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Design of a telehealth system adapted for health care delivery in rural areas: Tele-consults between general practitioners and specialists

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ABSTRACT: Several issues affect the delivery of care to patients, especially in rural and underdeveloped areas. Compared to big cities, issues of fewer resources, poorer access to services, limited availability of key health professionals, poorer health status, lower socioeconomic status, distance and travel mean have negative impact on health care delivery in rural areas. These differences mean that health care planning, program development and service delivery models that are appropriate for city-based communities, do not necessarily translate well into rural settings. Telehealth has proved to overcome geographical barriers, allowing the use of new technologies for health care providers to connect with each other or patients to receive care from distant providers. In this work we designed a telehealth system addressing issues related to the health care delivery in rural areas. Several use-case scenarios were designed and implemented. Data security playing a central role, a reliable telematics platform was developed with features ensuring a high data security and privacy according to the general data protection regulation of the European union. The system was applied for the cases of dermatology and diabetes care to patients in rural and remote regions of Germany and sub-Saharan Africa. During a two-month trial (2017 and 2018), 190 patients with skin disease were treated in the emergency department of the University Medicine Greifswald. The main reasons were hyperergic skin reactions 42%, bacterial, virus of fungal infections 34%, dermatitis 19%. 76% of the patients assessed the teledermatological approach as appropriate, 81% patients trusted in the treatment. 68 Subjects tested the system for diabetes management in Sub-Saharan Africa. Features of the ICT-based system together with the cross-sectoral collaboration between general practitioners, specialists and nursing services through the system, helped remedy to the shortage of medical care providers in rural areas and enhanced the quality of care delivery.

KEYWORDS: tele-consults, telehealth, telemedicine, rural area, mobile application, telematics platform, data security.

1 BACKGROUND

In recent years, there has been a growing interest in research on the application of digital technologies in the delivery of health and social care. These debates have ranged widely, focusing especially on the development of the technologies and their impacts on the quality and efficiency of health service delivery.

Rural and remote services are unlikely to enjoy the same economies of scale as metropolitan-based services. In Germany, article 72 of the basic law says" Establishment of equal living conditions" in all parts of the Federal Republic of Germany, including in public services, which includes the health services. In the north-eastern region of Germany (Mecklenburg-Vorpommern - MV), however, there is a significant shortage of medical doctors. For many patients, a waiting time of several

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months is common for a consultation appointment with a specialist doctor, [1]. As example, in 2016 were 61 dermatologists registered in MV region. One dermatologist for an area of 380 squared km, compared to Bavaria region where one dermatologist covered 135 squared km.

As in other western countries, rural areas in Germany are undergoing a transition concerning physician shortages and the age of their inhabitants. The percentage of the elderly is increasing, whereas the young are steadily moving into cities [2, 3]. Primary health care (PHC) is known to be of high benefit for these patients [4]. PHC is expected to provide acute and chronic medical service closely to patients' homes and to function as a gatekeeper and coordinator. Strong PHC leads to higher and equitable health levels, lower costs and improved patients' satisfaction [5]. In Germany PHC is mostly provided by general practitioners (GP). GPs are the most frequently consulted physicians in Germany [6]. Without counteractions however, the locally already beginning shortage of GPs will aggravate. In Germany an undersupply of GPs is defined as a supply rate less than 75% of the relevant planning area. Within this care planning, one GP is to take care of more than 1600 patients [7, 8]

In sub-Saharan Africa the situation is worse. The region is facing continuous health threats characterized by spread of infectious diseases, high levels of infant and maternal mortality, low level of life expectancy, and deteriorating healthcare facilities and access to prevent health. Widespread poverty along with general low-income levels of the population, low education levels, inadequate access to clean water and sanitation facilities and poor access to health services have contributed to this poor situation. Shortage of access to health services in the region is further complicated by the concentration of health care services in urban centers. An estimated 70% of sub-Saharan populations live in rural areas. The rural communities have no access to, or are far from, health facilities, resulting in over 65% of sub-Saharan African population lacking essential healthcare services, healthcare investments and retaining healthcare providers. This situation is further aggravated by the high population growth. The growing inequalities in health status, problems of access and the difficulty of controlling the growth of costs have prompted most sub-Saharan countries to engage in reforms of their health sector. Telemedicine initiatives represent an attempt to address some of these pressures, and have a real potential to improve accessibility, quality of healthcare, improving the provision of services in rural area and of giving access to distance training for rural community of sub-Saharan populations, [9, 10].

