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Integrating multiple clinical information systems using the Java message service framework to enable the delivery of urgent exam results at the point of care

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Title: Integrating Multiple Clinical Information Systems using the Java Message Service Framework to Enable the Delivery of Urgent Exam Results at the Point of Care

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ABSTRACT

The aim of this study is to determine if network enabled Personal Digital Assistants (PDAs) can be used to facilitate the timely delivery of urgent radiological exam results by reducing the interval from when the radiologist's initial interpretation is available to when it is first viewed by an Emergency Department (ED) physician. A web and Java Message Service (JMS) based application was built to replace the original fax based wet-read procedure. The new system allows radiologists to enter wet-reads from the PACS display station as well as track discrepancies between the wet-read and final report. It also notifies the ED physicians when exam results are available via the PDAs and permits them to view the full text of the wet-read and final reports from the devices. The new system is compared to the original procedure with the results showing improvements with the wireless method. Furthermore, feedback from a qualitative survey of PDA users was positive, suggesting that PDAs may provide one means for accessing urgent clinical data at the point of care.

KEYWORDS: integrated systems, Java Message Service (JMS), urgent exams, Personal Digital Assistant (PDA), mobile computing, Radiology Information System (RIS), Picture Archiving and Communication System (PACS), results reporting, handheld devices

TEXT

INTRODUCTION:

As part of an ongoing project to improve the communication of urgent exam results back to the requesting physician, the authors have developed a system for electronically capturing wet-reads during readout at the Picture Archiving and Communication System (PACS) display station and printing them in the emergency department (ED) as well as various clinics throughout the hospital[1, 2]. This system, known as the "wet-read module", has completely replaced the original faxed based procedure, where wet-reads were written on exam requisitions and faxed to the emergency department, a process which was fraught with problems including illegible handwriting and lost faxes. Additionally the wet-read module contains a quality assurance (Q/A) component for tracking the performance of residents and fellows who generate wet-reads during on call readout. Since it has been shown that the use of mobile computing technologies can facilitate the communication of radiological exam results to the requesting physician in an urgent care setting[3, 4], the wet-read module was extended to provide access to wet-reads and radiology reports at the point of care using wireless enabled PDAs (personal digital assistants) with the expectation that the physician's first encounter with the radiology results via the PDA would be faster than the original fax based procedure. This paper describes the extension of the wet-read module and provides an assessment of its performance versus the original fax based procedure.

MATERIALS AND METHODS:

Institutional Review Board (IRB) Exempt Certification was obtained prior to beginning work on this project.

SOFTWARE COMPONENTS-

An overview of the wet-read module's architecture is provided in Figure 1. Both the new and existing server and client-side components of the application were developed using the Java (Sun Microsystems, Santa Clara, CA) programming language. Java was chosen because its API (application programming interface) contains built-in support for developing database driven web applications. The software components, the web server, user interface and database, as well as the integration with the PACS display stations are described in detail in an earlier article by the authors[2].

As part of the extension of the wet-read module to support PDA based access, the JMS (Java Message Service) was used to provide a robust means for transferring wet-reads between the various remote components of the system, such as the printing service, email service and PDA application. JMS is a vendor agnostic specification from Sun Microsystems for enterprise messaging, which allows computer applications to exchange information in the form of messages. JMS centers on a JMS provider, which acts as a conduit through which JMS clients send and receive messages. The JMS specification places no restrictions on the structure and content of these messages. Therefore a message can contain text, numbers or an array of bytes. The JMS clients interact with the provider through the JMS API. The API allows a developer to write a single JMS client application that can interact with a variety of JMS providers without requiring any code modifications.

For developing the JMS clients on the PDAs, the iBus//Mobile (Softwired Inc., Zurich, Switzerland) JMS provider was used. The iBus//Mobile software package contains two pieces: the iBus//MessageServer, which is the actual JMS provider, and the iBus//Mobile Gateway, which acts as a proxy between the JMS clients and iBus//MessageServer. The iBus//Mobile Gateway provides an extra layer of robustness for handling the volatile nature of mobile device connections as well as the ability to connect to a variety of mobile devices including PDAs, pagers and cell phones using a multitude of protocols such as TCP (transmission control protocol), SMS (short message service), or WAP (wireless application protocol).

PDA TECHNOLOGY-

For this project the HP 4150 iPAQ PDA (Hewlett-Packard Company, Palo Alto, CA) running Windows Mobile 2003 (Microsoft, Redmond, WA) was used. The iPAQ 4150 has a 400 MHz Intel XScale CPU (Intel, Santa Clara, CA) with 64 MB of RAM as well as built-in support for Wi-Fi (802.11b) and LEAP (both are described below). The screen supports the display of 65,000 colors and has a 3.5" diagonal viewing area. With the 1800 mAH (milliamp hour) extended battery, it weighs approximately 7 ounces and is 4.47" by 2.78" by 0.73" in size. The extended battery allows the PDA to remain on and continuously connected to the wireless network for approximately 10 hours. Studies have shown that form factor is one the top considerations of PDA users[5, 6]. Since the iPAQ 4150 offered all the necessary functionality in the smallest form factor, it was chosen as the PDA for this project. The PDAs were given to each of the four residents who rotated through the ED each month. They were also given a charger and asked to take the devices home and charge them before each shift. The ED residents were chosen as participants because they were the ones most directly involved with the patients' care, and therefore potentially had the most to gain from this type of device. Since the project was only a pilot, wet-read printouts were still made available in the ED and usage of the PDAs was optional.

