

# DELIVERING KNOWLEDGE IN THE FIELD: A TELECOMMUNICATIONS SERVICE PROVISION AND MAINTENANCE CASE

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## Abstract

*This paper proposes a novel approach to providing knowledge management services in a business process wherein field engineers are the main process actors, providing and maintaining telecommunications services. Cooperating multi-agents play a central role for the provision of knowledge management services by integrating heterogeneous systems to collect related knowledge for the execution of mobile tasks. The proposed system is expected to increase both the performance of the mobile workforce and customer satisfaction by supporting and encouraging knowledge sharing.*

*Keywords: Knowledge management, multi-agent system, field engineer, workflow.*

## 1 INTRODUCTION

A mobile business process like the telecommunications service provision and maintenance process requires its process actors to have high-level engineering knowledge to solve problems in the field. However, the constraints of the mobile computing environment make it difficult to provide rich, easy to use knowledge management services to field engineers. These constraints include the relatively low performance of mobile devices (compared to the more familiar desktop PCs), limited screen size (making navigation of complicated and/or inter-related knowledge sources difficult), and limited usability of the system due to frequent disconnection from the Internet or Intranet because of wireless reliability issues.

This paper proposes an agent-based approach for knowledge management in the telecommunications service provision and maintenance domain. Multi-agent systems (MAS) technology provides many desirable features which can be used to achieve this goal. Firstly, a multi-agent system can be used to integrate heterogeneous systems. In this type of application, the integration of a workflow management system with one or more knowledge management systems is almost inevitable because they are very likely to be operating on heterogeneous platforms. Secondly, a multi-agent system provides a flexible architecture for service provision. For example, FIPA (the Foundation for Intelligent Physical Agents) [FIPA, 2000] mandates every MAS platform to have both service (so called 'yellow pages') and location (so called 'white pages') directories that are used to flexibly mediate the service transactions among application agents. Thirdly, the intelligence and autonomy of agents can be applied to assist field engineers who frequently travel from one job location to another and hence are not able to use their workflow system whilst in transit, which prevents them from responding in real-time to any jobs at those times. Furthermore, an agent's 'intelligence' enables it to reduce the time a fieldforce spends looking for solutions, as it is able to identify and navigate multiple relevant knowledge sources, in some cases before a query has been posed.

The organisation of this paper is as follows. Section 2 reviews work related to this paper. Section 3 describes the target business process and identifies some knowledge management requirements from the business process. Section 4 details the proposed system to fulfil the knowledge requirements of the target business process. Finally, section 5 summarises this paper and discuss the advantages of the proposed approach.

## 2 RELATED WORKS

IT (Information Technology) support for telecommunications service provision and maintenance is one of main issues in the workflow management area due to the large number of involved process actors and the technical knowledge involved in the business process.

Work Manager 0 is a centralized workflow management system used by BT (British Telecommunications plc.) to support large-scale telecommunications processes. Work Manager schedules approximately 150000 jobs to about 20000 field engineers each day. However, Work Manager does not provide field engineers with access to much of the knowledge related to their assigned jobs, which is the main motivation of this paper. This paper proposes the use of Work Manager as a job source for our Multi-agent System platform, which delivers job details, enriched with relevant knowledge, to the mobile devices of the field engineers.

MOSS 0 has been proposed as a supporting system for mobile telecommunications workers. A main focus of MOSS is the provision of ubiquitous accessibility to data and information within the Corporate Intranet. MOSS is focused on the delivery of related data for the execution of mobile tasks from the Corporate Intranet using a fixed architecture. The MAS-based approach described in this paper provides a flexible way for the provision of knowledge services to mobile telecommunications workers. These knowledge services facilitate knowledge sharing among workers as well as knowledge delivery.

The TMWE (Telecommunications Management Workflow Engine) architecture 0 has been proposed as a workflow management system engine to support telecommunications processes. TMWE is a workflow engine that can be used for the scheduling of activities in a telecommunications service provision and maintenance, but it does not deal with any knowledge management aspects.

