# A Jini-Based Solution for Electronic Prescriptions

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***Abstract*—In most countries today, handwritten, paper-based medical prescriptions are the norm. While efforts have been made in the past and are being made at present to migrate toward electronic dispensation of prescriptions, these have generally omitted to incorporate ubiquitous computing technology in their proposed solutions. In this paper, we focus on this issue and describe a Jini-based prototypical solution for electronic prescriptions, which allows for their wireless transmission to in-range pharmacies and the augmentation of the service levels rendered to the user, with, for instance, information about queue lengths and estimated waiting times being provided to the patients. Clinical and user evaluation revealed that there were high levels of agreement as regards the prototype's effectiveness, ease of use, and usefulness.**

***Index Terms*—Electronic prescriptions, Jini, ubiquitous computing.**

## I. Introduction

TODAY, in most countries, a handwritten medical prescription is the most common way of prescribing medicine. A prescribing doctor writes the prescription after a direct consultation with a patient. The prescription is then signed and handed over to the patient who carries it to the pharmacy for dispensing, with the patient being free to choose whichever pharmacy she/he wishes to go to. The pharmacist is handed over the paper prescription, and she/he enters the details into the system. The system then prints out the usage labels for the drug, and lastly the patient signs the prescription, pays for the expenses, and receives the drug.

While computerized systems for drug treatment have advanced simultaneously with the proliferation of computing and networking technologies, work in the field of electronic prescriptions has mainly taken place in the context of hospitals' computerized prescription order entry (CPOE) systems. Moreover, while considerable efforts have been undertaken in related areas, such as the representation and exchange of computerized medical information [1], [2], [3] and the impact of the Internet on online prescription and dispensation of drugs [4], research dealing with the propagation of electronic prescriptions through the practitioner–patient–pharmacy chain remains relatively scarce.

Pilots of electronic prescription systems (EPSs) took place as early as 1997 in the U.K. [5]. These were respectively, the Transcript, Pharmacy2U, and Flexiscript models. The Transcript model uses a two-dimensional (2-D) barcode on a paper prescription that the patients deliver to a pharmacy of their choice. The pharmacist scans in the barcode, validates the digital signature, and dispenses the drugs. The Pharmacy2U model relies on the patients using designated pharmacies. The general practitioner (GP) encrypts and digitally signs the prescription, and sends it directly to the designated pharmacy. Lastly, the Flexiscript model relies on using a central storage where the prescriptions are stored until retrieved by a pharmacist. The system also generates a paper prescription containing a unique data store identification number for the patient and a barcode representation of the digitally signed prescription. The patient takes the prescription to any pharmacy, and the pharmacist uses the identification number to retrieve the e-prescription from the central storage. Although they were all beset by various shortcomings, acceptability of the developed EPSs was high [6]. Other models suggest using a smartcard containing the medical history, which the patient always carries around. The idea is that the patients could deliver this smartcard, which the pharmacists could use to decrypt and to extract the prescription from [7], [8], [9]. Needless to say, none of these early developed solutions incorporated wireless technology. More recently, solutions that are wireless based have been piloted. Thus, solutions based on smartcards, where repeat prescriptions are transmitted wirelessly to the patients' doctor [10], have been piloted, as have point-of-care systems. Here, prescriptions are written on a personal digital assistant (PDA) at the point of care, and transmitted during cradle synchronization with a PC, to a predefined pharmacy [11]. However, all of these solutions suffer from either one (or both) of the two major drawbacks. First, they are not generic (involving specialized scenarios, such as repeat prescriptions, where problems encountered in the more general case of prescribing medicine, such as potentially toxic drug interactions do not occur). Secondly, they are not truly ubiquitous (since they involve only wireless data upload, in a given, localized, setting—such as a surgery or the patient's home—with all subsequent data communication taking place through a wired medium).

In this paper, we have sought to address the limitations identified earlier, and have developed a wireless prototype solution for an EPS. Our proof-of-concept solution is not intended as a replacement for the existing, non-wireless, EPS initiatives. On the contrary, it is complementary, harnessing Jini technology to offer enhanced levels of service to clinicians and patients alike. Accordingly, the structure of this paper is as follows. Section II presents an overview of the Jini technology and its applications in telemedicine. Section III then goes on to discuss the benefits of electronic prescriptions and current implementations of EPSs. In Section IV, a detailed description of the implementation of our solution is provided, while Section V presents a walkthrough of the proposed prototype. Lastly, Section VI presents the results

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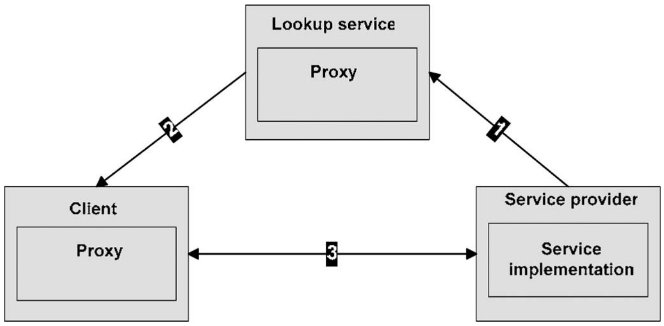



Fig. 1. Jini discover/join protocol.

of an evaluative study of our solution, while the implications of our work are elaborated upon in Section VII, where conclusions and possibilities for future work are presented.