Java support on the PDAs was enabled through the installation of the Jeode (Esmertec, Dübendorf, Switzerland) JVM (Java virtual machine). The Jeode JVM conforms to the PersonalJava specification version 1.2a, which describes a subset of the standard Java API for use in developing applications for higher end PDAs (http://java.sun.com/products/personaljava/). The PersonalJava specification includes most of Java's GUI (graphical user interface) as well as file and network I/O (input/output) APIs. This allows a developer to create a full featured, network enabled Java application that runs on a PDA.

PDA SOFTWARE APPLICATION-

Figure 2 illustrates the overall appearance of the application. The GUI contains three panels, one containing a list of the most recent exams for patients in the ED, one for displaying the full text of the wet-read or report associated with a study, and a third to allow the user to query the Radiology Information System (RIS) for prior exams. The PDA user starts the application by logging in using their PACS user name and password. The authentication process involves sending a JMS message through the iBus//MessageServer JMS provider to the PDA request handler JMS client running on the main application server. This client queries the PACS database to verify that the user name and password is valid and then sends the result back across the JMS provider to the client running on the PDA. When a radiologist enters a wet-reading at the PACS display station, it is broadcast via the JMS provider to the JMS client running on each PDA. If the requesting physician associated with the exam matches the current user logged into the PDA application an alert dialog is presented informing the user that a wet-read is available. The PDA user can choose to view the wet-read text by clicking on the appropriate tab to switch to the report text panel. Additionally the study is added to the patient list, where it remains for a user configurable period of time. While in the patient list the report status of the study is monitored, and a second dialog, which is similar in appearance to the wet-read alert dialog, is presented to the user when the report text associated with the exam is available. The monitoring process is similar to the authentication process and involves sending a JMS message to the PDA request handler client running on the main application server. When a request is received the JMS client queries the RIS for the report's status and text and sends the result back to the PDA. Furthermore the user can actively query the RIS for reports via the query panel by using either a patient name, medical record number or accession number as query criteria. The process used for querying the RIS is the same as the one used to poll the RIS for the report status.

WIRELESS CONNECTIVITY-

Connectivity to the JMS provider was achieved through the use of the hospital's 802.11b WLAN (wireless local area network). 802.11b, also known as "Wi-Fi", is a specification from the IEEE (Institute of Electrical and Electronic Engineers) that defines the operation of 2.4 GHz WLANs using Direct Sequence Spread Spectrum (DSSS) modulation. The theoretical throughput of 802.11b is 11 Mbps (megabits per second), though the practical operational limit is usually between 5 to 7 Mbps. The hospital's Wi-Fi network is based on Cisco's Aironet (Cisco Systems Inc., San Jose, CA) technology, which uses the proprietary Lightweight Extensible Authentication Protocol (LEAP) to encrypt all the data transmitted over the air. Additionally the DES (Data Encryption Standard) algorithm was used to encrypt all data between the PDA client application and the JMS provider. DES encryption was provided by the freely available Bouncy Castle (http://www.bouncycastle.org/) encryption library.

RADIOLOGY WORKFLOW-

An overview of radiology workflow for urgent exams requests is shown in Figure 3. The process begins with scheduling, where an exam is scheduled either by a radiology scheduler or ED desk clerk in the RIS. The next step encompasses image acquisition including the time during which the technologist performs the actual exam. The third step is study transmission, covering the time in which the images are transmitted to the PACS and made available to the radiologist for interpretation. This is usually done automatically without the need for the technologists' intervention. These three steps make up the "time to image availability" metric and the data for measuring the metric is captured from timestamps stored within the RIS and PACS.

After the images are available on the PACS, the radiologist interprets them and renders a wet-reading which is then transmitted to the ED or appropriate urgent care clinic. In the original fax based procedure the wet-reads were written on the exam requisition and then faxed, either by the radiologist or an assistant, to the ED. In the wet-read module, the wet-read is typed into a web form on the PACS display station and then printed in the ED or appropriate clinic as well as made available on the PDAs. These two steps, the rendering of the wet-read and its transmission to the ED, make up the "time to interpretation availability" metric. Under the original process, data for this metric was captured from the timestamp printed on each fax indicating when it was sent. With the wet-read module, this metric is derived from the timestamp recorded in the module whenever a wet-read is saved.

