Call-Handling by an IMS-HNB based Interactive eDoorbell

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***Abstract*— Available doorbell interphone systems are designed under the assumption that residents would be at home to enable the communication between them and their visitors. However, people spend a large fraction of their time away from home, thus undermining the basic assumptions of existing doorbell solutions. Recent developments in 3GPP Home Node B (HNB or Femtocell) and home gateway technologies, along with the growing proliferation of smart-phones, can offer interesting opportunities for the design and development of innovative doorbell solutions. Along this line, the paper describes a 3GPP-enhanced eDoorbell application prototype that relies on IMS to enable video-based communication between visitors and (possibly remote available) home residents. In our prototype, the visibility of context information, such as current location of residents, their diary, and their personal preferences, provides solid basis for definition and enactment of customizable management policies that determine the best suited home resident whom to route the notification of a visit to. While the paper presents no experimental results, it aims at assisting organizations such as the Femto Forum or the ETSI TISPAN to identify the requirements for standards and the different methods used to implement HNB-based or Home Gateway-based services, respectively.**

I. Introduction

So far, doorbell solutions have been trivially designed and available products on the market are simply video-enabled interphone systems interconnecting the door phone at the gate with a custom handset inside the residence. As a consequence, existing solutions still assume house residents to be at home to enable communication between them and their visitors. However, professional duties and recreational activities lead individuals to spend a considerable fraction of their time away from home, making it very difficult for them not to miss some visits.

Recent and on-going advances in home automation and networking technologies, such as home gateways [1] and the emerging Home Node B (HNB) technology [2] offer residents the possibility to remotely control their home appliances, anywhere and anytime [3], [4]. The paper discusses how to develop innovative doorbell solutions that take full advantage of recent developments in home gateways and HNB technologies. In particular, we here propose the Enhanced Doorbell (eDoorbell) service architecture that enables the residents of a house to be immediately notified of outsiders' visits, even when they are not at home. Whenever a visitor rings the bell of a residence and none of the residents is at home, a voice/video call is established between the outsider visitor (i.e., the doorbell) and the mobile terminal of a house resident, i.e., the resident's User Equipment (UE) [5]. The voice/video call permits house residents not to miss (possibly relevant) information from outsiders' visitors, and to re-schedule a meeting at a more convenient time for both parties.

However, designing a smart video door phone is not a trivial task, and requires to determine how, whom and when to forward a call. The paper suggests adopting the Internet Multimedia System (IMS) to establish cost-efficient and interactive video connections between the doorbell and a selected set of mobile terminals of the residents [6]. In addition, in our solution, the visibility of contextual information, such as the current presence locations of residents, their diary-entries and schedules, and so forth, provides solid ground to determine whom and when to forward doorbell calls. In particular, a context-based policy management support permits residents to tailor eDoorbell service provisioning according to their specific needs. For example, it is possible for residents to block calls (e.g., during a pre-scheduled meeting at work or in case of an undesired visitor), to decide who should be given higher priority in answering the call first (e.g., in a family scenario, parents should be intuitively given higher priority than their children), and to form a list of trustworthy members (e.g., relatives, neighbors, or even close friends) who may receive calls on their behalf (e.g., in case the visitor is a service delivery agent).

While in this paper, we consider IMS-HNBs due to their numerous benefits (e.g., efficient billing mechanisms, automatic plugging, etc), the devised service is not necessarily restricted to IMS or HNBs. Indeed, it is possible to implement the system on top of any suitable network based upon SIP (Session Initiation Protocol) [7]. Furthermore, HNBs can be also easily substituted by home gateways. This renders the service readily deployable with the currently available technologies.

The remainder of this paper is structured as follows. Section II presents related research works. Section III describes the envisioned eDoorbell service model, its architecture and some insights on its implementation. Concluding remarks follow in Section IV.