There are also plenty of commercial workflow systems to automate business processes such as BizFlow from HandySoft 0, Staffware 0, and CommerceQuest 0. The agent-based workflow system used in this paper can be differentiated from those products in that its end users are remotely distributed field engineers while the latter is more concerned with supporting in-office workers. In which case, it is worthwhile comparing the system described in this paper with other mobile workforce management solutions. For example, Vaultus Mobility 0 extends its target user base to include field engineers. However, it does not provide coordination support among field engineers to handle exceptional situations such as traffic jams or poor visibility. The agent-based workflow system in this paper uses coordination components to support field engineers for trading assigned jobs in such exceptional cases.

Knowledge management in process engineering 0 is also an important research issue. MILOS 0 has been proposed as a knowledge management tool for virtual teams within the software development process. MILOS “integrates a process enactment environment with an on-demand knowledge delivery strategy that is based on parameterized information needs models”.

Abecker et al. 0 integrate document analysis and information retrieval techniques within a workflow management context. In their approach, each task within a business process is linked with a related document source, and a workflow management system provides the related document data when a task is instantiated. On the other hand, Organizational Memory 00 is integrated with a workflow management system to provide related knowledge on the execution of process tasks. Staab and Schnurr 0 favour an ontology-based inference approach to retrieve related knowledge from an

Organizational Memory for the execution of process tasks. Kaathoven et al. [9] propose a mechanism for synchronizing conventional workflow management system scheduling activities with a concurrently running OM-based task support system, using knowledge flow chunks. The common limitation of this research is that their target business processes are supposed to be executed in an office environment where reliable network connections and powerful computing devices are provided to the process actors. Furthermore, they do not address the issue of knowledge sharing between process actors. Knowledge management issues in Computer Supported Cooperative Work (CSCW) also have been addressed by some researchers [10]. Fagrell et al. [10] identified “four aspects of mobile knowledge management as it took place in the mobile work setting: sharing, i.e., several parties exchange knowledge; indexing, i.e., one party explains to another which knowledge to retrieve; diagnosing, i.e., two parties make sense of how to interpret a situation, and; foreseeing, i.e., one party (or more) uses knowledge to project the future”. RoamWare [9] has been developed as a mobile CSCW to support physical/virtual meetings of field engineers and evaluated in Umea University and Telia Nara. From the evaluation, they argue that the meetings among mobile actors are crucial aspects of knowledge processes for knowledge-sharing, coordination and decision-making. Finally, O’Hara and Brown [10] address the fact that CSCW technologies can be used to facilitate face-to-face interactions among workers, which will increase the sharing of tacit knowledge. This paper is distinguished from those research efforts in that it proposes a mobile knowledge management approach in a workflow context.

### 3 KNOWLEDGE REQUIREMENTS BY FIELD ENGINEERS

#### 3.1 A typical mobile business process

BT operates a large mobile workforce to maintain its network and provide telecommunications services to residential and business customers across the UK. The process starts when a customer or a BT field engineers (a fieldforce) requests provision of a new service or repair of an existing one. One of two sub-processes is executed depending on the type of order (provision or repair): Configure Service (for provision) or Maintain and Restore Service (for repair).

The Configure Service process handles the request to deliver ordered services, or network re-configuration to overcome service problems or service restrictions. This process consists of sub-processes such as: Take Order (confirm that a request can be fulfilled and assemble an outline plan or notify the customer with the reason for order rejection); Order Plan (assemble a detailed plan, identifying relationships between orders and components for the same customer for order delivery, and reserve resources, e.g., network capacity, stores, workforce); Gain Agreement (recommend most suitable solution, and agree terms with the initiating process); Initiate Order (start agreed plan of work, ensuring that all reserved resources are implemented); Install Equipment (deliver assigned equipment and, where manual intervention is necessary, install and configure the equipment using the previously assigned workforce); Configure Network and Customer’s Premises Equipment (automatic configuration and testing of network and customer’s premises equipment); Close Order (close the order transaction with the initiating business process); and Handle Customer Contact (determine the appropriate contact method and contact point and communicate the results of a customer order to the customer).

