Mobile Workflow Management System Based on the Internet of Things

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Abstract— **The Internet of Things (IoT) is an emerging computing concept, which fuses the digital world and the physical world by bringing together different concepts and technical components. In this paper, we present a new mobile workflow management system (MWfMS) that handles the service of computer and peripherals repair and maintenance. It allows for (i) submission of service requests, (ii) provision of real-time notifications on work progress, (iii) automatic assignment and distribution of workload among the technical-support staff, and (iv) provision of quick solutions to known problems taken from database, without having to register for a new service request. The proposed MWfMS comprises a physical layer linked by the Internet to a remote workflow management hub (WfMH). The real objects (i.e. system stakeholders and their mobile devices represent the physical layer. The WfMH that hosts the main business logic and data storage is responsible for virtualization of physical objects, and creation and delivery of various management services to the end users. A fully functional prototype of the proposed system is designed and developed and its end-to-end functionality is tested successfully.**

Keywords—Internet-of-things; Internet and web services; mobile management; workflow management

I. INTRODUCTION

Mobile phones are quickly becoming the most popular and widespread form of communication worldwide. According to a recent Cisco study [1], the growth of mobile data traffic is more than doubling every year for the past several years. This increased usage over the world along with continuous advances in mobile technology have made great changes on handhelds devices in order to become a new way of data management and enterprise productivity [2]. Some companies are already using mobile applications to deliver increased customer satisfaction and productivity as well as help their employees to perform their work faster [3], [4].

Workflow management systems (WfMS) have been one of the important technologies proposed to optimize the management activities and reduce work complexity [5]. It organizes various aspects or tasks of business process depending on a number of pre-specified rules and policies. It also allows for accommodating constant changes that occur frequently in a dynamic environment. Workflow process can be managed manually or computerized, but usually a combination of both processes is carried out [6] – [8].

Many workflow management systems have been proposed to support automation of document-driven business processes such as office automation [9], inventory control and equipment management [10], equipment maintenance [11] – [14], electronic health records and disease managements [15] – [18], and more recently in smart cities [6] and mobile health systems for disease management and clinical decision support [19] – [23], and many other management applications. However, to satisfy the emerging requirements of the WfMS, we believe that the following key attributes/technologies must be combined with the existing capabilities of the WfMS:

1) Mobility and distributed object management to support user mobility, scalability and system interoperability.

2) Customized transaction management to ensures the correctness and reliability of applications implementing business or information processes.

3) Cognitive management to provide decision support on customized service generation and automatic assignment and distribution of workload.

This paper proposes a new mobile workflow management system (MWfMS) architecture based on the Internet of Things (IoT) to fulfil the above-mentioned emerging requirement, benefiting from the widespread usage of smartphones and other mobile devices as well as the emerging vision and architectures of the IOT applications. The proposed MWfMS comprises a physical-objects layer linked to a remote workflow management hub through an existing telecom infrastructure. The smartphones at the physical layer act as data exchange terminals between the system and its users. The business logic and main data-storage of the MWfMS that are hosted by remote hub are responsible for virtualization of physical objects, and creation and delivery of customized management services to the end-users. In

particular, the system allows for (i) submission of service requests, (ii) provision of real-time notifications on work progress, (iii) automatic assignment and distribution of workload among the technical-support staff, and (iv) provision of quick solutions to known problems taken from database, without having to register for a new service request.

The remaining of this paper is organized as follows. Section II provides an overview of the proposed MWfMS. The system architecture is described in Section III. The management process and application scenarios are presented in Section IV. The results are discussed in Section V. Finally; the presented work is concluded in Section VI.

II. System Overview

The proposed MWfMS is a web-centric application for workload management in the context of equipment maintenance, computers and associated peripherals. In addition to re-engineering the service-request management of a previously reported process by the authors in [13], [14], the proposed system supports several newly added features/processes, namely; users mobility, automatic distribution of workload, real-time tracking of work progress. Fig. 1 shows an abstract view for the MWfMS under study.