Telehealth can overcome geographical barriers, allowing use of new advances in ICT for health care providers to connect with each other or patients to receive care from distant providers. For example (Fig. 1), a patient with diabetes who must travel over hours, even days in some regions of Africa, to see an endocrinologist or a patient with skin diseases who must follow a dermatologist in the next city, could receive care close to them. These patients have complex conditions that would benefit from regular monitoring to avoid preventable emergency cases.

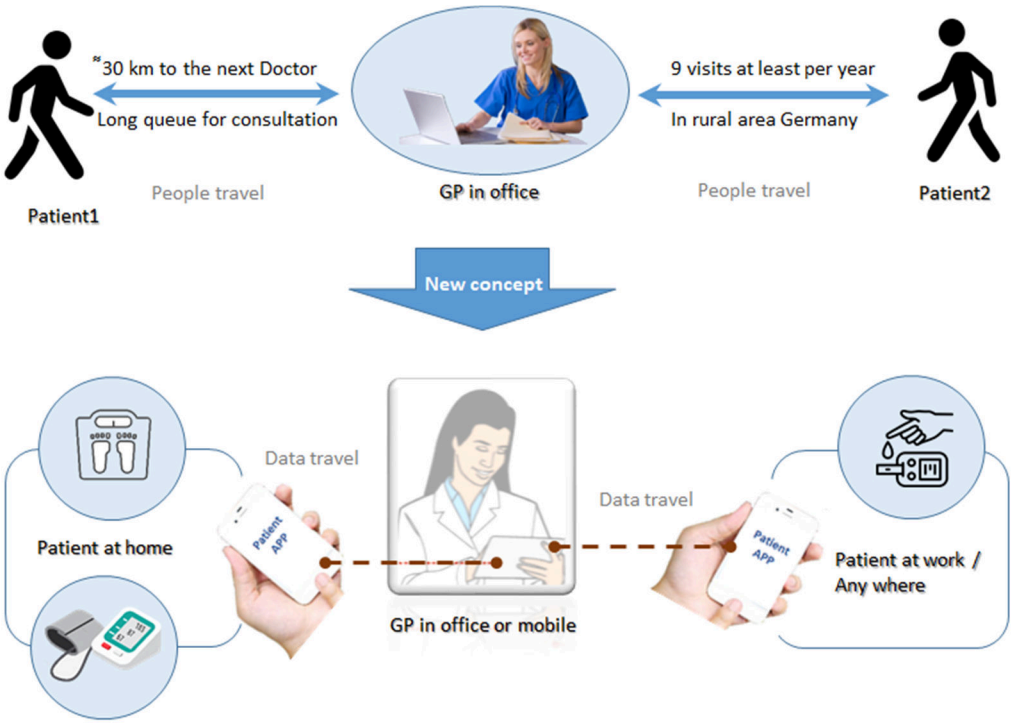

Fig. 1. Traditional health care delivery vs. new concept integrating ICT

The new concept uses ICTs to overcome geographical barriers and increase access to healthcare services. This is particularly beneficial for rural and underserved communities – groups that traditionally suffer from lack of access to health care.

Telehealth can help patients in several cases:

- Tele-consults with specialists: For chronically ill patients with no proximity to necessary specialists, the system may connect to remote specialist / or the GP gets second opinion from a specialist through tele-consults and can forward those instructions to the patient.
- Remote Monitoring for chronic care: Devices and systems can collect physical and mental health data while outside of the medical environment. This remote monitoring can be beneficial for certain chronic diseases. Health professionals can review these data for changes in health status that may prompt updates to treatment plans or visits with healthcare staff.
- Tele-consults for Emergency care: For some patients, staff can contact on-call emergency personnel who can triage common symptoms.
- Data sharing between health institutions and services. This may concern transfer letter of a patient, medical information about the patient, labs results, electronic prescription for the pharmacy.

