DIFFERENTIATED ACCESS TO EHRS FROM EMERGENCY MOBILE UNITS, CONSULTING ROOMS AND HOSPITALS

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Abstract: In this paper, a model is proposed for the support of anamnesis through Electronic Health Records (EHRs). These data are stored on a hybrid LDAP-SQL system, available on the Internet and accessed from Emergency Mobile Units (EMUs), consulting rooms and hospitals. Each of such scenarios corresponds to different network technologies, i.e. UMTS on EMUs, DSL in consulting rooms, WiFi and wired/fiber within a hospital. Furthermore, EHRs can be queried using heterogeneous devices, such as mobiles, PDAs, laptops and desktops. In consequence, it is important to reach the best trade-off between quality/quantity of data and reception rate. To this purpose, this paper proposes a possible methodology for choosing, scaling and adapting the data format (and consequently dimensions and response time) to actual necessities and technologies at disposal. Analytical calculations are also presented showing the download time in each scenario.

1 INTRODUCTION

An appropriate anamnesis plays a fundamental role in many medical contexts, ranging from hospital visiting and medical consulting to emergency medicine. The medical history of a patient, though, is generally neither precisely known nor simply available.

For instance, very rarely are such data collected together, completely stored on digital devices and accessible by means of an integrated environment. Conversely, the availability, effective management and efficient access to medical histories, possibly stored on Electronic Health Records (EHRs), could be of great help in the decision of which treatments the patient should undergo. This could also be useful in order to schedule resources in the best way, so as to provide the most serious cases with the best and quickest aids.

In this paper, the problem of EHRs as a support to anamnesis and release of services is faced, taking the following factors into consideration:

- EHRs can be queried from at least three distinct locations, i.e. Emergency Mobile Units (EMUs), consulting rooms and hospitals;
- these scenarios correspond to different network connection modalities and speeds (UMTS, DSL, WiFi, wired/fiber), as well as available devices (mobiles, PDAs, laptops, desktops, etc.);
- such situations lead to distinct possible ranges of medical intervention. For instance, no retrospective analysis of CAT scans is feasible from EMUs (meaning it can be made in an acceptable time), since they have low-speed connections.

In this context of heterogeneous access modalities, it is essential to reach the best trade-off between quality/quantity of information and reception rate. To this purpose, a possible approach is here proposed to reach an efficient access to data in each network scenario.

This paper does not claim to be anyhow rigorous in terms of medical concepts and procedures: it simply aims at giving a guideline for an effective management of information, facing the problem of EHRs in heterogeneous environments.

As a matter of fact, even though EHR systems exist from a long time [Smaltz & Berner, 2007, Dwight et al, 2006, Yun et al, 2005], their effective world-wide adoption and standardization are far from being reality. Furthermore, as long as the authors know, no precise criteria were fixed showing how such files should be used and optimised in order to fit different environments and connection technologies [Heier et

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al, 2002, Yuang et al 1994, Bronson et al, 1993, Caouras et al, 2003].

The main point of the suggested methodology is the following: the amount of data actually needed does not generally correspond to the whole information available on EHRs, so the only essential information must be required and uploaded, especially if low-speed connections are used.

For instance, treating an allergic reaction can require the history of allergies and blood tests results in text format, whereas past X-ray examinations are of no interest. Again, if an EMU is transporting a patient who was injured in a car accident, it can query name and blood group. In contrast, all X-rays and MRI scans can be needed when treating osteoporosis in case of hospital consulting. In this situation, all the available data are relevant for the definition of a correct treatment plan.

The proposed solution allows to query EHRs in a differentiated way (text-only modality, text and images, etc.), on the basis of the information needed, urgency and kind of network connection at disposal. In other words, the three scenarios depicted above are put in correspondence with as many types of feasible requests.

Access to EHRs is optimised using such criteria and access to services is made accordingly.

Behind the system lies a medical database which stores EHRs, as well as information about services, resources and their availability.

The main architecture of the whole system is described in Section 2; the database structure is discussed in Section 3; Section 4 deals with the optimisation methodology for querying EHRs and presents analytical calculations of response time in each situation.

2 MAIN ARCHITECTURE

As depicted in Fig. 1, two main components are considered: the *"User-System Communication Interface"* (A) and the *"Hospital System" (B)*.