The Maintain and Restore Service process, given information about problems with services from a number of sources, brings all of the information together to enable the earliest and most effective diagnosis to be performed. The main activities of the process are: Handle Customer Contact (obtains initial details of the problem from the customer); Confirm Problem (if problem is due to equipment rather than customer’s use of it or a known network problem, the equipment is tested. If the results indicate a problem with a BT product, a Trouble Ticket is created); Receive Problem Reports (report are converted to a standardized format and logged); Localise Root Cause (find the logical network

component that is causing problem and identify the physical realization of that component); Initiate Problem Resolution/Maintenance (get options and time-scale for reconfiguration and reserve the required capacity. Identify the task which needs to be performed to repair the problem and the required skill level and schedule the work. If the decision is to reconfigure, a request is sent to Configure Service committing to the earlier reserved solution. If the decision is to repair, Configure Service is requested to release the reserved capacity and a request is passed to Perform Maintenance Work to carry out the repair.); Optimise Network Topology (as part of network maintenance, model networks in order to optimize topology); Confirm Problem Solved (initiate a test for each of the products or services which were affected by the problem); Handle Customer Contact (receive the results of the problem closure. Communicate any information required by the SLA to the customer); and Schedule Maintenance Routines (for planned engineering works, identify the best way to maintain a schedule of required maintenance activities. When a routine becomes due, a job is sent to Initiate Problem Resolution Maintenance). Field engineers work on all types of network equipment that connect the local Exchange to the customer's premises. BT field engineers are organized according to geographical areas delineated by telephone exchange. Each field engineer team works within a certain area known as a 'patch' which comprises a number of exchanges. Patches vary in size and are grouped in areas.

### 3.2 Knowledge management requirements

It is a commonplace that field engineers are reluctant to show weakness or a need for support in difficult situations, as they are afraid of being branded as ineffective. This may be alleviated by providing a means for field engineers to ask for help directly from colleagues or even to do so anonymously. It has also been noted that there is both a lack of credit for those offering coaching and support to inexperienced people and little incentive to contribute to requests for help from colleagues and for submitting information to the corporate knowledge base. These requirements can be classified into three categories according to the knowledge management life cycle.

Knowledge search activities. One example of providing job related information is access to telecommunications network configuration blueprints, which show cable routes and the location of joints and access points. Currently, all the blueprints are stored on a server located on the Corporate Intranet. Each field engineer has copies of the maps for their patch on their laptop computer and takes them to their work location. However, the maps are sometimes not up to date and the laptop is difficult to carry on to a Customer's premises, along with tools, test equipment etc. Getting the maps on line and displayed on a lightweight device like a PDA is expected to improve work performance dramatically. Another example with regard to knowledge search is finding other jobs associated with a specific job. When a field engineer is working at a given Exchange, it would be more efficient if he executed other jobs in the Exchange that have been assigned to other field engineers for that day.

With regard to the maintenance of the knowledge repository, field engineers play an important role. During the execution of their jobs, field engineers frequently find that customer details and/or the descriptions of network equipment in certain locations are wrong. They thus act as important sources of information on both customers and equipment. A system that allows field engineers to update a corporate knowledge base is a highly desirable mechanism for maintaining accurate and complete knowledge on customers and network equipment.

Exchange of knowledge among team members. When a field engineer is faced with a problem, he can use the Corporate knowledge base to identify a colleague whom is likely to be able to help in the given problem domain. This might be a Customer Service Coach or a fellow field engineer. Alternatively, he might want to use the corporate knowledge base to access details of how a similar problem was solved previously. A case-based knowledge repository could be maintained in parallel and properly indexed for effective search. A background process could help build this knowledge from facts extracted from 'Update Knowledge Base'.

