonitoring possibilities

Disposition of patients with anaphylaxis depends on the severity of the initial reaction and the response to treatment. Patients with non–life-threatening symptoms may be observed for 4-6 hours after successful treatment and then discharged. Patients who have refractory or very severe anaphylaxis (with cardiovascular and/or severe respiratory symptoms) should be admitted or treated and observed for a longer period in the emergency department (ED) or an observation area. So after a successful treatment the patients could be discharge but they must be monitored to ensure that they are safe and without any risk of another anaphylactic shock.

Any way before the discharge the patient from the hospital the following points can be achieved:

- Providing the patient with Adrenaline autoinjector if there is a risk of re-exposure (e.g. stings, foods, unknown cause) and train the patient how to use it and provide him/her with an action plan.
- Providing the patient with blood pressure monitor and ECG and additionally oximeter for the oxygen level in the blood



5. Figure: Anaphylactic shock treatment pathway

Salmonella Infection

People can get sick because of several kinds of bacteria. One of the most known are different strains (serotypes) of Salmonella. The two most important serotypes are Salmonella Eneriditis and Salmonella Typhimurium. [32]
The first mentioned strain is very common in our everyday life and can cause wide range of gastrointestinal symptoms in humans. Usually this disease is treated spontaneously, but in some cases (like in case of little children, elderly people, or people with weakened immune system) professional treatment can be necessary. [32]
The typhoid fever is caused by the S. typhi strain.

Reasons

Most of the infections occur in the summer months due to the warm temperature. The usual sources of the Salmonella bacteria are diary, poultry and meat products. Chicken meat and eggs have the highest risk of infection. [33] Transmission among people is also possible via faecal-oral contact. Our pets (cats, dogs, turtles) can even be infected by Salmonella. [32]
The good news are that it is quite easy to kill these bacteria. If we cook the raw food properly and keep the rest of the food in a cool place we can avoid the disease. After touching raw meat or egg it is necessary to wash our hands with hot soapy water, otherwise we can contaminate the other foods which we consume raw.

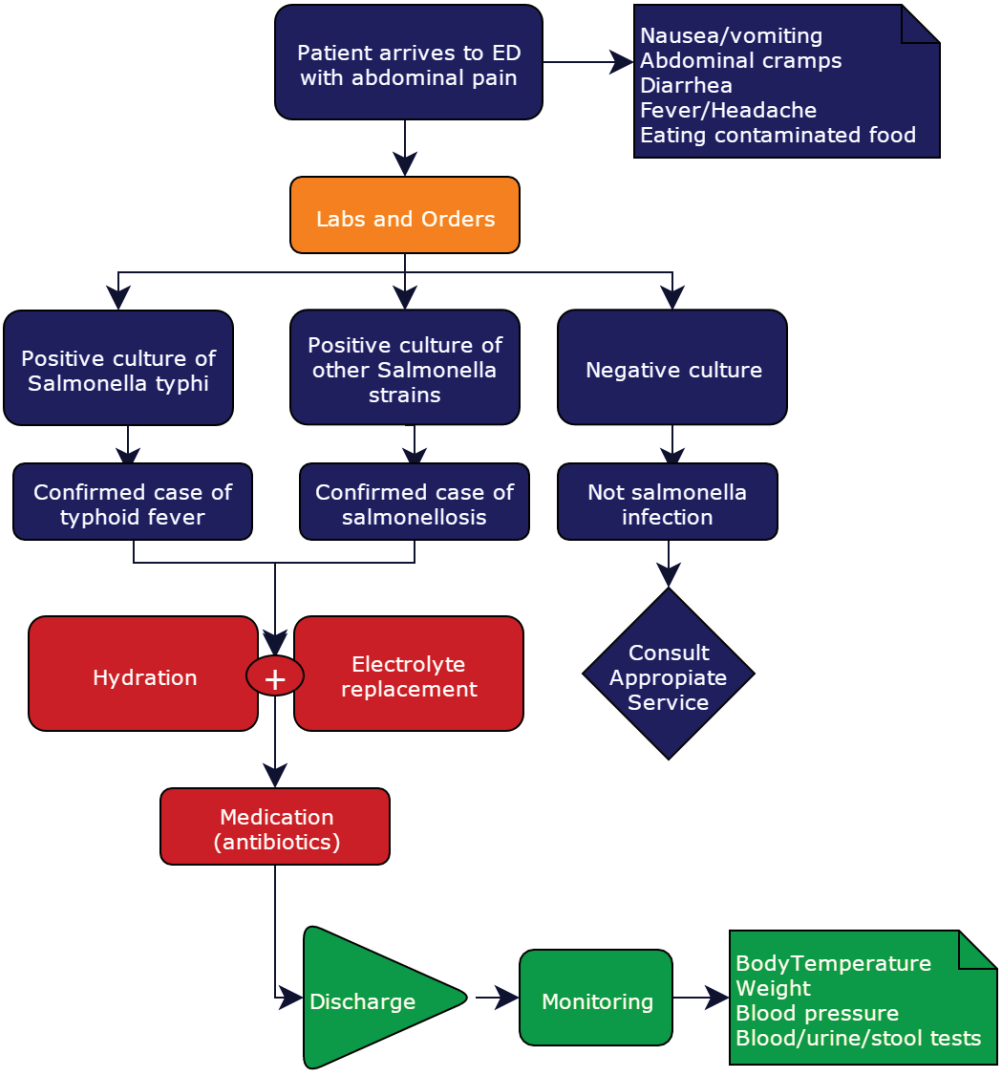
Treatment possibilities

The incubation period of this disease is usually 12-36 hours. Salmonella infection symptoms can be moderate or even more severe. It depends on the contamination level of the eaten food and on the immune system of the patient.
Salmonellosis usually begins with nausea, vomiting, abdominal cramps and diarrhoea, but it can cause also fever and headache. [34] In severe cases the patient gets into hospital, because of the volume loss. The treatment is symptomatic: the patient needs continuous volume and electrolyte (potassium, sodium, chloride) replacement and antibiotic treatment in parallel. However antibiotic treatment is not recommended in mild cases, because of the possibility of resistance. [32]
The excretion of the bacteria can be examined by blood or stool samples. After discharging it is necessary to monitor the status of the patient for a few weeks to avoid a new infection. Recovering usually takes 2-7 days [34], but the patient can excrete the bacteria for weeks. That is why it is forbidden to prepare food for the others after salmonellosis.
The symptoms of the typhoid fever can vary in a wide range too. In a simple case the patient has prolonged fever, disturbances of bowel function (constipation, diarrhoea), headache, anorexia and at the beginning bronchitic cough. In a severe case the abdominal discomfort is increased, sudden rise of pulse rate, hypotension, abdominal tenderness and rigidity can occur. Usually in the stool samples there is occult blood. These patients can have delirium or fall in coma too. The treatment

consists of hydration, appropriate nutrition and blood transfusions if it is necessary. Antibiotic therapy is also needed. [35]

Telemonitoring possibilities

After the volume replacement and antibiotic treatment the only thing what the healthcare providers do is the monitoring of the patient, which can be done also at home. Monitoring the weight, the body temperature and the blood pressure can give an overview image of the vital status of the patient. Only a blood pressure monitor, a weight scale is needed. To get information about the presence of the bacteria blood, urine and stool samples should be analysed. Professional care givers or even the patient or the family can do these particular measurements and with the help of the Hospital at Home application they can forward the message to the physicians to the telehealth centre, who can decide about the necessary intervention if it is needed. With this method the patient can be discharged from the hospital earlier. Figure 5 shows the treatment pathway in case of salmonellosis.