As for the first component, it acts as an interface between the user and the system. In this context, the word *user* indicates an operator (physician, paramedic, etc.) who queries EHRs or asks for hospital services availability. Such functionality is represented by the *"Query Layer"* module.

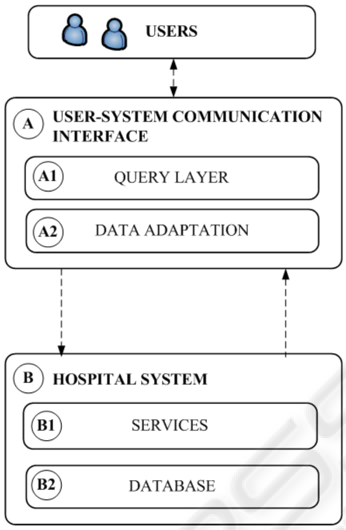

Figure 1: Communication and Hospital System.

The second role of the Communication Interface is to optimise the data exchange quantity and format between end users and the system, in order to fit different connections and actual needs. This process is represented by the *"Data Adaptation"* module.

As far as the Hospital System is concerned, it is viewed as a collection of services and data: hospital centres put services at disposal, such as consulting, tests, emergency surgery, etc., and users are meant to access an (ideally) integrated database storing EHRs, tests' results, bookings, and so on.

This approach can be described in more detail by means of the 4-layered architecture in Fig. 2, which is increasingly enriched from the left to the right.

The vertical axis on the left reflects the classification in Fig. 1; on the right, all the components are expanded and represented with respect to their interaction and to the data flow which takes place among them.

The main purpose and features of each block and its sub-modules are described in the following.

2.1 Communication Interface

This component must carry out the following tasks:

- collect the user's requests;
- transform them on the basis of the user's devices (mobile, PDAs, laptops, etc.);
- optimise access to data;
- forward queries to the hospital system and manage results;

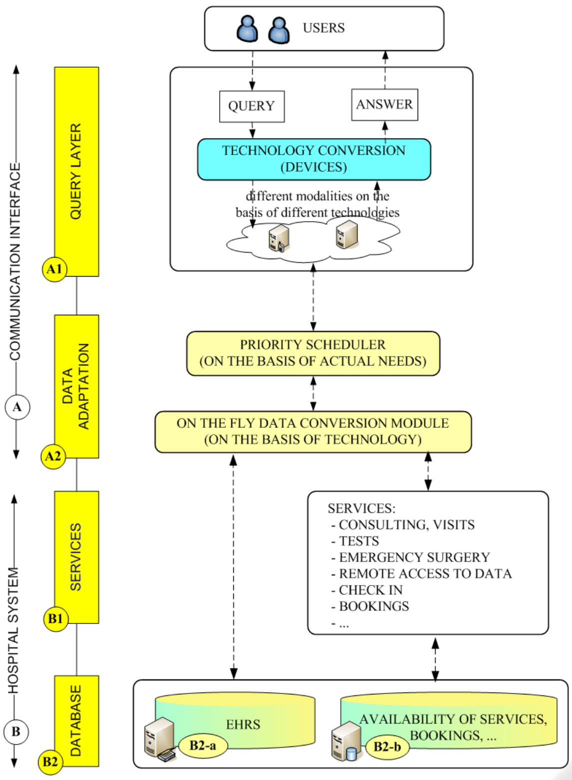

Figure 2: Main architecture.

The first two tasks concern the management of queries and data with respect to the user's device, and are accomplished by the Query Layer. The last two tasks concern data access optimisation and are fulfilled by the Data Adaptation module.

As for the Query Layer, the problem of converting data on the basis of available devices has not been mentioned yet, but, when talking of data format, two different - even not independent - operations must be distinguished. First, data transformation due to the type of device (*data conversion* on the basis of technology, Query Layer). Second, data format scheduling due to the type of network connection and to the request of the only information really needed (*data adaptation* on the basis of actual needs, Data Adaptation module).

Since the system must communicate on the basis of the user's device, the user's data must be converted in a format that both the front-end to services and the database system can understand.

