

Context for Securing EHRs in a Dynamic Healthcare Environment

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Abstract— Although many of the healthcare decisions are influenced by individual's characteristics and choices, highly dynamic nature of the healthcare environment has introduced numerous challenges to EHRs such as privacy and security. Some accumulating evidences show that adding context in an access control model can help improve the security of EHRs by providing dynamic levels of access to the records while taking into consideration environmental and healthcare professional's context. Contrary to its promises, when appropriately used, researchers in the healthcare environment are still using contextual attributes proposed by researchers from other domains such as Ubiquitous Computing (UbiComp). This act, in turn, reduces the rate of protection of EHRs as different domains consider some contextual attributes to be more important than the other.

Again, with the nature of information that is collected, processed and stored using Electronic Healthcare Information Systems, close attention should be paid out to who controls what is gathered, who has access to it and where that information is stored. Taking into consideration the need of knowing where EHRs are stored, then contrary to identity, location, time and activity, which are mostly used in UbiComp and other domains, in our ongoing work, we propose to use subject, time and activity while replacing location with resource as location cannot stand on its own without resource or subject to be associated with it.

In this paper we investigate how rich in context the general healthcare environment is and thereafter propose relevant contextual attributes for the domain. The proposed contextual attributes will be used as a guideline while identifying specific contextual attributes for the Tanzania's healthcare environment as different healthcare workflows have different context that need to be considered important. The approach being adopted for our main research is by adding specific contextual attributes, from the Tanzania's healthcare environment, into the Role Based Access Control model while developing a dynamic context-aware access control model for securing EHRs in Tanzania.

Keywords— Electronic Healthcare Record, Context, Access Control, Dynamic Healthcare Environment

I. INTRODUCTION

The concept of context intersects with a diverse range of research from Artificial Intelligence (AI), Ontology, Knowledge Representation to healthcare [1]. With this multiplicity of domains where context has been differently

defined and various contextual attributes have been proposed, it is therefore, not obvious to define context. However, in order to propose contextual features also known as contextual attributes that need to be considered while providing healthcare professionals with dynamic levels of access to patient's Electronic Healthcare Records (EHRs), clear definition of context as well as relevant contextual attributes from the domain need to be provided [2]. The term dynamic levels of access to patient's records means healthcare professionals will be provided with varying levels of access to the records depending on contextual attributes gathered. Consider, for example, two healthcare professionals requesting access the John's EHRs; the first healthcare professional is requesting to access records while outside of the healthcare centre and the other is in the ward (within the hospital). While considering location (context) before providing access, then these two professionals will be provided with two different levels of access to the record as the latter may be provided access to only basic information while the other being given full access.

For the whole hospital, context tends to improve operational efficiency by integrating real time contextual information, such as location and status of medical equipment and staff, into the healthcare workflow. As a result, context enhances the quality of patient care, increases staff efficiency while helping the healthcare organisation manage capital and operational costs. In relation to patients in general, context enables access to environmental information, such as temperature or humidity, to provide an optimal patient experience [3] while to patient's records, the inclusion of contextual attributes may result into healthcare professionals to be provided with dynamic levels of access to the records and hence ensuring confidentiality as well as security of records.

As an example, consider the following scenario for the applicability of the contextual attributes in the dynamic healthcare environment.

Within a hospital, a healthcare professional can move between theatre, ward, pharmacy, office, front desk and meeting room. He may also request to access Electronic

Healthcare Records while outside the hospital. This movement may occur at different times.

Let's say John is a healthcare professional at the Muhimbili National Hospital in Dar es Salam, Tanzania. He has the privileges to access Anna's sensitive Electronic Healthcare Records (EHRs). He requested to access Anna's records at 8:00 am when in a meeting room with other healthcare professionals and again requested to access the records at 3:00pm while at the front desk and lastly he requested to access Anna's records at 8:00 pm, he while outside the hospital.

From the above scenario, let's say we consider location (of the subject) and time as our contextual attributes whereby

Subject_role = (Consultant, Specialist, Doctor, Nurse)
Location = (theatre, ward, pharmacy, office, front_desk, meeting_room, outside_hospital)
Time = (6:00am < time < 5:00pm)

Note: Time indicates the duration where healthcare professionals can provide services to patients from outside (outpatients).

With these information then we can create a condition in an access control model by including these information and hence reducing the chances for breaching patient's confidentiality as well as security of the records. Example of the conditions may be

{subject: (can_access if subject_role = "doctor" ^ location = "theatre, ward, office" ^ time < 5:00pm)}

Again as the state-of-art for the protection of EHRs in the healthcare environment, various access control models such as Role-Based Access Control (RBAC) [4], Team-Based Access Control (TMAC) [5] and Task-Based Access Control (TBAC) [6] have been used. With RBAC, access control decisions are often determined by the roles individual users take on as part of an organisation while TMAC and TBAC consider group roles and progression of the tasks respectively to control access to information. Due to the nature of the healthcare environment, these models and others are considered insufficient for the dynamic healthcare environment. The RBAC does not support the use of contextual attributes as it may result into role explosion while TMAC and TBAC are special configurations of RBAC. Therefore, with the identified promises of context in the dynamic healthcare environment, in this paper we look at how researchers other domains have attempted to define context in their own work as well as propose relevant contextual attributes for the domain.