2 MATERIAL AND METHODS

2.1 USE CASE 1: PATIENT-GP

Implementing telehealth into the care management program for patients living with chronical diseases such as diabetes and skin diseases. In this case, the system helps in monitoring patient's vital signs or self-taken measurements. This is a Store-and-forward telemedicine, consisting of collecting clinical information and sending it electronically to another site for evaluation. Information typically includes vital signs, images, videos, medical history, documents such as laboratory reports. The health professional may use a desktop computer or a mobile device to access the data and depending on the analysis, he may adapt the therapy independently from time and location (Fig. 2). The patient receives feedbacks and recommendations through the system. This collaboration with the treating doctor improves patient's motivation.

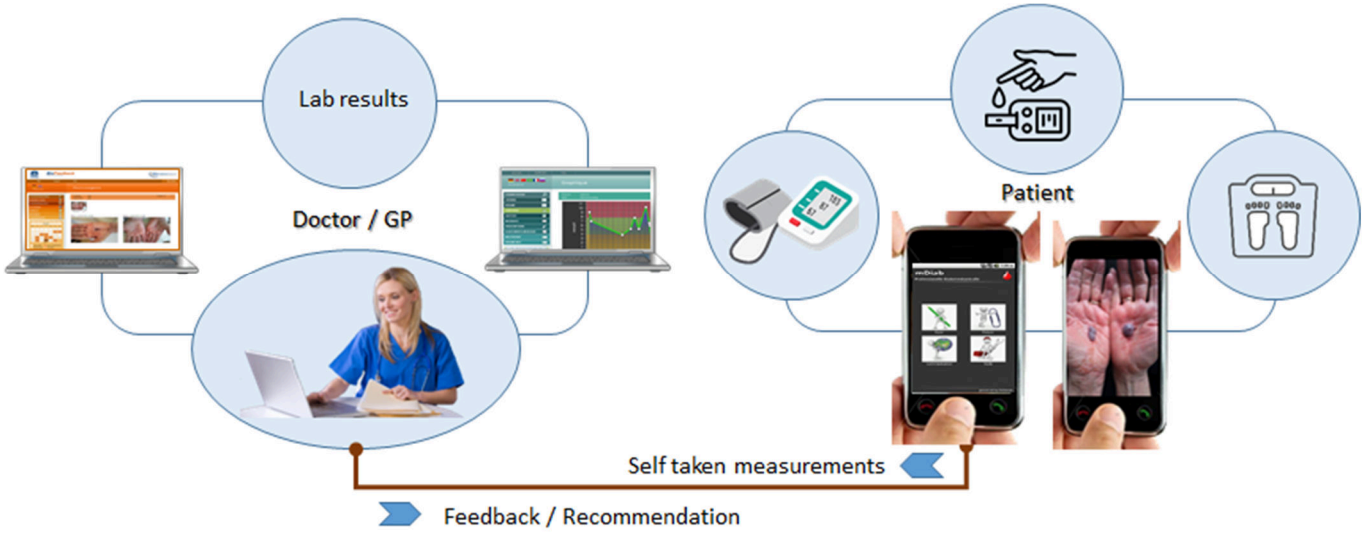

Fig. 2. Use case 1, Patient - GP

Benefits of store-and-forward consultations includes:

- the patient and GP do not have to be available at the same time – improving efficiency and convenience
- they do not need to travel – participants can be located anywhere
- waiting times are reduced – Doctor reports are often received within a few hours of the request
- outpatient appointments are freed up for patients that need them most
- unnecessary prescriptions and surgical procedures are minimized

A disadvantage of store-and-forward consultations is that the GP does not examine the patient physically. According to the analysis, it may be necessary to arrange an in-person or video consultation.

