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A IHE-Like Approach Method for Quantitative Analysis of PACS Usage

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Abstract Today, many hospitals have a running enterprise picture archiving and communication system (PACS) and their administrators should have the tools to measure the system activity and, in particular, how much it is used. The information would be valuable for decision-makers to address asset management and the development of policies for its correct utilization and eventually start training initiatives to get the best in resource utilization and operators' satisfaction. On the economic side, a quantitative method to measure the usage of the workstations would be desirable to better redistribute existing resources and plan the purchase of new ones. The paper exploits in an unconventional way the potential of the IHE Audit Trail and Node Authentication (ATNA) profile: it uses the data generated in order to safeguard the security of patient data and to retrieve information about the workload of each PACS workstation. The method uses the traces recorded, according to the profile, for each access to image data and to calculate how much each station is used. The results, constituted by measures of the frequency of PACS station usage suitably classified and presented according to a convenient format for decision-makers, are encouraging. In the time of the spending review, the careful management of available resources is the top priority for a healthcare organization. Thanks to our work, a common medium such as the ATNA profile appears a very useful resource for purposes other than those for which it was born. This avoids additional investments in management tools and allows optimization of resources at no cost.

Keywords PACS · PACS administration · Cost savings · Hospital information systems (HIS)

Background

One of the most important issues in acquiring, maintaining, and expanding a picture archiving and communication system (PACS) is the knowledge of its usage, especially in terms of how and when users work on the system and the consequent number of PACS workstations (WSs) required. The cost of a PACS is highly dependent on the number of workstations in which acquisition is as expensive as 20,000 euro each. A PACS WS is defined as a standard PC equipped with a MD (47/2007 CE) marked software which enables clinical evaluation of images and a MD display compatible with the intended use of the software.

Hence, the number of WSs must be carefully calibrated in order to satisfy the required/expected/programmed workload and to save resources. An insufficient number of WSs could be dangerous for patients, while a higher

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number of them represent a waste of economic resources for the organization. Our experience shows that frequently, the request for new PACS WSs is not supported by any report concerning the use of already existing ones. Thus, it is appropriate to develop a method to quantify the workload for each WS in use and to present an effective information to decision-makers.

Up to our knowledge, some modern PACS do not have built-in tools to analyze their use; others have this kind of tools, but they are not always made available to the PACS administrator, or the PACS administrator is not trained on their proper use. Often, he can view statistics on stored data but no information is provided on how and when the system is used. Information on system usage could include the number of exams viewed in a certain period (a week, a month, etc. …), segmented by single station or by hospital department.

Such information (segmented by operator, ward, and discipline and so on) would represent a valuable index to understand both the operators' behavior and the level of utilization of existing resources (PACS workstation and other clients/ modality workstation).

In the literature, some interesting solutions are reported [1–5]. Radiology information systems (RISs) usually generate reports on imaging studies using a speech recognition software for the dictation by voice. These systems are enabled to save information regarding the starting and the ending time of the dictation, so that information on the duration of the report activities for all the different kinds of images can be collected [1]. This is an interesting solution, but it assumes that a speech recognition software is available. Moreover, it can be useful for radiology departments, but could not cover the usage of PACS WSs in the wards.

Other authors [2, 3] include the development of specific tools based on Web solutions or network traffic monitors; however, in both cases, new software has to be developed. Furthermore, the potential offered by the creation of an Audit Trail and Node Authentication (ATNA)-based repository has already been explored in the past and its value as a decision support has been recognized [4]. In addition, it was found [5] that the use of PACS Audit Data can represent a considerable source of useful information for process improvement. Great attention has been paid to the possibility of improving the workflow of medical imaging through the information generated by the integration of an ATNA profile.

In order to size the WSs, in this paper, the possibilities offered by the ATNA integration profile [6] are again investigated. It was designed to ensure confidentiality and integrity of personal and sensitive data and accountability. The ATNA profile, indeed, is a way to achieve the traceability of accesses to sensible data among different systems.