II. Related Work and Design Guidelines

Femto cells are gaining a great momentum both in industry and academic research circles. Early deployments of HNBs-based commercial services will be launched by the end of 2010 [8], [9]. Femto Forum Ltd [10] defines HNBs as "low-power wireless access points that operate in licensed spectrum to connect standard mobile devices to a mobile operator's network using residential DSL or cable broadband connections."

The peculiarities of Femto cells, such as the increase of mobile core network capacity and the consequent emergence of new billing models, motivate the integration of users' mobile terminals in doorbell applications. The main advantage is to provide a uniform support to answer calls from outsider visitors, anywhere and anytime, without the need to rely on special-purpose handsets. However, despite the increased technical opportunities so far, no previous work has considered the use of HNB for video door phone applications. On the contrary, available proposals and research prototypes still tend to rely on basic networking support and to provide trivial call notification mechanisms.

For example, a high-end doorbell, manufactured by Panasonic [11], provides users with a mobile phone-like wireless handset, that permits home residents to answer doorbell calls when they are at home. When nobody is at home, the Panasonic doorbell is able to notify home residents of the missed visit by sending an email that contains a snapshot image of the visitor.

In [12], Oh *et al.* present a Real-Time Visitor Communication Service (RVCS) that does not require users to rely on a special-purpose handset. RVCS is based on a SIP-enabled home-gateway that notifies all (pre-registered) devices of a "visitor" event. Residents can, therefore, receive the call on one of the registered terminals, even when they are not at home. For example, if the resident is currently outside, he/she can pick up the call on his/her PDA, whereas if he/she is at work, it is possible to take the call on his/her PC.

However, when providing doorbell services to mobile users anywhere and anytime, it becomes important to forward doorbell calls to best suited home resident, and at the most convenient time. According to the above considerations, it seems natural to consider context information as a suitable basis for the design of innovative doorbell applications.

In the following, we will use context to define the information needed to determine the situation of a user, e.g., his/her physical location, preferences, characteristics, the activities he/she is currently involved in, and so forth [14]. The full visibility of context information permits to infer the best suited individual to whom to forward a call. For example, the visibility of residents' locations and schedules permits not to disturb them during work meetings. Similarly, the visibility of outsider's context information, such as, for example, their identity, also permits to determine whether to block or to pass the doorbell call.

According to the above considerations, the work presented in [13] describes a location-aware doorbell solution. In particular, the proposed system continuously track the physical locations of all residents who are currently at home. When a visitor rings the bell, the doorbell call is established between the visitor and the mobile terminal of the home resident who is currently closer to the door. When none of the residents is at home, an instant message is sent to the residents whose mobile devices are included in a message dispatching list.

The present paper extends available researches in the field and advocates the need to consider the visibility of the whole context information characterizing home residents and their visitors to determine the best suited individuals whom to forward doorbell calls. In contrast with previous research works [12], [13] where resident's location is tracked by a sensor network deployed in their home, we use IMS and Femto for localization support. In addition, we propose an enhanced doorbell service architecture able of gathering and managing further context information characterizing attributes of both visitors and residents, including the personal diaries of the latter, their schedules, and so forth.

As a final remark, the paper considers policy management as another important aspect to take into account in doorbell service design. In fact, doorbell services require suitable support to express and enforce context-based call forwarding policies that permit to adapt doorbell service provisioning according to actual users needs and preferences.

III. eDoorbell Service Description

Figure 1 depicts our proposed eDoorbell networking model. Users can exploit their mobile terminals to connect either to the home network or, when they are not at home, to the operator's cellular network. The home network comprises two major components, namely, an IMS-HNB access point and the eDoorbell interface. The IMS-HNB access point is administrated by a particular network operator. When a visitor rings the bell, it is the IMS-HNB access point that establishes a video/audio connection between the eDoorbell and the terminals of the residents. The eDoorbell interface is assumed to be set next to the door of a building/house.

The eDoorbell interface is equipped with a sensor video camera with the feature of face recognition; a message prompter, capable of describing the current operations being executed by the eDoorbell; audio input and output interfaces that enable voice communication between the visitor and the residents; and a screen which displays the resident that is currently communicating with the visitor.

