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Adaptive Notification Framework for Smart Nursing Home

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Abstract—**This paper presents an adaptive notification framework which allows to optimally deliver and handle multimedia requests and alerts in a nursing home. This framework is operated with various applications (e.g., health alert, medicine reminder, and activity proposition) and has been evaluated with different real end-users (elderly resident and medical staff) in a pilot site. Results of these evaluations are presented and highlight the added value of the framework technology to enhance the quality of life of elderly people as well as the efficiency of the medical staff.**

I. Introduction

The population of the world is aging. According to the World Health Organization [1], there were about 600 million people in the world aged over 60 in 2004. By 2025 this total is expected to double and by 2050 it is projected to reach two billions (21% of the total global population). Such accelerated population ageing will impact social and health care demands in all countries.

Maintaining high quality of life, autonomy, wellbeing and social inclusion of the aged population as long as possible is a wish of governments and health authorities. The preference is often in favor of keeping old people at home. However, as disabilities and dependency increase with age, nursing or assisted living homes are frequently the only solutions. In these institutions, personal services include a safe and secure environment, supervision and assistance as well as activities of daily living such as medication prescription, bathing, hair dressing, eating, laundry, entertainment, etc.

Up to now, alerts or assistance requests are sent to professionals through dedicated devices (such as pagers) and systems, which do not allow for efficient coordination. Moreover, residents being not aware of the progress of their requests, tend to call again and again, thus increasing stress and workload for the caregivers. The multiple problems encountered by the professionals in home care for elderly, due to the varieties of medical and mental situations, in addition to inappropriate communication equipment, lack of coordination, stress and workload, can lead to inadequate professional health management.

In this context, this paper presents an innovative notification framework for an assisting living home which allows to optimally deliver and handle the different requests and alerts over a telecom infrastructure combining both professional and consumer equipment as well as environmental sensors. In the following Section II, we provide further details related to the background of designing service frameworks for smart nursing home along with the challenges which may be faced in this area. In Section III, we present our adaptive notification framework aiming to tackle these challenges. This framework has been evaluated with real end-users, and the results of these evaluations are discussed in Section IV. Conclusions and scope for further work is presented in Section V.

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II. Background

Information and Communication Technologies (ICT) now offer real opportunities to make more efficient and cost effective healthcare and assistance to elderly as well as to provide an effective support to health professionals and nurses. Sensors can be used to monitor daily living activities, home automation devices make the environment more controllable and various terminals with user friendly interfaces allow an easy communication with everyone [2].

In a nursing home, several types of information may be notified to the residents and to the professionals: health alerts, reminders (e.g., medicine or appointment reminder), activity proposition (e.g., event proposal as touristic visit) or new contents which may interest the end-users (e.g., medical information or a new available video). However, due to the multitude of usable formats (e.g., text, image, audio, and video) and the diversity of targeted terminals (e.g., PC, PDA, TV, fixed and mobile IP phone), it becomes very complex for an application to select the right delivery mode taking into account criteria such as the semantics of the information to be notified, its priority and criticality, the end-user preferences and disabilities (limitations), their contexts, or the device capabilities.

Such a diversity is not tackled by existing adaptation approaches which are performed at a network level by adapting a service to the network and terminal characteristics [3] or which target a specific environment such as the web [4]. Other solutions address part of the problem taking into account only the end-user context or are specifically focused on alarm notification management [5][6]. But none of them supports all the types of applications and terminals, nor the various adaptation criteria such as content semantics and criticality, user profile and disabilities, or user reachability.

III. Adaptive Notification Framework

A. General overview

The intelligent delivery of the information notifications

can enhance the quality of life of elderly people as well as the efficiency of the caregivers' work in a nursing home. For this purpose, we propose an adaptive notification framework that automatically selects –from a wide range of applications– the right delivery mode and optimizes the impact and efficiency of the notified information [7]. From the semantic information on the notification (e.g., purpose of the notification, topics of the delivered information), this framework automatically determines when (delivery time), how (delivery channel, display rendering, notification behavior, terminal behavior), what (part of content to be displayed), and who (person(s) within a group) will receive this notification.