2.2 USE CASE 2: PATIENT-GP-SPECIALIST (TELE-CONSULTS)

Some geographical locations have relatively few specialist medical doctors, especially rural areas and remote communities. Getting an appointment might mean a long wait and a long journey. Telehealth offers a potential improvement to this situation through the electronic transmission of patient data and findings between professional health care providers. For some special cases, the GP can request a second opinion from a specialist, who will react with tips and instructions (Fig. 3). This helps patients just contact their GP and save themselves a trip to a specialist. Moreover, the contact to GP can also be enabled as illustrated in the use case 1.

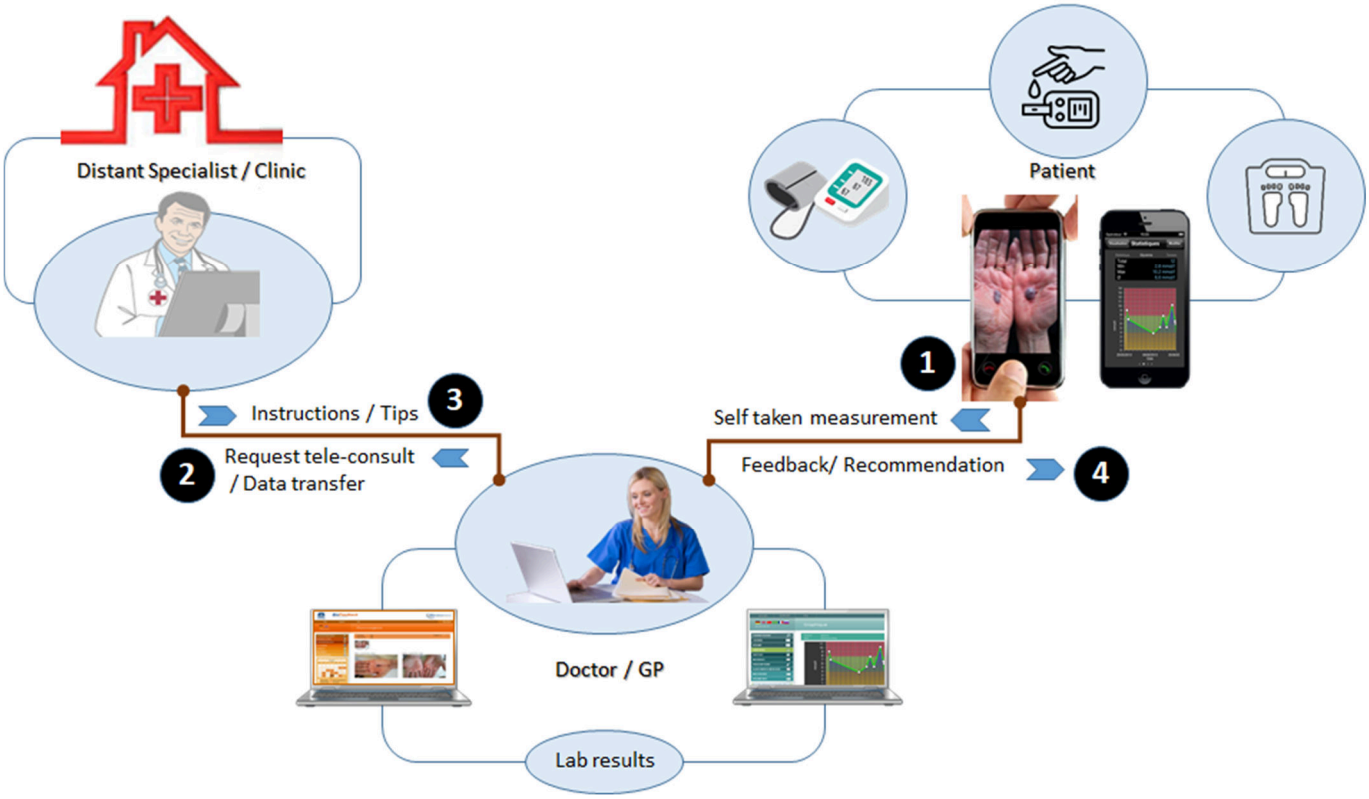

Fig. 3. Use case 2, Patient – GP-Specialist (Tele-consult)

Benefits of tele-consults includes:

- the patient, GP and specialist do not have to be available at the same time – improving efficiency and convenience
- they do not need to travel – participants can be located anywhere
- waiting times for Specialist appointment are reduced
- second opinions from specialist can be quickly obtained
- Knowledge and experience sharing between GP and Specialist
- unnecessary prescriptions and surgical procedures are minimized.