6. Figure: Salmonellosis treatment pathway [35]

Appendicitis

The inflammation of the appendix (which is a 9 cm long blind-ended tube located in the lower right quadrant of the abdomen) is called appendicitis. [36] The function of this small part of the gastrointestinal tract is still unclear. Fortunately humans can live without this organ, so surgical treatment can be one of the best choices.

Reasons

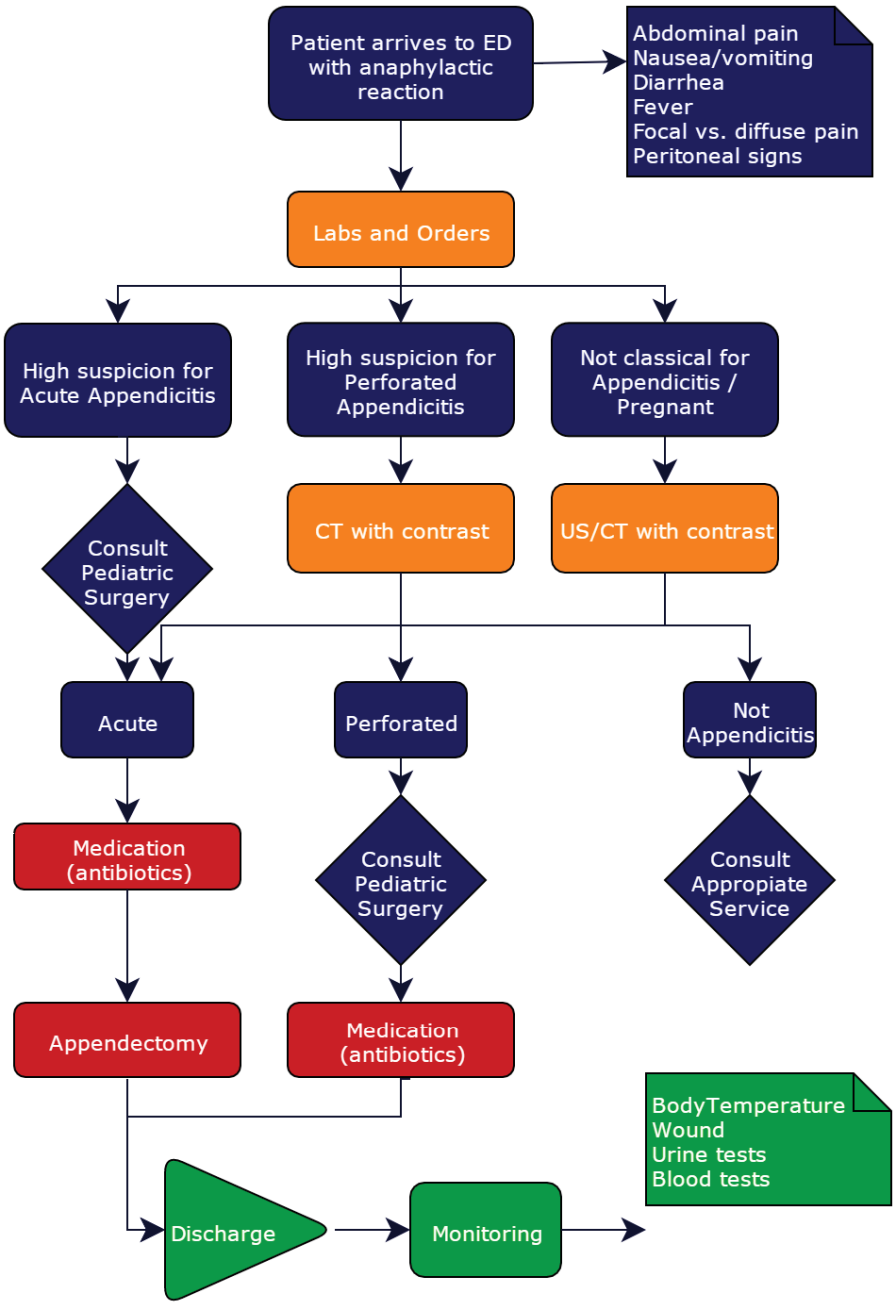
There are two types of this disease: chronic or acute inflammation. The chronic disease develops slowly and has milder symptoms. The acute one is more common and it mainly caused by a piece of food or stool which is trapped in the appendix. [37, 38] It can cause severe infections or even death, so it is considered as an emergency case.

Treatment possibilities

The first sign of appendicitis is dull pain near the navel. Other usual symptoms are loss of appetite, nausea, vomiting, abdominal swelling, inability to pass gas or even fever. [38] For the diagnosis physicians use often abdominal exam, urine- and blood tests, CT or ultrasound. [39, 40]
The chronic appendicitis can be treated with antibiotics. The acute one is a life-threatening state, which needs prompt surgery where the appendix will be removed (this procedure is called appendectomy). [37] A half day after the surgery the patient can get up. Total recovery takes around 2-3 weeks. If surgery is done with a laparoscope the incision is smaller and recovery is faster. [39]

Telemonitoring possibilities

Appendicitis can cause severe life-threatening complications. As far as the status of the patient is not stable he or she has to be kept in an intensive care unit of a hospital. Usually these patients needs appendectomy. After the surgery the patient has to be monitored, but this process can be done also at home.
The most important thing is to be sure that the infection is not in the body anymore, which can be examined with the help of different kinds of tests. Monitoring body temperature is the easiest way to detect infections. Furthermore the patient can also take pictures about the wound and forward it to the Telehealth Centre.
If the necessary urine and blood tests are available for non-professionals, the patient or somebody from the family can do these test and forward the results to the telehealth centre. If medical education is necessary for making the measurements a professional caregiver can visit the patient collect the samples and bring it to the laboratory department of a hospital.
The usual evaluation pathway of appendicitis is shown in figure 6.



7. Figure: Appendicitis treatment pathway in case of paediatrics patients [40]

2. Materials and Methods

Project structure, Workpackages

Tasks

Timeline planning for the next 2 semesters

The first step is to make a time-plan for the next 2 semesters. It is a common task, therefore every team member would participate in the planning.

Literature research in the field of:

IEEE: 11073-20601, 11073-10407

Continua: PAN-IF (Personal or Peripheral Area Network)

IHE: PCD (Patient Care Device)

Personal Health Devices

Android Application development

HL7 Messaging

Designing the architecture of the system

According to the standards and the principle of interoperability making a block diagram of the architecture of the Hospital at Home system. This task is also common, because all of the team members should understand the main architecture of the system.