Once the wet-read is available in the ED, it is usually viewed by a physician and is ultimately used to make a clinical decision. The delay between when the wet-read is available and when it is first viewed makes up the "time to results encounter" metric and is the primary focus of this project. To determine when a wet-read fax was first viewed, the ED physicians were asked to "sign-off" on each fax indicating who read it and when. The fax timestamp is then subtracted from this timestamp to give the time to results encounter. For the wet-read module, the PDA application records when a physician first views the wet-read. The difference between this timestamp and the timestamp of when the wet-read was saved gives the time to results encounter. Finally the "total exam time" metric measures the total time from when the exam is scheduled to when a physician first views the results. Data for this metric is derived from the timestamps described above. In addition to measuring timing metrics the ED residents were asked, at the end of their rotations, to complete a questionnaire regarding their experience with the PDAs. This qualitative survey consisted of 33 questions and attempted to gauge the users' prior experience with PDAs as well as to determine whether the devices were clinically useful. The residents were also asked to describe any problems they had using the PDAs and to recommend any feature additions they felt might improve the utility of the devices and application.

RESULTS:

<u>TIMING METRICS-</u>

The evaluation periods for the faxes and PDAs spanned 61 and 76 days respectively and were separated by approximately one year. During the fax period a total of 2644 ED cases were performed from which 165 (6.2%) signed faxes were collected and evaluated using the above timing metrics. It should be noted that faxes were only used for projection radiography exams because at the time it was policy for all cross-sectional exam results to be discussed over the phone. Two hundred ninety-eight wet-reads from a total of ED 4634 exams (not all of which had wet-reads associated with them) were accessed via the PDAs, of which 189 (4% of the total number of ED exams) were associated with projection radiography exams and therefore used in the comparison of the two processes. In comparison, during the same period 1036 projection radiography wet-reads (24% of the total number of ED exams) were accessed via the two PACS display stations located in the ED.

The distribution of exams types between the two periods was somewhat different. Chest exams made up the majority in both datasets, accounting for 50% of the exams during the fax period and 69% of the exams during the PDA period. This was followed by skeletal studies making up 43% versus 22%, and then by abdominal exams with 7% versus 8% for the fax and PDA periods respectively. Finally exams of the head and neck comprised 1% of each dataset. Reasons for the difference in the distribution of exams types are discussed below.

A histogram of the results indicates that all the timing metrics had long right tails and large standard deviations. A Kolmogorov-Smirnov test[7] was performed to check the results for normalcy from which it was determined that the results did not follow a normal distribution. Consequently a two-tailed Mann-Whitney test, also known as U-test or Wilcoxon rank-sum test,[8] was used to determine whether the fax and PDA metrics were statistically different. Table 1 summarizes the timing metrics data. It was found that the average and median times for all three metrics, imaging time, interpretation time, and results encounter time, were less during the PDA period. The results encounter time showed the greatest average reduction at 14.5 minutes. Though large, this different was not statistically significant (P>0.05), a consequence of the high variance of the datasets. The two-tailed U-test, however, did show the reductions in the times to image availability and interpretation availability to be highly significant (P<0.01). The total exam time was also found to be statistically significantly (P<0.01) smaller during the PDA period, with a mean reduction of 27 minutes.

<u>SURVEY-</u>

A total of 12 ED residents were asked, at the end of their rotation, to complete and mail back the questionnaire concerning their use of the PDAs, of which 9 (75%) responded. The survey consisted of two parts: one that covered the residents' personal experiences with any mobile computing device(s) they own or have previously owned and a second part which asked about their experiences using the wet-read PDA. Tallies from the first and second part of the survey are presented in Table 2 and Table 3 respectively.

It was found that 7 of the 9 respondents (78%) already owned a PDA (Table 2), all of which were Palm OS (palmOne, Inc., Milpitas, CA) based. The majority of those (6 out of 7, 86%) had already owned their PDA for 1 to 3 years and the same majority indicated they had some clinical application installed, the most popular of which was ePocrates, a drug and formulary reference program for handheld devices. Five of the 7 PDA owners (71%) expressed satisfaction with their devices, with poor battery life being the most common complaint (5 out of 7, 71%).

It was found that the PACS displays were the most used, with 7 (78%) indicating they used the display to access between 76% and 100% of their wet-reads (Table 3). This was followed by the PDAs, with 3 (33%) indicating they used the PDAs to access 76% to 100% of the wet-reads. The printouts came in last with all the residents saying they used them less than 50% of the time. When asked to comment about their usage patterns some indicated they still like to look at the images even when they had the findings via the PDA. When queried about problems with the devices, 4 (44%) indicated they had problems with connecting to the hospital's wireless network and 3 (33%) said they had issues with the battery life of the devices. Some of the battery life problems could be attributed to the fact the residents occasionally forgot to charge the PDAs when they took them home. Of the 9 respondents, 4 (44%) thought the PDAs saved them time and 3 (33%) commented that they felt it improved patient care. Finally when asked about what features they believed would be useful on a future version of the PDA application, all 9 ranked lab results as the most important feature with the ability to enter orders coming in second, and access to the radiological images themselves ranked third.