ATNA profile structure is pictured in Fig. 1. Any IHE actor, such as the image manager or the image display, should be grouped with a secure node actor. The latter is responsible to maintain consistent time and to record Audit Events to a repository called Audit Repository.

In this paper, the PACS application is grouped with a secure node actor; therefore, it keeps track of any access to sensitive data in the form of messages associated to each access event. In fact, the profile associates a message to each event (like "read" event), containing the details about the WS, physician, exam, and exact time of occurrence. The collection and processing of these messages can produce useful information for a proper sizing of the number of WSs. The purpose of the paper is to describe the way to obtain such goal.

Methods

Our work takes advantages of the implementation of IHE ATNA profile in a PACS software, so we had an implementation of several Secure Nodes and an Audit Repository. A specific kind of ATNA messages, defined for the event "instances accessed," was originally meant to track any access to sensible data and holds information related to each single visualization of an imaging exam, such as source machine, type of the exam, exact identification of the exam, and exact time of visualization.

Counting the number of visualizations is the basic way to generate statistics of PACS utilization, which can be then segmented by different criteria, but several other relevant parameters can be calculated. As an example, it would be useful to investigate about the time interval between each two successive visualizations.

More technically, the events that generate messages are called trigger events, and several message types are defined for the ATNA profile for different trigger events. To our investigation, as we said, the relevant events are those coded as "read" activities (R) and "instances accessed" action.

Below, an example of a relevant ATNA message is shown. In the message, which is an XML code, the fields representing the specific action, including the time of the action, can be recognized. In particular, the date and time at which the action occurred are preceded by the tag field "EventDateTime", while the action type is identified by a specific letter (the letter "R" stands for "read" action) preceded by the label "EventActionCode."


```
<?xml version=""1.0"" encoding=""utf-8""?>
<AuditMessage>
<EventIdentification EventActionCode=""R"" EventDateTime=""2014-09-01T07:11:05.9395114Z""
EventOutcomeIndicator=""0"">
        <EventID originalText=""DICOM Instances Accessed"" code=""110103"" codeSystemName=""DCM"" />
</EventIdentification>
<ActiveParticipant UserID=""user1"" UserIsRequestor=""true"" />
<AuditSourceIdentification AuditSourceID=""WS00007"" />
<ParticipantObjectIdentification ParticipantObjectTypeCode=""2"" ParticipantObjectTypeCodeRole=""3""
ParticipantObjectID=""1.2.826.0.1.3680043.2.619.9.1.1.71234.6666.4360"">
        <ParticipantObjectIDTypeCode originalText=""Study Instance UID"" codeSystem=""DCM""
        code=""110180"" />
</ParticipantObjectIdentification>
<ParticipantObjectIdentification  ParticipantObjectTypeCode=""1""  ParticipantObjectTypeCodeRole=""1""
ParticipantObjectID=""33333"">
        <ParticipantObjectIDTypeCode code=""PatientNumber"" />
</ParticipantObjectIdentification>
</AuditMessage>
```


The data was collected at the "Ospedali Riuniti" Hospital in Trieste (AOUTS) which is completely filmless and counts 113 PACS WSs, distributed within the various departments. The PACS is composed of an archive server and an image display software. In all viewing workstations, a Secure Node actor is implemented,