These requirements are considered difficult to satisfy with the current system (Work Manager) mainly because it does not allow peer-to-peer coordination amongst field engineers and adding a new knowledge service is impossible without the re-implementation of current client systems deployed on the laptops.

## 4 mPAF: MOBILIZED PERSONAL AGENT FOR FIELD ENGINEERS

### 4.1 General architecture and services

A large part of the information resources available to an organisation exist in the form of semi-structured or unstructured data i.e. free text, or text with some mark-up. These resources have the potential to be very useful but are often underused because the field engineers are ignorant of their existence, or are unable to locate them. Furthermore, new sources are continually being created and old sources are disappearing all the time. mPAF (mobile and Personalized Agents for Field engineers) is an extension of iPAF [Thint et al., 2003] to deliver the semi- and un-structured data within an organization to the field engineers.

At its heart, iPAF has a set of user profiles, and a directory of information sources from which it provides a number of services.

- **Personalised information retrieval.** iPAF can use the information contained in the interest profiles to personalise information searches by expanding queries, or filtering out replies which do not correspond to the user profile.
- **Federated queries across distributed information sources:** iPAF provides a central point from which information queries can be handled. From a given request it locates and queries all the relevant information sources and combines the replies.
- **Just-in-time information provision:** iPAF has services for *just-in-time information provision* i.e. providing relevant information for the current user activity.
- **User interest profile detection and handling:** iPAF employs a rich user interest profile, which can be accessed by agents. The profile can be built by hand, or can be automatically generated by a client with access to the user's PC.
- **Expertise location:** iPAF provides a service for querying the expertise of a user on a given subject. This can rely solely on the iPAF interest profiles, or can take into account alternative expertise sources, thus providing a distributed expertise location service.
- **Information push agents:** iPAF has some built-in information push agents including *myPaper* a personalised daily newspaper, based on the user profile; and *iRemind* a just-in-time information agent which monitors the user activity in Microsoft Word and recommends relevant documents and people. A high-level architecture of the overall system can be seen in Figure 1. The system has a set of individual user profiles, describing the interests of the users. The profile is arranged in a hierarchical fashion, with each interest containing privacy ratings, expertise ratings and sets of positive and negative key-phrases. The profiles can be generated in a number of ways: they can be built from scratch by hand, selected from a pre-defined set of default profiles or automatically generated from documents read by the user. In the latter case a client device is deployed on the user PC to generate a profile from the documents and emails accessed by the user.

As can be seen from Figure 1, each information source requires a source interface agent, which converts iPAF requests to an appropriate request for the information source. Naturally, the precise method of conversion depends on the information source itself.