DISCUSSION:

The observed reduction in the mean time to image availability during the PDA phase was 7.5 minutes. Since the implementation of the wet-read module did not directly intervene in the scheduling and imaging processes it cannot explain this difference. One possible explanation for the change is the different breakdowns in exam types between the two observation periods. This variation was eliminated as a cause by controlling for exam type when comparing the fax and PDA timing metrics (see Table 4). For the most common exam types (chest, skeletal, and abdominal) the PDA mean and median image availability times were all less than the fax times. When comparing only chest exams, which made up the majority in both the fax and PDA datasets, it was found that the fax and PDA mean times were 32.5 and 24.5 minutes respectively. This difference of 8 minutes is comparable to the 7.5 minute difference in the aggregate means (see Table 1). Furthermore the difference in the chest medians was 9 minutes, which is equal to the difference between the aggregate medians. The skeletal exams had the smallest difference in mean times (2.9 minutes); however, the difference between the medians (8.5 minutes) is similar to the 9 minute difference between the aggregate medians. Because the two evaluation periods were separated by approximately one year, other possible explanations (which were not explored) for the reduction in the time to image availability could be changes in technologist personnel or the implementation of more efficient examination procedures or techniques.

The reduction in the mean time to interpretation availability for the PDA period, while small (2.9 minutes), was still found to be highly significant (P=0.006). Additionally the difference in median times was greater (5 minutes) suggesting there was a real reduction in the delay between when an exam is available on PACS and when the results are available to the ED physician. As with the reduction in time to image availability, the observed reduction in the mean time to interpretation could not be explained by the ED physicians' use of the wet-read

PDAs, since the devices were not involved in this step. One possible explanation for this reduction was the implementation of "worklists" on the PACS display stations. A worklist allows a radiologist to quickly determine what exams need to be readout based upon a set of criteria, such as all unread ED exams done today. As part of the rollout of the wet-read module, radiologists were given and encouraged to use worklists when interpreting ED and other urgent exams. This allowed them to determine which cases needed to be read without having to wait for the exam requisition. The reduction in interpretation availability can also be partially explained by the practice of batch interpretation. In this scenario, during the fax phase wet-reads that were written down at the beginning of an interpretation session may not be available to the ED physician until the radiologist reads out the last exam in the batch and then faxes all the wet-reads to the ED. This practice adds an additional delay to availability of results. With the new wet-read module the results are now immediately available to the ED physician at the moment they are entered into the system, thereby eliminating the extra delay associated with batch interpretations.

The 14.9 minute reduction in the mean time to results encounter was the largest of the three metrics, however, this difference was found not be statistically significant (0.063). This detail can be explained by the large variances of both datasets (SD=104.8 and 54.6 for the fax and PDA periods respectively, see Table 1) caused by a number of "outliers". This variance is possibly a function of the irregularity of the ED physicians' schedules caused by the varied criticality of the patients they must treat. Imaging results are usually prioritized in the same manner as patients. In some situations, the physician may not review a wet-reading for several hours after it has become available or they may choose to view the wet-reads, along with the images, on the PACS display station. Furthermore, the periodically frantic pace of an ED environment can adversely impact a physician's ability to access results. The reductions in both the mean and median times to results encounter, however, suggest that the PDAs may have facilitated quicker access to radiology wet-readings, a conclusion qualitatively supported by the resident survey.

While it appeared the PDAs saved the ED residents some time, the results of the survey showed that the PACS display was still the favored means of accessing wet-readings (Table 3). This is supported by the low percentage of exams accessed by either the PDAs (298 out of 4634 exams, 6.4%) or faxes (165 out of 2644 exams, 6.2%) and the higher percentage accessed via the two ED PACS display stations (1036 out of 4634 exams, 22.3%). The residents indicated they preferred to view the images themselves, as they probably represented an educational opportunity. Given that the PDAs ranked higher than the paper printouts it is likely the devices may have gotten even more usage if the PACS display stations were not available.

The issues with battery life and network connectivity may have also contributed to the limited use of the PDAs. As was mentioned earlier, most of the battery life problems were avoidable and due to the residents forgetting to charge their devices when they got home. The network issues, however, were more complicated and varied. Some of the problems were due to user errors, such as the resident forgetting to enable the correct transmitter on the PDA (the PDAs had both Wi-Fi and Bluetooth support). At other times, the PDAs would loose their connections to the WLAN and would have to be soft reset before they would connect again. Finally there were instances when a PDA would need to be "reimaged" (have all it's software reloaded) before it would connect to the wireless network. Some of these problems appear to be similar to ones described in Siddiqui KM, et al, 2003[9] and may be due to inherent limitations in the current state of wireless technology which could potentially be remedied as the devices and software mature. Overall, however, the residents indicated the devices had some utility. When asked whether they would prefer a desktop PC or a PDA for clinical care, 2 (25%) said they preferred the PDA outright and the remaining 6 said they would like to use both. No resident said they would be averse to using a PDA for clinical care.