This process will last the whole lifespan of the medical assistance and can easily be done by means of XML conversions. As a matter of fact, this is a straightforward, general and effective way for exchanging data between heterogeneous environments.

As far as the Data Adaptation module is concerned, in order to optimise response time in each scenario, the following guidelines must be taken into account:

- data that contribute to an anamnesis have different formats, ranging from text (e.g.: allergies, remedies) to images (e.g.: X-rays, CTs, etc.);
- efficiency can be better achieved if physicians themselves decide which kind of data they really need (if simple text or images) and in which detail (complete description, medium-resolution images, high-resolution images, etc.);
- in the same way, the medical staff must be aware of which data can be downloaded in a reasonable time in each scenario;

This module requires the design of an appropriate database schema and of an optimised access methodology for filtering data on the basis of actual needs and connection speed. For instance, a consulting room will firstly download the main medical parameters and then, if needed, some images.

In more detail, on the basis of the user's scenario, the *"Priority Scheduler"* suggests him a selection of data that can be downloaded in acceptable times. According to such information, data are accessed and returned to the *"On the Fly Data Conversion Interface"*. On the basis of connection speed, this module adapts the data format, especially image resolution, and sends results to the user.

A possible way for achieving such targets is the core of Section 4.

2.2 Hospital System

As shown in Fig. 2, the Hospital System contains both services and data.

As for data, they are mainly divided in EHRs and data about bookings, availability of services and so on. As far as services are concerned, the main ones are consulting, visits, tests, emergency surgery, remote access to data, check in, booking facilities, check of nearest examinations' units, etc.

In this context, the focus is on the data flow among the components of the proposed architecture. In this representation, the database is accessed according to the UML-like diagram in Fig. 3: the medical staff queries the database B2-a (EHRs) by means of the Priority Scheduler. Once the most convenient format has been decided, such data are

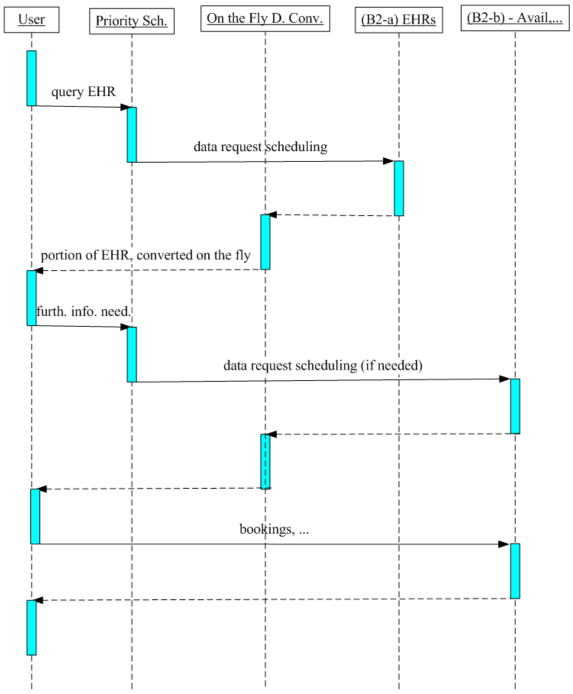

Figure 3: Data flow among modules.

processed by the On the Fly Data Conversion Interface, scaled - in case of images - to a proper resolution and returned to the user.
Such information helps physicians understand the patient's anamnesis and guides the choice of further data from EHRs or bookings, necessary tests to be performed, etc.
This means accessing database B2-b and check availability of services, book consultings, tests and so on.
Once the physicians or medical staff have been notified where and when such resources will be at disposal, access to hospital services can be effected.

3 DATABASE SCHEMA

In this section, the following issues are faced: how EHR are defined in the proposed model and which systems should be adopted to develop them.

3.1 EHR Definition

Medical histories vary in depth and focus by nature. For example, a simple checkup would require registry data such as name and age, as well as present conditions, pressure and blood tests. In contrast, the history of a neoplastic pathology involves many details about the patients' life, examinations, CAT scans and so on.
On the other hand, when the efficient access to data is considered, the only information should be queried which is really necessary and can be received in an acceptable time.