Documentation of the architecture

Making a clear description of the architecture, based on the existing block diagram.

Defining the resources what are needed for the bidirectional communication

We need to make a list of the needed medical and IT devices for the hospital.

Implementation of the data transfer between the medical devices and the tablet

Connecting a Personal Health Device (blood pressure monitor) to a tablet via Bluetooth, based on the IEEE standard. Sending the vital sign data from the PHD to the mobile phone.

Implementation of the data transfer between the tablet and the hospital server

Continuing the step before with the generation of HL7 version 3 messages from the collected data and send it forward to the server of the hospital.

Implementation the response process at the server-side

Finding a solution for the communication process back from the hospital towards the patient.

Sharing of Workpackages

Agnes Hermann:

Literature research: Existing devices
HL7 Messaging
Use cases

Documentation of the architecture

HL7 Message generation and sending it to the server

Houssam Almouhammed:

Literature research: Personal Health Devices
IEEE: 11073-20601, 11073-10407
Continua: PAN-IF (Personal or Peripheral Area Network)
Use cases

Implementation of the data transfer between the medical devices and the tablet

Mahmoud Alakraa:

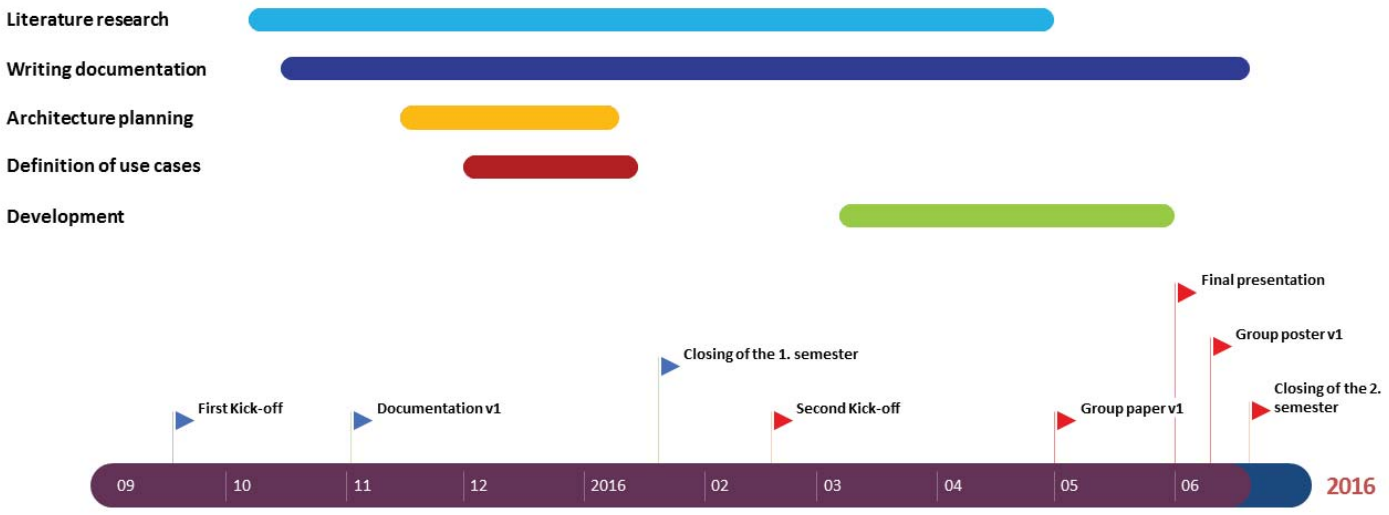
Literature research: Roles
Use cases
Server implementation

Defining the resources what are needed for the bidirectional communication

Implementation the response process at the server-side

Milestones

Figure 8 shows the basic tasks of the project and how we were working on them in parallel during the two semesters. The main deadlines are shown on the timeline with blue flags for the first and red flags for the second semester.



8. Figure: Milestones of the Hospital at Home Project

2015/2016 WS:

September 2015: first Kick-off, team completion

November 2015: first version of documentation

January 2016: closing of the 1.semester

2015/2016 SS:

February 2016: second Kick-off

June 2016: closing of the 2.semester

10 June: first version of the group poster

20 June 2016: final version of the documentation

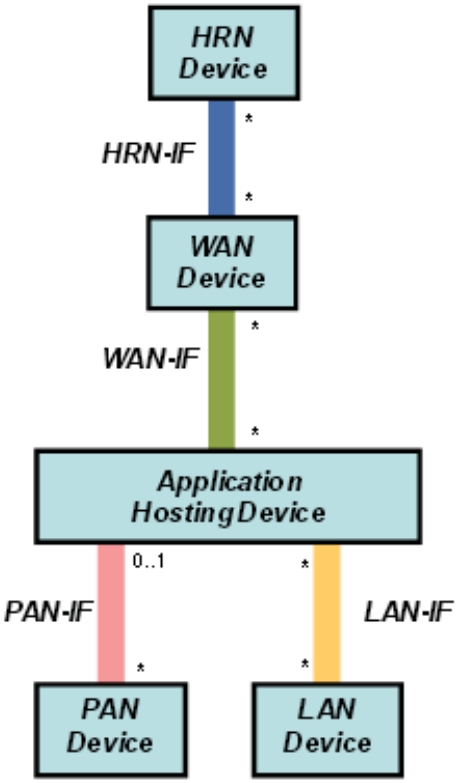
August 2016: final version of the group poster

September 2016: presentation at the 1.semester MBE students' Kick-off

Technical Documentation for software projects

System Architecture

As we mentioned before we should implement standards in our system, so our system architecture is based on the Continua Health Alliance Guidelines, which is shown on Figure 9.



9. Figure: Standard based architecture of the Hospital at Home system [10]

First of all we need a PAN or a LAN device which are monitoring the vital data of the patient. We would like to use a Continua certified blood pressure monitor as a PAN device. As an Application Hosting Device we use an Android based tablet. In our case the HRN device means the server of the telemedicine centre.

The first data transmission happens between the blood pressure monitor and the tablet. As a PAN-Interface we will use low-energy Bluetooth connection. As a next step the tablet sends the data towards the Web Service via HTTP connection, which means the WAN-Interface. At the end the Web Service pushes the data to the telemedicine server using HTTP again as a HRN-Interface.

We can provide a feedback if it is needed via HTTP from the WAN device to the Application Hosting Device. It sends a sending confirmation back to the tablet of the patient.

Actors

Blood pressure monitor

We use a Continua certified blood pressure monitor as a PAN device. Its task is to collect blood pressure data at different time points. It sends the collected signals in form of X73 messages via Bluetooth connection.

Tablet

The core element of the whole system is a tablet which runs Android as platform. It receives the incoming X73 messages from the Personal Health Devices (in our case from the blood pressure monitor). It extracts the values of the measurement results into HL7 version 3 messages and forwards it to the Telemedicine centre via HTTP connection.