## II. Jini Technology in Telemedicine

Jini is a service-oriented framework that enables the entities in a distributed environment to define, discover, and advertise their services in a robust and impromptu manner [12]. It provides a spontaneous and self-healing environment [13], where the services and service consumers can enter and leave a network without affecting or interrupting the existing network activities.

Services are the most important concept within Jini. They make use of the infrastructure and programming model to discover other services, take part in federations, and announce their presence to other services and users. To do this, the Jini technology revolves around a trio of protocols: discover, join, and lookup. The first two provide the service advertisement functionality. Thus, the discovery protocol is used when a new service provider in a Jini federation needs to register with a lookup service, in which the service provider uses either unicast or multicast discovery to locate a lookup service [12], [14].

Once this is done, the join protocol entails the service provider uploading a service object to the lookup service (arrow 1 in Fig. 1). This object represents the service and can be regarded as a proxy. The proxy is a part of the service that is visible to the clients, but its job will be to pass method calls back to the rest of the objects that form the total implementation of the service. At this stage, the service has entered the federation and is ready to be discovered. This is done by the lookup protocol.

Accordingly, the client locates a lookup service, finding an appropriate service by its type interface and attributes. The service object is then loaded into the client (arrow 2). The final stage involves the client communicating directly with the service provider via the proxy object (arrow 3). The client employs the methods provided in the proxy to invoke the service and perform operations specific to it. Depending on the type of service, the proxy could be a remote method invocation (RMI) reference to the actual service, a local copy of the entire service, or a combination of both. In the latter case, some of the functions of the service are provided locally and the remaining through remote calls to the service implementation.

### A. *Telemedicine Applications*

As expected, in the telemedicine area, Jini has been used to interface and integrate previously disparate devices. Accordingly, Jini has been applied in the Department of Nuclear Medicine at Wilhelminenspital, the largest community hospital in Vienna, Austria. In this study, Knoll *et al.* [15] integrated the combination-computed tomography (CT) scanner and the single-photon emission computed tomography (SPECT) camera. The evaluation confirmed that the Jini technology had increased Wilhelminenspitals' capacity to spot previously unseen tumors in their patients. From a different perspective, Petrovski and Grundy [16] integrated different development technologies to implement a health information system. As a part of their proposed solution, the Jini technology was utilized to support the interfacing of observational appliances, such as electrocardiogram (ECG) monitoring devices, and applet-enabled PDAs. From a similar context, Eko Systems developed a complete medical system named Frontiers [17]. In Frontiers, all observational devices are integrated in a system in which the Jini agents dynamically and without human intervention connect to a server and log their data. In a related work [18], a remote health care monitoring system that utilizes 2,5/3G public wireless networks is described. In particular, the system enables remote monitoring, real-time and store-and-forward mode, of patient data collected by a body area network (BAN). In this system, vital data from sensors and actuators, which are attached to the patient, is gathered using the Jini technology and forwarded to a gateway, which communicates with the Jini services resided in a remote back-end system.

Parkka *et al.* [19] also used Jini to develop a wireless monitoring platform for personal weight management. The platform provides the users with information on weight control, nutrition, and exercise, which can be accessed whenever needed from anywhere. Data from the measurement devices are captured using the Jini technology, and presented on a PDA or a mobile terminal. Finally, the authors argue that their system provides a platform and test-bed for assessing new techniques in the field of personal health management.

It is our belief that the dynamic networking features of Jini and its ability to integrate heterogeneous devices in *ad hoc* networks make it ideally suited for implementing an EPS. In particular, such a system is especially suited for overcoming the limitations of current paper-based prescription systems, limitations that shall now be elaborated upon in more detail.

## III. The Case for Electronic Medical Prescriptions

The advent of the Internet has raised new and complicated legal and ethical issues with respect to using it to procure prescription drugs [4]. Moreover, while debates with respect to the impact of EPSs on traditional communication patterns between clinical stakeholders [1] and the underlying informational representations are still ongoing [3], there seems to be a general consensus that EPSs benefit all the parties. Patients, for instance, would be assured of error-free prescriptions as the system would set the drug dosage and check for possible adverse drug interactions. It is also believed that the eradication of handwritten prescription pads will result in fewer medication errors [20] and transcript errors [21]. Medication errors often occur because of illegible handwriting, confusing drug names, and dosage mistakes [22]. Transcription errors presently occur when prescriptions are re-input from their paper format into the pharmacists' computer systems, and it is believed that EPSs will reduce them [22].

EPSs would allow the patient to choose whichever pharmacy she/he might wish to go to. The system sends the prescription electronically to the pharmacy while the patient is still in the doctor's office, thus allowing the pharmacy for immediate dispensation. Although recent evaluation of pilot systems in the U.K. showed that there was an increase in the overall waiting time for the patients, this was mainly attributed to the incomplete development state of the pilots and the users' unfamiliarity with the system [5]. Moreover, the quality of prescriptions is better using EPS: whereas doctors may forget to sign paper prescriptions, by its very design an EPS would have to be digitally signed in order for drugs to be dispensed. In practice, missing signatures cause the pharmacist to make a call back to the doctor, thus delaying the drugs being dispensed to the patient [22]. Similarly, patients may forget, or lose their prescriptions. With an EPS such situation would not have an impact on the dispensation process.