According to these observations, EHRs should be defined whose information is described at different levels using different formats.
This can be done representing EHRs by means of data of increasingly rich format (ranging from text to images). For instance, in this approach, an X-ray examination stores both a textual description of the result and the X-ray image itself.
Using this kind of representation allows to meet both requirements of actual necessity and efficiency.

In this model, an example of a possible structure for EHRs is proposed, which includes:

- demographics (data 1);
- medical (data 2) and first aid (3) parameters, such as:
  - examination and progress reports of health and illnesses;
  - allergy lists, and immunisation status;
  - side-effects and interactions of remedies used on the patient, etc.; recommendations for specific medical conditions; appointments, …
- symptoms, diagnosis and prescribed treatments (data 4) of past and current medical assistance.
- main examinations (data 5): list (5a), description of results in text format (5b) and images (5c), if any, such as:
  - laboratory test results (blood tests, etc.);
  - radiology images (X-rays, CATs, MRIs, etc.);
  - clinical photographs (endoscopy, etc.);
- main operations (data 6): list (6a), description of results in text format (6b) and images (6c), if any;

In this model, images are stored with the best resolution available and they can be queried and downloaded at different levels of precision. In more detail, if the medical staff reckons it sufficient or technology does not allow a better solution, the Data Adaptation Module scales resolution and returns data consequently.

Another important consideration in the design of the database schema is that information can be classified as follows:

(i) EHRs are *static data*, i.e. they are not meant to be frequently updated;

(ii) availability of services, bookings, etc. are *dynamic data*, i.e. they are time-varying by nature;

3.2 Database Layer: the Hybrid LDAP-SQL System

These requirements suggest the use of a hybrid database structure for data storage: an LDAP directory service [Yeong et al, 1995, Howes et al, 2003, Kandlur et al, 1998] for static data and a relational DBMS for dynamic information.

LDAP (*Lightweight Directory Access Protocol*) provides both a modelling and an implementation tool, it is used in a wide number of applications, including enterprise databases and network configuration. LDAP is highly indicated for Internet applications, both from the data representation viewpoint and for an efficient access. Furthermore, it is scalable, extendable and optimised for reading operations, so it is particularly suitable for static data. It also supports standards and interfaces of many multimedia broadband applications, as well as integrated access to services.

Another important feature is that the LDAP data model uses a hierarchy of classes, each class described by single-valued or multi-valued attributes. This tree structure allows to organise and navigate data in a very efficient, simple and user-friendly way. Furthermore, LDAP schemes can be very easily modified and extended in order to add new attributes and new classes. Such operations, in contrast, would be very time-consuming if traditional database systems were used.
This feature can be very useful when designing EHRs: as a matter of fact, new objects and new attributes are very likely to be modified or added, due to new needs, experiences or improvements made by the people who are developing them.

Finally, LDAP was built for the integration of distributed environments, so it suits the distributed location of medical material and patients' histories very well.

As far as the dynamic part of the database is concerned, it mainly concerns the time-varying information. In more detail, the dynamic database stores data about services, their scheduling, bookings, etc. In this case, an SQL database is more suitable. As a matter of fact, such models are optimised for reading/writing operations and time-varying data. The connection between the LDAP and the SQL databases are LDAP object identifiers which, used as user identifiers, guide the joint navigation of LDAP and SQL data.

3.3 LDAP Schema for EHRs

The approach sketched in 3.1 can be formalised by means of the LDAP tree structure in Fig. 4, where an EHR is defined by means of the following hierarchy. The 0-level class describes the EHR in general and addresses all its items, such as different examinations. This class stores the EHR identifier, the data source of each item (e.g.: the database of another hospital from which an examination comes from) and dimension of the component in KB (e.g.: dimension of an X-ray image).

The 1-level classes are *demographics* and *medical data*.
The former stores the patient's name, contacts and similar data.
The latter is defined by the following attributes: *type* of data, *description*, *date*, *physician*, *paramedic*, *technician*. A possible instance is: (examination, chest X-ray, June 24th 2008, Dr Robert Hill, --, Mr John Green), meaning that the information concerns a chest X-ray examination made on June 24th 2008, prescribed by Dr Robert Hill and made by the technician Mr John Green.