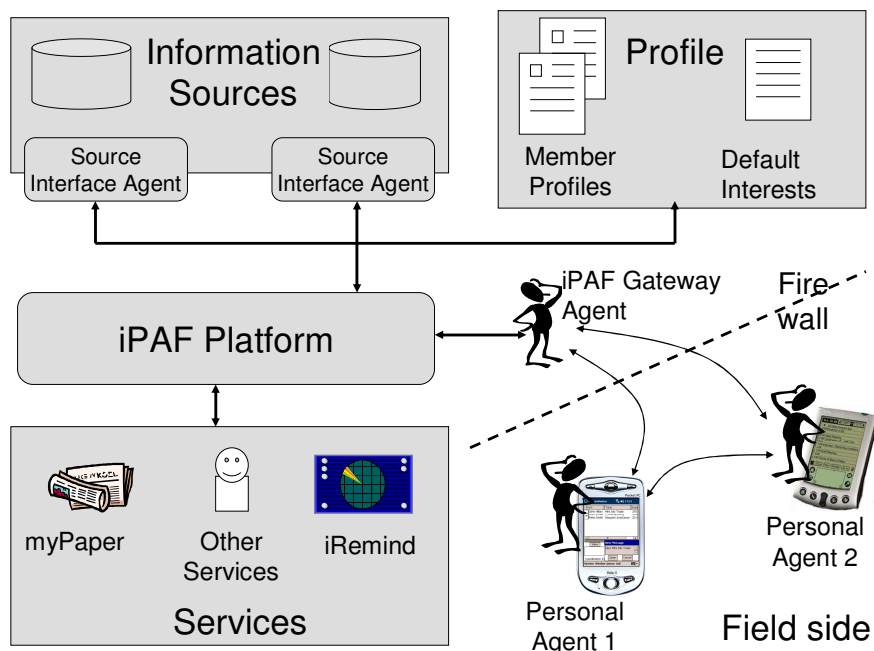


Figure 1 Architecture of mPAF

#### 4.2 Delivering iPAF services to the field

iPAF services are delivered to the field by the mediation of iPAF gateway agents. Each field engineer is assigned with a personal agent on his/her mobile device. A personal agent contacts a iPAF gateway agent if it requires a list of relevant knowledge or experts required for the execution of assigned tasks to its worker. The use of iPAF gateway agent makes the personal agents independent from iPAF so that they can communicate with iPAF regardless of any changes on iPAF as iPAF gateway agents will be adapted to the changes. Once an expert who can help with any problem for the execution of a task, the personal agent will contact the personal agent of the expert to set up a communication session to solve the problem.

##### 4.2.1 Information Sources

There are many potentially relevant information sources for a fieldforce depending on the precise nature of the job. These could include reference papers, customer profiles, portfolio information or technical manuals to name just a few. In the telecommunication provision and maintenance domain the most important sources are technical documentation, health and safety documentation, customer information, and process documentation. Information about other jobs carried out on the premises can be very helpful in diagnosis and in dealing with the customer. Technical documentation such as equipment manuals or area schematics can be referred to by the fieldforce in the course of their job. If for example the worker is unfamiliar with a piece of equipment they can readily access its maintenance documentation. Similarly, for any class of job, there will be health and safety procedures which must be adhered to. The worker may wish to consult this before embarking on a given job. In recent years all of these types of information have been transferred to electronic format – the large majority being available in HTML format. However, they are stored in different places and organized differently, some have their own search facilities which are of varying quality, others use a hierarchical approach to locating the information. Some sources, such as schematic diagrams, require additional hand mark-up. This variety is handled by the *source interfaces*.

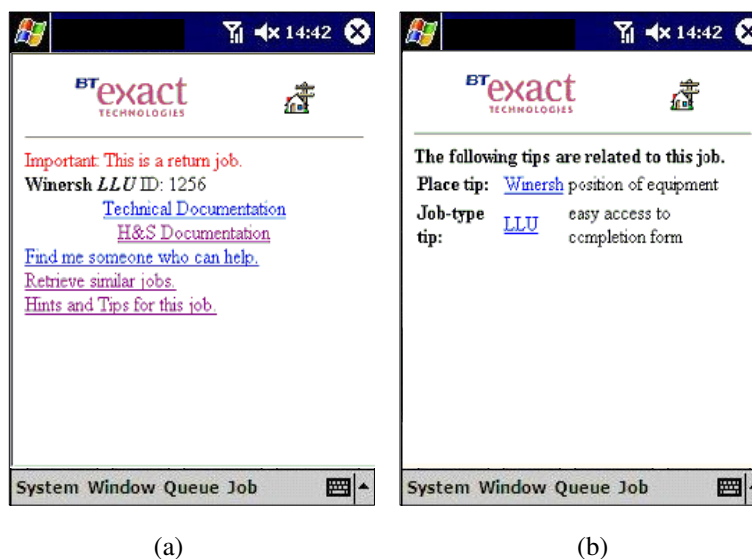


Figure 2 (a) List of KM services available for a job (b) hint and tips for the job

It is the purpose of the source interfaces to convert messages from the iPAF system to a query which can be applied to a given source and the convert the results into the iPAF format. Communication with the sources is over an HTTP connection, using an XML format.