From a different perspective, it is also widely believed that an EPS can help to greatly reduce fraudulent activity [20], [22]–[24]. Another benefit is highlighted by a research conducted in Denmark studying EPSs, which showed that the workload for pharmacists became more evenly spread over the day and both doctors and pharmacists appreciated the extra time gained [25]. One particular advantage was not having to spend so much time making call backs. Research [26] has shown that 75% of general practitioners (GPs) thought it would be useful to know whether or not all or some of their patients had retrieved their medicine. Furthermore, 80% preferred to know if specific patients collected their medicines. A last benefit is that an EPS can perform indication-based price screening of medications and suggest alternatives to the physician if the cost of the medication exceeds a critical value.

## IV. Implementation

### A. Aim

In this paper, we have sought to alleviate the problems identified earlier and develop a fully flexible and secure prototype for prescribing medicine. We have built a Jini-based context-aware prototype that, in addition to the advantages an EPS provides, will add more flexibility in the sense that patients can use pharmacies based on their current location, thus saving time, money, and energy.

In order to delineate requirements, input was sought from the three main stakeholder groups involved in the project: GPs, patients, and pharmacists. Accordingly, semistructured interviews were held with all such groups. Here, their opinions on a series of requirements extracted from the literature (see Section III) dealing with issues such as handwriting, mis-prescription, fraud, ease, and security of mobile-based interaction were sought. Additionally, stakeholders were asked to come up with suggestions of their own for functionality that a wireless EPS should have.

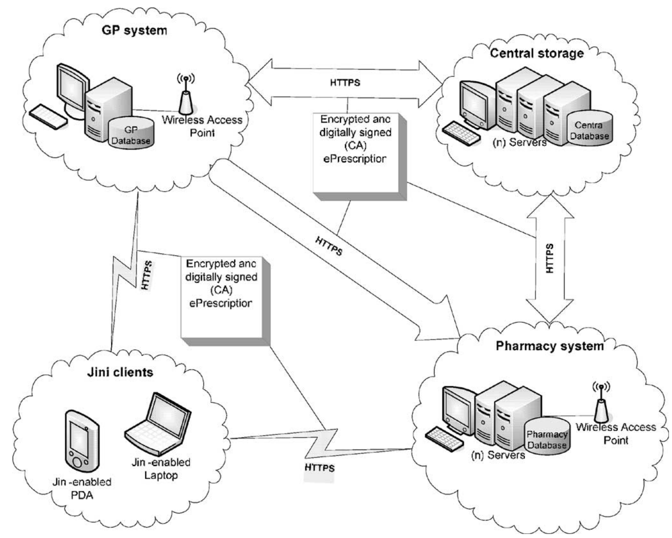



Fig. 2. System model.

Four London-based GPs and pharmacies took part in this initial study, as did ten patients. The outcome of this requirements gathering exercise was that the stakeholders wanted an EPS solution that would be easy to use, secure, and one that would reduce the risk of prescription errors or fraud. Thus, GPs and pharmacists wished to be able to access data regarding a patients' drug history, submission of prescriptions, and drug interactions. On the other hand, the patients indicated that they wanted to exploit the potential ubiquitous features of any solution to access a range of pharmacies, and made available information such as queue lengths and drug information (whether or not a particular drug is in stock, its price) available to them.

### B. Application Structure

The main components in the prototype are GP system, central storage system, pharmacy system, and Jini clients (Fig. 2). The GP system consists of a desktop computer with a local database, which is connected to a wireless access point. The pharmacy system has a similar structure, but in this case, there can be more than one server in order to handle multiple connections. The central storage system is comprised of several servers that are linked to a shared database. Finally, the Jini clients consist of Jini-enabled wireless devices such as PDAs and Smart Phones.

According to Fig. 2, the GP prescribes a drug and chooses whether to transmit it to a pharmacy of the patients' choice or to start a service containing the encrypted prescription. In the former case, the encrypted data is sent to the pharmacy server. In the latter, a Jini-enabled device connects to the wireless network and downloads the encrypted prescription for a particular patient. Whenever the patient is within the range of a Jini-enabled pharmacy system, the wireless device will detect it and the patient can commence the communication process with the pharmacy.