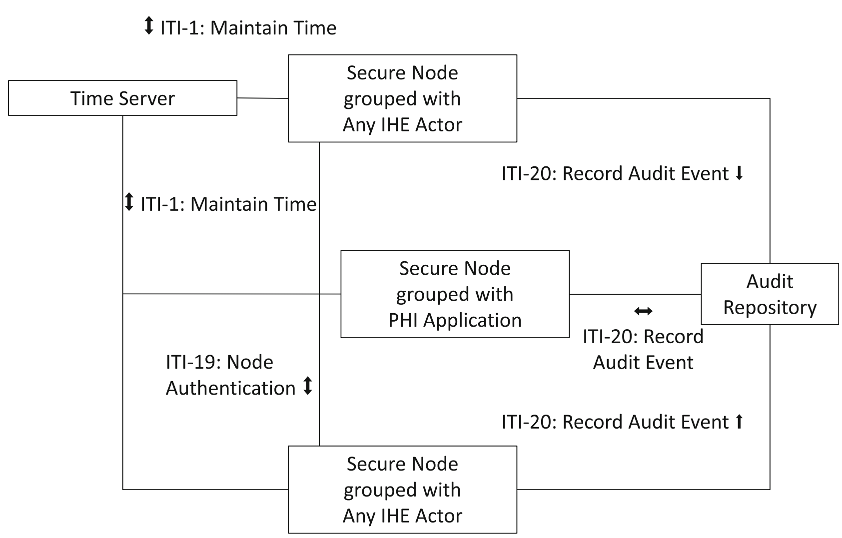

Fig. 1 IHE ATNA profile actors and transactions

mostly for accountability and tracking the access of sensible data.