The *medical data* class has as many subclasses as the types of medical information in EHRs. In particular: *medical parameters*, such as blood group; *first aid parameters*, such as the list of allergies; data about past and current *assistance*, such as symptoms, diagnosis and prescriptions.
Further subclasses are *examinations* and *operation*, here represented as a single class. By means of the subclasses *text result* and *images*, results of examinations and operations are stored in text format and images, if available.
For instance, the *examination* class, which inherits all the attributes of the parent classes, has two subclasses *text* results and *image* result. Possible instances of such subclasses are (fracture of the first and second ribs) and the available images respectively. A further subclass *other* was defined in case other data were needed.

3.4 SQL Schema for Accessing Services

Even if this issue is not the focus of the work, the main objects that must be represented in the dynamical part of the database are services, their availability and their booking. Roughly speaking, this means representing four classes of information:

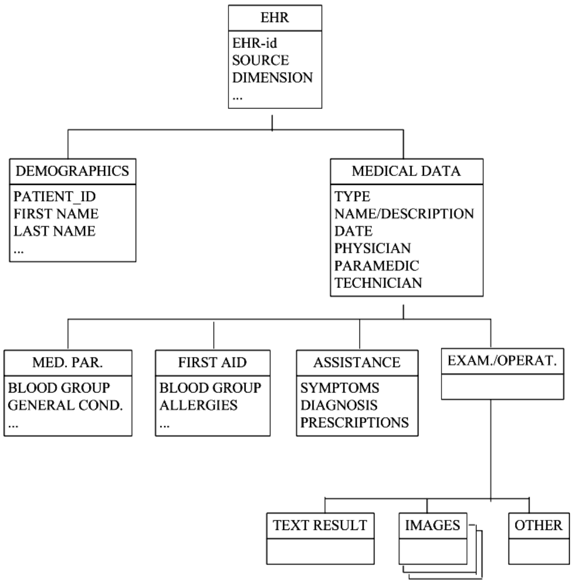

Figure 4: proposed LDAP structure for EHRs.

patients, medical staff, services at disposal and relationships among them. Data concerning people are stored in the LDAP tree and are meant to be retrieved from it using LDAP identifiers.

At least two main tables must be defined: *Services* (service_id, service_name, description, …), *Bookings*(patient_id, physician_id, service_id, date, time,…), where patient_id and physician_id correspond to patients (EHRs) and physicians within the LDAP tree.

4 PRIORITY SCHEDULER AND ANALYTICAL CALCULATIONS

Coming back to optimisation, let us consider again the Data Adaptation block in Fig. 2, as reported in Fig. 5. The *"Priority Scheduler"* suggests the user a feasible selection of data he can download. The *"On the Fly Data Conversion Module"* adapts the image resolution to the network connection at disposal, and returns data accordingly.

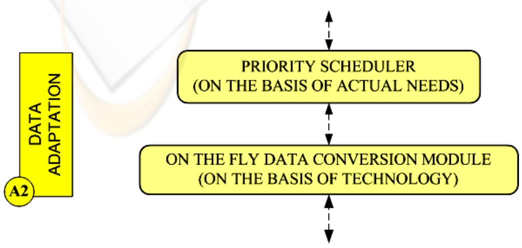

Figure 5: Data Adaptation Module.

A model is now described which guides the differentiated access to EHRs on the basis of these factors: (a) scenario, meaning connection speed; (b) data types and their dimensions; (c) order in which data are required in each scenario.

As for connection speed, four situations are considered, where EHRs are accessed through different technologies (Tab. 1). In this context, *download speed* should be more properly called *goodput*, i.e. throughput at application level.

Table 1: Scenarios and connection speeds.

Scenario	Technology	Download speed
EMUs	UMTS	200 Kbps
consulting rooms	DSL	2.6 Mbps
hospitals	wired/fiber	60 Mbps
physicians moving within the hospital	WiFi	8 Mbps

As for the data types and dimensions fixed in this model, they are summed up in Tab. 2, where images at different resolution are also considered. As a matter of fact, EHRs store images with the best resolution available, but, if the medical staff judges it sufficient, they can be queried and downloaded at different levels of precision.

Identifiers 5c_high, 5c_med and 5c_low in Tab. 2 indicate images of type 5c at high, medium and low resolution respectively, and 6c_high, 6c_med and 6c_low represent 6c.