Telemedicine Centre

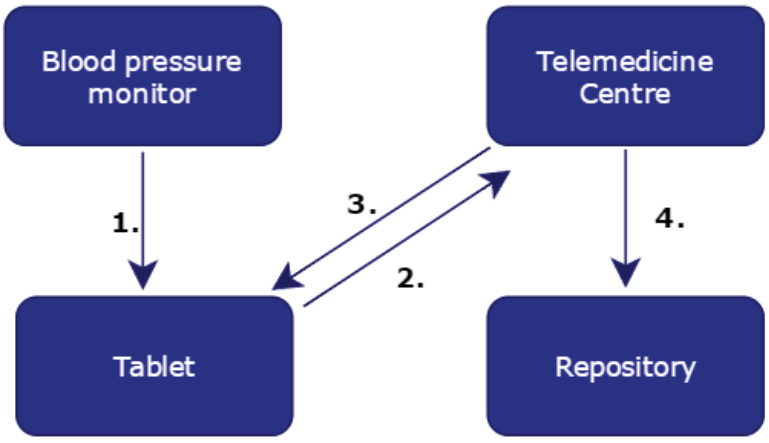
At the Telemedicine Centre physicians, nurses or other professional healthcare providers analyses the incoming vital signs. They means the decision points, if they found some unhealthy results they call the patient or the family and ask them to return to the hospital for further examinations. In case of emergency they can send an emergency car to the patient's address.

Repository

The data of the patients must be stored in a secure way. Therefor a server is needed where the incoming results can be stored.

Transactions

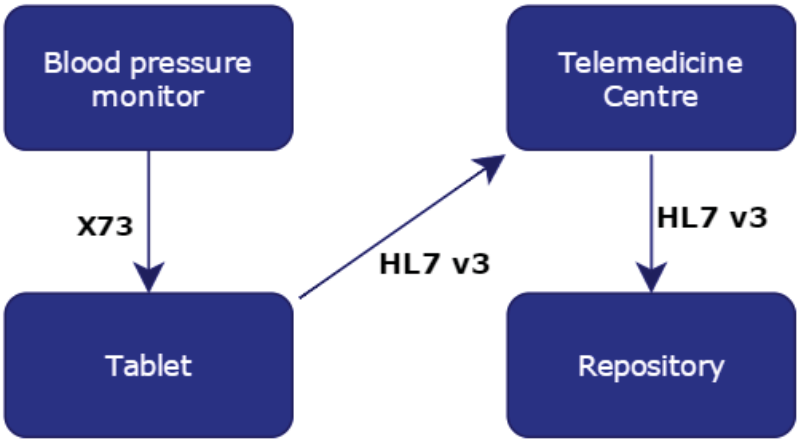
Between the different actors there are transactions (as shown in figure 10):



10. Figure: Transactions between the actors

1. The blood pressure monitor sends the measurement results to the tablet. This is a unidirectional connection.
2. The smartphone sends the data via HTTP connection.
3. The server sends a response back to the tablet, that the message has been received successfully. This status message appears at the user's tablet.
4. The incoming data are stored at the Repository for further usage.

The communication between the blood pressure monitor and the tablet and between the tablet and the telemedicine centre has to be wireless. The actors exchange messages in a coded form. Figure 11 shows the message types which are used among them.

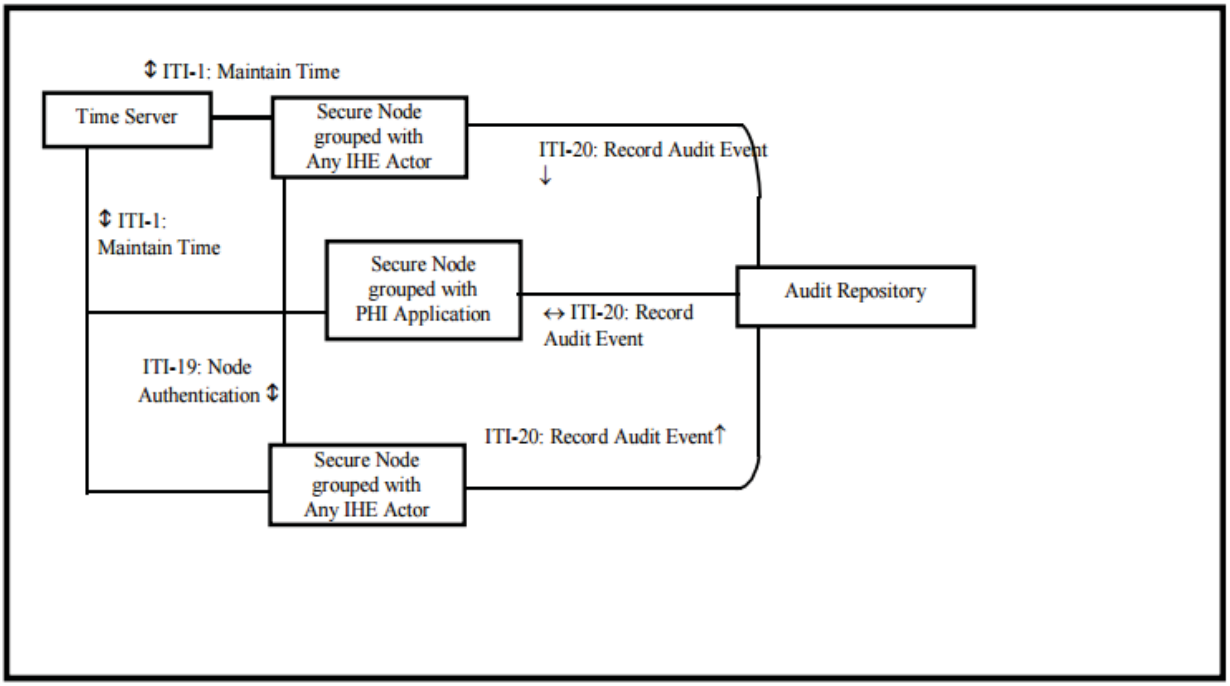


11. Figure: Message forms in the Hospital @ Home system

The measurement data are coming from the blood pressure monitor is in X73 form. The application on the tablet extracts the necessary information out of the X73 message and creates an HL7 version 3 message out of that. At the end of the chain in the telemedicine centre an HL7 message will arrive and that will be stored in the repository.

Security

As vital data of patients must be handled in a secure and confidential way it would be necessary to implement the ATNA (Audit Trail and Node Authentication) Security Profile of IHE. It provides secure access to patient data with the help of authentication of users and limitation of access based on authorization. [41]



12. figure: Audit Trail and Node Authentication diagram [42]

ATNA has three main parts:

- User Authentication: implements access control
- Connection Authentication: provides node authentication based on certificates
- Audit Trails: make audits to detect compliances

According to IHE standards each actors has to be grouped by ATNA. Furthermore each module needs connection to the Time Server to synchronize processes. The audits are stored in the Audit Repository parts. These processes are shown in figure 12.