Following the ATNA profile architecture, we collected the messages produced for the trigger events into a repository. Then, we wrote a simple code to process messages in order to extract from each one the following data: workstation name and date and time of the read event and Study Instance UID of the images viewed. The resulting data has been then grouped by the day of the week, and then, an average among the 7 days of the week was done. The code manages the statistics on an arbitrary period adding all the views for a certain day (e.g., Monday) and dividing for the number of those days in the same period. This trivial solution was chosen to more simply evaluate the typical different hospital activities between week/weekend and emergency/ordinary workflows. Following, we provided the MATLAB code to have a better understanding of how we processed the ATNA repository. The code starts the analysis from the data collected in a .txt file generated by the Audit Repository application, which contains the messages in plain text.

```
fid=fopen('AuditExport.txt');
tline=fgetl(fid);
i=1;
ver_duplicates=cellstr('0');
while tline~=-1
ttt=tline(tline~=0);
id5=strfind(ttt,'ParticipantObjectID=');
id2=strfind(ttt,'EventDateTime');
if ~isempty(id2)
id2=id2+16;
EDT1(i)=cellstr(ttt(id2:id2+9));
control_date=datenum(EDT1(i));
end
if (isempty(strfind(ttt, 'Application connected')) &&
isempty(strfind(ttt, 'Application disconnected')) &&
isempty(strfind(ttt, 'Application connection FAILED'))
&& ~isempty(id5) && ~isempty(id2) &&
control_date>datenum('2014-08-31'))
iid5=id5(1)+22;
fid5=strfind(ttt(iid5:iid5+80),'""');
POID(i)=cellstr(ttt(iid5:iid5+fid5(1)-2));
id1=strfind(ttt,'EventActionCode');
id1=id1+18;
%% duplicates elimination
load('extracted_data.mat');
[POID_unique, ia, ic]=unique(POID, 'stable');
for i=1:size(POID_unique,2)
EAC_unique(i)=EAC(ia(i));
EDT1_unique(i)=EDT1(ia(i));
EDT2_unique(i)=EDT2(ia(i));
EDT_unique(i)=EDT(ia(i));
UID_unique(i)=UID(ia(i));
ASID_unique(i)=ASID(ia(i));
POID_unique(i)=POID(ia(i));
DAY_OF_WEEK_unique(i)=DAY_OF_WEEK(ia(i));
if DAY_OF_WEEK_unique(i)==0
DAY_OF_WEEK_unique(i)=7;
end
end
save(['extracted_data_unique'],'EAC_unique','EDT1_u
nique','EDT2_unique','EDT_unique','UID_unique','ASID
_unique','POID_unique','DAY_OF_WEEK_unique')
%% generating overall table
```

```
EAC(i)=ttt(id1);
id2=id2+11;
EDT2(i)=cellstr(ttt(id2:id2+7));
temp1=char(EDT1(i));
temp2=char(EDT2(i));
temp=[temp1 ' ' temp2];
EDT(i)=datenum(temp);
jd=juliandate(temp1,'yyyy-mm-dd');
jd=jd+1.5;
DAY_OF_WEEK(i)=mod(jd,7);
id3=strfind(ttt,'UserID');
id3b=id3(1)+9;fid3=strfind(ttt(id3b:id3b+50),'""');
UID(i)=cellstr(ttt(id3b:id3b+fid3(1)-2));
id4=strfind(ttt,'AuditSourceID');
id4=id4+16;fid4=strfind(ttt(id4:id4+20),'""');
ASID(i)=cellstr(ttt(id4:id4+fid4(1)-2));
i=i+1;
end
tline=fgetl(fid);
end
fclose(fid);
save(['extracted_data'],'EAC','EDT','EDT1','EDT2','UID','
ASID','POID','DAY_OF_WEEK')
for i=1:size(ASID_label,1)
flag=0;
for j=1:size(txt,1)
if strcmp(ASID_label(i,1),txt(j,1))==1
hospital(i)=cellstr(txt(j,2));
ward(i)=cellstr(txt(j,3));
station(i)=cellstr(txt(j,4));
flag=1;
end
end
if flag==0
hospital(i)=cellstr('');
ward(i)=cellstr('');
station(i)=cellstr('');
end
end
hospital=hospital';
ward=ward';
station=station';
C=temp_table(ID_stazione,hospital,ward,station,temp
```

```
load('extracted_data_unique.mat');
[num,txt,raw] = xlsread('Wards.xlsx');
ASID_label=unique(ASID_unique);
temp_table=zeros(size(ASID_label,2),7);
for i=1:size(ASID_unique,2)
j=1;
while strcmp(ASID_unique(i),ASID_label(j))~=1
j=j+1;
end
temp_table(j,DAY_OF_WEEK_unique(i))=temp_table(j,
DAY_OF_WEEK_unique(i))+1;
end
giorni=zeros(1,7);
for
i=min(datenum(EDT1_unique)):max(datenum(EDT1_u
nique))
temp1=datevec(i);
jd=juliandate(temp1(1),temp1(2),temp1(3));
jd=jd+1.5;
temp2=mod(jd,7);
if temp2==0
temp2=7;
end
giorni(1,temp2)=giorni(1,temp2)+1;
end
temp_table_conteggio=temp_table;
for i=1:size(temp_table,1)
for j=1:size(temp_table,2)
temp_table(i,j)=temp_table(i,j)/giorni(j);
end
end
temp_table=round((10^1).*temp_table)./10^1;
ID_stazione=ASID_label';
ASID_label=ASID';
_table(:,1),temp_table(:,2),temp_table(:,3),temp_table
(:,4),temp_table(:,5),temp_table(:,6),temp_table(:,7));
C1=temp_table(ID_stazione,hospital,ward,station,tem
p_table_conteggio(:,1),temp_table_conteggio(:,2),tem
p_table_conteggio(:,3),temp_table_conteggio(:,4),tem
p_table_conteggio(:,5),temp_table_conteggio(:,6),tem
p_table_conteggio(:,7));
ASID_label=ASID';
save(['temp_table_riassuntiva'],
'ASID_label','temp_table', 'C', 'C1');
%% frequency of daily use
load('extracted_data_unique.mat');
load('extracted_data');
EDT_vector=datevec(EDT);
EDT_days=EDT_vector(:,1:3);
EDT_days_index=unique(EDT_days, 'rows');
label=datestr(datenum(EDT_days_index));
[a, b]=weekday(datenum(EDT_days_index));
b(:,4)=' ';
label=[b label];
for i=1:size(EDT_days_index,1)
temp=0;
for j=1:size(EDT_days,1)
if EDT_days(j,:)==EDT_days_index(i,:)
temp=temp+1;
end
end
EDT_days_f(i)=temp;
end
%% frequency of use per time slot

load('extracted_data_unique.mat');
load('extracted_data');
EDT_vector=datevec(EDT);
freq_hours=zeros(1,12);
temp=zeros(1,1);
for i=1:size(EDT_vector,1)
temp=EDT_vector(i,4);
temp=ceil(temp/2);
if temp==0
temp=1;
end
freq_hours(1,temp)=freq_hours(1,temp)+1;
  i=i+1;
end
freq_hours=freq_hours/sum(freq_hours)*100;
freq_hours = round((10).*freq_hours)./10;
for i=1:size(C,1)
Wards(i)=table2cell(C(i,3));
end
```