#### 4.2.2 Composing TeamWorker services from iPAF Services

Personal agents rely on the above functionality for their knowledge management tasks. The *find relevant information* task takes as its inputs a job description, and the user id. By accessing the *personalised information retrieval* and *federated queries* services it can find all the relevant information for a given job. The *find expert* service calls directly on the *expertise locator* service. The *find solution* service combines a specialised information source focused on very similar queries with the *federated query* service for broader information should the specialised source fail. The specialised source consists of a database of hints and tips contributed by the field engineer. Workers contribute free text describing the tip and then assign it to a piece of equipment, a place, or a job-type. The tips relevant to any of these aspects of a job can then be recalled later.

#### 4.2.3 Building the profiles

For a telecommunications provision and maintenance worker the user profile corresponds to the skills of the worker, and the types of jobs they usually undertake. A given profile is therefore much less individual than that of a knowledge-worker whose profile will be unique. The field engineer skills are kept on a separate database which is used as a basis for the profiles and in particular for the expertise ratings. These skills are public by nature, so the privacy ratings are public for all interests.

#### 4.2.4 Delivery of the iPAF services

For each job, the field engineer is shown a menu for the different types of information available. These are technical information, health and safety information, expertise location, access to records for similar jobs, and hints and tips for this job. A screenshot of this menu can be seen in Figure 2 (a).

The field engineer selects this page before starting a job. Important information is highlighted at the top of the page. In this case the field engineer has been informed that this is a return job. The field

engineer then checks the relevant health and safety information and checks the hints and tips for this job as shown in Figure 2(b). He notes that another field engineer has added a tip about the position of a piece of equipment at the exchange in Winersh where the job is located. Knowing that the piece of equipment is in an unusual place saves the field engineer a lot of time and he rapidly continues with the task.

During the job the field engineer is unsure whether a given product is compatible with the current LLU task. By accessing the technical documentation page as shown in Figure 3(a) he can see all the documents relevant for this job which are distributed in different help sites on the Intranet. After following one of the links he finds that the product is compatible. This both saves a lot of time for him, by pre-finding the documents prior to the job and makes him aware of some documents in intranet sites of which he was not previously aware. Figure 3(b) is one example of job-related information that is retrieved in this way - an engineering map which shows the network routing at the job location.