Organisation of the paper: Section 2 provides a review of various definitions of context proposed by researchers from different domains. Section 3 discusses categories of context. Section 4 presents a review of context specifically for the healthcare environment while section 5 provides descriptions

of contextual attributes. Section 6 provides discussion and future work

A. Aim of the Paper

Based on the survey performed on existing research literature, we intend to analyse how rich in contextual attributes the dynamic healthcare environment is and then propose relevant contextual attributes, with its associated subcategories, for the dynamic healthcare environment.

B. Methodology Used

For this study, research has been done through major electronic research databases (such as Medline, PubMed), scientific journals via their own sites as well as Web Search Engines (mostly Google Scholar). These resources were used to identify research published from different domains such as UbiComp that identify relevant contextual attributes for their domains.

Different themes were used to identify relevant papers for this study. The themes used include i. Context ii. Contextual attributes iii. Contextual attributes in healthcare iv. Context and electronic healthcare. To broaden our research references from the main papers were also studied.

II. CONTEXT

In this section we review various definitions of context that has been proposed by researchers from other domains and then evaluate them before proposing relevant contextual attributes for the dynamic healthcare environment.

The first and formal definition of context which enumerates context as location of use, identities of the nearby people and objects and changes to those objects over time was proposed by Schilit [7]. In a similar way, Ryan et al. [8] define context as user's location, environment, identity and time while Brown et al. [9] considered context as location, identities of the people around the user, orientation of the device, and time of the day, season of the year, temperature and so forth. Dey [10] enumerates context further as user's emotional state, focus of attention, location and orientation, date and time, objects and people in the user's environment.

Although these definitions provide examples of contextual attributes, it is difficult to apply any of them when we want to determine whether a type of information not listed in the definition is context or not. To solve the aforementioned problem, Dey and Abowd [11] provided a thorough definition which describes context as any information that can be used to characterise the situation of an entity where an entity is a person, place, or object that is considered relevant to the interaction between a user and an application, including the user and applications themselves. Therefore from the definition, Dey and Abowd propose location, identity, time and activity as relevant contextual attributes.

Contextual attributes proposed by Ryan et al. [8] are considered as the consensus to those proposed by Dey and Abowd [11]. The only difference that exists in terms of contextual attributes between the two is that the latter proposed activity as contextual attribute instead of environment proposed by the former. Dey and Abowd [11]

argue that environment is a synonym for context and does not add anything in their research while activity will characterise the situation by indicating what is really occurring in such a situation.

III. CATEGORIES OF CONTEXT

As highlighted in section 1, the principal aim of this paper is to propose relevant contextual attributes for the dynamic healthcare environment. The categorisation of context will help in identifying specific contextual attributes that need to be considered while providing healthcare professionals with dynamic levels of access to sensitive patient's EHRs.

Therefore, from section 2, different researchers have provided different categories of context. Dey and Abowd [11] while working in the UbiComp domain list location, identity, time and activity as important contextual attributes to the interaction between user and application while Schilit and Theimer [12] suggest location and identity as contextual attributes. Summary of the contextual attributes proposed by various researchers have been provided in table I.

TABLE I
SUMMARY OF CONTEXTUAL ATTRIBUTES

No.	Author	Contextual Attributes
1	Brown et al. [13]	Location, Time of the day, Season, Temperature, Identities of the people around the user, Orientation
2	Ryan et al. [8]	Location, Environment, Identity and Time
3	Dey [10]	User's emotional state, Focus of attention, Location of attention, Date and Time, Objects and People in user's environment
4	Dey and Abowd [11]	Location, Identity, Activity and Time.
5	Schilit and Theimer [12]	Location and Identity information
6	Coutaz et al. [14]	Location and Identity
7	Beresford [15]	Summarises Dey and Abowd's (2000) categories as Identity: identity of relevant entities. Location: geographical position of relevant entities Activity: activity or activities being performed Time: time period at which entities perform the activity
8	Kjeldskov and Skov [16]	Location, Time and Tasks.

Based on the literature review, as indicated in table 1, there is a huge variation on contextual attributes proposed by various researchers. Location, identity and time appear more compared to other attributes such as temperature and season. To resolve contextual attributes variation issue, Beresford [15],

claims that, there are primary and secondary context whereby secondary context requires an association with one or more primary context to be meaningful. Therefore, for example, temperature is a secondary attribute associated with location while date of birth and address are secondary attributes associated with identity

IV. CONTEXT IN THE HEALTHCARE ENVIRONMENT

For contextual attributes in the healthcare environment, Bricon-Souf and Newman [1] also argue that location, identity of the healthcare professionals and time are the most common attributes considered. However, from the literature review performed, we argue that the dynamic healthcare environment, which at the same time considered collaborative, is rich in context and there is lack of research to-date performed to identify contextual attributes specifically for the environment. For this paper identification of the contextual attributes together with their respective subcategories relevant for the dynamic healthcare environment is considered to be one of its contributions

Contrary to various contextual attributes proposed from other domains, for the dynamic healthcare environment we propose the use of resource rather than location. As EHRs are processed, stored (databases) and transmitted using EHISs then there is a need of using attributes of the database where these records are stored. The summary of the proposed contextual attributes and their sub categories has been provided in table II. In section 5 each proposed category together with its subcategory is briefly discussed.