To better understand the results in the next section, it should be underlined that data was collected during September, October, and December 2014 from 45 PACS stations. Not all the workstations still implement Secure Node actor because a software upgrade program is still ongoing. This would not affect the evaluation of the feasibility of the method.

Thirty-four thousand sixty-nine records were recorded in the central repository concerning type “R” and “instances accessed” events. A common situation is that the same study, and the same images, could be accessed several times by a workstation, mainly due to user distraction or, eventually, to software faults. This could lead to multiple records generated to the repository, although they are not “real” distinct accesses. To avoid incurring into multiple counts of the same study, we developed a system, like a filter, that mattered all records relating to a single study as a single occurrence: only messages regarding distinct exams for each workstation were considered. The filter permitted only distinct Study Instance UID values.

Finally, we generated summary tables to count all the viewed studies divided on different criteria as a measurement of the PACS usage.

Results

Among the several possible segmentations of collected data, two are presented in this paper. The first is to sum the data from all stations of each department, building a comprehensive table (Table 1), segmented by departments and days of the week. The last column shows the number of PACS stations inside the single department. The table was populated by the average of the daily studies per ward. This kind of table is useful to compare imaging activities of the various specialties, making possible a quantitative evaluation of how much the use of images is needed for each clinical sector. This preliminary work could be used in further analysis to obtain different goals, among which the most ambitious is to develop a method to size the number of PACS workstations in the hospital still in a design phase and not via the too common try and fail approach.

Usually, workstations are spread among the wards according to a centralized plan led by the medical management who would need such a method to quantify physician's needs for imaging in order to contain costs and maintain quality of care.

More pragmatically, the most useful and immediate result is obtained by recording the activity of each station. Table 2 shows an example of a summary record for one station located in the Department of Radiology. Each cell of the report, as described in the last section, is generated by calculating the average number of distinct studies accessed for each day of the week, through a period of 3 months. Data refers to a single WS.

This table would easily be the "state of the art usage indicator" and may be related to several other data such as the number of radiological acquisitions made in the ward/hospital, or the number of referring physicians to understand if each so costly workstation is used as much as the investment was justified. The several uses of this never ever measured data are addressed and discussed in the next section.

Table 2 Example of a summary record for one PACS station

Station ID	Dept.	Mon.	Tue.	Wed.	Thu.	Fri.	Sat.	Sun.
WS00044	Radiology	13.6	22.3	22.5	14.1	18.5	9.5	14.9

Discussion

In this study, our aim was to explore a new way to use a standard ATNA profile implementation to obtain a new way to quantitatively measure PACS utilization. The above-presented results show only the immediate ways of data aggregation, but the starting idea and the results seem very convincing and versatile: starting from standard ATNA events, it is possible to design several reports, such as the two tables proposed in the paper, which are useful in asset management. In fact, the table grouped by single workstation already offers several insights about the use of PACS stations within the hospital, which before were based on individual perception and not on quantitative proofs. Some evidences confirm what common sense suggested, first that the departments with the largest number of studies are just the two radiological depts., followed by echocardiography and nuclear medicine. More interesting is to have evidence of which specialties are more imaging consuming: orthopedics is the first, but cardiac, neuro-, pulmonary, and vascular surgery immediately follow. General surgery and medical wards need access to images, but make a low number of accesses. These evidences will be valuable when the development of a method to size a PACS will be developed.