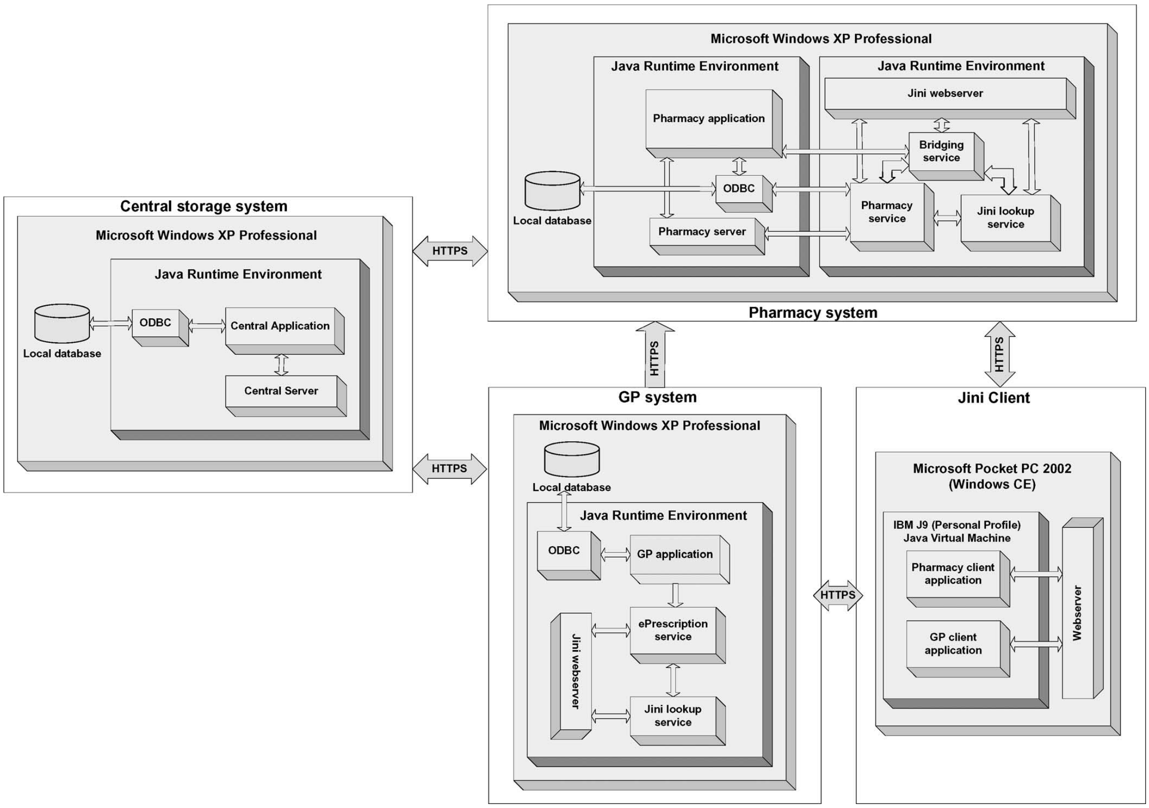



Fig. 3. System architecture.

Security and privacy of health care information is of paramount importance and entails that the unprotected transfer of plain textual prescriptions across insecure networks is clearly not an option. It is thus necessary to ensure that only medical professionals involved in an EPS can access the system and the prescriptions within it [22]. Given this, we decided to encrypt and digitally sign the prescriptions using session-key encryption. Session-key encryption is a way of using both symmetric and asymmetric encryption together to get the best of both. This means that one uses a symmetric algorithm to encrypt the data, and then encrypts the symmetric key with an asymmetric algorithm. In addition, session-key encryption offers added security. Some asymmetric key algorithms such as RSA [27] can be susceptible to text analysis attacks. Because text has recurring patterns, repeated cipher-texts can be analyzed to break the encryption contextually. However, if one encrypts the random-looking binary data of a session-key with an asymmetric algorithm, it is virtually impossible to contextually analyze it due to the way in which asymmetric encryption works [28]. Lastly, the encrypted prescription is digitally signed with an X. 509 public key certificate [8]. This certificate contains information about the public key (e.g., what cryptographic functions the key can be used for and its validity period), the owner of the key pair, and details about the certification authority, which is confirming the ownership. The encrypted data is transmitted using the hypertext transfer protocol over secure socket layer (HTTPS). Moreover, the connection between the entities and the wireless access point is itself secured using 128-bit wired equivalent privacy (WEP) encryption.

### C. Application Architecture

The prototype was developed at Brunel University during October 2004–June 2005. Java, Jini, and the eXtensible Markup Language (XML) were used to provide full platform independence, scalability, and flexibility. The system architecture diagram (Fig. 3) shows the main components that make the system model work. Accordingly, the Jini clients were implemented on an HP iPAQ 5450 PDA running on Microsoft Pocket PC 2002 (Windows CE) and IBM J9 Java Runtime Environment Personal Profile. To support Jini services, client applications need a web server for code transfer. However, in this case, the web server must be small enough to run on a resource-constrained device such as a PDA. Sun Microsystems do not include such web servers in their Jini bundle. Thus, for this purpose we chose the PicoWebServer 1.0 from Newmad Technologies. While in theory there is no cap on the number of devices that can participate in a Jini federation, in practice this is limited by the underlying networking infrastructure. Thus, in our particular case, in which we use the IEEE 802.11 g (WiFi) specification, this has an operational limit of between 20 and 30 devices, depending on their specific individual bandwidth requirements [5]. Bearing in mind that data transferred in our case is textual (non-bandwidth intensive), the upper limit of 30 devices is more than adequate

