Mobile Workers in Healthcare and Their Information Needs: Are 2-Way Pagers the Answer?

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The ability to have access to information relevant to patient care is essential within the healthcare environment. To meet the information needs of its workers, healthcare information systems must fulfill a variety of functional requirements. One of these requirements is to define how workers will interact with the system to gain the information they need. Currently, most healthcare information systems rely on users querying the system via a fixed terminal for the information they desire; a method that is inefficient because there is no guarantee the information will be available at the time of their query and it interrupts their work flow. In general, clinical event monitors -- systems whose efficacy relies on the delivery of time-critical information -- have used e-mail and numeric pagers as their methods to deliver information. Each of these methods, however, still requires the user to perform additional steps, i.e., log into an information system in order to attain the information about which the system is alerting them. In this paper we describe the integration and use of 2-way alphanumeric pagers in CLEM, the UPMC Health System's Clinical Event Monitor, and how the use of these pagers addresses the information needs of mobile workers in healthcare.

INTRODUCTION

Healthcare workers rely on information, e.g., lab results and radiology reports. The timely receipt of this information is essential within the healthcare environment. One often overlooked barrier to the timely receipt of information to these workers is their mobility.

In typical healthcare information systems, workers query the system (or multiple systems) for the information they desire. This query-result capability, commonly referred to as *pull*, is inefficient since there is no guarantee the information will be available at the time of query. Additionally, this method requires an interruption in healthcare workers' work flow, because they usually need to find and sit at a fixed terminal.

The problems and issues with existing computer information systems lead us to define additional functional requirements for an information system:

(1) The system should have the capability of *pushing* information to the worker, i.e., it should anticipate the worker's need for information and deliver it to him/her. (2) The system, at the request of the worker, should be able to deliver additional supportive information that will let him/her make better decisions. (3) The interface should be mobile. (4) The system should be able to support fail-safe delivery. In addition to these functional requirements the authors believe there are other requirements that need to be satisfied, such as affordable cost, low maintenance, and how the system could be integrated into existing information systems.

Since many of these requirements, specifically the requirement of mobility and size, looked like they could be met by wireless communication and computing devices, we were motivated to explore their use. We excluded solutions that required the development of an in-house wireless network., i.e., wireless LAN, not because they lacked functionality (or promise) but because of their initial cost; this limited us to considering cellular, packet radio, e.g., ARDIS® and RAM®, paging networks, and Cellular Digital Packet Data (CDPD).

One of the devices we evaluated was the SkyTel® SkyWriter, a 2-way alphanumeric pager. The pager was small, easy to use, and one could reply to as well as initiate messages from the unit. We obtained several of these pagers and issued them to interns and residents after we configured our system to send its messages to the pagers. The feedback we received was positive, so we acquired additional units and started a pilot study (August 1997 through December 1997). In January 1998 we signed a six-month contract with SkyTel® for 60 units.

The remainder of this paper describes our experience with the use of the SkyTel® 2-way pagers in CLEM, the UPMC Health System's clinical event monitor. In particular we describe: (1) the CLEM and SkyTel® systems, (2) the types of information we sent via the 2-way pagers, (3) how we utilized the reply feature of the pagers, and (4) the method and results of a survey that evaluated the acceptability and utility of 2-way pager.

SYSTEMS ENVIRONMENT

CLEM

CLEM is a clinical event monitor that was developed at the University of Pittsburgh Medical Center and has been in use since February 1997. New data flows to CLEM from our legacy systems, e.g., pharmacy, radiology, ADT, and laboratory, through an HL7 message router. All data coming through the router are also fed into the data warehouse, MARS (Medical ARchival System [1]). MARS provides CLEM with a list of new data and access to existing patient data that CLEM needs to interpret the new data [2].
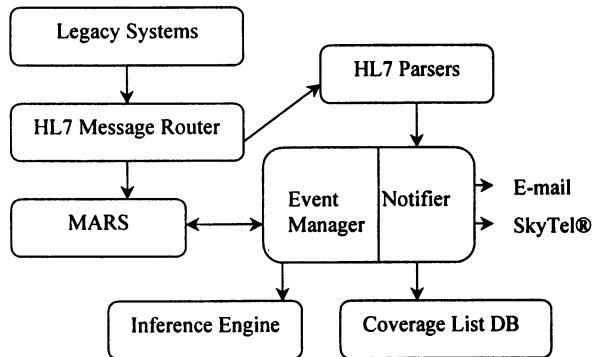

Figure 1: CLEM Architecture

CLEM's inference engine is based on CLIPS, a forward-chaining production system developed by the National Aeronautic and Space Admninistration (NASA). We extended CLIPS by adding a set of temporal functions that gives us the ability to create temporal abstractions (e.g., last potassium level) similar to those in the Arden syntax [3].