Security options are fundamental for each healthcare devices which makes patient data transmissions. On the other hand it would make the project more complicated so we do not implement that part during our work.

Used resources

To carry out the measurements an upper arm blood pressure monitor brand UA-767PBT-C was used which is equipped with Bluetooth wireless communication technology. For testing the Android application a Samsung Google Nexus 10 tablet was utilized. The symbolic telemedicine server was built on an Asus laptop (Intel Core i5, 8GB RAM).

Used message standards

HL7 Version 3

HL7 International specifies a number of flexible standards, guidelines, and methodologies by which various healthcare systems can communicate with each other. These standards enhance the compatibility between different healthcare applications therefor they support interoperability.
Version 3 messages are based on the Extensible Markup Language (XML). An HL7 v3 message template was used to create the outgoing HL7 messages by filling out the appropriate fields with the actual measurement values (see Figure 13).

```
<title>Labs</title>
<entry>
        <observation classCode="OBS" moodCode="EVN">
            <code code="251076008" codeSystem="2.16.840.1.113883.6.96" codeSystemName="SNOMED CT" displayName="Cuff blood pressure"/>
            <effectiveTime value="200004071430"/>
            <targetSiteCode code="368208006" codeSystem="2.16.840.1.113883.6.96" codeSystemName="SNOMED CT" displayName="Left arm"/>
            <entryRelationship typeCode="COMP">
                <observation classCode="OBS" moodCode="EVN">
                    <code code="271649006" codeSystem="2.16.840.1.113883.6.96" codeSystemName="SNOMED CT" displayName="Systolic BP"/>
                    <effectiveTime value="200004071530"/>
                    <value xsi:type="PQ" value="66" unit="mm[Hg]"/>
                </observation>
            </entryRelationship>
            <entryRelationship typeCode="COMP">
                <observation classCode="OBS" moodCode="EVN">
                    <code code="271650006" codeSystem="2.16.840.1.113883.6.96" codeSystemName="SNOMED CT" displayName="Diastolic BP"/>
                    <effectiveTime value="200004071530"/>
                    <value xsi:type="PQ" value="86" unit="mm[Hg]"/>
                </observation>
            </entryRelationship>
            <entryRelationship typeCode="COMP">
                <observation classCode="OBS" moodCode="EVN">
            <code code="364075005" codeSystem="2.16.840.1.113883.6.96" codeSystemName="SNOMED CT" displayName="Heart rate"/>
            <effectiveTime value="200004071530"/>
            <value xsi:type="RTO_PQ_PQ">
                <numerator value="84"/>
                <denominator value="1" unit="min"/>
            </value>
        </observation>
            </entryRelationship>
        </observation>
    </entry>
```

Figure 13.: A part of the template HL7 v3 message

ISO/IEEE11073 - X73

The ISO/IEEE11073 (X73) standard describes the communication between blood pressure monitor devices and management applications (for example a tablet or a cell-phone). It supports interoperability and plug-and-play usage of personal health devices.
The Bluetooth Health Device Profile (HDP) outlines requirements for Bluetooth healthcare help connect medical devices (such as pulse oximeters, blood pressure monitors, thermometers, weight scales, and glucose meters) to AHDs (such as mobile phones, service gateways, laptops, and desktop computers) without the need for cables. This profile can exploit the Bluetooth Multi-Channel Adaptation Protocol (MCAP) which defines a protocol for communicating with devices as if they were

connected over a locally attached cable. In addition, the profile also uses new Logical Link Control and Adaptation Protocol (L2CAP) features, such as an enhanced retransmission mode, streaming mode, and optional frame check sequence (FCS) to define interoperability requirements. [15]
When the Bluetooth health device is turned on, it initializes the software components in a specific order. Next, it executes the Bluetooth HDP agent to register the system by the AHD. When a Continua AHD intends to connect to the blood pressure monitor, the component Bluetooth HDP agent receives an indication that a control channel has been established. The Bluetooth HDP agent then notifies the ISO/IEEE 11073-10407 agent that the transport layer has been connected, and it prepares to establish a data channel.
When the ISO/IEEE 11073-10407 agent receives an indication that the transport layer has been connected, it triggers a change of state in the connection in the state machine, sending an association-request message to the AHD to establish an application data channel. Based on the control channel of the already established Bluetooth HDP, an application data channel is initiated, according to the x73-PHD communication protocol.
When users measure their vital signs, the corresponding module then acquires and decodes the data related to the vital sign and informs the ISO/IEEE 11073-10407 agent, which converts the raw data to the x73-PHD data format.
The application data—compliant with the data exchange protocol (ISO/IEEE11073-20601) and device data specifications ISO/IEEE 11073-10407 series)—is transmitted via the data channel.

The x73-PHD system model of the D40 is divided into three principal components: [43]

- domain information model (DIM)
- service model.
- communication model

These three models work together to represent data, define data access, command methodologies, and communicate the data from the blood pressure monitor to a Continua AHD.

The domain information model describes an agent as a set of objects. These objects and their attributes represent the elements that control behavior and report on the status of the agent and data that an agent can communicate to a manager. Communication between the agent and the manager is defined by the application protocol in IEEE Standard 11073-20601.

The service model provides services such as mapped to messages that are exchanged between the agent and the manager.

The communication model supports the topology of one or more agents communicating over Logical point-to-point connections to a single manager
The most important feature is application-level interoperability, in conjunction with the x73-PHD exchange protocol and the device's data specifications. According to this standard a blood pressure monitor provides a GET service to make it possible to retrieve the values of the measurements.

When the connection is established between the manager application and the blood pressure monitor, they are unassociated by default. The connection states includes seven states: disconnected, connected, unassociated, associating, sending config, waiting approval and operating. As a next step the medical device sends an association request, and then they will enter to the associated state.
The agent sends the event reports to the manager application which is running on the tablet. These reports contain the measurement observations. [43]

Android-based manager application implementation

For the Android application development Android Studio was used. The Bluetooth Health Device Profile (HDP) was implemented in Java programming language. The communication set up and the extraction of the measurement results coming from the blood pressure monitor was carried out based on the ISO/IEEE11073 - X73 standards. The format of the messages sent to the server by the application is defined by HL7 version 3.
The used communication protocols was Bluetooth between the tablet and the blood pressure monitor and HTTP between the tablet and the server.

Server implementation

On the server side Apache server program is used. PHP programming language was chosen for the implementation of the server side. A PHP class was created to deal with the HL7 message that will receive from the Android application. The PHP library reads the HL7 message and extracts the patient information (patient name, gender, age, birthday and social security number) and the measurement results (blood pressure data and heart rate).
With the help of Yii PHP framework two interfaces – one for users and one for admins - were created. We have built a database to store the incoming data and this database was connected with Yii framework.
To see the data received from android application, we created an interface to view and control the receiving data.