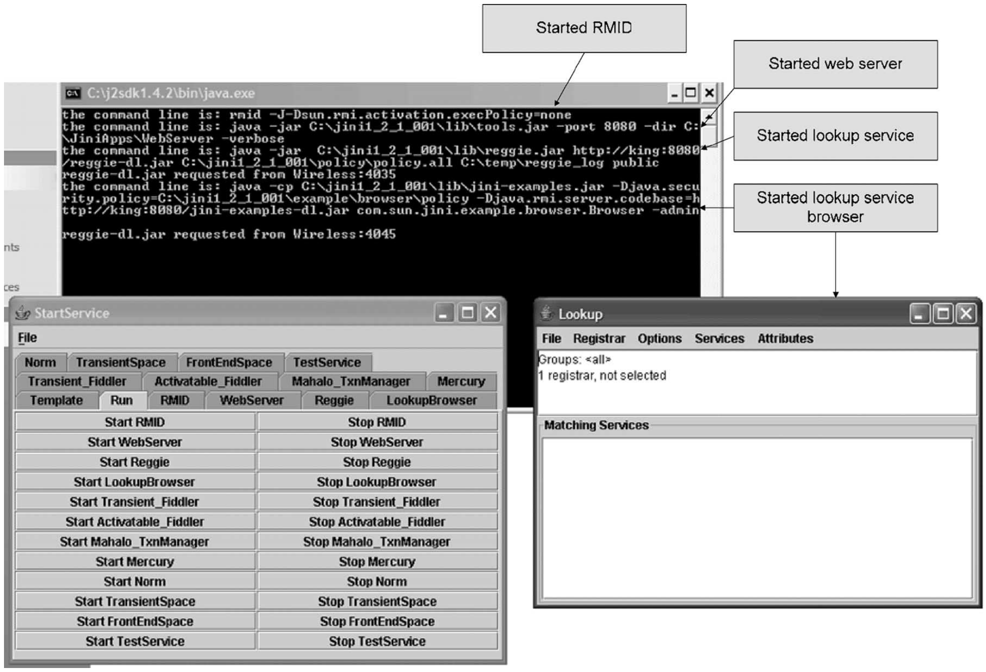



Fig. 4. Active Jini lookup service.

for most pharmacies. The GP and pharmacy system run on Windows XP Professional edition Service Pack 2 and Java Runtime Environment from Sun Microsystems.

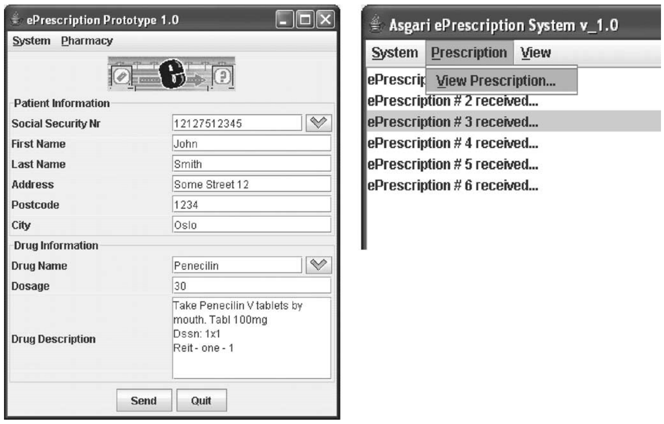
The central storage behaves as a repository for prescription runs as a bridging mechanism between GPs and the pharmacies. It runs Microsoft SQL Server 2005, receiving prescriptions in its central server from the GPs and sending requested prescriptions to the pharmacies. Once a prescription is issued by a pharmacy, a record of this is made in the central storage. The GP application retrieves patient and drug information from a local database using the open database connectivity (ODBC) to create the prescription. The stored data is used to read medical histories and perform security checks, such as prescription integrity and drug interactions on the patients. The prescription is always sent encrypted to a central storage, and by the patient's request to a designated pharmacy, or a Jini service. In the first two cases, the application uses a predefined port number and Internet protocol (IP) address to send the encrypted prescription. The pharmacy server receives the data, decrypts it in the pharmacy application, and stores it in a local database using ODBC. In the latter case, the GP application uses Jini protocols (join, discovery, and lookup) to create and start a prescription service that will use the Jini lookup service to register itself and announce its presence. The GP system also contains a Jini web/code server where the code to execute the service remotely can be downloaded. The same applies for all the web servers in all the entities that need to upload the code to remote units. A wireless device consisting of GP and pharmacy client applications uses the Jini protocols to detect a particular service and download the corresponding prescription. Subsequently, the device locates a pharmacy through the pharmacy's Jini lookup service and commences the interaction with the pharmacy service (Fig. 4). The pharmacy service will conduct some requests on the pharmacy server and the local database through the ODBC by itself, while other requests that require runtime values of objects are conducted through the bridging service. Furthermore, both the bridging and the pharmacy services register their abilities in the lookup service in order to broadcast their existence.

## V. Prescription Generation Scenario

### A. GP Application

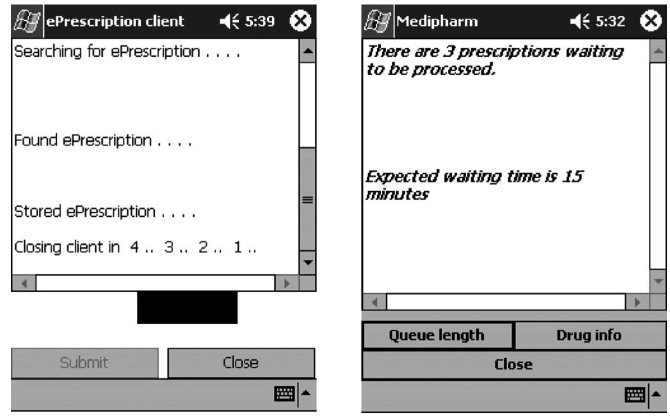
To be able to prescribe and process medicines, GPs have to log in to the system with a username, password, and a reference to the database. After the GP logs in, she/he then asks for the patient's social security number. If she/he is a former patient, his/her information is displayed. However, if she/he is a new patient, the doctor has to fill the necessary fields [Fig. 5(a)]. To avoid any possible input errors or adverse drug interactions, a confirmation request or error message is respectively displayed prior to the prescription being transmitted. If there are any such errors, the GP can re-input the prescription, after which she/he is again asked to confirm its contents. Only when the GP checks and explicitly confirms the prescription details, can she/he initialize the sending process. Lastly, a printout of the prescription is printed for extra confirmation.