After the inference engine generates an alert, CLEM consults a coverage list to determine the clinician currently responsible for the patient, and then notifies that clinician using either e-mail or a pager communication channel.

Some of the messages sent by CLEM, e.g., laboratory and radiology results, are not generated by the inference engine. The HL7 router passes laboratory and radiology data to a set of parsers that parse the HL7 message and then pass it to CLEM's notifier. The notifier checks a coverage list to determine the clinician responsible for the patient, and then notifies that clinician using the 2-way pager or e-mail.

SkyTel

SkyTel® 2-Way's two-way messaging service allows users to respond (and therefore acknowledge) pages they receive. Additionally, the service has "store and forward," "message mender," and message receipt confirmation features (these will be explained below), and provides nationwide coverage.

Network. The SkyTel® network is based on an asymmetrical two-way network architecture where outbound messages from the Network Operations Center (NOC) are sent to users via a different path than replies and confirmations. Messages to be sent to a pager can be received by the NOC via (1) Internet e-mail, by using a pager's identification number as the recipient, e.g., 9078075@skytel.com, (2) the Internet by a socket connection to the NOC, (3) telephoning a SkyTel® operator, (4) a modem connected computer, and (5) another two-way pager. At the time of this research, CLEM sent its messages to the NOC using the socket connection to the NOC and Internet e-mail. In August 1998, SkyTel® is scheduled to release a secure socket connection to the NOC with 128 bit RC-4 encryption from the sender's site to the recipient's pager.

The design of the SkyTel® network has several advantages over typical one-way paging systems: (1) The use of multiple transmitters and a satellite distribution system gives the network superior in-building reception (we have found only one call room at UPMC-HS where the reception is poor). (2) If a "garbled" message is received by a pager, it will be identified by the NOC when the pager is sending its confirmation of receipt and the NOC will re-send the "mended" message. (3) If a message cannot be received by a pager, e.g., pager is out of range or its battery is dead, the NOC will store the message and forward it once the pager is reregistered by the NOC. **2-Way Pagers.** Currently, there are two types of 2-way pagers that SkyTel® offers: the Wireless Access® AccessLink and the Motorola® PageWriter 2000. Since our experience has only been with the former, we limit our discussion to the features of the AccessLink.
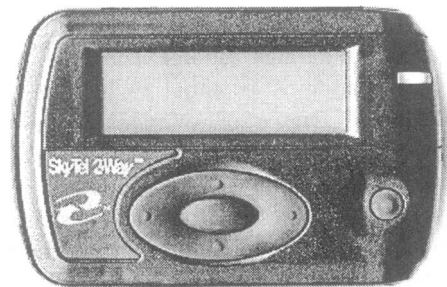

Figure 2: Wireless Access AccessLink

AccessLink pagers measure 3.75x2.50x0.75 inches and weigh 7 ounces with one AA battery installed. They have a mean battery half-life of approximately 2 weeks. The pagers have a 20 character by 4 line backlit LCD screen. The pagers can receive messages up to 500 characters in length; users read 80 characters at a time by scrolling through successive screens. Users can reply to

messages by choosing from a set of provided responses (the sender can provide a list of potential responses with the message being sent), or they can create a custom reply by navigating a character list using the cursor keys.
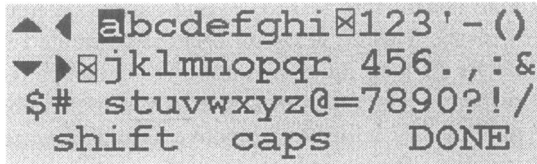

Figure 3: "Keyboard" of the AccessLink

These pagers also have an address book, which can hold other AccessLink pager numbers, e-mail addresses, phone numbers, folders for saving messages, and an alarm clock. Users can configure the beeping properties of this pager to be different from their other pager(s), and to set it not to beep during specified hours.

Implementation and Use

Types of Information Sent. CLEM sends two types of information to its users: *alerts* and *results*. We define *alerts* to be messages that are generated by CLEM's inference engine – for example, an alert which notifies the clinician that his patient has renal insufficiency and is on Meperidine. We define *results* as messages that are not generated by CLEM's inference engine. Information for these messages is generated by the legacy systems. For example, a new potassium result, received from the laboratory via the HL7 router is parsed and then processed by CLEM's notifier.