The policy support permits home residents to define different rules that use available context information to decide how and to whom a call (i.e., from a visitor) should be forwarded. For example, a resident may set the system in a manner in which no call is forwarded to that particular resident when he/she is overseas (e.g., to avoid large bills due to roaming service), when he/she is attending a pre-scheduled meeting, and when the visitor is an unwanted person (e.g., neighborhood's kids playing with the doorbell). Similarly, the

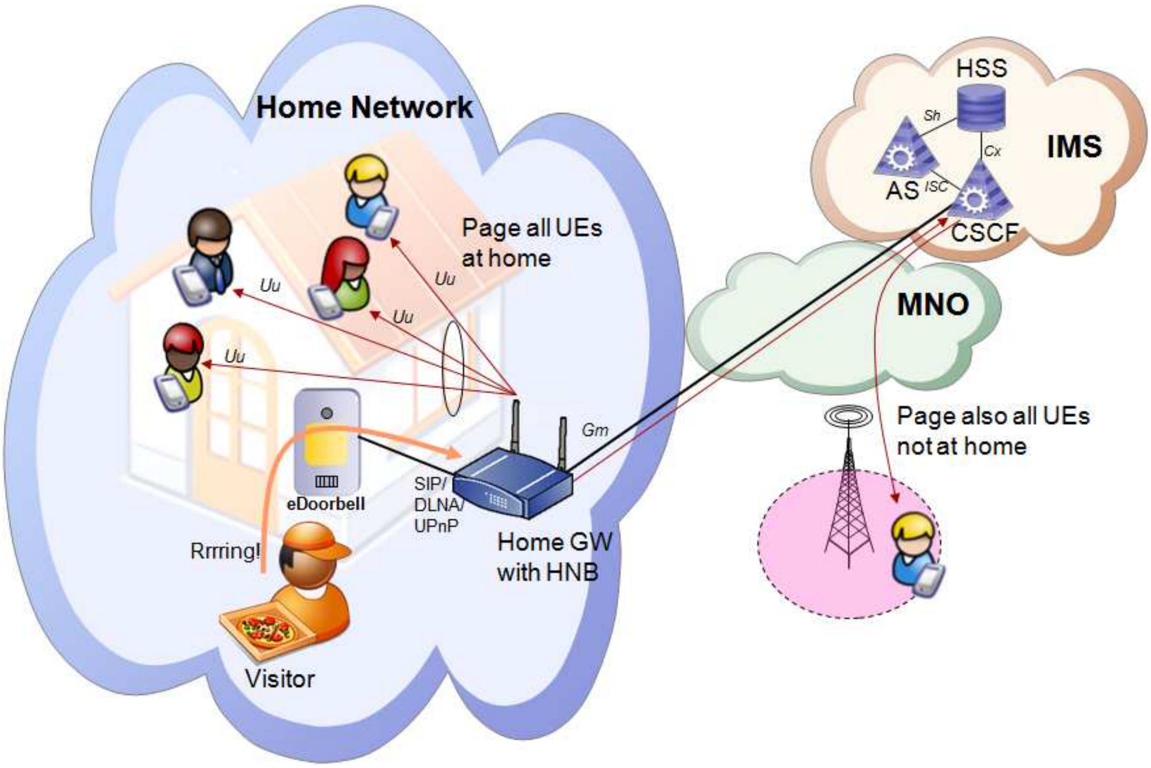

Fig. 1. Abstract configuration of the network topology.

system can be setup to immediately forward calls when the visitor is an important person (e.g., grandparents). Residents can prioritize the dwellers according to their roles in that residence (e.g., in a family case, parents should be given higher priorities in contrast with their children). Residents can also form a block list of undesired visitors and an emergency delegation comprising trustworthy members (e.g., neighbors) that can act on their behalf in emergency situations. Obviously, the members of this emergency delegation will be having restricted rights to be defined also by the residents. Additionally, another policy may be that if the visitor is person Y (based on face and/or voice recognition) and is more likely interested in speaking to resident X (e.g., friend of a family member), then the call may be forwarded directly to the latter. Other policies pertain to the settings of some timeouts used in the service. For example, if nobody answers the call within a specified threshold, it is possible to forward the call to a trusted neighbor.