The patient is asked if they would like to receive the prescription on their wireless device. If so, the prescription is uploaded to the Jini lookup service. However, if they wish to either send the prescription to a central storage or a designated pharmacy, this can also be done by the GP. The encryption process is started, and the GP digitally signs the prescription before it is sent to the pharmacy. This reduces the risk of prescription fraud




(a) (b)

Fig. 5. (a) GP main page. (b) Pharmacy menu.




(a) (b)

Fig. 6. (a) Prescription downloaded. (b) Queue status.

as only digitally signed prescriptions by the GP are accepted by the pharmacy.

### *B. Pharmacy Application*

When the pharmacy application is launched and the correct username and password are entered, the application launches and waits for incoming prescriptions. If a prescription is received, and the signature is authenticated, the prescription is displayed in the application. Each prescription received is displayed in the queue until processed. To view a prescription, one has to either double-click on one of the prescriptions in the list, or choose one and view it from the file menu [Fig. 5(b)]. After clicking to view the prescription, the pharmacist can then see when the prescription was sent, by whom, to whom, and what to prescribe. The pharmacist also has an option to alter the prescription with the patients consent. Although this is normally done to provide an alternative cheaper drug, a request is first sent to the central storage to check the patient's record for possible adverse interactions that prescribing the new drug might entail.

### *C. Downloading the Prescription*

At this point, the service is available for download. The user can now launch the GP client application from his/her device. It must be noted that the client can be started at any time whenever the user desires and it does not need to be in the vicinity of a prescription service. On launching the GP client, the user is prompted to insert his/her social security number. After the social security number is entered and verified by the user, the application commences the search process. When a matching prescription is located, it is downloaded to the device [Fig. 6(a)] and removed from the lookup service.

### *D. Pharmacy–Patient Interaction*

The user can start the process of getting his/her drug dispensed by launching the pharmacy client application. The application immediately starts searching for available pharmacies. When the application is in range of a pharmacy, it detects the service and adds it to its list of found pharmacies. The list grows bigger as new pharmacies are discovered. Pharmacies that no longer are available, due to their wireless network range or other failures, are removed from the list as well. The user can choose whichever pharmacy she/he desires from the list. Subsequently, the application downloads and displays the service the chosen pharmacy has to offer. It must be noted that the graphical user interface a device receives varies, depending on its resources (in our prototypical implementation, separate interfaces were created for laptops and PDAs).

After the services' user interface is downloaded, the user can perform different tasks on it. However, if no prescription is present on the device, an error message is shown. Assuming that a prescription is available, the user can submit the prescription directly to the pharmacy and check the actual length of the queue in the pharmacy [Fig. 6(b)], as well as lookup information about the prescribed drug.

Now that the user has obtained all the information needed, she/he can either submit the information or, if the queue is too long or the drug not in stock, choose another pharmacy within range. If the user does submit the prescription, she/he will be asked to input his/her telephone number, in order to receive a message when the prescription is ready for collection. When the transmission is completed, the user is displayed a confirmation message.

## VI. Evaluation

Evaluations of health care IT applications are by necessity multiperspective and multidisciplinary. To understand what causes new systems and procedures to succeed or fail, one has to take into account the social and work environment within which they are being introduced.

The prototype was evaluated using two questionnaires, one for the clinical staff and another for the patients, based on ratings on a five-point Likert scale (strongly agree, agree, neutral, disagree, and strongly disagree).

Both questionnaires (Table I) comprised 18 questions, grouped into three categories regarding the usefulness, effectiveness, and usability of the application. While for the first two categories, the questions were common for both the cohorts, they differed in the third. Moreover, for each such category