Table 1 Averages of daily studies per ward

Dept.	Mon.	Tue.	Wed.	Thu.	Fri.	Sat.	Sun.	Stations
1st univ radiology	236.2	249.4	227.0	212.2	188.6	74.7	63.9	9
Orthopedics	4.8	4.1	3.8	5.2	2.9	1.6	1.6	1
Gastroenterology	1.5	1.5	1.3	1.6	1.4	0	0	2
General medicine	0	0	0.0	0	2	0	0	1
Nuclear medicine	14.7	15.3	19.6	15.7	16.5	0	0	2
Neurosurgery	2.5	2.5	2.5	2.7	1.7	0	0	1
Pulmonology	4.8	5.1	4.2	5.6	4.4	1.2	2.8	1
Vascular surgery	0.8	2.2	1.7	2.2	1.3	1.1	0.1	1
2nd radiology	172.2	199.5	199.9	195.9	171.3	34.2	29.2	9
Dentistry	0.1	0.8	2.1	0.1	0	0	0	1
Cardiac surgery	7.2	6.4	7.2	6.2	6.8	2.7	2	3
Cardiology	5.2	4.4	6	5.9	5.5	1.1	0.3	1
Echocardiography	29.5	20.9	21.6	20.6	15.6	2.9	1	3

Moreover, some specialties, like cardiac surgery, share the same operating room, but are equipped with more than one WS. Physicians involved in this kind of specialties typically use WSs to view prior studies and prepare interventions. It results in a low number of exams viewed per WS daily because only one operating room is a bottleneck even for preparatory work. Therefore, decision-makers can avoid creating radiology-like reporting places, based on the number of physicians, and decide to place a single WS in a shared space such as the meeting room.

Focusing on the distribution of the data among the days of the week, in all departments, there was a considerable drop in the average of accesses from Friday until Sunday. On Mondays, the average number of accesses is lower than the average accessed on the most prolific days. This type of information could drive the choice of decision-makers to identify quantitatively the most critical workstation and correctly size the investment in backup equipment.

These confirmations, on one side, can be again a valuable factor in developing a PACS-sizing method; on the other, they may look as a first, even if weak, validation of the first numerical results obtained.

Moreover, the measured data may be related to other organization information, such as physician per ward, per specialty, number of hospitalizations, number of interventions or procedures, and so on, constituting many new quantitative indicators for decision-making which will be investigated in the future.

Going to the real world, in AOUTS enterprise, the management chose to put PACS WSs, due to the cost and the once unpredictable use, not in charge of each department but distributed across the enterprise according to a strategy defined by health direction. It is easily understandable how the quantitative record of images visualization for each station allows us to evaluate the use of the single workstation and identify if there were flaws and errors in the distribution strategy, thus allowing the proposal of station relocation with quantitative documented proofs.

Conclusion

Our goal in this article, as opposed to those proposed in the cited articles, is not to improve processes, but to describe the feasibility of a method of quantification of the usage of the PACS stations through the data generated by the implementation of the ATNA profile.

The new approach of leveraging solutions contained in IHE ATNA profile to extract PACS usage information is feasible and powerful. The drawback is that an ATNA-conformant PACS software is needed plus some technical skills and works to configure the system. A proposal to IHE committees would be proposed to consider the addition of an option for this innovative use of the data collected.

By our own, further explorations of possible uses of collected ATNA data will be investigated and the result of an enterprise-wide analysis presented in the next future.

Further exploration directions will be as follows:

- Use ATNA data to calculate the average age of prior studies opened by users, which will lead to a practical rule to evaluate the amount of storage needed in an PACS system;
- Start a multicentric analysis, once our enterprise-wide analysis is completed, to validate a rule to dimension storage and number of workstations in a PACS based on clinical specialties served.

Compliance with Ethical Standards

Conflict of Interest The authors declare that they have no conflict of interest.

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