The proposed eDoorbell system allows residents to use their mobile phones not only to talk to the visitor, but also for performing further actions, such as remote opening of the door. The alerting mechanism may distinguish between mobile phones that are currently camping on HNB and others that are connected to the macro network. By providing local call handling, HNB can establish the video call to a mobile terminal that is camping on the HNB locally, i.e., without the need to route the call through the operator's core network.

A. *Overall Architecture Description*

Figure 2 depicts the eDoorbell layered architecture. The Communication Layer permits to establish a call to house residents' mobile terminals. The layer includes the needed facilities to detect which mobile phones are within the HNB coverage area and which ones need to be paged outside via the IMS. In addition, a local SIP server, permits to register all user terminals inside HNB's coverage area. This allows the HNB to perform local call handling like a TISPAN Customer Network Gateway (CNG), i.e., it can route calls directly between the mobile terminals in its coverage without putting any signaling or user plane load on the DSL (or FTTH) link to the operator's network. However, if the system is unable to locally deliver the video call from the "Video Doorbell", the HNB will attempt to reach the mobile terminals of the rest of the family members via the macro network.

The Context Management Layer provides the needed facilities to gather context information from different and heterogeneous context sources. In particular, the Context Aggregation Service (CAS) is in charge of accessing context information from video-based face recognition service, the repository of residents' personal calendar and IMS presence information. CAS aggregates the whole information needed to infer current situation and to turn data to a higher level of abstraction. In addition, CAS can fuse information from heterogeneous sources to reduce the risk of errors in context management. For example, a resident may be at home even if, according

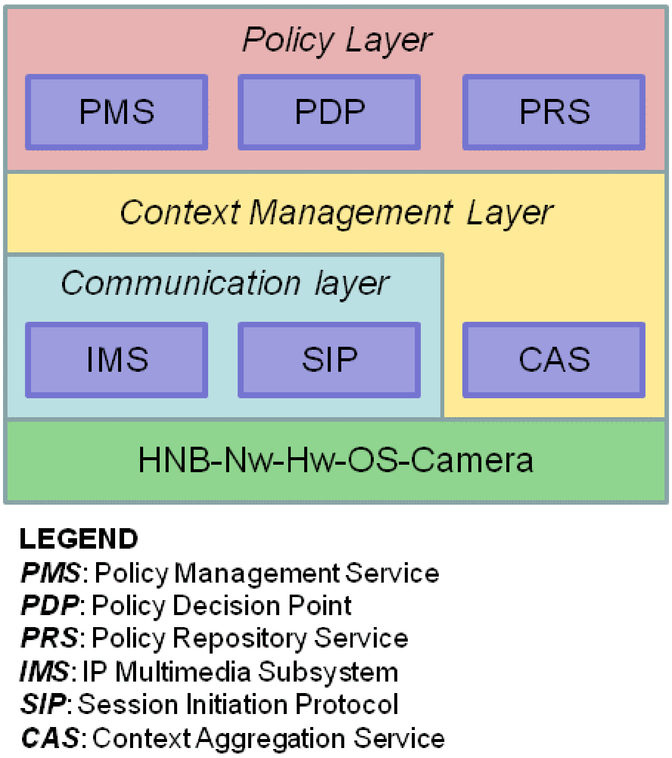

Fig. 2. eDoorbell layered architecture.

to his/her calendar, he/she is supposed to be at a meeting. Finally, CAS provides the visibility of available aggregated information to the policy layer to simplify the decision on whom to forward calls to.