The adaptive notification framework therefore receives various notifications coming from different applications (e.g., health monitoring and alerting system, medicine reminder, appointment reminder, activity or content proposal server, direct people requests). As shown in the two following examples, a notification can be sent to a single user (see first example) or to a group of users (see second example):

Notify [**From:** *Medicine reminder*, **To:** *Mr Yale*; **Content:** *"Take your medicine"*, **IMPORTANT**]

Notify [**From:** *Dr White*, **To:** *Dr White-Staff*; **Content:** *"Need a nurse and a caregiver"*, **URGENT**]

The personalization and adaptation capacities of our framework allow to automatically adapt such notifications to the end-user profile (e.g. disabilities, preferences, role or position), the terminal type (e.g., PDA, IP phone, TV) and its characteristics (e.g., screen size, content format supported, remote control possibilities), the end-user and device context (e.g., presence, location, availability, terminal state), and the notification characteristics itself (e.g., content semantics, priority, criticality). The processing of a notification sent to single or group of users includes adaptations such as:

- select the most appropriate terminal and adapt its behavior (e.g., automatically trigger beep, time-shift, or text-to-speech),
- decide on the best time to deliver the notification (e.g., immediately, in a context as 'when switching on TV'),
- adapt the content to display (e.g., all or part of the notification content may be displayed),
- adapt the graphical rendering and introduce possible interactivity (e.g., buttons for notification acknowledgement or call triggering),
- enable alarm escalation to supervisor (e.g., if no response received),
- orchestrate the delivery of a notification in a group (e.g., deliver the notification sequentially, simultaneously, or with any other group delivery policy),
- manage notification acknowledgement over the group.

B. *Notification data model*

In order to support a wide range of applications, terminals, and end-user adaptation requirements, we propose a generic notification data model (see XML schema in Fig. 1) composed of three main types of parameters:

- Intrinsic parameters such as the sender, recipient, notification content and semantics, or related actions.
- Non-functional parameters such as the notification criticality, confidentiality, or related activity domain.
- Parameters defining the notification delivery modalities such as the delivery properties and policies.

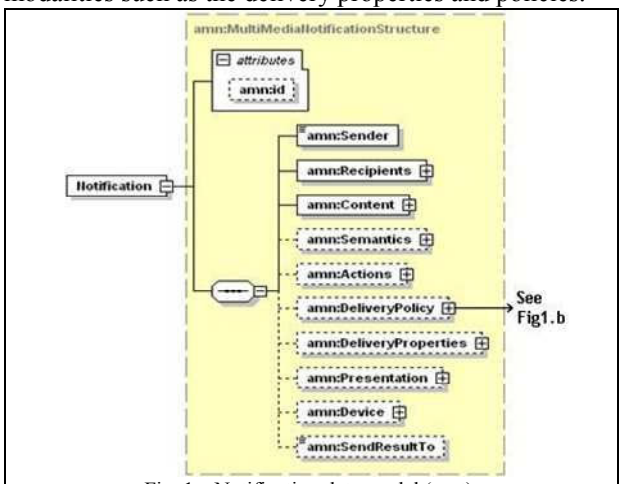

Fig. 1a. Notification data model (root).

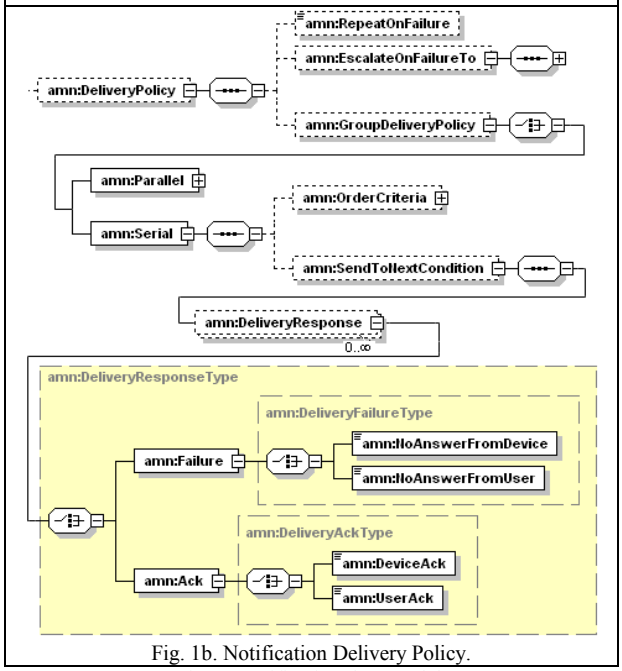

Fig. 1b. Notification Delivery Policy.