Test procedures

An interface was built to test the reception and the extraction of a sample HL7 message at the server side. Its main task was to simulate the connection between the Hospital@Home Android-based manager application and the server. The testing interface is shown on Figure 14.

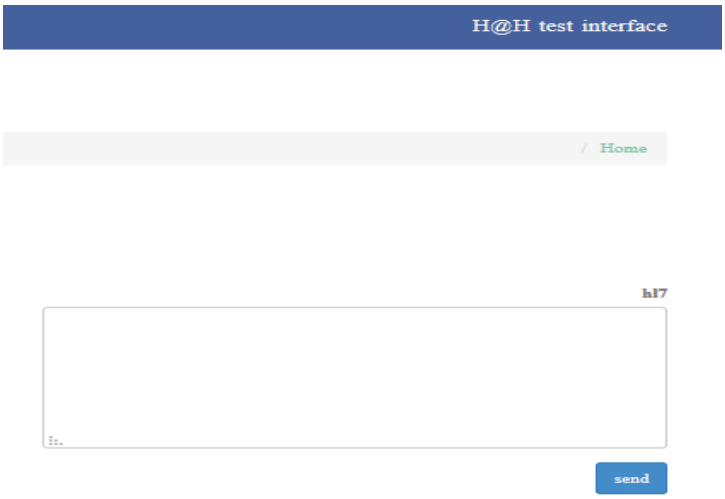


Figure 14.: Hospital@Home server testing interface

In parallel with testing the server with the test interface, we tested the Android application itself with real blood pressure measurements carried out on test patients. The aim of these tests was to check the Bluetooth connection between the blood pressure monitor and the manager application, furthermore to test the extraction process of the incoming measurement message.

Risk management

The Hospital @ Home system is very reliable in general. However, as every other devices and systems it has some weak points too. We considered the followings as potential risk factors:

- Lack of stable Bluetooth connection
- Lack of stable internet connection
- Security problems
- Mistyping of the patient personal data
- Improper measurement
- Battery of the blood pressure monitor is low

The transmission between the blood pressure monitor and the mobile phone happens via Bluetooth interface. If the connection is not perfect, the medical device will not be able to send the data to the smartphone. Forwarding the data to the telemedicine centre needs a stable internet connection. In the other case it can occur that the message would not be sent correctly.
Security issues are the most threatening, that is why secure connections and networks must be used. Protection of the personal data has to be implemented.
There are some risks according to the users as well. Mainly elderly people would use the Hospital @ Home system, so we have to consider that they do not have IT knowledge. As a first step the patient has to type in his or her personal data for the identification. It can happen that a misspelling occurs and the patient can be identified in a proper way. The application has to be user-friendly to avoid these kind of risks.
The system includes a medical device (in our case a blood pressure monitor) and the method of doing measurements is strictly regulated. If the measurements are not carried out correctly it can influence the measured vital data. False results can be sent to the telehealth centre which will cause unnecessary emergency calls.
Every device which uses a battery as the source of energy can go dead. To avoid that a warning sign could be used to warn the user for changing batteries in time.

3. Results

Application side

The Hospital @ Home manager application for Android platforms was developed successfully. A user with basic IT skills is able to use it without making errors. When a patient opens the application it will ask him or her to type in his or her personal data, such as social insurance number, first name and last name. The date of birth can be selected with the help of a calendar. Two checkboxes are used for the gender selection. By clicking on the 'SAVE INFORMATION' button, the data are stored for creating the outgoing HL7 message. The layout of the starting page of the application is shown on Figure 15.

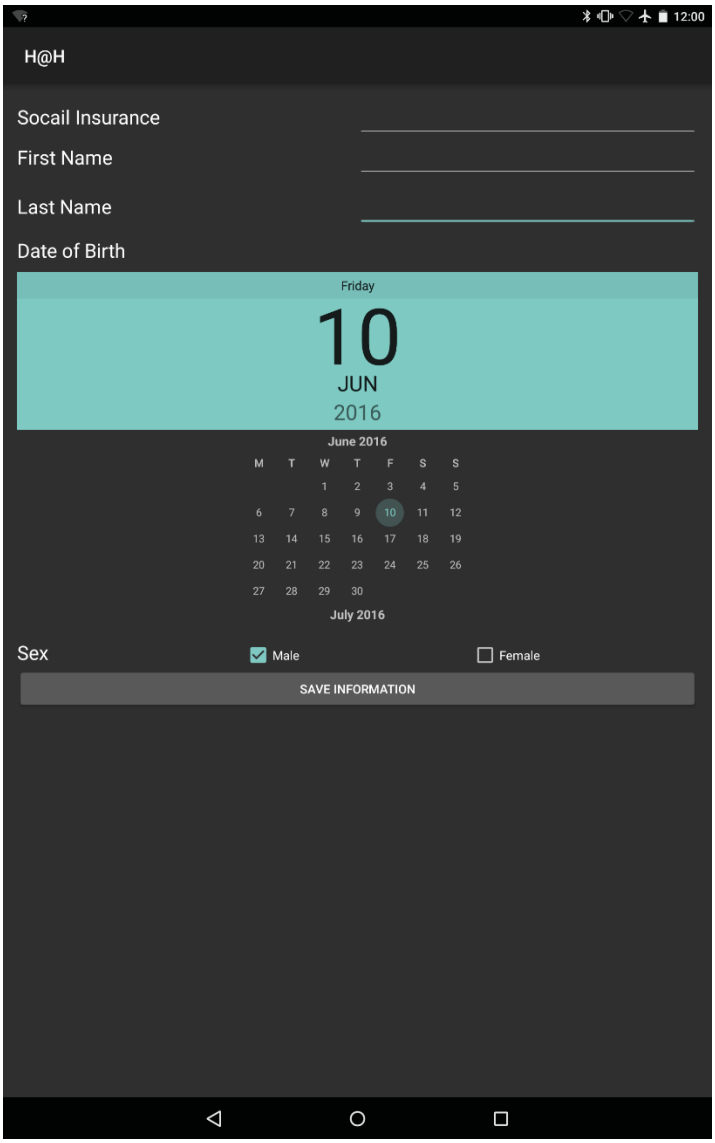


Figure 15.: Layout of the start page of the Hospital @ Home application

After saving the personal data, the second page appears. By clicking on the ‘REGISTER’ button the application will build up a Bluetooth connection with a Continua certified blood pressure monitor. The connection state is shown and a green light indicates if the connection is working. After the measurement was carried out the results are forwarded towards the tablet. The status message informs the user that the reading process is in progress. During the message extraction the systolic- and diastolic pressure values and the pulse rate are filtered out and they are shown on the screen of the manager application (see Figure 16).