2.3 USE CASE 3: PATIENT - NURSING SERVICE - GP

As the telehealth field grows, nurses in telemedicine are facing the question of how technology fits into nursing profession. Telehealth nursing is referred to as the delivery, management, and coordination of nursing care services provided via telecommunications technology to remote patients living in their home residence. But for this use-case, nurses provide support and care (taking patient samples, pulses, temperatures and blood pressures, administering medications, managing intravenous lines, observing and monitoring patients' conditions, maintaining records) when they are at home with the patients. They use ICT-based solution for management, documentation and forwarding results to the system, (Fig.4). GP can access the stored

data and check if some extra instructions are needed. It is also possible for a patient to contact the nursing service using the telehealth system for some questions and tips.

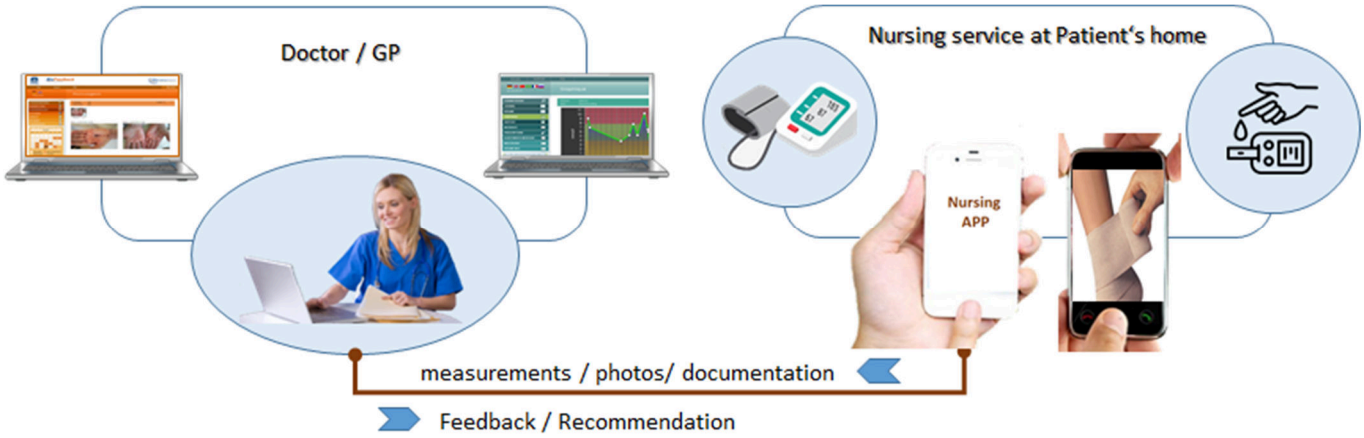

Fig. 4. Use case 3, Patient – Nursing service- GP

2.4 USE CASE 4: DIGITAL TRANSFORMATION IN HEALTH CARE - DATA SHARING BETWEEN HEALTH INSTITUTIONS AND SERVICES

Sharing and communicating information is a fundamental task in modern medicine and has to be conducted according to the data security and privacy regulations. The health care system is based on teamwork of professionals who participate in the care of patients. Exchange of information, results, documents, requires the communicating parties to agree on a communication channel, an exchange protocol, and a common language or following standards (Fig. 5).