The Policy Layer includes the needed support facilities to rule call forwarding. In particular, the policy layer facilities provide the needed support to edit, store and evaluate event-condition-action obligation policies [15]. When a visitor rings the bell, the Policy Manager Service (PMS) dynamically associates the visitor to an event, e.g., relative role, unknown person role, friend role, and so forth. Following to this, a set of applicable policies in response to the event is gathered from the Policy Repository Service (PRS). Finally, if policy preconditions are verified by the Policy Decision Point (PDP), then the associated action is executed, e.g., ignore the event, forward the call to a particular resident terminal and so forth.

B. Implementation Insights

Call Forwarding: Figure 3 depicts the major interactions among the components of the eDoorbell system. We assume that the doorbell is a SIP device that can setup a video call and that the HNB has an internal SIP server for handling the call. As a consequence, Steps 1-3 are preconditions for the eDoorbell service. The detailed description of the eDoorbell inter-component interactions follows:

1) Each mobile terminal roaming into the HNB coverage area (UE1 - UEx) performs a Location Update procedure. Upon "Location Update", HNB creates a SIP User Agent (SUA) for the mobile terminal as a local IMS instance. It is possible for the HNB also to route calls internally between these SUAs. All SUAs are IMS registered on behalf of the mobile terminals;
2) The video doorbell registers at HNB as a SIP device. Also, a registration at HNB with the help of UPnP would be possible;
3) For the doorbell service, HNB creates another SUA and registers it in the IMS;
4) A visitor presses the doorbell;
5) The doorbell ringing event prompts HNB to check which mobile terminals shall be paged in this case. This could be configured based on user preferences and will be detailed in the next sub-section. Since HNB knows which of these mobile terminals have a local SUA, they get paged locally. The remaining mobile terminals will be paged via IMS;
6) HNB pages the mobile terminals UE1 to UEx locally since they have an active SUA;
7) UEy has no local SUA since it is located outside home, somewhere in the macro network. Therefore, HNB pages UEy via IMS;
8) Some UEs respond to the paging and send an acknowledgement within a predefined time;
9) HNB either forwards the call to the UE that answers first, or selects/prioritizes the best suited UE to forward the call to according to the currently applicable policies. In the case of multiple UEs available with the same priority, eDoorbell forwards the call to the resident who first responded within a defined time;
10) The media from the doorbell is now routed locally to the selected UE without traversing the mobile operator's network.

Policy Evaluation: In the envisioned eDoorbell system, the decisions on call forwarding are taken according to the flowchart of Figure 4. As illustrated in this figure, the service instance is initiated when a visitor dials the apartment's number. The first timeout parameter, TO_1, is then set. During this timeout, the eDoorbell waits for response from any UE. Here, it is worth noting that TO_1 is set to a lower value when nobody is at home compared to the scenario when someone is present at home. The rationale behind this is to notify the residents of the visit as promptly as possible when nobody is at home. If TO_1 expires and the door has not yet been opened, the system dispatches messages to the appropriate family members (e.g., via email on their PDAs) and sets a second time out (i.e., TO_2).

If a family member responds within TO_2 to the issued notification, the system then asks him/her for selecting the mode of communication (i.e., voice only or video) with the visitor. The selection of the individual to whom the call is forwarded can be made on different basis; for example, on a "Fist-In-First-Call" basis, i.e., the member who responds first is forwarded the call, or on a priority basis, i.e, if the first responder is on top of the priority list, then he/she is