CONCLUSIONS:

The integration of the wet-read module into the radiologists' workflow has helped to reduce some of the delays and eliminate some of the drawbacks that were once associated with the original fax based wet-read process for the delivery of radiological results back to ED physicians. Additionally it has facilitated the capture of quality assurance data for tracking discrepancies (questionable, minor and major) between the wet-read and final report. Given their criticality, the communication of major discrepancies to the ED is done via the phone. Furthermore all major discrepancies are presented at monthly resident conferences. Consequently the system has become a vital resource for the radiology department and has been extended to handle nearly all the urgent care cases performed by the department.

Although not statistically significant, the decrease in the time to results encounter suggests that the PDAs might provide a viable mechanism for the timely delivery of urgent exam results. To advance the PDA component beyond the experimental stage, several modifications to the software would be required. Access to lab results and the addition of limited order entry are two features that would probably greatly increase the utility of these devices. Additionally it has been suggested that to more closely integrate the devices into the workflow of the ED, the PDA user base should be extended to include both the ED attendings and nursing staff. This would require the deployment of tens of more devices and the implementation of a library like system for tracking the devices as they are picked up and dropped off by users at the beginning and end of their shifts. The expense and complexity of such as system placed it beyond the scope of the pilot project. With evidence from this study, however, the hospital is now actively considering ways to leverage both the hospital wide WLAN and PDAs to facilitate access to clinical information at the point of care.

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TABLE 1 – Timing metric data. Note: mean and median times are in minutes.

Metric	Mean (Std Dev)		Median		U-Test P-Value (two tail)
	Fax	PDA	Fax	PDA	
Image availability	34.5 (27.0)	27.0 (25.7)	29	20	<0.001
Interpretation availability	54.9 (38.4)	52.0 (61.0)	42	37	0.006
Results encounter	54.2 (104.8)	39.7 (54.6)	24	18	0.063
Total time	143.6 (114.3)	118.8 (89.7)	120	93	0.001

TABLE 2 - Personal PDA Usage Survey Results

Total Respondents to the First Part: 7

Which handheld device are you using?

Handspring	1
Palm	1
Sony Clié	5

How long have you owned your handheld device?

1 to 3 months	1
1 to 3 years	6

How do you use your handheld device?

Address book/contact information	6
Formulary look-ups	1
Treatment algorithms	3
e-Prescribing	1
Drug information look-ups/interaction checks	5
Calendar/appointments	4
Dosing calculations	3

How often do you use your handheld device for *non-clinically* related tasks?

Never	4
1 to 5 times/day	2
5 to 10 times/day	1

Which of the following drug information applications do you have loaded on your own PDA?

ePocrates Rx	6
ePocrates QID	1
Tarascon ePharmacopoeia	2

How often do you use the drug information application(s) mentioned above?

Never	3
1 to 5 times/day	4

Which of the following clinical (*non-Drug*) applications do you have loaded on your device?

5 Minute Clinical Consultant	2
Clinical Practice Guidelines	2
Other	1 (UCSF Hospitalist Handbook)

How often do you use the clinical (*non-Drug*) application(s) mentioned above?

Never	1
1 to 5 times/day	4
Not applicable; I have not downloaded a clinical application onto my handheld	2

Did you have any problems learning to use your PDA?

Absolutely Not – it was easy	1
No	2
Some	4

What is your preferred means for entering information into your PDA?

Character recognizer	5
On screen keyboard	1
Thumb keyboard	1

What was the biggest problem or frustration you had with your PDA?

Too slow	1
Awkward to use	2
Screen too small	1
Desktop sync difficulties	1
Battery life	5

TABLE 3 - Wet-Read PDA Usage Survey Results

Total Respondents to the Second Part: 9

Breakdown of ED residents' access methods for wet-reads during the PDA evaluation period. The percentages indicate the amount of the time they felt they used a specific means for obtaining wet-reads.

	0%	1% - 25%	26% - 50%	51% - 75%	76% - 100%
PDA		3	3	1	2
PACS			2		7
Printouts		7	2		

Other comments (both positive and negative) regarding the wet-read PDA application

1)	I actually like to view the films
2)	Great when worked
3)	I always want to look at the actual films, so using wet-read PDA was best at notifying me that readings are actually available
4)	Not as useful as you still need to see the actual film

What was the biggest problem or frustration you had with the pilot PDA itself (not including the software applications installed on it)?

Too slow	2
Awkward to use	1
Quality and readability of screen	1
Difficulties connecting to wireless network	4
Battery life	3
Delicate/hard to carry	3

Did you feel the pilot PDA saved you time during your ED rotation?