Application modules of the system are distributed between the mobile devices of the physical layer and a remote workflow management hub, as illustrated. Details of these modules are presented in the next section (Section IV). This system allows users to report faults and request services through their mobile devices (i.e. smartphones, tablets, etc.) without restrictions of time or geographical location. Initially, the mobile device saves the submitted request temporarily in a local database, automatically uploaded to the back-end storage. Depending on the fault's descriptions, the system will suggest some potential solutions that may help the user resolving the problem without going through the request handling process. If not, the request execution is initiated and all stakeholders will be timely notified on the work progress throughout the active period of the request's lifecycle. The main management services provided by the system can be listed as follows:

- Allows end user to solve simple problems of computer and associated peripherals by providing quick solutions to resolve simple problems.
- Allows system stakeholders to closely follow-up the progress of their requests and get timely update through their own mobile devices.
- Provides decision support in terms of automatic workload distribution and provision of timely notifications to the system stakeholders on different stage of the request processing.
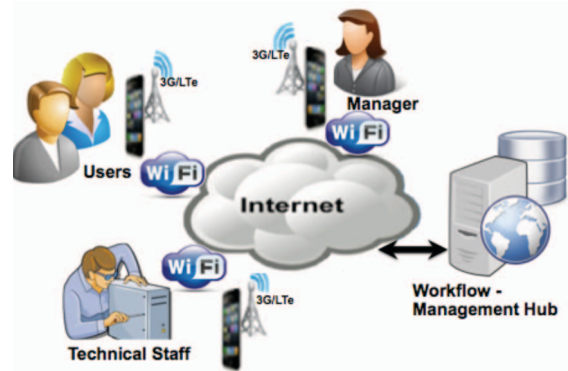

Fig. 1. Abstract view for the MWfMS

- Generates various reports on the frequency of certain faults, productivity accountability of technical support staff, and viewing the data collected from end users at various forms (table, graph, chart, etc.).

III. System Architecture

Architecture of the proposed MWfMS comprises a physical-objects (PO) layer linked to a remote workflow management hub (WfMH) through an existing telecom infrastructure, as illustrated in Fig. 2. The software design pattern that is unified at both system layers is based on the Model-View-Control (MVC) pattern. This pattern improves system security through isolating the control model (functionality and data) from user interface. It also improves system scalability, which is a critical requirement for distributed systems. The main function modules developed for each of these layers are described, as follows.

A. Mobile Applications

Software modules of the mobile applications are implemented in Java for devices running Android OS. These applications use a local SQLite database to store the data collected from the end user. These modules are described briefly as follows.

1) Data processing: This module consists of three sub-modules; data collection, data processor and SQLite database. It is responsible for collection and processing of data provided by the user through the mobile device GUI. It also handles data received from the WfMH such as potential quick solutions and other notifications generated by the system. The collected data is processed and temporarily stored in the local database.

2) Data management: It consists of three interfaces; data collection, database and communication interface. The former interface controls collection of processed data while the database inteface enables create, read, update and delete (CRUD) actions on the local database.
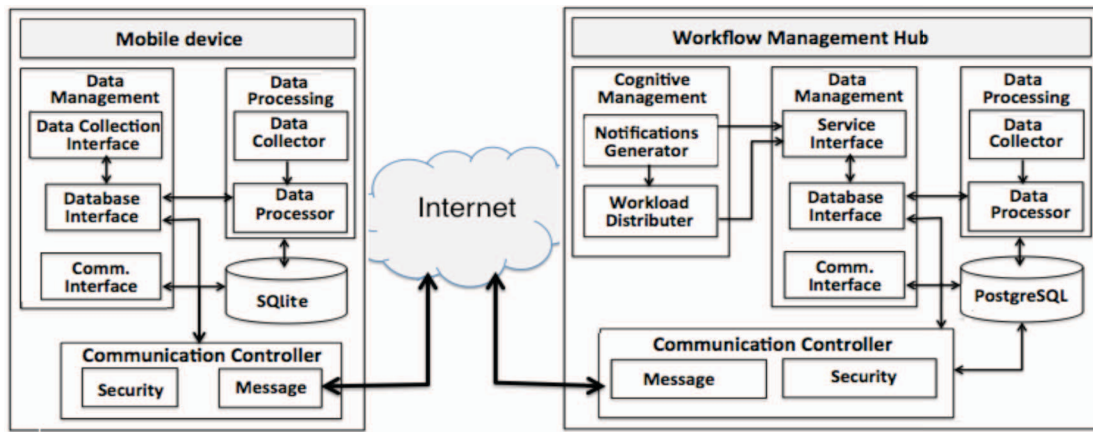
Fig. 2. Architecture of the proposed MWfMS

3) Communication interface: It synchronizes the local mobile database with the remote central database through the communication controller.