Table 2: Dimensions in KB of data in EHRs.

Identifiers	Data	Dim(KB)
1	demographics	100
2	medical parameters	300
3	first aid parameters	200
4	symptoms, diagnos.,..	1000
5a	list of examinations	200
5b	results (in text format)	500
5c_high	image of ex. (each)	600000
5c_med	image of ex. (each)	300000
5c_low	image of ex. (each)	100000
6a	list of operations	200
6b	results (in text format)	500
6c_high	image of op. (each)	600000
6c_med	image of op. (each)	300000
6c_low	image of op. (each)	100000

Factor (c) is the key to an optimised access to EHRs: as a matter of fact, on the basis of urgency and connection speed, the medical staff is assumed to query data in different quantity and order.

The download priority in Tab. 3 is supposed to be obeyed. Medical data are enumerated as in Tab. 2: 3 represents first aid parameters, etc.

EMUs (with UMTS) are expected to require first aid and medical parameters before any other information. Furthermore, using a low-speed technology, they are supposed to be aware they would not receive images in an acceptable time.
This is why the download priority in Tab. 1 is 3, 2, 1, 5a (first aid parameters, medical parameters, demographics, list of examinations and results in text format respectively).

Table 3: Download priority on the basis of connection.

Scenario	Download order
EMUs	3, 2, 1, 5a, 6a
consulting rooms	1, 2, 3, 4, 5a, 5b, 5c_low
hospitals	1- 4, 5a, 5b, 6a, 6b, 4x5c_high, 4x6c_high
physicians moving within the hospital	1- 4, 5a, 6a, 2x5c_med

If consulting rooms (with DSL connection) are considered, some images - even not extremely detailed – can be downloaded. In this context, a physician does not generally need to receive information with extreme urgency, so, beside all the data 1-6a in text format, he can query an image at medium resolution (5c_med), or wait for further ones.

In hospitals (with wired/fiber connection, the fastest possible), the whole EHR can be downloaded. A physician moving within the hospital with his laptop can use a WiFi connection, faster than a DSL and much slower than a wired/fiber. In this case, he downloads all the textual data and some images at medium resolution.

4.1 Numerical Results

The considerations above are formalised in Figg. 6-9, which show respectively the download time in the four scenarios.

The information is supposed to be downloaded progressively, as indicated in Tab. 3. The x-axis represents download time, the y-axis represents the amount of information.

As for EMUs (Fig. 6), first aid parameters (3 in Tab. 3) can be at disposal in 8 seconds; if further medical parameters (2) and demographics (1) are also requested, 24 seconds are necessary. The list of examinations and operations (5a and 6a) will require further 16 seconds. Downloading an image – even a low resolution one – would require more than 60 minutes.

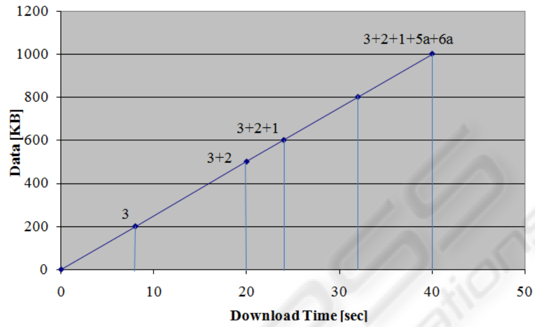

Figure 6: Download time on EMUs (UMTS technology).

As for consulting rooms (Fig. 7), downloading demographics, medical and first aid parameters, symptoms and diagnosis, lists of examinations and results in text format (1-4+5a+5b) requires 7 seconds, but, if an image at low resolution is requested, more than 5 minutes will be necessary.

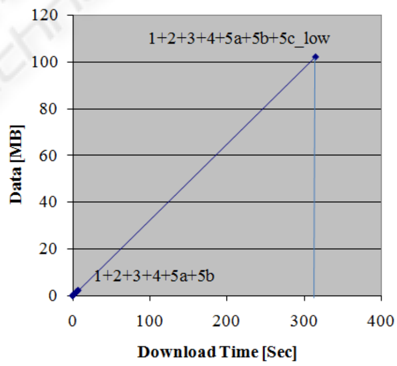

Figure 7: Download time in consulting rooms (DSL).