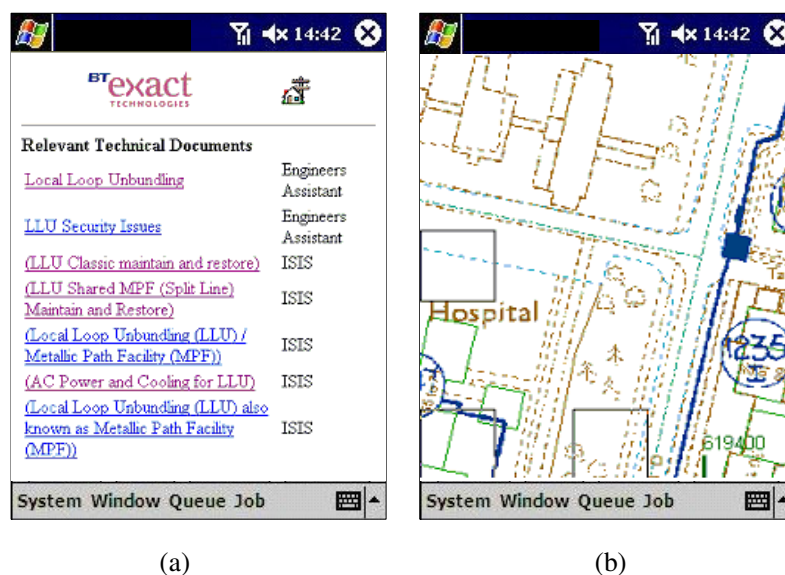


Figure 3 (a) List of job-related knowledge (b) Network routing details

Alternatively, the field engineer could have spoken to an expert by selecting the *Find someone who can help* link, in which case the system finds the contact number for any relevant experts currently at work as can be seen in Figure 4(a). When the field engineer has finished the job, he enters his own tip for this job on a simple form. The tips are first vetted by an administrator before being entered into the database. Figure 4(b) shows the second screen in this process. The field engineer has already indicated that he wants to include a tip specific to this type of job at this site and is about to enter a tip about the position of a padlock on a cage at the site.

## 5 CONCLUSION

This paper has described a real business process for telecommunication services provision and maintenance, and identified knowledge management requirements for the process. A system has also been proposed to fulfil these requirements by integrating heterogeneous systems within a multi-agent framework. The core of mPAF is a knowledge management system (iPAF) to provide integrated services for knowledge management among field engineers within a workflow management context. To our knowledge, mPAF is the first approach to integrate a knowledge management system with workflow system under mobile computing context.



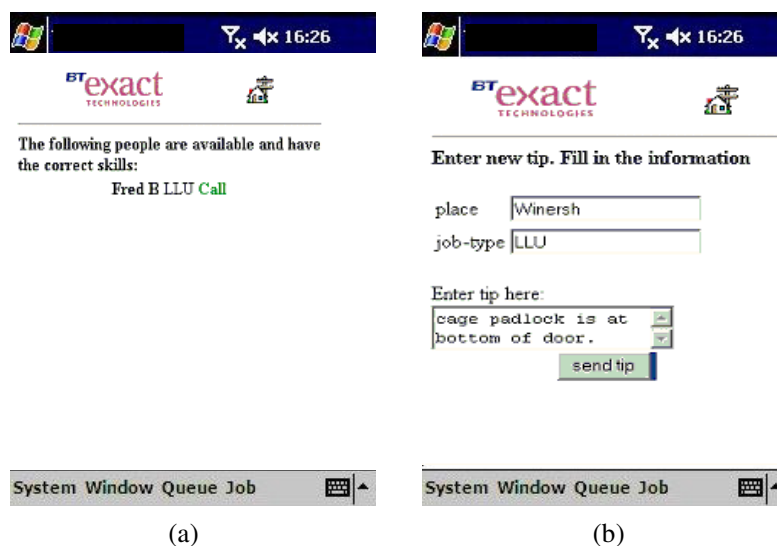


Figure 4 (a) Results of running 'Find Expert' query (b) Entering a new tip

The predicted benefits of deploying the new system are as follows. Firstly, more flexible management of customer jobs. The existing Work Manager manages jobs based on the expected behaviour of field engineers and the predicted road traffic situation. However, the gap between expectation and reality in the field frequently requires re-assignment of jobs to field engineers, which is difficult with the current system. TeamWorker enables the re-assignment of jobs dynamically during job execution based on the real life situation. Secondly, knowledge sharing between field engineers. Field engineers frequently use a paper-based process to record hints and tips and any customer feedback. In most cases, this valuable knowledge is not transferred into Work Manager to be reused by another field engineer. Capturing and processing these notes electronically on hand held devices is expected to ensure that relevant knowledge is made available to other field engineers. Thirdly, increased efficiency of job execution. The proposed new system provides all the necessary knowledge before a field engineers arrives at a job location. In the current business process, field engineers spend much of their time looking for useful knowledge relevant to the execution of their jobs by contacting colleagues (mostly via mobile phone calls). The new system is expected to reduce the rate of re-work for each job, which may improve customer satisfaction dramatically. These predicted business benefits will be quantified via a field trial in the near future.

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