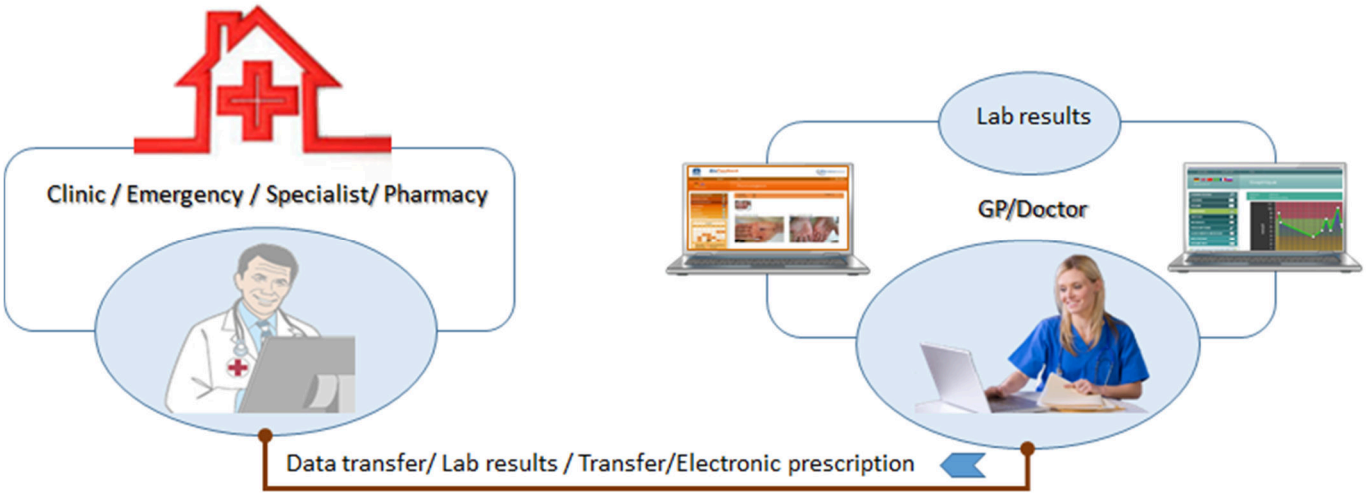

Fig. 5. Use case 4, Digital transformation in healthcare: transfer of digital data

Strategies in digital transformation in health care includes:

- **Making your business Interoperable:** The foundation of the healthcare digital transformation is an interoperable environment that enables the secure sharing of information across all levels. This is achieved by the support of standards.
- **Securing data and systems**: to address new and continuing security challenges
- **Empowering a more efficient workforce**: Today, there are not enough primary care doctors, some studies show that the doctors are already spending two-thirds of their time doing paperwork rather than seeing patients. Therefore, how to make healthcare providers as productive as possible, focusing on how new capabilities can help employees work better and faster, focusing their attention on patients instead of administrative tasks

- **Creating an innovation environment**: With the flexibility to adopt new approaches, healthcare organizations will be more responsive to market change, consumer demands and new approaches to care
- **Cultivating the right partners**: need to rethink their partner ecosystems, cultivating the best network of vendors, partners and contract workers is critical to an effective digital business transformation.

3 RESULTS

3.1 TECHNICAL IMPLEMENTATION ON A SECURE PLATFORM

We have developed a secure platform to help bridge the gap between health and mobility. Diverse healthcare modules have been implemented and tested together with different partners. These can be combined in a health care service package: diabetes, dermatology, stress, fitness and assistance systems for the independence of the elderly people. Other modules are under development. Mobility is guaranteed by integrating mobile apps and web-based applications. Moreover, interfaces to hospital information systems are supported and developed in a modular way. The security aspect is key factor, therefore, data are encrypted, stored and transferred anonymously according to the EU requirements of data protection regulations. Identification, authentication and authorization modules are integrated into the system to prevent unauthorized access to the data and services.

The five-layer architecture of the platform (Fig.6) enables users to securely share and store sensitive information. Using different devices, such as smartphones and computers, patients and health care providers can access functionalities of applications supported by the core of the platform (application-server) through the communication layer.