V. CONTEXTUAL ATTRIBUTES: DESCRIPTIONS

As presented in table II, contextual attributes in dynamic and collaborative healthcare environment can be categorised into four groups. These are attributes associated with the subject, time, activity and resource, whereby

- Subject involves individuals involved in the processing EHRs
- Activity: Includes activity or activities being performed
- Time: Is the time period at which entities perform the activity
- Resource: Is the storage space for Electronic Healthcare Records

As indicated in table III, Subject has various attributes associated with it such as Subject ID, Subject Name, Group ID, Group Name, Session Start Time, Session Start Date, Session Start Time and Date, IP Address, etc while Resource, as indicated in table IV, is associated with Resource Label, Resource Name, Row Label, View Label, Schema Label, Catalog Label, Database Label, Database Name, Column Name etc.

In addition to subject and resource's context, there is time and activity. Time is associated with Current Time, Current Date and Current Date and Time while Activity is associated with Activity ID, Activity Type and Activity Request Location.

With the presence of these and other attributes in the healthcare environment, which involves processing of sensitive patients information, combining with the fact that the

more contextual attributes used the more fine-grained access control system becomes then there is a need of identifying specific contextual attributes for certain environment if EHRs need to be protected.

TABLE II
SUMMARY OF CONTEXTUAL ATTRIBUTES

Subject	Time	Activity	Resource
Subject ID	Current Time	Action ID	Resource Label
Subject Name	Current Date	Action Type	Resource Name
Group ID	Current Time Date	Action Request Location	Row Label
Group Name			Table Label
Session Start Time			View Label
Session Start Date			Schema Label
Session Start Time Date			Catalog Label
IP Address			Database Label
DNS Name			Column Name
Session Label			Table Name
User Current Location			View Name
User Allocated Location			Schema Name
			Catalog Name
			Database Name
			Any-row field value

TABLE III
SUBJECT ASSOCIATED ATTRIBUTES

ATTRIBUTE	DESCRIPTION
Subject ID	This is the numerical user-ID of the database subject performing the current database operation
Subject Name	This is the text user-name of the database subject performing the current database operation
Group ID	This is the numerical group ID of the database project performing the current database operation
Group Name	This is the text group name of the database subject performing the current database operation
Session Start Time	This is the local time the database subject started the current database session
Session Start Date	This is the local date the subject started the current database session
Session Start Date Time	This is the local date and time the database subject started the current database session
IP Address	This is the IP network address from which the current database subject started the current database session
DNS Name	This is the Domain-Name Service host name from which the database subject started the current database session
Session Label	This is the database session label at the time the database operation was submitted
User Current Location	As healthcare professionals tend to move over time, this is the current location where the user is.
User Allocated Location	This is the permanent location where the healthcare professional is allocated as his/her area of duty.

TABLE IV
RESOURCE ASSOCIATED ATTRIBUTES

ATTRIBUTE	DESCRIPTION
Resource Label	This is the sensitivity label of the database object currently being acted upon. Example of the resource label include: For row select: the label is row label, for schema open, label is schema label and for database-open the label is database-label
Resource Name	This is the fully specified name of the database object currently being operated upon. For table open, then the table name will be its associated resource name while for view-create its associated resource name is view-name.
Row Label	This is the sensitivity label of the database row currently being operated upon. This attribute only is associated with row-associated attributes such as row-insert, row-select, row-delete etc.
View Label	This is the sensitivity label of the database view currently operated upon. Like in row, this attribute is only associated with the database view such as view-open, view-create, view-drop operations.
Schema Label	This is the sensitivity label of the database schema currently being operated upon.
Catalog Label	is the sensitivity label of the database catalog currently being operated upon
Database Label	This is the sensitivity label of the database currently being operated upon
Column Name	This represent multi valued bag of specified column names of the database row currently being operated upon
Table Name	This represents the fully specified name of the database currently being operated upon
View Name	This is the full specified name of the database view currently being operated upon.
Schema Name	This is the fully specified name of the database catalog currently being operated upon.
Database Name	This is the name of the database currently operated upon.

VI. CONCLUSION AND FUTURE WORK

In this paper we have proposed contextual attributes, together with their respective subcategories, relevant for the dynamic healthcare environment. Contrary to other domains where location, identity and time appear to be more important, in healthcare we propose the use of these three attributes together with resource rather than location. The reason behind our selection of resource rather than location is that location is basically associated with the subject or resource as it cannot stand on its own without resource or subject in place. Generally speaking, location is a secondary attribute to subject and resource. In addition, resource is more important in healthcare as it is where patient's Electronic Healthcare Record is stored.

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