Yes – without a doubt	1
Yes	3
Maybe	2
No	3

Do you feel the use of the pilot PDA has improved patient care? Please describe.

1)	No, mainly saved me small amounts of time
2)	Yes

3)	Yes, faster service
4)	Yes
5)	Would if given on inpatient wards for labs, radiology reads
6)	I am unsure as to whether overall quality improved with the PDA, given that I need PACS regardless of PDA wet-reads, however, efficiency for floor teams may be increased by this idea because PACS access there is much poorer
7)	No
8)	Helped when access to PACS limited, otherwise prefer to look at films

In your opinion, could other ED staff members use the pilot PDA? If yes, who and how? Please describe.

1)	It would me more useful if there was other info such as lab values
2)	Yes, orders could be on them and nurses could use them
3)	Yes
4)	Yes, but better in inpatient setting
5)	This can potentially be used by the nursing staff, however, it may be more practical if the patient list can be customized to only those for whom the nurse cares

For patient/clinical care, would you prefer to use software programs on a handheld device (assuming one is provided for you by the hospital) or via a dedicated desktop PC?

PDA- without a doubt	3
Both – they are useful in different ways	6

Thinking ahead to the future, please rank the desirability of the following features that could be included on the next generation of the pilot PDA.

Feature	**Average Ranking (1 = most useful, 6 = least useful)**
Receiving lab results	1
Receiving x-ray images	2.67
Providing order entry for tests or consults	2.8
Incorporating a problem list	5.8
Using the PDA for order entry for medications	3.4
Entering patient information	5.2

TABLE 4 – A comparison of time to image availability broken down by exam type. The mean and median times are in minutes. Note: there were an insufficient number of head and neck exams to calculate a standard deviation.

Exam Type	Count		Mean (Std Dev)		Median	
	Fax	**PDA**	**Fax**	**PDA**	**Fax**	**PDA**
Chest	82	131	32.5 (21.8)	24.5 (23.8)	28	19
Skeletal	71	42	36.4 (32.9)	33.5 (31.4)	29	20.5
Abdominal	11	15	39.8(19.8)	31.1 (22.9)	44	22
Head & Neck	1	1	10.0 (n/a)	26.0 (n/a)	10	26

FIGURE LEGENDS

Figure 1 – An overview of the architecture of the wet-read Web application. Wet-reads are entered on the (PACS) displays using a Web form. They are then sent from the Tomcat Web server to the Java message service (JMS) provider, which then routes them to the appropriate destination. JDBC = Java database connectivity; HTTP = hypertext transfer protocol; SQL = structured query language; RIS = radiology information system; ED = emergency department; PDA = personal digital assistant.

Figure 2 – This figure illustrates the various panels of the wet-read PDA application. When an ED physician logs into the application they are first presented with a panel containing a list of recent exams performed on patients currently in the ED. From this panel, the physician may choose to query the RIS for prior examinations associated with a patient or they may choose to view the wet-read or final report (if available) for a current exam. Furthermore when a radiologist enters a wet-read, the ED physician is notified via a dialog box that a wet-read is available. They may choose to view the wet-read at that time or ignore the prompt.

Figure 3 – This figures illustrates how the three metrics measured in this project, "time to imaging," "time to interpretation availability" and "time to results encounter," relate to the general workflow for a radiology patient.