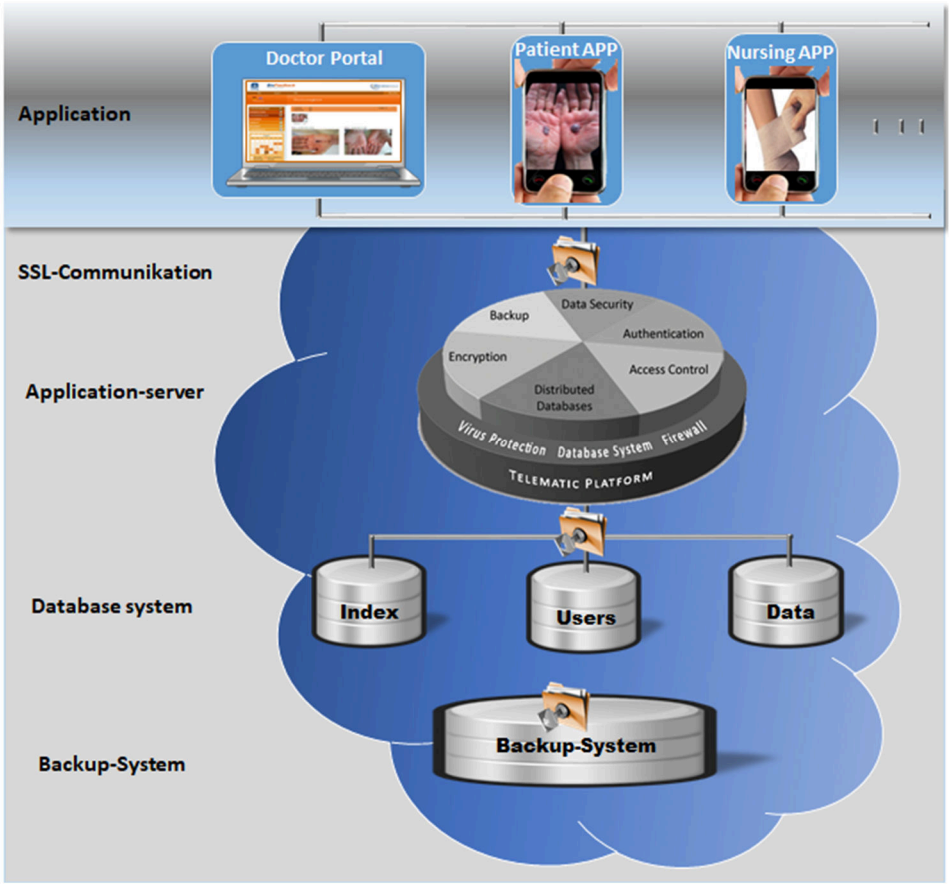

Fig. 6. Architecture of the telematics platform

Security is an imperative requirement in telehealth or eHealth systems since they handle very sensitive data like medical and personal data [11, 12]. The developed platform acquires features enabling the following.

- Authentication: methods and mechanisms which allow an entity to prove its identity to a remote end
- Authorization: access control mechanisms and the ability of an entity to access shared resources. According to a category, the access to a sector of data is authorized
- Data integrity: mechanisms which ensure that when there is an interchange of data between two peer entities, the received data and the original ones are the same, and that no intermediate alteration has occurred
- Data confidentiality: it assures that stored or transmitted data are well protected from possible disclosure. A mean used to achieve data confidentiality is through cryptographic mechanisms. Advanced Encryption Standard with different key length is applied
- Privacy: it can be defined as an entity's ability to control how, when, and to what extent personal information about the entity will be communicated to third parties
- Secure data communication and storage
- Support of major communication standards to health institutions
- Data availability: data can be accessed by authorized users independently from time and location

3.2 FIELD TEST AND EVALUATION RESULTS OF THE TELEHEALTH SYSTEM

3.2.1 CASE WITH DERMATOLOGY PATIENTS

The developed telehealth system was tested for the case of dermatology care delivery in the north-eastern region of Germany. During 2017 and 2018, 190 patients aged between 18 and 88 years were treated for skin disease at the Emergency Department of the Medical University of Greifswald (UMG). The emergency surgeons' staff was assisted by the dermatology specialist using the developed system mSkin® Doctor. Consultations in the emergency department were almost always outside the regular working hours. 59% came on weekends and public holidays, 39% on workdays but after 4 p.m. We should notice that 33% of patients came from rural areas (areas with less than 10,000 of population), 41% from regional centers or mid-sized centers. In the average, patients travelled 23 km from their homes to the emergency department.