Fig. 1. Notification data model.

Regarding these last delivery policies, numerous parameters may be considered, e.g.:

- The number of delivery attempts of a notification (*repeatOnFailure* parameter).
- The recipient of the notification in case of escalation; i.e., when the main recipient fails to respond (*EscalateOnFailureTo* parameter). The recipient of the notification may be a single user, a device, a group of users, a group of devices or a combination of these.

Moreover, delivery policies are defined to set the way a notification is delivered to a group (*GroupDeliveryPolicy* parameter). Two modes are considered (*Parallel* or *Serial*).

For the Serial delivery mode, two additional sub-parameters are defined: the notification order required by the framework to notify the list of recipients (*OrderCriteria* parameter), and the conditions under which the notification is sent to the next recipient in the group (*SendToNextCondition* parameter).

C. *Adaptive notification delivery mechanisms*

In the framework, the notification adaptation consists in automatically setting values to all the delivery parameters of the notification in order to optimize its efficiency and impact. The notification adaptation process is composed of several stages executed as shown in Fig. 2. Each stage achieves a unique goal (e.g., criticalness estimation, delivery mode adaptation, or device selection).

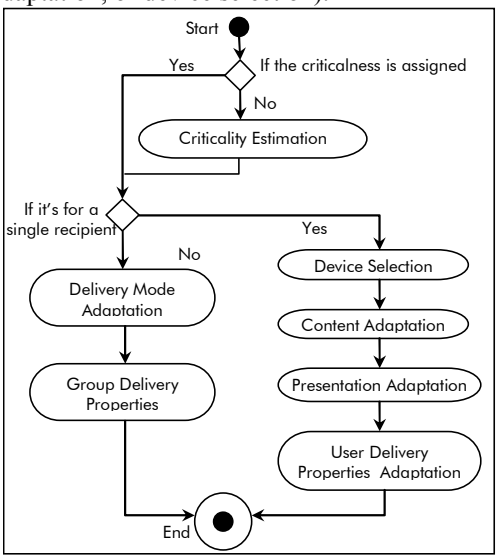

Fig. 2. Notification Delivery Mechanism.

Each adaptation stage relies on logic rules that use the intrinsic and non-functional notification parameters (mentioned beforehand) to infer the delivery modalities.

For instance, if we focus on the adaptation of the notification delivered to a single recipient:

- The *Criticality Estimation* stage aims at inferring the criticality from the notification semantics (e.g., health, leisure, news), type (e.g., alert, reminder, patient request) and the recipient profile (e.g., disabilities, diseases, or interest domains).
- The *Device Selection* stage aims at choosing the most appropriate device according to the notified content, the devices status and capabilities, and the user preferences.
- The *Content Adaptation* stage adapts the content format to the selected device and the user disabilities.
- The *Presentation Adaptation* stage adapts the way the notification is displayed according to the selected device, the adapted content and the user profile.
- The *User Delivery Properties Adaptation* stage adapts the delivery properties (e.g., timeout, response expected) according to the criticality and the presentation mode.

Analog adaptation mechanisms are performed for a notification sent to a group of users.

IV. Evaluations and Feedbacks

The goal of the evaluation is not only to improve the design of applications and services, but also to identify circumstances under which users (residents and professionals) operate and better understand how they use, interpret and perceive the proposed technology.

A. *Evaluation environment*

The evaluations of the adaptive notification framework have been carried out in a nursing home called "La Roselière" (in Kunheim, France) in the scope of the European project NUADU. These evaluations were performed in two phases, each phase lasting three days. Our studied population was selected among volunteers (residents and professionals) identified by the medical and administrative staff. In total, 7 residents (65 to 85 year-old) and 14 professionals (6 nurses and 8 caregivers) were involved to use the adaptive services and to answer related questionnaires. The successful achievement of defined tasks and a usability score (encompassing parameters as usefulness, ease of use, or user satisfaction) have then been evaluated. This process has been done in collaboration with the NUADU project partners (e.g., ergonomists) [8].

In the nursing home, a specific room has been selected to host all the required equipment and appliances for the users:

- For residents: TV, Set Top Box (STB) with its remote control, fixed IP phone (including a small screen), domotic appliances and sensors.
- For professionals: two PDAs, two fixed IP phones (with small screen) and one laptop.