FIGURE 1

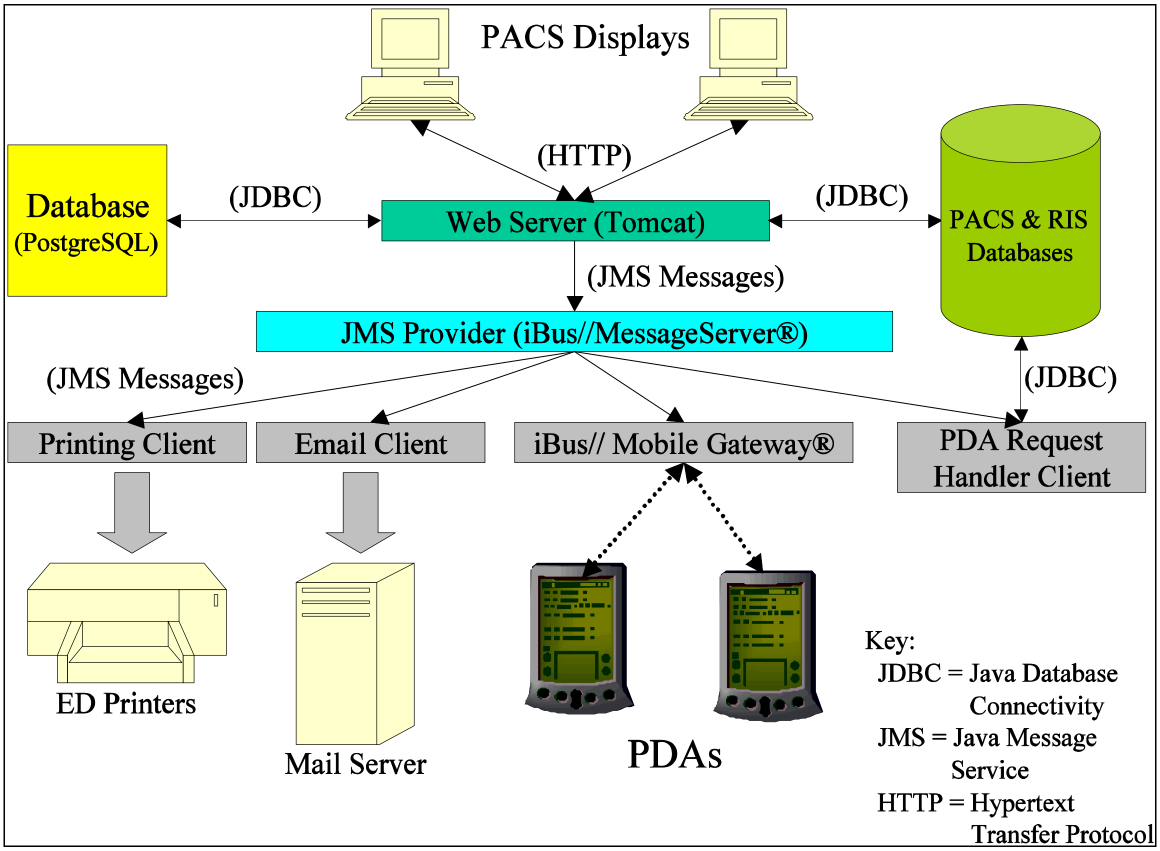

PACS Displays
(HTTP)
Database
(PostgreSQL)
(JDBC)
Web Server (Tomcat)
(JDBC)
PACS & RIS
Databases
(JMS Messages)
JMS Provider (iBus//MessageServer®)
(JMS Messages)
(JDBC)
Printing Client
Email Client
iBus// Mobile Gateway®
PDA Request
Handler Client
ED Printers
Mail Server
PDAs
Key:
JDBC = Java Database
Connectivity
JMS = Java Message
Service
HTTP = Hypertext
Transfer Protocol