4) Communication controller: This module handles the long-range communication tasks between the mobile device and the remote server of the WfMH through the message sub-module. The security sub-module deals with security-related tasks such as encryption/decryption [24], [25] of the data and messages exchanged with the remote server.

B. WfMH Applications

These applications represent the core cloud interface, business logic and back-end storage. The PHP scripting language is used to implement the server-side application whereas HTML, CSS and JavaScript are used to implement the client–side applications. In addition, the PostgreSQL database is developed and implemented as a back-end storage that hosts the entire data resources of the system. The server-side applications provide entry points (web services) for both browser and non-browser clients to access all system services. Data synchronization between the local database of the mobile devices and the back-end storage is also performed by these applications.

Applications of the WfMH virtualize the physical-objects (POs) (i.e. system stakeholders and their mobile devices) and handle key management requirements. Virtualization of the POs that tackles the heterogeneity challenge of the IoT applications is realized through the ceration of virtual objects (VOs) that are semantic features relevant to the corresponding POs [26]. This layer is also responsible for remote data collection, automatic generation of customized notifications and provides decision support through cognitive distribution of submitted request among the technical support staff, depending upon the attributes of the requested service and active workload assigned to each of the technical support workers. The main application modules of this layer are described briefly as follows.

1) Communication controller: This complements the tasks performed by the communication controller at the mobile devices. It handles all HTTP/HTTPS requests received from the mobile devices and system users through the message sub-module. The security sub-module deals with security-related tasks; authentication/authorization of system users and mobile devices as well as encryption/ decryption of the data and messages exchanged with the mobile devices of the physical layer.

2) Data processing: This module is responsible for collecting and preprocessing data collected from various physical layer devices. The collected data are then stored in the main system storage for further prcessing by other modules.

3) Data management: This module consists of three sub-modules; database interface, service interface, and communication interface. The database interface controls and coordinates data collection with the data processing modules and enable CRUD actions on the central database. The service interface provides set of functions that work closely with the cognitive management module. *The* communication interface controls connectivity between the database and its interface with the communication controller, as illustrated.

4) Cognetive management: This module is based on virtualization approach and semantic representation of POs that tackles the heterogeneity challenge of the IoT applications. It aims at adding smart capabilities to the virtualized real objects by implementing set of functions and rules to empower the virtual object with cognitive capabilities. It comprises two sub-modules; a customised-notification generator and an automatic-workload distributor. These sub-modules automates generation of various notifications tailored to the actual needs of various system stakeholders as well as distributes the

workload among the technical support workers. Delivery of these services is based on matching attributes of the created VOs with that of the submitted request that leads to creation of a more complex objects called composite virtual objects (CVOs). The CVOs that are created dynamically are responsible for delivering the appropriate decisions within the contexts of customised-notifications generation and workload distribution.

IV. MANAGEMENT PROCESS AND SCENARIOS

A. Management Process

The main stages of the service-request management process can be described with the aid of Fig. 3, as follows:

1) Place a service request: The management process starts once the user places a request via his/her mobile device. Information related to the faulty device and type of fault (e.g. hardware or software) are temporarily stored in the local database of the mobile device and then uploaded to the main datatbase at the WfMH.

2) Provide quick solutions: The request is preprocessed at the WfMH and some potential quick solutions are identified depending on the attributes of the submitted request. These solutions are fedback to the mobile database with an appropriate notification to the user. If the user finds the provided information helpful to resolve the problem, the process ends without going through the request handling process.