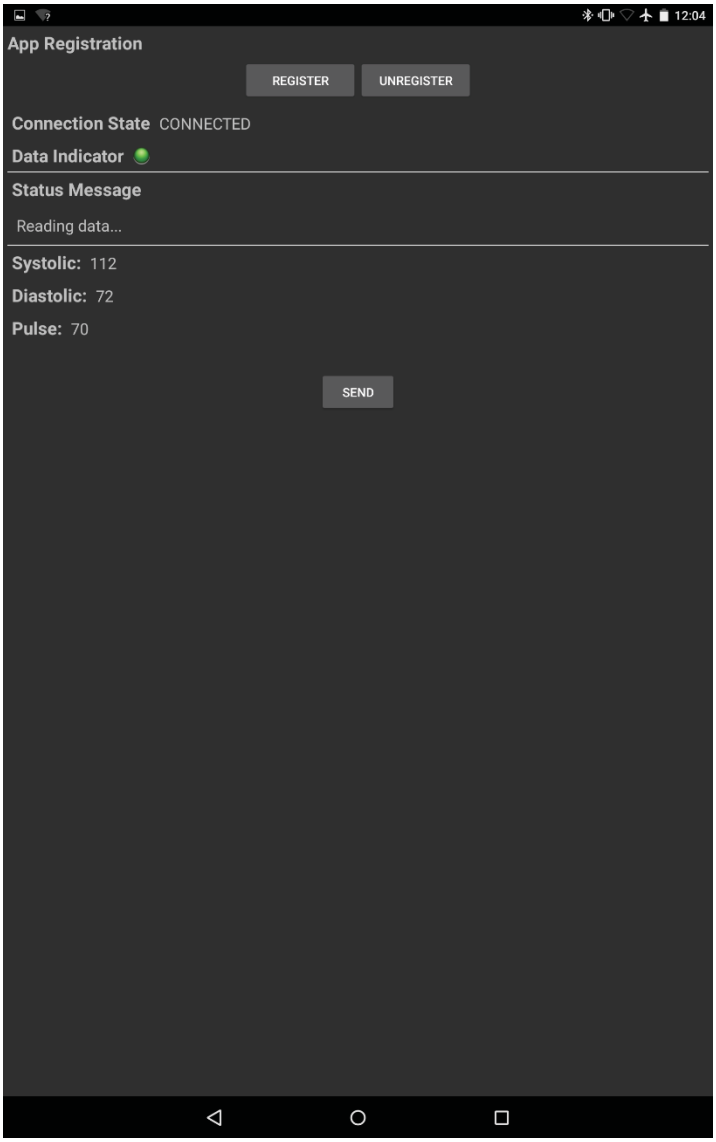


Figure 16.: Layout of the second page of the Hospital @ Home application

By clicking on the ‘SEND’ button an HL7 version 3 message is created by using a template mentioned in the Materials and Methods. The appropriate fields in the CDA header are filled out with the personal data of the patient. Furthermore the extracted measurement values are pasted into the fields of an observation of the Laboratory section of the CDA body. The user gets a feedback in form of a notification message if the data transmission was successful or not.

Server side

The main task of the server side is to extract the incoming messages and to show the patient data and measurement results on a webpage. To see the data received from android application an interface was implemented. To access this interface the person in charge must login by his or her username and password, this process ensures the security. The login page is shown on Figure 17.

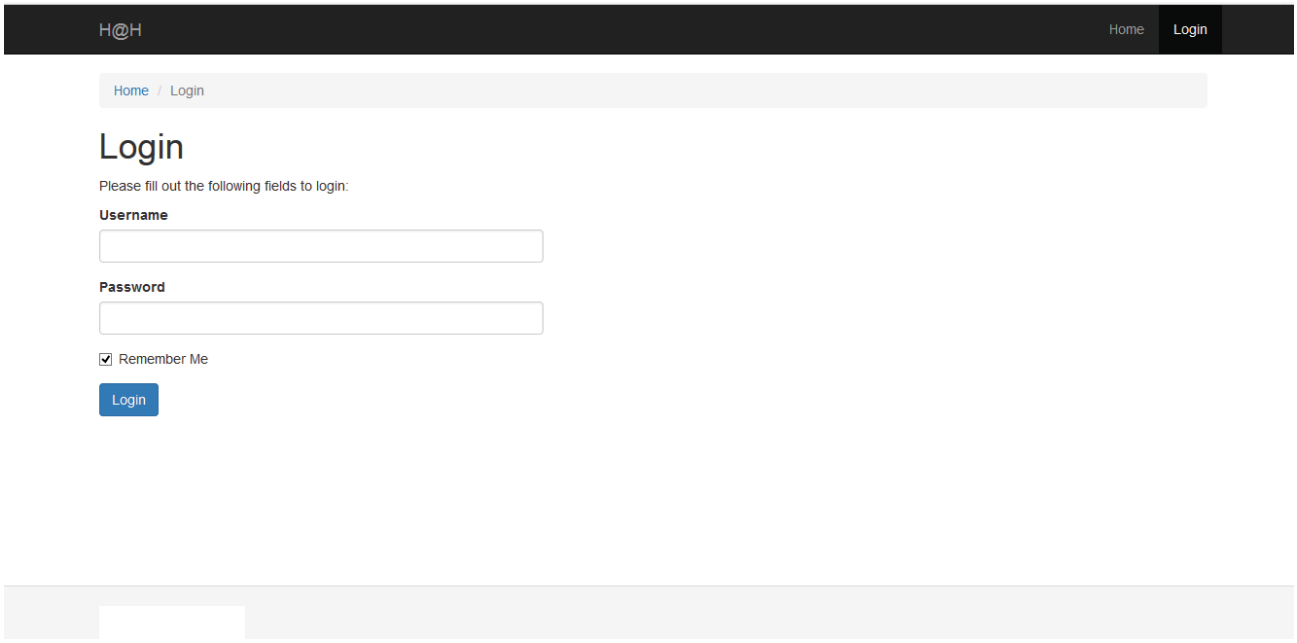
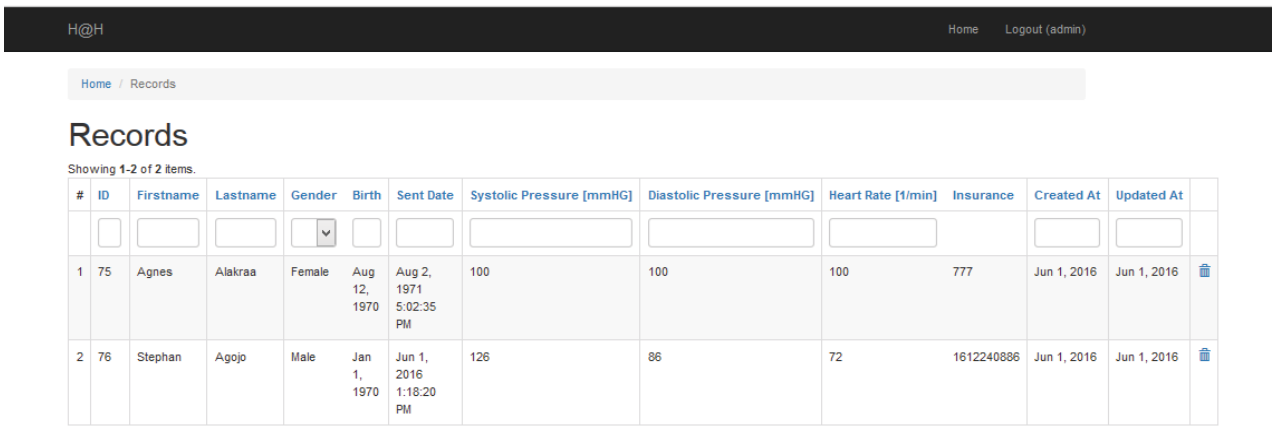


Figure 17.: Login window of the Hospital@Home server

After the login process the person can see all the information which was received from the Hospital@Home manager application in form of tables (see Figure 18). In the same time the incoming data will be stored in our database.