CLEM sends the following types of results: radiology impressions, drug levels (e.g., digoxin and gentamicin), and various lab values (e.g., lytes, CBC, ABG, and platelet counts). The alerts that CLEM sends are in one of the following classes: general, drugs and blood elements, drugs and renal function, geriatric care, potassium, therapeutic drug monitoring, or UPMC-HS practice guidelines.

Use of the Reply Feature. There are three types of replies that we have attached to the alerts being sent by CLEM (1) specific actions, (2) "worthiness," and (3) replies that retrieve information. Specific action replies let the recipient reply to the alert stating what his course of action will be. For example, the alert which informs the physician that his patient is on Sulfamethoxazole/Trimethoprin, which can cause granulocytopenia, and gives patient's white blood cell count has the following specific action replies: "Take no action," "DC antibiotic," and "Change antibiotic." "Worthiness" replies ask the clinician if he thinks the alert was "Page worthy," "Email worthy," "Both," or "Neither." Information–retrieving replies allow the clinician to have

information sent to him, via email or printed onto a network printer of his choice, which may help him understand why he received an alert. For example, an alert that informs a clinician of guidelines about the dosing of aminoglycosides, which is sent if there is a new order of Gentamicin with a dosing frequency of Q8H, has the following replies "Email me guidelines," "Print guidelines to 8S," "Print guidelines to 10W," etc.

The information–retrieving replies work in conjunction with an auto-reply program as follows: Replies to the paged messages are received in CLEM's e-mail account and forwarded to a parser. The parser extracts the following information from the reply: (1) who sent the reply, i.e., the recipient of the original message, (2) to which message is the reply (each message type has a unique identification number), (3) the reply proper, e.g., "Email me guidelines," and (4) additional information that is used for logging. Using a look-up table, additional information is obtained on the clinician replying to the message, e.g., email address and name. The program then retrieves the information being requested from a repository and either sends it to the recipient's e-mail account or to a print server that will print it to the network printer that has been selected by the user.

METHODS

At the end of August and September 1997 (second and third rotations of the academic year), we administered a survey to interns and residents who had been on each rotation and had been issued a pager at the beginning of their rotations (due to a limited number of pagers, 2 MICU and 2 Oncology service residents shared a pager; all interns and residents on medical ward teams and all MICU and oncology interns were issued pagers). The purpose of the study was to evaluate the acceptance and utility of information sent via pager in comparison with information being sent via e-mail. The survey (a modification of the questionnaire used in Rind [4]) elicited (1) basic information about the respondent, including postgraduate year, and e-mail and pager usage, (2) responses to four statements about receiving information by e-mail and by pager, and (3) three features of CLEM that they like and three that they thought needed improvement.

RESULTS

Response Rate

During the two study rotations, 62 unique house staff (38 interns and 24 residents) served on at least one of the medical services. All had been issued either personal (55) or shared pagers (7) and all had e-mail accounts to which CLEM had sent messages. Of

these 62 house staff, 39 completed the survey (response rate 63%). The response rate for interns (25/39 = 0.64) and residents (14/24 = 0.58) were similar (p = 0.64). Five respondents (all residents) indicated that they had not used a pager during their rotation: four had been issued a pager, or a shared pager, but had elected not to use it, and one had not received any messages on the pager due to a misconfiguration.

Acceptability of 2-way Pagers

Table 1 lists eight statements from the survey and the mean responses of the house staff who completed the survey to those statements. The strongest response to these statements was a desire to receive messages by pager during the next rotation. All but one of the subjects responded either 1 (Strongly Agree) or 2 (Agree) to this statement. To derive a summary statistic for each method of delivery, we calculated the mean response for the four statements about e-mail (statements 1, 3, 5, 7) and pager (statements 2, 4, 6, 8). This aggregation seemed warranted by the nature of these questions and the similar patterns of response. The mean response to statements about e-mail of 2.77 indicates a positive attitude towards this channel. The mean response the statements about receiving information by pager of 2.34 indicates a slightly stronger preference for this communication channel.

Table 1: Responses to statements about information being sent by CLEM via e-mail and page

	STATEMENT	Response*	SD
1	E-mail alerts have been helpful in the care of my patients.	2.42	1.06
2	Two-way-pager alerts have been helpful in the care of my patients.	1.64	0.99
3	E-mail alerts have been annoying.	3.39	1.17
4	Two-way-pager alerts have been annoying.	4.00	1.08
5	E-mail alerts have given me clinically useful information before I would otherwise have known it.	2.91	1.40
6	Two-way-pager alerts have given me clinically useful information before I would otherwise have known it.	1.91	1.13
7	I would like to continue receiving alerts by e-mail on my next rotation.	2.36	1.25
8	I would like to continue receiving alerts by two-way pager on my next rotation.	1.39	0.56