From the 190 Patients who attended the emergency department of the Medical University of Greifswald, 59 evaluated the care delivery provided through the use of the teledermatology system mSkin® Doctor: 76% of the patients felt that they had received adequate care, 81% had confidence in the proposed therapy and trusted the medical instructions and decisions. 68% rated the teledermatological care outside regular working hours as appropriate. However, 32% of the patients wished to see the physical presence of the dermatologist all the time. Details about the evaluation study itself can be found in [13]

3.2.2 CASE WITH DIABETES PATIENTS

Our first evaluation study for the case of diabetes management was conducted in 2010. From diabetic patients who were successively included in the medical rehabilitation at the specialized clinic for children and adolescents MEDIGREIF Inselklinik Heringsdorf GmbH, a total of 77 children and adolescents were registered and trained to participate to a three-month study. The aim was to investigate the impact of using novel ICT-based system in assisting the therapy and treatment of diabetes. After exclusion according to the fixed criteria, 68 subjects aged between 8 and 18 years, divided randomly into control and intervention groups, participated to the study. Metrics such as changes in the quality of metabolic control, changes in psychological parameters, usability and acceptance of the technology were used for evaluation purpose. Metabolic control was mainly assessed by the mean HbA1c. Analysis showed a good acceptance of the proposed system. An overall improvement in mean levels of HbA1c was observed. The system appeared to be an efficient and time saving tool in diabetes management. Details on the conducted study can be found in [14].

Another evaluation study was conducted in sub-Saharan Africa. In order to test the effectiveness of the developed telehealth system used for the case of diabetes management in the context of African health care system, a trial was conducted in two cities in the eastern part of the Democratic Republic of Congo (Goma and Butembo). Patients diagnosed with type 2 diabetes and aged between 35 and 75 years were recruited randomly. A total of 40 patients were included in the trial phase. For classification and evaluation purpose, the cohort was divided into a control group (conventional therapy without the use of telemedicine system) and an intervention group (treatment with the use of telemedicine system MobilDiab®). The use of the MobilDiab® showed improvement of clinical outcomes of the patients from the intervention group involved in the conducted trial. This has been demonstrated from the amelioration of both the HbA1c (from 8.67% to 6.89%) and the mean amplitude of glycemic excursions which is characterized from both the mean blood glucose and its standard deviation. The decrease of the blood glucose fluctuations is demonstrated from results of the mean blood glucose standard deviation from

the intervention group compared to the control group at the end of the study (33.0 mg/mL instead of 48.6 mg/mL). This proves how the use of the system could help patients stabilize better their glucose values. Positive evaluations of the system from patients and medical staff have been presented based on three metrics: usability and design, efficiency and therapy satisfaction, and acceptance and appreciations. The obtained scores are 7 points and greater out of the 10 maximum points. Specific details on this study are in [15].

4 CONCLUSION

In this work we have designed, implemented and tested a telehealth system addressing issues of the health care delivery in rural areas. A number of use-case scenarios have been developed: Patient-GP, Tele-consult between GP and Specialist, Patient-Nursing service-GP, Data sharing between health institutions and services. The integration of new advances of ICT in the developed telehealth system, together with the cross-sectoral collaboration between health care providers have helped reduce the negative impact of these issues: fewer resources, poorer access to services, limited availability of key health professionals, poorer health status, lower socio-economic status, distance and travel mean. The system has been successfully applied to deliver care and treatment for dermatology and diabetes patients in rural and remote regions of Germany and sub-Saharan Africa. The developed telematics platform establishes a secure communication and data storage and hence enables the implementation of the system according to the regulations of the EU Data protection.

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