TABLE I
EVALUATION QUESTIONNAIRE

| | Clinical Evaluation | | Patient Evaluation | |
|---|---|---|---|---|
| ***Effectiveness*** | *Mean* | *Std Dev* | *Mean* | *Std Dev* |
| Q1. The application is easy to learn | 4.5333 | 0.63994 | 4.5714 | 0.63413 |
| Q2. The process of inputting data on the application is fast enough | 3.8667 | 0.99043 | 4.0714 | 1.05158 |
| Q3. I would have preferred instructions that were easier to understand | 2.7333 | 1.75119 | 1.9286 | 0.81325 |
| Q4. I would not use this application in my everyday life | 1.8000 | 0.56061 | 1.8929 | 0.78595 |
| Q5. The application allows the patient to continue his/her every day life while waiting for the drug to be dispensed | 4.2000 | 0.67612 | 4.0714 | 0.66269 |
| Q6. It is not convenient to carry a wireless device around with me | 1.8667 | 0.91548 | 2.0714 | 0.81325 |
| ***Using the Program*** | | | | |
| Q7. Screen directions are consistent and easy to follow | 4.0667 | 0.88372 | 3.9643 | 0.63725 |
| Q8. I had difficulties navigating through the program | 1.7333 | 0.79881 | 2.0000 | 0.72008 |
| Q9. It is easy to make mistakes using this program | 2.7333 | 1.53375 | 2.1429 | 1.04401 |
| Q10. Program responds appropriately to any mistakes I made | 3.6667 | 0.72375 | 3.6071 | 0.83174 |
| Q11. Text on each screen is not clear | 1.5333 | 0.51640 | 1.6786 | 0.72283 |
| Q12. It is easy to submit the prescription | 4.4000 | 0.50709 | 4.1786 | 0.77237 |
| ***Usefulness of the application (clinical staff)*** | | | | |
| Q13a. I would rather use EPS instead of the current paper based system. | 4.0000 | 0.65465 | | |
| Q14a. I don't believe this system reduces the time for patients to retrieve their drugs. | 1.4667 | 0.51640 | | |
| Q15a. I believe EPS facilitates the process of prescribing a drug. | 4.5333 | 0.63994 | | |
| Q16a. EPS does not eliminate the issues in regards to fraud | 2.8667 | 1.45733 | | |
| Q17a. EPS will not eliminate dosage mistakes | 2.2000 | 1.52128 | | |
| Q18a. EPS eliminates the current paper based issues on incomprehensible handwriting. | 4.5333 | 0.63994 | | |
| ***Usefulness of the application (users/patients)*** | | | | |
| Q13b. I believe wireless device facilitates the process of prescribing and processing a drug | | | 3.9286 | 0.85758 |
| Q14b. I did not find the information about drug status to be useful. | | | 1.9286 | 0.81325 |
| Q15b. I believe it is practical to receive a message when the drug is ready for collection. | | | 4.3571 | 0.67847 |
| Q16b. I believe it is useful to have the flexibility of choosing a pharmacy | | | 4.2857 | 1.01314 |
| Q17b. I prefer a fixed solution instead of this wireless solution. | | | 2.5357 | 0.74447 |
| Q18b. The information about queue length is not useful. | | | 1.3571 | 0.55872 |

TABLE II
GP/CLINICAL TASKS

| | |
|---|---|
| Task 1 | Start the GP application; choose/enter a patient; choose a drug; write the prescription; submit the prescription. |
| Task 2 | Choose fixed transmission; enter choice of transmission for patient |
| Task 3 | If patient chooses a pharmacy, search for pharmacy and choose the pharmacy the patient wishes to use. If the patient only wants to use the central storage, choose only to send to central storage; press ok. |
| Task 4 | Write the password for the digital signature and send the prescription. |

there was an even balance struck in the number of positive and negative statements contained, so as to avoid participant bias. All participants regarded themselves as computer literate and used a mobile phone in their everyday lives.

## A. Clinical Evaluation

The implemented application was evaluated with 15 GPs from a sample of surgeries in London. The participants were given an overview of electronic prescriptions, and were then asked to write and process such a prescription (Table II). At the end of the experiment, participants were asked to complete the evaluation questionnaire. Their responses shall now be analyzed in turn.

*1) Application Effectiveness:* Clinical evaluation revealed that, with the possible exception of Q3 for which no clear trend could be established, participants' views of the prototype's effectiveness were generally positive (Table I). Thus, the application was perceived by clinical staff as being easy to learn (Q1), with 60% $(n = 9)$ strongly agreeing with this point of view. There was also a general agreement (strongly agree: 33.3%, $n = 5$; agree: 53.3%, $n = 8$) among participants that the application would be beneficial to patients, by freeing up time while the drug was being dispensed (Q5). Moreover, participants generally disagreed with them not using the developed application in their everyday lives (Q4), as well as with respect to the inconvenience presented by carrying a wireless device such as the one used in our experiments with them (Q6). The only question in this category for which the expressed opinions were not statistically significant was the one regarding the ease of understanding of the operating instructions (Q3). While this might reflect that most clinicians participating in our study did not have a technical background, the opinion is somewhat at odds with the fact that most applicants did find the application easy to learn (Q1) and relatively easy to input data (Q2).

*2) Using the Program:* Our evaluation highlighted that there was a general consensus that it was easy to submit prescriptions (Q12), with all polled responses to this question belonging to the strongly agree or agree categories. Moreover, there was a general agreement (33.3% strongly agreed and 46.6% agreed) that screen directions were consistent and easy to follow (Q7). On the other hand, they generally disagreed that the displayed text was unclear (Q11), as they did with respect to any potential navigational difficulties that our developed application might have had (Q8). While opinions with respect to how easy it was to err when using the program (Q9) were mixed (and not statistically significant), we were nonetheless pleased to note that clinicians

TABLE III
PATIENT EVALUATION TASKS

| | |
|---|---|
| Task 1 | Start the GP application; enter your social security number, 11 digits (e.g. 44444444444), and wait for the prescription to be downloaded. |
| Task 2 | Start the pharmacy application and choose an available pharmacy. |
| Task 3 | Get the drug status (price and in stock information) and the queue length (how many people in front of you, and how long you have to wait for the drug to be dispensed). |
| Task 4 | Submit your prescription. |

participating in our study did in main agree that the program does respond in an appropriate manner to any erroneous course of action (Q10).