#	ID	Firstname	Lastname	Gender	Birth	Sent Date	Systolic Pressure [mmHG]	Diastolic Pressure [mmHG]	Heart Rate [1/min]	Insurance	Created At	Updated At
1	75	Agnes	Alakraa	Female	Aug 12, 1970	Aug 2, 1971 5:02:35 PM	100	100	100	777	Jun 1, 2016	Jun 1, 2016
2	76	Stephan	Agojo	Male	Jan 1, 1970	Jun 1, 2016 1:18:20 PM	126	86	72	1612240886	Jun 1, 2016	Jun 1, 2016

Figure 18.: Records window of the Hospital@Home server

In case of any problems in the view interface, the responsible person can login to the original database where all data are stored and only authorized persons can access it. The layout of the database window is shown on Figure 19.

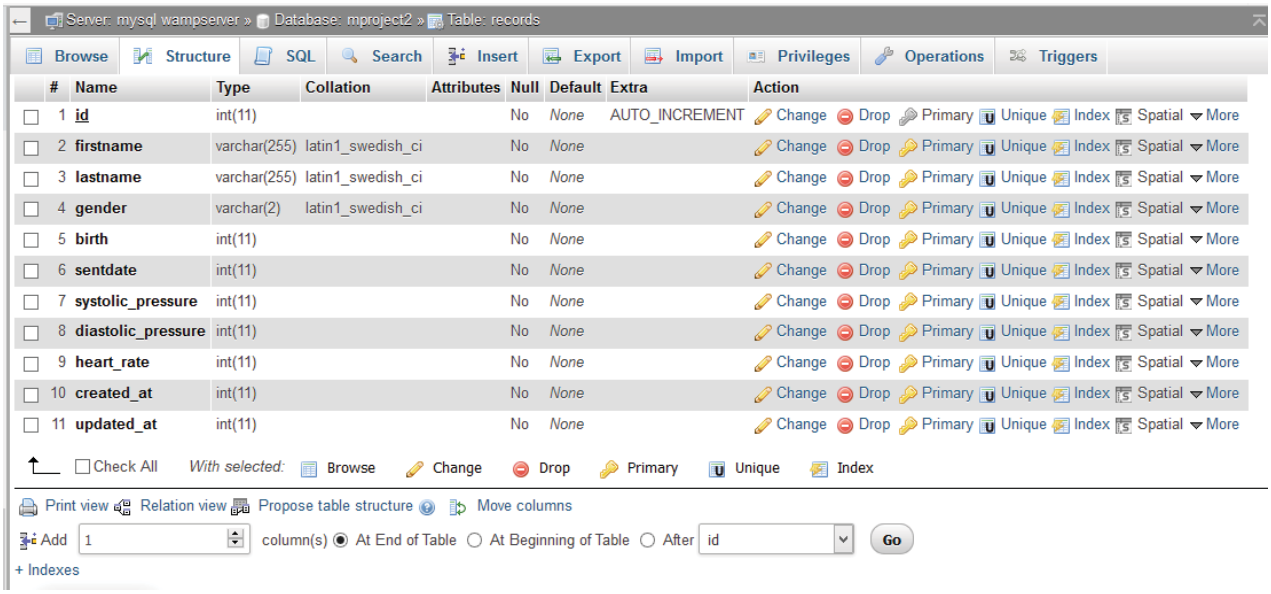


Figure 19.: The layout of the database of the Hospital@Home system

When data has received, the server will send a feedback message to the Hospital@Home Android-based manager application to inform the user that the sending process was successfully carried out.

Estimated costs

As we have already mentioned maintaining a bed in a department of a hospital is very expensive in comparison to implementing the Hospital@Home system at a patient's home.
Basically two devices has to be purchased for the patient:

- Samsung Google Nexus 10 tablet
- A&D Medical UA-767PBT Continua certified Bluetooth-capable blood pressure monitor

The tablet costs about 400 € at the moment and the price of the blood pressure monitor is approximately 600 €. These devices can be used later by further patients when the actual patient does not need it anymore.
The maintenance of a telehealthcare server is costly, but hospitals already have existing server infrastructures, which can be modified to be able to function as a telehealthcare server.
Further cost can be the salary of the telehealth nurses, but reorganization of already hired nurses can solve this too, because the introduction of telemonitoring systems will reduce the burden of nurses caring about patients laying in hospitals.

5. Discussion

Achieved results

We achieved the goals what we have defined at the beginning of the project. First we planned our milestones for the two semesters then we started to carry out a detailed literature research in the field of IT and medical standards and guidelines (IHE, Continua). The definition and examination of the five use cases was done in the aspect of technical feasibility.
The next step was designing the architecture of the system and the definition of the resources what are necessary. During the architecture planning Continua Health Alliance guidelines were used as a basis.
The data transfer between the medical devices and the mobile device (tablet or smartphone) was successfully implemented. At that point a message type conversion was necessary, because the incoming data are in X73 format and the sent message follows the HL7 version 3 standards.
The application was extended for forwarding the vital data to the telehealth centre. A success code is returned from the server side to the user to verify the receiving of the message.
To sum up a whole data transfer chain was implemented with the help of the Hospital@Home system. The communication between the devices is working in a standard based way and the sent messages are also standardized to ensure interoperability.

Future plans

Usually not only one vital parameter is monitored when somebody is spending his or her recovery time at home. Monitoring blood oxygenation, blood glucose level, blood pressure, body temperature, ECG or further parameters can be effective to get a clear picture according to the patient's health status. In the future the Hospital @ Home system can be extended to be able to handle more measurements in parallel coming from more devices at the same time.
Furthermore usability tests should be carried out on patients with different age and IT skills. Based on the results the user interface can be improved to provide a user-friendly layout even for elderly people without any IT skills. It can ensure that the patients can use the application easily and they will not make any mistakes during the usage.
Another possible feature could be to implement a result checking mechanism in a local level at the Android-based manager application. That would mean a basic data analysis on the incoming measurement results. The application could compare the actual data with the healthy reference levels and if the patient's results are out of the normal interval it can show up a warning message. In that case the patient would get an immediate feedback to his or her results. Of course forwarding these data to a healthcare professional would be necessary in that case as well.
The Hospital@Home system can be extended in various ways, which is advantageous for the future developments.

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