*Responses: 1, Strongly Agree; 2, Agree; 3, Agree/Disagree; 4, Disagree; 5, Strongly Disagree

Table 2: Features of CLEM That Are Liked or Need Improvement

FEATURES LIKED	Response	%
Liked the types of information		
Radiology Reports	19/34	55.9
Culture Reports	8/34	23.5
Drug Levels	7/34	20.5
Lab values for cross coverage patients	4/34	11.8
Blood Chemistries	3/34	8.8
Liked the 2-way pager		
As a way to communicate with other doctors	15/34	44.1
Portability, convenience, and mobility of unit	4/34	11.8
As a organizer and reminder	3/34	8.8
FEATURES WHICH NEED IMPROVEMENT		
On the delivery of information		
Shorten delivery times	4/34	11.8
On the 2-way pagers		
Incorporate house pager into 2-way unit	3/34	8.8
Better input device, easier way to type	2/34	5.9
Miscellaneous (didn't like weight, range, battery consumption, returning it)	4/34	11.8

Utility of 2-way Pagers

On analysis of the qualitative section of our survey, i.e., list three features of CLEM you like and three features of CLEM that need improvement, we found several themes that are relevant to this paper and these are outlined in Tables 2. In each table we have tried to classify the respondent's responses into one of the following categories: comments about the type of information being pushed to the pager or comments about the pager itself.

Additionally, one user stated that the 2-way pagers delivered important information before he would

have had the chance to find it on his own, and two users stated that they liked being able to print journal articles that pertained to a patient's admission diagnosis.

In addition to the above, respondents made the following comments: One respondent stated that the truncation of radiology reports made them less useful, another stated that he found the 2-way pager difficult to use, another informed us that the units did not work in one of the call rooms, and one stated that the pagers were not useful in the MICU. Two respondents stated that a directory of all users carrying a pager would aid communication.

DISCUSSION

The SkyTel® 2-way pagers satisfy the functional requirements we perceived at the beginning of our investigation. They are mobile and can push information to workers. In addition, we have found them to be durable, easy to maintain, simple for our users to use, and easy to integrate into our system.. Overall, our experience and survey data suggest that 2-way pagers are acceptable to house staff for fulfilling their information needs for certain kinds of information, data that is rate-limiting in the care process or that may significantly change the care of patients (e.g., culture and radiology reports), and have utility as a communication device.

We have, however, also found some limitations. The 500 character maximum message that the unit can accept limits the amount of information that can be sent in a message. For some messages that CLEM sent, e.g., radiology reports, the size limitation required us to truncate the report (the last line of these messages said "TRUNCATED REPORT" to inform the user). Additionally, some users have inquired whether the 2-way pagers could be integrated with the current paging system at UPMC-HS, since they always carry at least one other pager. This integration is not possible at our institution. Additionally, depending upon usage, the cost of the pager might offset any benefit: for example, 50 dollars a month covers rental fees and a message allowance of 2000 10 character messages (40 500 character messages), and each additional 10 characters over this allowance costs 10 cents. On average, CLEM sends a total of 60, 500 10 character messages per month.

During the last year and a half we have identified additional requirements that a system would need to have to more fully satisfy the needs of mobile workers. These additional requirements are: (1) The system must have a display that is large enough for a web browser that supports "forms," (2) it must be able to run applications, e.g., JAVA, (3) it must have an input device for the user that supports handwriting recognition software, and (4) it must support a variety of communication protocols, e.g., RF WAN/LAN, spread spectrum, and packet radio, so it could be used in different environments. Although there are many devices being offered by vendors with these features, e.g., NORAND®, TELXON®, and SYMBOL®, they are expensive (between 2,000 and 5,000 dollars per unit). Additionally, the current size and weight of some of these units could limit user acceptance.

To our knowledge, there is no previous published work on the use of 2-way pagers in sending alerts to physicians. Further research is needed to (1) define additional types of information that should be sent via 2-way pagers, (2) to determine whether 2-way paging reduces delays in the correction of critical lab values or potential errors in patient care, and (3) to evaluate the acceptance and utility of other wireless devices. This research has demonstrated the potential of small 2-way wireless devices in healthcare. We emphasize, however, that we do not believe that this potential is limited to the device we chose to use. We believe that other pagers e.g., the RAM® RAMfirst Interactive or ARDIS® RIM Inter@ctiv pager, and wireless devices, e.g., a PalmPilot™ with Minstrel™, a wireless IP modem by Novatel Wireless®, devices which have features similar to the SkyTel® 2-way pager, could also satisfy the information needs of the mobile worker in healthcare.

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