*3) Application Usefulness:* Evaluation with clinicians also revealed that 80% $(n = 12)$ of participants would rather use EPS instead of the current paper-based system (Q13a), with there being almost unanimous agreement (strongly agree: 60%, $n = 9$; agree: 33.3%, $n = 5$) that EPSs would solve problems linked to deciphering handwritten prescriptions (Q18a). An identical pattern of responses was observed with respect to the GPs' belief that using this system would facilitate the process of prescribing drugs (Q15a). There was, however, disagreement that the developed EPS would not reduce the time that patients would have to wait in order to retrieve their prescribed medication (Q14a). Opinions were mixed with respect to the potential occurrences of fraud that the EPS might or might not lead to (Q16a—some opinions were that it might eliminate fraud as it is currently known, but give rise to new forms). Similar feelings were echoed with respect to the complete elimination of dosage mistakes (Q17a). This was seen as a direct consequence of fraudulent activities, but was somewhat overridden by participants' agreement on Q18a, which is a current major source of dosage mistakes.

### *B. Patient Evaluation*

The implemented system was evaluated by a sample of 28 London-based patients. Each was given an introduction to the prototype, as well as a list of four tasks (Table III) to perform using the application.

Evaluation with this cohort of users generally revealed across the board, highly positive opinions indicating that the participants had a general consensus in respect of the prototype being effective, easy to use, and useful (Table I). The next three sections discuss the responses in more detail.

*1) Application Effectiveness:* Results showed that the patients believed the application was easy to learn (Q1), with 60.71% $(n = 17)$ of the patients strongly agreeing and 28.57% $(n = 8)$ agreeing with this statement. Furthermore, results highlighted a general consensus that the patients had in respect of the application facilitating their life by allowing them to continue their everyday life while waiting for their drug to be dispensed (Q5), with respectively 25% $(n = 7)$ of them strongly agreeing and 57.14% $(n = 16)$ agreeing. Lastly, we remark that the participants generally disagreed with the fact that carrying a wireless device was inconvenient (Q6) and that they would not be using such an application in their everyday life (Q4).

*2) Using the Application:* Here, the overwhelming majority of the participants, 93.86% $(n = 26)$, agreed or strongly agreed that it is easy to register a prescription in a pharmacy system using the application (Q12). Additionally, the participants found screen directions to be consistent and easy to follow (Q7—strongly agree: 17.85%, $n = 5$; agree: 60.71%, $n = 17$). It is also to be noted that the majority of participants were in disagreement with statements regarding navigational difficulty (Q8—strongly disagree: 21.43%, $n = 6$; disagree: 60.71%, $n = 17$) and the lack of text clarity (Q11—strongly disagree: 46.43%, $n = 13$; disagree: 39.29%, $n = 11$).

*3) Application Usefulness:* As Table I depicts, there was also a general consensus on the patient's part regarding the prototype's usefulness. Of particular interest is the fact that most of the patients appreciated the flexibility our application provided in the choice of pharmacies (Q16b). In this respect, 53.57% $(n = 15)$ of the patients strongly agreed whereas 32.14% $(n = 9)$ of them agreed. Moreover, patients found it practical to receive a message from pharmacies when their medicine was ready for collection (Q15b), as well as knowing the current queue length. In fact, this last feature was highly popular with our tested sample, the majority (67.85%, $n = 19$) of which strongly disagreed with the statement that knowing the applications' queue length was not useful (Q18b). Lastly, another EPS feature suggested by the users, namely the ability of the prototype to provide drug status information, was also well-received (Q14b).

## VII. CONCLUSION

Electronic prescription systems promise flexibility and efficiency in the prescription and dispensation of drugs. However, rarely do they deliver ubiquity. In this paper, we describe the design and implementation of a flexible, wireless-enabled prototypical solution for EPSs that effectively exploits the Jini technology and complements existing wired approaches to offer enhanced levels of prescription service.

Our solution is fully operational, secure, and ubiquitous, and was highly rated by both clinicians and users. By putting to good use the dynamic networking features of Jini as well as its service-oriented approach, it gives both categories of users the flexibility to choose the way in which the prescription is delivered, the particular pharmacy that will dispense the drug (these can either be a designated one or one of a number of pharmacies that happen to be in range of the user's Jini-enabled mobile device), and offers the users information on queue lengths and estimated waiting times for the prescription to be delivered.

We are aware though, of the limitations of our work. The developed prototype would benefit from supporting the prescriptions being forwarded to a third party. Being a proof-of-concept, no management tools have been incorporated in its design, nor have we investigated issues of performance. Patients would also benefit from knowing *a priori* if a prescribed drug was in stock at a particular pharmacy. From an evaluative perspective, a larger sample size would certainly have been desirable. Last but certainly not the least, in our prototype the Jini applications are implemented on single machines. The ideal solution, however, would include replications of services, lookup services, and web/code servers on different entities on the network to ensure a more fault tolerant system and increase scalability. All of these directions form part of our future efforts and endeavors.

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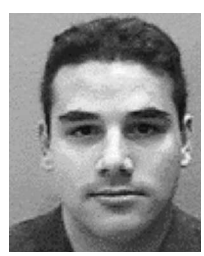


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