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Mobile Display of Information about Aggregated Antibiotic Resistance in the Hospital Setting Supported by Near Field Communication

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Abstract. Antibiotic resistance is a heterogeneous phenomenon. It does not only differ between countries or states, but also between wards of hospitals, where different resistance patterns have been found. To support clinicians in administering empiric antibiotic therapy, we developed software to present information about antibiotic resistance using a mobile concept. A pre-existing infrastructure was deployed as the server component. The systems analyze and aggregate data from laboratory information systems, generating statistical data on antibiotic resistance. The information is presented to the Android client using a Representational State Transfer (REST) interface. Geographical localization is performed using near field communication (NFC) tags. The prototype provides tabulated data concerning antibiotic resistance patterns in the wards of a hospital. Using Android, NFC, and data caching, the usability of the system is estimated to be high. We hypothesize that antibiotic stewardship in hospitals can be supported by this software, thus improving medical monitoring of antibiotic resistance. Future studies in a productive environment are needed to measure the impact of the system on the outcome of patient care.

Keywords. Clinical decision support systems, Android, near field communication, mobile health, antibiotic resistance

1. Introduction

Antibiotics are agents exerting selective effects on bacteria. Antibiotic resistance (AR) is a natural phenomenon, resulting from selection pressure. AR has become a serious threat because of the widespread use of antibiotic agents. In his Nobel Prize lecture, Sir Alexander Fleming—the discoverer of penicillin—noted the effect of AR and advised

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prudent use of antibiotics [1]. AR currently constitutes a significant threat to human health and the economy [2]. The phenomenon is by no means static, and does not respect time or geographical borders. Published resistance data showed heterogeneous AR patterns and changes over time between European countries [3], within individual countries (such as Austria [4]), and even within hospitals [5].

Empiric antibiotic therapy is necessary even when the pathogen causing the infection and its antibiotic susceptibility are unknown. Various factors, such as the patient's condition, distribution volumes, and the site of infection, have to be kept in mind when prescribing antibiotic therapy. These factors taken together limit the variety of antimicrobial drugs that may be used. The anticipated pathogen and its antibiotic susceptibility must also be taken into account. Antibiotic spectra cards provide information about antibiotic susceptibility. The cards are tables printed on hard paper, to be carried in the clinician's pocket. Antibiotics and bacteria are arranged in rows and columns, respectively. A color code in the intersections of the table indicates the respective susceptibility.

We report on software known as "qRe", which addresses the temporal and geographical irregularity of antibiotic spectra cards [6]. A more granular concept is required in order to do justice to the heterogeneity of AR patterns between hospital wards. Gierl et al. developed a specific software system for hospitalized patients, presenting resistance information for each ward of a hospital [7].

Several accurate applications exist for indoor geographical localizations. A common feature is the use of radio frequency-based technology (e.g., global positioning system (GPS), wireless local area network (WLAN), Bluetooth). A relatively new short-range radio frequency-based technology is near field communication (NFC). The use of NFC for geographical localization was evaluated recently [8].

2. Methods

We describe the expansion of qRe for use in a hospital environment. The working title of this version is "qReHospital". NFC tags were used for geographical localization. The software was designed as a client–server application, using Java EE version 6 as the server platform, and Android for clients. An architectural overview is provided in Figure 1. The primary objective of the server component was collection and aggregation of data from different sources. Once per customizable time interval, it receives all microbiological data recorded during the last interval from the specified data sources. The Android client communicates with the web service interface using Representational State Transfer (REST) over an encrypted connection based on Security Sockets Layer (SSL). All data are transferred using the JavaScript Object Notation (JSON).

2.1. Data

An antibiogram is a contingency table of all detected pathogens in a bacterial culture and the tested antibiotics. The date of the order and the department that ordered the testing are stored in order to put the antibiograms into spatial and temporal context. Therefore, a single data item must at least contain the date of resistance testing, the department where the patient resides, the identified pathogens, and the semi-quantitative results of the evaluated antibiotics. Pre-processing of data was performed, including normalization (eliminating erroneous records), clean-up of double findings, and sequential isolate clean-up. Performing these data-refining steps required access to the electronic medical records of the patient. Software that already performs these steps had been developed by an associated work group in the past [9, 10]. All of these records were condensed into single semi-quantitative values per department, pathogen, and antibiotic, for each week. To yield significant results, the software required at least ten antibiograms per germ–antibiotic–department combination. In case sufficient result numbers were not available, the retrospective interval of the application was expanded in week steps until the required case numbers were available.

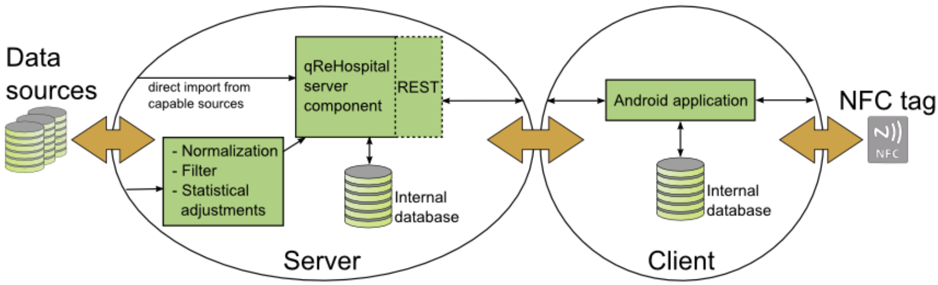

Figure 1. Architectural overview of the components of qReHospital.