FIGURE 2

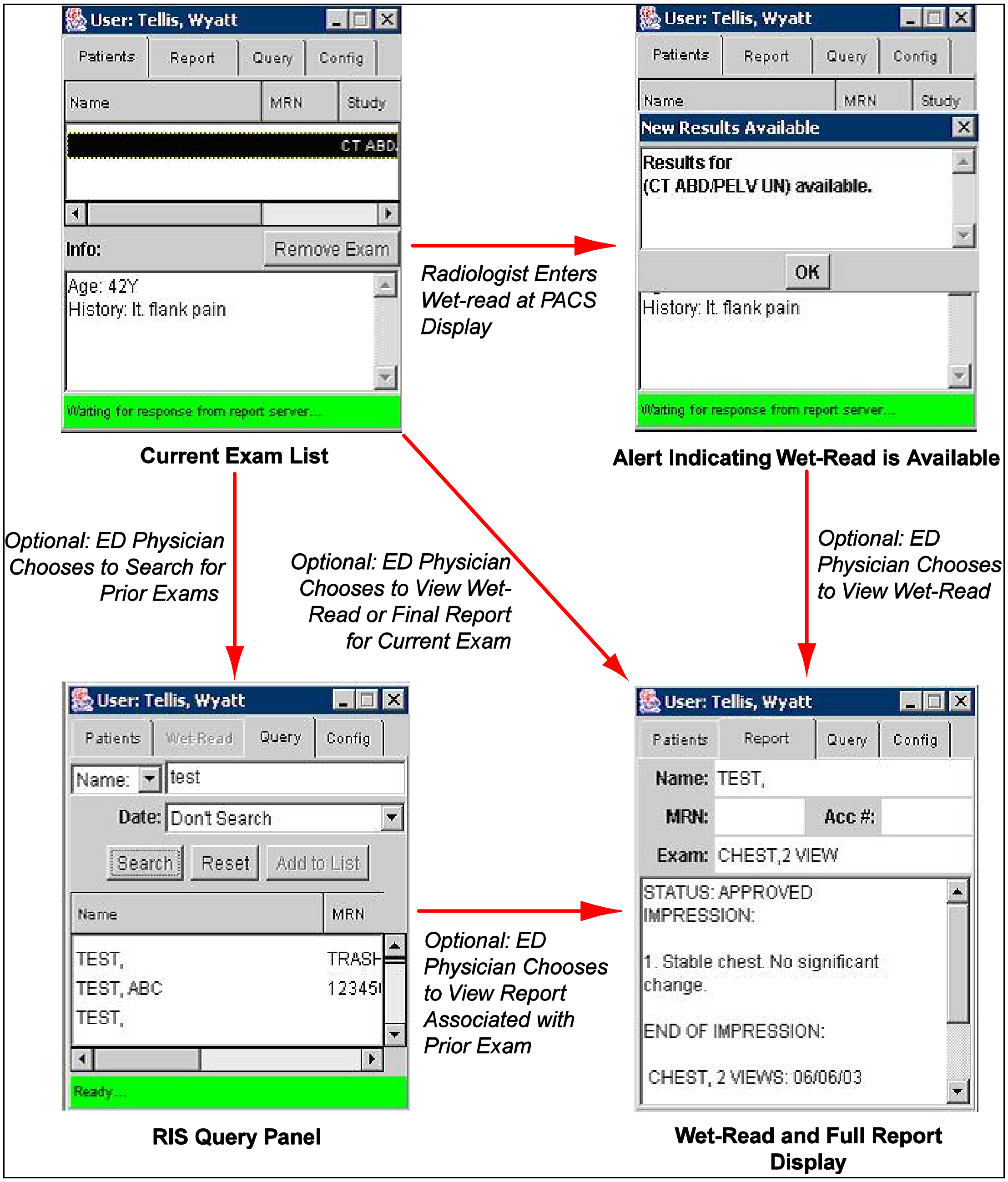
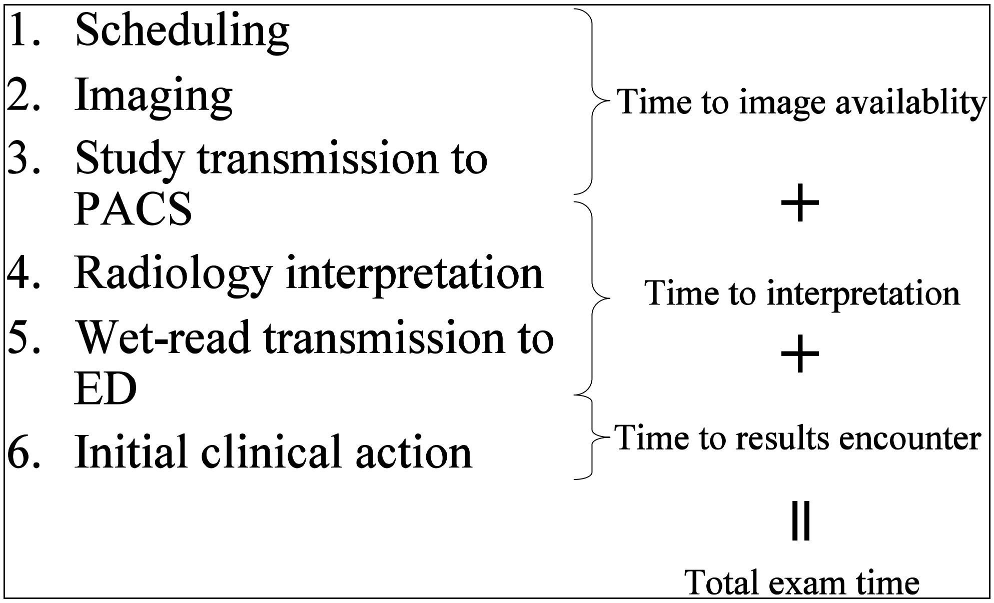

User: Tellis, Wyatt
Patients
Report
Query
Config
Name
MRN
Study
CT ABD
Info:
Remove Exam
Age: 42Y
History: lt. flank pain
Waiting for response from report server...
Current Exam List
Radiologist Enters Wet-read at PACS Display
User: Tellis, Wyatt
New Results Available
Results for
(CT ABD/PELV UN) available.
OK
History: lt. flank pain
Waiting for response from report server...
Alert Indicating Wet-Read is Available
Optional: ED Physician Chooses to Search for Prior Exams
Optional: ED Physician Chooses to View Wet-Read or Final Report for Current Exam
Optional: ED Physician Chooses to View Wet-Read
User: Tellis, Wyatt
Patients
Wet-Read
Query
Config
Name:
test
Date:
Don't Search
Search
Reset
Add to List
Name
MRN
TEST,
TRASH
TEST, ABC
12345
TEST,
Ready...
RIS Query Panel
Optional: ED Physician Chooses to View Report Associated with Prior Exam
User: Tellis, Wyatt
Name:
TEST,
MRN:
Acc #:
Exam:
CHEST,2 VIEW
STATUS: APPROVED
IMPRESSION:
1. Stable chest. No significant change.
END OF IMPRESSION:
CHEST, 2 VIEWS: 06/06/03
Wet-Read and Full Report Display

FIGURE 3


1. Scheduling
2. Imaging
3. Study transmission to PACS
4. Radiology interpretation
5. Wet-read transmission to ED
6. Initial clinical action
Time to image availablity
+
Time to interpretation
+
Time to results encounter
=
Total exam time