3) Approve request: At this stage, the requested service is approved either automatically by the system or manually by the director, depending on the system configuration. Once approved, the user is notified and the process proceeds to the next stage.

4) Assign a technical staff: Once approved, the request is handled by the cognitive module that will match the request's attributes (i.e. device type and fault) with that of the active technical staff (i.e. technical speciality) and their workload. The request will then be assigned to the matched staff to ensure balanced work distribution among the technical team.
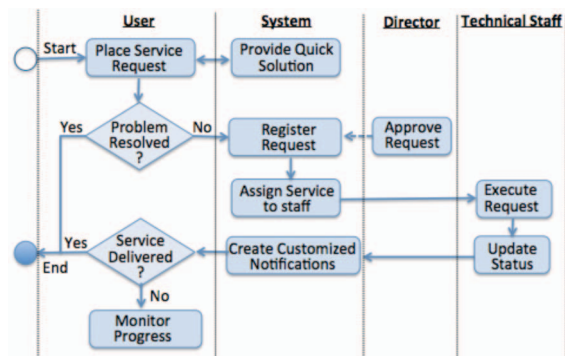
Customized notifications will then be sent to the selected technical staff, director and the corresponding user. This stage is automatically managed by the system without human intervention.

5) Work start/complete: Once assigned, the request will be designated a "pending status" until the technical worker starts working on the required service at which the status is changed manually by the worker to "started" or "in progress". Upon completion of the requsted service, the status is changed to "completed".

B. Application Scenarios

The workflow management application under study can be divided into two main scenarios; request submission and request execution. The user submits service-requests and monitor potential quick solutions suggested by the system and the technical-staff provides the requested service and update work progress. However, most of the management tasks at both scenarios are performed by the system, as explained in the management process. These scenarios are described briefly as follows:

1) Request submission: It is carried out by the user through filling in the request's information into a user-friendly GUI at the mobile device, as explained earlier. Once submitted, the system will suggest potential quick solutions to the submitted problem. If the user finds these solutions inadequate to resolve the problem, the request is registered in the system database and its management process continues. Fig. 4 shows a usecase diagram for this scenario.

2) Request execution and work progress monitoring: This task is carried out by the technical staff after the request's assignment manually by the director or automatically the system. Throughout the execution period, the worker manually update the work status (i.e. started, completed, pending or canceled) on the system which in turn generates appropriate customized notifications to the corresponding stakeholders. During the execution period of the request, the user can track work progress by viewing the timely generated system notifcations. Fig. 5 shows a usecase diagram for system interactions with both the technical support and the user at this scenario.

Fig. 3. Business process of the service request management

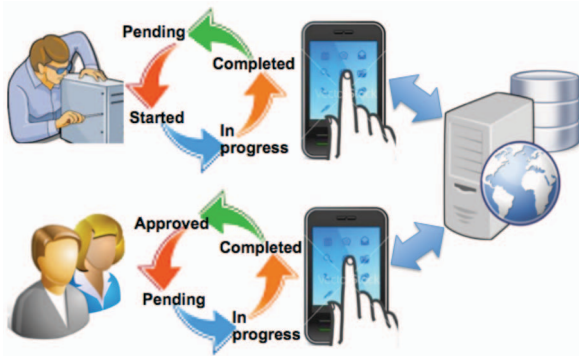Fig. 4. Service-request submission scenario

Fig. 5. Service-request execution and management scenario

V. Results and Discussion

A fully functional prototype for the proposed MWfMS is designed, developed and its end-to-end functionality is tested successfully. Fig. 6 shows example screenshots for user's interactions with the system. Fig. 6(a) shows the main menu of the mobile application. It comprises of several buttons through which, the user places new requests, views potential quick-solutions relevant to the requested service as well as system notifications, and sends messages to the system stakeholders, if necessary. Fig. 6(b) displays the form of submitting a service request. The user simply fills in some information relevant to the device to be maintained and type of fault (e.g. hardware or software. Each selection will lead to a dropdown list in which potential software or hardware problems are listed. S/he could also add some comments to further explain the fault, if necessary. Once submitted, the data is temporarily stored in the local database and then sent to the remote hub for processing. Once received successfully, an acknowledgment flag is sent back to

the mobile device upon which the request is removed from the local database.