2.2. Near field communication

The NFC Data Exchange Format (NDEF) is a standardized exchange format for data stored on NFC tags. Each NFC tag can hold one NDEF message, which by itself may hold a variable number of NDEF records. Also, an Internet Mail Extensions (MIME) type is defined, for facilitating correct encoding of the contained data. The NFC Forum has defined four NFC tag types [11]. We chose NTAG203 NFC type 2 tags, with a maximum capacity of 144 bytes, and a read-only bit that can be set to prevent further writes to the NFC tags [12].

The Android application programming interface provides elaborate tools for accessing and manipulating NFC tags. It offers a dispatch mechanism that distributes the NDEF messages, based on the MIME type of the NDEF records, to the application that is capable of further processing.

2.3. Geographic localization and security setup

Similar to the explicit reference model described in [8], the geographical position was stored on the NFC tag. In our setting, encrypted identifiers (using symmetric Twofish encryption) were used to increase data security. Subsequent activation of the read-only bit prevented further data manipulation. The key for decryption was stored in a hard-coded manner in the byte code of the Android application. After affixation of the NFC tags, holographic security seals protected them from subsequent physical movement.

2.4. The Android application

Resistance data were updated in the background in times of internet connectivity, thus providing resistance data in areas of no wireless reception. The actual position of the user and the age of the data set were shown to the user in the top left corner of the main view (Figure 2, left). By using a custom MIME type of the NDEF message, the Android client was started automatically when the user scanned one of our NFC tags.

The main view of the user interface (Figure 2, left) was a table with the antibiotics in the columns and the bacteria in the rows, with color codes corresponding to a specific resistance rate (Figure 2, right). A tap on an intersection displayed the course of resistance over time for the actual position, and the selected germ–antibiotic combination. To prevent the display of geographically incorrect data, the user was asked after every return from the standby mode to confirm the geographical location, or to scan a new NFC tag.

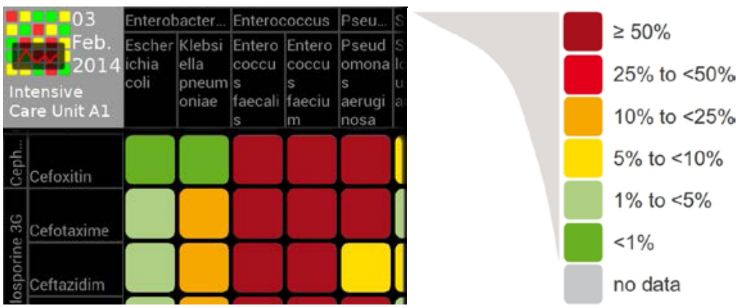

Figure 2. Left: Snippet of a screenshot of the main view of the Android client—antibiotics are placed in rows, bacteria in columns; Right: The color codes and their resistance ranges.

3. Results

A prototype of the application was developed using the methods described above. In our testing environment, we employed a dataset of 1,600 random antibiograms for a total of four clinical departments. We generated data for twelve different pathogens, with random antibiograms for twenty antibiotics. NFC tags were generated for the four different virtual departments in order to test NFC geographical localization.

4. Discussion

We show the feasibility of automatic aggregation of resistance information and geographically selected presentation of such information for Android clients. Improvements as compared to traditional antibiotics spectra cards include the topicality of the data, the high granularity of data, and the easy-to-use concept of NFC tags. The cost of administration is minimal; aggregation and analysis of the data are fully automatized. The NFC model used in our work differs in some respects from the approach reported in [8]. As data security and reliability are very important, we decided to implement a counterfeit prevention system with encryption of the data and the use of holographic security seals. The NFC tags hold all the necessary information about geographical location. No access to a server is needed to resolve the data to a geographical position.

We hypothesize that empiric antibiotic therapy for hospitalized patients can be improved by using qReHospital. Three major user groups are addressed. First, clinicians may instantly improve their empiric antibiotic therapy based on the current resistance situation. As resistance rates are calculated continuously, a higher rate of AR to a specific antibiotics class should lead to lesser use of the respective antibiotic class, and thus automatically counteract resistance. Second, details of the aggregated data help hospital hygienists to detect resistance problems early in specific wards. Third, infectiologists may use the data presented in qReHospital to advise clinicians in regard of complex infections.

5. Conclusions

The delivery of automatically calculated AR information—selected for the current location of the user in a hospital—on Android smart phones is shown. The concept of using NFC tags for geographical indoor localization in hospitals is new. Further evaluation is needed to determine the clinical impact of the software.

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