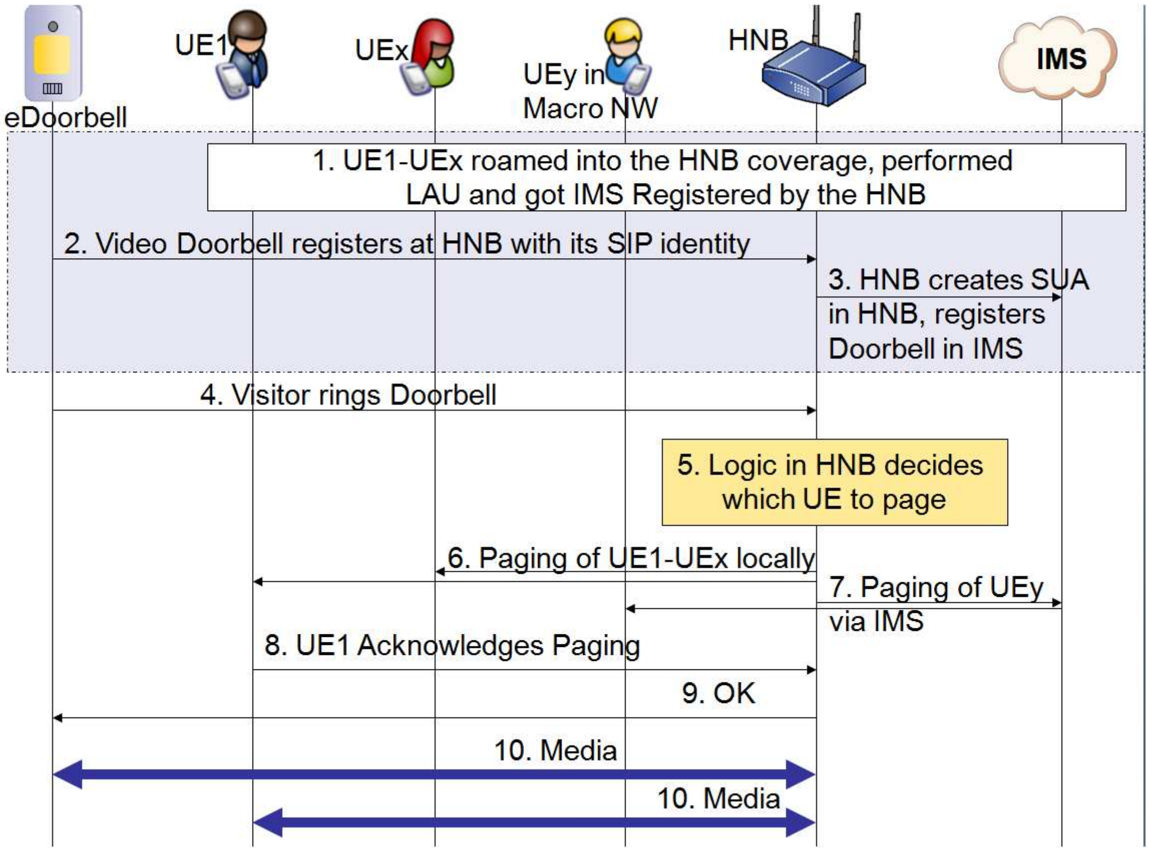

Fig. 3. Overall call setup mechanism.

immediately forwarded the call. If the first responder is the N^{th} one in the list, then the system waits for a timeout TO_3 (i.e., TO_3 is a function of "N") time within which if there is no response from the other higher-priority members, the call will be simply forwarded to the N^{th} member in the list. On expiration of TO2, if the system receives no response from any user, it declares, to the visitor, that nobody is available at the residence.

The eDoorbell policy support permits to further refine the above described schema and permits to dynamically determine the priority of residents in call forwarding, blocking calls, timeouts, and so forth. Some policy examples for the envisioned eDoorbell system are shown in Table I.

When a visitor rings the bell, PMS coordinates with CAS to obtain the information needed to classify the event. This information can be obtained either from video-based face recognition of previously known visitors, or from short-range communication (e.g., Bluetooth, RFID) between a visitor's portable/mobile device and the eDoorbell system. The visitor profile includes identifiers that allow the dynamic binding/selection of a profile based on certain identifiers, e.g., MAC address, Bluetooth ID, and so on.

Following to visitor identification, PMS can actually associate the event to a set of applicable policies. The association between visitor identity and eDoorbell events can be configured by home residents. For example, according to residents' preferences and needs, it is possible to define events representing previously unknown people, friends, neighbors, and so on. Then, PMS can coordinate with PRS to gather all available policies associated to the event.