Another room hosted the communication infrastructure (an IP-PBX call server and its service platform). Both rooms were connected via a local network extended with a secured WiFi access point for wireless communications.

B. *Notification use cases*

The notification framework has been evaluated through various use cases for both the professionals and the residents.

Fig. 3a. Nurse PDA interface.

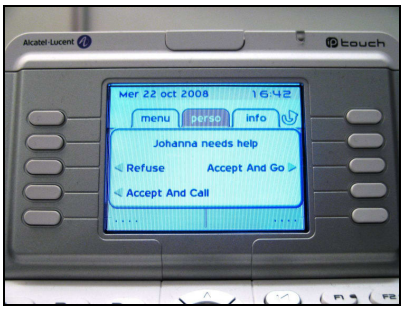

Fig.3b. Supervisor fixed IP phone interface.

The evaluated use cases for professionals are:

- *Health alerts* generated towards nurses when a suspect situation is detected by sensors (e.g., a person fallen down or going out of the room during the night).
- *Response to a help request* made by a resident via his

TV interface. A nurse (or a caregiver) is automatically notified on her PDA that he needs help (see Fig. 3a). The notification is escalated to the supervisor (e.g., on his IP phone) if the notified nurse has not responded on time (see Fig. 3b).

The evaluated applications and use cases for residents are:

- *Help request*: the resident is asked to make a help request (e.g., asking for help to go to the toilet, to drink water, for emergency) via a specific interface on the TV using the remote control (see Fig. 4).
- *Task reminder* (e.g., take medicine): while the user is watching TV, a reminder is displayed on his TV through a time-shift message. This message reminds him to take his medicine with the option to request the help of a nurse (by triggering a phone call with his TV remote control).
- *Invitation to leisure activities* (e.g., concert, museum visit). Different modalities are used to appropriately inform the users (e.g., time-shift pop-up, sliding text message, or use of automatic text-to-speech) depending on each resident's profile, preferences (e.g., music or tourism) and disabilities (e.g., sight or hearing impairments).

Fig. 4. Real end-user during evaluations achieved in the nursing home.

C. Evaluation feedback and lessons learned

The evaluations have allowed to collect rich feedback from all the involved users (residents and professionals).

Regarding the residents, the average usability score was about 70% with a better successful achievement for the *Task reminder* and *Activity proposition* use cases than for the *Help request*. Indeed, it seems that they were more comfortable in being solicited (for doing tasks or activities) than in performing an action (as requesting help), although they find the phone call through the TV very useful. The users appreciated the adapted and personalized delivery of information and the friendliness of the system for the help request (e.g., automatic display of the name of the staff member managing the request). The TV appears as the suitable interaction device for elderly people. However, a dedicated remote control with bigger button size can certainly be more suitable and more accessible for them.

Regarding the professionals, the average usability score was about 92% for the *Health alert* use case and 100% for the *Response to help request*. Usability was clearly related to the habit and easiness of nurses to use a PDA (better for young nurses). Qualitatively, the nurses have much appreciated that alerts are generated on automatic abnormal situations detection, especially when elderly are dependent and have some cognitive limitations, as some of them tend to use the classical alert button very often, for no particular reason. Being able to tell the difference between real emergencies and false or non urgent alarms can significantly increase the work efficiency of the staff. They confirm that the services must be closely adapted to their environment and context (staff availability, organization such as the number of employees in each role, residents type) in order to be well accepted. Configurability is also key; the time-out used to escalate a notification (if no response is sent) to the supervisor needs to be adaptable. Contextual aspects have been evoked by professionals to be considered while sending notification; targeting the nearest professionals when sending a help request, or directing resident requests to caregivers and emergency situation alerts to nurses. These aspects are already under consideration for integration in our adaptive notification framework.

V. Conclusion

In this paper, we have presented an adaptive notification framework to optimally deliver and handle multimedia notifications in a nursing home. The proposed approach has been evaluated with various applications and use-cases (e.g., health alert, help request, task reminder, and invitation to leisure) by involving real end-users (both elderly residents and nurses) in a pilot site. Numerous feedback have been obtained from these evaluations which highlighted the added value of the framework to enhance the quality of life of elderly people as well as the efficiency of the medical staff. The system has been used in a nursing home in a rural environment. However, extensions are envisaged for home (using a secure link between the user home and the nursing home or hospital) which also allows to target a younger population (less than 70 years) and therefore offer more valuable services and usages.

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