If a wired/fiber connection is used within a hospital (Fig. 8), the whole EHR can be downloaded in a few minutes. All the data in text format, including examinations, operations and descriptions of results can be available in less than one second; an image at high resolution in 80 seconds; further images 80 seconds each.

If a WiFi connection is used by a physician moving within a hospital (Fig. 9), it takes less than a second to download the main parameters, demographics and the list of examinations and operations, and 300 more seconds for each medium-resolution image.

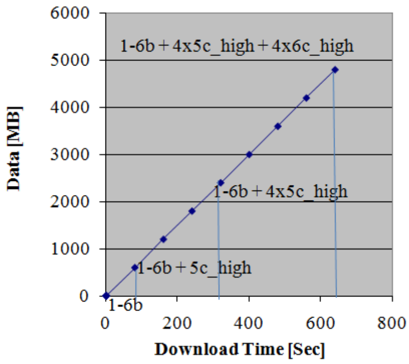

Figure 8: Download time in hospitals (wired/fiber).

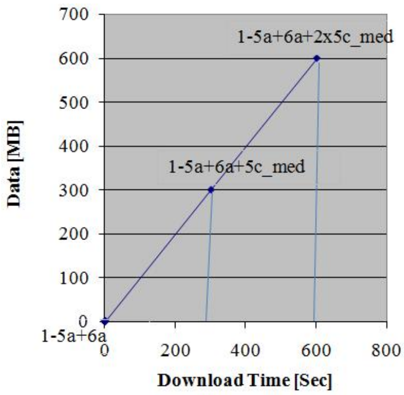

Figure 9: download time in hospitals (WiFi).

5 CONCLUSIONS

In this paper, a possible approach to EHR utilisation was proposed, based on the location from where data are accessed and the kind of use.

In particular, a selective access to a EHR was suggested, based on three degrees of detail of information: textual data; results in text format (descriptions); results by means of images at different resolution.

Computations were also presented which should guide the medical staff in the choice of the priority of information that can be feasibly downloaded or not.

Further work will be devoted to the design of a complete environment for a simulation.

REFERENCES

Evans, D. C., Nichol, W. P., & Perlin, J. B., 2006. Effect of the implementation of an enterprise-wide Electronic Health Record on productivity in the Veterans Health Administration, *Health Economics, Policy and Law, 1,* 163-169, Cambridge University Press.

Smaltz, D. H., & Berner, E. S., 2007. *The Executive's Guide to Electronic Health Records,* Health Administration Press.

Yun, H.Y., Yoo, S.K., & Kim, D.K., 2005. Performance Evaluation of Telemedicine System based on multicasting over Heterogeneous Network, *Engineering in Medicine and Biology Society IEEE-EMBS 2005. 27th Annual International Conference of the,* 2175 – 2177.

Heier, S., Heinrichs, D., & Kemper, A., 2002. Performance evaluation of Internet applications over the UMTS radio interface, *Vehicular Technology Conference,* IEEE VTC 2002, *4,*1834-1838.

Yuang, M.C., & Hsu, S.J., 1994. LAN protocol modelling and performance evaluation, *Communications, ICC 94, SUPERCOMM/ICC '94, IEEE International Conference on Serving Humanity Through Communications, 2,* 685 - 689.

Bronson, G., Pahlavan, K., & Rotithor, H., 1993. Performance evaluation of wireless LANs in the indoor environment, *18th Conference on Local Computer* Networks, 1993, 452 – 460.

Caouras, N., Freda, M., Monfet, F., Aldea, V.S., Naeem, O., Tho L., & Champagne, B., 2003. Performance evaluation platform for xDSL deployment in a complex multi-segment environment, *Canadian Conference on Electrical and Computer Engineering, 2003. IEEE CCECE 2003, 1,* 61 – 64.

Howes, T., Smith M., & Good G., (2003). *Understanding and Deploying LDAP Directory Services*, Addison Wesley 2003, 2^ ed.

Kandlur, D., H. Schulzrine, H., Verma, D., & Wang, X., 1998. *Measurement and Analysis of LDAP Performance*, Network Systems Department - IBM T.J. Watson Research Center.