Fig. 6(c) shows sample feedback from the WfMH on potential quick solutions relevant to the most recently submitted request. The cognitive module, depending on the attributes of the reported fault, selects these solutions based on pre-specified set of rules. These solutions may help the user to fix simple problems and thus reducing the workload on the technical support staff and avoiding potential maintenance delay. These solutions are automatically delivered by the system. If the user finds these suggestions not helpful, the system proceeds with the request management process and all stakeholders will be timely notified on the work progress. Fig. 6(d) shows another example for the technical support staff through which s/he can display summary for the service-request information and update work status, as illustrated. Once updated, the system sends customised notifications to corresponding user.

VI. Conclusions

A mobile workflow management system based on the future application architecture of the Internet of Things was designed, developed and its end-to-end functionality was tested successfuly. Seamless and accurate data exchange between the mobile devices of the physical layer and the remote management hub was demonstrated. The main objective of this research were implemented throughout the development lifecycle of the system and demonstrated during the functional tests. The developed prototype is currently undergoing further testing by system stakeholders and some positive feedback has been received along with recommendations for further improvements.
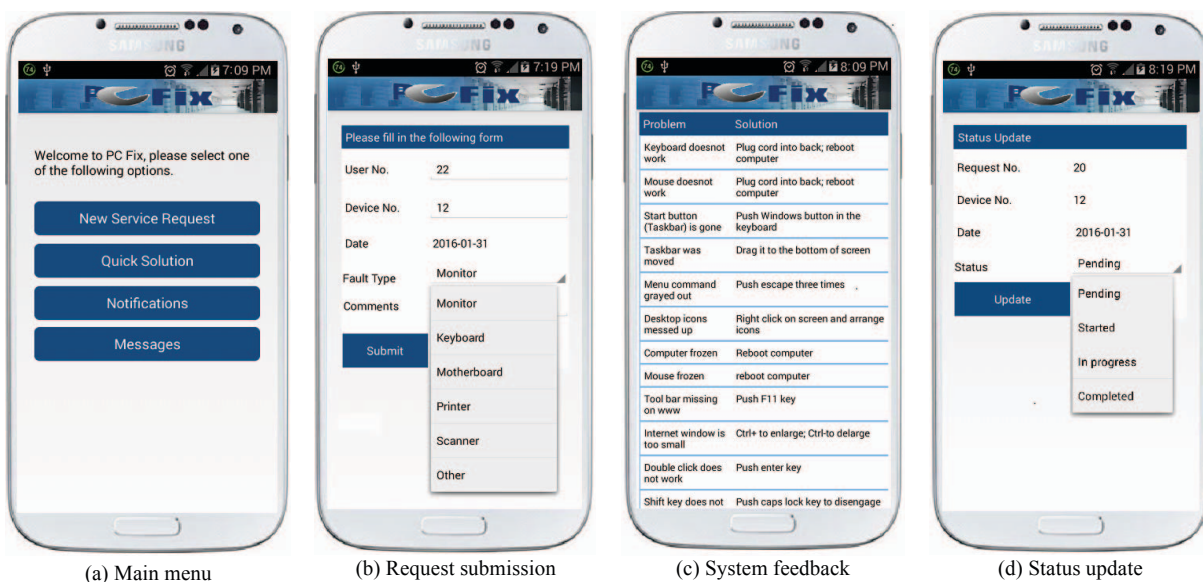

(a) Main menu   (b) Request submission   (c) System feedback   (d) Status update

Fig. 6. Sample screenshots for users' interactions with the system

The developed system prototype , however, is still open for further improvements; first, the system can be expanded to include more automation options based on computational intelligence such as generation of daily work schedules for the technical support staff, and provision of online summaries on worker productivity. Second, the cognitive management that tackles the heterogeneity challenge of enduser devices can also be further improved by enriching the cognitive capabilities of the virtual objects at the service handling and management layer. Third, implementing multi-security mechanism to preserve confidentiality, integrity and availability of data in transit and at rest in the central database. These work extensions and others are currently part of the on-going work of the authors.

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