EDoorbell policies are expressed in Ponder language and are compiled in XML [15]. In particular, we extended the Ponder language to map policy actions with a set of defined operations, i.e., forwarding a call, blocking a call, displaying a defined message on eDoorbell display, and so forth.

In eDoorbell, policies are evaluated by PDP. In particular, PDP is in charge of parsing policies provided by PMS, and of determining the currently applicable policy on the basis of the evaluation of policy conditions. As a consequence, it is possible for PDP to coordinate with CAS to obtain context information needed to evaluate the policy condition. When the currently applicable policy is identified, it is up to PMS to enforce it by executing the set of actions associated with the policy.

IV. Concluding Remarks

This paper introduced an intelligent eDoorbell service based on IMS-HNB with the following features. The eDoorbell service immediately notifies residents of an outsider's visit, establishes interactive video/voice call between the visitors and the residents, even when the latter are outside their home.

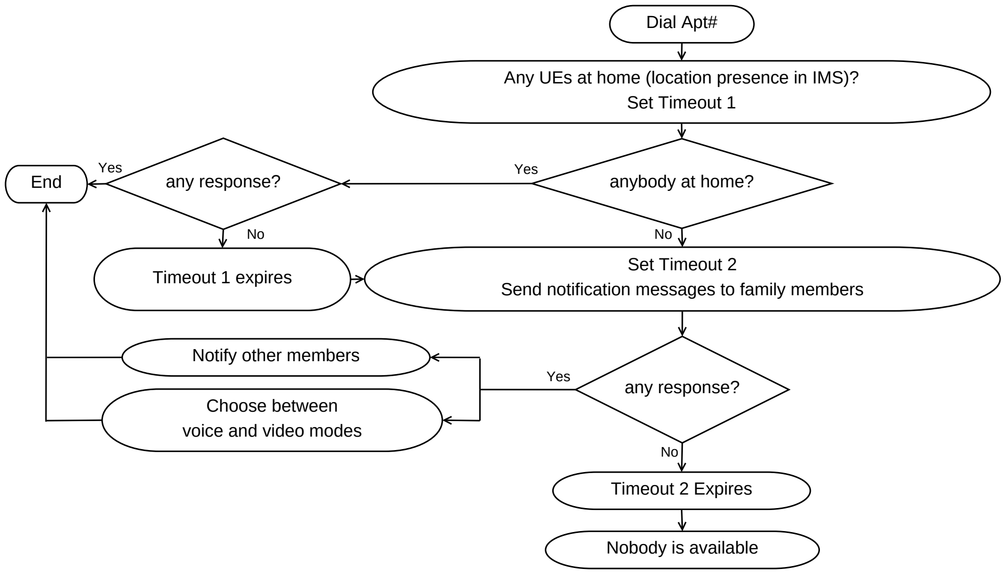

Fig. 4. Overall mechanism of the service.

TABLE I
SOME POLICY EXAMPLES FOR THE ENVISIONED EDOORBELL SYSTEM.

Action	Event
Do not call when	- UE is overseas - During a meeting - Visitor is X
Call when	- Visitor is Y - Etc
Priority	- Parents - Kid 1 - Kid 2
Block list	- X1 - X2
Emergency Delegation	- Y1 - Y2
Timeout setting	- Automatic - Manual - Manual when visitor is Y

In case of multiple individuals sharing the same residence, the service coordinates among the residents and decides who should receive the call first. This coordination procedure is based on a set of policies customizable by the residents according to their current circumstances and their timely-varying requirements. The call forwarding decision takes also into account a wide set of contextual information, regarding both the residents (e.g., diary, calendar information, and so forth) and visitors, obtained from different sources (e.g., IMS, sensor video cameras) and stored at an application server in the HNB access point.

Whilst the paper presents no experimental results, the main objective of this paper is to provide relevant standardization organizations, such as the Femto Forum or the ETSI TISPAN, with insights on novel services that can be provisioned using HNBs or Home Gateways, along with requirements for their implementations and standards.

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